MSc Thesis

Environment and Natural Resource

Geothermal Power Plants as CDM Projects

The Financial Premise for Registering Geothermal Power Plants as CDM Projects

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HÁSKÓLI ÍSLANDS

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Thesis submitted in partial fulfillment of a *Magister Scientiarum* degree in Environment and Natural Resources

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Preface

The idea of writing a thesis on the participation of geothermal projects within the Clean Development Mechanism was a result of my work for the startup company KOLKA. As a student in the Environment and Natural resource masters program at the University of Iceland, the CEO of KOLKA, Eyrún Guðjónsdóttir, decided to give me the chance of participating in the makings of the company. Eyrún also pointed me in the direction of this subject and it was a perfect fit to my interest in energy development and climate change. Eyrún deserves all my gratitude.

The Environment and Natural Resources programme supervisor, Dr. Brynhildur Davíðsdóttir, deserves great gratitude for her selfless assistance, dedication, interest, and most of all patience. Dr. Brynhildur provided essential guidance to the completion of this thesis. Lastly, I would like to thank my instructor, Dr. Daði Már Kristófersson, who provided guidance and more importantly the approach needed to perform this research. Dr. Daði's attempts to explain to me the nature of supply curves and marginal energy did not go in vain.

Abstract

Climate change presents a serious threat to various systems on earth that provide essential services to humans. The nature of the problem called for intergovernmental action, which has been provided through the UNFCCC and its Kyoto Protocol. The Kyoto Protocol provides for a mechanism, the CDM, to tackle climate change in a global manner by abating emissions and sequestrating greenhouse gases.

Electricity generation from a geothermal resource is applicable under the CDM framework and its potential worldwide capacity and low carbon emissions can assist in reducing global emissions. By replacing carbon intensive electricity production with a geothermal one, projects can earn tradable emission allowances under the CDM, adding to the revenue stream from electricity sales. The aim of this research was to examine whether this additional revenue could prove to be a financial premise for registering geothermal power plants as CDM projects.

A case study was performed where the investment cost of Icelandic geothermal projects, and emission factors from U.S. geothermal projects were used to convey the ones in Chile. The impact of additional revenue per kWh associated with CDM registration on long-term geothermal electricity in Chile was examined in order to assess whether there is a financial premise for such activity. The results indicated that registration would not have an impact on the supply in Chile as the entire geothermal fields can be developed without it. However, a revenue increase by 27%, 43%, and 46%, depending on replaced or prevented non-renewable generation, indicate that registration can have substantial impact on the feasibility of geothermal power plants. To conclude, further research on the investment costs associated with development and emission factors of the Chilean geothermal field is recommended for a more accurate display of the potential in the country.

Údráttur

Ýmsum mann- og vistkerfum, sem veita mannkyninu nauðsynlega þjónustu, stafar veruleg ógn af loftlagsbreytingum. Eðli vandans er þannig að þörf er á alþjóðlegu ríkjasamstarfi til að leysa hann, en því hefur verið komið á í gegnum Loftlagssamning Sameinuðu Þjóðanna og Kyoto sáttmálann. Í gegnum Kyoto sáttmálann komst á laggirnar framkvæmdaregluverk, CDM, sem hefur að markmiði að sporna við loftlagsbreytingum á alþjóða grundvelli með því að draga úr útblæstri og binda gróðurhúsalofttegundir.

Framleiðsla jarðvarmavirkjanna á rafmagni er gild til þátttöku í CDM. Möguleg framleiðslugeta þeirra um allan heim og lág meðallosun kolefna býður upp á möguleika til að draga úr útblæstri gróðurhúsalofttegunda á alþjóðlega vísu. Með því að skipta frá rafmagnsframleiðslu sem háð er mikilli losun á gróðurhúsalofttegundum yfir í framleiðslu frá jarðvarmavirkjunum er mögulegt fyrir framkvæmdaraðila nýju virkjananna, í gegnum CDM, að ávinna sér seljanlegar losunarheimildir. Þessar heimildir auka á tekjustreymi virkjanna. Markmið verkefnisins var að meta hvort að þetta auka tekjustreymi færði forsendur fyrir því að skrá jarðvarmavirkjanir sem CDM verkefni.

Rannsóknin fólst í því að meta stofnkostnað og útblástursstuðla jarðvarmavirkjanna í Síle út frá gögnum og forsendum íslenskra og bandarískra rannsókna. Áhrif auka tekjustreymis á langtíma framboð rafmagnsframleiðslu jarðvarmavirkjanna í Síle var metin sem tekjuaukning á hverja kílóvattstund framleidda. Niðurstöðurnar gáfu til kynna að CDM skráning jarðvarmavirkjanna í Síle hefði engin áhrif á framboð rafmagns frá jarðvarma, enda með gefnu rafmagnsverði sé fjárhagslega fýsilegt að virkja alla jarðvarmaauðlindina í Síle. Hinsvegar gáfu niðurstöðurnar til kynna að tekjuaukning vegna skráningar gæti orðið 27%, 43%, eða 46% eftir því hvaða rafmagnframleiðslu yrði skipt út. Niðurstöðurnar benda því til þess að skráning jarðvarmavirkjanna til þátttöku í CDM regluverkinu geti haft töluverð áhrif á fýsileika þeirra. Að lokum var mælt með frekari rannsóknum á stofnkostnaði jarðvarmavirkjanna í Síle sem og útblæstri gróðurhúsalofttegunda frá jarðvarmaauðlindum svæðisins til þess að frá skýrari mynd af hugsanlegum áhrifum.

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Abbreviations

AAU – Assigned Amount Units

CER – Certified Emission Reduction

CDM – Clean Development Mechanism

DNA – Designated National Authority

DOE – Designated Operational Entity

ERU – Emission Reduction Unit

IPCC – Intergovernmental Panel on Climate Change

JI – Join Implementation

RMU – Removal Units

UNFCCC – United Nations Framework Convention on Climate Change

1 Introduction

Climate change and its consequences presents various threats to ecosystems, water resources, human health, to name a few, and has, over the last two decades, received increasing attention in the international community. Regardless of opposing opinions regarding the actual threat of climate change, an international regime has been implemented by the United Nations aiming to counter the observed changes in the atmosphere.

The Kyoto Protocol is a piece of the climate regime puzzle and entails limiting emissions in industrialized countries. The Protocol also implements the Clean Development Mechanism (CDM); the main objective of which is to reduce emissions, sequestrate greenhouse gases, and further aid sustainable development globally. The CDM is further intended to provide incentives for private investment in developing countries.

The geothermal resource fits the requirements of the Clean Development Mechanism, as it is a renewable electricity source able to provide emission reductions through replacing conventional electricity sources. This thesis aims at discussing the role of geothermal power plants within the framework of the Clean Development Mechanism and whether there is a financial premise for participation in the mechanism.

The thesis and its subject relates to the academic and professional interest and experience of the author. As an M.Sc. student in Environment and Natural Resource Studies at the University of Iceland, the author has gained knowledge through courses in energy economics, environmental economics, energy technology and energy markets. As professional experience the author has practical experience through working at the start-up company KOLKA, which intends to operate in the carbon market in the near future.

1.1 The Subject

The subject of the thesis concerns the Clean Development Mechanism of the Kyoto Protocol, the CDM, and the development of geothermal projects within this framework established by the United Nations Framework Convention on Climate Change (UNFCCC). The CDM is defined in Article 12 of the Kyoto Protocol, which allows parties subject to quantified emissions limitations to take part in emission reducing projects in developing countries. The development of such projects yields emission allowances, which can be used to cover actual emissions. These projects provide means to assist governments as well as non-government parties to fulfill their mitigation commitments (Conference of the Parties 1998).

Projects utilizing renewable energy technologies are eligible for participation in the CDM framework and, as such, geothermal projects have been registered and earned emission allowances (Shrestha, Sharma, Timilsina, and Kumar 2005). The potential capacity of electricity generation from geothermal resources worldwide is vast and the emissions associated with such are far less than those of conventional electricity production. As a result, the potential for emissions abatement through the use of geothermal electricity is of a significant magnitude (Fridleifsson, Bertani, Huenges, Lund, Ragnarsson, and Rybach 2008). However, only 18 geothermal projects have been registered, representing a small fraction, 0,3% of total projects and issued CERs (UNEP Riso Center 2011).

1.2 Thesis Statement

The thesis is intended to answer the question of whether a financial premise exists for registering geothermal power plants as CDM projects. In order to answer this question the impact of CDM registration on long-term supply of geothermal electricity will be examined.

1.3 Objective

The main objective of the thesis is to answer the question asked in section 1.2. In order to do that, the author will perform a case study where the impact of CDM registration and subsequent earning of emission allowances on the long-term supply of geothermal electricity will be examined. The country of Chile was chosen as the site for the case study as it provides the necessary requirements of a geothermal resource and existing electricity generation from conventional non-renewable sources. To convey the investment costs necessary for the long term supply calculations and emission factors for abatement, studies on geothermal power plants from Iceland and the United States will be used, as no data regarding these elements in Chile exist.

The thesis also aims to document the process that renewable electricity projects need to complete prior to earning emission allowances. The process is extensive and entails 8 steps that a demonstrating that the projects fulfill requirements regarding sustainability, actual emission reduction, and voluntary participation.

When completed the thesis is intended to display a clear picture of the process that geothermal projects go through, from the initial drawings to issuance of emission allowances. By documenting the process parallel to examining financial feasibility of geothermal projects within the framework the thesis can prove helpful when deciding whether there is a premise for participation or not.

1.4 Thesis Structure

The thesis is divided into 9 main chapters. Following the introduction is a chapter regarding climate change. The chapter focuses mainly on climate change and especially global warming and its origins in the greenhouse effect. Additional effects of climate change are also briefly discussed as together these systemic problems present an overwhelming threat to ecosystems, water resources, human health, industry, and society (Parry, Canizani, Palutikof and co-authors 2007).

The third chapter covers the international climate regime implemented as a means to counter the effects of climate change and global warming. The regime in discussion is comprised of the UNFCCC, the Conference of the Parties to the UNFCCC, and the Kyoto Protocol. The main focus is on the Kyoto Protocol as it provides the flexibility mechanisms at the center of this thesis, the CDM

Emissions trading is the subject of chapter 4. It enables trading with the allowances issued as a result of CDM projects. The chapter discusses the ideas behind emissions trading, conditions for participation, and how initial tradable allowances are allocated. Following chapter 4 is an extensive chapter on the CDM framework. The chapter provides a discussion on project management and requirements for renewable energy projects within the framework. The chapter is a documented overview of the CDM process in accordance with the objectives of this thesis.

Chapter 6 is dedicated to geothermal projects and their potential worldwide capacity as well as potential contribution to emissions abatement. The chapter also briefly discusses application of geothermal resource utilization and adhering costs. A case study is performed in chapter 7 where elements from the CDM and geothermal chapter are applied to examine the potential impact CDM registration could have on long-term supply of geothermal electricity in Chile.

Chapter 8 discusses the results of the case study and concerns regarding project management as well as the CDM beyond 2012. It also provides some thoughts from the author regarding the research defects and possible further research. Lastly, chapter 9 is dedicated to providing a conclusion to the thesis and answering the question asked in thesis statement.

2 Climate Change

The foundation for this thesis lies in the systemic problem of climate change; especially the warming of the earth's atmospheric temperatures. Growing concerns within the international community regarding increased average temperatures led to the creation of the Intergovernmental Panel on Climate Change (IPCC) in 1988. The IPCC is the leading scientific body of climate change on an international level and is supported by the United Nations Environmental Program and the World Meteorological Organization, which are institutions under the United Nations. To understand the necessity of countering climate change it is important to understand its origins and effects.

2.1 Global Warming

The last two decades of the 20th century were the warmest ever recorded since the beginning of accurate monitoring. The unusual high temperature has been persistent through the beginning of the 21st century, but 1998 was the warmest year recorded in history (Houghton 2004). According to the scientific estimate of the IPCC, the average temperatures of the earth's surface increased about 0.3°C to 0.6°C during the last century. During the same time period the ocean's surface has risen a corresponding 10-20 cm (IPCC 1990). In the post industrialization era, the concentration of carbon dioxide in the atmosphere has increased by roughly 30% as a direct cause of the burning of fossil fuels, change in land use, and other anthropogenic emissions (Keeling and Whorf 2001).

The IPCC was founded in 1988 for the purpose of investigating the scientific effect of global warming as well as policy implementation regarding the subject. The establishment is the primary body of international scientific research as it evaluates the work of the field's scientists. The IPCC's assessment report publishes the work of several thousand scientists all across the globe (IPCC n.d.). These assessment reports are the most reliable publications one can find regarding the subject of global warming and climate change. In this discussion of climate change and global warming the IPCC assessment report provides a solid foundation of the scientific knowledge of the subjects.

The warming of earth's climate system is unequivocal as regular observations since 1970 demonstrate of the warming of earth's atmosphere and oceanic temperatures, melting of glacier areas, and rise in sea level. The warming of earth's atmosphere is observable on a global scale, the most severe impact being evident in the Arctic Circle. Observations from all of earth's continents and most oceans provide evidence for impacts of climate change, especially global warming, on ecosystems and their services. The primary examples of impacts on ecosystems are; the increase in number- and enlargement of glacier lakes, increased imbalances in permafrost ground, rock avalanches in mountain areas, and an alteration of ecosystems in the Arctic. Beyond these effects, effects of climate change can be documented as being the cause of the following effect on managed and human systems (IPCC 2007):

- Earlier spring planting of crops in agricultural and forestry management at the Northern Hemisphere along with alterations and disturbances of forests caused by fires and pests
- Increase in heat-related mortality in Europe, alterations in infectious disease vectors in Europe, and increase in seasonal production of allergenic pollen in Northern Hemisphere high and mid-latitudes
- Human activities in the Arctic such as hunting and travelling

The cause of climate change has been the vexed question of scientists and scholars since the dawning of the subject. Since both analysis of change in the climate and the reason for it are subject to observations it is difficult to determine the reason for climate deviations in the long-term as the data is relatively limited. However, the science of climate change has improved greatly as quantitative research is now founded in highly sophisticated statistical analysis which studies the complex pattern of climate change. Research conducted with multiple variables has demonstrated that the change in earth's atmosphere is caused by human activities (LeTreut, Somerville, Cuasch, Ding, Mauritizen, Mokssit, Peterson and Prather 2007).

The change in the concentration of so-called green-house-gases (GHG) and aerosols in earth's atmosphere, land cover, and the sun's radiation alter the energy balance in the climate system and influence climatic change. In the discussion of the cause of climate change and global warming the most significant issue is the emission of long-lived GHGs. The rate of anthropogenic emission on a global scale has increased approximately 70% since the dawning of the industrialization. Carbon dioxide (CO_2) is the most important GHG emitted through human activities as annual emissions of the gas increased from 21 to 38 gigatons, or 80%, in the period between 1970 and 2004. The increase is mostly due to energy generation, transportation, and industrial activities (IPCC 2007:26-73). CO_2 is not the only GHG emitted by anthropogenic sources as five other types of gas are listed as GHGs in the Kyoto-Protocol to the UNFCCC: methane (CH_4), nitrous oxide (N_2O), hydro fluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6) (Conference of the Parties 1998). The global increase in emission of CO_2 stem mainly from the increased burning of fossil fuels as is the case with CH_4 although agricultural activities also play a role in the emission of CH_4. Besides emitting CH_4, agricultural activities are also the main source of the increased concentration of N_2O in the atmosphere. The increased concentration of HFCs, PFCs, and SF_6 can traced directly to human activities as it was nearly non-existent prior to industrialization.

Predictions and models showing the continuing warming of earth's atmosphere in the 21st century display individual events by geographical locations. Warming is mainly expected over land areas, primarily in the northern hemisphere. According to the IPCC, extreme heat waves and precipitation and tropical storms can be expected to become more frequent because of climate change (IPCC 2007). However, as a safeguard, it has to be mentioned here that the range of natural variations in the earth's atmosphere is large and extreme variations in the climate system are by no means unprecedented. Long- term changes in the system can only be verified through years of research and documentation of climate. (Houghton 2004. The following section focuses on the greenhouse effect that causes the warmth of earth's climate (Houghton 2004).

2.1.1 Greenhouse effect

The term greenhouse effect draws its name from the fact that the earth and its atmosphere can be compared to a greenhouse since the atmosphere delivers the same role as glass in greenhouses. Short-wave solar radiation passes through the atmosphere relatively unobstructed, but long-wave terrestrial radiation emitted by the surface of the earth is partially consumed. An increase in the concentration of GHG's in the atmosphere causes the gases to intercept more radiation and through these effects the average surface temperatures in the atmosphere rise to a higher level (IPCC 1990). Through this process the atmosphere decreases heat loss from the earth and without it the average temperatures would be -19°C instead of 14°C (Umhverfisstofnun n.d.). Figure 1 explains this process in a simple manner.

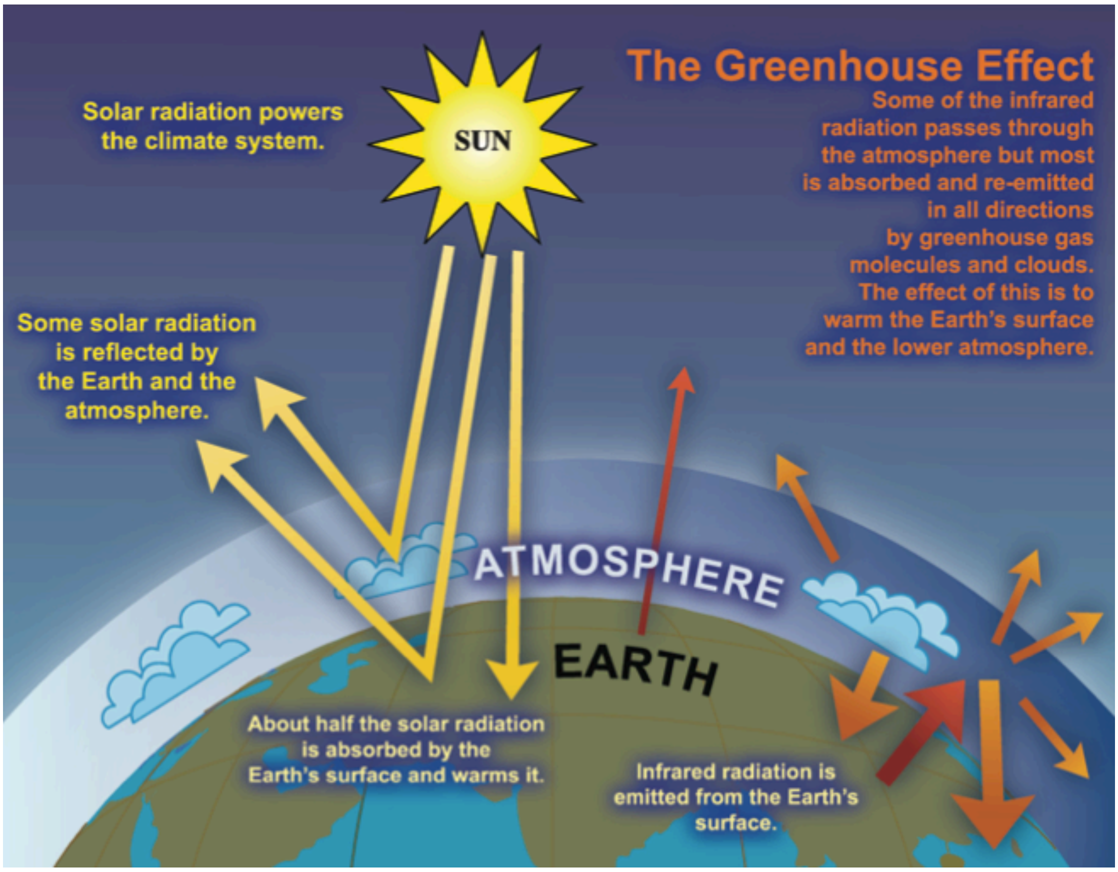

Figure 1 The Greenhouse effect. Source: Le Treut et al 2007.

The greenhouse effect is a natural process but the concentration of gases has varied throughout earth's history. Prior to the industrialization the concentration was relatively stable. Increased population, industrialization, changes in agriculture and land use make up the factors that have increased the emission of GHGs. Additionally, new gases were created through human activities which have added to the effect that greenhouse gases have on the warming of earth's surface temperatures (IPCC 1990).

2.2 Additional effects of climate change

Climate change does not only affect the average temperatures at earth's surface. The effect will most likely vary by geographical locations e.g. precipitation will increase at some locations but decrease at others (Houghton 2004). Current knowledge regarding the future impacts of climate change suggests widespread effects on various sectors of human systems. Table 1 provides a list of some of the main effects of climate change and the effect they will have on different sectors of human activities.

Table 1 Effects of climate change on different sectors. Source: Parry, M.L., O.F. Canziani, J.P. Palutikof et al 2007.

Phenomenon[a] and direction of trend	Likelihood of future trends based on projections for 21st century using SRES scenarios	Examples of major projected impacts by sector			
		Agriculture, forestry and ecosystems	Water resources	Human health	Industry, settlements and society
Over most land areas, warmer and fewer cold days and nights, warmer and more frequent hot days and nights	Virtually certain[b]	Increased yields in colder environments; decreased yields in warmer environments; increased insect outbreaks [5.8.1, 4.4.5]	Effects on water resources relying on snow melt; effects on some water supply [3.4.1, 3.5.1]	Reduced human mortality from decreased cold exposure [8.4.1, T8.3]	Reduced energy demand for heating; increased demand for cooling; declining air quality in cities; reduced disruption to transport due to snow, ice; effects on winter tourism [7.4.2, 14.4.8, 15.7.1]
Warm spells/ heatwaves. Frequency increases over most land areas	Very likely	Reduced yields in warmer regions due to heat stress; wildfire danger increase [5.8.1, 5.4.5, 4.4.3, 4.4.4]	Increased water demand; water quality problems, e.g., algal blooms [3.4.2, 3.5.1, 3.4.4]	Increased risk of heat-related mortality, especially for the elderly, chronically sick, very young and socially isolated [8.4.2, T8.3, 8.4.1]	Reduction in quality of life for people in warm areas without appropriate housing; impacts on elderly, very young and poor [7.4.2, 8.2.1]
Heavy precipitation events. Frequency increases over most areas	Very likely	Damage to crops; soil erosion, inability to cultivate land due to waterlogging of soils [5.4.2]	Adverse effects on quality of surface and groundwater; contamination of water supply; water stress may be relieved [3.4.4]	Increased risk of deaths, injuries, infectious, respiratory and skin diseases [8.2.2, 11.4.11]	Disruption of settlements, commerce, transport and societies due to flooding; pressures on urban and rural infrastructures; loss of property [T7.4, 7.4.2]
Area affected by drought increases	Likely	Land degradation, lower yields/crop damage and failure; increased livestock deaths; increased risk of wildfire [5.8.1, 5.4, 4.4.4]	More widespread water stress [3.5.1]	Increased risk of food and water shortage; increased risk of malnutrition; increased risk of water- and food-borne diseases [5.4.7, 8.2.3, 8.2.5]	Water shortages for settlements, industry and societies; reduced hydropower generation potentials; potential for population migration [T7.4, 7.4, 7.1.3]
Intense tropical cyclone activity increases	Likely	Damage to crops; windthrow (uprooting) of trees; damage to coral reefs [5.4.5, 16.4.3]	Power outages cause disruption of public water supply [7.4.2]	Increased risk of deaths, injuries, water- and food-borne diseases; post-traumatic stress disorders [8.2.2, 8.4.2, 16.4.5]	Disruption by flood and high winds; withdrawal of risk coverage in vulnerable areas by private insurers, potential for population migrations, loss of property [7.4.1, 7.4.2, 7.1.3]
Increased incidence of extreme high sea level (excludes tsunamis)[c]	Likely[d]	Salinisation of irrigation water, estuaries and freshwater systems [3.4.2, 3.4.4, 10.4.2]	Decreased freshwater availability due to salt-water intrusion [3.4.2, 3.4.4]	Increased risk of deaths and injuries by drowning in floods; migration-related health effects [6.4.2, 8.2.2, 8.4.2]	Costs of coastal protection versus costs of land-use relocation; potential for movement of populations and infrastructure; also see tropical cyclones above [7.4.2]

3 Climate Regime

In order to counteract the effects of climate change the United Nations have, through various organizations, created a framework, which is intended to establish grounds for anthropogenic emission reductions. The following chapter is dedicated to the framework, its institutions, and the binding agreements that the parties have committed to. The framework provides the foundation for this thesis, the CDM.

3.1 United Nations Framework Convention on Climate Change

In 1992 the UNFCCC was approved at the Earth Summit in Rio The framework was intended to be the foundation of international response to the troubles stemming from climate change. The Convention is supported by 194 nations, which made it near universal when it entered into force in 1994. Its main objective is to: "stabilise greenhouse gas concentrations in the atmosphere at a level that will prevent dangerous human interference with the climate system" (UNFCCC (a), 1, n.d.). The Convention further states that its objective should be reached within a sufficient time frame which provides ecosystems with the means to adjust naturally to climate change, ensures that food production is not jeopardized, and enables economic development to continue on a sustainable path.

UNFCCC establishes an overall framework for intergovernmental action to tackle climate change. Furthermore, the convention states that it is a blueprint that is subject to change and appendices as appropriate. The convention recognizes that the climate system is a universal resource threatened by industrial and other emission of GHGs. Through the UNFCCC, governments can collect and share information on GHGs, national policies and best appropriate practices to fight climate change. In addition, the Convention provides governments with the means to launch domestic strategies for addressing climate change, including the provision of financial and technical assistance to developing countries (UNFCCC (b) n.d.). Nations that have ratified the Convention agree to consider climate change when deciding on issues regarding agriculture, industry, energy generation, natural resources, and coastal activities (UNFCCC (c) n.d.).

Industrialized nations are made to carry the heaviest burden in the Convention since the origin of most past and current GHGs emissions stem from them. They are referred to as Annex I nations as they are registered in the first appendix in the text of the Convention. Annex I nations are assigned the task of providing the largest decrease in emissions as well as supporting developing nations financially in their quest of reducing emissions of GHGs. The support is granted due to the fact that economic development and growth is essential to the world's poorer countries and it has proved difficult to ensure progress in these parts even without the complications of climate change. The Convention realizes that emissions in developing countries will increase in the near future; nevertheless every effort will be made to assist these states in minimizing emissions without hindering economic development (UNFCCC (c) n.d.).

The initial benchmark of the Convention, which as stated before entered into force in 1994, was to reduce emissions in Annex I countries, as well as 12 economies in transition (countries and Central and Eastern Europe), down to 1990 levels by the year 2000 (UNFCCC (c) n.d.). As means to cut emissions the parties focused mainly on energy for example by switching from coal- and fossil fuel burning to natural gas in the generation of energy (Houghton 2004). As a group they succeeded to reach this goal (UNFCCC (c) n.d.). However, emissions from fossil fuels in 2000 increased by an average of 5% in the OECD countries but the goal was reached due to the participation of the former Soviet Union countries where emissions were cut by 40%, mostly due to the collapse of their economies (Houghton 2004). It must be stated here that the reduction targets which the states committed to were not legally binding as negotiators were unwilling to write such inhibitory objectives into the law, especially because of U.S. opposition (Oberthür and Ott 1999). As early as their first conference in Berlin 1995, the parties reached a joint conclusion that the commitments of the Convention would not suffice to meet its ultimate objective. A mandate was therefore established and given the task of coming up with suggestions to a more strict commitment, which later emerged in the Kyoto-Protocol (Umhverfisstofnun 2002). The Protocol will be covered in detail in section 3.2.

To stabilize the concentration of GHGs in the atmosphere can only be a short-term objective but the long-term mission is to achieve a considerable reduction of emissions (Houghton 2004). The most important scene that the Convention has established is the Conference of the Parties that serves as the reviser of the Convention, which is continuously being developed, and amended.

3.1.1 The Conference of the Parties

The Conference of the Parties (COP) is the supreme body of the UNFCCC. The Conference is an association of all of the countries that are parties to the Convention and is intended to meet annually, unless decided otherwise (UNFCCC (d) n.d.). The Conference can establish subsidiary institutions, make recommendations, and decide upon and enforce protocols and amendments to the Convention. The authority and responsibilities of the Conference are, among other things, to (UNFCCC 1992):

- Review the Convention's implementations and objectives
- Support development and refinement of comparable methodologies regarding the registration of GHG emission
- Tend to all activities that the Convention requires in order to fulfill its commitments

Immediately after the Earth Summit, parties began preparations for the first Conference of the Parties, which was hosted in Berlin 1995. The Convention's parties formed a negotiating committee whose task was to prepare international talks regarding climate issues (Oberthür and Ott 1999). At COP1 in Berlin, foundations were laid for what would later be called the Kyoto-Protocol. The COP1 established the Berlin Mandate, which received the task of shaping a legally binding scheme for emission commitments of the parties post the millennium (Conference of the Parties 1995). The period between COP1 and COP2, which was held in Geneva in 1996, proved to be a milestone as the Berlin Mandate submitted a draft to the Geneva Ministerial Declaration. The Geneva Ministerial Declaration states that the leaders of the parties present at the COP2 of the UNFCCC acknowledge and support the IPCC as: "the most comprehensive and authoritative assessment of the science of climate change, its impacts and response options now available" (Conference of the Parties, 9, 1996). Furthermore, the leaders of the Convention's parties will instruct their representatives to accelerate negotiations regarding a legally binding protocol or other statutory means presented at the third Conference of the Parties. The results of the negotiations should contain the remit of the Berlin Mandate, in particular the issues listed in Box 1.

- Commitments for Annex I Parties
    - Policies and measures including, as appropriate, regarding energy, transport, industry, agriculture, forestry, waste management, economic instruments, institutions and mechanisms
    - Quantified legally-binding objectives for emission limitations and significant overall reductions within specified time-frames, such as 2005, 2010, 2020, with respect to their anthropogenic emissions by sources and removals by sinks of greenhouse gases not controlled by the Montreal Protocol
- Commitments for all Parties on continuing to advance the implementation of existing commitments in Article 4.1
- A mechanism to allow the regular review and strengthening of the commitments embodied in a protocol or other legal instrument;
- Commitments to a global effort to speed up the development, application, diffusion and transfer of climate-friendly technologies, practices and processes; in this regard, further concrete action should be taken

Box 1 Necessary issues to be included in a legally binding protocol. Source: Conference of the Parties, 73, 1996

3.2 Kyoto Protocol

The Kyoto Protocol is an international agreement of the UNFCCC. The most significant implication of the Protocol is that it sets legally binding targets for 37 industrialized countries for decreasing GHGs emissions. The Kyoto Protocol was signed at COP3 in Kyoto, Japan on 11 December 1997 and became effective on 16 February 2005. The commitment targets of each country are referenced to the emissions of 1990 and aim at reducing the emissions of industrialized countries of an average of 5% during the commitment period of the Protocol from 2008-2012 (UNFCCC (e), n.d.).

3.2.1 History

Negotiations on the Kyoto Protocol began at COP1 in Berlin when the Conference adopted the decision to create the Berlin Mandate. The decision included statements regarding the inadequacy of the UNFCCC's non-binding commitment targets and the need for a protocol or some form of a legal instrument for appropriate emission reduction beyond 2000 (Depledge 2000). The European Union insisted that the negotiation's mandate would include both policies and measures, and quantified emissions limitation and reduction objectives for Annex I countries (Oberthür and Ott 1999).

The negotiation was a difficult process but after nearly two weeks of talks the parties were able to reach an agreement resulting in the Kyoto Protocol (Oberthür and Ott 1999). Most Parties to the Convention agreed to the Protocol, however some decided against ratifying. Therefore, it was decided that it would not enter into force until the ratification of 55 developed countries accounting for 55% of global emission in 1990 (Porter, Brown, and Chasek 2000) This was achieved in November 2004 with the ratification of Russia (UNFCCC (f) n.d.)

One of the most significant aspects of the Kyoto Protocol was the establishment of a market-based mechanism to assist Parties in achieving their commitments. A framework for the so-called flexibility mechanisms was provided in the negotiations at COP3 although detailed rules could not be established until the COP7 in Marrakesh, 2001 (Porter, Brown, and Chasek 2000). The flexibility mechanisms introduce a mean for Parties to achieve their commitment through emissions trading, creation of emission reduction unit, and the creation of tradable emission allowances through emission decreasing projects (UNFCCC (g) n.d.)

3.2.2 Content

The Protocol includes 28 articles and 2 annexes regarding policies and measures, emission limitations and reduction commitments, compliance, Parties participation, et cetera. The most significant feature of the Protocol is Article 3, which states that:

> 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"(Conference of the Parties, 5, 1998).

Article 2 of the Protocol enlists the spirit that policies and measures of Annex I Party of the UNFCCC shall consider in order to promote the sustainable development. The article's emphasizes especially the enhancement of energy efficiency through research, development, and increased use of alternative renewable energy. Article 12 further conditions Annex II Parties of the UNFCCC to support developing Parties by providing financial resources, and a transfer of technology (Conference of the Parties 1998). These two Articles (2 and 11) along with Article 12 provide the essential notion of the scheme that is the subject of this thesis as it pertains to a transfer of geothermal power plant technology to a developing nation. Two other articles are also important to this subject as they, and the CDM, make up the flexibility mechanisms. These are Articles 6 and 17 and relate to Joint-Implementation and emission trading and will be given further attention later in the discussion on the Kyoto Protocol.

Annex A of the Protocol lists the GHGs adhering to emission limitation, as previously stated those are (Conference of the Parties 1998):

- Carbon dioxide (CO2)
- Methane (CH4)
- Nitrous oxide (N2O)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulphur hexafluoride (SF6)

Annex A further enlists the source categories of emissions by sectors that are subject to emission limitations. Box 2 provides a list of these sectors. As seen the energy industry is included in the enumeration and is underlined as it concerns the subject of this thesis.

- Energy
    - Fuel combustion
        - Energy industries
        - Manufacturing industries and construction
        - Transport
        - Other sectors
        - Other
    - Fugitive emissions from fuels
        - Solid fuels
        - Oil and natural gas
        - Other
- Industrial processes
    - Mineral products
    - Chemical industry
    - Metal production
    - Other production
    - Production of halocarbons and sulphur hexafluoride
    - Consumption of halocarbons and sulphur hexafluoride
    - Other
- Solvent and other product use
- Agriculture
    - Enteric fermentation
    - Manure management
    - Rice cultivation
    - Agricultural soils
    - Prescribed burning of savannas
    - Field burning of agricultural residues
    - Other
- Waste
    - Solid waste disposal on land
    - Wastewater handling
    - Waste incineration

Box 2 Sectors subject to emission limitation according to Annex A of the Kyoto Protocol. Source Conference of the Parties, Annex A, 1998

Annex B of the Protocol lists the Parties subject to quantified emission limitation and their commitment targets, which will be further discussed in the following section.

3.2.3 Commitment targets

Table 3 shows the numerical commitments of the Parties to the Protocol in the commitment period from 2008 through 2012. All these states with the exception of the USA have signed the Protocol and the figures behind their names show the commitment to emission reduction in comparison with 1990 levels. These countries are Annex B parties to the Protocol and have committed to reducing their emissions. Developing countries that are members of the Protocol do not have emission targets but certain measures are in place for limiting GHG emission from those countries (UNFCCC 1998). States were allowed to fulfill their obligations jointly and the European Union chose to do so. Because of that individual states within the EU can increase their emissions while others will have to reduce emissions (Davíðsdóttir, Loftsdóttir, Hallsdóttir, Skúladóttir, Kristófersson, Rúnarsson, Haraldssson, Reimarsson, Einarsson, Sigfússon, 2009).

Table 2 Parties subject to emission limitation and their commitment target. Note that USA has not ratified the Protocol. Source: Conference of the Parties 1998.

Australia	108%	Estonia	92%	Japan	94%	Romania	92%
Austria	92%	Finland	92%	Latvia	92%	Russia	100%
Belgium	92%	France	92%	Liechtenstein	92%	Slovakia	92%
Britain	92%	Germany	92%	Lithuania	92%	Slovenia	92%
Bulgaria	92%	Greece	92%	Luxemburg	92%	Spain	92%
Canada	94%	Holland	92%	Monaco	92%	Switzerland	92%
Croatia	92%	Hungary	94%	New Zealand	100%	Sweden	92%
Czech	95%	Iceland	110%	Norway	101%	Ukraine	100%
Denmark	92%	Ireland	92%	Portugal	92%	USA	93%
EU	92%	Italia	94%	Poland	94%		

3.2.4 Compliance

Compliance to the Protocol's commitment targets is legally binding for Annex B Parties. The Convention and the Protocol provide the Parties with assistance to fulfill their commitments through policies and measures, information sharing on best practices, and the flexible mechanisms.

In the case of non-compliance the Conference of the Parties adopted the *Bonn Agreements on the Implementation of the Buenos Aires Plan of Action* at COP6 in Bonn, documenting the agreements on essential issues, including on compliance. According to that agreement the Parties established an enforcement branch, which is responsible for deciding whether a Party included in Annex I is in compliance with the commitment of the Protocol. The enforcement branch also serves to determine the consequences of non-compliance, which can include any of the following penalties (Conference of the Parties 2001):

- Deduction from the Party's assigned emission amounts in the second commitment period of the Protocol
- Development of an action plan that includes an analysis of the cause of non-compliance, structuring of an policies and measures to reach quantified emission limitation in the subsequent commitment period, and a timetable for implementing these policies and measures
- Suspension of eligibility to take part in emissions trading

3.2.5 Flexible Mechanisms

The innovative flexibility mechanisms of the Kyoto Protocol are probably one of the most significant accomplishments of the COP. The mechanisms provide countries with commitments under the Protocol with additional means for the sake of achieving their commitments. These measures are emission trading, the CDM, and joint implementation (JI). As an implement these mechanisms are supposed to:

> Stimulate sustainable development through technology transfer and investment, help countries with Kyoto commitment to meet their targets by reducing emissions or removing carbon from the atmosphere in other countries in a cost-effective way", and: "encourage the private sector and developing countries to contribute to emission reduction efforts (UNFCCC (g), 1, n.d.)

CDM and JI are project based mechanisms which supply the carbon market with emission allowances to be traded. JI allows industrialized countries to participate in emission reducing projects in other developed countries. The CDM, on the other hand, enables privately owned entities to invest in sustainable development projects that lead to a reduction in emissions in developing countries (UNFCCC (g) n.d.)

Parties that wish to undertake any activities regarding the flexibility mechanisms must fulfill eligibility requirements outlined by the Convention. Through their national communications under the Protocol they must demonstrate that the use of the mechanism is additional to domestic activities to fulfill their commitments. Among other conditions the Parties must also have ratified the Kyoto Protocol, have calculated their assigned amount in tons of CO_2 equivalent emissions, record and track the creation and movement of emission reduction units (ERU), certified emission reductions (CER), assigned amount units (AAU), and removal units (RMU), often called Kyoto unites, and report annually pertaining information to the secretariat, and annually report information on emissions and removals to the secretariat (UNFCCC (g) n.d.). Appendix III provides detailed explanation regarding these emission allowances and their origins. Emission trading will receive further attention in this thesis in a later chapter called the Carbon Markets but the JI is not relevant to this paper and will not be further discussed.

4 Emission Trading

Article 17 of the Kyoto Protocol provides an initiative for emissions trading known as the carbon market (Conference of the Parties 1998). At the first session of the meeting of the Parties to the Kyoto Protocol the COP implemented decision 11/CMP.1, which allows for trading of Kyoto units by any legal entity. Each of these emission allowance units is equal to 1 metric ton of carbon dioxide equivalent (Conference of the Parties 2006). The decision to implement a trading scheme involves assigning the right to emit GHGs a financial value, subject to commercialization on a market. The purpose of such a market is to create incentive for companies to increase energy efficiency or improve their emission control technology, and therefore, conserve their emission allowances. It is clear however, that the incentive is only feasible if the market value of the allowances is higher than the cost of abatement (Lefevere 2005).

Figure 2 illustrates the idea behind the emission trading scheme presented in the Kyoto Protocol. Legal entities, whether it is governments or companies, are allocated emission units (equivalent to one ton CO_2 equivalence). The entities can then submit those units to cover actual emission or, if they are allocated units in excess of actual emissions they can sell the extra units on a global market. Another legal entity can also create extra units through the flexibility mechanisms, such as the CDM, and sell those on the global market, i.e. the forester in Figure 2.

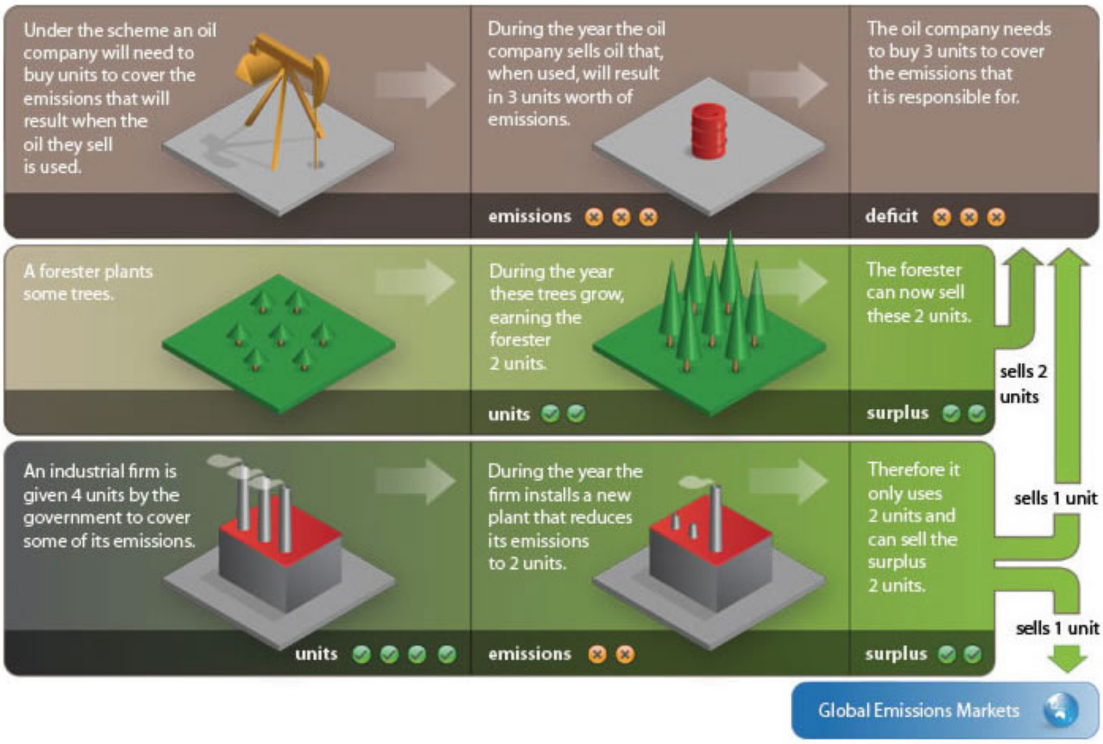

Figure 2 Emissions trading scheme diagram. Source: Climate Change Information 2010

4.1 Existing Conditions

As previously stated any Annex I Party of the UNFCCC that wishes to engage in trading emission allowances has to satisfy the conditions laid out in the Kyoto Protocol. One of these conditions requires a Party to have in place a National Registry. The National Registry has the role of administering the accounting of, and any other activity pertaining to, emission allowances of the respective Annex I Party. A National Registry performs, among other things, the issuing of emission allowances, transferring of allowances between private entities within the registry and between National Registries, and the writing off allowances that the respective state intends to use to fulfill its commitment target according to Annex B of the Protocol (Conference of the Parties 2006).

The National Registry shall exist in an electronic format and be consistent with the requirements laid out by the decisions of the Conference of the Parties to the Kyoto Protocol. The registry shall contain various accounts of emission allowances, including the respective state's account, entailing information regarding all of the states' emission allowances, and accounts for each private entity that is authorized to possess allowances (Conference of the Parties 2006).

Emission trading is also conditioned to limitation, a commitment period reserve. The commitment period reserve is intended to prevent that Annex I countries would be tempted to sell their emission allowances needed to fulfill their commitments. The minimum reserve is calculated as 90% of their total allocated allowances or a five-fold total emissions according to the latest inventory reports, whichever is the lower one (Conference of the Parties 2006).

4.2 Allocation

In order to trade, a party has to be allocated allowances. AAUs are allocated to each Annex I Party on the basis of their commitment targets listed in Annex B to the Kyoto Protocol. The allocation to private entities can vary between states. In the case of Iceland, the Ministry of the Environment allocated Iceland's AAUs to operational entities subject to emission limitations on the basis of their emissions output at full capacity (Úthlutunarnefnd losunarheimilda 2007). The EU allocated emission allowances to operational entities through the National Allocation Plans of each member state of the European Emissions Trading Scheme (EU-ETS) (European Commission 2010). Each member state was given the right to decide the total number of allocated allowances and how to distribute them, conditioned on the premise of a EU directive (Mortensen 2004). An additional condition existed stating the requirement that states would allocate 90% of gratuitous (Lee 2005).

4.3 Trading

According to Article 17 of the Protocol, emission trading involves an exchange between two sovereign states (Hobley and Hawkes 2005). States can nevertheless authorize private parties to engage in such trading, under the condition that they observe the regulations of the Protocol and the domestic regulation regarding trading according to Article 17 of the Protocol (Conference of the Parties 2006).

Annex I parties can decide to establish domestic or regional schemes for entity-level emissions trading. Kyoto Protocol emissions trading creates an operational framework for such schemes as any entity-level trading uses Kyoto units which need to be registered in the Protocol's accounting (UNFCCC 2008).

The credits which can be traded are the previously mentioned AAUs, ERUs, CERs, and RMUs; the Kyoto units. ERUs and RMUs are allocated allowances converted into JI units and CER are additional allowances created by the CDM Executive Board and generated by CDM projects (Bragadóttir 2009). Trading of the Kyoto units is carried out through both negotiations and contracts (over-the-counter trade) and climate exchanges operating in a secondary carbon market. Trading with AAUs and project related allowances basically adhere to the same principals and joint regulation according to the Kyoto Protocol (Bragadóttir 2009).

Trading with AAUs is simple in principal. Annex I Party A buys a specific number of allowances from Annex I Party B and pays for them with money or other valuables negotiated between the two states. Following the trade the agreed allowances are transferred from the National Registry of Party B to the National Registry of Party A. Subsequently Party A can now emit more GHGs than initially prescribed in Annex B of the Protocol but Party B less (Bragadóttir 2009). In the case of CER credits generated by CDM projects, which prior to the project did not exist, the allowances are created by the CDM Executive Board and then transferred to the respective account in a National Registry (UNFCCC 2011).

Emission trading according to the Kyoto Protocol can be divided into two steps: a trade contract agreement and the delivery of allowances. The Protocol does not include any specific regulation regarding the format or the content of a trade contract agreement. States and private entities are therefore able to negotiate a trading agreement despite the non-existence of material conditions. As an example of this a large part of emission trading is carried out through forward contracts, whereby the seller guarantees a delivery of allowances at a specified time in the future in exchange for a pre determined price payment of the buyer (Streck 2007). Rights and obligations of the trading parties depend on the contract itself and general regulation. Where private entities are concerned they have to determine what regulation should apply to the contract and how a possible dispute will be resolved (Witt Wijnen 2005). The contract usually includes the principal issues regarding business agreements such as description of the good (quantity and type of allowances), payment, and delivery date (Wilder, Willis and Guli 2005).

Delivery (transfer of allowances between National Registrations) however, cannot take place unless material conditions are met (Witt Wijnen 2005). The allowances only exist on an electronic format and therefore any trade is also carried out through an electronic system. Delivery is conditional upon approval from the international transactions log (ITL) which: “verifies transactions proposed by registries to ensure they are consistent with rules agreed under the Kyoto Protocol” (UNFCCC (h), 1, n.d.). National Registries sends transfer proposals to the ITL, which checks every proposal and approves or rejects them. When approved registries complete the transfer (UNFCCC (h) n.d.). Transfers of private entities go through the respective National Registry, as it is ultimately the state’s responsibility to fulfill the commitment targets of the Protocol (Conference of the Parties 2006).

Parties to the Protocol can establish domestic or regional emission trading schemes as policy instruments where legal entities can trade emission allowances to reach their individual quantity limitations. In such a case the domestic or regional scheme requires legal entities, subject to emission limitation by the Kyoto Protocol, to submit emission allowances matching their emission (UNFCCC 2008). The EU-ETS is an example of such a scheme. The EU-ETS is the largest existing carbon market and the commodity traded there is mostly European Emission Allowances (EUA). The EUAs are not formally Kyoto units but as they are transferred the respective National Registries are required to transfer a matching amount of AAUs between the corresponding accounts (European Commission 2008). EU legislation allows its participants to use most categories of JI/CDM credits towards fulfilling their obligations under the EU-ETS (European Commission 2010). This means that private entities subject emission limitation in the EU-ETS can use the CERs generated from CDM projects when submitting allowances for their emissions.

5 Clean Development Mechanism

In article 12 of the Kyoto Protocol the CDM is introduced as a mechanism to assist the Annex I parties in achieving their commitment targets of quantified emission limitation and reductions. More importantly, the CDM exists to assist non-Annex I Parties in realizing sustainable development and contributing to the fundamental objective of the Convention (Conference of the Parties 1998). Projects can generate CERs equivalent to the quantity of the emissions reduced, compared with the "business-as-usual" baseline of emissions. Thus, each project needs a baseline methodology to calculate estimated emissions without the project and a monitoring methodology to measure real quantity of emissions with the project (UNFCCC 2010). The CDM and the framework surrounding it presented by the UNFCCC is the central subject under research in this thesis. This chapter provides a discussion on the history of CDM along with the objective of the mechanism, its processes and governance. Finally the chapter covers the issuance of certified emissions reductions (CERs) which institutes can submit as means for achieving their emission limitations.

5.1 History

In the final moment of the COP3 in Kyoto 1997 the work of informal contact groups under the leadership of the Brazilian delegation supported by the US was presented to the negotiations. Prior to COP3 the Brazilian delegation had proposed a Clean Development Fund (CDF) in a meeting of the Ad Hoc Group on Berlin Mandate. The CDF proposal implied that Parties that fail to fulfill their emission limitations in a given budget period should receive monetary fines owed to the CDF. The CDF would in turn contribute to the issue of sustainable development in the developing countries. In Kyoto the CDF evolved into the CDM mechanism, providing an alternative for Annex I countries to meet their quantified emissions limitation through assisting developing countries achieving sustainable development (Sari and Meyers 1999).

5.2 Objective

As previously stated the objective of the CDM is to assist the Annex I parties in achieving their commitment targets and to endorse sustainable development and contribution to the UNFCCC by developing countries. The CDM is intended to provide incentives for private investment in developing countries. Increased investment and imports of the latest knowledge and technologies delivers improved growth in many areas of these countries (Davíðsdóttir et. al 2009).

5.3 Governance

Figure 3 shows an organizational chart regarding the governance of the CMD. The highest authority of the CDM is the COP and it serves as the regulating body of the mechanism. The mechanism is then supervised by the CDM Executive Board (EB) under the authority and direction of the COP. The Executive Board is fully responsible for the CDM framework and is the: "ultimate point of contact for CDM project participants for the registration of projects and the issuance of certified emission reductions" (UNFCCC (h), 1, n.d.).

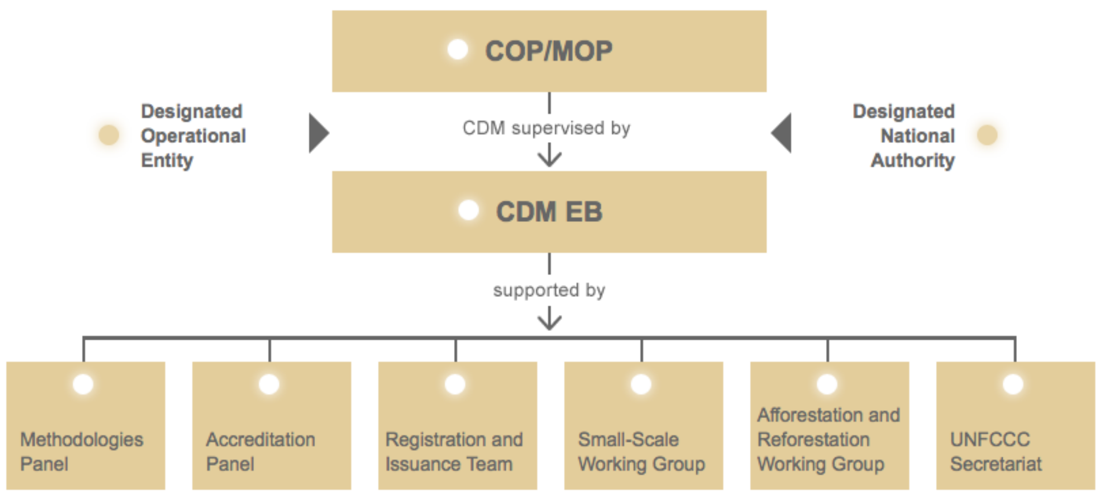

Figure 3 CDM governance hierarchy. Source UNFCCC (m) n.d.

Supporting the CDM Executive Boards are various panels, working groups, a registration issuance team, and the UNFCCC secretariat. The methodologies panel develops recommendations on guidelines for methodologies for baseline and monitoring plans and recommendations on proposals for new baseline and monitoring methodologies. The accreditation panel supplies preparations for the decision of the board. The registration and issuance team assist the board in its assessment. The small-scale working, and the afforestation and reforestation working groups prepare recommendations for new baseline and monitoring methodologies of projects and, finally the supports cooperative actions by states to combat climate change and contributions to a sustainable world (UNFCCC (h) n.d.).

A designated operational entity (DOE) is either a respective state legal entity or an international organization accredited and designated on a provisional basis by the EB. It has mainly two key functions: validating and subsequently requesting registration of a proposed CDM project and verification and certification of reduction by a CDM project (Global Environment Centre Foundation 2004). Parties partaking in the CDM are required to have a designated national authority (DNA) or the CDM. Registration of a proposed project can only be completed once approval letters from each party's DNA is obtained (UNFCCC (h) n.d.).

5.4 Criteria and eligible projects

CDM projects need to suffice global criteria of sustainable development and financial support to developing countries. The three major criteria are laid out in article 12 of the Kyoto Protocol (Shrestha et al. 2005):

1. The participation of country governments of respective partners in the CDM is voluntary
2. The projects result in real, measureable, and long term benefits related to mitigation of climate change
3. The reductions in GHG emissions from the CDM project should be additional to any that would occur in the absence of the CDM

Criteria 1 relates to an emission baseline to compare with reductions and criteria 2 is often referred to as the additionality criterion. These two criteria will be explained further in the process section of this chapter.

GHG mitigation project activities and techniques that reduce emissions from energy use and production, industrial processes, use of solvents, and other products, the agriculture sector, and waste management are eligible for CDM registration as well as projects that sequester carbon in biomass, afforestation and reforestation. The following, Box 4, is a complete list of types of GHG mitigation or sequestration projects and activities.

- Renewable energy technologies
- Energy efficiency improvements – supply side and/or demand side
- Fuel switching
- Combined heat and power
- Capture and destruction of methane emissions
- Emissions reduction from such industrial processes as manufacture of cement
- Capture and destruction of GHGs other than methane
- Emission reductions in the transport sector
- Emission reductions in the agricultural sector
- Afforestation and reforestation
- Modernization of existing industrial units/equipment using less GHG-intensive practices/technologies
- Expansion of existing plants using less GHG intensive-practices/technologies
- New construction using less GHG-intensive practices/technologies

Box 3 Types of GHG mitigation or sequestration projects and activities eligible for CDM. Source: Shrestha et.al, 12-13, 2005

Organizations that are eligible as project developers and operators are: governmental bodies, municipalities, foundations, financial institutions, private sector companies, and NGOs. CDM investors or the CERs buyers are entities that purchase the CERs generated by a CDM project and can be corporations, a government body, or an NGO (UNDP 2003).

5.5 Process

To earn CERs a CDM project activity goes through an extensive progress of design, approval, validation, registration, and monitoring. The CDM is an innovative mechanism and has potential to redirect the flow of investment to various groundbreaking projects such as transportation initiatives and energy conservations at both large and small scales. The project cycle includes numerous safeguards and checks, which ensure that registered activities work towards accomplishing the important goals of the mechanism. The project design document is the most important step in the CDM process as it describes the project and demonstrates how it will contribute to emission reduction and sustainable development (UNDP 2003). The project participant is fully responsible for the project design document and the involved methodologies. The rest of the process involves various activities carried out by the project participant, the designated national authorities, designated operational entities, and the CDM Executive Board. Figure 4 illustrates the project cycle in the correct order, step by step, and further indicates which party is responsible for each step.

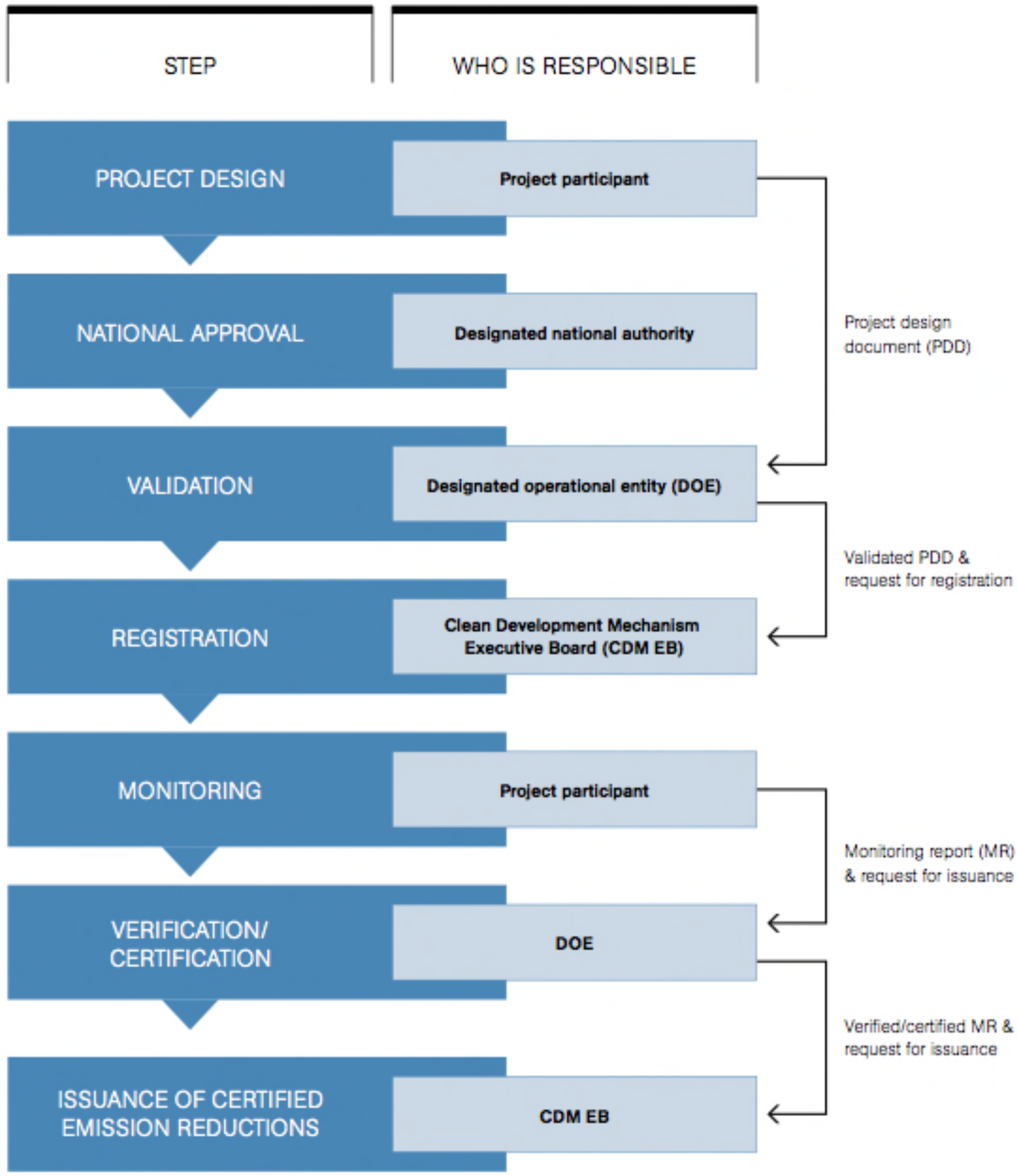

Figure 4. The CDM project cycle. Source: UNFCCC 2010

5.5.1 Project design

The project design is submitted to a designated operational entity in the form of a standardized document (UNDP 2003). The project design document (PDD) is necessary to all CDM projects, as they cannot earn any CERs without the development, validation, and Executive Board's acceptance of it. It can also serve as a valuable sales tool for investing partners of projects (UNDP 2003).

The standard PDD is divided into 5 content chapters and 4 annexes, as seen in Box 4.

Contents

A. General description of project activity
B. Application of a baseline and monitoring methodology
C. Duration of the project activity / crediting period
D. Environmental impacts
E. Stakeholder's comments

Annexes

Annex 1: Contact information on participants in the project activity

Annex 2: Information regarding public funding

Annex 3: Baseline information

Annex 4: Monitoring plan

Box 4 Contents of a project design document. Source: CDM Executive Board (e), 1, n.d.

Whether a proposed project is successful or not depends heavily on a clear, accurate, and comprehensive PDD. Concerned parties will use the PDD to evaluate the project and its merit. It needs to clearly demonstrate that the project will lead to additional GHG emissions reduction, beyond what would occur in its absence and, that the project will contribute to the host country's sustainable development. Establishing a baseline and assessing the project's additionality is the most technically challenging aspect of the PDD (UNDP 2003). A CDM project should yield a measureable decrease in GHG emission, they can result in a non-negative reduction of emissions, and therefore the concept of measurable reduction is based on a comparison with some defined level of GHG emissions. The baseline refers to this comparative level of emissions and reductions from a project activity are measured as deviation from that level (Shrestha et.al 2005). Project participants can decide to use an existing baseline methodology that has already been approved by the CDM Executive Board; these are listed at the official CDM website and are available to anyone. Participants can also choose to create a new methodology not included in the list. However, any new methodology has to be approved by the Executive Board before any project developer can use it (UNDP 2003).

The additionality criteria states that a proposed project activity should not only result in a reduction or sequestration of GHGs, but reductions beyond what would have occurred in the absence of the CDM project. Even without CDM, countries are likely progressing towards more efficient energy use and increased renewable energy. Thus, for a project to be eligible under the CDM scheme, reduction of GHGs should be greater than or additional to the reductions that are expected to occur in any case (Shrestha et.al 2005). Eligibility demands that a project developer distinctly demonstrates that the activity is additional to what would otherwise have occurred. The project developer is also required to demonstrate that the project was initiated, at least in part, with the purpose of reducing GHGs emissions (UNDP 2003).

5.5.2 National Approval

A designated national authority (DNA) is responsible for securing a letter of approval for a proposed CDM project (UNFCCC (i) n.d.). A DNA is one of the requirements for participation by a Party to the UNFCCC in the CDM. The main responsibility of the DNA is to evaluate proposed CDM projects to determine whether they will assist the host country, where the project takes place, in achieving its sustainable development goals. If the DNA decides that this is the case, it is then responsible for submitting a letter of approval to the CDM Executive Board (UNFCCC (j) n.d.). The letter of approval is prepared by the host country's DNA and should indicate the following (UNFCCC (i) n.d.):

- That the country is a Party to and has ratified the Kyoto Protocol
- That the project participation is voluntary
- A statement that the proposed CDM project activity contributes to the sustainable development objective of the host country

In practice there are two Parties, to the UNFCCC, involved in a CDM project, a host Party and an Annex I party. As previously stated the host party authorizes the participation within in its jurisdiction, and the Annex I party authorizes the participation of an Annex I entity (project developer). Prior to the request for registrations of a project activity a letter of approval is needed from the DNAs of both the host country and the Annex I party (Conference of the Parties 2006).

5.5.3 Validation

The PDD is validated by an accredited designated operational entity (DOE), a private, independent third-party certifier. When the PDD has been finalized and the host country approval is obtained, all documents are submitted to a designated operational entity (DOE), for review and approval, a process called validation (UNDP 2003). Validation of a CDM project as defined by the UNFCCC is:

> The process of independent evaluation of a project activity by a designated operational entity against the requirements of the CDM as set out in the CDM modalities and procedures and relevant decisions of the Kyoto Protocol Parties and the CDM Executive Board, on the basis of the project design document (UNFCCC (k), 1, n.d.).

Validation is carried out at the outset of a project and differs from verification, which occurs during the operation of the project. The process of validation ratifies that all the information registered and assumptions made within the PDD are accurate and/or reasonable. The DOE examines the data on GHGs emissions, as well as data and assumptions concerning technical, social, political, regulatory, and economic impact of the project in order to verify whether the applied methods and their results are factual (UNDP 2003).

The responsibility of arranging a validation for a CDM project by a DOE is at the hands of the developer. DOEs are private entities, which are contracted and compensated to validate and verify the projects and its emissions reduction. A project developer is required to contract a DOE listed and accredited by the CDM Executive Board. Accredited DOEs are listed at the official website of the CDM. The DOE is responsible for receiving consultation for the CDM project at an international level. International consultation is carried out simply through posting the validation on its website and by making the PDD publicly available for comments by parties, stakeholders and other UNFCCC accredited observers (UNDP 2003). From the publication of the PDD, a DOE must allow for 30 days for receipt of comments. All comments must be recorded and published in a report submitted to the CDM Executive Board (Conference of the Parties 2006).

5.5.4 Registration

The task of submitting a valid project to the CDM Executive Board is at the responsibility of the DOE, but the Executive Board performs the registration itself. Registration if the official acceptance by the CDM Executive Board of a validated project as a CDM projects activity. A registration acceptance is a prerequisite for the verification, certification and issuance of CERs for a project activity (UNFCCC (i) n.d.). Figure 5 shows the process of a CDM project prior to registration to the CDM Executive Board.

The registration is final after a maximum of eight weeks after validation and submission to the CDM Executive Board unless a review is requested (UNDP 2003). The registration step is four-fold and includes (UNFCCC (i) n.d.):

1. Completeness verification by UNFCCC secretariat
2. Vetting by the UNFCCC secretariat
3. Vetting by CDM Executive Board
4. Depending upon whether a Party or three members of the CDM Executive Board request review, a project undergoes a review, otherwise proceeds to registration

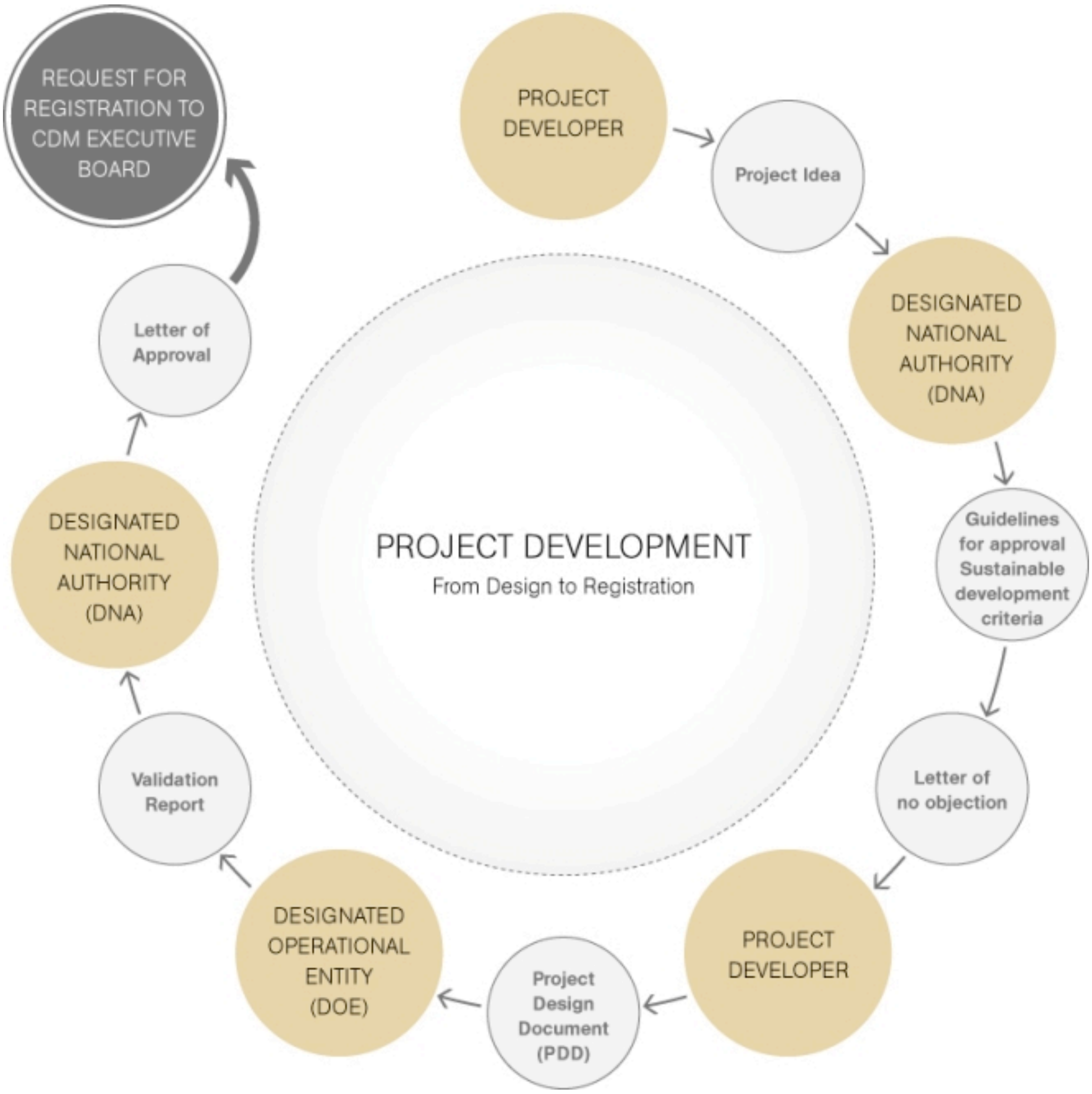

Figure 5 The process of a CDM project prior to registration to the CDM Executive Board. Source: UNFCCC (n) n.d.

If requested, the review by the CDM Executive Board must concern the issues related with the validation requirements for CDM projects. The validation of the project is not final until the review has been finalized, thus the project cannot be registered (UNDP 2003). If a project activity is rejected by the CDM Executive Board the reason for rejection must be published at the official website of the CDM. If a proposed project activity is not registered the first time it is submitted, it may be resubmitted and registered later (CDM Rulebook n.d.). Once the registration process is complete and the project activity has been accepted as a CDM project the project developer can carry on to the next step of the project cycle, monitoring.

5.5.5 Monitoring

Monitoring of a CDM project activity is the basis upon which the amount of issued CERs is calculated and determined as a deviation from the previously mentioned baseline. The project participant is responsible for monitoring the actual emissions of a project activity according to an approved methodology (UNFCCC (i). Monitoring is subject to verification and both activities are carried out at multiple times. From the point of implementation of the project, the developer is required to start monitoring the performance, according to the procedures described in the validated monitoring plan of the PDD. The monitoring results have to be submitted to a DOE for verification and certification. The project features subject to monitoring is at the very minimum the technical performance or the output and related GHG emissions. Additionality, environmental impacts and GHG leakage effects have to be monitored and recorded. If possible, the monitoring should be performed in accordance with existing monitoring activities. For example, the monitoring of a power generation project should be tied to activities related to the sales of electricity (UNDP 2003).

The monitoring plan needs to involve a specification of the frequency of monitoring activities, even though no specific frequency is required. Grounded on the monitoring outcomes, the GHG emission reductions from the project activity can be calculated and submitted for verifications as CERs. CERs are based on emission abatement quantity during the specific time period for which the monitoring results are provided (UNDP 2003).

5.5.6 Verification

> Verification is the independent review and ex post determination by the designated operational entity of the monitored reductions in anthropogenic emissions by sources of greenhouse gases that have occurred as a result of a registered CDM project activity during the verification period (UNFCCC (i), 1, n.d.).

As one can tell from the official definition concerning CDM projects by the UNFCCC, verification is at the responsibility of a DOE. The DOE verifies that emissions abatement occurred in the amount claimed, according to the approved monitoring plan. A single DOE can perform both validation and verification only if requested. However, using a single DOE for both tasks can result in a conflict of interest, and should be considered with caution (UNDP 2003).

The purpose of validation is to have a comprehensive evaluation of a proposed CDM project activity by a DOE, intended to ensure that the project meets all identified and applicable criteria. The COP derives this criterion from the Kyoto Protocol's, the CDM Modalities and Procedures, and decisions to the Kyoto Protocol, and the CDM Executive board. The assessment by the DOE should include (CDM Executive Board (a) n.d.):

1. Assessment of the evidence supporting the claims that the project would not be implemented without the benefits of the CDM
2. Ensure that the approved methodology is applicable and correctly applied
3. Ensure that the monitoring plan was developed in accordance with requirements and adequately implemented
4. Ensure that approval from Parties involved has been received, along with stakeholders consultation, the analysis of environmental impacts, and if necessary an environmental impact assessment has been undertaken
5. Ensure that decision of the COP/MOP and the CDM Executive Board have been complied with
6. Ensure that the stated emissions reductions and calculations have been performed in a sound and conservative manner

The verification process confirms the total quantity of CERs generated by a CDM project during a specific period of time. The frequency of verification is optional and a choice of the project developer, depending upon acceptance from the DOE. Frequent verification allows for more frequent delivery of CERs but is increases the transaction cost paid by the project developer or CER investor (UNDP 2003).

The DOE is also responsible for the certification included in the verification step. Certification is a ratified guarantee by the DOE that during the specified period, the CDM project accomplished the abatement as verified (UNFCCC (i) n.d.). The certification report submitted to the Executive Board should consist of a request to issue the amount of emission reductions, verified by the DOE, as CERs. Ultimately the DOE is responsible and liable for any underperformance, fraud, mistakes and misrepresentations for the verified emission reductions The DOE shall make the monitoring report available to the public and submit the verification report to the CDM Executive Board, which shall also be publicly available (UNDP 2003).

5.5.7 CER issuance

Once the CDM project cycle has been sufficiently completed by the project developer and the DOEs contracted, the project can earn CERs. Upon the receipt of the DOE's certification report the issuance of CERs, the issuance of CERs goes through the same process of completeness check, vetting by secretariat and Executive Board as in the registration process, unless a Party is involved, or at least three members of the CDM Executive Board request a review (UNFCCC (i) n.d.). If a review is requested, the Executive Board decides on the course of action. If it decides that the request has merit is performs a review and determines whether the suggested issuance of CERs should be approved. The review shall be completed within 30 days and the Executive Board shall inform the project participants of the outcome and make its decision public (Conference of the Parties 2006).

When issuance has been approved, the CDM registry administrator, instructed by the Executive Board, issues CERs corresponding to the specified amount into a pending account of the Executive Board in the CDM registry (Conference of the Parties 2006). The Executive Board receives a share of the CERs equivalent to the share of proceeds to cover administrative expenses and to assist adaptation by developing country Parties vulnerable to the adverse of climate change (Conference of the Parties 1998). The adaptation fund receives a standard 2% share of CERs (UNDP 2003). The remaining CERs are finally forwarded to the registry accounts of Parties and project participants involved, in accordance with their request (Conference of the Parties 2006).

5.6 Renewable electricity requirements

As stated earlier, projects involving renewable electricity generation are eligible for CDM registration. The idea is that installing renewable electricity generation, and subsequently replacing or diverting development of non-renewable generation, should provide for emission abatement. The CDM website offers applicable methodologies for developers of CDM projects. The approved methodology for large-scale grid-connected electricity generation from renewable sources is referred to as ACM0002. Large-scale power projects are those with more than 15 MW of capacity (CDM Executive Board (b) n.d.)

The ACM0002 provides a method for identifying the baseline to which reduction is compared to, and developing a monitoring methodology to monitor and register abatement. The ACM0002 is the standard method applied by geothermal power plant developers. The methodology document also refers to the latest versions of tools to calculate the emission factor for an electricity system, tools for the demonstration and assessment of additionality, and a tool to calculate project or leakage CO_2 emissions from fossil fuel combustion (CDM Executive Board (c) n.d.). For the purpose of this discussion, the project definition applied will be the one regarding installed power generation capacity, as described on page 2 in the ACM0002.

5.6.1 Baseline scenario

The baseline scenario for an installed power generation capacity is described as:

> The methodology procedure describes the identification of the baseline scenario as: Electricity delivered to the grid by the project activity would have otherwise been generated by the operation of grid-connected power plants and by the addition of new generation sources, as reflected in the combined margin (CM) calculations described in the "Tool to calculate the emission factor for an electricity system" (CDM Executive Board (c), 4, n.d.).

The combined margin described is:

> The result of a weighted average of two emission factors pertaining to the electricity system: the "operating margin" (OM) and the "build margin" (BM). The operating margin is the emission factor that refers to the group of existing power plants whose current electricity generation would be affected by the proposed CDM project activity. The build margin is the emission factor that refers to the group of prospective power plants whose construction and future operation would be affected by the proposed CDM project activity (CDM Executive Board (d), 2, n.d.).

The *tool to calculate the emission factor for an electricity system* provides a detailed description to identify and quantify an emission level for a baseline scenario. The tool requires participants to apply six steps (CDM Executive Board (d) n.d.):

1. Identify the relevant electricity system
2. Choose whether to include off-grid power plants in the project electricity system
3. Select a method to determine the operating margin
4. Calculate the operating margin emission factor according to the selected method
5. Identify the group of power units to be included in the build margin
6. Calculate the build margin emission factor
7. Calculate the combined margin emission factor

The relevant electricity system is defined by the spatial extent of the power plants that are connected to a grid to which the CDM project will be dispatched. The operating margin can be calculated by various means depending on the situation. The operating margin, build up margin, and the combined margin are expressed as tCO_2/MWh (CDM Executive Board (d) n.d.). The baseline emissions levels include only CO_2 emissions from electricity generation in fossil fuel fired power plants that are displaced or prevented by the CDM project. The methodology assumes that all project electricity generation above baseline emission levels would have been generated by existing grid-connected power plants and the addition of new-grid connected power plants. The baseline is calculated as the electricity generated by the CDM project in a year multiplied by the combined margin emission factor and expressed as tons of CO_2 per year. As a result, the baseline represents emissions of fossil fuel fired power plants at a generation capacity equal to that of the CDM project. The emission reductions are then calculated by subtracting the project emissions from the baseline emissions and expressed as tons of CO_2 equivalent per year (CDM Executive Board (c) n.d.). The baseline scenario can be found when demonstrating additionality as described in the following section, where the same calculation method applies. For further information regarding the calculation of the baseline emissions, project, emissions, operating, build up and combined margin, see the documents provided at the CDM website, www.cdm.unfccc.int.

5.6.2 Additionality

To demonstrate and prove additionality, developers of projects defined as installed power generation capacity, use the *combined tool to identify the baseline scenario and demonstrate additionality*. The tool provides a step-by-step procedure to demonstrate additionality as follows (CDM Executive Board (d) n.d.):

1. Identification of alternative scenarios
2. Barrier analysis
3. Investment analysis (if applicable)
4. Common practice analysis

Step 1 should identify all alternative scenarios to the CDM project. These alternatives should be available to the project participants, cannot be implemented parallel to the CDM project, and serve the same output as the CDM project. These alternatives, including the proposed activity undertaken without being registered as a CDM project, should be consistent with applicable laws and regulations. The outcome of step 1 provides a list of realistic and credible alternatives to the CDM project which all undergo a barrier analysis in step 2 (CDM Executive Board (d) n.d.).

The barriers can be technological or financial in nature. Step 2 should result in a list of barriers that may prevent one or more alternative scenarios and a list of alternatives that are not prevented by any barrier. If the proposed project without CDM registration is the only alternative scenario not prevented by any barrier; then the CDM project is not additional, therefore not applicable for registration as a CDM project. If there is only one alternative not prevented by any barriers and that alternative is not the proposed project without CDM registration, that alternative will be the baseline scenario. If CDM registration alleviates the barriers, the developer can proceed to step 4. If there are several alternative scenarios remaining, including the project without being registered as a CDM project, the developer proceeds to step 3. Finally, if there are several alternative scenarios remaining, not including the project without CDM registration, and registration alleviates barriers, project participants can either proceed to step 3 or identify the alternative scenario with the lowest emissions as the baseline scenario and proceed to step 4. If CDM registration does not alleviate the identified barriers, the project is not additional (CDM Executive Board (d) n.d.).

Step 3, investment analysis, results in a ranking of alternative scenarios provided in step 2 according to the most suitable financial indicator (net present value, internal rate of return, cost benefit ratio etc.) and a sensitivity analysis of the results. If the sensitivity analysis is not conclusive, then the alternative scenario with the least emissions among the alternatives is considered the baseline scenario. If the sensitivity analysis confirms the results of the investment comparison, then the most economically attractive scenario is considered the baseline scenario. If the alternative considered as the baseline is the proposed project without CDM registration, then the project is not additional. If not, the project participant can proceed to step 4 (CDM Executive Board (d) n.d.).

Finally, step 4, the common practice analysis is complementary to the prior steps and is an analysis of the extent to which the proposed project type has already diffused in the relevant sector or geographical area. It is a credibility check to demonstrate additionality and complements the barrier analysis, and where applicable, the investment analysis. Project participants are required to provide an analysis to which extent similar activities to the proposed CDM project have been implemented and are previously or currently underway, other CDM projects no included. If similar activities cannot be observed or are observed but essentially distinct from the proposed CDM project, and similar activities can be reasonably explained as distinct, for example, new barriers have arisen, then the project activity is additional (CDM Executive Board (d) n.d.). The process of demonstrating additionality is a rather complex one. Figure 7 is a flow chart of the process and can provide for a better understanding of the practice.

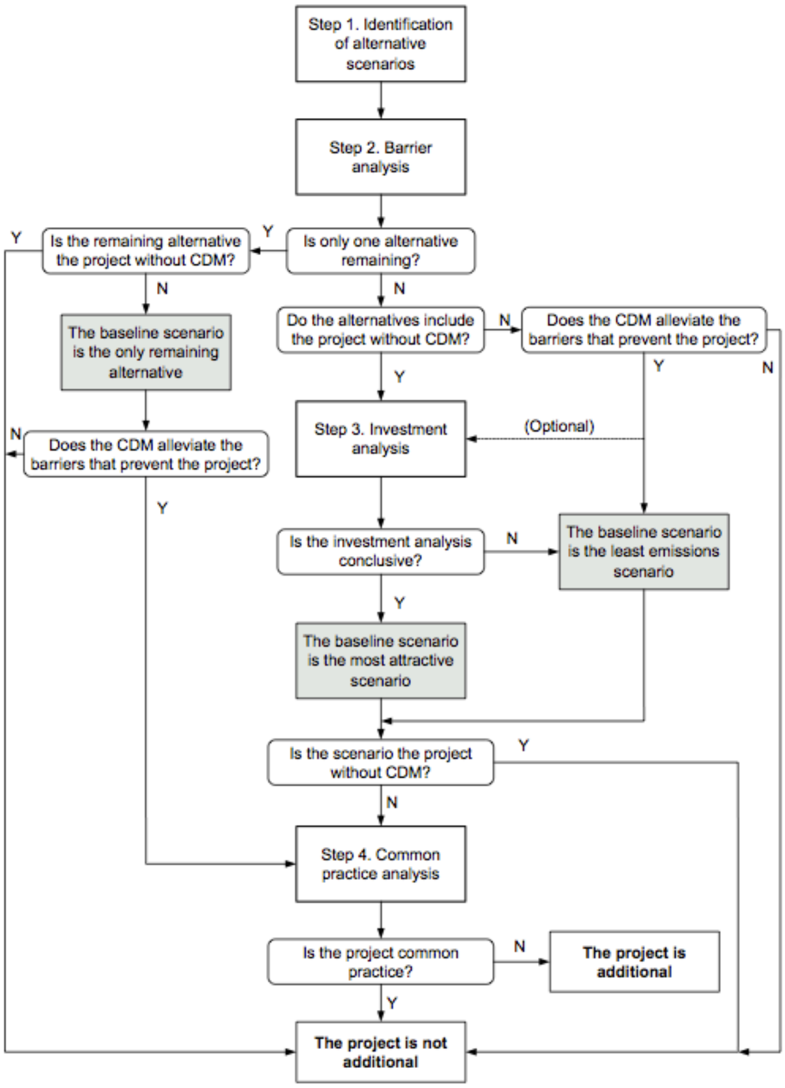

Figure 6 Flow chart of the additionality process. Source: CDM Executive Board (d) n.d.

5.7 Registered renewable electricity CDM projects

Since the Kyoto Protocol entered into force February 16th 2005, a total of 7,939 projects have applied for CDM registration. Out of these projects 6,559 are in the pipeline, excluding the ones that have been withdrawn, rejected by DOEs, or the CDM Executive Board. 3,337 have already received registration and, finally 1,135 projects have got CERs issued. A total of 670,128 thousand CERs have been issued as of August 1st 2011 (UNEP Riso Center 2011).

The majority of the projects in the pipeline categorized as renewable electricity generation are either hydropower or wind power projects. Renewables are also expected to earn the largest share of CERs until 2012, or 35%. Geothermal power plants represent however, only a very small part of projects in the CDM pipeline as well as of issued CERs. Only 18 projects are registered in the pipeline representing 0.3% of total projects as well as issued CERs (UNEP Riso Center 2011). Considering the fact that geothermal electricity is categorized as renewable energy, promotes sustainable development, has enormous potential capacity for electricity generation, and provides a substantial possibility for GHG mitigation, geothermal energy generation is an ideal project within the CDM framework (Fridleifsson, Bertani, Huenges, Lund, Ragnarsson, and Rycach 2008). The above mentioned qualities of geothermal electricity generation will be further discussed in the following chapter.

6 Geothermal Potential

Electricity generation by geothermal steam has existed since 1913, and geothermal energy has been used on a large scale for both electricity generation and direct use for the past five decades. Geothermal resources have been identified in 90 countries and utilization has been recorded in 72. Utilization of the energy source has increased rapidly during the last three decades and electricity production from geothermal steam increased by 16% from 1999 to 2004 while the direct use increased by 43% during the same time period (Fridleifsson et al 2008). Geothermal energy has the potential to provide long-term, secure base-load energy and GHG emission reductions (Goldstein, Hiriart, Bertani, Bromley, Negrín, Huenges, Ragnarsson, Tester, and Zui 2011). The installed world capacity of geothermal electricity is currently around 10 GW and it is considered possible to increase that figure up to 70 GW with present technology and to 140 GW with enhanced technology (Fridleifssson et al 2008). As stated in chapter 2, the IPCC is the leading scientific body of climate change, as such it has published numerous reports on the issue and ways to counter affect it. Two reports (Fridleifsson et al 2008 and Goldstein, Hiriart et al 2011.) include a discussion on geothermal potential for mitigating GHG emissions, and are a major source of information in this chapter

Average CO_2 emissions from geothermal power plants in high-temperature fields are around 120 g/kWh. Geothermal heat pumps that are driven by electricity generated from fossil fuels provide an emissions abatement of at least 50% compared with fossil fuel fired boilers. Furthermore, if the electricity that drives the heat pump is produced by a renewable energy source the emission abatement can reach up to 100%. Total annual CO_2 abatement achievable through the utilization of geothermal electricity and heat pumps has been estimated to be 1.2 billion tons per year. That represents about 6% of global emissions (Fridleifsson et al 2008). As stated in the preceding chapter the CDM framework allows for renewable electricity projects to be registered with the mechanism and receive CERs. Geothermal electricity production is categorized as a renewable energy source and therefore eligible for registration. To this date 11 such projects have been registered dating from April 2006. These projects have recorded emission savings of over 3 million tons of CO_2 equivalents (UNFCCC (k) n.d.).

6.1 Application

Geothermal resources are supplied by the thermal energy from earth's interior stored in rocks, and trapped steam or liquid water (Goldstein, Hiriart et al 2011). Generation of electrical power using the thermal energy contained in the fluid circulating in geothermal areas is generally feasible in the fluid temperature range of 200°C to 320°C, or a high-temperature geothermal field. Geothermal energy is currently extracted by using wells or other means that produce hot fluids from geothermal reservoirs. The geothermal fluid is typically mined using current technology at depths between about 1200 meters to 2500 – 3000 meters in most geothermal fields of the world (Elíasson, Thorhallsson, and Steingrímsson 2011). The heat is transferred to earth's interior towards the surface mostly by conduction, and this conductive heat flow makes temperature rise with increasing depth in the crust on average 25-30°C/km. There are three various types of geothermal resources and various types of systems for converting the resource into electric power. Geothermal resources are generally classified as convective (hydrothermal) systems, conductive systems, and deep aquifers. The convective or hydrothermal systems include liquid and vapor-dominated types. They are found in areas of magmatic intrusions, where temperatures above 1,000°C can occur at less than 10 km depth (Goldstein, Hiriart et al 2011). Conductive systems include hot rock and magma over a wide range of temperatures (Mock, Tester, and Wright 1997). Deep aquifiers contain circulating fluids in porous media or fracture zones at depths typically greater than 3 km, but lack a magmatic heat source (Goldstein, Hiriart et al 2011).

The most common method of electricity generation from a geothermal resource takes place in conventional steam turbines. The steam, usually above 150°C, is piped directly from dry steam wells or after separation from wet wells through a turbine which drives the electric generator (Dickson and Fanelli 2003). Various types of conversion systems, however, do exist. The conversion to electricity from a geothermal source is achieved through one of the following three basic conversion systems (Elíasson, Thorhallsson, and Steingrímsson 2011):

- Flashed steam/dry steam condensing system
- Flashed steam back pressure system
- Binary or twin fluid-system

The flashed steam or dry steam condensing system utilizes resource temperature ranging from about 320°C to some 230°C. This is the most common type of power conversion currently in use. A special focus is put on improving thermal efficiency and the hallmark of the condensing type system is the ability to achieve long and reliable service at a reasonable thermal efficiency, and good load following ability. A back pressure type system is the simplest of the above and has the lowest overall thermal efficiency. They are mostly used in multiple use application, i.e. both electricity production and hot water production. The resource temperature range for a back pressure type system is around 320°C to 200°C. Finally the binary type system is a different concept than the prior two. It utilizes a resource temperature significantly lower or between about 190°C to 120°C. The advantage of these types of systems is its ability to convert low-temperature geothermal energy to electric power, although at a low overall thermal efficiency. In addition to the three basic systems there are so called hybrid systems, which are combined systems made up of two or more of the above; condensing, back pressure, and binary system in series and/or in parallel (Elíasson, Thorhallsson, and Steingrímsson 2011). The hybrid conversion system's hallmark is its versatility, increased overall thermal efficiency, improved load following capability, and ability to efficiently cover the medial, 200-260°C, resource temperature range (Tester et al 2006).

Enhanced geothermal systems (EGS) are currently at the experimental stage in a number of countries. EGS technologies provide a means to utilize geothermal resources that previously were considered suitable for neither electricity production nor direct use (Goldstein, Hiriart et al 2011). A large scientific and industrial community has been involved in promoting these EGS systems for more than 20 years. EGS plants can have a substantial impact on the potential electric capacity of geothermal resources as well as positive environmental effects. Once operational, they can be expected to emit zero

CO_2 so the benefits from such plants could prove to serve the fight against climate change (Fridleifsson et al 2008).

6.2 Potential Energy Production

The heat content of the earth as well as the heat in its crust, measured in megajoules, is significantly higher than the total world electricity generation in megajoules, the majority of potential stemming from EGS production. The thermal energy is therefore immense, however only a fraction of that can be utilized. So far utilization is limited to areas in which geological conditions permit a carrier (water or vapor) to transfer the heat from hot fields to or near the surface (Fridleifsson et al 2008).

Geothermal utilization is usually divided into two categories: electric production and direct application (hot water production). The topic of this paper concerns electric production, which is commonly limited to fluid temperatures above 180°C, however considerably lower temperatures can be used with the application the binary fluids mentioned in the previous section (Fridleifsson et al 2008)

At the end of 2009 the total electricity generation from conventional geothermal resources (hydrothermal) was at a capacity of 10.7 GW, and the average annual growth over the last 40 years measured at 7%. At the end of 2008, geothermal electricity contributed only around 0.3% of the overall worldwide electric generation. Figure 7 shows the installed capacity by country in 2009 as well as the worldwide average heat flow and tectonic plate boundaries.

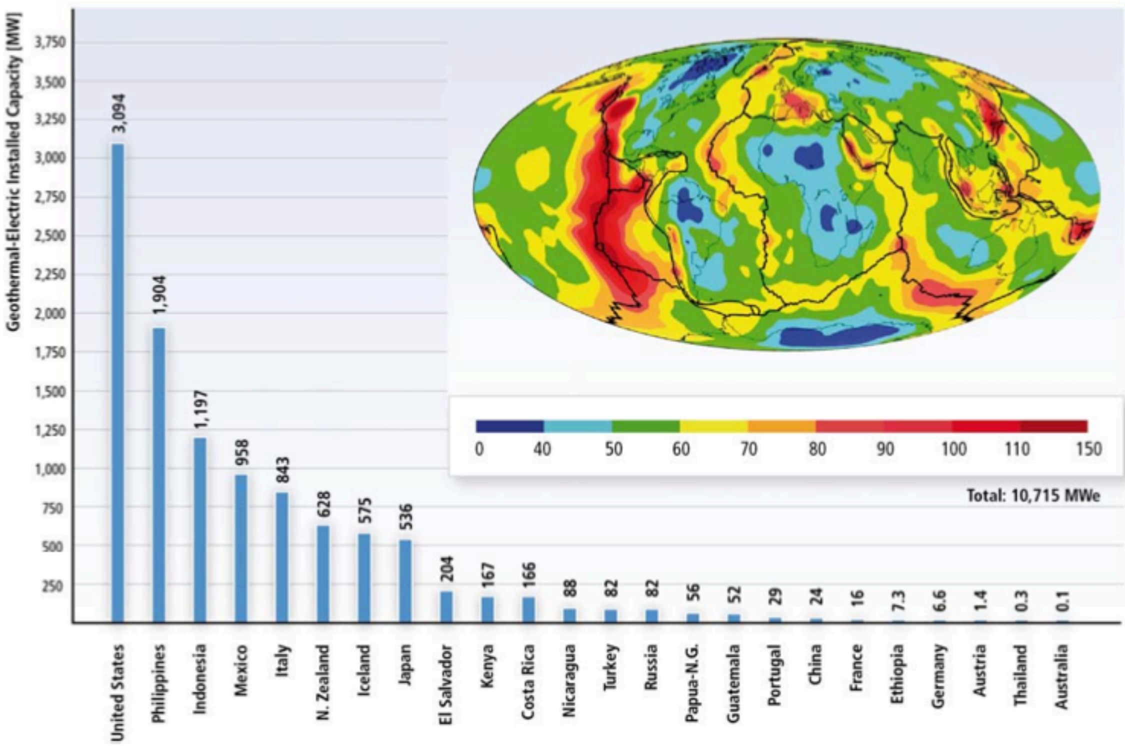

Figure 7 Installed capacity of electricity from geothermal by country in 2009 and the worldwide average heat flow and tectonic plate boundaries. Source: Goldstein, Hiriart et al 2011.

Estimating the overall worldwide potential electricity generation from geothermal resources is difficult due to the presence of too many uncertainties. Nevertheless, some studies have been performed to identify a range of estimations, including considerations of the possibilities presented by new technologies like the EGS. Stefánsson (2005) presented a comprehensive estimate for conventional hydrothermal resources in the world. Stefánsson calculated the global technical potential for identified hydrothermal resources as 200 GW with a lower limit of 50 GW. He further assumed that unidentified resources are 5-10 times more abundant than the already discovered ones and then estimated the upper limit for the worldwide geothermal technical potential as between 1.000 and 2.000 GW, with a mean value of 1,500 GW (Goldstein, Hiriart et al 2011). Bertani (2003) presents a compilation of data on geothermal electric potential published by different authors. Although the data is strongly scattered, the methods seem to be realistic and Bertani estimates the potential to be a minimum 35-70 GW and a maximum of 140 GW. Bertani's estimates can be seen in Figure 8 as well as the current capacity (Fridleifsson et al 2008).

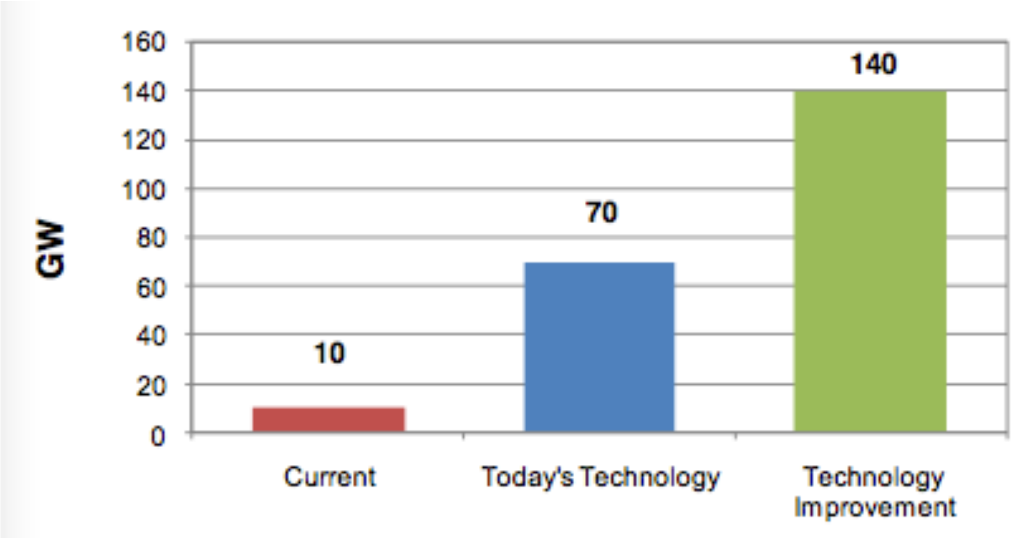

Figure 8 Estimated geothermal electricity potential with present technology and technology improvements as well as current installed capacity. Source Fridleifsson et al 2008

The potential capacity can be a magnitude higher if estimations are based on EGS technology. A MIT-study performed by Tester et al. (2006), indicated a potential of more than 100 GW for USA alone and further 35 for Germany alone (Paschen, Oertel, Grünwald 2003). Theoretical considerations, as stated before, reveal that the magnitude of undiscovered resources is expected to be 5-10 times larger than the estimate of identified resources (Fridleifsson et al 2008). Geothermal resources could produce up to 8.3% of the total world electricity and serve 17% of the world population. Furthermore, 39 countries, located mostly in Africa, Central-, and South-America and the Pacific, can potentially obtain 100% of their electricity from geothermal sources (Fridleifsson et al 2008).

6.3 Contribution to mitigation of GHGs

According to Goldteins Hiriart et al 2011, environmental impact from geothermal energy utilization is generally negligible. The hot fluid can however emit varying quantities of GHGs. These GHGs originate from naturally sourced CO2 fluxed that would eventually be released into the atmosphere (Goldstein, Hiriart et al 2011). The amount of GHG emissions depends on the geological conditions of different fields. The range in CO_2 emissions from high-temperature geothermal areas used for electricity production in the world is variable, but much lower on average than that for fossil fuels. Adding to that, the GHG emissions from low-temperature geothermal resources are usually only a small fraction of the ones from the high-temperature fields (Fridleifsson et al 2008).

USA is the leading producer of electricity from geothermal, with generation of roughly 18,000 GWh/yr in 2005. Bloomfield, Moore, and Nelson (2003) compared the average values for all geothermal capacity in the USA, including binary power plants. Bloomfield et al 2003 reported that the emissions of the geothermal power plants in CO_2 equivalents was 91 g/kWh. These findings are compared to emissions from electricity production from natural gas, oil, and coal in the U.S in Figure 9 as presented by Fridleifsson et al (2008). This data will be used later on in a case study estimating the impact of CDM registration on the feasibility of geothermal power plants.

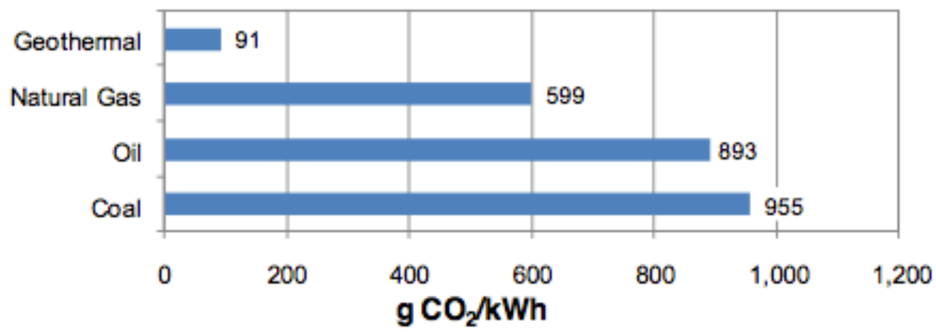

Figure 9 Average CO2 emissions per kWh from different electricity generation sources. Source: Fridleifsson et al 2008

Further studies on the emission of CO_2 from electricity generated from a geothermal resource indicate similar figures as Bertani and Thain (2002) reported on data obtained in 2001 from 85 geothermal power plants operating in 11 countries around the world. These plants represented 85% of the world capacity of geothermal power plants and their weighted average emissions was reported to be 122 g CO2/kWh, which compares fairly with the 91 g/kWh reported by Bloomfield et al (2003). However, the collected data displayed a wide spread of range between power plants, from 4 g/kWh all up to 740 g/kWh.

With current technology, it is possible to increase the installed capacity of geothermal power plants from 11 GW for the year 2010 up to 70 GW. Through gradual improvements of new developments, it is considered possible to boost the growth rate by exponential increments after 10-20 years, and reach a global installed capacity of 140 GW by the year 2050. Table 3 provides an overview of the status of installed capacity of geothermal power plants and a forecast for 2010 to 2050.

Table 3 World installed capacity in the past, future forecasts, and the capacity factor of geothermal power plants. Source: Fridleifsson et al 2008

Year	Installed Capacity (GW)	Electricity Production (GWh/yr)	Capacity Factor (%)
1995	6.8	38,035	64
2000	8.0	49,261	71
2005	8.9	56,786	73
2010	11	74,669	77
2020	24	171,114	81
2030	46	343,685	85
2040	90	703,174	89
2050	140	1,103,760	90

Using the data in Table 3 Fridleifsson et al (2008) provided a possible mitigation scenario as can be seen in Figure 10. According to the scenario provided, geothermal production of about 100 TWh/yr in 2050 would mitigate (depending on what is substituted) hundreds of million tons CO_2/yr. Present technology with dominant open systems and released emissions can provide some tens of millions tons CO_2/yr, whereas future technology with re-injection will result in near zero emissions (Fridleifsson et al 2008). Future technology also includes the previously mentioned EGS power plants, which are likely to be designed as liquid-based closed-loop circulation systems, with zero direct emissions (Goldstein, Hiriart et al 2011).

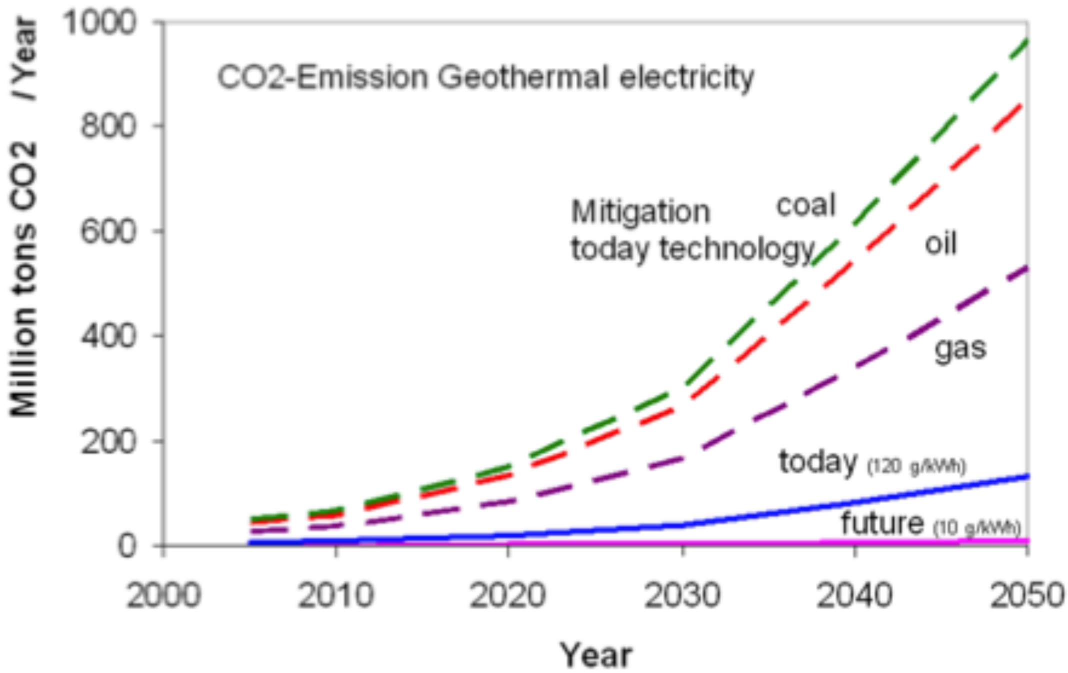

Figure 10 Mitigation potential of geothermal power plants based on data of Table 3 and assumptions for emissions of 120 g CO_2/kWh for today and 10 g CO_2/kWh for future technology. Source: Fridleifsson et al 2008

As stated earlier and demonstrated in Figure 10 the emission savings per kWh that electricity generation form a geothermal resource can provide is of a significant magnitude. If the technical potential is as large as the upper limit range of 1-2 TW, as presented by Stefansson (2005), the contribution of geothermal electricity to the mitigation of GHGs could be immense.

6.4 Cost of Geothermal Electricity

Geothermal projects are capital intensive but have a relatively low operational and maintenance cost. The high upfront investment is required to drill wells and construct power plants. Cost estimates for geothermal installations can vary greatly; up to 20-25% between countries and different factors can affect them (Goldstein, Hiriart et al 2011).

Investment cost falls upfront, prior to any electricity generation. The current worldwide range of estimates suggests that investments costs lie in the range of 1.780 – 3,560 USD_{2005}/kW for conventional plant and 2,130 – 5,200 USD_{2005}/kW for binary cycle plant (Bromley, Mongillo, Hiriart, Goldstein, Bertani, Huenges, Ragnarsson, Tester, Muraoka, and Zui 2010). The investment cost is composed of the following components, which are usually independent from each other (Goldstein, Hiriart et al 2011):

a) Exploration and resource confirmation
b) Drilling of production and injection wells
c) Surface facilities and infrastructure
d) The power plant

Operation and maintenance costs consist of fixed and variable costs directly related to the electricity production. It includes field operation (labor and equipment), well operation and facility maintenance. An additional factor is the cost of replacement wells (new wells to replace failed ones and restore lost production or injection capacity). Each geothermal power plant has specific O&M costs that depend on their quality and design, the resource, environmental regulations and the efficiency of the operator. The major factor of these costs is the extent of work-over and replacement well requirements, which can vary greatly (Goldstein, Hiriart et al 2011). These costs have been proposed to be $UScents_{2005}$ 1.9 and 2.3 per kWh (Lovekin 2000; Owens 2002) and Hance (2005) proposed an average of $UScents_{2005}$ 2.5 per kWh.

Master Plan for hydro and geothermal energy resources in Iceland (2011) (hereafter *Master Plan)* provides findings on the protection and utilization of areas in Iceland containing hydropower and geothermal resources. The study is the most extensive work existing that includes the feasibility of geothermal power plants. It provides a list of 44 possible geothermal power plants with a combined capacity of 3,773 MW and estimates of their individual feasibility. The feasibility of the power plants is calculated as initial investment cost and measured as ISK per kWh per year. Table 4 provides an overview median of the categories converted into US_{2010} dollars and an extra category, 2,5, as did the results of the study (Jóhannesson, Olsen, Þóroddsson, Friðriksson, Ingólfsson, and Karlsdóttir 2011). The findings presented by Jóhannesson et al (2011) are comparable to those of Lovekins (2000) and Owens (2002).

Table 4 Feasibility categorization from Master Plan converted to U.S. dollars. Original categories can be found in Appendix I

Feasibility $		
Feasibility	**ISK/kWh/yr**	**$/kWh/yr**
1	24	0.19
2	30	0.24
2.5	33	0.26
3	36	0.29
4	46.5	0.37
5	59.5	0.48
6	68	0.54

The majority of the possible power plants landed in category 3 with the median feasibility of $0.29 kWh/yr. 9 power plants landed in category 2 with the median feasibility of $0.24 kWh/yr and finally 3 landed in category 2.5 with a median feasibility of $0.25 kWh/yr. These results, as well as the emissions data provided in Fridleifsson (2008) will be used in the case study provided in the next chapter.

Concerning future cost trends of geothermal power, the prospect for technical improvement indicates cost reductions in the near and long term future for both conventional technology and the EGS. According to Goldstein, Hiriart et al (2011) foreseeable engineering and technology improvements can result in a 7% global average reduction in levelized cost of electricity of geothermal power plants by the year 2020.

7 Case Study

The potential impact of CDM registration and subsequent CER issuance on geothermal power plants can be explored by performing a case study involving a regional scenario in a country eligible according to the Kyoto Protocol. In this case, a scenario involving the country of Chile will be used. Chile is a good example because its location in the Pacific Ring of Fire provides the country with the possibility of geothermal electricity production from high-temperature fields (Lahsen, Muñoz and Parada 2010). Chile also currently has a large share of the installed electricity capacity generated from sources such as natural gas, oil, and coal that have a substantially higher emission factor than geothermal. The total amount of installed electricity capacity in Chile in 2008 was 13,137 MW of which, 8,007 MW were generated through the use of the above mentioned sources (International Energy Agency 2009). Therefore, Chile provides excellent premises for switching sources of energy production from non-renewable sources to renewable ones, such as geothermal electricity generation.

According to the work of Alfreda Lahsen et al, at the Department of Geology in the University of Chile, the geothermal fields in Chile with fluids temperatures exceeding 150°C at a depth less than 3,000 meters are capable of producing 16,000 MW of electric energy for at least 50 years. (Lahsen, Muñoz and Parada 2010).

To obtain the effect of emission reduction incentives on long run electricity supply it is necessary to have access to detailed data on the cost of individual projects, e.g. feasibility studies. This data is unfortunately not available for Chile. In fact, the only comprehensive feasibility study for geothermal energy is the comprehensive plan for energy development (*Master Plan*) of Iceland. This is therefore adopted as a reference for a simple model of long run supply of geothermal power and applied to geothermal energy production in Chile. This approach relies on several simplifying assumptions. Firstly, it is assumed that cost structure of geothermal projects is similar between Iceland and Chile. This assumption is supported by comparing the cost structure of hydropower projects in the two countries, since data is available for hydropower in both countries. Secondly, it relies on the assumption that geothermal energy is part of marginal energy in the Chilean energy market; that is the energy made profitable by an increase in price.

The Icelandic *Master Plan* provides a feasibility study of 43 possible locations for geothermal electricity generation with a combined power of 3,773 MW as well as 39 possible locations for hydro power plants with a combined power of 2,994 MW (Jóhannesson et al 2011).

7.1 Assumptions

The study is limited to the extent that the assumptions made indicate that the geothermal resource in Chile can be utilized at a similar investment cost as the Icelandic one, adding a multiplication factor. The multiplication factor was found by comparing the investment costs of hydropower plants in Iceland presented by Jóhannesson et al (2011) to those presented by the Chilean Economic Development Agency in *Renewables in Chile – Investment opportunities and project financing – Project directory* (2009) (hereafter the Project Directory) (CORFO 2009)

The study and its findings are further limited by an assumption regarding emissions. Emissions from geothermal power plants in the Chilean resource are assumed to be identical to the ones in the U.S. as presented by Fridleifsson et al (2011). Furthermore, the emissions stemming from electricity generation from natural gas, oil, and coal resources were also assumed to be identical to the ones presented by Fridleifsson et al (2011).

As stated in chapter 5, both investment costs and emission factors can vary greatly between countries depending on various different factors such as technology, access to resource, character of the resource etc. (Goldstein, Hiriart et al 2011; Fridleifsson et al 2008). However, these assumptions provide means for achieving a reasonable estimate of the impact of CDM registration for geothermal power plants.

7.2 Data collection

The data collected for the study regards the investment cost of geothermal power plants and hydrothermal power plants, as well as emission factors for various kinds of electricity generation sources, CER prices, and finally electricity prices. The more extensive data will be listed and displayed in appendices.

Data on the feasibility of both possible geothermal power plants and hydro power plants in Iceland was retrieved from *Master Plan*, which is a framework plan for protection and utilization of natural areas with emphasis on hydropower locations and geothermal high temperature fields. The report includes figures for possible installed capacity for every possible power plant in Iceland, geothermal (44) and hydro (39), as well as possible annual generation, and finally the feasibility as investment cost per kWh per yr. The information was first published in 2010 and the data on the power plants is from March 2010. This data can be found in Appendix I.

The *Project Directory* provided data on the feasibility of hydropower plants in Chile. The report offers information regarding installed capacity, estimated capacity factor, annual electricity generation, and investment cost in U.S dollars of 19 hydropower plants in Chile. The report is relatively new or from 2009. The data used can be found in Appendix II.

Emission data for electricity generation by source was retrieved from Fridleifsson et al (2008), *The possible role and contribution of geothermal energy to the mitigation of climate change,* published by the IPCC in February 2009. It contains emissions figures for geothermal, natural gas, oil, and coal power plants in the U.S. in 2003. These figures can be found in section 6.3 of this thesis.

The price of electricity per kWh was needed to estimate the effect additional earnings from CER revenue compared to power plants without these earnings. The CRU Analysis (2011) report *Aluminium Smelter Power Tariffs the 2011 edition* provided figures suited for this kind of comparison as it represents the absolute minimum a power plant can receive for its production. The tariffs used for the purpose of this case study were the global, excluding China, 2009 nominal tariffs expressed in U.S. mills per kWh. The electricity price can be seen in section 7.4 where the impact of CDM registration on the supply of geothermal electricity is discussed.

To estimate CER revenue, the CER spot price dating from January 3rd 2011 to August 8th 2011 from the BlueNext exchange in France was used. The figures provided by the BlueNext are expressed in euros per ton of CO_2 equivalents. BlueNext is a leading environmental exchange where large quantities of CER transactions are carried out on a daily basis (BlueNext 2011).

Finally, currencies other than USD where converted to USD by the 2010 yearly average currency exchange rate provided by the U.S. IRS at www.irs.gov (IRS 2011).

7.3 Method

Estimating the potential impact CDM registration would have on the feasibility of utilizing the potential 16,000 MW capacity of the Chilean geothermal resource required a process entailing several steps. The feasibility categories presented in *Master Plan* represented a range of figures that needed to be converted into a single figure, the median. Appendix I shows the data and calculations adopted from *Master Plan*. The median was then converted into U.S. dollars and Chilean hydropower plants from *The Project Directory* were categorized identically to those in *Master Plan*. Categorized hydropower plants in Chile can be viewed in Appendix II and the Icelandic ones in Appendix I. After categorizing the hydropower plants from *The Project Directory*, the average investment cost was calculated to achieve a multiplication factor necessary to estimate the possible investment cost associated with the geothermal power plants in Chile as compared to those in *Master Plan*. The multiplication factor was calculated as described in Equation 1.

Equation 1:

$$Multiplication\ factor = \frac{Average\ Chile}{Average\ Iceland}$$

The potential capacity of geothermal power plants in *Master Plan* was presented as 3,773 MW. According to *Master Plan,* the capacity could be developed in step-by-step order according to financial feasibility. To transfer the results of *Master Plan* to Chilean surroundings the capacity in each feasibility step needed to be scaled so as to equal the size difference between the Icelandic figures in *Master Plan* (3773 MW) and the one presented by Lahsen et al (2010) (16.000 MW). Equation 2 shows how the scaling factor was achieved.

Equation 2:

$$Scaling\ Factor = \frac{Capacity\ Chile}{Capacity\ Iceland}$$

Using the information on the incremental feasibility categories above, it was possible to build a supply curve for geothermal electricity in Chile. The incremental investment cost can be adjusted and calculated as to reflect a supply curve compromised of minimum-selling price required to supply a certain amount of electricity. The minimum-selling price is the sum of the required return on investment, the operation and maintenance cost, and the depreciation rate. The required ROI was set equal to a 30 year U.S. treasury security at 4.38%, the operation and maintenance was set at 2%, equal to the figure used by the authors of *Master Plan*, and the depreciation rate was set at 2.5% representing the estimated 50 year lifetime of the power plants. The investment cost was multiplied by the sum of percentages so it would represent the minimum-selling price required for economically feasible utilization.

The points of increase in the empirical supply curve, as reported in *Master Plan*, were used to estimate a straight line fit, representing the linear supply curve that is then applied to Chilean geothermal electricity generation. The straight line was calculated by ordinary least squares using the Excel function linest. The linear supply curve can be seen in Figure 12. The horizontal axis represents the amount of installed capacity in MW and the vertical axis represents the minimum sales price necessary required for the installed capacity to be feasible.

To estimate the potential emission abatement achievable through harnessing of electricity through the geothermal resource in Chile figures presented by Fridleifsson et al (2008) in *The possible role and contribution of geothermal energy to the mitigation of climate change* were used. The report provides emissions data from various sources of electricity generation expressed in grams per kWh. The figures were converted to tons per kWh for the purpose of calculating expected revenue from CER sales later. To calculate abatement the data presented was converted to tons per kWh as can be seen in Equation 3. The emission from the different electricity generation sources was then subtracted from the emission from geothermal power plants. The difference reflects the potential abatement associated with switching a single kWh of electricity generation from each individual source to a geothermal electricity generation.

Equation 3:

$$g/kWh * 1.000.000 = t/kWh$$

The supply in installed MW is determined by the price earned from electricity generation, which is normally expressed in earnings per kWh, or $/kWh. To estimate the impact of CER revenue on the supply the potential CER revenue was added to the electricity price. Three mutually exclusive revenue streams, depending on electricity generation source dispatched by the geothermal one, were available: revenue resulting from the dispatching of generation from a natural gas -, oil -, or a coal resource. To calculate the CER revenue price the average closing price of CER from the BlueNext exchange dating from the 3rd of January 2011 to the 8th of August 2011 was used. CER prices are expressed in Euros per ton of CO_2 equivalent at the BlueNext, thus they had to be converted from Euros to US dollars through the annual average currency exchange rate provided by the U.S. IRS (www.irs.gov). Appendix IV presents the price date obtained from BlueNext. The revenue was estimated through the method seen in Equation 4.

Equation 4:

$$CER\ Revenue_{\$/kWh} = CER\ Price_{\$/kWh} * Abatement_{t/kWh}$$

7.4 Results

The results from calculating the median and converting the feasibility categories of *Master Plan* from ISK to US dollars can be seen in Table 5, as well as the possible quantity of MW capacity achievable in each category. The Icelandic geothermal resource has an estimated installable capacity of 715 MW at an investment cost of 0,24 $/kWh per year. A further 130 MW can be achieved at a cost of 0,264 $/kWh per year and finally 2928 MW for 0,288 $/kWh per year.

Table 5 Potential capacitity and feasibility in Iceland

Master Plan		
Feasibility	**$/kWh/yr**	**Capacity MW**
1	0,192	0
2	0,240	715
2,5	0,264	130
3	0,288	2928
4	0,372	0
5	0,477	0
6	0,545	0
	Total Capacity	**3773**

The multiplication factor for transferring investment costs from *Master Plan* was 1,1038, Equation 5.

Equation 5:

$$Multiplication\ Factor = \frac{0{,}3559}{0{,}3928} = 1{,}1037696\ USD$$

The factor for scaling the size of the Icelandic geothermal resource to the Chilean one was, 4,241, Equation 6.

Equation 6:

$$Scaling\ Factor = \frac{16000}{3773} = 4{,}24065\ MW$$

Table 6 shows an identical step-by-step harnessing potential of the geothermal fields in Chile. The investment cost has increased slightly and the capacity increases substantially due to the investment cost multiplication factor, Equation 5, and the scaling factor, Equation 6. According to the calculations 3,032 MW can be utilized at an investment cost of 0.265 $/kWh per year. A further 551 MW can be harnessed at an investment cost of 0.292 $/kWh per year and the final 12,417 MW at a rate of 0.318 $/kWh per year.

Table 6 Potential capacity and feasibility in Chile

Chile Geothermal Potential

Feasibility	$/kWh/yr	Capacity MW
1	0.212	0
2	0.265	3032
2,5	0.292	551
3	0.318	12417
4	0.411	0
5	0.526	0
6	0.601	0
	Total Capacity	**16000**

The minimum-selling price was found to 8,3% of the investment cost, or the required revenue needed to cover the required return on investment, the operation and maintenance cost, and the depreciation rate. At a an investment cost of 0.265 $/kWh/yr a selling price of 0.0220 $/kWh was required, at the rate of 0.292 $/kWh/yr the required price was 0.0242 $/kWh, and at the investment cost of 0.318 $/kWh/yr the required price was 0.0264 $/kWh. Figure 10 shows the potential supply curve of electricity generated from the geothermal resource in Chile. The supply curve is composed of the minimum-selling price of the electricity generated at the various feasibility categories.

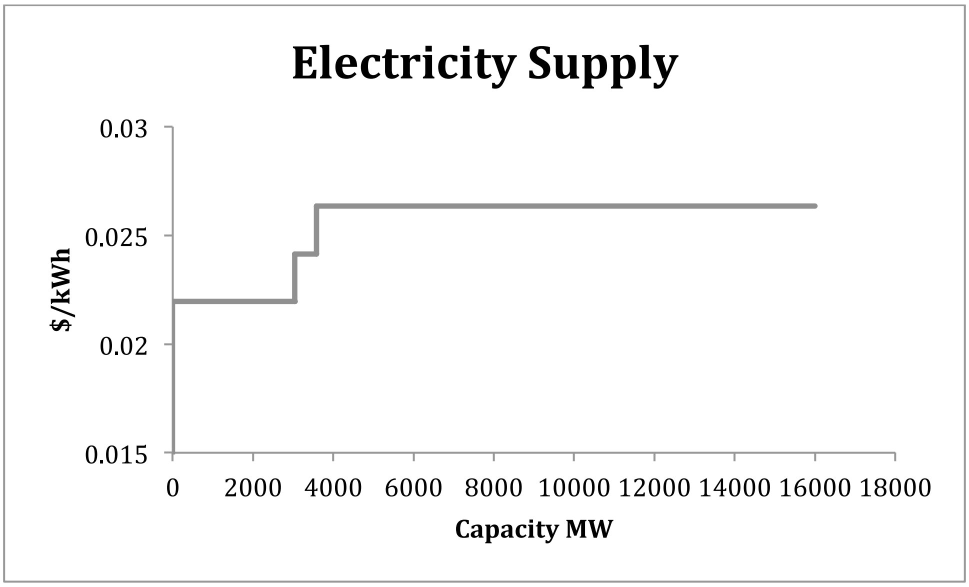

Figure 11 Potential electricity supply from the geothermal resource in Chile

Table 7 provides a numerical display of the step-by-step increase in Figure 10. In the first step it is possible to feasibly install 3032 MW of electric energy at a minimum-selling price of 0..022 $/kWh. Additional 551 MW can be installed if a minimum-selling price of 0.242 $/kWh can be secured, and the remaining 12,417 MW can be installed if the minimum-selling price remains above 0.264 $/kWh.

Table 7 Potentiial capacity feasible at various electricity prices

Quantity MW	Electricity Price $/kWh
3032	0.0220
3583	0.0242
16000	0.0264

The data in Table 7 could be used as X and Y points for the purpose of creating a linear supply curve for the potential energy generation. The Excel function linest was used to plot the linear supply curve seen in Figure 11. The linear supply curve will be used later for further explanations.

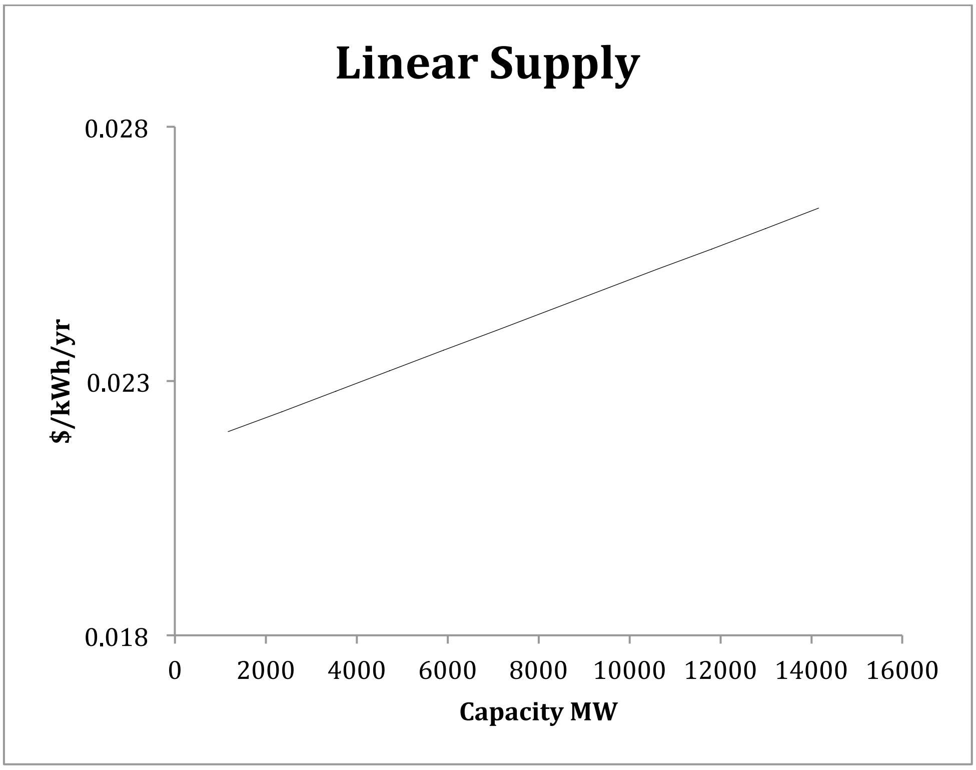

Figure 12 Linear supply curve of geothermal electricity in Chile

Table 8 displays the results from the calculations of emission reduction associated with switching from various different sources of electricity generation to a geothermal resource one. Switching from a natural gas sourced electricity production with an emission factor of 599 grams of CO_2 per kWh to a geothermal sourced one provides for a reduction of 508 grams of CO_2 per kWh or 0.000508 tons. Switching from oil to geothermal results in possible reduction of 802 grams of CO_2 per kWh, or 0.000802 tons. Lastly, replacing or preventing coal generation possibly provides abatement of 864 grams of CO_2 per kWh, or 0.000864 tons.

Table 8 Emission and abatement associated with switching to a geothermal electricity generation

	Emissions		**Reduction**
Electricity Source	**g/kWh**	**t/kWh**	**t/kWh**
Geothermal	91	0.000091	-
Natural Gas	599	0.000599	0.000508
Oil	893	0.000893	0.000802
Coal	955	0.000955	0.000864

Switching from the variety of electricity generation sources and the abatement associated has the potential of earning revenue additional to the sale of electricity as can be seen in Table 9. The average closing price of CERs from the date of 3rd of January 2011 to the 8th of August 2011 was 10.936 Euros per ton of CO_2 equivalents. Converted to US dollars the average closing price of one ton of CO_2 equivalents was $15.599. The possible revenue associated with switching from natural gas was therefore estimated to be 0.00792 $/kWh. Switching electricity production from an oil resource was estimated to be 0.01251 $/kWh and 0.01348 $/kWh by switching from the production of electricity from coal.

Table 9 Abatement and CER revenue associated with switching to a geothermal electricity generation

Electricity Source	Reduction t/kWh	CER Price $/ton	CER Revenue $/kWh
Geothermal	-		-
Natural Gas	0.000508	15.59875886	0.007924169
Oil	0.000802	15.59875886	0.012510205
Coal	0.000864	15.59875886	0.013477328

Table 10 shows how revenue per kWh of electricity generation from a geothermal resource increases as a result of the additional revenue provided by the sale of CERs. Depending on the displaced energy source, the revenue increase reach 27% when natural gas generation is dispatched, 43% through the dispatch of generation by oil, and 46% by switching from coal generation.

Table 10 Price increase per kWh associated with CER revenue

	$/kWh	% Increase
Electricity Price $	0.0294	-
+ CER Natural Gas	0.03732	27%
+ CER Oil	0.04191	43%
+ CER Coal	0.04288	46%

A graphical representation of the supply of geothermal electricity generation in Chile and the price of electricity as well as the additional price earning from the mutually exclusive CER sales can be seen in Figure 12. It shows that the absolute minimum power tariff a power plant can charge as presented by CRU Analysis (2011), 0.0294 $/kWh, is higher than the minimum-selling price required for the development of the entire geothermal capacity in Chile. In order to be able to feasibly harness the entire capacity, the minimum-selling price was 0.0264 $/kWh; substantially lower than the power tariff for aluminium smelters.

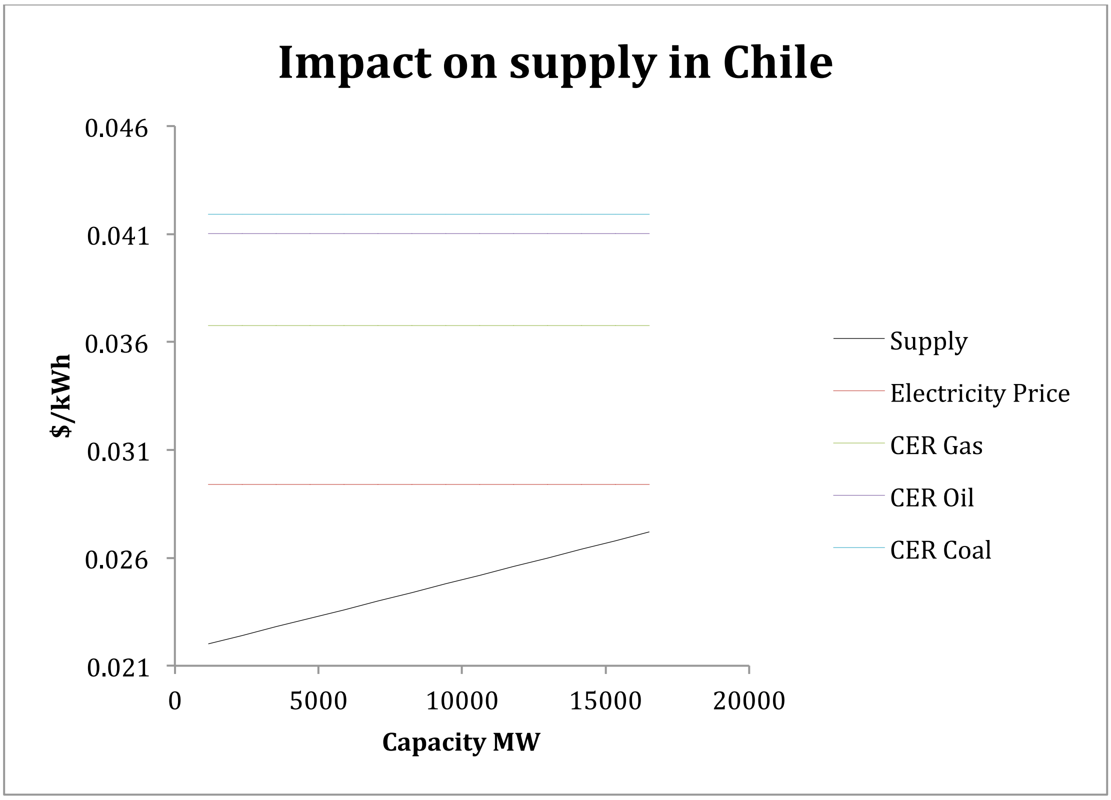

Figure 13 Impact of CER revenue on long term geothermal electricity price in Chile

Additional calculations plotting the linear supply to match a larger resource potential are displayed in Figure 13. The figure shows how the impact of CDM registration would affect a resource subject to the same investment cost as the one in Chile and capable of providing 100,000 MW of geothermal installed capacity, based on the assumption that geothermal energy is the long-run marginal energy in Chile. The capacity below the electricity price (red line) could be feasibly harnessed. When the additional earnings of CER sales are added to the electricity price, additional capacity can be harnessed up to a point of 59,978 MW.

8 Discussion

The global potential of identified as well as unidentified geothermal resources in the world is vast. Combined with the low level emissions from electricity generation, the potential for GHG mitigation is of a similar magnitude. The resource fulfills the crucial requirement of providing carbon-free, base-load electricity that can be dispatched on a wide scale in both developed and developing countries. It is a proven technology that is able to generate reliable base load electricity at a high capacity factor. A widespread deployment of geothermal electricity would have a very positive impact on energy security, environment, and on global economic health (Fridleifsson et al 2008). Utilizing the geothermal resource to produce electricity and subsequently remove generation by resources with high GHG emission factors, can definitely add power to the fight against climate change. There is however, an inherent limitation to the utilization of the resource on a global scale, as high grade hydrothermal systems are too localized and relatively small in numbers. The EGS approach could possibly provide a solution to this problem and significant CO_2 reduction by exploiting the vast resource characterized by high temperature but low permeability and lack of natural fluid circulation (Fridleifsson et al 2008).

The subject of the case study, the impact of CDM registration on long-term supply of geothermal electricity in Chile, relates to the mitigating GHG emissions through carbon-free renewable energy production. The results indicate that the entire geothermal field could be feasibly utilized, even without CDM registration. Thus, it would be somewhat difficult to prove additionality for geothermal power plants in Chile.

The research's defects relate to estimations of the investment costs of geothermal power plants as well as the emission factors assumed. Further research regarding the subject regard these defects, as the feasibility of utilizing the Chilean geothermal field could be explored as well as the GHG emissions stemming from geothermal power plants in the region. To this date an extension of the Kyoto Protocol has not been agreed upon which, inevitably places the CDM scheme and its continuation under uncertainty.

8.1 CDM impact on feasibility

The possibility for deploying geothermal electricity production and registering power plants as CDM projects exists in Chile. The results of the case study however, indicate that the entire Chilean geothermal field could be harnessed feasibly if the minimum price received for the electricity is 0.0294 $/kWh as reported by CRU Analysis (2011). The Chilean government is actively seeking to attract investors and project developers of geothermal power plants to the country. Incentives in the form of allocating subsidies and grants to developers exist in the Chilean government system (CORFO 2009: CORFO n.d.). Given this information it is likely that the Chilean government concerns the option of utilizing the geothermal resource as an economical means to provide base-load carbon low electricity.

The results of the case study indicate that the impact of CDM registration on long-term supply of geothermal electricity could potentially be significant. The additional CER revenue created by replacing natural gas production could on its own provide means for utilizing the entire capacity of the geothermal fields in Chile if the electricity price was insufficient for feasible harnessing, assuming that the investment costs from the case study apply.

The GHG emissions from geothermal power plants depend on geological conditions and vary between regions as discussed in section 6.3. The figures for emissions given in the case study may not accurately reflect the potential emissions of the geothermal fields in Chile. Nevertheless, they are comparable to the global average emissions reported by Bertani and Thain (2002). The abatement presented in the case study and the revenue associated with the sales of CERs provide a ballpark estimate of how CDM registration might affect the long-term supply of geothermal electricity in developing countries. Without any doubt, the potential revenue increase in a range from 25-43% per kWh can have a substantial effect on the future development of geothermal electricity.

8.2 Project Management and Additionality

The management of CDM projects is an extensive and delicate process. A successful registration of a CDM project and subsequent CER issuance depends heavily on a thorough project management and the demonstration of additionality as discussed in chapter 5. Each step of the CDM process challenges the project developer and other related parties to prove that the project suffices criteria of sustainability, additional GHG emission reduction, etc. Considering the extent of the process it could be possible that costs associated with completing would negatively affect the net revenue from CER sales.

The requirement for renewable electricity CDM projects state that the emission reduction should be compared to a baseline scenario which represents the emission factors of the electricity already generated at the respective grid. Providing a baseline scenario is a relatively basic procedure but still it requires data collection on emission factors on the grid. When data has been gathered the CDM website offers standard methods for calculating the baseline scenario. Demonstrating additionality is a more complex process dependent on various conditions.

The four steps of demonstrating additionality are listed in section 5.6.2. The first step involves identifying a set of alternatives. If there are no alternatives the project cannot be considered additional. In the case of electricity production there are however, many alternatives, such as the production of electricity from natural gas or coal. In step 2 a barrier analysis is performed. Since no geothermal power plants have been developed in Chile, the argument can be made that there exists a technical barrier, which subsequently fulfills step 4 of additionality and demonstrates that the project is additional. An optional investment analysis of the project, and is mainly used to identify a baseline scenario. Step 4, the common practice analysis, aims to determine whether geothermal power plants were already being developed regardless of the CDM scheme. Currently, no geothermal power plants have been developed in Chile, thus such practice cannot be considered common. However, the common practice condition indicates that in the event of a large scale development of a country's geothermal resources, such as the one explored in this thesis, there comes a point when such development becomes the common practice. Given this condition it is obvious that only a portion of a gradual development of a country's entire geothermal field could successfully be registered as CDM projects.

8.3 CDM beyond 2012

The Kyoto Protocol is the first step towards a global scheme for emission reduction that provides the necessary framework for any future international agreement on climate change. By the end of the end of the first commitment period, beginning in 2008 through 2012, an extension to the Protocol or a new international framework needs to have been negotiated and ratified. An extension or a new agreement has to be capable of delivering the stringent emission reductions the IPCC has called for (UNFCCC (k) n.d.) As of now, no such agreement has been negotiated at the COP meetings.

The CDM exists as a part of the Kyoto Protocol. However, the CDM itself is a long-term mechanism that continues from one period to the next (UNFCCC (l) n.d.). Thus, it is not contingent on the agreed upon commitment period or its continuation. Emission targets for a second commitment period are currently being negotiated under an Ad Hoc working group appointed by the COP. The outcome of the working group is not clear yet. If the targets will be expressed in a form other than a second commitment period of the Kyoto Protocol, the CDM will most likely be adapted to the new instrument (UNFCCC (l) n.d.).

8.4 Research Defects

The limitations to the research and its results presented in the case study mainly regard the investment costs of geothermal electricity generation in Chile and the emissions associated with such generation. The assumption that the investment cost of geothermal projects in *Master Plan* can be used to convey the costs in Chile simply by comparing hydropower plants in *Master Plan* and the Chilean *Project directory* is questionable. The same goes in the case of using emission factors from U.S. plants to convey the potential emission stemming from geothermal electricity generation in Chile.

The investment costs of geothermal projects can, as stated in section 7.1., differ somewhat between regions depending on the character of the resource. Adding to that, concerns regarding the high- altitude of the resource in Chile have inevitably raised questions regarding the cost of constructing power plants in Chile (Kristinn Ingason, interviewed March 11 2011). However, a significant portion, 40-81%, of the investment cost is made up power plant components such as the turbine, generator, condenser etc.

(Goldstein, Hiriart et al 2011). These costs should not differ between regions, excluding transportation, and should therefore decrease the potential error associated with the method of transferring costs from *Master Plan* to the Chilean surroundings.

Nevertheless, the results of the case study have limited significance as interpretation of actual investment costs of Chilean geothermal projects.

Emission factors for geothermal projects also differ depending on the character of the resource (Goldstein, Hiriart et al 2011). In fact, Bertani and Thain (2003), reported a range from 4 g/kWh CO_2 to 740 g/kWh CO_2 from data collected from 85 geothermal power plants around the world which constituted 85% of the world geothermal power plant capacity at the time. Accurate data on emissions stemming from geothermal power plants in Chile do not exist; as such plants have not been developed there yet. Consequently, the emissions level figures do not accurately display potential emissions in Chile.

8.5 Further Research

Further research regarding investment costs of geothermal projects in Chile, as well as their emission factors, would display a more accurate picture of the impact CDM registration would have on long-term supply. Assuming that the results of the case study are reasonably accurate, which indicate that it already is feasible to develop most geothermal fields in Chile, it would also be interesting to investigate why a large-scale development has not begun. Furthermore, an interesting subject of investigation is the fact that geothermal projects only represent a minor fraction of CDM projects. Since geothermal electricity generation fulfills all requirements of the framework it seems odd that only 18 projects have applied for registration since 2003.

9 Conclusion

. The nature of climate change is such that it is a problem on a global scale. As such, an international climate regime, partially composed of the UNFCCC and its Kyoto Protocol, was created to counter the change. The UNFCCC establishes an overall framework for intergovernmental action to tackle the problem. The Kyoto Protocol was created as an international agreement relating to the UNFCCC. The Protocol sets a legally binding target for industrialized countries for decreasing GHG emissions. Emission allowances were allocated to these countries matching the quantified emission targets.

The flexibility mechanisms of the Kyoto Protocol provide means for the industrialized countries to trade with the emission allowances and create additional allowances through developing emission reduction projects. One of these mechanisms is the CDM, which enables parties subject to emission limitation to develop these projects in the developing countries, mainly created developing countries to contribute to the UNFCCC and realize sustainable development.

The CDM allows for projects pertaining to renewable electricity generation to be registered and earn emission allowances. The projects however, are subject to extensive criteria and demonstration of genuine abatement. The nature of the requirements necessitate that renewable electricity generation displaces the generation stemming from a non-renewable energy source. The projects undergo a comprehensive process where claimed reductions are monitored and vetted by independent parties and then reviewed by the CDM Executive Board prior to any earning of allowances.

Geothermal electricity generation is eligible for CDM registration and its vast worldwide potential combined with associated emission reductions geothermal projects are ideal for participation in the framework. This thesis examined the financial premise for the participation of geothermal power plants within the CDM. The financial premise was examined by estimating the potential impact CDM registration would have on the long-term supply of geothermal electricity in Chile. The results indicated that the entire geothermal resource in Chile could be feasibly developed without the additional revenue created by additional emission allowances. However, the results also indicated that CDM registration could have substantial increasing effects on the price earned per kWh generated by geothermal power plants. The respective increase was measured as a 23%, 43%, and 46% addition depending on the nature of the non-renewable electricity generation displaced.

The CDM is truly an innovative and successful means of tackling the effects of climate change. It provides a win-win situation for the developed and the developing world and if genuinely applied the framework provides a significant assistance to realizing sustainable development in the developing world. Whether or not a second commitment period of the Kyoto Protocol will be agreed upon, it is of the upmost importance that the Clean Development Mechanism will be kept alive.

Appendix I

Results of Master Plan and feasibility adapted to U.S dollar

1. Undir 27 kr/(kWh/ár)
2. 27-33 kr/(kWh/ár)
3. 33-40 kr/(kWh/ár)
4. 40-53 kr/(kWh/ár)
5. 53-66 kr/(kWh/ár)
6. Yfir 66 kr/(kWh/ár)

Feasibility $		
Feasibility	**ISK/kWh/yr**	**$/kWh/yr**
	Exchange Rate	**124,857**
1	24	0,19
2	30	0,24
2,5	33	0,26
3	36	0,29
4	46,5	0,37
5	59,5	0,48
6	68	0,54

Feasibility of hydropower plants in Master Plan

Location	Capacity MW	GWh/yr	Feasibility	ISK/kWh/yr	$/kWh/yr
				Exchange rate	124,857
Hvítá í Borgarfirði	20	125	5	60	0,4765
Glámuvirkjun	67	400	5	60	0,4765
Skúfnavatnavirkjun	8,5	60	6	69	0,5526
Hvalá	35	259	5	60	0,4765
Blönduveita	20	131	4	47	0,3724
Skatastaðarvirkjun B	184	1260	3	36	0,2883
Skatastaðarvirkjun C	156	1090	4	47	0,3724
Villganesvirkjun	33	237	4	47	0,3724
Fljótshnúksvirkjun	58	405	6	69	0,5526
Hrafnabjargarvirkjun A	89	622	3	36	0,2883
Eyjadalsárvirkjun	8	58	5	60	0,4765
Arnardalsvirkjun	570	4000	2	30	0,2403
Helmingsvirkjun	270	2100	4	47	0,3724
Djúpá	75	498	4	47	0,3724
Hverfisfljót	40	260	4	47	0,3724
Skaftárveita með miðlun		245	2	30	0,2403
Skaftárveita án miðlunar		465	1	24	0,1922
Skaftárvirkjun	125	760	3	36	0,2883
Hólmsárvirkjun án miðlunar	72	450	3	36	0,2883
Hólmsárvirkjun - miðlun	72	470	3	36	0,2883
Hólmsárvirkun neðri	48	360	3	36	0,2883
Markarfljótsvirkjun A	14	120	5	60	0,4765
Markarfljótsvirkjun B	109	735	4	47	0,3724
Tungnárlón		270	1	24	0,1922
Bjallavirkjun	46	340	3	36	0,2883
Skrokkölduvirkjun	30	215	4	47	0,3724
Norðlingaölduveita		635	1	24	0,1922
Búarhálsvirkjun	80	585	3	36	0,2883
Hvammsvirkjun	82	665	4	47	0,3724
Holtavirkjun	53	415	4	47	0,3724
Urriðafossvirkjun	130	980	2	30	0,2403
Gýgjarfossivrkjun	21	146	4	47	0,3724
Bláfellsvirkjun	76	536	4	47	0,3724
Búðartunguvirkjun	50	320	4	47	0,3724
Haukholstvirkjun	60	358	4	47	0,3724
Vörðufell	52	170	6	69	0,5526
Hestvantsvirkjun	40	300	4	47	0,3724
Selfossvirkjun	30	250	3	36	0,2883
Hagavantsvirkjun	20	140	5	60	0,4765
Búlandsvirkjun	150	970	2	30	0,2403
Total Combined Cacpacity	**2993,5**		**Average**	**44,438**	**0,3559**

Feasibility of geothermal power plants in Master Plan

Location	Capacity MW	GWh/yr	Feasibility	ISK/kWh/yr	$/kWh/yr
Krísuvíkursvæði	50	410	2	30	0,2403
Krísuvíkursvæði	40	328	2	30	0,2403
Þeystareykir	90	738	2	30	0,2403
Austan Mývatns	90	738	2	30	0,2403
NA-Mývatns	40	320	2	30	0,2403
Við Mývatn	45	369	2	30	0,2403
Hágöngulón 2	90	738	2	30	0,2403
Há-N Mývatns og V Gjástykkis	180	1476	2	30	0,2403
Krafla 2	90	738	2	30	0,2403
Yst á sunnanverður Reykjanesskaga	80	568	2,5	33	0,2643
N við Reykjanestá	40	328	2,5	33	0,2643
Ofan Hveragerðis	10	82	2,5	33	0,2643
Líklega samtengd svæði	50	410	3	36	0,2883
Lengra SV við Kleifarvatn	40	328	3	36	0,2883
Milli Kleifarvatns og Keilis	50	410	3	36	0,2883
Milli Kleifarvatns og Heiðarinnar háu	25	200	3	36	0,2883
S Gráuhnúka	45	369	3	36	0,2883
S vegar í Hveradalsbrekku	45	369	3	36	0,2883
Sunnan vegar á há-Hellisheiði	90	738	3	36	0,2883
Nálægt Kolviðarhóli	90	738	3	36	0,2883
Í suðaustanverðum Hengli	45	369	3	36	0,2883
Austan Hengils	90	738	3	36	0,2883
Við NA-jaðar háhitasvæðisins	90	738	3	36	0,2883
N frá Hveragerði	120	984	3	36	0,2883
Geysir	25	200	3	36	0,2883
Suðvestan Hofsjökuls	49	392	3	36	0,2883
Suðvestan Hofsjökuls	49	392	3	36	0,2883
Suðvestan Hofsjökuls	49	392	3	36	0,2883
Suðvestan Hofsjökuls	49	392	3	36	0,2883
Kjölur	70	560	3	36	0,2883
A Rauðfossafjalla, SV Reykjadala	181	1448	3	36	0,2883
V Landmannalauga, V Hrafntinnuhrauns	181	1448	3	36	0,2883
V Landmannalauga, V Hrafntinnuhrauns	181	1448	3	36	0,2883
V Torfajökuls	181	1448	3	36	0,2883
Sunnan Jökulgils, Vestan Kaldaklofsfjalla	181	1448	3	36	0,2883
V Torfajökuls	181	1448	3	36	0,2883
N Torfajökuls	181	1448	3	36	0,2883
Hágöngulón	45	369	3	36	0,2883
Milli Vatnajökuls og Tungnafellsjökuls	145	1160	3	36	0,2883
Norðan Vatnajökuls	155	1240	3	36	0,2883
Dyngjufjöll	135	1080	3	36	0,2883
Ódáðahraun, NNV af Herðubreið	20	160	3	36	0,2883
Milli Mývatns og Herðubreiðafjalla	45	369	3	36	0,2883
Norðan Kröflu	45	369	3	36	0,2883
Total Combined Capacity	**3773**		**Average**	**34,57**	**0,28**

Appendix II

Hydropower plants in Chile

	kW	Capacity factor	Investment	GWh	kWh/yr	Feasbility	$/kWh/yr
Cap E 12	2.500	80%	4.500.000	15	15.000.000	1	0,300
Anihueraqui	2.000	82%	4.363.742	14,3	14.300.000	1	0,305
Callaqui	16.800	55%	35.000.000	73	73.000.000	1	0,479
Caunahue	20.000	70%	45.000.000	122	122.000.000	1	0,369
Coyanco	1.200	44%	3.479.900	4,61	4.610.000	1	0,755
El Aguila	12.000	65%	29.000.000	69	69.000.000	1	0,420
El Calabozo	8.829	85%	18.408.000	65,7	65.700.000	1	0,280
Las Flores	5.000	75%	12.929.000	34,6	34.600.000	1	0,374
Las Vizcachas	2.990	75%	3.485.185	19,6	19.600.000	1	0,178
Los Padres	2.000	60%	4.000.000	9	9.000.000	1	0,444
Maihue	16.250	63%	37.000.000	88,6	88.600.000	1	0,418
Mariposas	6.300	74%	17.000.000	40,8	40.800.000	1	0,417
MCH Antuco	1.000	65%	2.000.000	5,6	5.600.000	1	0,357
MCH Chacayal	400	90%	2.000.000	3,1	3.100.000	1	0,645
MCH Liai	1.500	70%	3.500.000	7,8	7.800.000	1	0,449
Melipue	22.620	61%	33.939.000	122,05	122.050.000	1	0,278
Pue E 6	10.000	77%	15.000.000	67,5	67.500.000	1	0,222
San Jose	2.029	68%	5.654.686	12	12.000.000	1	0,471
Santa Julia	4.905	85%	11.038.000	36,5	36.500.000	1	0,302
						Average	**0,3928**

Appendix III

Type of Allowance		Origin	
AAU *Assigned Amount Units* Country Allowances	Emission allowance equal to one ton of CO_2 or equivalent GHG. Allowances are assigned to industrialized countries on the basis of the Kyoto Protocol. Assigned allowances are registered at relevant Party's National Registry and from there to entities subject to emission limitation	Kyoto Protocol	International agreement of 175 member states from 1998, entered into force in 1995, on quantified GHG emission limitations. Effective from 1. January 2008 to 31. Desember 2012.
RMU *Removal Units* JI Units	Emission allowance equal to one ton of CO_2 or equivalent GHG. Country allowances relating to removal of CO_2 via forest sinks etc. Issued by states according to agreements with the UN.	JI Project *Joint Implementation*	The mechanism known as "joint implementation," defined in Article 6 of the Kyoto Protocol, allows a country with an emission reduction or limitation commitment under the Kyoto Protocol (Annex B Party) to earn emission reduction units (ERUs) from an emission-reduction or emission removal project in another Annex B Party, each equivalent to one tonne of CO_2, which can be counted towards meeting its Kyoto target.
ERU *Emission Reduction Units* JI Units	Emission allowance equal to one ton of CO_2 or equivalent GHG. JI credits relating to reduction projects in industrialized countries, including most importantly Eastern Europe.		
CER *Certified Emission Reduction* CDM Units	Emission allowance equal to one ton of CO_2 or equivalent GHG. CDM credits relating to reduction projects in countries without reduction commitments (developing countries).	CDM Projects *Clean Development Mechanism*	The Clean Development Mechanism (CDM), defined in Article 12 of the Protocol, allows a country with an emission-reduction or emission-limitation commitment under the Kyoto Protocol (Annex B Party) to implement an emission-reduction project in developing countries. Such projects can earn saleable certified emission reduction (CER) credits, each equivalent to one tonne of CO_2, which can be counted towards meeting Kyoto targets.
EUA heimildir *European Union Allowance* Company Allowance	Emission allowance equal to one ton of CO_2 or equivalent GHG. Assigned to companies subject to emission limitation cover by the EU ETS.	EU ETS *European Union Emission Trading Scheme*	The EU ETS has the objective of assigning EUA emission allowances to industry. Each member to the scheme submits a National Allocation Plan that determines the upper limit of the overall emissions quantity within the scheme. The EU ETS covers some 11,000 power stations and industrial plants in 30 countries.

Appendix IV

Daily CER closing prices at the BlueNext exchange

Date	Product	Daily Closing Price	Total Volume	CER
08/08/2011	BNS CER	7,75	72000	7,75
05/08/2011	BNS CER	7,65	60000	7,65
04/08/2011	BNS CER	8,04	83000	8,04
03/08/2011	BNS CER	8,34	50000	8,34
02/08/2011	BNS CER	8,68	170000	8,68
01/08/2011	BNS CER	9,05	10000	9,05
29/07/2011	BNS CER	9,33	60000	9,33
28/07/2011	BNS CER	9,55	10000	9,55
27/07/2011	BNS CER	9,59	5000	9,59
26/07/2011	BNS CER	9,99	80000	9,99
25/07/2011	BNS CER	9,99	0	9,99
22/07/2011	BNS CER	10,03	0	10,03
21/07/2011	BNS CER	10,14	15000	10,14
20/07/2011	BNS CER	10,08	10000	10,08
19/07/2011	BNS CER	10,07	10000	10,07
18/07/2011	BNS CER	9,94	0	9,94
15/07/2011	BNS CER	10,2	0	10,2
14/07/2011	BNS CER	10,07	10000	10,07
13/07/2011	BNS CER	10,03	0	10,03
12/07/2011	BNS CER	10,21	0	10,21
11/07/2011	BNS CER	10,1	10000	10,1
08/07/2011	BNS CER	10,45	120000	10,45
07/07/2011	BNS CER	10,79	0	10,79
06/07/2011	BNS CER	10,88	50000	10,88
05/07/2011	BNS CER	11,11	20000	11,11
04/07/2011	BNS CER	11,07	5000	11,07
01/07/2011	BNS CER	11,04	17000	11,04
30/06/2011	BNS CER	11,08	30113	11,08
29/06/2011	BNS CER	10,9	49000	10,9
28/06/2011	BNS CER	10,88	20000	10,88
27/06/2011	BNS CER	10,65	90000	10,65
24/06/2011	BNS CER	10,48	110000	10,48
23/06/2011	BNS CER	10,45	180000	10,45
22/06/2011	BNS CER	11,1	60000	11,1
21/06/2011	BNS CER	10,98	139000	10,98
20/06/2011	BNS CER	11,27	281000	11,27
17/06/2011	BNS CER	11,89	277000	11,89
16/06/2011	BNS CER	11,89	200000	11,89
15/06/2011	BNS CER	12,07	499000	12,07
14/06/2011	BNS CER	12,21	318000	12,21
13/06/2011	BNS CER	12,29	130000	12,29
10/06/2011	BNS CER	12,3	20000	12,3
09/06/2011	BNS CER	12,34	117000	12,34
08/06/2011	BNS CER	12,24	87000	12,24
07/06/2011	BNS CER	12,41	80000	12,41

06/06/2011	BNS CER	12,46	172000	12,46
03/06/2011	BNS CER	12,53	37000	12,53
02/06/2011	BNS CER	12,54	10000	12,54
01/06/2011	BNS CER	12,69	10000	12,69
31/05/2011	BNS CER	12,82	78000	12,82
30/05/2011	BNS CER	13	0	13
27/05/2011	BNS CER	12,72	180000	12,72
26/05/2011	BNS CER	12,27	100000	12,27
25/05/2011	BNS CER	12,32	10000	12,32
24/05/2011	BNS CER	12,27	55000	12,27
23/05/2011	BNS CER	12,2	23000	12,2
20/05/2011	BNS CER	12,4	142000	12,4
19/05/2011	BNS CER	12,52	171000	12,52
18/05/2011	BNS CER	12,57	47794	12,57
17/05/2011	BNS CER	12,6	25000	12,6
16/05/2011	BNS CER	12,79	10000	12,79
13/05/2011	BNS CER	12,75	90000	12,75
12/05/2011	BNS CER	12,88	20000	12,88
11/05/2011	BNS CER	12,91	0	12,91
10/05/2011	BNS CER	13,1	40000	13,1
09/05/2011	BNS CER	13,17	39000	13,17
06/05/2011	BNS CER	13,11	111000	13,11
05/05/2011	BNS CER	12,99	116000	12,99
04/05/2011	BNS CER	13,01	46000	13,01
03/05/2011	BNS CER	13,11	87000	13,11
02/05/2011	BNS CER	13,08	0	13,08
29/04/2011	BNS CER	13,11	40000	13,11
28/04/2011	BNS CER	13,14	140197	13,14
27/04/2011	BNS CER	13,13	137000	13,13
26/04/2011	BNS CER	13,07	73000	13,07
21/04/2011	BNS CER	13,01	111058	13,01
20/04/2011	BNS CER	13,21	193000	13,21
19/04/2011	BNS CER	13,05	310000	13,05
18/04/2011	BNS CER	12,9	269044	12,9
15/04/2011	BNS CER	13,21	378224	13,21
14/04/2011	BNS CER	12,97	25176	12,97
13/04/2011	BNS CER	12,85	32000	12,85
12/04/2011	BNS CER	12,83	119000	12,83
11/04/2011	BNS CER	12,98	2000	12,98
08/04/2011	BNS CER	13,09	74759	13,09
07/04/2011	BNS CER	13,08	235000	13,08
06/04/2011	BNS CER	13,3	601000	13,3
05/04/2011	BNS CER	13,23	26000	13,23
04/04/2011	BNS CER	13,4	208000	13,4
01/04/2011	BNS CER	13,04	16000	13,04
31/03/2011	BNS CER	13,15	71000	13,15
30/03/2011	BNS CER	12,94	147000	12,94
29/03/2011	BNS CER	12,97	17000	12,97
28/03/2011	BNS CER	13,02	316000	13,02
25/03/2011	BNS CER	12,78	411000	12,78
24/03/2011	BNS CER	12,64	191027	12,64
23/03/2011	BNS CER	13,06	263000	13,06
22/03/2011	BNS CER	12,93	320000	12,93
21/03/2011	BNS CER	12,94	0	12,94
18/03/2011	BNS CER	13,05	144000	13,05
17/03/2011	BNS CER	12,82	64000	12,82

16/03/2011	BNS CER	13,03	140000	13,03
15/03/2011	BNS CER	13,14	335000	13,14
14/03/2011	BNS CER	12,34	103000	12,34
11/03/2011	BNS CER	11,83	15000	11,83
10/03/2011	BNS CER	11,88	116000	11,88
09/03/2011	BNS CER	11,88	23000	11,88
08/03/2011	BNS CER	11,86	62000	11,86
07/03/2011	BNS CER	11,93	54000	11,93
04/03/2011	BNS CER	11,92	260000	11,92
03/03/2011	BNS CER	11,84	0	11,84
02/03/2011	BNS CER	11,93	25000	11,93
01/03/2011	BNS CER	11,86	50000	11,86
28/02/2011	BNS CER	11,91	0	11,91
25/02/2011	BNS CER	11,95	26000	11,95
24/02/2011	BNS CER	11,85	0	11,85
23/02/2011	BNS CER	11,83	856177	11,83
22/02/2011	BNS CER	11,72	205000	11,72
21/02/2011	BNS CER	11,71	830000	11,71
18/02/2011	BNS CER	11,59	503000	11,59
17/02/2011	BNS CER	11,53	324000	11,53
16/02/2011	BNS CER	11,41	446000	11,41
15/02/2011	BNS CER	11,36	106000	11,36
14/02/2011	BNS CER	11,37	73000	11,37
11/02/2011	BNS CER	11,49	370000	11,49
10/02/2011	BNS CER	11,41	80000	11,41
09/02/2011	BNS CER	11,35	604000	11,35
08/02/2011	BNS CER	11,39	195000	11,39
07/02/2011	BNS CER	11,39	479000	11,39
04/02/2011	BNS CER	11,5	20000	11,5
19/01/2011	BNS CER	11,25	15000	11,25
18/01/2011	BNS CER	11,42	347000	11,42
17/01/2011	BNS CER	11,38	130000	11,38
14/01/2011	BNS CER	11,3	36000	11,3
13/01/2011	BNS CER	11,16	185000	11,16
12/01/2011	BNS CER	11,23	116000	11,23
11/01/2011	BNS CER	11,26	310000	11,26
10/01/2011	BNS CER	11,25	114000	11,25
07/01/2011	BNS CER	11,5	1123000	11,5
06/01/2011	BNS CER	11,5	23000	11,5
05/01/2011	BNS CER	11,71	309000	11,71
04/01/2011	BNS CER	11,75	19000	11,75
03/01/2011	BNS CER	11,9	10000	11,9
			Average	11,77706294

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