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GEOTHERMAL PROJECT FUNDING THROUGH THE CLEAN DEVELOPMENT MECHANISM

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ABSTRACT

The United Nations have established the United Nations Framework Convention on Climate Change, the Kyoto Protocol, and the Clean Development Mechanism (CDM) in response to indications of human induced climate change that, if left unchecked, has the potential of altering the global environment significantly. One way to stem this development is to reduce the emissions of greenhouse gases into the atmosphere through the use of renewable energy sources, such as geothermal energy, in place of fossil fuels. In this paper, the role of CDM in supporting geothermal energy projects in the developing countries is discussed and the registration process for Certified Emission Reduction (CER) credits is explained. The rules and formulas for calculation of emission reductions are presented along with project activity statistics and latest developments.

1. INTRODUCTION

Paleoclimatic studies indicate that Earth's average surface temperature has varied significantly through the eons (Figure 1). For the better part of the last 100 million years, the temperature has been warmer than at present, resulting in a substantially different global environment from that which humanity or its immediate ancestors have known. The records for the last 3 million years, however, show that the mean global temperature during that period has been lower than at present and it is necessary to go back to the Mid-Pliocene (about 3.3 to 3.0 million years ago (Ma)) to find a sustained period when the

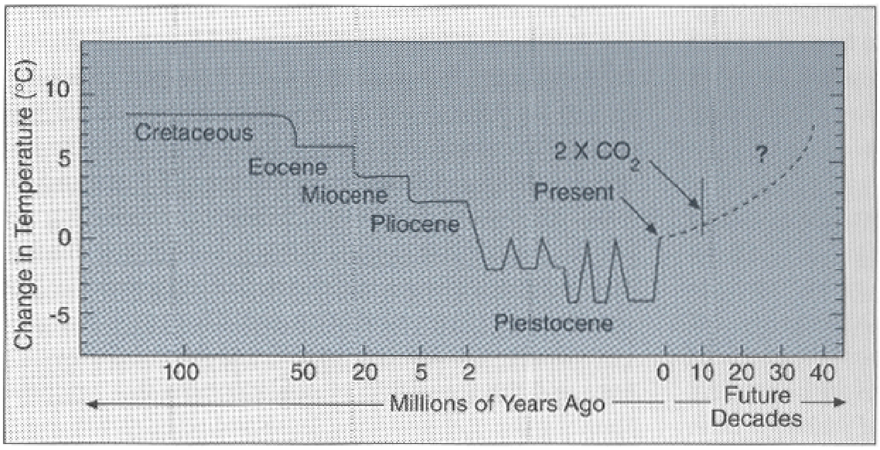


FIGURE 1: A schematic reconstruction of mean global surface temperature through the last 100 million years, based on analyses of various marine and terrestrial deposits (Crowley, 1996)

temperature was significantly warmer (Jansen et al., 2007). Paleontology, archaeology, genetics and other fields put this period in perspective with human evolution (New Scientist, 2012):

- The first hominines moved from the forest to the savannah 3.5-1.8 Ma;
- Homo habilis appeared around 2.5 Ma, introducing the first simple stone tools;
- Homo erectus appeared about 2 Ma;
- The first wave of migration out of Africa took place about 1.8 Ma;
- The first use of fire took place around 1.6 Ma;
- Purpose-built shelters appeared around 0.5 Ma;
- Homo sapiens appeared about 195,000 years ago;
- Clothing was invented about 72,000 years ago;
- Agriculture began and the first villages appeared about 10,000 years ago, soon after the onset of the present interglacial period, the Holocene.

Thus, humanity has been brought up on a planet where the average surface temperature has not significantly exceeded the current average temperature and for the most part, it has been lower.

The agricultural revolution and the consequential population increase slowly started to affect the climate with the associated clearing of forests and changes in land use. The recent industrial revolution allowed humanity to process and consume natural resources at a much faster rate than had previously been possible, leading to improved living conditions and further population increase, but with more pronounced effects on the planet‘s climate. Although Nature dictated the climatic and environmental conditions in which the human species evolved, humanity has itself now become a major influence on climate through its use of fossil fuels for energy supply, chemical industry, and changes in land use. While life has been interacting with the climate for hundreds of millions of years (e.g. through the effect of photosynthesis on CO_2/O_2 concentrations), humanity can be looked upon as a very recent forcing influence, the likes of which the planet has not witnessed before.

About 343 W/m^2 of solar energy strikes the Earth on average and 30% is reflected back to space, leaving about 240 W/m^2 to be absorbed (Seinfeld and Pandis, 1998). The annual average surface temperature of the planet is controlled by this input, the opaqueness of the atmosphere to infrared radiation, and the balancing of radiation input with heat emission into space. If the atmosphere were completely transparent to infrared radiation, the average surface temperature would be around -19°C, as can be derived by looking at the Earth as a blackbody and applying the Stefan-Boltzmann law to balance outgoing radiation with absorbed solar radiation. Fortunately, the absorption of infrared radiation by greenhouse gases keeps the current annual mean surface temperature considerably higher, at around 14°C. Greenhouse gases are therefore responsible for keeping the surface about 33°C warmer than it would be if the atmosphere were completely transparent to infrared radiation and thus contribute significantly to current environmental conditions and habitability of the planet.

Some major greenhouse gases are water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), oxygen and ozone (O_2/O_3), and nitrous oxide (N_2O), and each has a distinct absorption band signature (Figure 2). The combined effect of these and other greenhouse gases is that only about 10% of the infrared radiation emitted from the Earth‘s surface penetrates the atmosphere directly through the atmospheric window (Nazaroff, 2004). The remainder is absorbed. An increase in the infrared opacity of the atmosphere brought about by the accumulation of these gases has a similar effect as adding insulation to a building or covering a veranda with glass. In order for the outgoing energy flux to balance the incoming flux, the temperature has to rise.

The onset of the industrial revolution called for increased usage of coal and later oil and gas. In 2009, fossil fuels accounted for 81% of the global primary energy supply of 12,150 Mtoe (508.70 EJ) and the associated CO_2 emissions were estimated at 28,999 Megatons (Mt) (OECD/IEA, 2011a). In 1973, the corresponding figures were 6,111 Mtoe (255.9 EJ) and 15,624 Mt. Fuel CO_2 emissions have thus increased almost 86% over 36 years.

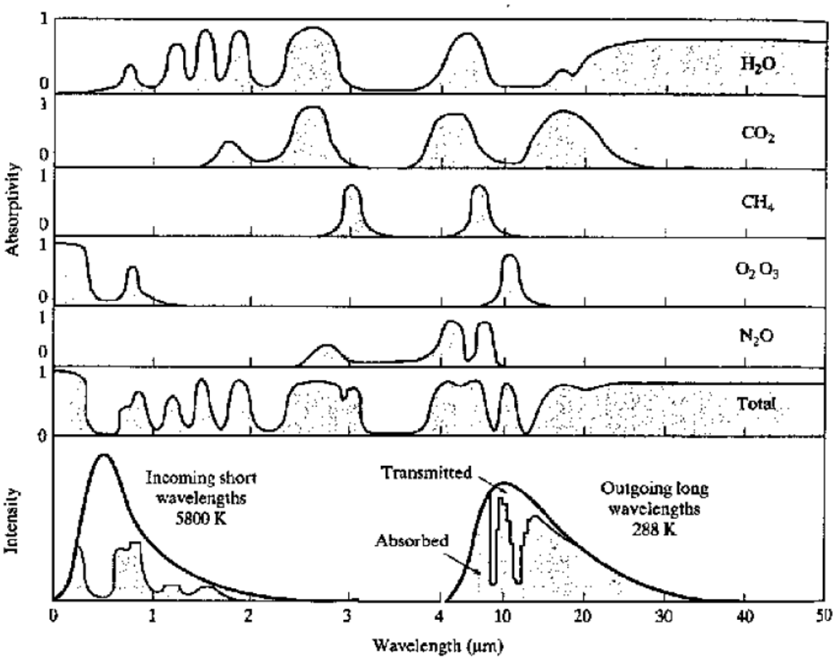


FIGURE 2: Absorptivity as a function of wavelength for several major greenhouse gases and the total absorptivity of the atmosphere (Masters, 1998)

The pre-industrial level of CO_2 over the last 1000 years, as determined from ice core records, was 280 ppm with fluctuations up to 10 ppm (Seinfeld and Pandis, 1998). In January 2012, the average CO_2 concentration measured at Mauna Loa on Hawaii was 393.09 ppm, which is a 40% increase from pre-industrial levels (NOAA, 2012). The concentration has increased from about 316 ppm in 1959 (Figure 3), with an average increase in the annual mean growth rate over the last 5 decades (Figure 4).

In 1895, Svante Arrhenius suggested that a 40% increase or decrease in the atmospheric abundance of the trace gas CO_2 might trigger the glacial advances and retreats (Le Treut et al., 2007). Over the more than a century that has passed since then, a greater understanding of the effects of CO_2 and other greenhouse gases on climate, as well as of the climate system itself, has gradually been attained. Scientists have come to realize that continued pumping of greenhouse gases into the atmosphere and the resulting increase in concentrations, has the potential of triggering significant climate change over a short time scale. In response to rising concerns about such human-induced climate change, the World Meteorological Organization and the United Nations Environment Programme established the Intergovernmental Panel on Climate Change (IPCC) in 1988, with the mandate of filling knowledge gaps and to transfer information on climate issues to governments and intergovernmental organizations. The first IPCC assessment report (FAR), which was published in 1990, played an

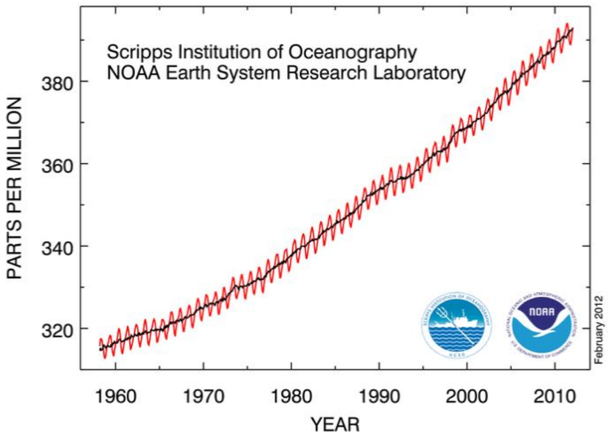


FIGURE 3: Atmospheric CO_2 at Mauna Loa Observatory (NOAA, 2012)

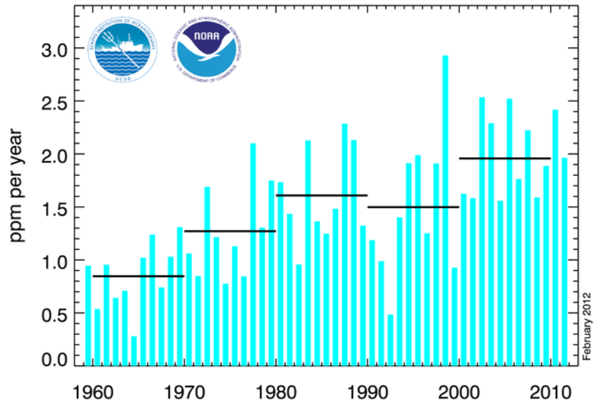


FIGURE 4: Annual mean growth rate of CO_2 at Mauna Loa (NOAA, 2012)

important role in the discussions of the Intergovernmental Negotiating Committee for the United Nations Framework Convention on Climate Change (UNFCCC), which was adopted in 1992 and entered into force in 1994. The second assessment report (SAR), which was published in 1996, provided key input to the negotiations that led to the adoption in 1997 of the Kyoto Protocol (Le Treut et al., 2007).

2. UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC)

The United Nations Framework Convention on Climate Change was adopted at the Rio Earth Summit in 1992, along with the UN Convention on Biological Diversity and the Convention to Combat Desertification (UNFCCC, 2012a).

The Convention sets an overall framework for intergovernmental efforts to tackle the challenge posed by climate change (UNFCCC, 2012b). It recognizes that the climate system is a shared resource whose stability can be affected by industrial and other emissions of carbon dioxide and other greenhouse gases.

The UNFCCC establishes a Conference of the Parties (COP) as the supreme body of the Convention and bestows upon it the responsibility to keep under review the implementation of the Convention and any related legal instruments that the COP may adopt and shall make, within its mandate, the decisions necessary to promote the effective implementation of the Convention (UN, 1992). The first meeting of the COP was held in Berlin in 1995 and since then the meetings have been held almost annually. They are usually referred to by their sequential number and often also the place name where they are held, e.g. COP 17 in Durban.

Article 2 of the Convention presents its objective:

> The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

The Parties to the Convention are divided into two main groups and one subgroup: Annex I, Non-Annex I, and Annex II.

Annex I Parties include the industrialized countries that were members of the OECD in 1992, plus countries with economies in transition (the EIT Parties), including the Russian Federation, the Baltic States, and several Central and Eastern European States (UNFCCC, 2012c).

Non-Annex I Parties are mostly developing countries. Certain groups of developing countries are recognized by the UNFCCC as being especially vulnerable to the adverse impacts of climate change. The Convention emphasizes activities that promise to answer the special needs and concerns of these vulnerable countries, such as investment, insurance and technology transfer (UNFCCC, 2012c).

Annex II Parties consist of the OECD members of Annex I, but not the EIT Parties. They are required to provide financial resources to enable developing countries to undertake emissions reduction activities under the Convention and to help them adapt to adverse effects of climate change. In addition, they have to take all practicable steps to promote the development and transfer of environmentally friendly technologies to EIT Parties and developing countries. Funding provided by

Annex II Parties is channeled mostly through the Convention's financial mechanism (UNFCCC, 2012c).

The Convention does not set specific limits on greenhouse gas emissions and contains no enforcement mechanisms. It is considered as being legally non-binding and enjoys nearly universal membership, as 195 countries have signed on.

Article 17 allows the COP to adopt protocols to the Convention.

3. THE KYOTO PROTOCOL

COP 2 in Geneva in 1996 called for legally binding emissions targets and COP 3 in Kyoto subsequently adopted the Kyoto Protocol on 11 December 1997. The detailed rules for its implementation were laid out at COP 7 in Marrakesh (the Marrakesh Accords) in 2001, and the Protocol entered into force on 16 February 2005.

The Protocol set binding targets for 37 industrialized countries and the European Community for reducing greenhouse gas emissions (the Annex I Parties of the UNFCCC) (UNFCCC, 2012d). The Protocol has been ratified by 192 States (UNFCCC, 2012e).

Article 3 of the Protocol addresses the targets (UN, 1998):

> The Parties included in Annex I shall, individually or jointly, ensure that their aggregate anthropogenic carbon dioxide equivalent emissions of the greenhouse gases listed in Annex A do not exceed their assigned amounts, calculated pursuant to their quantified emission limitation and reduction commitments inscribed in Annex B and in accordance with the provisions of this Article, with a view to reducing their overall emissions of such gases by at least 5 per cent below 1990 levels in the commitment period 2008 to 2012.

Several important points are addressed in this clause:

- Emission reductions are benchmarked to 1990 emission levels;
- A commitment period is spelled out: 2008-2012;
- A target is set for *overall* emissions reduction: 5% below 1990 emission levels;
- Targets are set for *each* Annex I country as listed in Annex B of the Protocol: 92-110%.

The greenhouse gases that the Protocol addresses are listed in Annex A as:

- Carbone dioxide (CO_2);
- Methane (CH_4);
- Nitrous oxide (N_2O);
- Hydrofluorocarbons (HFCs);
- Perfluorocarbons (PFCs);
- Sulfur hexafluoride (SF_6).

As the international community had reached an agreement on the phase-out of chlorofluorocarbons (CFCs) in the Montreal Protocol of 1987, it was unnecessary to include them in the list, despite their potency as greenhouse gases.

The Kyoto Protocol envisions successive commitment periods for which the Parties commit to emission ceilings that may differ from one period to the next. According to the Protocol, the COP shall initiate the consideration of commitments for subsequent periods at least 7 years before the end of the first commitment period (UN, 1998).

The Conference of the Parties of the UNFCCC serves as the Meeting of the Parties (MOP) of the Kyoto Protocol. It is worth noting that the groups comprising the Parties to the Convention and the Parties to the Protocol are not the same. The group of Parties to the Kyoto Protocol is a subset of the group of Parties to the Convention. The United States is an example of a country that is a Party to the Convention, but that has not ratified the Protocol. The text of the Protocol refers to meetings of its Parties as the *Conference of Parties serving as the meeting of the Parties to this Protocol*. These meetings are often abbreviated as COP/MOP or CMP, e.g. COP 17/MOP 7 in Durban.

While Parties must meet their targets primarily through national measures, the Protocol also offers additional means of meeting these targets through 3 market based flexibility mechanisms (UNFCCC, 2012d):

- Emissions trading (carbon markets);
- Clean Development Mechanism (CDM);
- Joint Implementation (JI).

One of these, the Clean Development Mechanism, and its role in supporting geothermal development is discussed in the following sections.

4. THE CLEAN DEVELOPMENT MECHANISM (CDM)

4.1 Introduction

As stated in Article 3 of the Kyoto Protocol, the goal was 5% overall emissions reductions compared to 1990 levels for the Annex I countries in the first commitment period, but the Non-Annex I countries did not commit to any reductions. While this arrangement constrained emissions of developed countries, global emissions could be expected to increase over the period due to industrialization of the developing countries. As designing and implementing new efficient processes (e.g. in electricity generation or chemical industry) is often more economical than re-designing and altering older ones to reach the same efficiency, the Kyoto Protocol presents CDM as a way for developed countries to partially fulfill their obligations by supporting the implementation of efficient processes in the developing countries where other more inefficient ones could otherwise be expected. In this way, some of the expected increase in emissions in developing countries is moved over to the developed countries to legitimately raise the negotiated emission limitations. This arrangement should not lead to increased overall emissions for Annex I and Non-Annex I countries as a whole, but should save money on both sides as well as encouraging technology transfer from developed to developing countries.

Article 12 of the Kyoto Protocol presents the Clean Development Mechanisms in the following manner (UN, 1998):

- The purpose of the Clean Development Mechanism shall be to assist Parties not included in Annex I in *achieving sustainable development* and in contributing to the ultimate objective of the Convention, and to assist Parties included in Annex I in *achieving compliance* with their quantified emission limitation and reduction commitments under Article 3.

- Under the Clean Development Mechanism:

  - Parties not included in Annex I will benefit from project activities resulting in *Certified Emission Reductions*; and
  - Parties included in Annex I may use the *Certified Emission Reductions* accruing from such project activities to contribute to compliance with part of their quantified emission limitation and reduction commitments under Article 3, as determined by the Conference of the Parties serving as the Meeting of the Parties to this Protocol.

- The Clean Development Mechanism shall be subject to the authority and guidance of the Conference of the Parties serving as the Meeting of the Parties to this Protocol and be supervised by an *executive board*...

- Emission reductions resulting from each project activity shall be *certified* by *operational entities* to be designated by the Conference of the Parties serving as the Meeting of the Parties to this Protocol on the basis of:
  - *Voluntary participation* approved by each Party involved;
  - *Real, measurable, and long-term benefits* related to the mitigation of climate change; and
  - Reductions in emissions that are *additional* to any that would occur in the absence of the certified project activity.

- The Clean Development Mechanism shall assist in *arranging funding* of certified project activities as necessary.

- The Conference of the Parties serving as the Meeting of the Parties to this Protocol shall ... elaborate modalities and procedures with the objective of ensuring transparency, efficiency and accountability through *independent auditing and verification* of project activities.

- The Conference of the Parties serving as the Meeting of the Parties to this Protocol shall ensure that a share of the proceeds from certified project activities is used to cover *administrative expenses* as well as to assist developing country Parties that are particularly vulnerable to the adverse effects of climate change to meet the costs of adaptation.

- Participation under the Clean Development Mechanism, including in ... the acquisition of certified emission reductions, may involve *private and/or public entities*, and is to be subject to whatever guidance may be provided by the *executive board*...

Several important concepts of the CDM that are italicized in the text above, as well as some additional ones, are addressed in the following subsections.

4.1.1 Baseline emissions

It is taken for granted that developing countries need to increase energy consumption and various production activities in order to industrialize. That can be achieved by running business as usual, e.g. by developing new projects that are replicas of projects that already exist in the countries and therefore emit the same amount of CO_2 equivalents per unit output, on average. Such expansion of activities is one example of a *baseline* scenario, as it provides a reference to which different scenarios can be compared. Other possible baseline scenarios may assume the gradual introduction of more efficient processes, which lower the average CO_2 equivalent emissions per unit output with time. The emissions resulting from expansion under a baseline scenario are referred to as *baseline emissions* (Figure 5).

A report of the COP 11/MOP 1 in Montreal in 2005 defines the *baseline* for a CDM project activity as the scenario that reasonably represents the anthropogenic emissions by sources of greenhouse gases that would occur in the absence of the proposed project activity (UNFCCC, 2006).

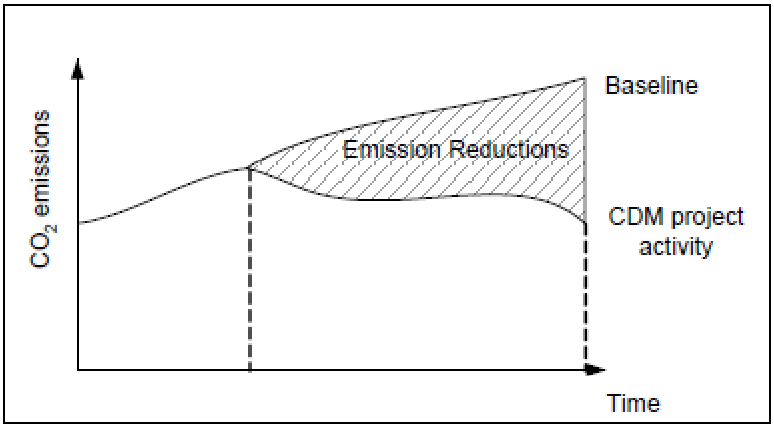


FIGURE 5: Identification of emission reductions as the difference between baseline and project emissions (Salas, 2008)

4.1.2 Project emissions

Project emissions refer to the emissions of a new project.

4.1.3 Certified Emission Reductions (CERs)

If accumulated project emissions over a specific period are lower than accumulated emissions under the baseline scenario would be over the same period, emission reductions develop (Figure 5). An independent monitoring/auditing entity can verify that such emission reductions have taken place over the period and issue Certified Emission Reduction credits (CERs) that can be sold by the developing country project operator to parties in developed countries that are interested in buying, for example because it is cheaper to raise their emission quotas that way to match real emissions than to retrofit their projects to emit less. In this way, CERs become a commodity that can be traded. One credit is issued per ton of CO_2 equivalent that is kept from entering the atmosphere, in the developing country, as a result of the project.

A certain amount of CERs are allowed into the European Union Emissions Trading Scheme (EU ETS), which expands the market for the credits. A 2% levy on CERs issued by the CDM is used as the main source of income for the UNFCCC Adaptation Fund, which was established to finance adaptation projects and programs in developing country Parties to the Kyoto Protocol that are particularly vulnerable to the adverse effects of climate change (UNFCCC, 2012f).

4.1.4 Executive board (UNFCCC, 2012g)

The CDM Executive Board (CDM EB) supervises the Clean Development Mechanism under the authority and guidance of the Conference of the Parties. The CDM EB is fully accountable to the COP. The CDM EB is the ultimate point of contact for CDM Project Participants for the registration of projects and the issuance of CERs.

4.1.5 Designated National Authority (UNFCCC, 2012h)

A Designated National Authority (DNA) is the body granted responsibility by a Party to authorize and approve participation in CDM projects. Establishment of a DNA is one of the requirements for participation by a Party in the CDM. The main task of the DNA is to assess potential CDM projects to determine whether they will assist the host country in achieving its sustainable development goals and to provide a letter of approval to project participants in CDM projects. This letter of approval must confirm that the project activity contributes to sustainable development in the country. It is then submitted to the CDM Executive Board to support the registration of the project.

4.1.6 Designated Operational Entities – Validators and verifiers (UNFCCC, 2012i)

A Designated Operational Entity (DOE) is an *independent auditor* accredited by the CDM Executive Board to *validate* project proposals or *verify* whether implemented projects have achieved planned greenhouse gas emission reductions.

4.1.7 Monitoring

The glossary of CDM terms defines *monitoring* of a CDM project activity in the following way (UNFCCC, 2009a):

> Monitoring refers to the collection and archiving of all relevant data necessary for determining the baseline, measuring anthropogenic emissions by sources of greenhouse gases (GHG) within the project boundary of a CDM project activity and leakage, as applicable.

Monitoring methodologies are issued by the CDM Executive Board in order to set the rules for monitoring (UNFCCC, 2009a):

> A monitoring methodology refers to the method used by project participants for the collection and archiving of all relevant data necessary for the implementation of the monitoring plan.

These methodologies may differ depending on project type. The applicant may propose a new monitoring methodology, which needs to be approved by the CDM EB. If a methodology is approved, it is made publicly available along with any relevant guidance for use by others. Two such approved methodologies exist for geothermal projects (Section 5). The COP/MOP may request revision of an approved methodology.

The applicant for CDM registration of a project needs to present a *monitoring plan* to the DOE responsible for emission reductions verification (UNFCCC, 2009a):

> The monitoring plan shall include a description of the proposed statistically sound sampling method/procedure to be used by DOEs for verification of the amount of reductions of anthropogenic emissions by sources or removals by sinks of greenhouse gases... In case the coordinating/managing entity opts for a verification method that does not use sampling but verifies each CDM program activity (whether in groups or not, with different or identical verification periods) a transparent system is to be defined and described that ensures that no double accounting occurs and that the status of verification can be determined anytime for each activity.

The project participants shall also provide to the DOE, contracted by the project participants to perform the verification, a *monitoring report* in accordance with the registered monitoring plan (UNFCCC, 2006).

4.1.8 Voluntary participation

One of the fundamental principles of the CDM is that the participation by Parties is voluntary. Written approval of voluntary participation is a requirement for validation as stated in a report of the COP 11/MOP 1 in Montreal (UNFCCC, 2006):

> The Designated Operational Entity shall prior to the submission of the validation report to the Executive Board, have received from the project participants written approval of voluntary participation from the Designated National Authority of each Party involved,

including confirmation by the host Party that the project activity assists it in achieving sustainable development.

4.1.9 Real, measureable and long-term benefits (Baker & McKenzie, 2012a)

The Designated Operational Entity engaged to verify and certify the emission reductions from the registered project must ensure that those emission reductions are *real, measurable and long-term*. In verifying that emission reductions are *real*, the DOE must conduct an ex post examination of the monitoring report to ensure that emission reductions have taken place and are attributable to the project activity. Emission reductions must be *measurable* in the sense that they are calculated using approved baseline and monitoring methodologies (Section 5), or new methodologies developed in accordance with the rules for submitting new methodologies and subsequently approved by the Executive Board. Finally, the requirement that emission reductions be *long-term* is particularly relevant for afforestation and reforestation, where the permanence of emission removals by forest sinks must be confirmed to ensure that climate benefits will not be reversed.

4.1.10 Additionality

In a report of the COP 11/MOP 1 in Montreal, additionality is addressed in the following way (UNFCCC, 2006): A CDM project activity is *additional* if anthropogenic emissions of greenhouse gases by sources are reduced below those that would have occurred in the absence of the registered CDM project activity. CERs should thus not be issued unless additionality can be demonstrated. The calculated emission reductions resulting from a new project depend upon the baseline scenario used as a reference. As mentioned before, this can be done by assuming that all new projects implemented over a specific period after the commissioning of the CDM project in question would emit the same amount of CO_2 equivalents per unit output as the average greenhouse gas emitting project at that point in time. Alternatively, the gradual introduction of more efficient processes can be assumed to take place over the period as a consequence of advances in technology and increased availability of such technology, or other measures resulting in lowered emissions. The determination of the baseline and emission reductions is therefore not straightforward and is always subject to some hypothetical arguments. Due to the possibility of subjective influences playing a role in this determination, the CDM EB issues specific methodologies for each type of project that lay out the rules on how to calculate baselines and emission reductions. It is worth noting, however, that in order to demonstrate *additionality*, it suffices to show that emissions from the most efficient baseline scenario that can be considered plausible, are still higher than the emissions from the CDM project in question.

Additionality is demonstrated and assessed using the latest version of the *Tool for the demonstration and assessment of additionality*, published by the CDM Executive Board.

4.1.11 Arrangement of funding

In response to the requirement that the Clean Development Mechanism assist in *arranging funding* of certified project activities, the UNFCCC has established the CDM Bazaar, which is a web based facility that serves as a platform for exchange of information on CDM project opportunities. It was established by the CDM Executive Board to make publicly available relevant information on proposed CDM project activities in need of funding and on investors seeking opportunities, in order to assist in arranging funding of CDM projects activities, as necessary (UNEP Risø Center, 2012). The key objective is to facilitate the creation of an efficient global CDM market through sharing information related to project activities and transactions of CERs among stakeholders worldwide. The Bazaar therefore provides a cost-free venue to link sellers and buyers of CERs, with the aim of minimizing transaction costs.

4.1.12 Administrative expenses

The COP 11/MOP 1 in Montreal decided (UNFCCC, 2006):

> ...with a view to accruing resources to cover *administrative expenses* for operational functions as of 2008, and with the understanding that the issuance of Certified Emission Reductions ... shall be effected only when the share of proceeds to cover *administrative expenses* has been received, that the share of proceeds to cover *administrative expenses* of the Clean Development Mechanism ... shall be:
>
> - USD 0.10 per Certified Emission Reduction issued for the first 15,000 tons of CO_2 equivalent for which issuance is requested in a given calendar year;
> - USD 0.20 per Certified Emission Reduction issued for any amount in excess of 15,000 tons of CO_2 equivalent for which issuance is requested in a given calendar year.

Project developers that apply for issuance of CERs through the CDM must also pay a registration fee as an advance payment of the share of proceeds due for the issuance of CERs likely to be achieved during the first year (UNFCCC, 2010a).

4.2 Project cycle

A developer interested in registering a project as a CDM project eligible for CERs issuance, must subject to the CDM project cycle (Figure 6), which is described below.

4.2.1 Project design (UNFCCC, 2012j)

If the project participant proposes a new baseline and/or monitoring methodology, it is passed on to the CDM Executive Board through the relevant Designated Operational Entity. When the methodology has been approved, or if a previously approved methodology is used, the participant prepares and submits a Project Design Document (CDM-PDD) detailing information about the proposed CDM project to a Designated Operational Entity, using the CDM-PDD form developed by the CDM EB.

4.2.2 National approval (UNFCCC, 2012j)

The project participant secures a letter of approval from his country, which is a Non-Annex I Party to the Kyoto Protocol. The Designated National Authority of the country submits a letter indicating that:

- The country has ratified the Kyoto Protocol;
- Participation is voluntary;
- The project activity contributes to sustainable development, as stated by the host Party.

4.2.3 Validation (UNFCCC, 2012j)

Validation is the process of independent evaluation of a project activity by an accredited Designated Operational Entity, a private third-party certifier, against the requirements of the CDM on the basis of the project design document.

4.2.4 Registration (UNFCCC, 2012j)

If the DOE deems a project valid, it is submitted to the CDM Executive Board for registration. Registration is the formal acceptance by the Executive Board of a validated project as a CDM project activity. Registration is the prerequisite for the verification, certification and issuance of CERs related to that project activity.

4.2.5 Monitoring (UNFCCC, 2012j)

After the project has been registered, the participant/operator is responsible for monitoring the project's emissions in accordance to the approved methodology relevant for the project.

4.2.6 Verification and certification (UNFCCC, 2012j)

Verification is the independent review and ex post determination by the Designated Operational Entity of the monitored reductions that have occurred as a result of a registered CDM project activity during the verification period. Consequently, the DOE issues certification for the verified emission reductions and submits a verification report to the CDM Executive Board.

4.2.7 CER issuance (UNFCCC, 2012j)

The CDM EB appraises the verification report and issues the CER credits, provided that no faults are found.

4.2.8 Transaction costs

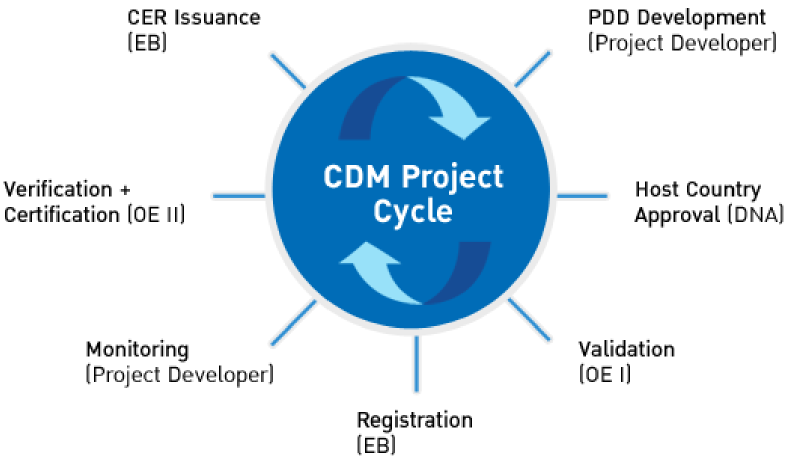


FIGURE 6: The CDM project cycle (ClearBlue Trading, 2012)

Before the Kyoto Protocol entered into force in 2005, there were speculations that transaction costs and institutional rigidities would reduce the attractiveness of the Protocol's flexibility mechanisms, including the Clean Development Mechanism (Michaelowa and Jotzo, 2005). The payment of a registration fee and the use of a share of proceeds from sales of CERs to cover administrative expenses have already been mentioned, as has the 2% levy used as the main source of income for the UNFCCC Adaptation Fund.

Transaction costs were addressed in a United Nations Environment Programme information paper in 2006, when the Clean Development Mechanism had only been operational for a limited time. Estimated transaction costs for large scale CDM projects were given in the range USD 123,000 – USD 233,000 (UNEP, 2006). Indicative timelines and transaction costs under CDM as estimated in 2006 are shown in Figure 7.

The European Commission supported SETatWork project, which was run from 2008 to 2010 estimated the transaction costs as varying from USD 40,000 to USD 150,000 per project (SETatWork, 2010). In addition to the fees already mentioned, these costs cover the hiring of external experts (DOEs) and in some cases fees for receiving national approval by the host countries.

Transaction costs were expected to come down with time, as the system developed and became more streamlined. The CDM Executive Board has been conscious of the potential barriers that transaction costs may pose on projects and has therefore introduced some measures to try to bring these costs down. The transaction costs for Least Developed Countries were thus reduced by abolishing the

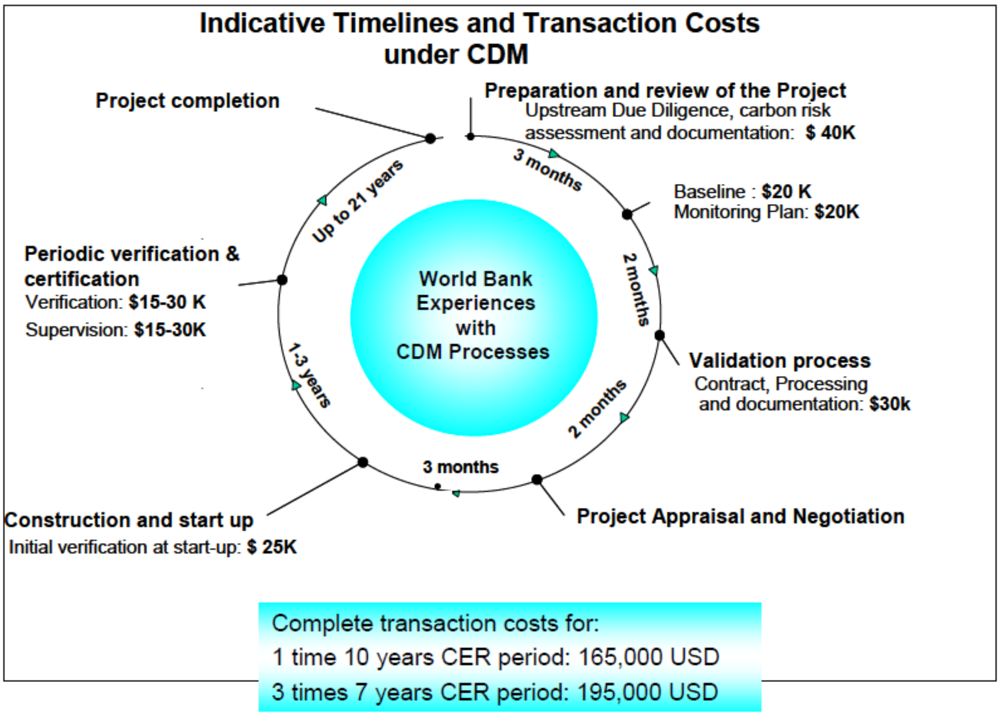


FIGURE 7: Indicative timelines and transaction costs for CDM projects as estimated in 2006 (UNEP, 2006)

payment of the registration fee and share of proceeds at issuance for CDM project activities hosted in these countries (UNFCCC, 2008). The board also encouraged Designated Operational Entities to establish offices in developing countries in order to bring transaction costs down.

4.3 Crediting period(s)

The glossary of CDM terms defines a crediting period for a CDM program activity as (UNFCCC, 2009a):

> ... the period for which reductions from the baseline or net anthropogenic greenhouse gas removals by sinks are verified and certified by a Designated Operational Entity for the purpose of issuance of Certified Emission Reductions (CERs) ...

A report of the COP 11/MOP 1 in Montreal in 2005 addresses the choices and duration of crediting periods (UNFCCC, 2006):

> Project participants shall select a crediting period for a proposed project activity from one of the following alternative approaches:
>
> - A maximum of 7 years which may be renewed at most two times, provided that, for each renewal, a Designated Operational Entity determines and informs the Executive Board that the original project baseline is still valid or has been updated taking account of new data where applicable;
> - A maximum of 10 years with no option for renewal.

The commencement of a crediting period must take place after the date of registration and it can continue only while the project activity is operational (Baker & McKenzie, 2012b).

In order to renew a 7 year crediting period, the project participant must update those sections of the Project Design Document (CDM-PDD) relating to the baseline, estimated emission reductions and the monitoring plan using an approved baseline and monitoring methodology (UNFCCC, 2011a). This updated PDD is then forwarded to the DOE, which must address the validity of the original baseline, the impact of new policies and circumstances and the continued validity of the baseline (Baker & McKenzie, 2012b).

The option of renewing a 7 year crediting period twice, gives the project participant the possibility to reap the benefits of emission reductions for an extended time, while submitting to the workload and costs associated with reassessment. This may be preferred when there is a large difference between the projected baseline scenario and the project scenario at the outset and/or the difference between the scenarios is unlikely to decrease much over the two decades after the commissioning of the project. The selection of a single 10 year crediting period may be preferred when there is only a narrow difference between the baseline scenario and the project scenario at the outset and/or when the baseline emissions scenario is expected to approach the project emissions scenario over the commitment period (i.e. the accumulated emission reductions are projected to be small over the period – though large enough to justify applying for CDM registration).

5. GEOTHERMAL BASELINE AND MONITORING METHODOLOGIES

Two methodologies have been approved by the CDM Executive Board for geothermal projects: one for power plants connected to an electricity grid and another for geothermal space heating.

5.1 Baseline methodology for grid-connected geothermal power plants

The approved consolidated baseline and monitoring methodology ACM0002 version 12.2.0, which bears the specific title *Consolidated baseline methodology for grid-connected electricity generation from renewable sources* is applicable to geothermal power plants (UNFCCC, 2011b). The basic ideas and formulas are addressed in the following subsections, but the reader is referred to the original document on the UNFCCC website for details.

5.1.1 Emission reductions

The basic idea behind the calculation of emission reductions is simple. All that is needed is to find the difference between the cumulative baseline emissions and project emissions over a given period, i.e. the shaded area in Figure 5. This is done for one year at a time. The emission reductions are thus calculated according to the following formula:

$$ER_y = BE_y - PE_y \tag{1}$$

where ER_y = Emission reductions in year y (tCO_2eq/yr);
BE_y = Baseline emissions in year y (tCO_2eq/yr);
PE_y = Project emissions in year y (tCO_2eq/yr).

5.1.2 Baseline emissions

The baseline emissions are calculated from the electricity generation over the year and the emission factor for the grid:

$$BE_y = EF_{grid,CM,y} \cdot EG_{PJ,y} \tag{2}$$

where $EF_{grid,CM,y}$ = Combined margin CO_2 emission factor for grid connected power generation in year y (tCO_2eq/yr);
$EG_{PJ,y}$ = 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/y).

For updating the baseline at the start of the second and third crediting period, new available data are used to revise the baseline scenario and emissions. Project participants shall assess and incorporate the impact of new regulations on baseline emissions (UNFCCC, 2011b).

5.1.3 Grid emission factors

The rules for the calculation of the combined margin emission factor, $EF_{grid,CM,y}$, are set out in the *Tool to calculate the emission factor for an electricity system*, published by the CDM EB (UNFCCC, 2011c). The calculation method depends on both grid characteristics and choices of the applicant. As the name implies, the factor is a combination of two other margin factors, the operating margin factor and the build margin factor:

$$EF_{grid,CM,y} = w_{OM} \cdot EF_{grid,OM,y} + w_{BM} \cdot EF_{grid,BM,y} \tag{3}$$

where w_{OM} = Weighting of operating margin emission factor;
$EF_{grid,OM,y}$ = Operating margin CO_2 emission factor in year (tCO_2/MWh);
w_{BM} = Weighting of build margin emission factor;
$EF_{grid,BM,y}$ = Build margin CO_2 emission factor in year (tCO_2/MWh).

The operating margin factor refers to the group of existing power plants whose current electricity generation would be affected by the proposed CDM project activity, while the build margin factor refers to the group of prospective power plants whose construction and future operation would be affected by the proposed CDM project activity (UNFCCC, 2011c). The former is therefore a measure of business as usual extending over the crediting period, while the latter captures the latest trend in additions to the grid and provides a way to factor that trend into the evaluation of the emission factor to be used for the baseline scenario. The use of weights is a way to quantify the contribution of each factor.

The default weights for the first crediting period are w_{OM} = 0.5 and w_{BM} = 0.5 and for successive periods w_{OM} = 0.25 and w_{BM} = 0.75. However, applicants may propose alternative weights, in which case thorough justification is needed. Exceptions are made for the Least Developed Countries or countries that have fewer than 10 registered CDM projects at the starting date of validation. In those cases w_{OM} = 1 and w_{BM} = 0.

There are 4 methods of calculating the operating margin factor, each of which may have restrictions, limitations and sub-options:

- Simple OM;
- Simple adjusted OM;
- Dispatch data analysis OM;
- Average OM.

For the simple OM, simple adjusted OM and the average OM, the emission factor can be calculated using either the *ex ante* option or the *ex post* option:

- If the *ex ante* option is chosen, the emission factor is determined once at the validation stage of a crediting period;

- If the *ex post* option is chosen, the emission factor is determined for the year in which the project activity displaces grid electricity, requiring the emission factor to be updated annually during monitoring.

The build margin emission factor takes into account the emissions of the most recent power plants to be added to the grid (possibly excluding CDM power plants) that together supply at least 20% of the grid electricity. It can be calculated either *ex ante* or *ex post*.

From the previous discussion it follows that the determination of the combined margin emission factor, $EF_{grid,CM,y}$, is not straightforward and is dependent both on grid characteristics and choices of the project participant. Readers are referred to the *Consolidated baseline methodology for grid-connected electricity generation from renewable sources* for details.

5.1.4 Electricity generation

The method of calculation of the annual electricity generation depends on whether the CDM project is a greenfield plant, retrofit, replacement, or a capacity addition.

a) Greenfield power plants

If the project activity is the installation of a new grid-connected renewable power plant/unit at a site where no renewable power plant was operated prior to the implementation of the project activity, the electricity generation is simply that of the new power plant:

$$EG_{PJ,y} = EG_{facility,y} \tag{4}$$

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

b) Retrofit or replacement of an existing power plant

If the project activity is the retrofit or replacement of an existing grid-connected renewable power plant, the baseline scenario is the continuation of the operation of the existing plant. The methodology uses historical electricity generation data to determine the electricity generation by the existing plant in the baseline scenario, assuming that the historical situation observed prior to the implementation of the project activity would continue (UNFCCC, 2011b).

The power generation of renewable energy projects can vary significantly from year to year, due to natural variations in the availability of the renewable source (e.g. varying rainfall, wind speed or solar radiation). The use of few historical years to establish the baseline electricity generation can therefore involve a significant uncertainty. The methodology addresses this uncertainty by adjusting the historical electricity generation by its standard deviation. This ensures that the baseline electricity generation is established in a conservative manner and that the calculated emission reductions are attributable to the project activity. Without this adjustment, the calculated emission reductions could mainly depend on the natural variability observed during the historical period rather than the effects of the project activity (UNFCCC, 2011b).

One of the advantages of geothermal energy is that it is independent of weather conditions contrary to solar, wind, or hydro applications and can be used both for base load and peak power (Fridleifsson and Haraldsson, 2011; Goldstein et al., 2011). It is true that reservoir conditions may change slowly with time (e.g. pressure drawdown leading to a decline in output) and maintenance activities may lead to variations in electricity output between years, but overall geothermal power plants can be expected to show greater stability in electricity generation between years than many of the other types of renewable energy power plants, due to the independence from variable surface conditions. Variance in annual time series over a specific period may therefore be smaller than that of some of the other renewables.

In this case, the project electricity generation is calculated according to the following formula:

$$EG_{PJ,y} = EG_{facility,y} - (EG_{historical} + \sigma_{historical}); until\ DATE_{BaselineRetrofit} \quad (5)$$

where $EG_{historical}$ = 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);

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

To determine the annual average historical electricity generation, $EG_{historical}$, project participants may choose between two historical periods:

- The 5 last calendar years prior to the implementation of the project activity;
- The time period from the calendar year following $DATE_{hist}$, up to the last calendar year prior to the implementation of the project, as long as this time span includes at least five calendar years, where $DATE_{hist}$ is latest of the following points in time:
  - The commercial commissioning of the plant/unit;
  - If applicable: the last capacity addition to the plant/unit;
  - If applicable: the last retrofit of the plant/unit.

This allows some flexibility, as the use of the longer time period may result in a lower standard deviation and the use of the shorter time period may allow a better reflection of the circumstances observed during the more recent years (UNFCCC, 2011b).

Two choices are offered for the determination of the point in time when the existing equipment would need to be replaced or retrofitted in the absence of the project activity, $DATE_{BaselineRetrofit}$:

- The typical average technical lifetime of the type equipment may be determined and documented, taking into account common practices in the sector and country, e.g. based on industry surveys, statistics, technical literature, etc.;
- The common practices of the responsible company regarding replacement/retrofitting schedules may be evaluated and documented, e.g. based on historical replacement/retrofitting records for similar equipment.

If a range is identified, the earliest date should be chosen.

In the case of geothermal energy, examples of replacements can be either when power plants/units are replaced due to the outdating or breakdown of equipment, or when older plants/units, such as backpressure turbines, are replaced by more efficient plants/units. An example of a retrofit is the installation of a bottoming cycle to a pre-existing power plant, such as a low pressure steam turbine or a binary cycle system.

c) Capacity addition to an existing power plant

In the case of hydro or geothermal power plants, the addition of a new power plant or unit may significantly affect the electricity generated by the existing plant(s) or unit(s). For example, a new hydro turbine installed at an existing dam may affect the power generation by the existing turbines. Therefore, the same approach as for retrofits and replacements is used for hydro power plants and geothermal power plants. In this case, $EG_{facility,y}$ corresponds to the total electricity generation of the existing plant(s) or unit(s) and the added plant(s) or unit(s) (UNFCCC, 2011b).

In the case of geothermal power plants, additions of units will probably in most cases not affect the generation of older units much. Stepwise development is common, where units are added incrementally through time in order to allow the monitoring of reservoir response to production before expansion, thus providing the necessary data to assess the capacity of the reservoir to support the increased production. In this case, it might be more proper to treat the capacity addition as a greenfield power plant/unit and apply Equation 4 rather than Equation 5. If one assumes no variance in electricity generation of the older units over the historical period, the two equations will give identical results provided that the older units will not need replacement over the crediting period. It is however unlikely that the variance will be zero, in which case Equation 5 leads to an underestimation of the contribution of the new units to the grid compared to Equation 4.

5.1.5 Project emissions

Unlike many other renewable energy conversion processes, the generation of electricity from geothermal resources usually leads to some greenhouse gas emissions, albeit significantly lower than emissions of fossil fuel fired power plants. This is due to the presence of gases such as CO_2 and CH_4 in the geothermal fluid extracted, which in most cases need to be released to the atmosphere.

In general, project emissions from renewable power generation project activities are to be calculated using the following formula:

$$PE_y = PE_{FF,y} + PE_{GP,y} + PE_{HP,y} \tag{6}$$

where $P_{FF,y}$ = Project emissions from fossil fuel consumption in year y (tCO_2/yr);
$PE_{GP,y}$ = Project emissions from the operation of geothermal power plants due to the release of non-condensable gases in year y (tCO_2eq/yr);
$PE_{HP,y}$ = Project emissions from water reservoirs of hydro power plants in year y (tCO_2eq/yr).

For geothermal power plants, $PE_{FF,y} = PE_{HP,y} = 0$.

The methodology assumes that all non-condensable gases entering a geothermal power plant are released to the atmosphere, but fugitive emissions due to well testing and well bleeding are not considered. The emissions are thus calculated using the following formula:

$$PE_{GP,y} = (w_{steam,CO2,y} + w_{steam,CH4,y} \cdot GWP_{CH4}) \cdot M_{steam,y} \tag{7}$$

where $w_{steam,CO2,y}$ = Average mass fraction of carbon dioxide in the produced steam in year y (tCO_2/t steam);
$w_{steam,CH4,y}$ = Average mass fraction of methane in the produced steam in year y (tCH_4/t steam);
GWP_{CH4} = Global warming potential of methane valid for the relevant commitment period (tCO_2eq/tCH_4);
$M_{steam,y}$ = Quantity of steam produced in year y (t steam/yr).

For the first commitment period, GWP_{CH4} = 21 tCO_2eq/tCH_4.

5.1.6 Monitoring

Many of the parameters used in the methodology equations may need to be monitored. These are:

- The combined margin CO_2 emission factor for the year, $EF_{grid,CM,y}$ (if determined ex post, but not applicable if the ex ante option has been used, except at the start of a new crediting period);
- The annual project net electricity generation supplied to the grid, $EG_{facility,y}$;
- The annual steam production, $M_{steam,y}$;
- The average mass fraction of methane in the steam over the year, $w_{steam,CH4,y}$;
- The average mass fraction of carbon dioxide in the steam over the year, $w_{steam,CO2,y}$.

The monitoring methodology stipulates the methods to be used for carrying out measurements. All data collected as part of monitoring should be archived electronically and be kept for at least 2 years after the end of the last crediting period.

The reader is referred to the original document on the UNFCCC website for further information.

5.2 Fossil fuel displacement by geothermal resources for space heating

The approved baseline and monitoring methodology AM0072 version 02, which has the specific title *Fossil fuel displacement by geothermal resources for space heating*, is applicable to space heating in buildings (UNFCCC, 2009b). The methodology can apply to new facilities or to a geothermal district heating system seeking to expand its operations through the addition of extra geothermal wells to the system.

Emission reductions are calculated by Equation 1, as leakage emissions are not identified with the project activity.

All alternative scenarios available to the project participants that provide output or services with comparable quality as the proposed CDM project activity must be identified as potential baseline scenarios, including the implementation of the geothermal project activity without the benefits of CDM. These alternatives are screened in accordance with the following instructions:

- If any of the alternatives do not comply with applicable enforced mandatory legal and regulatory requirements, they are eliminated;
- If any of the remaining alternatives face prohibitive barriers, such as technology barriers, acceptability barriers, or financial barriers, they are eliminated;
- An investment analysis and a common practice analysis are carried out on the remaining alternatives in accordance with the latest approved version of the *Combined tool to identify the baseline scenario and demonstrate additionality*.

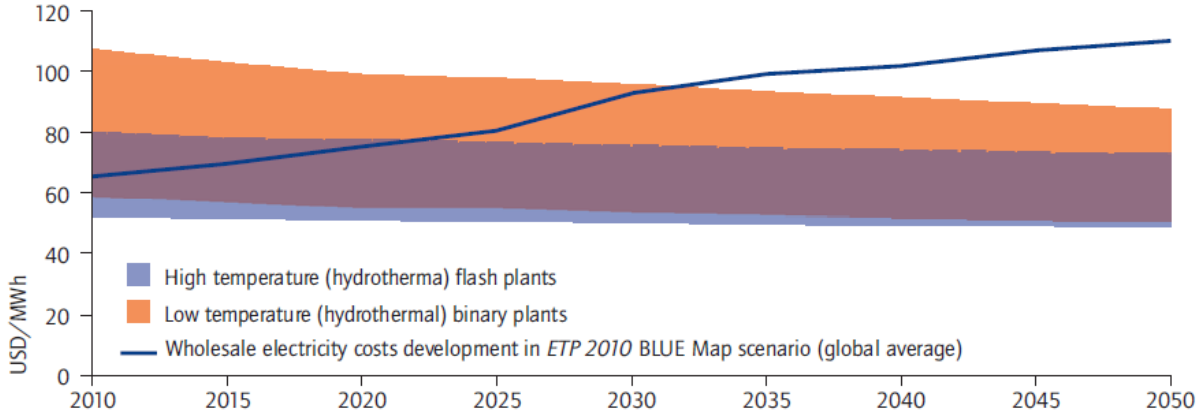
When the most plausible baseline scenario has been identified, baseline emissions are calculated in accordance with the rules set out in the methodology.

Project emissions are determined in a similar way as for grid-connected geothermal power plants, i.e. by considering fugitive emissions of CO_2 and CH_4.

The reader is referred to the original document on the UNFCCC website for details.

6. BENEFITS

The Clean Development Mechanism provides a venue for providing partial funding of geothermal projects in developing countries. While this funding may only be a fraction of the total financing needs, it can still be enough to matter. In some cases, CDM funding can be the deciding factor in the economic viability of a project. The International Energy Agency expects wholesale electricity prices to increase with time, while costs of electricity production in geothermal flash and binary plants decrease (Figure 8). These trends are expected to lead to "full" competitiveness of geothermal flash plants between 2020 and 2030, and binary plants after 2030 (OECD/IEA, 2011b). By reducing other funding needs, CDM funding can shift the electricity production cost curves in Figure 8 downwards and in effect push the intersection between the electricity production cost curve for a particular resource and the wholesale electricity cost curve back in time. In this way, CDM funding can hasten the adoption of renewable technology projects in developing countries, where a large portion of the world's geothermal resources is found (Figure 9). Such encouragement may lead to faster learning curves, spillover effects to non-CDM projects and associated long term benefits for the climate.



Note: Assumptions: interest rate 10%, technical lifetime 35 years, O&M costs 2.5%
Source: IEA analysis.

FIGURE 8: Range of reduction of average levelized costs of electricity production in hydrothermal flash plants and binary plants (OECD/IEA, 2011b)

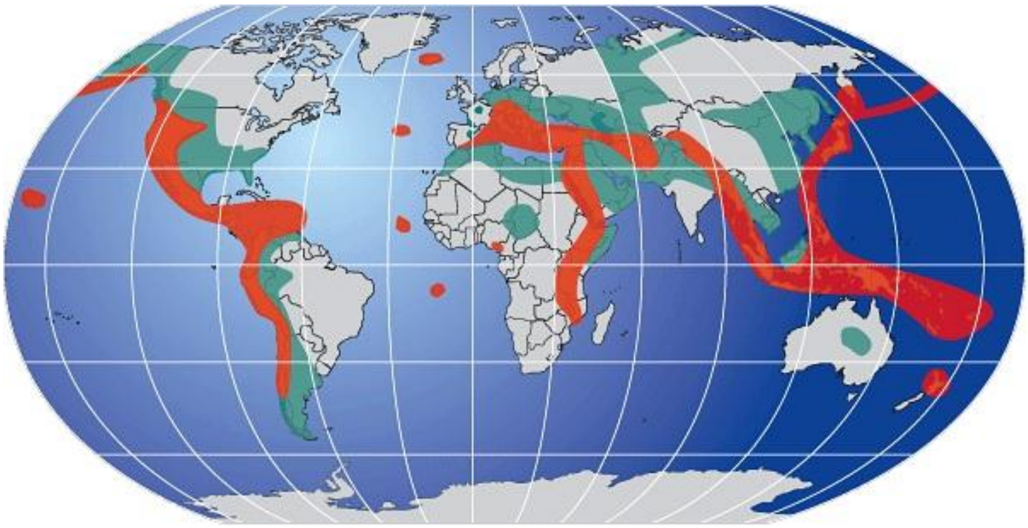


FIGURE 9: A large part of the geothermal regions of the world is located in developing countries (Red: areas where high quality geothermal resources can be found; Green: Areas where lower quality geothermal resources can be found) (BRGM, 2012)

Bertani and Thain (2002) informed that the weighted average CO_2 emission intensity/factor for geothermal power plants was 122 g/kWh a decade ago, based on 85% of the world geothermal power plant capacity at the time. They also gave some typical CO_2 emission intensities for fossil fuelled power plants (Table 1). By comparison, Bloomfield et al. (2003) reported that the weighted average CO_2 emissions intensity for geothermal power plants in the United States was 91 g/kWh. This value includes binary power plants, which generally do not emit CO_2 and represented 14% of the surveyed capacity. The weighted average emission intensity for Icelandic geothermal power plants was 50 g/kWh in 2009, when installed geothermal capacity was 575 MW_e (Baldvinsson et al., 2010). These weighted average CO_2 intensities are summarized in Table 1 along with estimates for fossil fuelled power plants. Bertani and Thain estimate the latter based on the assumed efficiencies of the conversion processes and seemingly the carbon content of the fuels, while Bloomfield et al. state that their calculations are based on data from the US Energy Information Administration, without giving further details.

TABLE 1: Weighted average CO_2 emission intensities for different sets of geothermal power plants and estimates for fossil fuelled power plants

	Geothermal (g/kWh)	**Natural gas (g/kWh)**	**Oil (g/kWh)**	**Coal (g/kWh)**
Bertani and Thain (2002)	122 (World)	315	760	915
Bloomfield et al. (2003)	91 (USA)	599	893	950
Baldvinsson et al. (2010)	50 (Iceland)			

Table 1 indicates that CO_2 emission intensities vary on large spatial scales, but this is also the case on smaller scales. A plot of the annual average CO_2 emission intensities from 6 geothermal power plants in Iceland (103,000 km^2) over the period 1979-2009 reveals that there is considerable variation between the plants/fields (Figure 10). Furthermore, the intensity of each plant varies in time.

In spite of the variations and differences in estimates, these data clearly indicate that geothermal power plants can reduce greenhouse gas emissions significantly if installed in place of fossil fuelled power plants. Fridleifsson et al. (2008) report that hundreds of millions of tons of CO_2 could be mitigated per

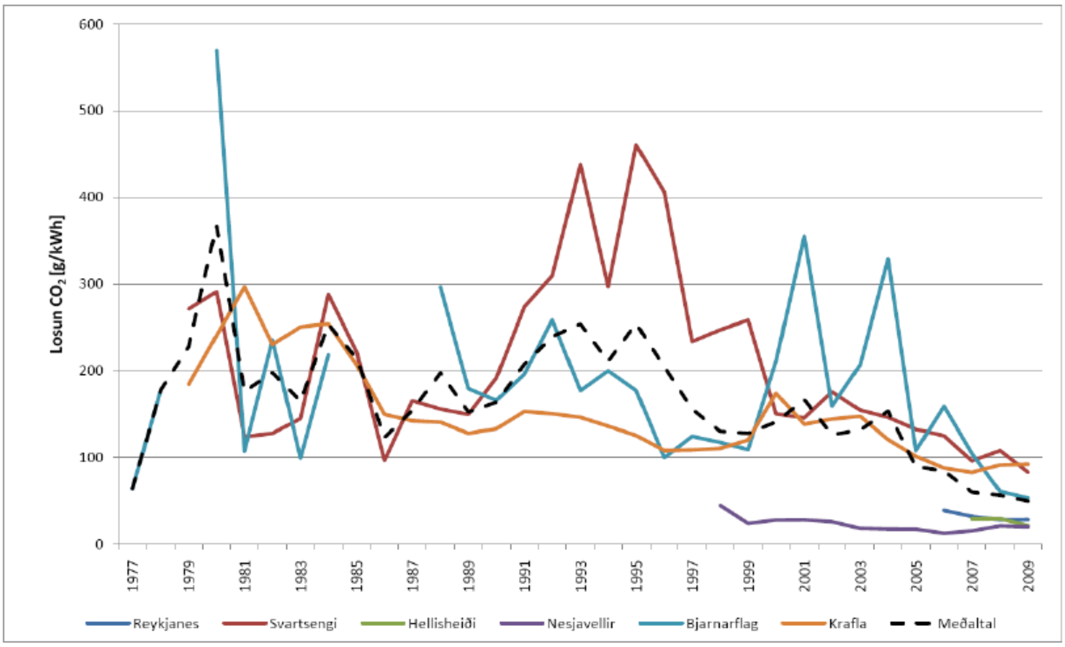


FIGURE 10: Historical annual average CO_2 emission intensities for Icelandic geothermal power plants over the period 1979-2009. The black dotted line indicates the weighted average intensities, while the colored lines indicate intensities for specific power plants (Baldvinsson et al., 2010).

year in the middle of the century, assuming a geothermal electricity production of about 100 TWh/yr in 2050 (Figure 11).

7. CDM STATISTICS

In addition to containing extensive information about the Clean Development Mechanism, the UNFCCC CDM website offers statistics on projects that have been approved or are currently undergoing the registration process. As of February 2012, 11 geothermal power plant projects in 7 countries had been approved, all using the ACM0002 methodology. Out of these, the San Jacinto Tizate geothermal project in Nicaragua was the first to request registration on 8 April 2006 and the Kamojang geothermal project in Indonesia was most recently registered on 16 December 2010 (UNFCCC, 2012k). Other countries that had registered projects were: El Salvador, Guatemala, Kenya, Papua New Guinea, and the Philippines. The United Kingdom and the Netherlands were the most active buyers of the CERs, but Austria, Belgium, Canada, Italy, Denmark, Finland, Germany, Japan, Norway, Spain, Sweden, and Switzerland also bought credits.

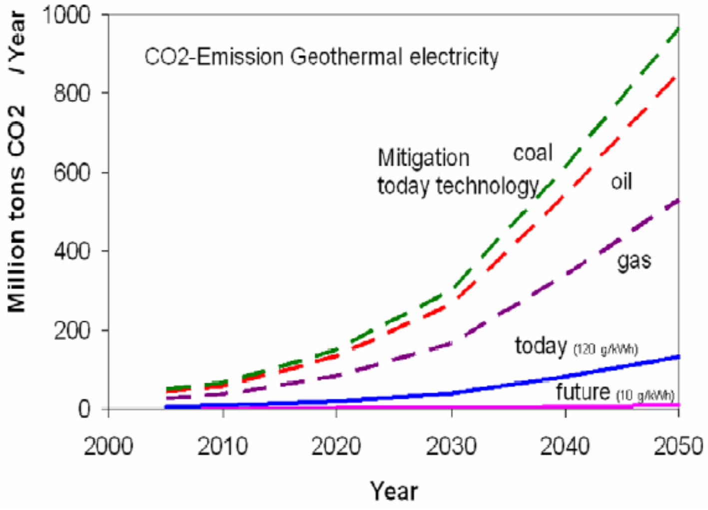


FIGURE 11: Mitigation potential of geothermal power plants in the world and assumptions for CO_2 emission intensities of 120 g/kWh for today and 10 g/kWh for future technology (Fridleifsson et al., 2008)

Only one geothermal district heating project had submitted to the CDM process using the AM0072 methodology. This is the geothermal district heating project in Xianyang City in China, which submitted its application in June 2011 and was requesting registration as of February 2012. At that time, the ratio of issued CERs to those requested was 0.95.

About 68% of registered CDM projects in February 2012 were categorized as energy industry projects (renewable or non-renewable). The second largest category was waste handling and disposal, which accounted for almost 14% of projects. Thirteen other categories accounted for the remaining 18%.

The largest number of projects had been registered in Asia, a sizable number in Latin America, but relatively few in Africa (Figure 12).

The number of projects entering validation rose from 4 in December 2003 to 97 in December 2007. The rising trend prior to the first commitment period seems to have changed to a flat trend at the beginning of the period (Figure 13). Over the period January 2008 to December 2010, the average number of projects entering validation was 116.5. In 2011, the number rose markedly and stood at 190 in January 2012 (UNFCCC, 2012m). The development of these numbers is shown graphically in Figure 13.

As of 20 February 2012, 3,848 project activities had been registered, since the first project was registered on 18 November 2004 (UNFCCC, 2012n; Baker & McKenzie, 2012b). A total of 866,482,093 CERs had been issued.

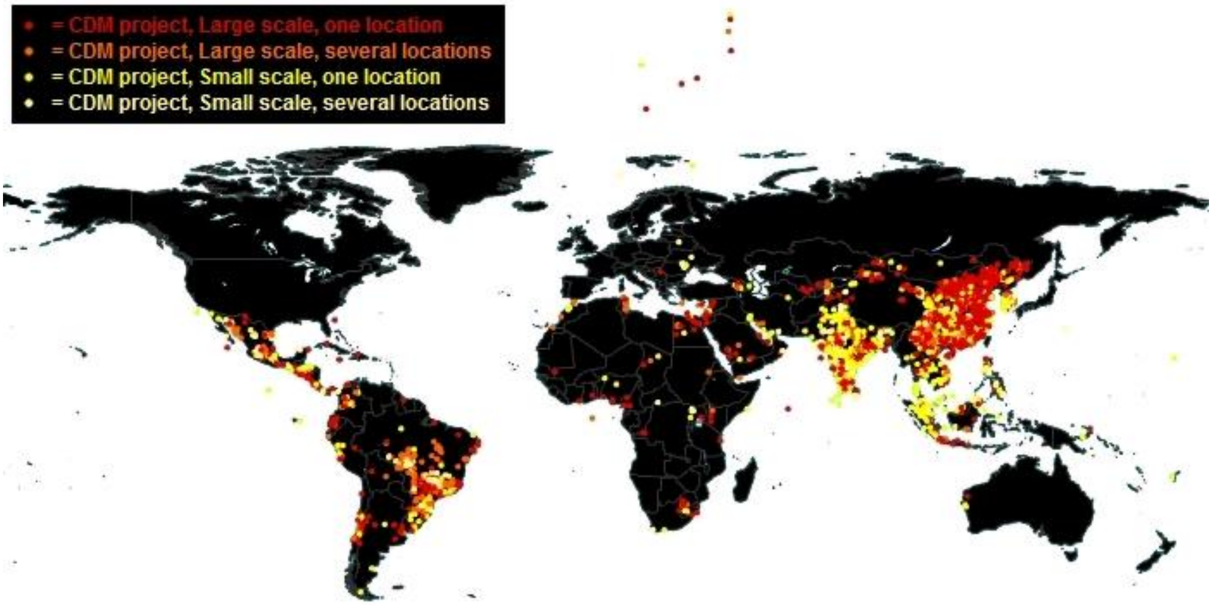


FIGURE 12: Registered CDM projects as of February 2012 by location (UNFCCC, 2012l)

8. RECENT DEVELOPMENTS AND OUTLOOK

Last minute negotiations at COP 17 in Durban resulted in an agreement between States to:

> ...launch a process to develop a protocol, another legal instrument or an agreed outcome with legal force under the Convention applicable to all Parties, through a subsidiary body under the Convention hereby established and to be known as the *Ad Hoc Working Group on the Durban Platform for Enhanced Action* (UNFCCC, 2011d).

The working group was to start its work in the first half of 2012 and report to future sessions of COP. Its work on the new protocol, legal instrument or agreed outcome with legal force is to be completed as early as possible, but no later than 2015 in order for it to be adopted by COP 21, which will be informed by the fifth assessment report of the IPCC, and to take effect from 2020.

The *Ad Hoc Working Group on Further Commitments for Annex I Parties under the Kyoto Protocol at its sixteenth session* decided that the second commitment period under the Kyoto Protocol should begin on 1 January 2013 and end either on 31 December 2017 or 31 December 2020, to be decided by the *Ad Hoc Working Group on Further Commitments for Annex I Parties under the Kyoto Protocol at its seventeenth session* (UNFCCC, 2011e).

The Protocol's market based flexibility mechanisms, including CDM, will continue. The Durban decisions streamlined and expanded Clean Development Mechanism rather than limiting it, for example by calling for the simplification and standardization of baseline and monitoring methodologies and by including carbon capture and storage as an allowable scheme to offset greenhouse gas emissions (UNFCCC, 2011f; Zelljadt, 2012).

The market outlook for CERs, however, is uncertain. CERs have been tradable within the European Union Emissions Trading System (EU ETS), but in 2009 the EU banned the use of CERs from projects registered after 2012 in all but the Least Developed Countries (LDCs) within the scheme, in order to encourage emerging economies to take tougher climate action (Thomson Reuters, 2012a).

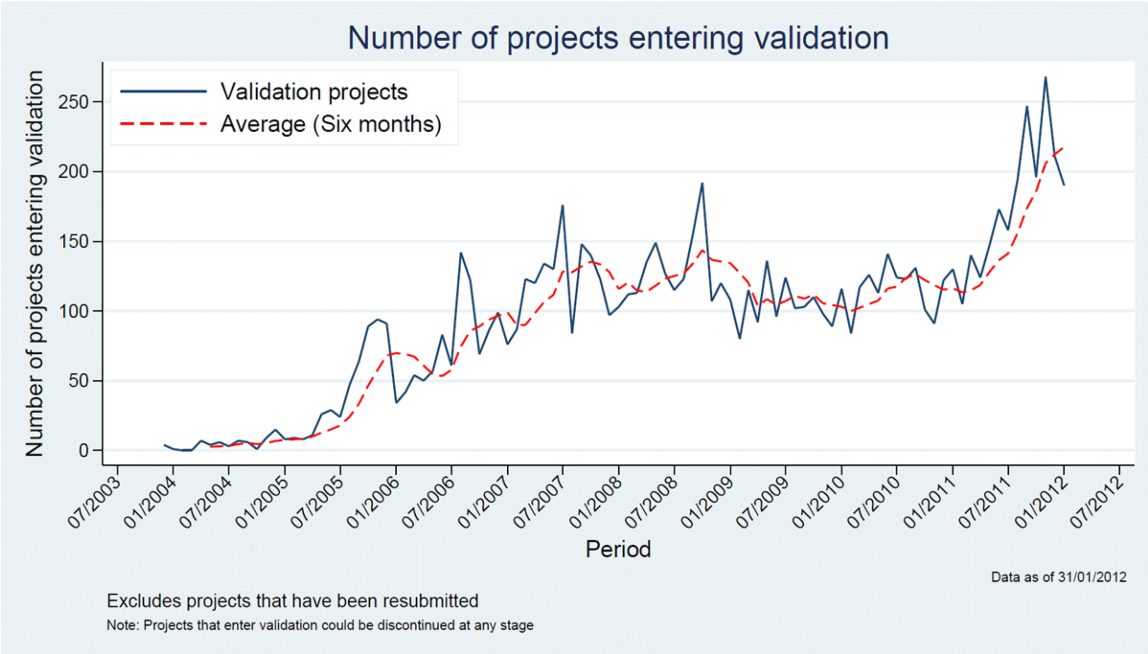


FIGURE 13: Number of projects entering validation (UNFCCC, 2012m)

This will create a greater uncertainty about demand for CERs. Although other markets, such as the New Zealand Emissions Trading Scheme, are also open to CERs, the EU ETS is by far the largest.

Due to the barring of acceptance of CERs from projects registered after 2012 in all but the LDCs and the banning of CERs from most industrial gas projects, including HFC-23 and adipic acid projects, from May 2013, a flurry of new projects have been entering validation (Figure 13). At the same time, prices of secondary CERs (resold credits) have been going down from a peak of above EUR 30 in 2008 to around EUR 4 in mid Q1 of 2012 (Figure 14). Investment in primary CERs (sold by project participant) fell from USD 7.4 billion in 2007 to USD 1.5 billion in 2010 (Thomson Reuters, 2012b). The World Bank noted that some investors, banks, and sovereign buyers saw exposure to post-2012

FIGURE 14: Secondary CER price evolution (Thomson Reuters, 2012c)

CERs as risky in an assessment of the carbon market published prior to COP 17 in Durban (Linacre et al., 2011).

The CDM Executive Board agreed in 2011 to investigate whether to bar some projects from participation where revenues from selling carbon credits make up a tiny proportion of the project costs. There have also been questions of whether some government funded infrastructure projects are an addition to business as usual. In 2012, the board may have to tackle some fundamental questions about additionality (Thomson Reuters, 2012d).

It is possible, though by no means certain, that it will be more difficult for some geothermal projects in the developing countries to sell CERs in the future due to contraction in demand and perceived risk by potential buyers. Beside demand, prices are also a concern, as they must be high enough to reduce other financing needs of the projects in order to be meaningful. Projects in the LDCs should however have a good chance to register CDM projects and sell CERs to the EU ETS, where higher prices may possibly be obtained than outside the scheme. Countries with known geothermal potential within the group of LDCs are: Burundi, Comoros, Democratic Republic of the Congo, Djibouti, Eritrea, Ethiopia, Malawi, Mozambique, Rwanda, Uganda, Tanzania, and Yemen (Figure 15; Georgsson, 2010).

Africa (33)

1	Angola	18	Madagascar
2	Benin	19	Malawi #
3	Burkina Faso #	20	Mali #
4	Burundi #	21	Mauritania
5	Central African Republic #	22	Mozambique
6	Chad #	23	Niger #
7	Comoros *	24	Rwanda #
8	Democratic Republic of the Congo	25	São Tomé and Príncipe *
9	Djibouti	26	Senegal
10	Equatorial Guinea	27	Sierra Leone
11	Eritrea	28	Somalia
12	Ethiopia #	29	Sudan
13	Gambia	30	Togo
14	Guinea	31	Uganda #
15	Guinea-Bissau *	32	United Republic of Tanzania
16	Lesotho #	33	Zambia #
17	Liberia		

Asia (14)

1	Afghanistan #	8	Nepal #
2	Bangladesh	9	Samoa *
3	Bhutan #	10	Solomon Islands *
4	Cambodia	11	Timor-Leste *
5	Kiribati *	12	Tuvalu *
6	Lao People's Democratic Republic #	13	Vanuatu *
7	Myanmar	14	Yemen

Latin America and the Caribbean (1)

1	Haiti *

* Also a Small Island Developing State
\# Also a Landlocked Developing Country

FIGURE 15: A list of Least Developed Countries (UN-OHRLLS, 2012)

9. FINAL REMARKS

In the Copenhagen Accord, which was drafted at COP 15 in 2009, the heads of State, governments and delegations stated that (UNFCCC, 2010b):

> …climate change is one of the greatest challenges of our time. We emphasise our strong political will to urgently combat climate change in accordance with the principle of common but differentiated responsibilities and respective capabilities. To achieve the ultimate objective of the Convention to stabilize greenhouse gas concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system, we shall, recognizing the scientific view that the increase in global temperature should be below 2 degrees Celsius on the basis of equity and in the context of sustainable development, enhance our long-term cooperative action to combat climate change. We recognize the critical impacts of climate change and the potential impacts of

response measures on countries particularly vulnerable to its adverse effects and stress the need to establish a comprehensive adaptation programme including international support.

Climate models indicate that stabilizing atmospheric CO_2 concentration at 450 ppm would likely result in a global equilibrium warming of 1.4°C to 3.1°C, with a best guess of about 2.1°C (Meehl et al., 2007). February 2012 measurements at Mauna Loa in Hawaii show a CO_2 concentration of 393 ppm. The average annual mean growth rate of atmospheric CO_2 concentration at Mauna Loa over the first decade of the 21st century was close to 2 ppm per year (NOAA, 2012). At that growth rate, the 450 ppm limit will be reached in 2040. Taking into account the contribution of other greenhouse gases to global warming, and the trend of acceleration in emissions over time suggests that the limit will be reached earlier. The only realistic way to prevent the global temperature increase to reach 2°C is to reduce the discharge of greenhouse gases into the atmosphere and stabilize their concentrations at an acceptable limit.

Renewable energy sources play a key role in this strategy. In particular, geothermal resources are of significant value in specific regions of the world (Figure 9).

Humans are creatures of the ice age and even though the species has never witnessed a global climate significantly warmer than the present, it has seen temperatures change before – as ice sheets have advanced and receded. The onset of the Quaternary ice age at 2.75 Ma (Rose, 2010) coincides approximately with the movement of the first hominines from the forest to the savannah. Homo habilis appeared around 2.5 Ma and introduced the first stone tools. Later, humans learned to use fire and invented clothing to keep warm. In the current era, man has acquired the means to change the temperature of the planet as a whole and is as a result entering uncharted territory. While the adaptability of the species is significant on short time scales, the same cannot be said of all other species and the ecosystem as a whole. In addition to affecting the mean global temperature, global warming is likely to push out the boundaries of temperature and precipitation extremes, changing precipitation patterns and leading to increased droughts in some regions, changing the extent and thickness of ice sheets, causing sea level to rise, leading to changes in ocean circulation, changing the whole carbon cycle, causing ocean acidification, affecting the monsoons, increasing the frequency of hurricanes and storms (Meehl et al., 2007), and all of this is bound to put strain on ecosystems.

Learning how to make use of fire was a big milestone in the progress of humans, but they also learned that it had to be kept under control, for if left unchecked it could cause damage that could not be repaired. Current global warming – a consequence of the ingenuity of homo sapiens – has the potential to alter the environment on a global scale and cause damage to ecosystems beyond repair. In this case, it is probably wise to be safe rather than sorry.

As a great inventor and toolmaker, man has acquired the skills to put out fires and certainly has the capability to keep the global temperature from rising beyond the 2°C which the UNFCCC has deemed acceptable. To that end, a good deal of will and effort is needed, as well as the proper tools to manage emissions and encourage the use of renewable energy sources such as geothermal. Some of those are contained within the toolbox of the Clean Development Mechanism, while others – more powerful – await invention.

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