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CDM PROJECTIONS FOR KENYA: TOWARDS A GREEN GEOTHERMAL ECONOMY – THE CASE OF OLKARIA AND MENENGAI GEOTHERMAL POWER PROJECTS

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ABSTRACT

The current climate-energy concerns and effects have resulted in shifting developmental perspectives towards clean development mechanisms (CDM). Sustainable economic development has its roots in clean energy development. The 1997 Kyoto protocol, a legally binding instrument, implemented the CDM for the first commitment period, 2008-2012, as investments by Annex I countries in non Annex I countries to foster emission reductions and sustainable development. Developed nations fund 'green' projects in developing nations and gain Certified Emission Reductions to achieve their emission reduction targets. In the energy sector, several renewable environmentally friendly projects like geothermal have qualified under the CDM, with less green house gas emissions. Geothermal energy projects are environmentally benign and, globally, about nine projects are registered with the United Nations Framework Convention on Climate Change (UNFCCC), accruing CDM benefits. Kenya, with a current energy deficit of about 8% per annum, is in the process of expanding existing energy resources with a focus on clean renewable energy. Hydropower yields most of the energy but has been unreliable due to unpromising hydrological conditions. Contributing about 12% of installed capacity, geothermal energy presents a potential in excess of 7000 MWe along the Kenyan Rift Valley, and the thrust to develop 5000 MWe by the year 2030. Although a high initial capital investment is required, CDM could help unlock this potential. Three 140 MWe geothermal power plants are envisaged: Menengai I, Olkaria IV (Domes) and Olkaria I (Units 4 and 5) between the years 2012 and 2014. This report examines the CDM potential for the three projects and the estimated emission reductions upon implementation of each project. The Approved Consolidated Methodology ACM0002 version 12 was used in the computation of the emission reductions. Upon registration under the CDM, various environmental, economic and social benefits are expected. This achievement is anticipated to ensure both intra and inter-generational equity.

1. INTRODUCTION

One of the key components crucial in national economic and social development is energy. A supply of secure, equitable, affordable and clean sustainable energy is indispensable for global and future prosperity. The majority of energy produced in the world today is obtained from fossil fuels, i.e. coal, petroleum, natural gas, and nuclear energy (Celik and Sabah, 2002). In addition, sustainable and environmentally friendly resources, such as hydro and geothermal, sunlight, wind, biogas, and wood, are also utilised. With increasing awareness of the detrimental environmental effects that result when fossil fuel is burned to generate energy, an increasing global interest has sparked towards using green renewable energy sources such as geothermal energy. Geothermal energy is one of the most promising among renewable energy sources due to its proven reliability and environmentally friendly nature, and thus its potential for power generation and direct uses with little or no greenhouse gas emissions (Kömurcu and Akpinar, 2009). It is a power source that produces electricity with minimal environmental impacts at low unit costs compared to other sources, thus, it is suitable for base load. According to Fridleifsson et al. (2008) and Rybach (2010), further deployment of geothermal energy is envisaged as CO_2 emissions could be reduced even more significantly. Bertani (2009) has also reported that geothermal electricity production of about 1000 TWh/yr in 2050 would mitigate up to 1000 million tons CO_2/yr (given the substituted fuel to be coal). The Clean Development Mechanism (CDM) is becoming a powerful incentive for geothermal projects. Matthíasdóttir et al. (2010) state that CDM has the potential to produce incentives for promoting and accelerating the development of geothermal energy utilisation in developing countries.

In Kenya, geothermal plants are situated in the greater Olkaria field (Rift valley) with a current installed capacity of 202 MWe and 18 MWt. Simiyu (2010) reports an exploitable potential exceeding 7000 MWe which, if developed, would aid in meeting the current electric power demand of about 8% of Kenya. Thus, additional expansion is envisaged. The existing Olkaria power plants have generated base load power with an availability factor of more than 95% and have, thereby, saved the country on imported fuel costs and power outages during unreliable weather conditions; this is the foreseen capability of geothermal development. CDM could help unlock prospective geothermal development. According to the least cost power development plan (2010) for the years 2010 - 2030, Kenya anticipates an electricity expansion programme where 30 geothermal power stations of about 140 MWe will be constructed over the next 20 years (Ministry of Energy, 2010). This massive capital (US$ 16 billion) undertaking can only be realised through a joint effort by both the public and private sectors. Upon completion of these projects, significant annual tonnes of emission will be abated and the power plants will contribute to sustainable development. This report recapitulates CDM opportunities *inter alia,* and the sustainable development for Kenya´s anticipated large scale geothermal power projects aimed at the installation of 420 MWe between the years 2012 and 2014. Expected emission reductions and equivalent benefits over a seven year crediting period are evaluated and presented upon the construction of Menengai I (140 MWe), Olkaria I (140 MWe) and Olkaria IV domes (140 MWe) geothermal power plants.

2. SUSTAINABLE ENERGY DEVELOPMENT

The energy sector has entered a new phase in its evolution, one in which emissions of greenhouse gases (GHGs) can no longer be assumed to be costless. This fact will gradually and profoundly change energy generation and utilisation in the coming decades (Sioshansi, 2010).

According to OECD/IEA (2008a; 2008b) projections, most of the current world energy infrastructure will need to be replaced by 2030. In global terms, it is anticipated that annual investments in renewable energy for electricity capacity will exceed those for fossil-fuel power plants in the projection period between 2007 and 2030 (REN21 Secretariat, 2009). With today's impetus on sustainable development and environmental conservation, diverse and abundant clean renewable energy has the advantage of reducing reliance on finite or imported energy resources. It includes, but is not limited to biomass, solar power, wind power, hydropower, tidal power and geothermal power which can improve energy security, especially for non-oil producing countries, create employment and help fight poverty by improving energy accessibility, particularly for remote or rural populations

(NEPAD, OECD Africa and African Union, 2009). It is in this light that the quest for sustainable development has evolved along with the adoption of economic policies with a variety of co-benefits including utilising new improved clean and renewable energy technologies.

2.1 The climate-energy paradigm

Reports by Stern (2007) and IPCC (2007a) indicate that anthropogenic climate destabilization represents both a market failure and an immediate threat to human welfare, ecosystems, and the temperate climate for which life on earth has evolved. According to OECD/IEA (2009), the direct combustion of fossil fuels, a process leading to large emissions of CO_2, dominates the energy sector. A by-product of fuel combustion, CO_2 results from the oxidation of carbon in fuels (in perfect combustion conditions, the total carbon content of fuels would be converted to CO_2). CO_2 from energy represents about 80% of the anthropogenic greenhouse gas emissions for Annex I countries and about 60% of global emissions. The IPCC (2007b) further indicates an increase in equivalent carbon emissions (CO_2-eq.) from industrial societies, primarily caused by fossil fuel combustion to 49 GtCO_2-eq./yr, precipitating a concomitant increase in atmospheric carbon concentrations from a pre-anthropogenic level of 280 parts per million in volume (ppmv) to current levels of 430 ppmv CO_2-eq. (WMO, 2008). Comparable growth has also occurred in levels of methane (CH_4) and nitrous oxide (N_2O) as in CO_2. Greenhouse gas (GHG) concentrations at the current level cause a global disequilibrium and even emission stabilization at these intensities will result in temperatures rising (Hansen et al., 2008). The IPCC (2007a; 2007c) projections indicate an increase in the global mean surface temperatures between 1.1 and 6.4°C by the year 2100. This time-dependent relationship demands that future generations compensate for present emissions. In order to avoid further disruption to the earth's thermal equilibrium and negative effects on human society, it has been recommended that greenhouse gas emissions be stabilized at levels below 350 ppmv (Hansen et al., 2008).

2.1.1 Global synergy: UNFCCC, Kyoto Protocol and CDM

The global response to climate change began with the adoption of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 which was not legally binding and subsequently the Kyoto Protocol in 1997, a legally binding instrument. The objective of the convention is to stabilize greenhouse gases (GHGs) from anthropogenic sources. To achieve this objective, the Kyoto protocol commits signatories from the industrialised nations to reduce their GHG emissions such as carbon dioxide (CO_2) and methane (CH_4) by an average of 5.2% in the period 2008-2012. To facilitate the achievement of this target, three flexible market based mechanisms were introduced, i.e.: Joint Implementation (JI), Clean Development Mechanism (CDM) and Emission Trading (ET).

Established under Article 12 of the Kyoto Protocol, the CDM is a mechanism between Annex I (developed) and Non-Annex I (developing) countries that helps the industrialized countries meet their emission targets by earning credits for their contribution to the developing countries 'emissions reductions'. This investment, which is directly related to the extent that emissions are reduced, could make greenhouse gas reducing projects in developing countries (such as renewable energy) more viable. In other words, developed countries will pay for projects in developing countries that reduce emissions of GHGs by purchasing a commodity, which is referred to as Certified Emission Reductions. The project developer may then obtain additional revenue streams from interested carbon buyers in Annex I countries registered under the Kyoto protocol (Kollikho, 2007). CDM project investments must contribute to the sustainable development of non-Annex I host countries, and must also be independently certified. This latter requirement gives rise to the term "Certified Emissions Reductions" or CERs, the output of CDM projects (Figure 1). Geothermal energy projects are prospective CDM projects, if implemented in place of non-renewable energy sources which are a significant source of GHG emissions (Ogola, 2010). Generally, development of the geothermal resource has been impeded by financial constraints in developing countries, such as Kenya, with massive exploitable potentials. However, through the Kenya Vision 2030 policy, economic transformation is envisioned with plans to expand the energy sector through clean renewable options such as geothermal energy in a bid to meet the current and future energy demand (Republic of Kenya, 2007).

2.2 The CDM project cycle

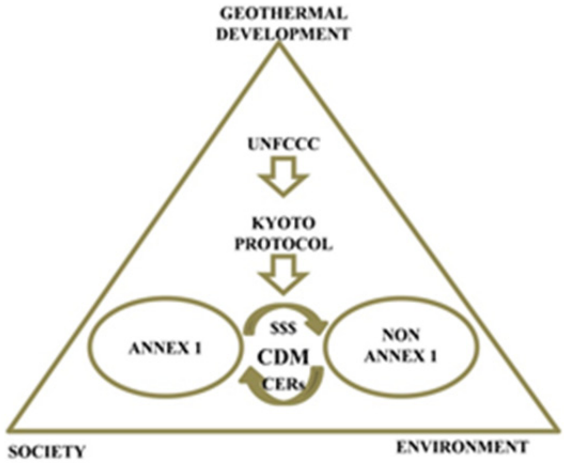

FIGURE 1: Conceptual model – CDM towards sustainable development (modified from Munasinghe, 2010)

A CDM project is an investment or activity in a developing country that reduces emissions of the six greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3), water vapour (H_2O) and chlorofluorocarbons (CFCs) through energy efficiency, the generation of clean renewable energy or other measures. The emission reductions (carbon credits) resulting from CDM projects, CERs, are expressed in tonnes of CO_2 equivalent (tCO_2-eq) and may be sold to a government or company in the industrialised world to help meet their Kyoto compliance targets (Cahyono, 2010). All CDM projects must satisfy certain requirements specified in either the Kyoto Protocol or the Marrakesh Accords. These include requirements that the project:

- Complies with the eligibility criteria (such as the sustainable development criteria) of the host country and other parties. A letter of approval (project approval) from the Designated National Authority (DNA) of each party involved is then issued, including confirmation by the host party that the project activity assists it in achieving sustainable development.
- Provides real, measurable, and long-term benefits related to the mitigation of climate change using an approved baseline and monitoring methodology.
- Delivers reductions in emissions that are additional to any that would occur in the absence of the project activity.
- Does not result in significant environmental impacts and undertakes public consultation.
- Does not result in the diversion of Official Development Assistance (ODA).

In order to fulfil these criteria, some critical concepts are assessed as discussed below:

Baseline
The baseline outlines what would have occurred in the absence of the project and permits the calculation of emission reductions due to the project. It is a hypothetical reference case, representing the volume of greenhouse gases that would have been emitted if the project was not implemented. The baseline can be used to determine the additionality of CDM project activity and the volume of additional greenhouse gas emission reductions achieved by the project activity. All emissions from all gases, sectors, and source categories listed in Annex A of the Kyoto protocol occurring within the project boundary are significant in this assessment.

The physical and geographical extent of project activities delineates the project boundary. To date, baseline methodologies have been derived guided by modalities and procedures and approved by the UNFCCC Executive Board for accuracy purposes. Approved baselines thus represent the most likely alternate scenarios to project implementation. In the case of geothermal energy, an average five year grid of electricity consumption prior to project execution could be used as a reference to estimate what the emissions would be if the geothermal CDM project was not implemented (Salas, 2008).

Additionality
GHG emissions after implementation of a CDM project activity are required to be lower than those

that would have occurred in the most likely alternate scenario to the implementation of the CDM project activity. The project activity is thus termed 'additional' and eligible under the CDM. The alternate case may be the business-as-usual (continuation of current emission levels in the absence of the CDM project activity), or another scenario which would result in gradual reduction of emissions. The Kyoto Protocol assigns operational entities designated by the Conference of the Parties to certify emission reductions resulting from each project activity. Real, measurable and long-term benefits related to the mitigation of climate change and consequent emission reductions, that are additional to any that would have occurred in the absence of the certified project activity, justify the additionality concept (UN, 1998). During validation, the Designated Operational Entity (DOE) confirms additionality as part of the validation report. CDM methodologies by the UNFCCC have incorporated tools to determine the additionality of proposed CDM projects.

Leakage
The net measurable change in anthropogenic emissions (by sources of greenhouse gases) occurring outside the project boundary but attributable to CDM project activity is termed leakage. Leakage emissions are deducted from the emission reductions generated by the project activity for the issuance of CERs.

Emission reductions
Total emission reductions are calculated from the emissions that occur in the baseline scenario discounted from the emissions caused by the project activity and possible leakage emissions. The difference is the total emission reductions generated from implementation of the project activity within a specified crediting period.

CDM cycle
The key stages in the CDM project cycle (Figure 2) include the initial feasibility assessment, development of a Project Design Document (PDD), approval by both parties involved (through a Letter of Approval; LoA), project validation, registration, emission reduction verification and credit issuance. The stakeholders involved include the CDM project developer, the CDM Executive Board (EB), the Designated Operational Entity (DOE) responsible for validation and verification of the project, and the Designated National Authority (DNA), which has the authority to grant parties

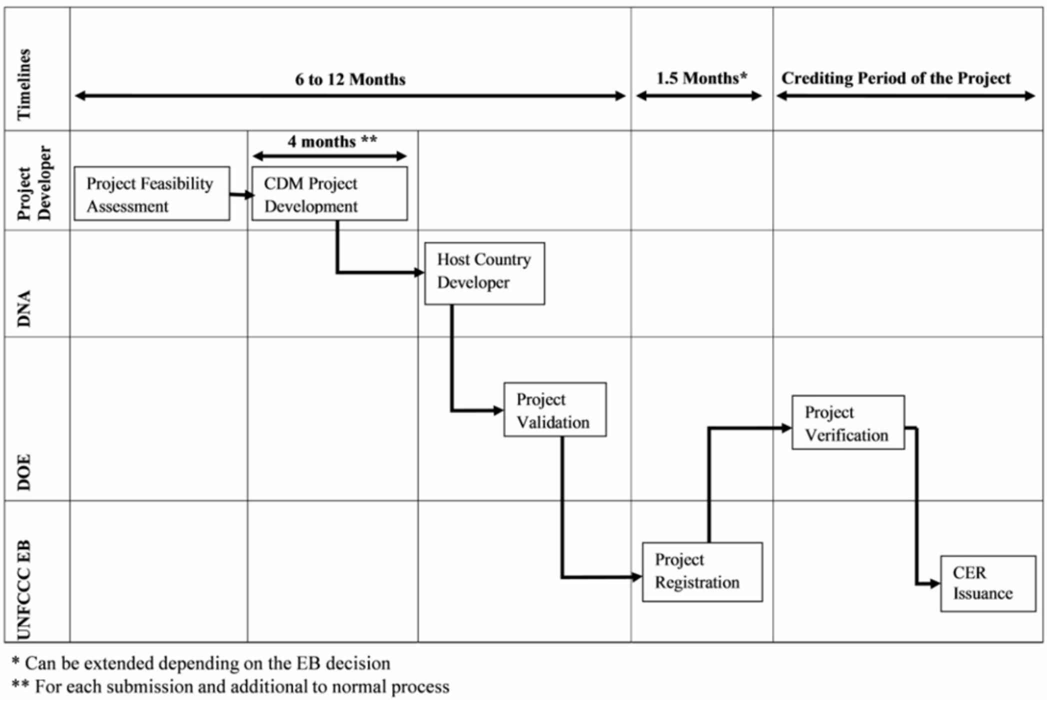

FIGURE 2: CDM project cycle (UNEP, 2007)

involved approval for the project. Once the project is registered, CERs may be issued at any time, following verification by a DOE and a formal request for issuance to the CDM EB. The CDM EB supervises the CDM under the authority and guidance of the Conference of the Parties. The EB's core tasks include:

- Accreditation of independent auditors (DOEs) for validation and verification;
- Review of validation reports and PDDs;
- Approval of new baseline and monitoring methodologies;
- Registration of projects; and
- Issuance of CERs.

The document involved in the validation and registration of CDM project activity is the PDD. It is among three vital documents required for registration of CDM projects, along with a validation report from the DOE and letters of approval from the DNA parties involved. Described in the PDD is the proposed project and project boundary, baseline methodology, crediting period, additionality, project environmental impacts, public funding opportunities for the project, stakeholder comments and a proposed project monitoring plan. The DOE reviews the PDD during the validation process to verify that a project meets the validation requirements. The PDD is also used as the basis for stakeholder's consultation conducted by making the PDD and related documentation publicly available on the UNFCCC website. The PDD is then included in the request for registration which is submitted by the DOE to the Executive Board (CDM rulebook, 2008).

It must, however, be noted that the timescales can vary significantly according to project specific circumstances. The duration of time selected by the project participants (crediting period), during which the CDM project activity will be implemented and CERs generated, is either for a 7-year crediting period, renewable twice, or a single 10-year crediting period.

2.3 Geothermal development: toward a carbon constrained economy

The imperative to act on climate change has affected nearly every sector; however, emphasis has been placed on the electricity sector due to its contribution of about 25.9% of world carbon emissions as current fossil-fuel generation emits between 400 and 989 tonnes of carbon per gigawatt-hour of electricity produced (IPCC, 2008c). Fridleifsson et al. (2008) stated that there is a need to have large sources of carbon-free, base load electricity dispatchable on a wide scale to achieve high levels of CO_2 emission reductions using renewable energy in both developed and developing countries. A comparison of geothermal energy with other electricity sources shows less CO_2 emissions (Figure 3) rendering a very positive impact on the global environment. Bertani (2002) reports that replacing a combined cycle natural gas fired plant with a geothermal power plant having a CO_2 emission rate of 55 g/kWh would give a net savings of 260 g/kWh of generation. Similarly, if a fuel oil plant is replaced, the net savings would be 705 g/kWh, and for a coal-fired plant the savings would be 860 g/kWh.

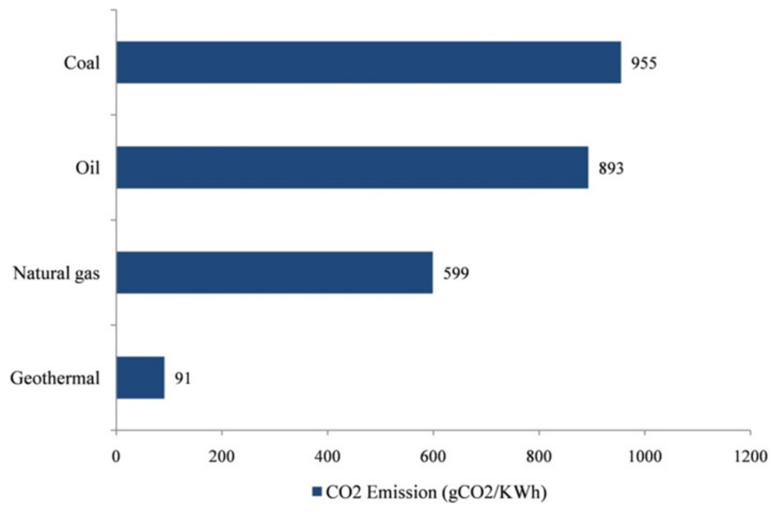

FIGURE 3: CO_2 emission from electricity generation from different energy sources, USA, data from Rybach (2010)

2.4 Electricity capacity in Kenya

The current effective capacity of 1,351.5 MWe (under normal hydrology) in Kenya has not increased to match the demand growth rate, thus requiring emergency power (medium-speed diesel plants) to satisfy the peak demand at 1,113 MWe (The Departmental Committee on Energy, Communication and Information, 2010). Kenya's electricity demands are satisfied by hydro, thermal, geothermal, wind and the Bagasse co-generation sources, with hydropower dominating production with about a 55% share (Table 1). The current challenge at hand, though, is the execution of an energy expansion programme to sustain the increasing demand. Hydropower plants, for example, are dictated by hydrological conditions. This results in reservoirs operating below the minimum rule curve during low hydrology conditions in order to minimise the use of high cost oil fired diesel plants. Kenya's 2030 vision acknowledges the need to generate environmental friendly, cost effective and energy efficient technologies. In recognition of the importance and reliability of geothermal power and the energy requirements to meet the 2030 objectives, the government has embarked on an ambitious electricity generation expansion plan. Deployment of geothermal energy is currently underway as the resource's exploitable potential is in excess of 7000 MWe along the Kenyan rift valley, in more than 14 locations. The expansion of existing geothermal operations will offer the least cost, environmentally benign source of energy with great potential in the country. Over the years, development of the resource has, however, been hampered by limited funds and private sector participation. The major reason is attributed to high exploration risks associated with development of the sites. The Geothermal Development Company, Ltd. (GDC) is fast-tracking development of the resource with the expectation of incorporating 5000 MWe to the national grid by year 2030. This will reduce reliance on the hydrology driven hydropower and thermal (high-carbon content) source, replacing them with a sustainable energy source.

TABLE 1: Power generation in Kenya (MWe) as of July 2010 (Ministry of Energy, 2010)

Category	Installed capacity	Effective capacity
Hydro	761	748.3
Geothermal	202	191.9
Wind	5.45	5.0
Thermal	419.6	401.1
Off grid	14.2	12.5
Co-generation	26	26
Sub-total	**1,428.25**	**1,384.7**
Emergency power	290	290
Total capacity	**1,718.25**	**1,674.7**

2.5 CDM and geothermal application

The potential of carbon finance has attracted several geothermal projects to be registered under the CDM. As of September 2010, nine geothermal projects (Table 2) had been registered and were eligible to receive carbon credit revenue, although as time progresses the number is subject to change, depending on the registration rate (UNFCCC, 2010). According to Ogola (2010) the few registered projects could be attributed to investment risks associated with geothermal development in comparison to wind, solar, landfill, energy efficiency and biomass projects which dominate the energy portfolio under CDM statistics.

2.5.1 Geothermal utilisation in Kenya

Geothermal energy is harnessed from the Olkaria site, located in the Hell's Gate National Park, approximately 132 km northwest of Nairobi by road, near Naivasha Town. The Olkaria geothermal field is located 6 km to the south of Lake Naivasha in Kenya's Rift Valley Province and occupies an area of roughly 80 km^2. Olkaria I, II, III and Oserian generate electricity from geothermal resources within the Olkaria field. Olkaria east production field supplies steam to the 45 (15×3) MWe Olkaria I power plant while Olkaria Northeast field provides steam to a 105 (3×35) MWe power plant, and Olkaria Northwest field provides steam to a 48 MWe power plant (Table 3).

TABLE 2: Registered geothermal CDM projects as of September 2010 (UNFCCC, 2010)

Country	Project	Average annual emission reduction (tonsCO_2-eq/year)	Crediting Period	Total tCO_2-eq
El Salvador	Berlin binary cycle power plant (11.56 MWe)	44,141	7 years (2007 – 2014)	308,984
El Salvador	LaGeo S.A de C.V., Berlin geothermal project phase 2 (44 MWe)	176,543	7 years (2006 - 2012)	1,235,798
Guatemala	Amatitlan geothermal project (25.2 MWe)	82,978	7 years (2008 - 2015)	580,849
Indonesia	Darajat Unit III geothermal project (110 MWe)	652,173	7 years (2006 – 2013)	4,565,211
Indonesia	Lahendong II 20 MWe geothermal project	66,713	7 years (2009 – 2016)	466,990
Kenya	Olkaria III Phase 2 geothermal expansion project in Kenya (35 MWe)	177,600	7 years (2009 – 2016)	1,243,198
Nicaragua	San Jacinto - Tizate geothermal project (66 MWe)	280,703	7 years (2005 – 2011)	1,964,919
Papua New Guinea	Lihir geothermal power project (55 MWe)	278,904	10 years (2006 - 2016)	2,789,037
Philippines	Nasulo geothermal project (20 MW_e)	74,975	7 years (2008 – 2015)	524,825

TABLE 3: Geothermal power plants in Kenya (Simiyu, 2010)

Power plant name	Year commissioned	No. of units	Type of unit	Total installed capacity (MW_e)
Olkaria I	1981, 1982	3	Single flash	45
Olkaria II	2003	3	Single flash	105
Olkaria III	2000, 2008	2	Binary	48
Oserian	2004, 2007	2	Binary	4
Total				**202**

Olkaria Central field is manned by a private company; Oserian Development Company Ltd. (ODLC) generates 4 MWe (2× 2 MWe), utilising steam from a well (OW-306) leased from Kenya Electricity Generating Company Limited (KenGen). The plant provides electrical power for the farm's operations. The two power plants (Olkaria I and II) are under the ownership of KenGen whilst Olkaria III is owned by an Independent Power Producer (IPP), Orpower, and currently produces 48 MWe.

CDM interest and clean renewable energy project development in Kenya's energy sector stems from the year 2000 when KenGen showed interest in obtaining benefits from CDM projects to develop energy resources. In 2005, Kenya ratified the Kyoto protocol, paving the way for the country to engage with developed countries in CDM projects. The Kenya National CDM Guidelines were formulated in 2001 and further on the Designated National Authority (DNA) and the National Environment Management Authority (NEMA) in 2007. Efforts to register clean renewable energy progressed with significant achievements with the registration of Olkaria III (Orpower) phase 2 (35 MWe) project in March 2010; the 35 MWe Bagasse Based Cogeneration Project by Mumias Sugar Company Limited (MSCL) was the first energy project to be registered in 2008 under the CDM in Kenya.

Olkaria III (Orpower) Phase 2 (35MWe) geothermal project

The objective of the second phase of Olkaria III geothermal project (Figure 4) is to add 42.48 MWe of gross power to the existing plant, which has been in continuous operation since 2000. At the outset, three Ormat Energy Converter (OEC) units were installed with a net generation capacity of 12 MWe (113,800.23 MWh/year). Optimisation studies of the existing plant were conducted between March 2002 and September 2003 with the objective of increasing the net generated capacity to 13.6 MWe. Implementation of the second phase brought the total net generation capacity up to 48 MWe, an increase of 35 MWe. About 47 MW of net electricity is now sold to the Kenya Power & Lighting Company (KPLC) under a power purchase agreement. The PDD (Orpower, 2009) indicated an estimated emission reduction of 177,600 tCO_2-eq/year (ACM-0002 version 8 UNFCCC CDM methodology) from an annual generation of 420,480 MWh for an initial 7 year crediting period (renewable twice) at an average combined grid emission factor of 0.6 tCO_2/MWh. With an average US$ 12.7 (Kossoy and Ambrosi, 2010) for one ton of CO_2-eq reduced annually, Orpower benefits from CDM are estimated at US$ 2.3 million annually. The PDD further points out that these gains would be used for project development in addition to corporate social responsibilities within surrounding communities. The results are expected to reduce green house gas emissions and boost the economy in addition to improving livelihoods with a clean and renewable energy campaign.

FIGURE 4: Olkaria III 35 MW_e power plant under construction

Olkaria II 35MW_e extension project

Olkaria II geothermal extension project (Figure 5) is yet another CDM project in the pipeline whose PDD document has been developed and submitted (June 2010) for registration. The single-flash geothermal project was aimed at increasing capacity at the existing Olkaria II 70 MWe geothermal power plant to generate 35MWe more renewable energy for sale to KPLC on the basis of a power purchase agreement (PPA), and was commissioned in 2010. The project activity will result in GHGs emission

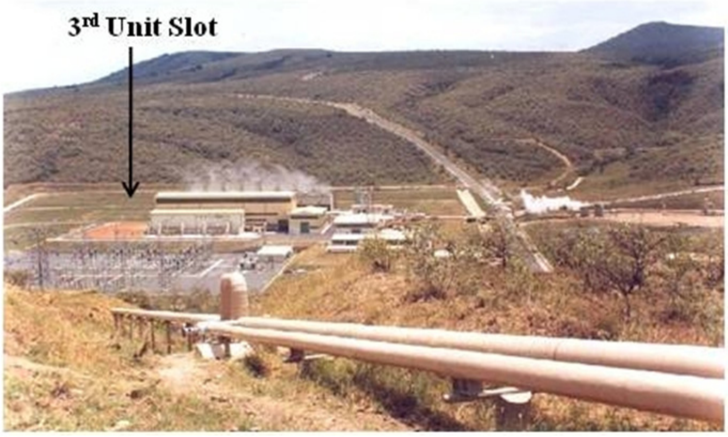

FIGURE 5: Olkaria II Unit 3 (35 MWe) extension project

reductions by curtailing CO_2 emissions from electricity generation by fossil fuel power plants. During the initial 7 year crediting phase, an estimated emission reduction of 171,026 tCO_2-eq/year is expected using a combined grid emission factor estimated at 0.6396 tCO_2/MWh. Overall emission reduction over the 7 year duration is an expected total of 1,197,186 tCO_2-eq at an annual estimated generation of 276,000 MWh/year. Upon registration, CDM proceeds at an expected price of US$ 12.7 (Kossoy and Ambrosi, 2010) per tCO_2-eq, and the sales from CERs will generate about US$ 15.2 million in the first 7 years. Economic and social welfare will also be greatly improved from the CDM proceeds (KenGen, 2010).

Other earmarked large scale geothermal projects planned for implementation between the years 2012 and 2014 are three 140 MWe (2×70 MWe) power plants: Menengai I, Olkaria I and Olkaria IV, whose CDM potential, if unlocked, could improve economic and sustainable development in Kenya.

3. GEOTHERMAL PROJECTS AND CDM POTENTIAL IN KENYA

3.1 Rationale and location

CDM is herein assessed as a tool to help unlock the potential for Menengai I 140 MWe power plant, Olkaria I (East) fourth (70 MWe) and fifth (70 MWe) units, and Olkaria IV 140 MWe (Domes) power plant located along the Kenyan rift valley (Figure 6). The Menengai geothermal area is situated about 180 km northwest of Nairobi, Nakuru District, while Olkaria I and IV are located about 120 km

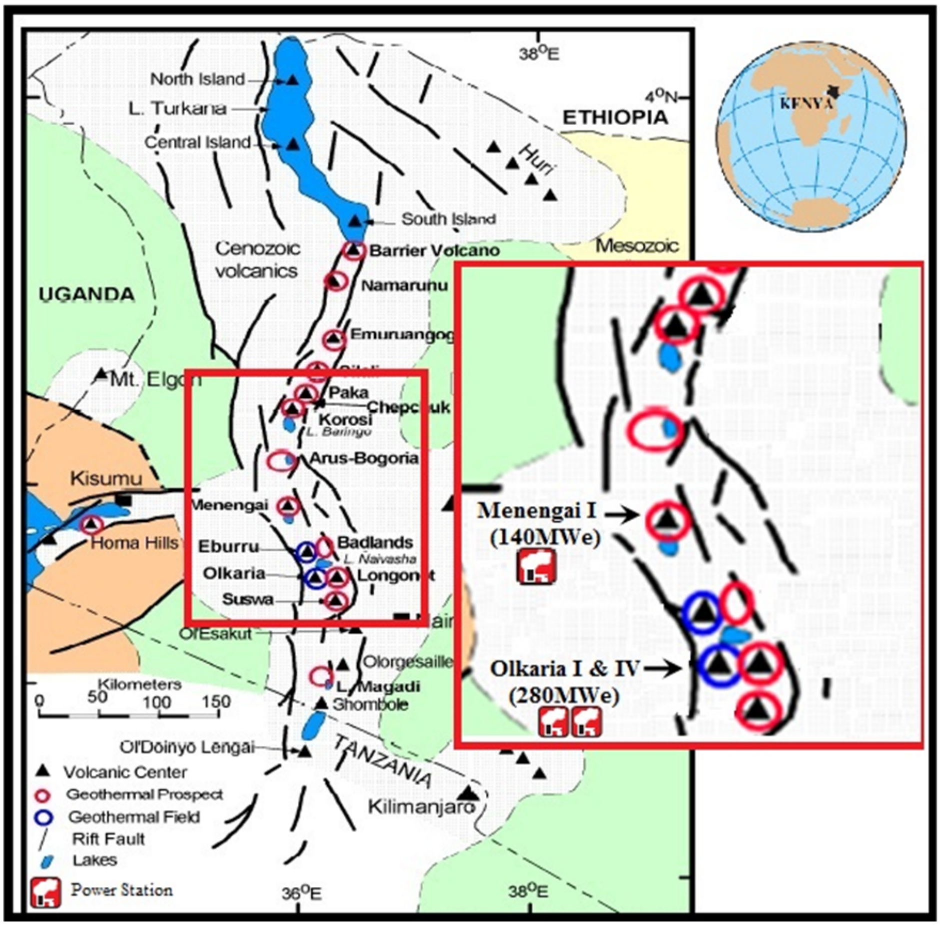

FIGURE 6: Simplified geological map of Kenya showing locations of Menengai I, Olkaria I (4^{th} & 5^{th} units) and Olkaria IV geothermal power plants in Kenya (modified from Simiyu, 2010)

northwest of Nairobi in Naivasha District. Non-condensable gases (NCGs) data from 15 wells which supply steam to the existing Olkaria II 70 MWe power station, and whose technology is expected to be similar to the new projects, are used to estimate project emissions and equivalent CERs for an assumed seven year crediting period. The Approved Consolidated Methodology ACM0002 version 12 (2010) 'Consolidated baseline methodology for grid-connected electricity generation from renewable sources' published by the UNFCCC CDM-Executive Board (2010) is employed.

3.2 Description of projects

The Government of Kenya plans to start construction of three large-scale geothermal power plants, each with a 140 MWe installed capacity, in Menengai (Menengai I) and Olkaria (Olkaria I and IV) geothermal fields. Menengai is a new geothermal field; the proposed project upon implementation will mark the first geothermal power plant in the area. Olkaria geothermal field on the other hand is currently under expansion as it has been in production since 1981. Olkaria I 4^{th} and 5^{th} units will be a capacity addition to the existing 45 MWe (3×15 MW_e) power plant. Olkaria IV (Domes) is also a new power project, within the Olkaria area, with implementation of a 140 MWe power plant. All the fields have proven steam capability to yield 140 MWe.

3.2.1 Project objectives

The purpose of the three power plant projects is to abate the tight supply/demand balance and promote a stable power supply in the country. Through utilisation of geothermal energy, a positive contribution to sustainable development in Kenya is achieved. The projects will enhance environmental quality, positive health impacts and foster private sector participation, thus attracting investors to Kenya. This will contribute to economic development. Social development will accelerate as increased power availability will create more opportunities for expanded rural electrification with far reaching impacts on employment creation and improved livelihoods in the rural areas. The projects will also result in GHG emission reductions by displacing fossil fuel-based (thermal sources) electricity generation in the Kenyan grid with clean geothermal power.

3.2.2 Components and process activities

The main components of the projects that constitute the project boundaries are illustrated in Figure 7. Geothermal energy continuously flows from magma within the Earth's interior towards the surface.

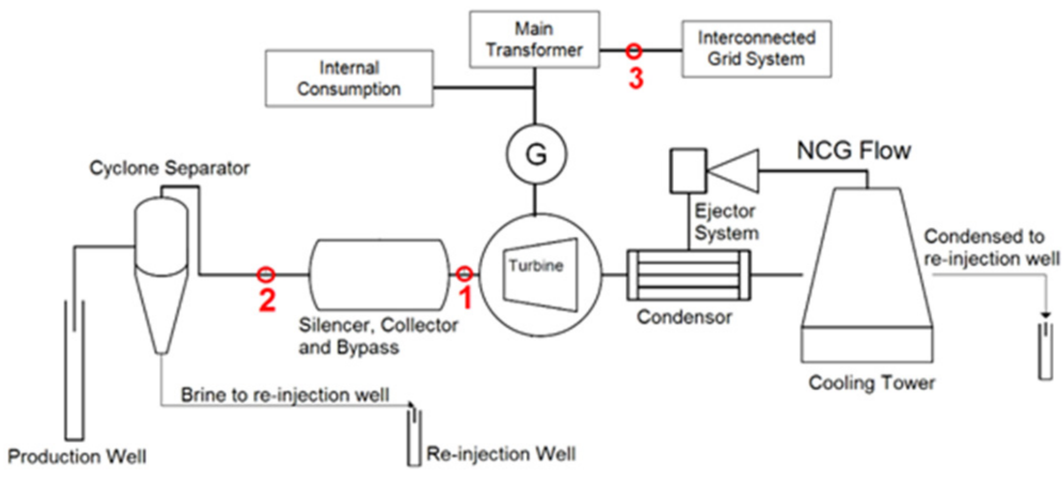

FIGURE 7: Simplified process flow (single flash) diagram showing sampling points 1 = Principal CO_2, CH_4 and steam sampling points; 2 = Secondary CO_2, CH_4 and steam sampling points in case of overhaul or outage (UNFCCC requirement); and 3 = Electricity measuring point (modified from CEC, 1980)

When this heat naturally produces hot water or steam, it can be piped to the surface and then used to turn a steam turbine to generate electricity.

Geothermal wells will be drilled to provide steam for electricity generation. Physical structures that will be constructed include new power stations, cooling tower blocks, steam gathering systems, switchyards and transmission lines. The process of generating geothermal electricity at Menengai I, Olkaria I and IV is purposed to be single-flash condensing type as that of the existing Olkaria II power plant (Appendix I). All the units for the three power projects will be identical in power generation and configurations (Table 4) and will embrace optimal utilisation of the available geothermal resource to ensure a 70 MWe capacity for each of the units.

TABLE 4: Power plant performance indicators (operation and effect indicators) (JICA, 2010)

Indicator	**Target value 2 years after project completion (2015)**
Maximum output (MW_e)	140
Plant load factor (%)	93.4
Availability factor (%)	96.7
Internal consumption rate (%)	4.27
Outage hours by cause (hours/year): Human error	0
Machine failure	240
Planned outage	336
Net electric energy production (GWh/year) – 140 MWe	1,097
Net electric energy production (GWh/year) – 420 MWe	3,291

The following steps will mark the process:

- Steam from the production wells will pass through a separator, where the liquid phase (brine) will be separated from the steam.
- The liquid phase consists mainly of brine and will be channelled through to a re-injection well.
- Steam (containing non-condensable gases (NCGs)) will be channelled through steam scrubbers and further to the turbine at the power station. The steam will then run a steam turbine/alternator for electricity generation.
- Upon transmission from the turbine, steam will be condensed; the hot condensate (containing NCGs) will be pumped to the cooling towers. NCGs will be expelled at this point through the cooling towers into the atmosphere. Cool condensate will then be re-circulated to the condenser.
- As the circulating condensate will be acidic, it will be dosed with soda ash (sodium carbonate) to prevent corrosion. In addition, the condensate will be dosed with biocide (hypochlorite) to prevent bacteria growing in the fins of the cooling tower.
- Any additional condensate will be pumped into different re-injection wells.
- The design steam pressure and temperature is expected to be 6 bar and 158.7°C.

The main constituents of geothermal fluids are geothermal steam and a small quantity of geo gas (carbon dioxide (CO_2), hydrogen sulphide (H_2S), oxygen (O_2), nitrogen (N_2) and methane (CH_4). Geothermal steam will be used to drive the two 70 MWe turbines in each of the three cases. The main waste products expected will include:

- Brine, which is separated from the steam at the production wells;
- Condensate, produced when the steam passes over the turbine; and
- Non-condensable gases, which will be released through the cooling towers.

Menengai I 140 MWe geothermal power project

The mapped potential area (Figure 8) in Menengai is about 48 km^2 translating to over 750 MWe of electric power. GDC plans to undertake the drilling of exploratory, appraisal and production wells in the prospect from October 2010. A total of 41 wells will be drilled. Construction of a 140 MWe power plant (Menengai I) is planned to be commissioned in the year 2012. A decision has yet to be made on the power plant location.

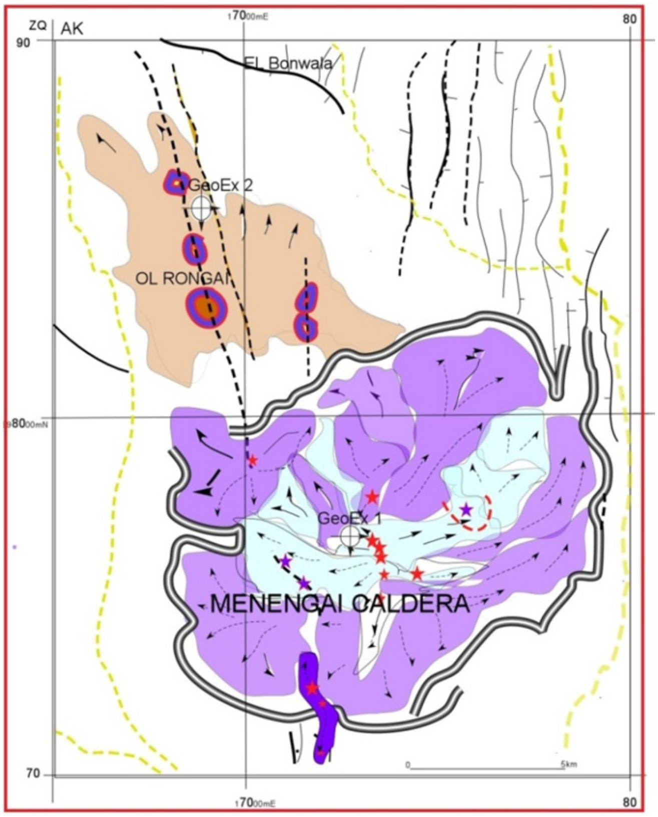

FIGURE 8: Menengai geothermal project area

Olkaria 1 units 4 and 5 140 MWe geothermal power project

The proposed power plant site for units 4 and 5 is the wide flat area between wells OW-24 and OW-28 at Olkaria I (Figure 9). The two units will be additional to the existing units 1, 2 and 3 (3×15 MWe) in the existing Olkaria I power plant. Olkaria East field, which supplies steam to Olkaria I power plant, has thirty three wells drilled. Currently, twenty six of them are in production while the rest have become non-commercial producers due to a decline in output over time; some of these are earmarked for reinjection or for deepening (Simiyu, 2010). A further twenty three wells will be drilled. The 140 MWe power plant is expected to be commissioned in the years 2013 and 2014.

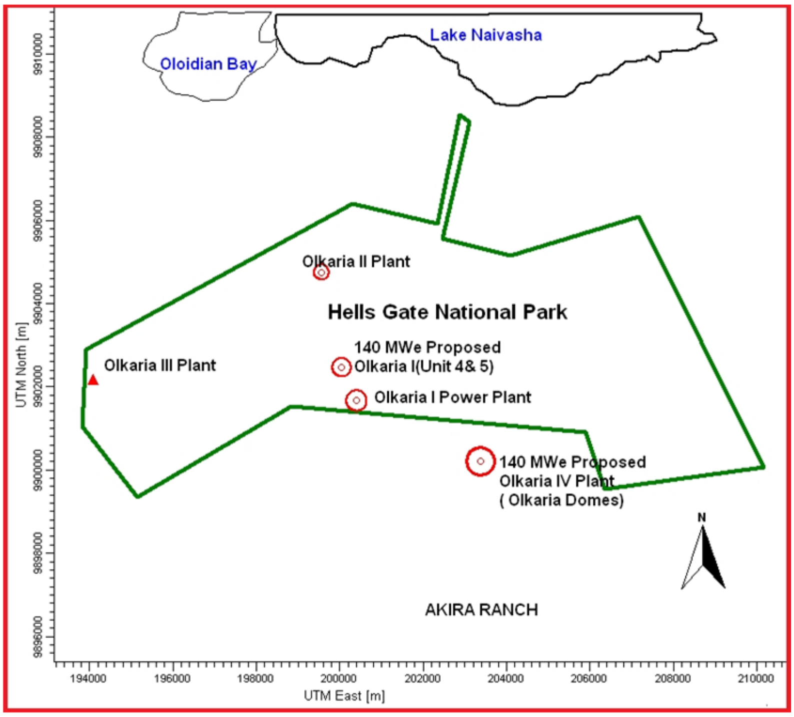

FIGURE 9: Proposed Olkaria I and IV geothermal projects

Olkaria IV (Domes field) 140 MWe geothermal power project

Two 70 MWe power plants totalling 140 MWe will be constructed in Olkaria Domes (Figure 9), to be commissioned in the years 2013 and 2014, respectively. Currently, six appraisal wells have been drilled, out of which five are directional and one is vertical with a capacity range between 4 and 13 MWe. Production drilling is currently in progress and a total of twenty three production wells will be drilled. Tender documents for the construction of the steam gathering system and the power plant are in preparation to be floated later in the year 2011. The proposed power plant location is expected to be close to the main production zone of the Olkaria Domes field.

3.3 CDM methodology

In order to qualify for CDM and generate Certified Emission Reductions (CERs), projects must follow approved methodologies for estimating and monitoring emission reductions. The UNFCCC CDM Executive Board (2010) methodology of Geothermal and CDM application used in this case is ACM0002 (Version 12), applicable for renewable electricity generation plants such as geothermal power projects which are connected to interconnected power grids, not an activity that involves switching from fossil fuels to renewable energy at the project activity sites. Two case scenarios are used as required by the methodology in determining the baseline and project emissions:

- Project activities include the installation of 140 MWe in Menengai I and Olkaria IV as new geothermal power plants which will supply electricity to the grid, thus they are classified as the installation of new power plants.
- Project activities include the capacity addition of Olkaria I units 1, 2 and 3; (3×15 MWe) with the new Olkaria I (2×70 MWe) units 4 and 5, thus being classified as capacity addition by the installation of new power units, besides the existing power units. The existing power plant/units continue to operate after the implementation of the project activity.

4. ESTIMATION OF EMISSION REDUCTIONS

Baseline and project emissions are calculated to determine emission reductions in tCO_2-eq/year. All calculated estimations are based on the ACM0002 version 12 UNFCCC CDM methodologies (UNFCCC CDM Executive Board, 2010).

4.1 Baseline emissions

Baseline emissions include only CO_2 emissions from electricity generation in fossil fuel fired power plants that are displaced by project activity. Equation 6 of the methodology is used:

$$BE_y = EG_{PJ,y} \times EF_{grid\,CM,y} \qquad (1)$$

where BE_y = Baseline emissions in year y (tCO_2/year);
$EG_{PJ,y}$ = Quantity of net electricity generation that is produced and fed into the grid as a result of the implementation of the CDM project activity in year y (MWh/year);
$EF_{grid,\,CM,\,y}$ = Combined margin CO_2 emission factor for grid connected power generation in year y (tCO_2/MWh).

Leakage
The main emissions potentially giving rise to leakage in the context of electric sector projects are those arising due to activities such as power plant construction and upstream emissions from fossil fuel use (e.g. extraction, processing, and transport). Since the expected projects are geothermal, no leakage emissions are considered.

Combined grid emission factor
Kenya is pursuing renewable energy and energy efficient grid connected projects such as hydropower, geothermal and wind, most of which are intended to be CDM. The Grid Emission Factor (GEF) is critical when considering the commissioning of new clean energy projects, as the baseline scenario keeps on changing with respect to the latest CDM projects incorporated. Many renewable and energy efficient grid connected projects translate to low emissions in the environment and thus low GEFs. Regular up-to-date databases of new grid connected projects in the electricity system are relevant for calculating the emission factor as per the latest approved methodology (ACM0002 version 12). This

methodology includes the CDM tool for calculating the emission factor for an electricity system based on available data. The CERs generated are dependent on the GEF. The emission reductions are calculated over a seven year crediting period (renewable) and an average combined grid emission factor of 0.594 tCO_2/MWh[1] is used.

Calculating baseline emissions – Menengai I 140 MWe and Olkaria IV 140 MWe
The project activities (Menengai I 140 MWe and Olkaria IV 140 MWe) entail the installation of new grid-connected renewable power plants at sites where no renewable power plants were operated. The quantity ($EG_{PJ,y}$) of net electricity generation produced and fed into the grid is estimated at 1,097,000 MWh/yr for 140 MWe (Table 4); that for 280 MWe (both power plants) is estimated to be:

$$= 1{,}097{,}000 \text{ MWh/yr} \times 2$$

$$= 2{,}194{,}000 \text{ MWh/year}$$

The combined margin CO_2 emission factor for grid connected power generation in year y ($EF_{grid,\ CM,y}$), 0.594 tCO_2/MWh (KenGen, 2010) is used:

$$BE_y = 2{,}194{,}000 \text{ MWh/yr} \times 0.594 \text{ tCO2-eq/MWh}$$

$$= 1{,}303{,}236 \text{ tCO}_2\text{/year}$$

Calculating baseline emissions - Olkaria I 4th and 5th units 140 MWe
According to the UNFCCC, investment in Olkaria I 4th and 5th units entails capacity addition of 140 MWe besides the existing 45 MWe and is therefore not a new project.

The average 5 year (2004-2009) historical electricity generation data for Olkaria I (3×15 MWe) units 1, 2 and 3 was used to determine the generation by the existing plant in the baseline scenario, the assumption being that the historical situation observed prior to implementation (operation of additional power units) of the project activity would continue. The statistical standard deviation of the historical electricity data was adjusted to check for errors and offset uncertainty; otherwise, the calculated emission reductions might depend primarily on the natural variability observed during the historical period rather than on the effects of the project activity.

The quantity of net electricity generation that is produced and fed into the grid as a result of the implementation of the CDM project activity in year y (MWh/year), $EG_{PJ,y}$ was calculated using Equation 8 of the methodology ACM0002 version 12:

$$EG_{PJ,\,y} = EG_{facility,y} - (EG_{historical} + \sigma_{historical});\ until\ DATE_{BaselineRetrofit} \tag{2}$$

where $EG_{PJ,y}$ = Quantity of net electricity generation that is produced and fed into the grid as a result of the implementation of the CDM project activity in year y (MWh/year);

$EG_{facility,\,y}$ = Quantity of net electricity generation supplied by the project plant/unit to the grid in year y (MWh/year);

$EG_{historical}$ = Annual average historical net electricity generation delivered to the grid by the existing renewable energy plant that was operated at the project site prior to the implementation of the project activity (MWh/yr);

$\sigma_{historical}$ = Standard deviation of the annual average historical net electricity generation delivered to the grid by the existing renewable energy plant that was operated at the project site prior to the implementation of the project activity (MWh/yr); and

[1] The GEF is the latest value as of September 2010, computed using the latest CDM tools (as given by ACM0002version 12) from the KenGen CDM database office.

$DATE_{BaselineRetrofit}$ = Point in time when the existing equipment would need to be replaced in the absence of the project activity (date).

$EG_{historical}$ is estimated as the annual average electricity delivered by Olkaria I to the grid during the last five years, prior to the implementation of the project activity (Table 5). The standard deviation (σ) of the net electricity delivered to the grid in the past five years is estimated as follows:

TABLE 5: Recent net electricity generation to the grid for Olkaria I (45MWe) (KPLC, 2009)

Year	Net electricity delivered to the grid (GWh)
2004/2005	371
2005/2006	324
2006/2007	360
2007/2008	359
2008/2009	368
Total	1782
Average/year	**356.4**

$$\sigma = \sqrt{\sum \frac{(X_i - \bar{X})^2}{n-1}} \tag{3}$$

where σ = Standard deviation;
X_i = Represents an individual value;
$\bar{X}$ = Arithmetic mean; and
n = Number of values.

$$\sigma_{historical} = 18.8 \text{ GWh}$$

$EG_{facility,\,y}$ is the net electricity delivered to the grid by the plant/unit. The average historical value over the last five years was used (356,400 MWh/yr) for the existing Units 1, 2 and 3 (Table 5). The value used for the new project is 140 MWe (1,097,000 MWh, Table 4). Hence, if both units 1, 2 and 3 and the new 140 MWe power plant were in production:

$$EG_{facility,\,y} = 356{,}400 \text{ MWh/year} + 1{,}097{,}000 \text{ MWh}$$

$$= 1{,}453{,}400 \text{ MWh/year}$$

The quantity of net electricity generation that is produced and fed into the grid as a result of the implementation of the CDM project activity (MWh/yr) is estimated as:

$$EG_{PJ,\,y} = 1{,}453{,}400 \text{ MWh/yr} - (356{,}400 \text{ MWh/year} + 18{,}800 \text{ MWh/year})$$

$$= 1{,}078{,}200 \text{ MWh/yr}$$

$DATE_{BaselineRetrofit}$ is the typical average technical lifetime of the existing turbines. With continuous routine maintenance practices, the plant life is given about 25 years from the commissioning date, assuming an average load factor of 93% (JICA, 2010); $EG_{PJ,y}$ is, therefore, estimated at 1,078,200 MWh/yr for a 25 year period.

The combined margin CO_2 emission factor for grid connected power generation in year y, $EF_{grid,\,CM,\,y}$ = 0.594 tCO_2/MWh (KenGen CDM office, 2010), was used to estimate the baseline emissions in tCO_2/yr:

$$BE_y = 1{,}078{,}200 \text{ MWh/yr} \times 0.594 \text{ tCO}_2\text{/MWh}$$

$= 640{,}451$ tCO_2/year

Total baseline emissions
Summing up the three individual baseline emissions gives the overall baseline emissions for the projects:

1,303,236 tCO_2/year (sum; Menengai I and Olkaria IV) + 640,451 tCO_2/yr (Olkaria I)

= 1,943,687 tCO_2/year

4.2 Project emissions

Fugitive emissions of carbon dioxide and methane, due to the release of NCGs from produced steam, will account for project emissions. NCGs in geothermal reservoirs consist mainly of CO_2 and H_2S, containing a small quantity of hydrocarbons, predominantly CH_4. In geothermal power projects, NCGs flow with the steam into the power plant. In the cooling water circuit, a small quantity of the CO_2 is converted to carbonate or bicarbonate with parts of the NCGs re-injected into the geothermal reservoir. As a conservative approach, however, the methodology assumes that all NCGs entering the power plant are discharged to the atmosphere through the cooling towers. Fugitive carbon dioxide and methane emissions due to well testing and well bleeding are not considered, as they are negligible (UNFCCC, 2010).

Calculating fugitive CO_2-eq/year
Fugitive carbon dioxide and methane emissions due to the release of non-condensable gases from the produced steam ($PE_{GP,\,y}$) are estimated using Equation 1 of the methodology ACM0002 version 12;

$$PE_{GP,\,y} = (W_{steam,\,CO2,\,y} + W_{steam,\,CH4,y} \times GWP_{CH4}) \times M_{Steam,\,y} \tag{4}$$

where $PE_{GP,\,y}$ = Project emissions from the operation of geothermal power plants due to the release of NCGs in year y (tCO_2-eq/year);
$W_{steam,\,CO2,\,y}$ = Average mass fraction of carbon dioxide in the produced steam in year y (tCO_2/tsteam);
$W_{steam,\,CH4,\,y}$ = Average mass fraction of methane gas in the produced steam in year y (tCH_4/tsteam);
GWP_{CH4} = Global warming potential of methane valid for the relevant commitment period (tCO_2/tCH_4); and
$M_{Steam,\,y}$ = Quantity of steam produced in year y (tsteam/year).

Data was obtained from a study conducted by KenGen during normal monitoring of 15 Olkaria II production wells (OW701, OW-705, OW-706, OW-709, OW-710, OW-713, OW-714, OW-715, OW-716, OW-720, OW-721, OW-725, OW-726, OW-727 and OW-728) to determine the NCG composition in the produced steam. Estimated project emissions were determined using average readings from the 15 wells, although the steam monitoring data from all producing wells were used ex-post. Project emissions from the operation of a 140 MWe geothermal power plant due to the release of NCGs (Appendix II) in year y ($PE_{GP,\,y}$) were estimated. Table 6 presents the input values and estimated project emissions for one geothermal power plant (140 MWe):

TABLE 6: Project emission (tCO_2-eq/year) input values

Input values	**140 MWe**
Annual quantity of steam produced ($M_{steam,y}$); tsteam/year	4,140,000
Fraction of CO_2 in produced steam (W_{steam},$CO_{2,y}$); tCO_2/t steam	3.269×10^{-3}
Fraction of CH_4 in produced steam (W_{steam},$CH_{4,y}$); tCH_4/t steam	8.213×10^{-9}
GWP_{CH4} (tCO_2-eq/tCH_4)	21
$PE_{GP,y}$ (tCO_2-eq/yr)	13,533

$$[(0.003269\ tCO_2/tsteam) + (0.000000008213\ tCH_4/tsteam \times 21\ tCO_2\ /\ tCH_4)] \times 4{,}140{,}000\ tsteam/year$$

$$= 13{,}533\ tCO_2\text{-eq/year}$$

Total project emissions for the three geothermal projects were estimated at (13,533 tCO_2-eq/year × 3) 40,599 tCO_2-eq/year. The annual quantity of steam produced was also estimated using data from Olkaria II with the assumption that the steam flow from the wells for all the cases was the same.

4.3 Emission reductions

Emission reductions (ERs) for the projects were estimated for a 7 year (renewable) crediting period using Equation 11 of the methodology ACM0002 version 12:

$$ER_y = BE_y - PE_y \tag{5}$$

where ER_y = Emission reductions in year y (tCO_2-eq/year);
BE_y = Baseline emissions in year y (tCO_2/year); and
PE_y = Project emissions in year y (tCO_2-eq/year).

Menengai I and Olkaria IV ER_y
The total baseline emissions for both projects were estimated at 1,303,236 tCO_2/year; each project will, therefore, yield BE_y at 651,618 tCO_2/year (Appendix III). With estimated PE_y of 13,533 tCO_2-eq/year for each project:

$$ER_y = 651{,}618\ tCO2/yr - 13{,}533\ tCO_2\text{-eq/year}$$

$$= 638{,}085\ tCO_2\text{-eq/year}$$

Estimated ERs for Menengai I (Figure 10) and Olkaria IV (Figure 11) were calculated, each at 638,085 tCO_2-eq/year. With the annual estimated generation of 1,097,000 MWh in each case, implementation of each project was estimated to reduce 638,085 tCO_2-eq, generating an expected total of 4,466,595 tCO2-eq for the duration of the initial 7-year CDM crediting period.

Olkaria I units 4 and 5 ER_y
The baseline and project emissions were estimated as 640,451 tCO2/yr (BE_y) and 13,533 tCO_2-eq/year (PE_y) respectively. The calculated reduction in emissions is therefore:

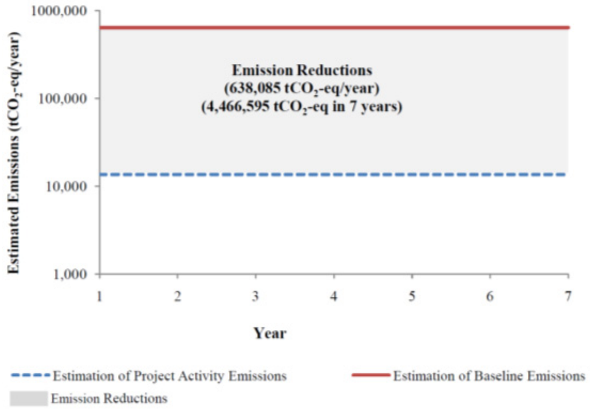

FIGURE 10: Menengai I estimated emission reductions

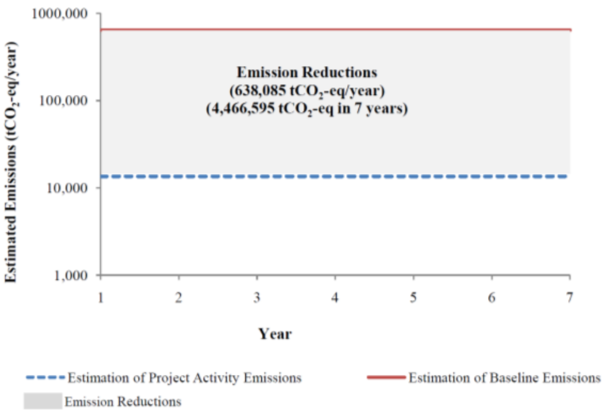

FIGURE 11: Olkaria IV estimated emission reductions

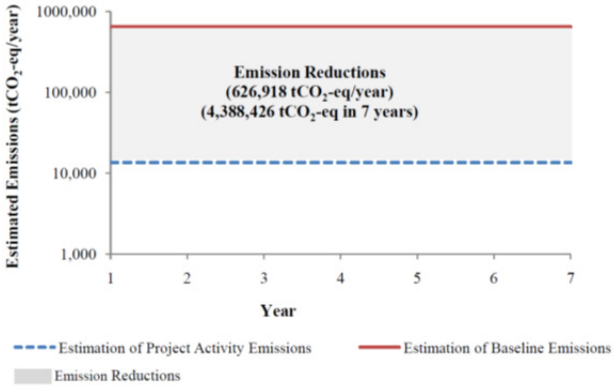

FIGURE 12: Olkaria I Units 4 and 5 estimated emission reductions

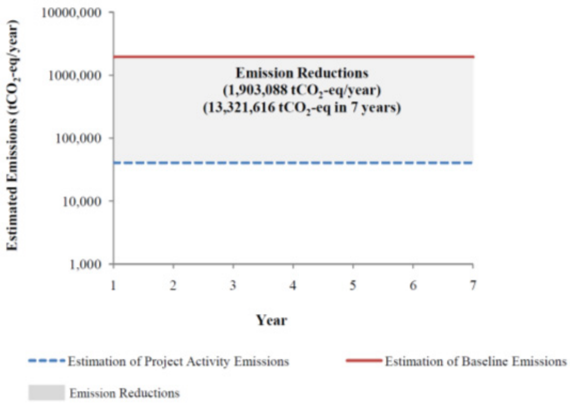

FIGURE 13: Total estimated emission reductions in 7 years

$$640{,}451 tCO2/yr - 13{,}533\ tCO_2\text{-eq/year}$$
$$= 626{,}918\ tCO_2\text{-eq/year}$$

Approximately 626,918 tCO_2-eq/year would be reduced upon implementation of the additional Olkaria I (Units 4 and 5) project (Figure 12) at an estimated generation of 1,078,200MWh/yr.

An expected total of 4,388,426 tCO_2-eq would be reduced for the duration of the first phase of the 7-year CDM crediting period (Appendix III).

Overall estimated emissions reduced in 7 years
Total baseline and project emissions were estimated at 1,943,687 tCO_2/year (*BEy*) and 40,599 tCO_2-eq/year (PE_y). The total emission reduction (Figure 13) for Menengai I, Olkaria I and IV was therefore estimated as:

$$ER_y = BE_y - PE_y = (1{,}943{,}687\ tCO_2/\text{year} – 40{,}599\ tCO_2\text{-eq/year})$$
$$= 1{,}903{,}088\ tCO_2\text{-eq/year}$$

4.4 Discussion

A key feature of the Clean Development Mechanism is *additionality*, the test of whether a project results in emission reductions in excess of those that would have been achieved in a "business-as-usual" scenario and determines whether a project should be awarded carbon credits that can be used by an Annex I country to meet its Kyoto commitments. Paragraph 43 of the protocol's Marrakech Accord establishes that a CDM project activity is additional if anthropogenic emissions of greenhouse gases by sources are reduced to levels below those that would have occurred in the absence of the registered CDM project activity (Escoto, 2007).

Based on the Emission Reduction evaluations, electricity supplies from the three geothermal project activities would enhance economic sustainability. Presently, Kenya has to rely on fossil fuel based power when hydroelectric power supply is depressed by variations in the water columns during drought periods; implementation of the projects is foreseen to ease the instability in the electrical grid power. The Republic of Kenya is therefore committed to offset the current 8% power supply deficit in the country through renewable and energy efficient technologies. Due to its high availability and reliable base load power (average of more than 95%), geothermal energy is currently the most promising indigenous resource for power development in Kenya, having an exploitable potential of about 7000 MWe against a present installed capacity of only 202 MWe.

Upon implementation of Menengai I, Olkaria I and IV geothermal projects, the total project emissions of 40,599 tCO_2-eq/year are estimated at 0.0124 tCO_2-eq/MWh. In total, about 1,903,088 tCO_2-eq will be reduced annually and 13,321,616 tCO_2-eq during the initial 7 year crediting period at an annual expected generation of 3,272,200 MWh. Carbon credits are measured in units of Certified Emission Reductions (CERs) where each CER is equivalent to one ton of carbon dioxide not emitted into the atmosphere when compared to "business as usual". Kossoy and Ambrosi (2010) report that a ton of CO_2-eq reduced gains US$ 12.7, thus the three projects, if implemented under the CDM, could generate about US$ 170 million in the initial 7 year period. Since initial geothermal projects have been modelled in units of 140 MW at an estimated capital cost of US $ 3,839/kW, according to the least cost power development of Kenya for the period 2010-2030 (Ministry of Energy, 2010), high upfront costs are involved which require intensive loans that are difficult to access. By implementation of CDM projects, financial hurdles will be eased as they will provide revenue to the project income, improving cash flow. The foreign income will minimise considerable foreign exchange risks during the purchase of power plant equipment, overcoming the high development costs of geothermal plants and thus financial and investment barriers (Kollikho, 2007). Another barrier that CDM could help overcome includes electricity tariff barriers by the Energy Regulatory Commission (ERC) of Kenya to KPLC, caused by poor financial performance (Kollikho, 2007). These tariffs have led to high interest rates being charged by commercial banks vis a vis low rates of return. CDM can be considered an additional source of revenue and can help surpass the hurdle for the Internal Rate of Return. According to Rodriguez and Henriquez (2007), roughly 5-7% of the revenue streams can be accrued from a CDM certification of a geothermal project, having an impact of between 1 and 2% on the Internal Rate of Return (IRR).

CDM benefits will hasten the development of Kenya's earmarked geothermal potential, consequently enhancing sustainable economic development. With regard to economic development, the following positive outcomes are envisaged from the project:

- Decreased dependence on fossil fuels improving the hydrocarbon trade balance through the reduction of oil imports. This will reduce the use of thermal power generation plants and leave them only for stand-by power generation. By generating energy without GHG emissions, expensive heavy fuel, diesel, and gas-fired generation will be displaced, thus reducing CO_2 emissions to the atmosphere.
- Employment opportunities for local communities within the project vicinity, especially in construction and plant management.
- Contribution to Kenya's economic revenues through the payment of taxes.
- Participatory rural appraisal through corporate social responsibilities. A designated percentage of the revenue streams can be set aside for community and infrastructure development. Facilities such as health centres, clean water and education can be appraised as most communities near the project boundaries are marginalised with limited opportunities.

5. MONITORING

The Interconnected Grid System (IGS) of Kenya is under the management of the Kenya Power and Lighting Company Ltd (KPLC) and the Kenya Transmission Company (KETRACO). KPLC takes charge of the existing transmission lines and power distribution to final consumers whilst KETRACO (recent establishment) will be in charge of the new transmission systems in the country. Monthly and daily reports of IGS actual operation will be maintained by KPLC, including half hourly generation data for all power units. KenGen and GDC will be responsible for monitoring the data and parameters required in updating the CO_2 emission factor of the Kenyan grid.

The UNFCCC-EB requires adherence to a monitoring programme with regular report submissions even after registering a project to CDM. The objective is to encourage proper project planning and development as regards robust data collection, processing, instrument calibration and archiving procedures. Key areas that will be monitored include (see Figure 7):

- Total net electricity generation delivered to the grid by each project activity; readings will be obtained from electrical meters. During installation, the meters will meet all relevant local standards and shall be factory calibrated by the manufacturer. To ensure accurate meter measurements, regular maintenance shall be upheld. Meter information including type, model, brand and calibration documentation will be archived in the quality control system on-site.
- Steam quantity consumed by the projects. Steam flows in pipelines from several production wells and is used by the project to produce electricity. A Venturi steam flow meter will thus be used to measure the steam flow rate consumed by the project at the production wells. Measurements will be done on a daily basis and recorded regularly in production reports.
- The average mass fraction of carbon dioxide in the produced steam. Measurements and monitoring will be carried out at least every 3 months. The sampling procedure and method of analysis to be used must be in accordance with the procedures required by the approved methodology.
- The average mass fraction of methane in the produced steam. Measurements and monitoring will be carried out at least every 3 months. The sampling procedure and method of analysis to be used must be in accordance with the procedures required by the approved methodology.

Commissioning dates of the projects will define the commencement of the monitoring plan to the end of the crediting period. All measurements will be conducted with calibrated measuring equipment according to relevant industry standards. Monitoring data is to be archived both electronically and physically and kept for at least two years after the end of the last crediting period. Information and data will be backed up regularly and records stored electronically. Hard copies of the data shall also be maintained for verification purposes.

6. CONCLUSIONS

Stable, renewable and local supply of electricity from geothermal energy will permit the displacement of carbon-intensive power generation and thus contribute to sustainable development. Accelerated deployment of geothermal energy in Kenya will foster a reduction in CO_2 emissions which has global implications in terms of climate change mitigation. CDM will help offset key geothermal development hurdles and revenue returns will enhance economic development. Implementation of the proposed projects as CDM will derive great environmental, social and economic benefits for Kenya, becoming the cornerstone of sustainable development.

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APPENDIX I: Site layout of the power plants

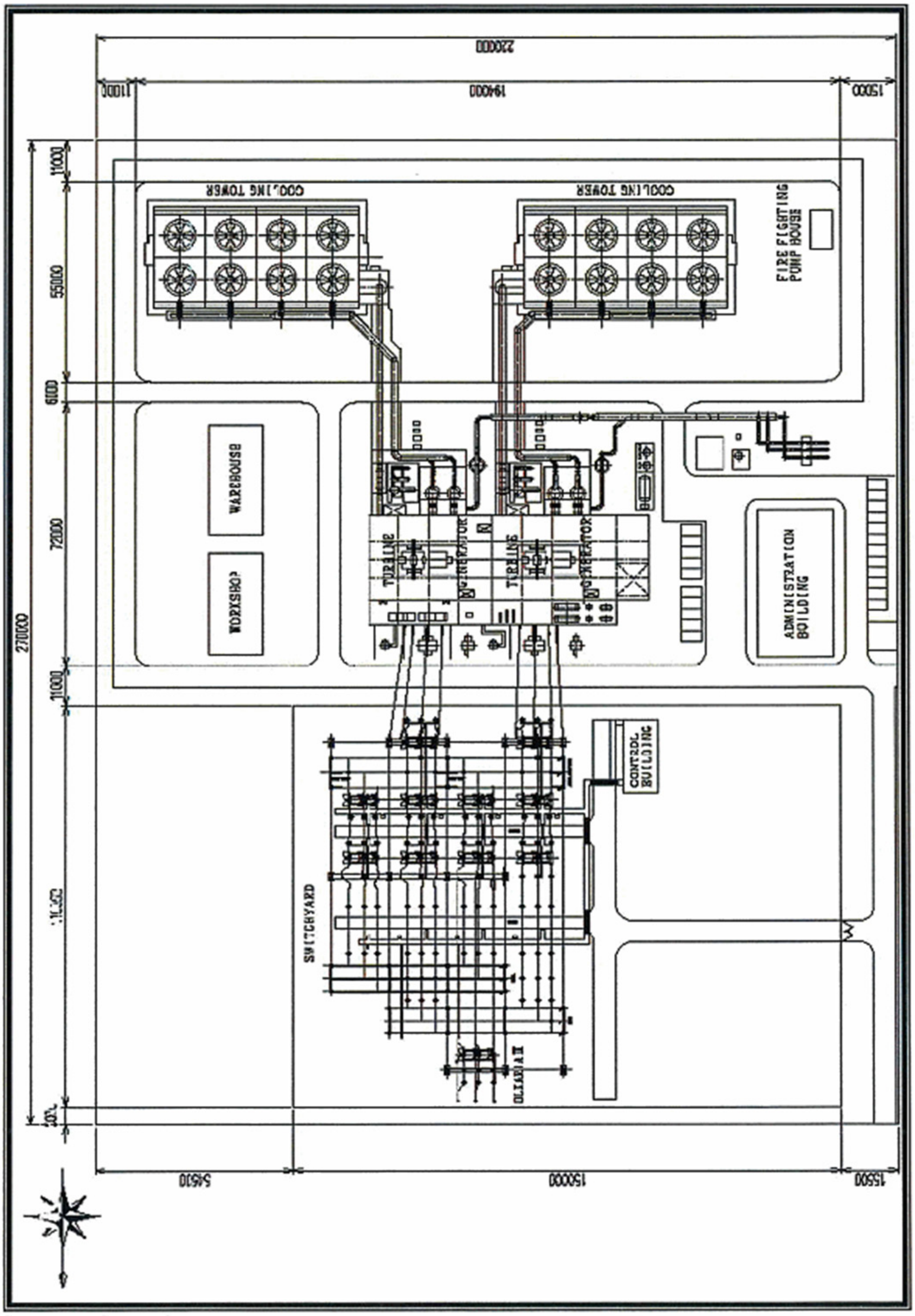

FIGURE 1: Site layout (GIBB Africa, 2009a; 2009b)

APPENDIX II: $W_{steamCO2,\,y}$ (tCO$_2$/tsteam) and $W_{steamCH4,\,y}$ (tCH$_4$/tsteam) – Olkaria II production wells

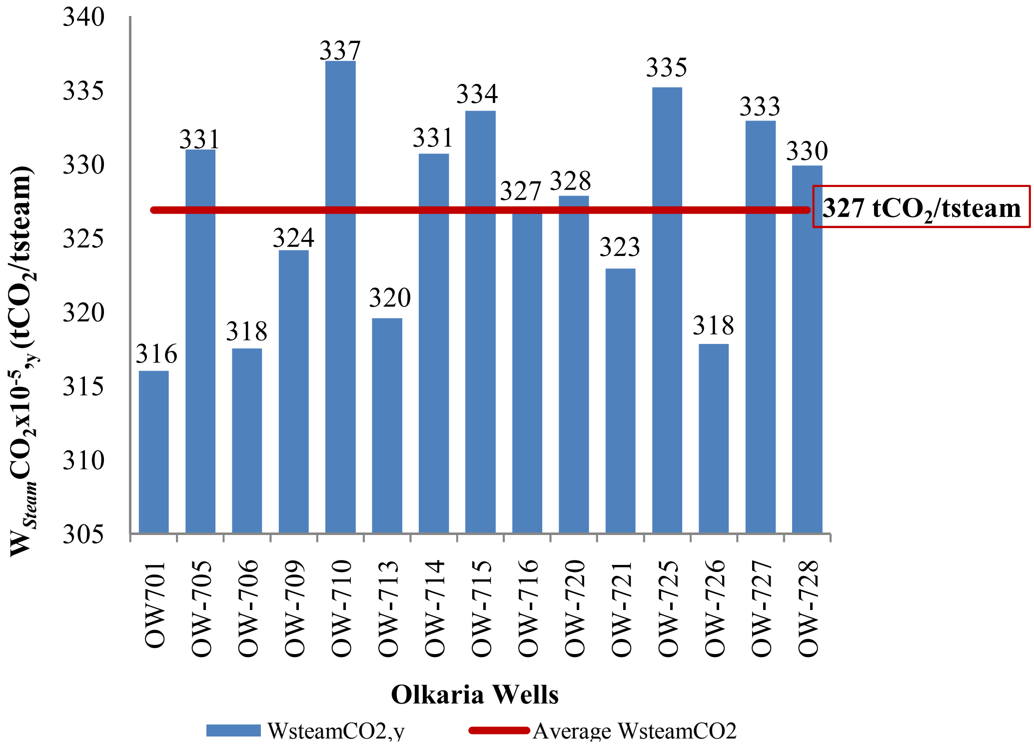

FIGURE 1: $W_{steamCO2,\,y}$ (tCO$_2$/tsteam) – 15 Olkaria II production wells

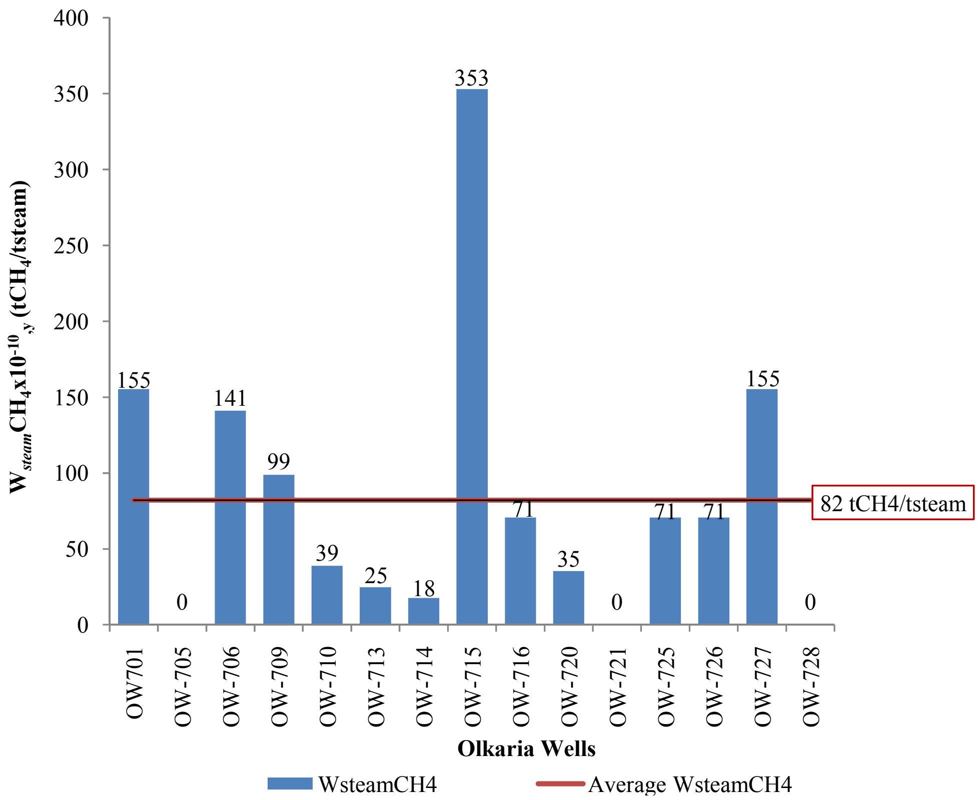

FIGURE 2: $W_{steam}CH_{4,\,y}$ (tCH$_4$/tsteam) – 15 Olkaria II production wells

APPENDIX III: Summary of the ex-ante estimation of emission reductions

TABLE 1: Menengai I (140 MWe)

Year	Estimation of project activity emissions (tCO_2-eq/yr)	Estimation of baseline emissions (tCO_2-eq/yr)	Estimation of leakage (tCO_2-eq/yr)	Estimation of overall emissions reductions (tCO_2-eq/yr)
July2012 – June2013	13,533	651,618	0	638,085
July2013 – June2014	13,533	651,618	0	638,085
July2014 – June2015	13,533	651,618	0	638,085
July2015 - June2016	13,533	651,618	0	638,085
July2016 - June2017	13,533	651,618	0	638,085
July2017 – June2018	13,533	651,618	0	638,085
July2018 – June2019	13,533	651,618	0	638,085
Total	**94,731**	**4,561,326**	**0**	**4.466.595**

TABLE 2: Olkaria IV (140 MWe)

Year	Estimation of project activity emissions (tCO_2-eq/yr)	Estimation of baseline emissions (tCO_2-eq/yr)	Estimation of leakage (tCO_2-eq/yr)	Estimation of overall emissions reductions (tCO_2-eq/yr)
July 2013 – June 2014	13,533	651,618	0	638,085
July 2014 – June 2015	13,533	651,618	0	638,085
July 2015 – June 2016	13,533	651,618	0	638,085
July 2016 - June 2017	13,533	651,618	0	638,085
July 2017 - June 2018	13,533	651,618	0	638,085
July 2018 – June 2019	13,533	651,618	0	638,085
July 2019 – June 2020	13,533	651,618	0	638,085
Total	**94,731**	**4,561,326**	**0**	**4,466,595**

TABLE 3: Olkaria I Units 4 and 5 (140 MWe)

Year	Estimation of project activity emissions (tCO_2-eq/yr)	Estimation of baseline emissions (tCO_2-eq/yr)	Estimation of leakage (tCO_2-eq/yr)	Estimation of overall emissions reductions (tCO_2-eq/yr)
July 2013 – June 2014	13,533	640,451	0	626,918
July 2014 – June 2015	13,533	640,451	0	626,918
July 2015 – June 2016	13,533	640,451	0	626,918
July 2016 - June 2017	13,533	640,451	0	626,918
July 2017 - June 2018	13,533	640,451	0	626,918
July 2018 – June 2019	13,533	640,451	0	626,918
July 2019 – June 2020	13,533	640,451	0	626,918
Total	**94,731**	**4,483,157**	**0**	**4,388,426**

TABLE 4: Total emissions from Menengai I, Olkaria IV, and Olkaria I Units 4 and 5 (420 MWe)

Year	**Estimation of project activity emissions (tCO_2-eq/yr)**	**Estimation of baseline emissions (tCO_2-eq/yr)**	**Estimation of leakage (tCO_2-eq/yr)**	**Estimation of overall emissions reductions (tCO_2-eq/yr)**
July 2013 – June 2014	40,599	1,943,687	0	1,903,088
July 2014 – June 2015	40,599	1,943,687	0	1,903,088
July 2015 – June 2016	40,599	1,943,687	0	1,903,088
July 2016 - June 2017	40,599	1,943,687	0	1,903,088
July 2017 - June 2018	40,599	1,943,687	0	1,903,088
July 2018 – June 2019	40,599	1,943,687	0	1,903,088
July 2019 – June 2020	40,599	1,943,687	0	1,903,088
Total	**284,193**	**13,605,809**	**0**	**13,321,616**