Program: **Iceland - Nicaragua:**
Geothermal Capacity Building Project 2008 – 2012

Component: **Report on the External Final Evaluation of Iceland - Nicaragua: Geothermal Capacity Building Project 2008 - 2012**



Prepared for the Government of Reconciliation and National Unity of Nicaragua - Ministry of Energy and Mines, Ministry of the Environment and Natural Resources and the Government of Iceland - Icelandic International Development Agency
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ABBREVIATIONS AND ACRONYMS

AECID	Spanish Agency for International Development Cooperation
APO	Annual Plan of Operation
CC	Coordination Committee
CDM	Clean Development Mechanism
CNE	National Energy Council
EAI	Environment Agency of Iceland - Agencia Islandesa del Medio Ambiente
EFEP	External Final Evaluation Project
EIA	Environmental Impact Assessment - Evaluación de Impacto Ambiental
ENEL	National Electricity Company
FINNIDA	Finnish Development Organization
GCBP	Geothermal Capacity Building Project
GCBP-FPD	Geothermal Capacity Building Project - Final Proyect Document
GGE	Greenhouse Gas Effects
GIS	Geographic Information System
GoI	Government of Iceland
GoN	Government of Reconciliation and National Unity of Nicaragua
IAIA	International Association for Impact Assessment
ICEIDA	Icelandic International Development Agency
IGA	International Geothermal Association
IIE	Geothermal Directorate of the Mexico Institute for Electrical Studies
ISOR	Iceland GeoSurvey
JICA	Japan International Cooperation Agency
MARENA	Ministry of the Environment and Natural Resources
MARENA–DGCA	General Directorate for Environmental Quality
MARENA-ONDL	National Clean Development Office - Office Nacional de Desarrollo Limpio
MEM	Ministry of Energy and Mines
MEM-DDG	Ministry of Energy and Mines - Dirección De Geothermia - Direction of Geothermal Development
MEM-DSV	Ministry of Energy and Mines - Dpto. Supervision
MEM-DIG	Ministry of Energy and Mines - Dpto. Investigación geotérmica - Department of Geothermal Investigations
MEM-UGA	Ministry of Energy and Mines - Environmental Management Unit - Unidad de Gestión Ambiental
MEM-GeLab	Ministry of Energy and Mines - Geochemistry and Geothermal Laboratory
MINREX	Ministry of Foreign Affairs Ministerio de Relaciones Exteriores
NPA	National Planning Agency of Iceland
PID	Project Identification Document
SC	Steering Committee
ToR	Terms of Reference
ONA	Oficina Nacional de Acreditación
UCA	Central American University
UNAN-Managua	National Autonomous University Managua campus
UNAN-León	National Autonomous University León campus
UNI	National Engineering University
UNU-GTP	United Nations University Geothermal Training Programme - Universidad de las Naciones Unidas - Programa de Formación Geotérmica (UNU-PFG)
USGS	United States Geological Survey

NOTE:Unless otherwise indicated, monetary values are expressed in US dollars

EXECUTIVE SUMMARY

It is the policy of the Government of Reconciliation and National Unity in Nicaragua (GoN) to increase the use of renewable energy resources for the production of electric power. The geothermal sub-sector has been identified as a key component to this end, as Nicaragua has abundant geothermal fields, almost all of which have not yet been developed. In 2004, the GoN structure was, however, lacking in human capacity and logistics to oversee and administer the planned increase in geothermal utilization. To address this problem, GoN specifically requested development co-operation in the field of geothermal energy from the Government of Iceland (GoI), in 2004.

After extensive preparation work, a contract was finalized between the Ministry of Energy and Mines (MEM) on behalf of GoN and the International Development Agency of Iceland (ICEIDA) on behalf of the Government of Iceland (GoI) in January 2008. It embraced the 5 year 2008 - 2012 Geothermal Capacity Building Project (GCBP). The Ministry of the Environment and Natural Resources (MARENA) was involved already during the preparation period for the GCBP. However, it was not until later that MARENA became formally a member of the Steering Committee of GCBP.

The aim of ICEIDA through the GCBP was to assist Nicaragua to enhance its use of environmentally benign geothermal energy resources for power production in line with the energy policy of GoN.

The objective of this External Final Evaluation Report is to assess the outcomes of the GCBP, report on the lessons learned and obtain a detailed answer to the following key questions:

- To what extent has the GCBP assisted the GoN in enhancing the utilization of geothermal resources in Nicaragua?
- To what extent has the GCBP enhanced the institutional capacity at the national Government level to manage geothermal resources?

In order to achieve this objective, ICEIDA in consultation with GoN made a contract with Alta Consulting Inc. in Iceland to carry out the External Final Evaluation of the GCBP. The team leader responsible for the execution of the EFE was Halldóra Hreggvidsdóttir of Alta Consulting. Geothermal expertise was provided by Prof. Stefán Arnórsson under a subcontracting agreement between Alta Consulting Inc. and Reykir Inc.

The objective of the EFE is threefold:

- Gather information on the outcome of the GCBP
- Assess the success of the GCBP
- Give recommendations from lessons learned.

This External Final Evaluation Report covers the findings and success of the GCBP as envisaged by the External Final Evaluation Team (EFET). The principal objective of the EFET was to ascertain the outcomes and impacts of the GCBP and examine the effects on the target beneficiaries in the target areas.

THE ENERGY SECTOR IN NICARAGUA

The electric energy system in Nicaragua is a reflection of its predominant social, economic, technological and environmental conditions. In comparison to countries with a similar level of economic and social development, per capita energy consumption in Nicaragua was in 2005 low, or 3.3 barrels of oil equivalent (BOE), the lowest in Central America. Per capita energy consumption is also among the lowest in Latin America. Per capita energy consumption rates are directly linked to the satisfaction of people's basic needs. It is estimated that approximately 60% of the population has access to electrical services. However, in rural areas that figure does not reach 40%. Among all countries in Central America and the Caribbean, per capita electricity consumption in Nicaragua is higher only than that of Haiti.

Energy resources in Nicaragua include hydro, wind, biomass and geothermal, so called native energy resources. The first three are renewable in the sense that these resources are renewed at the rate equal to or higher than they are being consumed. Opinion is divided to what extent geothermal systems which are of the hydrothermal type, like those in Nicaragua, are renewable (see Stefánsson, 2000; Sanyal, 2005, O'Sullivan et al., 2010). The renewability is affected by the extent of exploitation relative to natural heat loss from these systems. The estimated potential of hydro, wind, biomass and geothermal energy resource in Nicaragua is summarized in Table 2.1, together with information on effective installed power.

Geothermal energy potential for power production has been estimated as 1,200 MW_e (Table 2.1). However, other estimates have been presented which are both higher 1,519 (Geothermal Masterplan, 2001; Ruiz-Mendieta, 2009) and 3,194 (Ruiz-Cordero, 2008) MW_e, respectively. It needs to be pointed out here that this generation capacity is highly uncertain, as it is based on limited information rather than data on reservoir characteristics that can only be obtained by expensive drillings.

Today, total installed capacity of geothermal power plants is 150 MW_e (Momotombo 78 MW_e, San Jacinto-Tizate 72 MW_e). The plans to develop the Managua-Chiltepe and El Hoyo-Monte Galán by 2014-2015 have been delayed due to poor outcome of the exploration drillings. In Managua-Chiltepe, an exploration drillhole did not strike high temperatures (about 80°C). Drillings in another part of the field have been proposed (Hersir and Ólafsson, 2009a) and will be continued by ALBANISA. At El Hoyo-Monte Galán sufficiently high temperatures have been proved in one of the two exploration holes drilled. Temperatures are low in the second hole, probably because of downflow from shallow aquifer. An evaluation of the field will contunue for a year. GeoNica has concessions to develop El Hoyo-Monte Galán. However, the concession for Managua-Chiltepe was returned by Geonica at the beginning of 2012 and granted to Alba Geotermia.

PROJECT PROFILE AND EVALUATION METHODOLOGY

The GCBP was divided into 3 main components. Their purpose was to:

- To strengthen the capacity for technical and scientific supervision by the Ministry of Energy and Mines (MEM) and the Ministry of the Environment and Natural Resources (MARENA) to coordinate, supervise and monitor the development of geothermal resources in Nicaragua.

- Develop a process for building capacity to follow-up, monitor, supervise and manage the development of geothermal projects in Nicaragua including environmental oversight. The development process was geared towards civil servants.
- Endow the geochemical laboratory at MEM with technical resources, infrastructure and equipment.

The expected outcomes of each component are detailed in Section 3.5 of this report and the methodology applied is described in Chapter 4.

FINDINGS

It is the overall impression of the EFET that the GCBP has been overall very successful with respect to all components. The geochemistry laboratory is already in operation and with competent staff. It, however, still needs to be credited. Training involving participation of MEM and MARENA experts and other civil servants in workshops, lecture courses, meetings, fieldwork and reporting has been very extensive in Nicaragua, as well as in Iceland and El Salvador. It is clear that there has been much progress in capacity building within the civil sector, in particular at MEM and MARENA. However, for this report, the EFET considers that it would have been desirable to have more information on infrastructure that relates to changes in the organizational structure of MEM and MARENA with respect to definition of responsibilities, co-operation, effectiveness and duties of staff, as well as civil servants outside the mentioned ministries. Also, norms for the permit process for the geothermal sector, roles of MEM and MARENA and their co-operation.

From the analysis of the findings of the EFET study, it is concluded that the overall success of the GCBP has been effective. It has had much positive impact and satisfies well environmental requirements and gender equality. The goal of building up sustainable knowhow within the geothermal field has, however, not been attained. It is considered that it takes more than 5 years to build up such capacity. This is especially the case for efficient, high quality data interpretation and reporting. Therefore a continuation of the 2008-2012 GCBP is considered

important in order to guarantee permanent, i.e. sustainable, capacity in Nicaragua for continued development of the country's geothermal resources, including all the necessary preparation stages, environmental studies and monitoring. If continued, the project ought to concentrate on specific topics and hence be less intensive than the GCBP.

BUDGET

By the end of 2012 the overall expence on behalf of ICEIDA is 3,583 thousand US$ which is 467 thousand US$ less than the budget plan of 4,050.8 thousand US$. These sums only cover the period 2008-2012. They do not cover preparation work for the planning of the Project carried out in 2007 and earlier as described below. The total expenditure is expected to increase somewhat as in 2013 there will be some more expences.

In terms of cost / benefit of the GCBP, the overall support provided by ICEIDA is comparable to the cost of drilling one 2000-2500 deep well into a high-enthalpy geothermal field. The average global steam yield of geothermal wells drilled in such fields is equivalent to around 5 MW_e. By comparison, the installed capacity of the San Jacinto geothermal plant is 72 MW_e. Drilling cost for a typical geothermal power plant is some 30% of the total cost. The money spent on the GCBP must therefore be only a very small fraction of the recently built plant at San Jacinto. This comparison indicates that the money spent on the GCBP is well worth its effort.

CONCLUSIONS, RECOMMENDATIONS AND LESSONS LEARNED

A summary of conclusions, recommendations and lessons learned that are based on the EFET work are given in Chapter 6-8 of this report. The recommendations and lessons learned that are considered to carry the most weight are the following:

RECOMMENDATIONS

- Extended support to the Government of Nicaragua in building up knowhow in geothermal development is recommended.
- It is recommended that the Government of Nicaragua seeks further external assistance to build up the needed capacity to develop their geothermal resources.
- It is also recommended that continued support, if realized, should be on a reduced scale and scaled down gradually.
- The Government of Nicaragua is encouraged to collect all existing surface exploration data on known geothermal fields within Nicaragua, both high and low-enthalpy, with the purpose of re-interpreting the data and envisaging whether additional data should be collected to prioritize areas for exploration drillings and aid skillful siting of exploration wells within these areas.
- It is considered important to link the development of geothermal resources in Nicaragua with the development of other energy resources in such a manner that geothermal energy can come on line at any time after a new field has been characterized and quantified through drillings. Also, it should be borne in mind that geothermal power plants ought to be used as base load, i.e. with high load factor on the electric power market.
- It is recommended that ICEIDA have a designated project manager for all projects, with clear mandate to oversee implementation and success.

- It is recommended that the ongoing certification process for the GeLab should be completed soonest possible for its commercial operation to be realized.

LESSONS LEARNED

- The Geothermal Capacity Project, as defined in the GCBP-FPD, is too detailed. It is considered that a more favorable approach to the planning of a project like GCBP would involve the employment of a Project Manager at an early preparation stage, construct a more general project layout and give a Steering Committee, headed by the Project Manager, the authority to specify in detail activities for each coming year including revision of the initial project layout, yet within a specified budget.
- Development of geothermal resources requires expert knowledge in many fields including biology, engineering, geochemistry, geology, geophysics, hydrology, mathematics and planning and design. This calls for teamwork that should be taken into account when planning geothermal development.

01

INTRODUCTION

1.1 PURPOSE OF THE EXTERNAL FINAL EVALUATION

This External Final Evaluation (EFE) Report represents the last activity of the 2008-2012 Geothermal Capacity Building Project (GCBP) of the Government of Reconciliation and National Unity of Nicaragua (GoN) and the Government of Iceland (GoI). The scope of the EFE is the entire GCBP implementation period, from 2008 to 2012. The objective of this EFE is to assess the outcomes of the GCBP, report on the lessons learned and find out:

- To what extent has the GCBP assisted the GoN in enhancing the utilization of geothermal resources in Nicaragua?
- To what extent has the GCBP enhanced the institutional capacity at the national Government level to manage geothermal resources?

as well as to give recommendations based on lessons learned. For the GoN, the evaluation will provide input and lessons learned to continue further the development and utilization of geothermal resources in Nicaragua. For ICEIDA the evaluation will provide input and feedback for future planning of development projects, especially in the field of renewable and benign energy resources and institutional capacity building.

The Icelandic International Development Agency (ICEIDA) in consultation with GoN made a contract with Alta Consulting Inc. to carry out this External Final Evaluation of the GCBP. The team leader responsible for the execution is Halldóra Hreggvidsdóttir of Alta Consulting. Geothermal expertise is provided by Prof. Stefán Arnórsson under a subcontracting agreement between Alta Consulting Inc. and Reykir Inc.

1.2 SCOPE OF THE GEOTHERMAL CAPACITY BUILDING PROJECT

Geothermal resources in Nicaragua are considered to be of value for the economy of the country. A five year agreement was made between the GoN and GoI in 2008, where Iceland would assist Nicaragua in building up knowhow to develop geothermal resources within the country*, "The Iceland - Nicaragua Geothermal Capacity Building Project 2008 - 2012"* (GCBP). The GCBP is financed jointly by GoI, 75% of cost and GoN, 25% of cost.

The principal GCBP objective was to create and strengthen the necessary national capacities, so that government institutions involved in geothermal exploration, development and use would be in a position to comply with their responsibilities and facilitate the development of its geothermal resources in an economic, environmentally benign and sustainable manner in the medium and long term. These institutions are the Ministry of Energy and Mines (MEM) and the Ministry of the Environment and Natural Resources (MARENA). The GCBP project is described in detail in the GCBP Final Project Document (GCBP-FPD).

The GCBP is split into the following three components (GCBP - Final Proyect Document):

- To strengthen the capacity for technical and scientific supervision at MEM and MARENA for the monitoring, oversight and follow-up to geothermal resources projects in Nicaragua.
- To implement a process of institutional capacity building for purposes to follow-up, monitoring, supervision, management and environmental oversight of Nicaragua´s geothermal development projects. It is aimed at essentially all civil servants.

» To endowment technical resources, infrastructure and equipment.

02

THE GCBP CONTEXT

2.1 ENERGY SYSTEM AND STATUS OF ELECTRICITY USE IN NICARAGUA

The energy system in a country reflects its predominant social, economic, technological and environmental conditions. In comparison to countries with a similar level of economic and social development, per capita energy consumption in Nicaragua was in 2005 low or 3.3 barrels of oil equivalent (BOE), the lowest in Central America.

Per capita energy consumption is also among the very lowest in Latin America. Low per capita energy consumption rates are directly linked to the satisfaction of people's basic needs. Low per capita energy consumption rates, together with inefficient energy use, reflect low standards of living and comfort among the Nicaragua's population, in particular if the unequal distribution of income and wealth are taken into consideration. It is estimated that approximately 60% of the population has access to electrical services. However, in rural areas that figure does not reach 40%. Among all countries in Central America and the Caribbean, per capita electricity consumption in Nicaragua is higher only than that of Haiti. The generation of electricity in Nicaragua is the main bottleneck facing any economic reactivation programme.

The country's electricity generation matrix is predominantly thermal and a high degree of dependency on imported hydrocarbons, which combined with high oil prices, made for an oil bill that in the year 2006 was equivalent to 65% of exports, the highest ever, leaving the country exposed to fluctuations in international oil prices

While it has long been known that the country has substantial geothermal and hydroelectric potential, the persistent political and institutional crises and the prevalence of more pressing short-term problems have historically limited the adequate use of these energy resources. Only scarce use is made of the energy potential contained in the natural resources available. Insufficient use is thus made of the country's energy potential (Extract from GCBP-FPD).

2.2 ENERGY RESOURCES IN NICARAGUA

Energy resources in Nicaragua include hydro, wind, biomass and geothermal, so called native energy resources. The first three are renewable in the sense that these resources are renewed at the rate equal to or higher than they are being used. Opinion is divided to what extent geothermal systems which are of the hydrothermal type, like those in Nicaragua, are renewable (Stefánsson, 2000; Sanyal, 2005, O'Sullivan et al., 2010). The renewability is affected by the extent of exploitation relative to natural heat loss from these systems. The estimated potential of hydro, wind, biomass and geothermal energy resource in Nicaragua is summarized in Table 2.1, together with information on effective installed power.

Geothermal energy potential for power production has been estimated as around 1,500 MW_e (Table 2.1). However, other estimates have been presented which are both higher 1,519 (Geothermal Masterplan, 2001; Ruiz-Mendieta, 2009) and 3,194 (Ruiz-Cordero, 2008) MW_e, respectively.

It needs to be pointed out here that estimated generation capacity for geothermal energy is highly uncertain as it is based on indirect information rather than data on reservoir characteristics.

Table 2.1 Energy resources in Nicaragua by type, resource size and installed electric capacity in 2007a.

TYPE OF RESOURCE	ESTIMATED GENERATION CAPACITY (MW_E)	EFFECTIVE INSTALLED CAPACITY (MW_E)	PERCENTAGE DEVELOPED
Hydro	3,280	98	3.0
Geothermal	1,519[b]	150	3.1
Wind	800	0	0.0
Biomass	200	60	30.0
Total	5,480	195	3.6

a Taken from Ministry of Energy and Mines (MEM), Nicaragua Energy Sector Strategic Plan, (2007-2017). Does not include wood, only plant residues.
b Other estimates have been presented, e.g. 1519 MW_e as weighted risk reserve, in Vol I Summary Report-A.pdf pg 162, GeothermEx (2001). Both numbers are highly speculative and only indicate that the geothermal resources in Nicaragua are important for the economy of the country.

The total installed electric power in Nicaragua was 767 MW_e in 2009 (Ruiz-Mendieta, 2009). Native energy resources account for only 28% of this, the rest being imported fossil fuel. Installed geothermal capacity is presently 102 MW_e, or roughly 13% of the total (i.e. 102 MW_e in 2012 of the total of 767 MW_e in 2009). However, the load factor of geothermal power plants is expected to be higher than that of other types of power plants. Thus the annual electric energy production will be higher from geothermal energy than indicated by the installed capacity numbers. The EFET has no data on load factors for the different types of power plants in the country, making it impossible for them to estimate the percentage of annual energy contribution from geothermal power plants in Nicaragua.

2.3 ENERGY DEVELOPMENT PLANS IN NICARAGUA

It is the policy of the GoN to increase the use of "renewable" or benign energy resources for the production of electric power. The geothermal sub-sector has been identified as a key component to this end, as Nicaragua has abundant geothermal fields, most of which have not been developed.

GoN made a Master Plan for geothermal development in 2001, where the generating capacity was estimated as 1,519 MW_e, in 12 fields some of which are in protected areas and all of them are close to such areas. GoN plans to revise the existing Master Plan by 2014.

The Energy Sector Strategic Plan of 2007-2017 envisages development within the energy sector during the 10 years period. The 2007-2017 Plan incorporated major increase in power production through development of Nicaragua´s own energy resources but also an increased use of imported fossil fuel. Thus the Plan aimed at increasing the installed capacity by the year 2017 as follows:

- Hydro, geothermal and biomass by 466, 156 and 20 MW_e, respectively.
- Wind power 20 MW_e.

» Thermal plants, based on coal, diesel and fuel oil by 540 MW_e.

This would increase the total installed electric power by 1,167 MW_e corresponding to an increase of 167%.

By the Plan, the contribution of native energy resources would increase from 28% in 2007 to 44% in 2017. However, use of fossil fuel may not increase as much as planned during the period in question, depending on market needs.

In the "Plan Nacional de Desarrollo Humano Actualizado 2009 - 2011, technical report", from 2009, the following plan was introduced for the development of geothermal energy:

» San Jacinto-Tizate: started operation the first 36 MW_e in January 2012 and another 36 MW_e in December 2012 (González, oral communication).

» For the El Hoyo-Monte Galán and Managua-Chiltepe fields that were both being explored at the time, the Plan assumed that production would start in 2014 and 2015, respectively.

» A tendering process was to be finalized for exploration of the Casita-San Cristóbal field in 2013-2016 with expected three stages of 20 MW_e, 40 MW_e and 40 MW_e.

» It was considered that three more fields (Apoyo, Ometepe and Mombacho) would be in place in 2016, 2016 and 2017, respectively. This plan was emphasizing the importance of the GCBP for the energy resource development in Nicaragua.

2.4 CURRENT STATUS OF ENERGY RESOURCES IN NICARAGUA

Today, total installed capacity of geothermal power plants is 150 MW_e effective (Momotombo 78 MW_e (effective), San Jacinto-Tizate 72 MW_e). The plans to develop the Managua-Chiltepe and El Hoyo-Monte Galán by 2014-2015 have been delayed due to poor outcome of the exploration drillings. In Managua-Chiltepe, an exploration drillhole did not strike high temperatures (about 80°C). Drillings in another part of the field have been proposed (Hersir and Ólafsson, 2009a) and ALBANISA will continue the exploration with their concession. At El Hoyo-Monte Galán sufficiently high temperatures have been proved in the the first exploration hole drilled but permeability is low, certainly below the production casing in the open hole. The highest temperature was at a depth level within the production casing but temperatures in the open hole were lower. The lower temperatures measured in the second borehole are probably due to downflow in the well (Fridriksson and Ármannsson, pers. comm.). For that reason the project is also on halt. Three slim holes have been drilled at El Hoyo (Fridriksson, pers. comm.). The EFET has not received any information on these drillings and did not learn about them until at the very final stages of writing this report. GeoNica has concessions to develop El Hoyo-Monte Galán however the concession for Managua-Chiltepe was returned by Geonica at the beginning of 2012 and granted to Alba Geotermia.

The Casita-San Cristóbal prospect may be ahead of schedule. Exploration drillings have yielded positive results proving a hot, vapor-dominated reservoir (230°C) It is not known whether the shallow vapor-dominated reservoir represents a steam cap over a liquid-dominated reservoir or if the vapor zone extends to considerable depths. These results are favorable for decision to continue the development of this field. At the time of writing this report, information was not available on exploration at the Apoyo, Ometepe and Mombacho fields.

Following is an overview of proven and indicated high-temperature geothermal resources.

Proven resources:

- Momotombo, with expected potential of 30-35 MW_e, current real capacity 23 MW_e.
- San Jacinto - Tizate with current capacity of 72 MW (José Antonio Rodriguez, personal communication).
- El Hoyo - Monte Galán - proven temperatures of around 200°C (Mortensen and Egilsson, 2012).
- Casita - San Cristóbal - proven temperature of 230°C and a steam zone, possibly overlying a liquid-dominated reservoir (José Antonio Rodriguez, personal communication).

Indicated resources in the Master Plan from 2001:

- Managua-Chiltepe
- Volcan Cosigüana
- El Ñajo-Telica
- Tipitapa
- Masaya Granada-Nandaime
- Ometebe Island.

In Appendix III, information is given how the United States Geological Survey (USGS) classifies mineral resources depending on the extent of available information on the resources. They use a specific nomenclature that gives a better background for the understanding of the uncertainty involved for the exploration and evaluation of mineral resources. This nomenclature also applies to geothermal development and it is also very helpful for envisaging clearly the implementation status of individual geothermal projects. It is for this reason that we suggest that the nomenclature of the USGS should be adapted in the context of geothermal development in Nicaragua.

2.5 INSTITUTIONAL ROLE IN GEOTHERMAL DEVELOPMENT IN NICARAGUA

Despite Nicaragua's geothermal potential, the country has lacked technical experience as concerns its management, the necessary research, and resource exploration and exploitation. Specifically, MEM and MARENA needed to improve capacity as regards geothermal development and the process to grant concessions, permits and licenses, as they are the national institutions responsible for follow-up, control and evaluation of geothermal production and environmental oversight to ensure a sustainable management of the resource.

MEM is charged with planning, proposing, coordinating and implementing the Strategic Plan and public policy in general in the energy sector. It is charged with drawing up the technical standards, criteria, specifications, rules and regulations that will govern the activities of reconnaissance, exploration, exploitation, production, transport, transformation, distribution, management and use of energy resources, as well as approving and making effective the technical norms for regulating the generation, transmission and distribution activities in the

electricity sector upon receiving proposals to that effect from INE. MEM is in charge of the exploitation of geothermal resources.

It also comes under the purview of the MEM to grant, modify, extend and cancel reconnaissance and concession permits for the use of any source of energy (geological or energy resources). Further, to grant licenses for the operation, generation and transmission of energy, as well as concessions for its distribution and the negotiation of contracts for the exploration and exploitation of geological resources. MEM also directs the functioning and administration of state-owned companies that operate in the energy sector.

Finally, it is a MEM responsibility to administrate and regulate the National Electrical Industry Development Fund, decrees, regulations and resolutions related to the electricity, hydrocarbons and geological energy resources, including the approval of their internal norms.

For its part, MARENA is responsible for carrying out strategic environmental assessments, the environmental management of geothermal plants located in protected areas, and the promotion of clean development of geothermal production by making effective use of the environmental regulations that govern its exploitation.

To the overall weakness of government institutions must be added, the lack of capacity at the universities to provide training in geothermal exploration, geochemistry and environmental impact studies concerning research, exploration and exploitation of geothermal energy, as well as follow-up, oversight and evaluation of geothermal production (Extract from GCBP-FPD.

The geothermal projects in Nicaragua are carried out by private developers and concessions are given to “concessionaires”, through direct negotiation. The role of the GoN, MEM on its behalf is to prepare documents for the tendering process and then to give concessions to developers with duties and norms to follow. The concession process is divided into two steps:

1. a concession is given for the exploration of the geothermal fields and then if the first step is successful,
2. concession is request by developers for exploitation,

Environmental Impact Assessments (EIA) have to be prepared by the concessionaires for each step, where MEM, MARENA and the relevant municipalities have to set the Terms of Reference for the EIA.

2.6 GON AND ICEIDA CONTEXT

It is the policy of the GoN to increase energy production by using local power supplies, with the overall aim to reduce poverty and promote poverty reduction and social stability

ICEIDA's Development Strategy is to alleviate poverty and emphasises support to people and institutions in a partner country towards self-sufficiency. The aim of ICEIDA is to accomplish this through the transfer of knowledge and skills in fields where Icelanders are in possession of particular expertise like geothermal development. ICEIDA's aim is also to promote democracy, human rights and gender equality through economic growth and social reform, seen as one of the prerequisites for poverty reduction, emphasizing environmental sustainability in particular throughout this process. The needs and roles of both women and men are taken into account during the preparation and implementation of the Agency's projects i to ensure equal opportunity for men and women to influence, participate in and benefit from the projects.

03

PROFILE OF THE GEOTHERMAL CAPACITY BUILDING PROJECT

3.1 GENERAL INFORMATION

Country of Implementation: Nicaragua
Project Title: Iceland – Nicaragua: Geothermal Capacity Building Project 2008 - 2012 (GCBP)
Donor: Government of Iceland through ICEIDA
Project Period: 01.01.2008 – 31.12.2012
Current Status: The GCBP has been finished by ICEIDA
Sector - DAC: Geothermal Energy – 23066
Type of Aid: Project Type Interventions – C01

Total Estimated Project Cost: USD 5,646,516 million
ICEIDA Estimated Contribution: USD 4,231,516 million / 75%
GoN Estimated Contribution: USD 1,415,000 million / 25%

ICEIDA Actual Contribution: USD 3,583 million [1]
GoN Actual Contribution: C$ 28193,158.33[2]

[1] *This contribution will increase as some expenses will be accounted for in 2013.*

[2] *This is total cost as of april 2013.*

The Government of Nicaragua requested assistance from the Government of Iceland in 2004, to develop an institutional support project for the geothermal sub sector in Nicaragua. A five year agreement was made by the Government of Reconciliation and National Unity of Nicaragua and ICEIDA, on behalf of the Government of Iceland in January 2008, to start the "*The Iceland - Nicaragua Geothermal Capacity Building Project 2008 - 2012"* (GCBP). The objective to enhance the utilization of geothermal resources in Nicaragua, by assisting Nicaragua in building up know-how within the public sector on how to develop geothermal resources within the country.

The GCBP is designed on the base of the ICEIDA Development Strategy and is fully in line with the strategic development plans of GoN, to increase energy production by using local power supplies. The overall aim is to reduce poverty and promote poverty reduction and social stability.

ICEIDA opened a country office in Nicaragua in the beginning of 2006. The office was closed August 1st, 2009, due to economic crisis in Iceland. This made no change to the financial support of the GCBP. See further an historical overview of the GCBP in Appendix I.

The box above summaries financial and other information on the GCBP project. More detail is given in Table 3.1. The numbers for 2012 are expected to be low as some expenses will be accounted for in 2013. The overall expense (including 5% contingency) on behalf of ICEIDA is 3,583 thousand US$ which is 467 thousand US$ less than the budget plan of 4,050.8 thousand US$. These sums only cover the period 2008-2012. They do not cover preparation work for the planning of the Project carried out in 2007 and earlier as described below.

During the first two years of the contract beween ICEIDA and GoN the budget plan from ICEIDA was considerably excessive. The reason is considered to be that initiation of all the phases (components) of the project took longer than envisaged. In the years 2010-2012 the budget plan was overall inherited to as were the balances of individual items.

It is not considered possible to assess whether or not individual tasks were supported excessively or not because so many of them are subjective rather than objective, like e.g.

training courses. The overall support provided by ICEIDA is similar to the cost of drilling one 2000-2500 deep well into a high-enthalpy geothermal field. The average global steam yield of geothermal wells drilled in such geothermal fields is equivalent to around 5MW_e. By comparison, the installed capacity of the San Jacinto geothermal plant is 72 MW_e. Drilling cost for a typical geothermal power plant is some 30% of the total cost. The money spent on the GCBP must therefore be only a very small fraction of the recently built plant at San Jacinto. This comparison indicates that the money spent on the GCBP is well worth its effort.

Table 3.1 An overview of ICEIDA's expenditure and annual components

TYPE OF ACTIVITY	BUDGET PLAN – THOUSAND US $	ACTUAL EXPENSE THOUSAND US $	DIFFERENCE THOUSAND US$
2008			
Technical assistance	729,7	170,2	559,5
Training	151,3	216,7	-65,4
Infrastructure, equipment	183,9	244,6	-60,7
Administration	94,2	74,7	19,5
Evaluation	12,0	25,3	-13,3
Subtotal	1.171,1	731,5	439,6
Contingencies, 5%	58,6	58,6	0,0
Grand total	**1.229,7**	**790,1**	**439,6**
Difference		**439,6**	
	1.229,7	1.229,7	
2009			
Technical assistance	530,1	405,3	124,8
Training	174,8	244,7	-69,9
Infrastructure, equipment	11,8	49,0	-37,2
Administration	96,8	105,3	-8,5
Evaluation	50,0	9,9	40,1
Subtotal	863,5	814,2	49,3
Contingencies, 5%	43,2	43,2	0,0
Grand total	**906,7**	**857,4**	**49,3**
Difference		**49,3**	
	906,7	906,7	
2010			
Technical assistance	376,1	327,1	49,0
Training	192,9	242,0	-49,1
Infrastructure, equipment	2,0	0,0	2,0
Administration	98,3	119,8	-21,5
Evaluation[1]	0,0	0,0	0,0
Subtotal	669,3	688,9	-19,6
Contingencies, 5%	33,5	33,5	0,0
Grand total	**702,8**	**722,4**	**-19,6**
Difference		**-19,6**	
	702,8	702,8	
2011			
Technical assistance	324,5	351,6	-27,1

Training	170,1	156,7	13,4
Infrastructure, equipment	2,0	2,0	0,0
Administration	103,6	120,4	-16,8
Evaluation	15,3	15,5	-0,2
Subtotal	615,5	646,2	-30,7
Contingencies, 5%	30,8	30,8	0,0
Grand total	**646,3**	**677,0**	**-30,7**
Difference		**-30,7**	
	646,3	646,3	
2012			
Technical assistance	292,4	290,5	1,9
Training	42,0	42,0	0,0
Infrastructure, equipment	0,0	0,0	0,0
Administration	124,1	124,1	0,0
Evaluation	80,0	80,0	0,0
Subtotal	538,5	536,6	1,9
Contingencies, 5%	26,9	0,0	26,9
Grand total	**565,4**	**536,6**	**28,8**
Difference		**28,8**	
	565,4	565,4	
[1]Included under "administration"			

3.2 PARTNERS, IMPLEMENTING INSTITUTIONS AND STAKEHOLDER'S PARTICIPATION

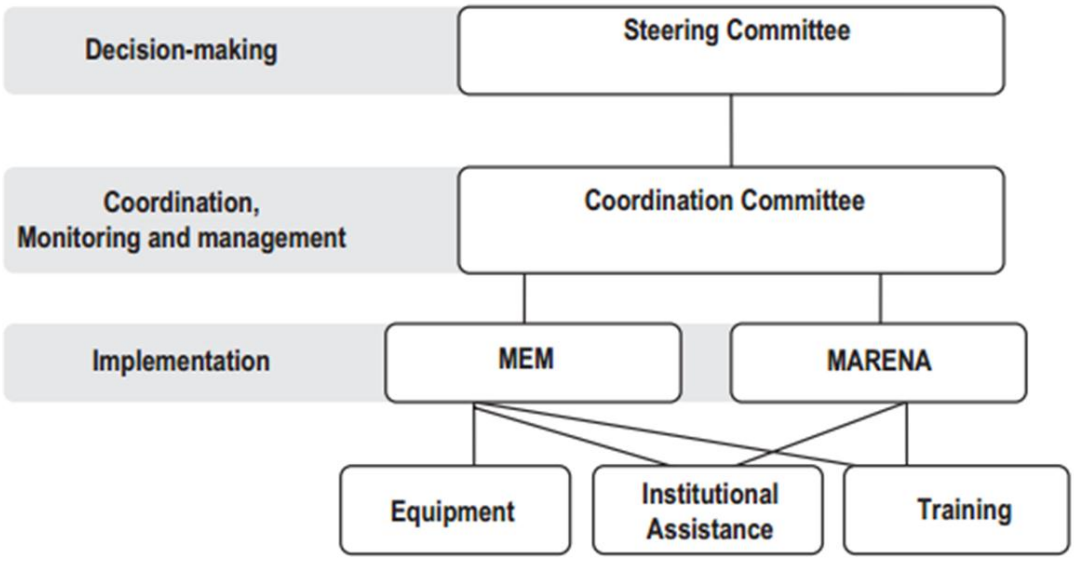
The Partners: Government of Nicaragua (GoN) through the Ministry of Energy and Mines (MEM). Government of Iceland (GoI) through the Icelandic International Development Agency (ICEIDA)

Implementing Institutions: Government of Nicaragua (GoN) through the Ministry of Energy and Mines (MEM) and the Ministry of the Environment and Natural Resources (MARENA).

T**he main stakeholders** are concessionaires in geothermal areas, as well as municipalities that have high-enthalpy geothermal fields and universities. These bodies were invited to allow staff to participate in courses organized by GCBP (see Chapter 4.2).

3.3 GCBP MANAGEMENT ORGANIZATION

The ICEIDA Country Office Director in Nicaragua was initially responsible for the overall management of the GCBP through his seat in the Steering Committee of the GCBP. Mr. Gísli Pálsson was the first Country Director for ICEIDA. Mr. Geir Oddsson took over as a Country Director in 2008. When the Country office was closed August 1st. 2009, the management role was moved to ICEIDA's office in Iceland, where Mr. Gísli Pálsson took again seat in the Steering Committee and followed the project to the end.



The Steering Committee (SC) was the highest authority of the GCBP. It met twice a year and approved the Annual Plan of Operation, the budget, followed up on project implementation and set the Annual Strategy. There were three official members in the SC on behalf of ICEIDA, ICEIDA Director, ICEIDA geothermal consultant and the ICEIDA Coordinator. One official member from MEM the vice minister of MEM and two from MINREX. The third member, from MARENA, the vice minister of MARENA was added to the SC after a mid-term evaluation in 2009, as an observer. Other staff members from MARENA and MEM took seat as observers as needed. The SC took decisions by consensus, and the persons on the committee had equal rights and duties vis-à-vis the project.

For their work on the project those persons appointed to the SC by MEM, MARENA, MINREX and ICEIDA did not receive a salary, stipends or remuneration of any kind.

For their work on the project those persons appointed to the SC by MEM, MARENA, MINREX and ICEIDA did not receive a salary, stipends or renumeration of any kind from the GCBP budget.

A Coordination Committee (CC) was appointed by the SC. It had initially two members, one coordinator from MEM and one coordinator from ICEIDA, who was also the General coordinator for the project. The third member from MARENA was added to the CC after a mid-term evaluation in 2009.

The role of the General coordinator was to represent the GCBP in its inter institutional relations, and keep up official communication with the minister of MEM and the ICEIDA director. After the

2009 mid-term evaluation the General coordinators role was also to keep up official communication with the minister at MARENA. No official project manager was identified.

The CC was in charge of project follow-up, project coordination and project progress reports, monitoring and evaluation. The CC took decisions by consensus, and the persons on the committee had equal rights and duties vis-à-vis the project. ISOR was the main project contractor and took on responsibilities according to an agreement with CC. See further GCBP project design in chapter 11 of the GCBP-FPD.

For their work on the project, those persons appointed to the CC by the SC did not receive a salary, stipends or remuneration of any kind, from the GCBP budget.

3.4 GCBP OBJECTIVE, COMPONENTS, ACTIVITIES AND OUTPUT

The GCBP concentrated on support to geothermal development in Nicaragua by encompassing three major areas of strategic importance: technical assistance; the training and education of human resources; and endowment with the equipment necessary to strengthen national capacity in coordination with the geothermal sector. The overall objective was to enhance the utilization of geothermal resources in Nicaragua. The project had three components which reflected those areas in which cooperation had been requested by Nicaragua through the Ministry of Energy and Mines and the Ministry of the Environment and Natural Resources (ICEIDA – MEM (2008).

Component 1: To strengthen the capacity for technical and scientific supervision by the Ministry of Energy and Mines (MEM) and the Ministry of the Environment and Natural Resources (MARENA) to coordinate, supervise, monitor and develop the exploration and exploitation of geothermal resources in Nicaragua.

Component 2: Develop a process of building capacity for follow-up, monitoring, supervision, management and environmental oversight of geothermal development projects in Nicaragua, geared toward civil servants.

Component 3: Endow the geochemical laboratory at MEM with technical resources, infrastructure and equipment.

Outputs component 1:

1. A short and medium-term technical assistance project is developed for the creation of capacities at MEM as regards monitoring, follow-up and evaluation of the management and development of geothermal production in Nicaragua.
2. Capacity is created at MARENA and MEM for the monitoring and evaluation of Environmental Impact Assessments (EIA).
3. Capacity is created at MARENA and MEM for the incorporation of the sustainable use of geothermal resources to the management plans for protected areas.
4. Strengthen the National Clean Development Office (ONDL) at MARENA and the Environmental Management Unit (UGA) at MEM by applying the Clean Development Mechanism (CDM) to geothermal projects.

Outputs component 2:

1. Technical capacity is created among public sector technicians and public servants for the supervision, monitoring and environmental oversight of geothermal development projects in Nicaragua.
2. Technical capacity is strengthened among government sector employees through other training techniques and the study of issues in support of the development of geothermal projects.

Outputs component 3:

1. The MEM Investigation Unit is equipped and strengthened.
2. The geochemical laboratory at ENEL is transferred to MEM and is rebuilt and conditioned in order to supply the demand regarding development of research in geochemistry and geothermal production in Nicaragua.

MAIN PROJECT ACTIVITIES

Activities for Output 1, component 1:

The case of technical assistance for the building of capacity at MEM for the monitoring, follow-up and evaluation of management and development of geothermal production in Nicaragua, the project will carry out the following activities:

1. Provide technical assistance to MEM in order to evaluate the possibilities for increasing the generation of steam at the Momotombo geothermal field and evaluate the results of geoscientific research carried out by GeoNica in its exploration concession, as well as for the evaluation and management of the San Jacinto – Tizate reservoir.
2. Provide technical assistance for the drafting of policies intended to govern the implementation of geothermal projects and the evaluation of tendering processes for geothermal concessions.
3. Provide technical assistance in order to create the MEM Investigation Unit and determine its role and structure. Review the geothermal master plan, support the

Investigation Unit activities, and validate the geochemical analysis methods being used. Review and update the geochemistry database.

4. Provide technical assistance to MEM for the identification of industrial potential in low enthalpy geothermal areas and for the heat pumps project for agricultural uses to be carried out by MEM and UNAN León campus.

Activities for Output 2, component 1:

This output refers to technical assistance for building capacity at MARENA and UGA- MEM with which to monitor and evaluate Environmental Impact Assessments (EIA). The main activities are:

1. Provide technical assistance in order to review the scope of the Terms of Reference (ToR) and EIA documents on geothermal development activities in its different phases. Review the EIA methodology concerning geothermal projects and environmental audits of geothermal projects. Publish the manual and poster on steps for carrying out EIA.
2. Provide advisory services for the preparation of mandatory technical guidelines for geothermal projects and hold conferences, meetings and seminars on laws, environmental regulations and the development of geothermal resources in its different phases.

Activities for Output 3, component 1:

This output consists of technical assistance for the building of capacity at MARENA and MEM to include the sustainable use of geothermal resources in the management plans for protected areas (parks). The following activities are foreseen:

1. Technical assistance for identifying protected areas with potential and feasibility for geothermal development and the subsequent protection of natural assets in those areas.
2. Include the use of geothermal resources in the management plans for the volcanic complexes at Momotombo - Momotombito, Managua - Chiltepe, Telica, Santa Clara and El Chonco.

Activities for Output 4, component 1:

This output is expected from the technical assistance being provided to strengthen the National Clean Development Office (ONDL) at MARENA and UGA –MEM so they are capable of applying the Clean Development Mechanism (CDM) to geothermal projects.

1. Strengthen the institutional framework of the ONDL and UGA-MEM as concerns the application of the CDM to geothermal projects.
2. Seek international consultancies for the preparation of a methodology for the sale of greenhouse gas emission reduction certificates at geothermal projects and publish information on the financing of geothermal projects under the CDM.

Activities for Output 1, component 2:

This output reflects the training of human resources in order to build capacity among public sector technicians and civil servants as concerns the supervision, monitoring and environmental oversight of geothermal projects in Nicaragua. The activities to be carried out are:

1. Implement a training programme with several levels of specialisation, such as post-graduate work, master's degrees, technical courses, seminars, workshops and meetings.

Activities for Output 2, component 2:

This is also an output pertinent to the training of human resources, in this case with a view toward strengthening technical capacities among civil servants at government institutions and staff at universities and among private developers, through additional training techniques and the study of issues relevant to a geothermal project.

1. Implement a training programme with specialised courses on specific subjects, the exchange of experience and membership in international organisations that work with geothermal issues.

Activities for Output 1, component 3:

This output covers the endowment with technical resources, equipment and infrastructure to rebuild and condition the Investigation Unit at MEM. The planned activities are as follows:

1. Define the structure and framework for the functioning of the MEM Investigation Unit and endow it with furniture and office equipment.

Activities for Output 2, component 3:

The output in this instance will be the endowment with technical resources, equipment and infrastructure to rebuild and condition the geochemical laboratory at MEM. The planned activities are as follows:

1. Rebuild and condition the MEM geochemical laboratory and provide it with additional work instruments and equipment, as well as human resources who have been properly trained in their uses and applications.

3.5 PROJECT MILESTONES

The GCBP contains the following five milestones.

1. The first milestone is the specialised technical assistance in the area of geothermal activity. This will allow for creating the necessary capacity with which to coordinate, supervise, monitor and develop the exploration and exploitation of geothermal resources in Nicaragua, thus overcoming an institutional weakness at MEM and creating conditions for institutional sustainability in the supervision and management of geothermal plants.
2. The second important milestone is the creation of the MEM Investigation Unit, or MEM-DIG, which will be endowed not only with equipment and qualified human resources, but will also have a clearly defined role and set of activities to carry out. In addition, the Investigation Unit will provide services to the geothermal industry under self-sustainable conditions.
3. The third milestone is the certification and validation of the geochemical laboratory that marks quantitative changes in the MEM institutional capacity for managing research and providing attention to geothermal production.

4. The fourth milestone is related to capacity building at MARENA and MEM in order to manage the processes leading to the Environmental Impact Assessments at geothermal plants, as well as geothermal production in protected areas. This will lend greater comprehensiveness to MARENA's mandate to promote and protect the environment and natural resources.
5. The fifth milestone concerns the development of capacity at MARENA and UGA-MEM to provide advisory services to project developers on the use of Clean Development Mechanisms for the purpose of selling greenhouse gas emission reduction certificates at geothermal projects. This will open up an area of institutional incentives for geothermal investments.

04

METHODOLOGY FOR PROJECT EVALUATION

4.1 EVALUATION TEAM, ISSUES AND QUESTIONS

The team leader responsible for the External Final Evaluation, project and process is Halldóra Hreggvidsdóttir, Alta Consulting Inc. Geothermal expertise is provided by Prof. Stefán Arnórsson under a subcontracting agreement between Alta Consulting Inc. and Reykir Inc.

For the GoN, the EFE shall provide input and lessons learned to continue further the enhancement of the utilization of geothermal resources in Nicaragua. For ICEIDA the EFE shall provide input and feedback for future planning of development projects, especially in the field of renewable and benign energy resources and institutional capacity building.

Various issues and questions have been identified to evaluate the outcome and impact of the GCBP on the target beneficiaries in the target area. The main focus to ascertain the outcomes of the GCBP is on the following:

- To what extent has the Project assisted the GoN in enhancing the utilization of geothermal resources in Nicaragua?
- To what extent has the Project enhanced the institutional, scientific and technical capacity at the national Government level to manage, develop and use geothermal resources in a sustainable manner?

Some of the key questions relate to the outputs identified through the three GCBP components and if they have been fulfilled as specified in the log matrix and in the overview of activities and tasks in the Appendices of the Geothermal Capacity Building Project Final Project Document (GCBP-FPD). Through those, it will be evident if the GoI through ICEIDA has fulfilled the specifications of this project for the following commitments:

- To provide funds for technical assistance to the Nicaraguan institutions involved in the development and monitoring of geothermal resources for a 5 year period.
- To provide technical training to Nicaraguan professionals.
- To provide the necessary equipment to Nicaraguan institutions, as defined by the GCBP, for effective monitoring and development of geothermal resources.

Another set of issues and questions relates to the commitment of the GoN through MEM and MARENA, if it has fulfilled the following:

- To implement and follow-up on the technical assistance activities.
- To establish a Geothermal Investigation Unit at MEM, MEM-DIG.
- To coordinate the re-activation and installation of a geochemical laboratory.
- To provide financial sustainability for the Geothermal Investigation Unit at MEM the long term.
- To establish efficient coordination between MEM and MARENA in the topic of environmental training and environmental monitoring for the activities of the projects.

Expanding on the above:

- Is there currently existing general knowhow within Nicaragua to make the country fully qualified to undertake relevant scientific investigations for the development of geothermal resources?
- How does GoN foresee continuation of work started through the GCBP?
- Has there been an improvement likely to last regarding knowhow - sustainability of training?
- If there is mutual understanding of the impact of the project?

The following questions will address and summarize particular issues including:

- Has training and education, including courses and material issued covered all relevant topics?
- What was the quality of technical assistance, the expert approach and recommendations regarding the development of geothermal resources?
- What are the comments on infrastructure, facilities and instrumentation, equipment and materials provided for?
- Institutional support, roles of individual units and job descriptions.
- How well were the roles of institutions and ministries fulfilled regarding responsibilities and capacity, the decision making process while developing geothermal resources sustainably?
- What is the opinion on how the GCBP has been defined, including its management and efficiency?
- Lessons learned - The way ahead.
- How was the cooperation between GoN and ICEIDA?

Information is also needed on:

- The Energy Policy of GoN, number and type of power plants, which energy sources are being used and total installed power in the country when GCBP was initiated and at present.
- Available facilities in Nicaragua to carry out investigations aimed at developing geothermal resources.
- The number of known geothermal fields in Nicaragua, their size, if known, and estimated subsurface temperatures.
- Which areas have been developed, which ones are under development and which have been drilled.
- If MEM has a strategy as how to develop geothermal fields and to monitor their response to the exploitation load.
- How the geothermal fields that are of greatest interest today can be linked to high voltage transmission lines.
- If fluid disposal is of concern environmentally and for what reasons (fluid chemistry, effects on reservoir performance etc).

» The protocol for all aspects of EIA and Strategic Land-Use Planning for the development of geothermal resources.

Issues covered by the above are used to assess and analyze the project related to the following:

» **Relevance**. Examining relevance in to the context of:

- Government of Nicaragua (GoN) policy goals concerning poverty alleviation.
- GoN policy goals regarding energy production.
- Cross-cutting issues related to environmental sustainability (e.g. climate change impacts) and gender equality as stated in GoN policies.

» **Efficiency**. Assessing the use of financial and human resources available for the GCBP. Of importance in this context is also examination of the coherence and complementarities between different government projects and programs, as well as coherence with other Icelandic and/or international development assistance programs in Nicaragua.

» **Impact**. Analysis of positive and negative impact in society, relating to all parties affected by the Project.

» **Effectiveness**. Examining the extent to which the Project's objectives were achieved, taking into account their relative importance.

» **Sustainability of Results**. Assessing if net benefits are likely to continue after the completion of the assistance. Sustainability of the institutions may be examined in terms of their absorption and retention capacity of the expertise developed under the Project.

4.2 METHODOLOGY AND DATA GATHERING

The External Final Evaluation Team (EFET) carried out data gathering and analysis in close consultation with ICEIDA. There were essentially three major sources of data for this review: people, documents and one site visit. The EFET reviewed numerous documents and reports (see References and Reports). The Team consulted and interviewed representatives from Partners of the Project and stakeholders through semi-structured face-to-face meetings and over the telephone. One site visit was made to Nicaragua from November 25th to December 7th, 2012 for data collection and interviews during the implementation phase. The list of Partners and stakeholders consulted are presented in Appendix II. The evaluation approach was consultative, participatory, and utilization-focused, and was executed in conformity with the principles, standards, and practices set out by the Canadian International Development Agency (CIDA) presented in the CIDA Evaluation Guides from 2002 and 2004. Use was also made of Evaluation Guidelines from the Danish International Development Agency (DANIDA, 2006).

The evaluation has been divided into the following steps:

1. Setting the baseline for the EFE study. Finalized in the ICEIDA Inception Report of Nov. 14, 2012.
2. Assessment by Partners and other stakeholders on the success and impact of GCBP as based on interviews in Nicaragua and Iceland. The questions raised by the EFET can be seen in Chapter 4.1 of the current report, "Evaluation Issues and Questions". See further GCBP First Draft Report, January 9th, 2013. Sent out for review January 9th to January 21st, 2013.

3. Evaluation, conclusions, recommendations and lessons learned based on the conclusions, supported by the experience and knowledge of the EFET in this field presented in the Second Draft Report, sent out for review on February 5th with comments received by February 18th, 2013.
4. A Third Draft Report, sent out for review on February 28th for comments received by March 4th, 2013.
5. A final meeting in Managua, March 21st 2013, with the steering committee of the GCBP, where the conclusions of the EFE were presented.
6. There were revisions from the Nicaraguan team after the meeting, March 21st and the final report released in June 2013.

The EFET used descriptive, content and comparative analyses to analyze the data for this Current Third Draft Report and, to the extent possible, ensured validity through data triangulation, confirming data from multiple sources. Based on the data analysis, the EFET developed findings, conclusions and recommendations.

4.3 KEY CHALLENGES: EVALUATION AND LIMITATIONS

Availability of information on the GCBP. After the contract was finalized between Alta Inc. and ICEIDA, the EFET had very short time to prepare the Inception Report and the visit to Nicaragua, 12 days to be exact. ICEIDA sent two batches of reports that had been prepared for the GCBP. Later the EFET received many more reports, from interviewees in Iceland before and after their field trip to Nicaragua and during their stay there. Apparently, ICEIDA had not received some of these reports. One of the problems here is the overlap in time between the work of the EFET and the final phase of the GCBP including finalizing some reports. However, the EFET considers that the very good assistance provided by all Partners involved in the GCBP has made up for this.

05

FINDINGS

This chapter summarizes the status of implementation of the Geothermal Capacity Building Project and the overall project performance based on the evaluation criteria, issues and questions listed in chapter 4.1. The extend of the execution of the three components is evaluated based on identified activities and tasks in the GCBP-FPD, administration and evolution and the overall GCBP performance based on reports, annual reports, memos and documents provided through the regular activities of the Steering Committee, interviews with Partners, key stakeholders and consultants.

5.1 EVALUATION AND STATUS OF IMPLEMENTATION OF PROJECT COMPONENTS

5.1.1 Component 1 - Technical Assistance

BASELINE OF COMPONENT 1

In January 2007 the new Government of Reconciliation and National Unity took office, and the Ministry of Energy and Mines (MEM) was created as the agency charged with planning, proposing, coordinating and implementing the Strategic Plan and Public Policy of the energy and geological resources sector. These were functions that used to be carried out by the INE and the National Energy Commission. MEM was thus newly established as such at the start of the GCBP in 2007/2008 (see the history of the GCBP in Appendix I). At that time there was lack of experience and general knowhow on geothermal resources at MEM and MARENA, how they should be developed and which norms should apply when concessions were given. There was also lack of overview on the abundance of low and medium enthalpy geothermal resources in Nicaragua. The capacity was limited at MEM for the coordination, supervision, monitoring and development of exploration and exploitation of geothermal resources. A clear need and demand for technical assistance in these areas was identified. A similar situation was identified at MARENA and the Environmental Management Unit at MEM (MEM-UGA) regarding knowledge on the environmental effects of the development of geothermal systems. Assistance was needed to improve the efficiency of environmental impact assessments (EIA). At MARENA and MEM-UGA there was capacity and oversight on how to develop natural resources in protected areas, like national parks in general, but not regarding the development of geothermal resources within these areas.

The objective of component 1; technical assistance, was thus to build up a general understanding of geothermal resources within the civil service, in particular MEM and MARENA. At the Direction of Geothermal Development in MEM (MEM-DDG), there was need to create capacity to evaluate and monitor the development by concessionaires of geothermal areas. At MARENA, MEM-UGA and MEM- DDG there was need to gain knowledge to set norms for geothermal development, during both exploration and exploitation. At MARENA and MEM-UGA there was also need to create capacity to evaluate EIA. Capacity should also be created at MARENA and MEM to manage sustainable use of geothermal resources within protected areas through management plans. At the start of the GCBP there was a plan to strengthen the National Clean Development Office (ONDL) at MARENA and MEM-UGA by applying the Clean Development Mechanism (CDM) to geothermal projects. This output was abandoned in 2009 and changed into studies of so called Forest Fragmentation in protected areas. This involved technical assistance in various fields.

The overall objective of component 1, the expected results, baseline, verifiable indicators and means of verification along with internal and external risk factors is being described in the Logical Framework for the GCBP, in Annex I of the GCBP-FPD. Individual activities and tasks required to fulfill this objective, directly related to the means of verification for component 1 are detailed in Annex III of the GCBP-FPD. It was found advantageous for the evaluation of tasks required by the EFET to use the activities and tasks in Annex III of the GCBP-FPD, as verifiable indicators for means of verification for expected results. As such to give an overview of the status of implementation. This overview is shown below.

Status of implementation: The capacity building was the most extensive component of the GCBP. The activities under this component are described in detail in a final report covering ISOR activities within the Nicaragua GCBP (Fridriksson, 2012b). Following is a short overview of each activity, how it progressed and key results.

Activities 1a and b, were the re-assessment with MEM-DDG of the reservoir at the Momotombo geothermal field and studies to find ways to increase energy production. This was fulfilled (Fridriksson et al., 2012; Egilsson et al., 2012 and Fridriksson, 2012b). The most important result was that the capacity of the present wellfield is around 30-35 MW_e (Egilsson et al., 2012) which is to be compared with the current production of 30 MW_e. The participation of MEM-DDG personnel in the review and interpretation of Momotombo Historical Data, was seen as one of the important outputs of the project.

Activities 2a to e, were the evaluation of geoscientific investigations to be carried out by GeoNica in El Hoyo-Monte Galán and Managua-Chiltepe. The aim was to train staff at MEM-DDG to cover the exploration and exploitation phases of geothermal fields, using the fields in El Hoyo-Monte Galán and Managua-Chiltepe as examples. This turned out to be unrealistic as the original development plan for these two geothermal fields changed, due to disappointing results during

the exploration stages. Instead ISOR gave feedback to MEM-DDG on the surface exploration work and the results of the exploration drillings in each field (Hersir and Ólafsson, 2009a; 2009b and Mortensen and Egilsson, 2012). No thermal anomaly was discovered at Managua-Chiltepe. At El Hoyo-Monte Galán, permeability was low but temperatures of around 200°C were proved. No decisions have been made so far to continue exploration drillings in new parts of the two fields in question (see Appendix V).

Activities 3a and b were to provide technical assistance to MEM-DDG in the development phases during expansion of the San Jacinto-Tizate geothermal area and give support for the evaluation of the management of the San Jacinto-Tizate reservoir. ISOR supported MEM-DDG in the evaluation of plans to monitor the reservoir, of drilling reports from Polaris (Thórhallsson and Mortensen, 2008), development plans in 2009 and development and monitoring plans in 2011 and 2012 (Steingrímsson and Fridriksson, 2012). Several reports were published during this process (see further Fridriksson, 2012b). A study was also carried out by ISOR on the technical feasibility of the power plant, now already in operation as there was some dispute over the type and size of the turbines to be purchased by Polaris (Ingimundarson and Thórhallsson, 2012). The purchase was approved by GoN, before this study was finished. As a part of this activity, a course on power plant design and efficiency was given by Jóhannesson (see Jóhannesson, 2011, see also Appendix V).

Activity 4 covered technical assistance in drawing up regulations and norms for the geothermal sector and tendering evaluation processes for new concessionaires. It was to include review of regulations from other countries and the drawing up of regulations relevant for the use of geothermal resources in Nicaragua and technical assistance in tendering processes. ISOR initiated a study in 2008 on regulations on the permit process for geothermal development by analyzing the regulatory framework of the geothermal sector in Iceland and comparing it with the regulatory framework in USA and New Zealand (Steinsdóttir and Ketilsson, 2008; Steinsdóttir et al. 2009). MEM did not complete their studies on the regulatory framework in Spanish speaking countries, as it was thought to be irrelevant. This task was taken further in 2011, jointly by MARENA and MEM, to lay out norms for the permit process for the geothermal sector with the assistance of Ana María González from El Salvador (see also Zeledón, 2011 and Hernandez, 2012). Feedback was given on drafts by ISOR and the National Planning Agency of Iceland (Ármannsson et al., 2011). The following guidelines have been drafted: general guide "Terms of Reference for the Preparation of Environmental Impact Assessments for Geothermal Projects, Exploration Phase (MARENA Environmental Quality Department, 2011). A second draft of the norms has been sent to key stakeholders for comments, to be discussed at a common meeting planned in February 2013. MARENA and MEM will finalize the norms considering the outcome of the February 2013 meeting, taking into account the feedback and the valuable inputs from concessionaires and other stakeholders. They will be adopted as a legal instrument, when they have been finalized. ISOR also assisted MEM-DDG in the tendering processes for Casita-San Cristobal field.

Activity 5 included general support in building up structure and knowhow at MEM-DIG.

Activity 5.1 was to provide short-term technical assistance to define the role and structure of MEM-DIG. Task 5.1a, the identification of activities to be carried out by MEM-DIG. This task was carried out without ISOR participation. Task 5.1b included study on market needs for

Map of Nicaragua showing geothermal areas visited by MEM Geothermal Group for reconnaissance purposes since 2010.

geochemical analysis covering also validation and accreditation for the GeLab. Studies on market needs were delayed from 2008 to 2011 due to various reasons (Fridriksson 2012b). The results of the marketing study indicated a need for the GeLab services (Sandino, 2011).

The GeLab is already in operation. At present the GeLab accreditation process is underway, by ONA (The National Accreditation Office). The laboratory has already been audited twice and it is planned to finish the process for the first set of elements during the first semester of 2013. See further assistance to the development of GeLab in various reports (e.g. Ármannsson, 2008; Ármannsson et al. 2009; Renderos, 2009, 2011; and completed Quality Control System Documents (Fridriksson, 2012b). See also further task 5.4a.

Task 5.1c, the definition of the relation between departments under MEM-DDG. This was not carried out formally under the GCDP but by staff at MEM-DDG. The GeLab was originally a part of MEM-DDG,but later located directly under the Dirección General de Recursos Energéticos Renovables. This important change was to ensure that there is not a conflict of interest between MEM-DDG and private organizations. It also emphasizes the wide range of geochemical services to be offered by the GeLab.

Activity 5.2a should provide short-term technical assistance to review the Nicaragua Geothermal Master Plan carried out by GeothermEx in 2001, where the generating capacity was estimated as 1,519 MW_e (GeothermEx, 2001). Task 5.2b was to specify areas in which pre-feasibility studies need to be completed. As no new data are available for the high-temperature geothermal fields, except for Casita - San Cristóbal and San Jacinto - Tizate, the generating capacity of these fields only was reassessed using the Monte Carlo method (Ruiz-Mendieta, 2009). The revised generating capacity at the 90% probability level is slightly lower for Casita - San Cristóbal (53-188 MW_e as compared to 225 MW_e) but for San Jacinto - Tizate the early estimate was within the range given by the reassessment (91-237 MW_e as compared to 167 MW_e).

Activity 5.3 was to provide MEM-DDG with short and long-term technical assistance, Task 5.3a to undertake pre-feasibility studies in high-enthalpy areas and Task 5.3b to undertake pre-feasibility studies in low-enthalpy areas. Support has been given to MEM-DIG in carrying out

geological and geochemical reconnaissance studies in high- and low-enthalpy areas. This has involved field training and cooperation and support in data interpretation and writing reports that staff at MEM-DIG has been responsible for. So far, geological field work has been completed for 8 areas and 4 reports. Geological maps have been completed for all 10 areas and geological reports for all of them are already in drafts. Results of geochemical field work in all 10 areas by GeLab are ready in the MEM Data Management System; geothermometry temperatures computed and plots prepared but not a single report has been completed by MEM-DIG. The following reports have been written that relate to this activity (Gíslason, 2009; Kristinsson and Ruiz, 2010a, 2010b, 2011a, 2011b,2012; Kristinsson 2011, 2012a, 2012b, 2012c; Ármannsson and Óskarsson, 2012; Óskarsson, 2012. Task 5.3c, which is to to offer geochemical services to the industry, is ongoing. A brochure has been made to market the GeLab services, and the necessary accreditation is under way (see also task 5.1b above).

Activity 5.4 covered the validation methods for geochemical analysis at the GeLab. Task 5.4a related to the standardization of methods, processes and equipment at the GeLab, as well as the training of the staff. This task has progressed mostly according to plans (see further task 5.1c).

In Activity 6.1a, the plan was to develop capacity to use heat pumps where MEM and UNAN-LEÓN would jointly develop agricultural use by this technology. The original plan was to use joint funding from GCBP and funds requested to the Regional Program Alliance in Energy and Environment for Central American countries, or Alianza en Energia y Ambiente para Centroamérica in Spanish. Since the joint funding did not come through the GCBP funding was thus moved to activity 7.

Activity 7 should provide assistance to MEM and UNAN-LEÓN in exploring possibilities for wider usage of geothermal energy in Nicaragua. Activity 7.1 and task 7.1b (there was no task labelled no. 7.1a) was to identify the industrial potential for low-enthalpy geothermal fields in 2010 and 2011. The activity did not evolve as planned in the GCBP for several reasons. One was the death of the leader of the group involved at UNAN-LEÓN, as well as limited capacity of that group to take on the planned activities. Instead personnel from UNAN-LEÓN participated in several training activities by the GCBP (Fridriksson, 2012b). GCBP supported two staff member at UNAN-LÉON to attend UNU-GTP in Iceland in 2006 and 2010 respectively (see appendix IV). The GCBP supported lecturers to teach half of a Geothermal Module in a M.Sc. program on Renewable Energies in collaboration with La Salle Technical University and the National University of El Salvador. Major support for this course was given by the Spanish Agency for International Development Cooperation (AECID). The program started in 2011 and was run again in 2012, in both cases with contribution from GCBP.

Activity 8.1 should provide short and long-term technical assistance to the General Directorate for Environmental Quality (DGCA) at MARENA and MEM-UGA in reviewing the scope of ToR for EIAs documents in geothermal projects. Task 8.1c (there were no items marked a and b) included support to lay out ToR for the EIA at San Jacinto - Tizate where the National Planning Agency of Iceland (AIOT) provided feedback. Task 8.1d included review and evaluation of the EIA's at San Jacinto – Tizate, El Hoyo – Monte Galán and Managua – Chiltepe, as well as the follow-up and environmental audit of documents to be submitted by GeoNica. This task was carried out without assistance from ICEIDA. Task 8.1e covered the follow-up and environmental

audit of document to be submitted by GeoNica. This task was also carried out without assistance from GCBP.

The aim of Activity 9.1 was to review the evaluation methodology for EIA in geothermal projects, task 9.1a being technical assistance in this field to MEM-UGA and MARENA-DGCA. It was decided in late 2010, after a slow start on activities 8 and 9, to concentrate on writing a general ToR for EIA for geothermal projects under the facilitation of a consultant from El Salvador. Experts from ISOR and the National Planning Agency of Iceland (AIOT) gave feedback on drafts. For further detail on progress, the reader is referred to Fridriksson (2012b). The final document on this task is “Guía de Procedimientos para desarrolladores Geotérmicos en Nicaragua” (MARENA Department of Environmental Quality, 2011).

Activity 10.1 focused on the identification of protected areas in need for management plans followed by assistance in making such plans. Several tasks were identified: task 10.1a included identification of protected areas with geothermal potential, task 10.1b was to establish feasibility for development of areas with geothermal potential, task 10.1c involved collection of information to prepare baselines for protected areas with geothermal potential, task 10.1d execution of a baseline follow-up program, task 10.1e development of capacity to protect natural assets in protected areas with geothermal potential and task 10.1f assistance to lay out management plans for the volcanic complexes of Momotombo - Momotombito, Managua - Chiltepe, Telica, Santa Clara and El Chonco. To make a long story short, the execution of these tasks turned out to be a bit sporadic and broad, rather than specific. The activity was thus redefined with respect to cooperation between MARENA and specialists from the Environment Agency of Iceland (former Environment and Food Agency in Iceland) following a workshop given in November 2009 (Jensson and Fridriksdóttir, 2009) where guidelines were provided for a methodology for assessing sites values. MARENA identified protected areas with geothermal potential and took the lead to study the conservation value for the 10 protected areas identified which resulted in the excellent overview the “Forest Fragmentation in Geothermal Areas” or “Estado de Fragmentación de Bosques en Areas Protegidas con Potencial Geotérmico". This thorough and extensive study was done in the following areas; Volcan Masaya, Volcan

Cosigüana, Managua - Chiltepe, San Cristóbal – Casita, Pilas – El Hoyo, Telica – Rota, Volcan Momotombo, Península de Chiltepe, Volcán Mombacho and Isla de Ometepe (Diaz et al., 2012).

A management plan was also made for the Volcano Masaya National Park that is partially based on the forest fragmentation study for the park. The management plan is very thorough, includes protection objectives, defines protection zones based on the conservation values of the area and detailed overview of flora and fauna, done with a participatory approach. The management plan also includes a management program for the park (Castañeda E., 2012).

Activity 11.1 covered meetings with MARENA-DGCA and MEM-UGA on environmental legislation related to the environmental impacts of geothermal development with the purpose of reviewing the environmental legislation in Nicaragua. Tasks identified were 11.1a meetings on environmental law, 11.1b local seminars and 11.1c study on environmental aspects in Central America. GCBP supported 4 workshops for this activity (Casanova, 2010). Participants were from public and private entities, including representatives from local environmental authorities and universities.

Activity 12.1, task 12.1a on the coordination between MARENA-DGCA and universities regarding EIAs, including MEM-UGA. The Coordination Committee (CC) decided to drop this task in 2010 due to lack of interest by the parties involved.

Activity 13.1 was defined as unforeseen consultancies. The unforeseen consultancies were defined in the budget to respond to any unplanned or urgent activity necessary for MEM or MARENA. One task under this activity was the development of Data Management System for MEM and training of staff members (Einarsson and Ketilsson, 2009; Einarsson, 2010; Ragnarsson, 2011 and 2012; Flores, 2012; Gunnarsdóttir, 2012a and Gunnarsdóttir et al., 2012). Another task added was the revision by ISOR for MEM-DDG on an exploration report for the Casita - San Cristóbal geothermal prospect (Hersir et al., 2009). The results were also presented in a seminar (see Fridriksson, 2012b).

Regarding other technical assistance, activity 14.1 which aimed at strengthening the National Clean Development Office (ONDL) at MARENA and MEM-UGA was omitted since other donors like United Nations Development Programme (UNDP) and the Alliance on Energy and the Environment (AEA) had several projects on this topic, so the execution would have duplicated other projects. The effort was thus changed into studies of forest fragmentation in protected areas that was considered more relevant to the project (see activity 10 above).

Activity 15.1, the drawing up of EIAs technical standards with MARENA-DGCA and MEM-UGA, tasks 15.1a the preparation of environmental mandatory technical regulations on geothermal projects, 15.1b seminars on technical regulations and 15.1 c publication on technical regulations, has been met by writing up technical norms for EIA (see activity 4, as those were combined).

Activity 16.1, task 16.1b (there is no activity labelled 16.1a) writing a manual and a poster for EIA. This task has been fulfilled as a guide has been published and a poster printed (see activity 9.1, Guía De Procedimientos para Desarrolladores Geotérmicos en Nicaragua).

5.1.2 Component 2 - Technical Capacity Building

BASELINE AND OBJECTIVE

Adequate technical capacity was lacking in 2007 among civil servants at MEM, MARENA and municipalities regarding the management, monitoring and development of geothermal energy resources. There was also lack of knowledge and understanding on the environmental impact of geothermal energy utilization and mitigation measures that could minimize this impact.

The objective of component 2; Technical Capacity Building in the GCBP was to build up capacity within the civil sector that is needed to oversee, monitor and follow up on geothermal projects. Improved understanding of the nature of Nicaragua's geothermal systems in relation to volcanism, tectonism, heat source and structure is also highly relevant. Further, mastering the scientific disciplines needed for all aspects of geothermal resource development and monitoring is very important. Improving of knowhow is not only achieved through training and learning at various levels but also by gaining experience.

The overall objective of component 2, expected results, baseline, verifiable indicators and means of verification along with internal and external risk factors is being described in the Logical Framework for the GCBP, in Annex I of the GCBP-FPD. Individual activities and tasks required to fulfill this objective, directly related to the means of verification for component 2 are detailed in Annex IV of the GCBP-FPD. It was found advantageous for the evaluation of tasks required by the EFET to use the activities and tasks in Annex IV of the GCBP-FPD, as verifiable indicators for means of verification for expected results. As such to give an overview of the status of implementation. This overview is shown below.

STATUS OF IMPLEMENTATION

Several training courses, seminars, workshops, field trips and other activities were organized during the duration of the project (see Fridriksson, 2012b for detailed overview). There were altogether 34 activities in this field, and 25 to 30 attendants for the seminars from MEM, MARENA, municipalities, UNAN-León and concessionaires from San Jacinto-Tizate, Momotombo

and Casita San – Cristobal. All the tasks detailed in Annex IV of the GCBP-FPD have been fulfilled except for the course on atmospheric contaminant dispersion modeling.

Training on promotion, publication and dissemination of information of geothermal projects under the Clean Development Mechanisms was reduced to one training course under ICEIDA, because this topic had already been covered in another project by consultants from Costa Rica. Instead of these, a project on the mapping of Forest Fragmentation in all protected areas with potential high-enthalpy geothermal fields was initiated as it was thought to be more relevant to the needs of the GoN (see activity 10 in Section 5.1.1). Finally, MEM and MARENA have not registered as members of the International Geothermal Association (IGA) and the International Association for Impact Assessment (IAIA). Several other courses were, however, held as determined by the Steering Committee (SC) of GCBP.

The Steering Committee met twice a year and at the latter meeting each year, a revised plan was approved of for the following year. As part of the revision by the Steering Committee (SC) of the initial plan, several courses were added. They included database training (see Gunnarsdóttir, 2012a, 2012b). Also, a short course on geophysics for non-geophysicists was held (Hersir and Gunnarsson, 2011). Finally, Sigurdur G. Kristinsson trained geologists at the Department of Geothermal Investigation (MEM-DIG) in fieldwork, twice in 2011 (Kristinsson, 2011) and also twice in 2012 (Kristinsson and Ruiz, 2012).

During the 2008-2012 period of the GCBP, a total of 8 experts attended the 6 months UNU-GTP course in Iceland (see Appendix IV). In addition, one student is presently carrying out M.Sc. studies at the University of Iceland. This student is supported financially by UNU-GTP. The initial idea was to support 2 master students by the GCBP, but MEM decided that it would be difficult to lose staff for such a long period of time, so the funding was used on other tasks. Mario González, director of Direction of Geothermal Development (MEM-DDG), visited Iceland in October 2010. The aim of the trip was to get an overview of geothermal development in Iceland and the environmental regulatory framework (Fridriksson et al., 2010).

Finally, MEM and MARENA have not registered as members of the international Geothermal Association (IGA) and the International Association for Impact Assessment (IAIA). This is due to procedural and technical difficulties, as GCBP was unable to pay a lump sum for the annual fee to these organizations. The payment must be carried out by individuals directly causing problem to pay by credit cards because they have to use a personal credit card or to look for another way to pay.

The tasks identified to fulfill the objective to build up infrastructure at MEM and MARENA needed for the development and use of geothermal resources are presented in Annex V, of the GCBP-FPD. Inspection by the EFET shows that all these tasks have been fulfilled.

5.1.3 COMPONENT 3 - GEOCHEMICAL AND GEOTHERMAL LABORATORY

BASELINE AND OBJECTIVE OF COMPONENT 3

In order to take on the commitment to carry out investigations and other activities related to the development of geothermal resources in Nicaragua, a need was clearly identified to build up infrastructure and adequate manpower for chemical analysis of natural waters at the MEM-DDG. The needs for this activity are detailed under component 3 of Annex V of the GCBP-FPD.

The objective of component 3; Infrastructure and Equipment was to build up a Geochemical and Geothermal Laboratory (GeLab) at MEM with infrastructure, equipment and manpower. The original expected outputs were to equip and strengthen the Department of Geothermal Investigations MEM-DIG, to fulfill demands for analysis of natural waters, including interpretation of the analytical data needed for surface exploration, well testing and monitoring studies in geothermal areas.

Initially, the GeLab part was part of the Department of Geothermal Investigations (MEM-DIG) under MEM-DDG. MEM decided in 2011 to operate the GeLab as a separate entity under the Dirección General de Recursos Energéticos Renovables (Direction of Renewable Energy Resources). By moving the GeLab from MEM-DDG, the laboratory became independent from MEM-DDG and thus being in a position to carry out analysis for companies and institutions in Nicaragua without any possible conflict of interest. For such chemical analytical services quality certificates are necessary, as for instance concession holders in Nicaragua working with investment banks must use the services of certificated laboratories.

The overall objective of component 3, expected results, baseline, verifiable indicators and means of verification along with internal and external risk factors is being described in the Logical Framework for the GCBP, in Annex I of the GCBP-FPD. Individual activities and tasks required to fulfill this objective, directly related to the means of verification for component 3 are detailed in Annex V of the GCBP-FPD. It was found advantageous for the evaluation of tasks required by the EFET to use the activities and tasks in Annex V of the GCBP-FPD to give an overview of the status of implementation. This overview is shown below.

STATUS OF IMPLEMENTATION

Activity 1.1, task 1.1a was to strengthen the laboratory infrastructure at MEM and condition the laboratory building. It was decided to not to support the renovation of the old geochemical laboratory of ENEL in Managua to avoid delays within the timeframe of the project, but to establish a new laboratory for MEM. The laboratory (GeLab) was built up in another building, which the GoN provided and renovated to meet the specific needs of the new laboratory. The renovation of the building for the new laboratory was completed in 2009. However, use of the new analytical facilities started in May 2008 before all the equipment had arrived and the building completed.

Activity 2.1 Laboratory and training: The new GeLab is already in full operation in the facilities of MEM-DDG. At present, the number of staff is six (Table 5.1). Two of the six staff members have attended the United Nations University Geothermal Training Programme (UNU-GTP) in Iceland.

Table 5.1 Employees working in the GeLab at MEM.

NAME	POSITION	STARTED WORK	BACKGROUND
José Francisco Ruiz Cordero	Analyst	02.01.2007	Chemical engineer
Ernesto Ramón Martinez Loáisiga	Head, GeLab	08.05.2008	Biologist
Azucena del Carmen Espinales Martinez	Analyst	05.08.2008	Chemical engineer
Claudia Reyes Linares	Analyst	01.10.2008	Chemical engineer
Isaura Porra Cruz	Analyst	01.09.2009	Chemist
Marcos Delgado Siria	Analyst	05.07.2010	Chemist

INSTRUMENTATION

GeLab is presently equipped with the following major analytical instruments, according to activities defined in the GCBP-FPD:

1. Task 2.1a: Atomic absorption spectrophotometer with both flame and graphite furnace for sample excitation and an auto-sampler. As much as three elements can be determined simultaneously. This instrument allows analysis of sodium, potassium, calcium and magnesium, together with as many as 12 trace elements when using the graphite furnace.
2. Task 2.1b: An UV-VIS spectrophotometer that is suitable for analysis of silica and boron and many more elements present in trace amounts in natural waters.
3. Task 2.1c: A gas chromatograph with three separation columns and three detectors that allow simultaneous analysis of the following gases: Carbon dioxide, hydrogen sulfide, hydrogen, methane, nitrogen, oxygen, argon and carbon monoxide. This satisfies the needs of all geothermal exploration and monitoring studies.
4. Task 2.1d: An ion chromatograph equipped with an anion separation column. Sulfate, chloride and fluoride can be determined with high precision by this instrument, together with nitrate and some more anions, if present in sufficiently high concentrations in the samples.

In addition to these instruments, the laboratory is equipped with an automatic titrator, pH-meter, two ovens for drying of glassware, etc. and finally various apparatus needed in any laboratory engaged in analysis of aqueous fluids as well as ion exchange columns for production of high-quality de-ionized water needed for the chemical analysis. There is also a storage room for chemicals. Used hazardous chemicals are collected into special containers for appropriate disposal (tasks 2.1f-l).

In the GCBP-FPD it was planned to purchase a fluorometer (task 2.1d) for possible tracer tests, which is useful for determination of aluminium, boron and some other elements at low

concentrations. This was however, not done as it was considered that GeLab can operate satisfactorily without this instrument. Aluminium can be analyzed at low concentration level by the Atomic Absorption Spectrometer using the graphite furnace, and boron spectrophotometrically.

Activity 3.1 Equipment and furniture, tasks 3.1a-f, were to endow MEM with the following equipment; 1 vehicle, 6 computers and their accessories, office furniture for 6 staff members, projector, scanner and a digital camera. This has all been fulfilled, and another vehicle added to the group as well as GPS equipment.

It is expected and indeed the intention of MEM to expand the role of GeLab by offering analysis on a commercial basis. Sandino (2011) has written a detailed and a clear and well organized report that deals with the business plan for GeLab. The fact is that the GeLab has already started carrying out chemical analyses on a commercial basis. Concession holders of the two geothermal fields under exploitation at present are, however, not prepared to send fluid samples to the GeLab for analysis until the laboratory has achieved a quality certificate, by the Oficina Nacional de Acreditación.

Over the last year, GeLab carried out analysis of 200-300 samples, both for geothermal investigations and water quality assessment. Last year income from sold analytical chemical services amounted to 15,700 USD. The services provided by GeLab to MEM for their geothermal projects was evaluated by the Head of GeLab to amount to 69,000 USD over the last year. This evaluation was based on costs involved if an external laboratory had been contracted to carry out the analytical work in question.

GeLab is seeking a quality certificate (ISO standard 17025). It will work on the certification of its key analyses in steps. Its staff has devoted considerable time to prepare for this. The first step to get a quality certificate was taken in November of 2012. Having a quality certificate opens up the possibility to offer chemical analysis services on a commercial basis. MEM plans to do so in order to increase the income of GeLab. One other geochemical laboratory in Central America, LaGeo in El Salvador, offers service on a commercial basis for gas analysis. It is though difficult to export gas samples as some components can react upon sample storage, changing the initial sample composition. They can neither be opened in customs, as the sample composition will change upon opening. Both ICE in Costa Rica and LaGeo in El Salvador operate commercial geochemical laboratories for analysis of geothermal waters and they are in possession of quality certificates.

The tasks identified in the GCBP-FPD (Annex 5) to fulfill the objective of building up well equipped chemical laboratory for analyses of geothermal gases and natural waters have been fulfilled according to the inspection of the EFET. The GeLab is already functioning for analysis all major gases in geothermal steam samples and all major components in waters and some trace elements as well. On the other hand, there seems to be little capacity to interpret analysis of geothermal fluids. There is no geochemist among the staff of the GeLab. An individual is needed with background in geology and geochemistry for data interpretation work, on top of which is required specialization in geothermal fluid chemistry.

5.1.4 Administration and evaluation

The main activities for the "Administration and Evaluation" activities were laid out in Annex VI of the GCBP-FPD. Activities related to this issue were also described in chapters V to XI in the GCBP-FPD. See chapter 3.3 for GCBP Organization and Management.

STATUS OF IMPLEMENTATION

Activity 1, An Annual Plan of Operation (APO) should be prepared each year, with deadlines and persons and institutions responsible for carrying out the work proposed for each activity and tasks to be carried out. A review of the progress of the plan should be carried out every 6 months. Annual Progress Reports have been prepared for all years, with other quaternary and / or semester reports. See further Chapter 9. References and Reports.

Activity 2, external evaluation, task 1 involved an overall mid-term evaluation schedule for the second quarter of 2009. This external mid-term evaluation assessed the progress achieved and identified difficulties during the implementation of the GCBP with the purpose of updating the project plan (Rodriguez, 2009). Following the mid-term evaluation, the SC decided to modify the GCBP to improve implementation efficiency and overall project effectiveness and added a representative from MARENA in the SC and the CC. The main problems were related to the work of MARENA-DGCA on EIA, in part because of language barriers and prioritization of MARENA. Ana Maria González environmental consultant from El Salvador was hired by ISOR with the acceptance of GCBP SC to serve as a coordinator for MARENA activities on behalf of ISOR and prioritization was given by MARENA to the GCBP. Task 2, a final external evaluation to be carried out at the end of the project, is the current GCBP External Final Evaluation.

5.2 PARTNER AND STAKEHOLDERS EVALUATION ON PROJECT PERFORMANCE

Following is a summary of the evaluation of Partners, key stakeholders and consultants on the GCDP performance, based on the evaluation issues and **questions** listed in Chapter 4.1. Included are also recommendations from the interviewees.

1. To what extent has the GCBP assisted the GoN in enhancing the utilization of geothermal resources in Nicaragua?

   It was the general view of the interviewees that the GCBP had been very important and has made a big difference for building up and enhancing capacity for geothermal development within the ministries, municipalities and universities involved, thus strengthening institutional capacity to manage the geothermal resources. The interviewees were very satisfied with the project overall and felt that the GCBP had been of good quality, real knowledge had been built up, thus enhancing the country's possibilities for the utilization of geothermal resources.

2. To what extent has the GCBP enhanced the institutional, scientific and technical capacity at the national Government level to manage, develop and use geothermal resources in a sustainable manner?

   Most staff within the GoN had very limited knowledge and experience of geothermal resources, their development and the environmental impact of their use, when the

GCBP started. As a consequence, there was lack of knowledge to give consents and execute EIA of geothermal areas. Representatives from MEM, MARENA and MINREX all emphasized the importance of the GCBP in improving governmental capacity to assess the data from the concessionaires and to participate in the development of new geothermal areas for power production. The objective of the GCBP was extensive and called for major changes at the ministries, almost from scratch. The basic capacity is now already in place, with firm intention to build on it in the future. It was also felt that the project had led to improved working methods within and between the divisions involved at MEM and MARENA resulting in more cooperation between the ministries. Work with the UNAN-León during the GCBP has also provided a good knowledge base which will be built on in the nearest future.

Other relevant questions are:

3. Is there currently existing general knowhow within Nicaragua to make the country fully qualified to undertake relevant scientific investigations for the development of geothermal resources?

   Although much advance in capacity has been gained during the GCBP, the opinion was frequently expressed that more experience was needed, especially with respect to data interpretation. This would involve continued support by ICEIDA, yet on a reduced scale.

4. How does GoN foresee continuation of work started through the GCBP?

   It is apparent from interviewees that there is full intention by GoN to continue work on geothermal development in Nicaragua by building on the experience gained so far through the GCBP. They feel ready to enter into the next step of developing knowledge within the governmental bodies. Interviewees pointed out that it is always an important step in building up knowledge to step into a phase of less reliance on support. Some questioned the timing and concerns were raised regarding capacity now existing within the GoN to keep on building up new knowledge when ICEIDA has left. Prioritization might also automatically change towards routine tasks.

5. Has there been an improvement likely to last regarding knowhow - sustainability of training?

   Although the knowledge of the staff at MEM and MARENA has strengthened substantially during the GCBP, it was frequently mentioned that there is still a lack of practical experience within the group and more knowledge is still needed in some areas. Improved understanding of the geothermal industry and stepwise development of geothermal areas during exploration and exploitation, as well as the environmental impact of geothermal development were issues mentioned in this context. It was mentioned that it would be of great help to get some kind of coaching or mentoring in the coming years with respect to key tasks related to geothermal development within the governmental bodies in order to sustain and build on present knowledge.

6. Is there a mutual understanding of the impact of the GCBP?

   There was a general mutual understanding that the impact of the GCBP was very favorable.

7. Has training and education, including courses and material issued covered all relevant topics?

In general, participants were very satisfied with the courses given and other training. Specifically, however, inadequate understanding of English by the participants had some negative impact. Also, interpreters apparently lacked to some extent the technical vocabulary in the geothermal and environmental fields. For EIA, some participants considered that the course material was too much of general nature, rather than specifically catered towards geothermal energy, but the plan for the relevant courses assumed that these courses would start with general methodology for EIA, followed by material specific to geothermal energy.

8. What was the quality of technical assistance, the expert approach and recommendations regarding the development of geothermal resources?

It was generally noted that the quality of assistance and recommendations had been very good from all parties involved. The knowledge of the Icelandic experts on geothermal development was envisaged as being very good and with good insight that turned out to be very useful for governmental staff, municipalities and universities involved as well as the concessionaires. Specialists from El Salvador were also mentioned as being of great support who made it achievable to finish certain tasks which otherwise would not have been doable due to lack of resources.

9. What are the comments on infrastructure, facilities and instrumentation, equipment and materials provided for?

These tasks include the building up of the laboratory (GeLab) at MEM and provision of analytical and petrological equipment, as well as office facilities, including computers and software for GIS and data management for MEM-DIG. The laboratory is already in operation (see section 5). It was pointed out that it takes more than 2-4 years to build up a group of experienced staff. The basic infrastructure and manpower is there, but there is need for continued technical support and in particular knowledge in interpretation of chemical data. As the laboratory was built up from scratch, the staff at GeLab had the best opportunity in making use of the facilities and to learn to use all the instruments and to collect and analyze samples of geothermal fluids, but they received limited training in data interpretation. MEM-DIG also got basic training in GIS and in setting up a data bank to store geothermal data (12 high enthalpy areas and 11 low enthalpy areas).

There were some discussions amongst interviewees regarding the GeLab, its financial status and independence. Some questioned the actual need of the GeLab and pointed out that there are already a few laboratories within Nicaragua, which could take on most of the analysis of the GeLab. It was mentioned that it might have been a mistake to start building up the laboratory before carrying out a market study. The sustainability of the laboratory was also questioned. It might be difficult for the government to sustain the laboratory with all the cost included. Some emphasized that the key to a lasting success of the laboratory would be the accreditation and good marketing to make sure that the laboratory would have enough work for running as there is competition on the market.

There was also a discussion regarding the position of the laboratory within the organizational chart of MEM, the move of the GeLab to assure its independence and thus to increase the likelihood of selling analysis on a commercial basis. On the other hand, it was felt that by separating the laboratory from the rest of the geothermal group, the connection between the geothermal team would be loosened, which counteracts the original aim of building the laboratory, mainly investigations of low- and high-enthalpy geothermal areas and monitoring studies for concessionaires.

10. Institutional support, roles of individual units and job descriptions.

The EFET got very limited feedback on this issue during interviews.

11. How well were the roles of institutions and ministries fulfilled regarding responsibilities and capacity, the decision making process while developing geothermal resources sustainably?

On the permit process including the EIA process, there were conflicting views. Some considered that the process was clear and the time frames acceptable, similar to what is seen in other countries. Others found the time frame to be unclear and delays regarding feedback from the government to concessionaires very difficult, with very limited time for carrying out studies during the concession period. It was suggested that a fixed time limit should be set.

EIA studies were found to be much too detailed. Interviewees pointed also out that thorough knowledge and understanding by governmental officials of geothermal fields, their response to production load and uncertainties regarding their estimated potential is essential for a successful and sustainable development. An important issue in this respect would be very good and trustworthy collaboration and discussion about the development of a reservoir between concessionaires and governmental officials, which is not currently in place. It was pointed out that more flexibility within concession permits could be positive for effective development of geothermal areas.

Significant improvement has been seen regarding improved knowledge and understanding of geothermal development by governmental officials since the cooperation between GoN and ICEIDA started. Open meetings and dialogues between concessionaires and the government bodies for the past years are also seen as a big improvement and it was considered very important to have a platform for discussions that have been offered. It was found highly favorable by concessionaires to be able to participate in courses offered by the government through the GCBP. Good collaboration with the ISOR specialists was also mentioned by concessionaires. It was felt that the 5 year capacity building period is not sufficiently long to build up sustainable experience for government officials, when considering the diversity of geothermal systems worldwide and presumably also in Nicaragua. A longer time is needed, possibly 10 years would be more realistic in building up lasting experience.

Roles of the governmental bodies were discussed and it was pointed out that there could be a conflict of interest within the these bodies, as the same body, i.e. MEM-DDG hands out concessions to concession holders and monitors compliance of these concession holders, i.e. that is a dual role. It was pointed out that improved cooperation,

coordination and sharing of knowledge within and between MARENA, MEM and other ministries in the geothermal field would be very helpful for successful development in this field. Regular forums would be of great assistance.

It was also considered beneficial for the governmental organizations, developers and scientists at the universities to work together to share mutual knowledge. Regular forum where certain issues are being discussed would be of great assistance as well as continued courses on various geothermal issues.

12. What is the opinion on how the GCBP has been defined, including its management and efficiency?

It was noted that the project had been clear and well-designed initially in the GCBP-FPD, with well-defined milestones. Lack of mutual vision between MEM-DDG, MEM-UGA and MARENA during the definition of the GCBP was mentioned as a downside, which resulted in a slow start on behalf of MARENA. This was partially due to lack of departmental cooperation during the original definition of the GCBP, lack of understanding due to linguistic barriers and less knowledge of geothermal issues at MARENA than at MEM and also to changes in the technical personnel at MARENA after the Geothermal Capacity Building Project - Final Proyect Document had been prepared and the Project was already underway. MARENA came into the GCBP with full force, when a mutual agreement between MARENA, MEM and ICEIDA about objectives of the work was established.

It was also mentioned that the original log matrix had been too detailed for a five year project and it was suggested that it should have been more general at the start. This snag was counteracted by the Steering Committee by adapting tasks to needed improvements. This flexibility to change was in fact seen as playing an important role in the success of the GCBP.

It was pointed out that the overall project management could have been more efficient, with more involvement of key personnel in charge at MEM and MARENA and better communication within the group on regular basis. The short notice and unclear aim of the meeting with the EFET was taken as an example.

The closing down of the ICEIDA Country Office in Nicaragua in 2009 was mentioned as a downside for the project management, as it lessened the direct involvement of the head of ICEIDA and thus the visible interest of ICEIDA in the GCBP.

The definition of what should be achieved with a particular task could also have been better in some cases to make sure that tasks would match needs. The definition of the EIA course was mentioned as an example, as it would have been more efficient to adjust the training from start towards training in the EIA of geothermal areas, as there was substantial knowledge on EIA in general. It was also pointed out that the EIA course was being held during a period in the GCBP where MEM and MARENA were organizing their cooperation.

Language barrier was also mentioned as an impeding factor in some cases, as some staff at MEM and MARENA lacked knowledge in English. The same applies to some interpreters involved in the project, as some lacked background in the technical

vocabulary on geothermal energy, which led to some confusion especially during seminars and workshops on environmental issues. This was compensated for by hiring Spanish speaking experts for certain tasks. How this was solved was taken as an example of good collaboration between ICEIDA and GoN. Staff at MEM and MARENA has also attended English classes and they have shown good progress and pointed out the importance of knowing English to be able to read literature on geothermal resources and communicate with outside colleagues.

Some interviewees pointed out that the GCBP had added new tasks to an already busy schedule. This was solved in part by hiring consultants for specific tasks. Interviewees within the governmental sector expressed the opinion that the past years had been challenging while getting into new fields and learning a second language at the same time. They were pleased with the challenge and the new knowledge they had gained so far in the GCBP and they were eager to continue along that path.

13. Lesson learned - the way ahead.

At the end of the GCBP there is some uncertainty regarding further capacity build up. In general there is a consensus that Nicaragua has acquired good basic knowledge, but 3-5 years time frame to build up real capacity with experience was felt as a bit too short, 8-10 years being a more realistic time frame for gaining sustainable knowledge on geothermal development. There was concern that the group within the GoN would not be in position to stay on the learning curve when the support is gone, due to high workload. Some follow up is considered to be needed in the nearest future.

It was pointed out that it is a challenge to build up and preserve know-how in the geothermal field because the knowledge is so specialized. It would be vital in this sense for governmental organizations, concessionaires and scientists at universities to work together to learn from each other and share mutual knowledge and experience. More cooperation and knowledge sharing within and between ministries would be very important as well.

The supply of electricity is still a problem in Nicaragua and geothermal energy is an important element in increasing electricity production. Challenging tasks lie ahead in policy-making regarding future development of geothermal energy in Nicaragua. It was felt that a long term vision is needed and vital for the GoN to understand that there is uncertainty regarding the renewability of geothermal systems. A conservative, yet save approach, is to look at individual geothermal systems as mines of heat. Sustainable extraction under the supervision of governmental officials is thus vital for the nation. Good overview of the geothermal resources of Nicaragua would be essential in this sense as well as specialists with solid knowledge on geothermal resources and their nature within GoN.

Continued collaboration and support from ICEIDA was mentioned by many interviewees, as an important element to ensure lasting change in building up knowledge in geothermal development. It was felt that it would be important to continue the work with the same group, which knows the situation in Nicaragua and has the needed know how and experience.

The wish to continue collaboration between GoN and ICEIDA was explicitly described, where the importance of being able to send more governmental employees to UNU-GTP was thought to be vital, as well as some continued mentoring support. It would also be of great value to get assistance to continue the important surface exploration studies in the high-enthalpy areas before entering the bidding process ahead.

14. How was the cooperation between GoN and ICEIDA?

Interviewees, including representatives from GoN, ICEIDA and concession holders, expressed the opinion that the cooperation throughout the project had been excellent

15. Notes on specific projects by interviewees.

The Study of Forest Fragmentation: It was pointed out that one of the major achievements of the GCBP, is the study on Forest Fragmentation in 10 protected areas with high-enthalpy geothermal fields in Nicaragua, initiated and supported by GCBP, that it is an impressive piece of work by the GoN, which interviewees felt that can be used to improve understanding and cooperation during geothermal development in these areas and serve as a base for EIA. The Management Plan for the Masaya Volcano National Park, is also an excellent example of good use of the Forest Fragmentation Study.

The Geothermal Master Plan from 2001: It was pointed out that a very important task that lies ahead is the update of the Geothermal Master Plan from 2001. It was felt that the present Geothermal Master Plan might be too optimistic. Experience from some of the geothermal areas suggests that the estimates for the geothermal capacity in the Master Plan may be too high for drilled fields. The suggestion was made that the government should carry out more extensive surface exploration than hitherto with combined geophysical, geological and geochemical studies before entering the tendering process to increase the probability of success.

The study of low-enthalpy areas: The importance of continuing surface exploration in these areas was emphasized to improve oversight of the possible importance of this resource by the GoN. UNAN-León has shown great interest in taking this development further and has already started some studies with agricultural uses in mind. The government has also been in touch with the Japan International Cooperation Agency (JICA) for support to study direct use of geothermal heat for agricultural purposes.

The normatives: The normatives are seen to be very important guideline for sustainable development of geothermal fields by Partners and stakeholders alike. There was though some concern regarding the evaluation of the norms by interviewees, as they thought it to be too specific at this point in time to be realistic, with too many issues and lacking necessary flexibility. It was emphasized that a mutual consensus should be reached by the parties involved.

5.3 RELEVANCE, EFFICIENCY, IMPACT, EFFECTIVENESS AND SUSTAINABILITY OF RESULTS

5.3.1 Relevance

The social benefits of developing Nicaragua's energy resources, including geothermal, are general rather than specific. Having access to electricity which is an important basic need in modern society has many advantages. It will increase the standard of living, contribute to social stability through decrease in poverty and lead to reduction in social tension by inefficient power service. It will also stimulate all kinds of businesses and small industries and increase security for the citizens. Last but not least, electrification of rural areas may turn out to have revolutionary effect on the standard of living, through use of machinery and preservation of crops. This could be further stimulated by the use of low-enthalpy geothermal resources, at least in some areas.

The objectives of the Geothermal Capacity Development Project (GCBP) are seen as highly relevant to the GoN, as the Project´s output will has already proved to be useful in assisting Nicaragua in developing its geothermal energy resources for the production of electric power which is in line with the Energy Policy of the GoN as reflected in its Energy Master Plan. Some two thirds of Nicaragua's export income is spent on importing fossil fuel. Even modest decrease in this import by developing geothermal resources will have a big positive impact on the economy. The objectives of the GCBP are still valid as the objectives are still important and there is still need to continue the support to strengthen capacity in geothermal development, yet on a reduced scale. The activities and outputs of the project are consistent with the overall goal and the attainment of its objectives, as well as its impacts and effects.

The focus on the GCBP has been concise throughout the whole Project period and resulted in the building up of capacity to monitor, oversee and follow-up geothermal energy projects. There has also been a large increase in installed capacity of geothermal power plants.

5.3.2 Efficiency

It is difficult to comment quantitatively on the cost effectiveness of the GCBP because there is no direct comparison with similar projects on behalf of ICEIDA. The EFET will study further the distribution of funds allocated to the project. However, the overall cost budget has been adhered to. It is clear that all main objectives have been achieved as initially set out in the GCBP-PID and GCBP-FPD reports. A few tasks were, however, omitted, as decided by the Steering Committee, but others considered to be more important or relevant were added, that did fall under the initial objective of the GCBP. It is the vision of the ETET that the different component tasks have in general been efficiently implemented due to generally very good cooperation between the parties involved.

Regarding human resources it is noted that the Nicaraguan team involved with the GCBP was well qualified and enthusiastic in acquiring new knowledge and showed initiative that resulted in some exceptional studies like the forest fragmentation studies. The same can be said by the team of experts as they had very good knowledge in their field of expertise and were eager to achieve lasting change. The GCBP started at a slower pace than originally anticipated, due to lack of mutual vision between ministries MEM and MARENA on the importance of the GCBP, but this was amended at a later stage. This initial delay has probably had an overall delaying effect on the whole project.

Regarding coherence there was no similar project going on in Nicaragua at the time of the GCBP and little other activity on behalf of ICEIDA. There were crossings between planned activities in the field of strengthening the National Clean Development Office, so they were omitted and funds used for other activities relevant to the objectives of the GCBP.

5.3.3 Impact

The changes produced by the Project are without exception positive as far as the EFET can see. During the GC BP period, effective installed geothermal electric capacity has increased from 32 to 102 MW_e. Building up of infrastructure within the public sector, which was one of the main objectives of the GCBP, has been substantial and quite satisfactorily fulfilled goals. A competent geothermal unit has been set up at MEM with total staff members of 13. Capacity has been built-up within MEM and MARENA for monitoring, oversight and follow-up to geothermal resources projects. Some capacity has also been built up at UNAN-León. However, it is considered that the 5 year period of the GCBP is not long enough for this capacity to be sustainable. The Project has already had a significant impact on the electric energy sector in Nicaragua which is expected to lead to that more people will get access to electricity. This is indeed the main goal of the GoN when it comes to their Master Energy Plan.

5.3.4 Effectiveness

Almost all the main objectives of the project have been well achieved as discussed in Chapter 5.1. The only concern of the EFET is that the knowhow already built up may not be sustainable, unless further support is provided by an external body although it need not be on the same scale as the GCBP. The main reason for the good success was good preparation work which is reflected in the GCBP-PID and the GCBP-FPD reports. External assistance from Iceland, El Salvador and other countries was of high quality and all parties showed willingness to cooperate and serve the Project's objectives. This input contributed much to the success of the Project.

5.3.5 Sustainability of Results

The GCBP was initially planned for 5 years with the possibility to extend ICEIDA's support. For political reasons, due to economic crisis in Iceland, it was decided to terminate the project at the end of 2012. From the point of view of the needs to build up sustainable knowhow in Nicaragua in the spirit of the GCBP, it is considered desirable to continue external assistance, yet on a reduced scale. This view was expressed by many of the interviewees and is supported by the EFET.

5.3.6 Cross-Cutting Issues

There were two cross-cutting priorities in the Project, gender and environment. This subsection examines how the GCBP has integrated these cross-cutting themes of ICEIDA into the Project. It is difficult to track how these issues were integrated into the Project with respect to gender equality although the results are clear.

Environmental impact - The GCBP is seen as having had a positive environmental impact both locally in Nicaragua and on a global scale. The project assisted the GoN in understanding how geothermal fields can be developed leading to an increase in the use of geothermal energy for power production and at same time save on fossil fuel combustion. In this way Nicaragua will

contribute to reducing the effects of such combustion on global climate change. The increased knowledge and understanding of nature of geothermal systems and their response to exploitation is also likely to assist the GoN in managing their geothermal resources in a more sustainable and environmentally friendly fashion. The GCBP has also established a base to promote a more sustainable management of natural resources in protected areas by mapping baseline and assessing their value, if they will not be developed for geothermal energy production.

Impact on Gender Equality - It was part of ICEIDA's policy for the GCBP to favor gender equality amongst outside experts participating in the Project with the emphasis to bring in as high number of female experts as possible. Information is not available on the percentage of females that participated in the GCBP as a whole. Overall it is estimated that over one hundred Nicaraguan individuals participated in training activities during the GCBP. Participants came from MEM, MARENA, concessionaires, municipalities and universities. The build up of knowhow on geothermal development at MEM-DDG, including MEM-DIG and MEM-GeLab has been an important pillar in strengthening the institutional capacity in Nicaragua. Of a total of 11 expert-staff members that received training during the GCBP, 5 were women. The ICEIDA project coordinator was also a woman. Of all interviewees of the External Final Evaluation team in Nicaragua, related to this project there were total 19 individuals, thereof were 13 women, thereof 12 in key management or expert positions.

5.4 EVALUATION OF THE COMMITMENT OF THE GOVERNMENT OF NICARAGUA

As a result of the findings above, it is concluded that MEM and MARENA on behalf of the Government of Nicaragua have participated effectively in the technical assistance activities outlined in the GCBP-FPD, taking into account the necessary flexibility in adjusting activities according to project needs. MEM has established a geothermal investigation unit (MEM-DIG) and installed a geochemical laboratory (MEM-GeLab) and provided housing for both. The EFET does not have information that explicitly states that GoN has made commitments needed to secure operation of the GIU in the long term. To the understanding of the EFET a formal cooperation between MEM and MARENA for environmental studies relevant for geothermal development has been established. The level of participation is detailed in sections 5.2 and 5.3. The EFET has not yet got confirmation from GoN on its actual finance contribution.

5.5 EVALUATION OF THE COMMITMENT OF THE GOVERNMENT OF ICELAND

As a result of the findings above, it is concluded that the Government of Iceland through ICEIDA has fulfilled its commitments regarding the GCBP. Funds have been provided for technical assistance to Nicaraguan Institutions and technical training to Nicaraguan professionals as well as necessary equipment for the GeLab..

06

MAIN CONCLUSIONS

This Chapter of conclusions focuses on overall performance of the GCBP according to the GCBP-FPD especially those topics of the GCBP that are considered to be important for continued development of geothermal resources in Nicaragua and continued building up of capacity within governmental institutions to monitor, oversee and follow-up on geothermal energy projects.

SUCCESS

- The External Final Evaluation Team (EFET) considers that the 5 year Geothermal Capacity Building Project (GCBP) has been overall very successful with respect to all components. The reason is good planning in the beginning on behalf of ICEIDA and GoN, good skills of those providing external support and willingness and devotion within Nicaragua to make the GCBP successful.
- Almost all the tasks delineated in the GCBP Final Project Document have been satisfactorily completed. A few were though omitted and replaced by new ones that were considered to be more relevant. Key tasks that still remain to be completed are the normatives which are seen to be very important guidelines for sustainable development of geothermal fields and the accreditation of the GeLab. It is very important for the success of the GCBP that these tasks are completed as soon as possible.

SUSTAINABILITY AND SKILLS

- The five year GCBP plan is not considered sufficiently long to guarantee maintenance and further building up of knowhow on the nature of Nicaragua´s geothermal resources that would be sustained in the long term, including assessment of the environmental impact of geothermal exploitation.
- The present state of knowledge is such that both MARENA and MEM are not yet in a position to overtake all the tasks necessary to promote geothermal utilization in a sustainable manner as geothermal fields have such varied characteristics. Nicaragua, therefore, still needs external support.

FURTHER TRAINING

- The training courses, seminars and workshops that have been held are considered very important as well as the forest fragmentation study and its combination with the making of a management plan for the Masaya National Park.
- However it is noted that it would have been very useful to provide more training on monitoring of well performance in production fields as well as interpretation of geophysical and geochemical data.
- More training on resource size methodology estimates and generating capacity are also very important (see Appendix III for the USGS methodology on subsurface resources).
- Training on the use of physical land-use planning in relationship to the planning of developing geothermal fields, expanding further on the current studies of forest fragmentation.

PROJECT MANAGEMENT

- It would have strengthened the implementation of the project to have a designated project manager with clear mandate to oversee implementation and success for all partners involved.
- It would also have been beneficial that leading individuals had specified roles and duties.
- Systematic and efficient reporting and standardized filing of data would have been of great assistance in gaining overview of the GCBP for all parties involved.
- One of the main difficulties encountered during the evaluation process was to gain an overview on the project, its history, success and reporting because filing of information was not consistent.
- Open and effective sharing of information on project progress and more cooperation within and between ministries and other institutions could have been better.

ENERGY MASTER PLAN

- The estimated size of the high-enthalpy geothermal systems (1,519 MW_e) carries much uncertainty because it is based on limited data.
- There is always uncertainty regarding the success of individual geothermal projects in new areas. It is of major importance that this clearly appreciated at MEM and MARENA.
- It was felt that a long term vision is needed and vital for the GoN to understand that geothermal systems should be regarded as mines of heat as their renewability is highly uncertain (Williams, 2008).

BUDGET

The expenditure of ICEIDA is well within the budget plan (around 10%). In terms of cost / benefit, the overall support provided by ICEIDA is comparable to the cost of drilling one 2000-2500 m deep well into a high-enthalpy geothermal field. This comparison indicates that the money spent on the GCBP is well worth its effort.

MEM-GELAB AND MEM-DIG

- The GeLab is already in operation with all the equipment and staff required. However, the GeLab needs to receive a quality certification for it to be commercially viable.
- MEM has to decide whether staff at GeLab or staff at MEM-DIG should take on the responsibility to interpret geochemical geothermal data. Also, the amount of work involved in data interpretation needs to be carefully evaluated.

As far as the EFET knows, MEM has not yet employed experts for interpretation of geothermal fluid data (geochemist) and results of geophysical surveys (geophysicist). A specialist is also needed with background in geology and geochemistry for data interpretation work, on top of that required for specialization in geothermal fluid chemistry.

07

MAIN RECOMMENDATIONS

SUSTAINABILITY AND SKILLS

- It is recommended that GoN seeks further external assistance to build up the needed capacity to develop their geothermal resources.
- It is also recommended that continued support, if realized, should be on a reduced scale and scaled down gradually.
- The EFET further recommends that continued support should involve some coaching and mentoring over a few years' time aiming at building up lasting capacity at MEM and MARENA that would allow these ministries to become self-sufficient to oversee and monitor development and use of geothermal resources in sustainable manner.
- It is recommended to define the scope of this support through a new GCBP plan.
- It is considered advisable to build up a forum for governmental organizations, developers and scientists at universities to work together to share, maintain and build up mutual knowledge on geothermal resources.
- To promote sustainability, the EFET considers that it is important to keep in mind the value of having staff and experts working on geothermal within the ministries for a relatively long time and that there is some overlap when experienced staff retires and new staff members are employed.
- The EFET wishes to point out, when institutions like MEM and MARENA take on duties in a new field, that it is important to give experts some unrestricted time and money to read literature, improve their English, attend international conferences to order to learn and build up skills and experience.

PROJECT MANAGEMENT

- It is recommended that ICEIDA have a designated project manager for all projects, with clear mandate to oversee implementation and success.
- It is further recommended that ICEIDA develops concise project design and methodology for all reporting.
- It is also recommended that a summary of glossary terms, including specific technical terms and systematic abbreviations be one of the first key tasks during the startup of a project.
- In projects like GCBP, the EFET recommends that active use be made of web-sites to distribute and make available all project information.
- Lastly, it is recommended that workload for every participating individual be quantitatively assessed to guaranty that she/he can cope effectively with working duties.

ENERGY MASTER PLAN AND OVERVIEW OF POWER PRODUCTION

- The Government of Nicaragua is encouraged to collect all existing surface exploration data on known geothermal fields within Nicaragua, both high and low-enthalpy, with the purpose of re-interpreting the data and envisaging whether additional data should be collected to prioritize areas for exploration drillings and aid skillful siting of exploration wells within these areas.
- It is considered important to link the development of geothermal resources in Nicaragua with the development of other energy resources in such a manner that geothermal

energy can come on line at any time after a new field has been characterized and quantified through drillings. Also, it should be borne in mind that geothermal power plants ought to be used as base load with high load factor on the electric power market.

- ≫ It is recommended that MEM and MARENA should carefully consider adapting the terminology (nomenclature) of the USGS to geothermal resources development and use (see Appendix III).
- ≫ It is considered essential to document accurately statistics on the annual electric power usage in Nicaragua, including load factors of each power plant.

MEM-GELAB AND MEM-DIG

- ≫ On the basis of MEM´s intention to operate the GeLab on a commercial basis, it is recommended that experts involved in interpretation of geochemical data should be under MEM-DIG as their work requires cooperation with experts in other disciplines who are also working on geothermal projects.
- ≫ It is recommended that the ongoing certification process for the GeLab should be completed soonest possible for its commercial operation to be realized.
- ≫ Having received the certification, thorough marketing of the GeLab´s services is recommended.

08

LESSONS LEARNED

As there is overlap between the contents of Chapters 6 (Main Conclusions) and 8 (Lessons Learned), the EFET has spilt the content of these two Chapters in such a way that Chapter 6 uses information that may be regarded as “hard facts” whereas Chapter 8 contains a reflection of the experience of the EFET on more “subjective” items.

- The Geothermal Capacity Project as defined in the GCBP-FPD is too detailed. It is considered that a more favorable approach to the planning of a project like GCBP should involve employment of a Project Manager at an early preparation stage, construct a more general project layout and give a Steering Committee the authority to specify in detail activities for each coming year including revision of the initial project layout, yet within a specified budget.
- Accounting should be in the hands of the donor (ICEIDA). Plans proposed by the Steering Committee should be approved by ICEIDA and also by the counterpart.
- The concept of sustainability was clearly defined in the GCBP-FPD and fitted into the project activities at all stages. This is considered to very important and the planning of new projects should follow the mentioned example.
- The workload of all individuals participating in a project needs to be carefully evaluated to avoid that insufficient manpower leads inadequate success or excessive manpower to unnecessary expenses (manpower needs).
- Although the layout of the GCBP was very detailed with respect to tasks and their time of implementation, it is considered that definite milestones (sequential and parallel) required for assessing progress and success in relation to the ultimate goal of the project should have been clearer.
- Development of geothermal resources requires expert knowledge in many fields including biology, engineering, geochemistry, geology, geophysics, hydrology, mathematics and planning and design. This calls for teamwork that should be taken into account when planning geothermal development projects.
- Apparently, there was no evaluation of the validity of the very foundation of the GCBP, namely whether the abundance and estimated size of geothermal resources really indicated that these resources were important for the economy of Nicaragua. The Momotombo geothermal field has been under exploitation for several decades and the performance of the geothermal reservoir has not been very favorable. When the ultimate goal of a development project involves utilization of an Earth´s resource, it is of utmost importance to evaluate with as much confidence as possible the value of the resource to be utilized and phase the activity on a scale that harmonies with expectations.

09

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Guía de Procedimientos para Desarrolladores Geotérmicos en Nicaragua- MARENA.

Completed Quality Control System Document consisting of 72 documents, including a Quality Manual, Function Description Manual, Quality Policy, Customer Guidelines, Document Structure, 29 Management Procedures, 5 Technical Procedures, 21 Instrument Operation Instruction, and 12 Procedures for Uncertainty Estimation, Validation Test Methods, etc.

Términos de Referencia Elaboración de Estudio de Impacto Ambiental Proyectos Geotérmicos – Fase de Exploración a Través de Perforaciones – Fase de Explotación. MARENA.

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SEMINARS AND COURSES

This compilation is from Thráinn Fridriksson, based on the final report on the GCBP (Fridriksson, Th., 2012b) submitted to ICEIDA in January 2012. The list, presented in the table below, contains both independent short courses given by ÍSOR and its subcontractors and more and less formal workshops given within other project activities, according to Thráinn.

DATE	TOPIC	TRAINERS	PARTICIPATING INSTITUTIONS
10-2008	Reservoir engineering	Th. Egilson	MEM, MARENA, Polaris, GeoNica, UNAN-León
01-2009	Borehole geology	A.K. Mortensen, Th. Fridriksson	MEM, Polaris
09-2009	Geothermal drilling	S. Thórhallsson	MEM, Polaris, GeoNica, MARENA, Mateare Municipality, Amictlan
11-2009	Workshop "Assessment of environmental values of protected areas, with geothermal potential."	H. Jensson, S. Fridriksdóttir	MARENA
12-2009	Reservoir data analysis	Th. Egilson, S. Halldórsdóttir	MEM
11-2010	Geophysical exploration	G.P. Hersir, E.Á. Gudnason	MEM, ENEL, GeoNica, CCP, Polaris, UNAN-León
11-2010	Geothermal geochemistry	Th. Fridriksson, I.	MEM, ENEL, GeoNica, CCP,

		Gunnarsson	Polaris, UNAN-León, Ormat
02-2011	Power plant design	Th. Jóhannsesson	MEM, Polaris
05-2011	Momotombo reservoir results	Th. Egilson	MEM
11-2012	Momotombo chemistry results	Th. Fridriksson	MEM
06-2009	El Hoyo Monte Galan and Managua Chiltepe exploration results	G.P. Hersir, M. Ólafsson	MEM
09-2009	El Hoyo Monte Galan and Managua Chiltepe exploration results	G.P. Hersir, M. Ólafsson, S. Halldórsdóttir	MEM, GeoNica
07-2010	El Hoyo Monte Galan drilling results	A.K. Mortensen	MEM, GeoNica
05-2009	San Jacinto Technical feasibility	A. Ingimundarson	MEM
04-2011	San Jacinto field development	B. Steingrímsson	MEM, Polaris
05-2012	San Jacinto field development	B. Steingrímsson, Th. Fridriksson	MEM, Polaris
09-2009	Casita San Cristobal exploration results	G.P. Hersir, M. Ólafsson, S. Halldórsdóttir	MEM
05-2008	Analytical chemistry methods	H. Ármannsson	MEM
03-2009	Analytical chemistry methods	H. Ármannsson, R. Renderos	MEM
10-2011	Interpretation of geochemical exploration data	H. Ármannsson, F. Óskarsson	MEM
04-2012	Interpretation of geochemical exploration data	F. Óskarsson	MEM
10-2009	Geothermal data management	J. Ketilsson, G.M. Einarsson	MEM
10-2012	Relational data base	S. Gunnarsdóttir	MEM

	structure and management		
05-2009	EIA for geothermal projects	H. Ármannsson, Th.F. Thóroddsson	MARENA, MEM
12-2009	Environmental impacts of geothermal development	H. Ármannsson, Th.F. Thóroddsson	MARENA, MEM

PROGRESS REPORTS AND MINUTES FROM STEERING COMMITTEE

- 2008
  - Annual Report 2008- "Final Report 2008".
  - Minute Meeting, First Steering Committee Meeting, March 11, 2008.
  - Meeting Minutes, Second Steering Committee Meeting GCBP, November 12.
- 2009
  - Annual Report 2009 - "Final Report 2009".
  - Meeting Minute, First Steering Committee Meeting, February 10 (dated to: February 9, 2008).
  - Meeting Minute, Second Steering Committee Meeting - 2009 GCBP, July 22, 2009.
  - Minutes, Third Steering Committee Meeting GCBP, December 3, 2009.
  - First Semester Report - January - June.
- 2010
  - Annual Report 2010 - "GCBP - 2010".
  - Aide-Memoire, First Steering Committee Meeting - 0101 GCBP, May 5, 2010.
  - Ayuda Memoria, Segunda Reunión del Comité de Dirección - 2010 Proyecto Fomracioón de Capacidades en Geotermia, Noviembre 3, 2010.
- 2011
  - Annual Report 2011.
  - Aide-Memoire, First Steering Committee Meeting 2011, Strengthening GCP Nicaragua, May 4, 2011.
  - Aide-Memoire, Second Steering Committee Meeting - 2011 GCBP, November 30, 2011.
  - First Semester Report - January - June.
- 2012
  - Annual Report 2012.

CONFIRMATION OF DONATIONS

- 13 letters signed by MEM and ICEIDA, as a confirmation of ICEIDA's donation to MEM.
- 1 letter signed by UNAN-León, as a confirmation of ICEIDA's donation to UNAN-León.
- 10 letters signed by MARENA and ICEIDA, as a confirmation of ICEIDA's donation to MARENA.

MEMORANDUM AND PROGRESS REPORTS

- Proposal from MARENA for classification of Protected Areas based on their conservation value which is based on the forest fragmentation in each area (2008-2009, not dated).

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- Comments on the information system design from MEM's IT department and costs, ISOR, Einarsson, G. M., Hauksson, K. R., November 4, 2009.
- Coordination Committee Observations for MARENA proposal last quarter 2009. To Gísli Pálsson, from Magdalena Perez - MEM and Gioconda Guevara - ICEIDA, September 28, 2009.
- Meeting with the Director of Natural Heritance on Geothermal Master Plan Information and proposal of working plan from Helgi Jensson, October 7, 2008.
- Warning Report, Project Situation with the DGCA-MARENA, Geothermal Capacity Building Project - ICEIDA. 2008.
- Letter from MEM: Justification del Imcumplimeinto de Los Puntos 1 y 2 del Convenio de Cooperación ICEIDA-MEM "Programa Formación de Capacidades en Geotermia" - Año 2008, 28. de abril de 2009.
- Plus other memos written during the GCBP.

APPENDIX I: HISTORICAL OVERVIEW OF THE GCBP FROM ICEIDA

2004

The first request for assistance made by the Government of Nicaragua (GoN) through MINREX to the Government of Iceland (GoI) involved the development of an institutional support project for the geothermal subsector. At that point in time the process of identifying the needs in Nicaragua began, both in the energy sector in general, and in the geothermal sub-sector. After an initial visit to Nicaragua by an ICEIDA delegation in late 2004, it was decided to develop further the cooperation between the two countries in the geothermal field.

2005

ICEIDA invited three GoN representatives to visit Iceland in August. During the visit, emphasis was placed on the legislative and regulatory framework for geothermal utilization, teaching of the nature of geothermal resources and training to governmental officials involved in granting concessions for geothermal exploration and exploitation. Subsequently, the Nicaraguan authorities presented ICEIDA with their views and ideas regarding further cooperation. A request was made to GoI to assist with building up local capacity in Nicaragua with the purpose of making the country self-sufficient in managing the geothermal sub-sector at the national governmental level in accordance with national legislation.

To follow up on the visit to Iceland, a delegation from ICEIDA, ISOR and the Ministry of Trade and Industry in Iceland visited Nicaragua in September and had further discussions with representatives of the Nicaraguan authorities. During these discussions, it was decided to organize a workshop on geothermal development in Nicaragua with participants from ministries, governmental institutions and universities in Nicaragua, as well as geothermal experts from Iceland and other countries. The main objective of the workshop was to give stakeholders the opportunity to meet with each other and familiarize themselves with the situation from both sides of the partnership. In this manner, the Icelanders got first-hand information about the real needs of Nicaragua in the energy sector and could at the same time inform the Nicaraguan representatives about the expertise of Iceland in the energy sector.

2006

ICEIDA opened up an office in Nicaragua in the beginning of the year, with Mr. Gísli Pálsson as a country director. A workshop entitled “Future of Geothermal Energy in Nicaragua and Icelandic Cooperation” took place in June. The workshop’s main goal was to promote the exchange of experience on geothermal issues between the two countries. Thus, Nicaraguan specialists learned of and became familiarized with the experience and capacity developed by Iceland in the energy sector, while Icelandic experts gathered information on Nicaragua’s real needs in that sector, specifically in the geothermal sub-sector. A group of about 30 people attended the workshop, from Nicaraguan ministries, institutions and universities as well as main power companies. Geothermal lecturers came from Iceland, Kenya and El Salvador.

A Project Identification Document (PID) was completed in August, edited by Árni Ragnarsson. The PID set forth the basic guidelines for the planning of a Nicaraguan Geothermal Capacity Building Project (GCBP) with Icelandic support. The main emphasis was on capacity building within the public sector for the development of geothermal energy. Icelandic and Nicaraguan authorities approved the PID.

GCBP funded the participation of environmental scientist from UCA, Jorge Cisne in the UNU-GTP.

2007

In January 2007 the new Government of Reconciliation and National Unity took office, and the Ministry of Energy and Mines (MEM) was created as the agency charged with planning, proposing, coordinating and implementing the Strategic Plan and Public Policy of the energy and geological resources sector. These were functions that used to be carried out by the National Energy Commission.

In early 2007, after the Nicaraguan Government of Reconciliation and National Unity (GoN) took office, ICEIDA took up the process of preparing a project proposal for the GCBP. MEM was established in February this year and took over all functions from the National Energy Council (CNE), as the agency charged with planning, proposing, coordinating and implementing the Strategic Plan and Public Policy of the energy and geological resources sector. Árni Ragnarsson and Thráinn Fridriksson visited Nicaragua in January/February to work with officials from MEM, MARENA and the universities (UNAN-León, UNAN-MANAGUA, UCA, and UNI) on defining the activities to be included in the GCBP. In May, Halldór Ármannsson, Sigurrós Fridriksdóttir and Thóroddur F. Thóroddson visited Nicaragua to work with MARENA on defining the activities directed towards the environmental aspects of geothermal utilization. Overall objectives and tasks were defined and presented in the so called „GCBP Final Proyect Document". The GCBP proposal was carried out jointly by officials from MEM Geothermal Department (Ariel Zuniga and Magdalena Perez), MARENA (Engracia Merlo and Petrona Gago), the ICEIDA project manager, Gioconda Guevara and Thráinn Fridriksson, the project manager on behalf of ISOR. Marvin Ortega, local development collaboration expert, was the editor of the GCBP-FPD. Ariel Zuniga was the project manager on behalf of MEM during the preparation of the GCBP-FPD and Engracia Merlo on behalf of MARENA. Ariel Zuniga was replaced by Magdalena Pérez near the end of the year 2007.

2008

The GCBP Final Project Document (GCBP-FPD) became officially active through its confirmation by Mr. Emilio Rappaccioli, Minister of Energy and Mines in Nicaragua and Mr. Sighvatur Björgvinsson, Director General of ICEIDA. One of the first actions taken was the formation of a Steering Committee (SC) and a Coordination Committee (CC) and the establishment of the tools needed for monitoring of project activities and the administration of project funds.

A general coordinator, Mrs. Gioconda Guevara, was appointed to represent the GCBP in its inter-institutional relations and to keep up official communication with the Minister of MEM and the ICEIDA Director. Gioconda Guevara was also the ICEIDA project coordinator.

Initial members of the SC were Mrs. Lorena Lanza, Vice Minister MEM, Mrs. Francis Maria Rodriguez, at MINREX, Mr. Gísli Pálsson, Country Director of ICEIDA, Mrs. Gioconda Guevara, Mr. Thorkell Helgason, and Mrs. Magdalena Pérez, the GCBP coordinator at MEM. Magdalena took over as director of MEM – DDG in 2009. GCBP coordinator at MARENA was Mrs. Engracia Merlo. Initial members of the CC were Mrs. Magdalena Pérez and Mrs. Gioconda Guevara.

Mr. Geir Oddsson took over as a Country Director for Nicaragua in June 2008.

The implementation of the three main GCBP components started in March 2008.

Main activities carried out in 2008 under Component 1 “Technical Assistance”.

At MEM-DDG:

- Several consultancies were provided that included a collaborative effort between MEM and the National Energy Authority in Iceland to the draft standards for geothermal development.
- Evaluation of drilling reports from San Jacinto - Tizate, by assistance of Halldór Ármannsson at ISOR.
- The definition of the role and structure of the MEM-DDG.
- A short-term assistance to review the Nicaragua Geothermal Master Plan from 2001.
- The creation of a video on the geothermal potential of Nicaragua for investment, promotion and awareness raising.

At MARENA:

- MARENA began to prepare EIA guidelines with assistance of consultants Halldór Ármannsson at ISOR and Thoroddur F. Thoroddsson at the Icelandic National Planning Agency (NPA).
- MARENA started to lay out measures to put values on protected areas with geothermal manifestation with support from Icelandic consultants at ISOR and Helgi Jensson and Sigurrós Fridriksdóttir from The Environment Agency of Iceland (EAI).
- The publication of five thousand brochures of the EIA and one thousand posters of the EIA process in Nicaragua by MARENA were funded as part of the awareness raising and promotion of environmental law in the country.

Main activities for Component 2of the GCBP “Training and Capacity Building”.

- Seminars and workshops for technicians from MEM, MARENA (central and territorial offices), UNAN-LEÓN, private firms (Polaris, ORMAT and GeoNica) and the environmental units of municipalities with geothermal potential. The seminars were delivered by experts from ISOR, the Geothermal Management of the Mexican Institute of Electrical Investigation (IIE) and consultants from Costa Rica. Topics included reservoir engineering, geochemistry, and clean development mechanism. Around eighty professionals from the Nicaraguan private and public bodies above, participated in these training courses.
- An exchange of experiences with experts at LaGeo, El Salvador in a week-long workshop about the environmental aspects of geothermal development. Twenty five experts from Nicaraguan public bodies participated in this training at LaGeo facility in San Salvador and in field trips to the geothermal fields in El Salvador.
- There was also a training workshop on analysis and data management of Geographic Information System (GIS).
- A number of MEM staff continued to being trained in English.
- GCBP funded the participation of a MEM-DDG chemical engineer in the United Nations University Geothermal Training Programme in Iceland.

Main activities for the Component 3 “Infrastructure and Equipment”.

- The construction and installation of the GeLab within MEM-DDG was started, with key equipment for chemical analyses of geothermal fluids and natural waters, like chromatographs, spectrophotometers, titrators, as well as equipment for taking geothermal samples in the field
- Furthermore geological equipment such as a petrographic microscope, stereoscope, field loupes, GPS and other equipment for the MEM-DIG.

2009

The decision was taken by the government of Iceland in February 2009, to close the ICEIDA country office in Nicaragua, due to the adverse effects of the financial crisis on the Icelandic economy. ICEIDA Country office was closed in June 2009 in Nicaragua. Mr. Gísli Pálsson took over again as a representative on behalf of ICEIDA in the Steering Committee and Gioconda Guevara, ICEIDA coordinator, moved into an office in the Finnish Embassy.

Main activities for Component 1 “Technical Assistance”.

- A series of seminars related to the evaluation, review and monitoring of geothermal exploration studies undertaken in geothermal fields and projects in Nicaragua, covering geology, geochemistry and geophysics. Staff from UNAN-León, Amictlan (NGO/Municipalities), and Polaris (private concessionary) were invited to participate with MEM staff in the field training.
- Technical assistance was provided to MEM-DDG on the evaluation of geothermal well drilling data and reservoir engineering
- The MEM-DIG received technical assistance and accompaniment when carrying out geothermal exploration studies in high-enthalpy areas
- Special attention was given to technical assistance regarding calibration of the MEM-GeLab, starting up processes for geochemical analysis and methods for sampling water and gas. An expert from ISOR taught a course for MEM lab staff, together with an expert from LaGeo.
- MARENA started the preparation of general guidelines on EIA with technical assistance from NPA.
- Further, a training workshop was held on the evaluation of environmental value of sites and the classification of protected areas for the making of management plans by an expert from the Environment Agency of Iceland (EAI) who, together with MARENA technicians, identified and established priority activities to be undertaken in the year 2010 by the Ministry.

Main activities for Component 2 “Training and Capacity Strengthening”.

- Seminars and workshops were held on the following topics: petrographic analysis, data analysis and management, geothermal well drilling, and reservoir engineering.
- Seminar on Environmental Impact Assessment in May, by Thóroddur F. Thóroddsson from NPA and Halldór Ármannsson, ISOR.
- Training on GIS continued with MEM-DIG team.

- A two-week theoretical-practical training course was held in Mexico. Three staff members from MEM-DDG participated, as did an expert from UNAN-LEÓN. The subject was analytical geochemistry and the seminar was led by experts at the Geothermal Directorate of the Mexico Institute for Electrical Studies (IIE). It consisted of both theoretical and practical classes at the Los Azufres geothermal field in Mexico.
- A number of MEM staff continued with their English classes.
- One MEM-DDG geologist attended the UNU-GTP in Iceland with ICEIDA support.
- A one week visit to Iceland by five Nicaraguan specialists, three from MEM and two from MARENA. During the visit they had the opportunity to visit geothermal fields and several institutions that work on environmental issues and the development of geothermal projects in Iceland.

Main activities for Component 3 "Infrastructure and Equipment".

- The construction of the GeLab at MEM was completed. This includes the procurement and installation of laboratory equipment such as a gas chromatograph, an ion chromatograph and an atomic absorption spectrophotometer, as well as lesser accessories such as scales, glassware and reagents. The equipment has been calibrated and methodological validation has begun for the analysis of samples at the laboratory.
- Laboratory technicians at MEM-GeLab were also trained.

It was scheduled to have an external mid-term evaluation in late 2009 according to the GCBP-FPD. The Steering Committee decided to move the evaluation up to the second quarter of the year. A consultant from El Salvador, José Antonio Rodriguez, at Epsylon 3 consulting, with broad-based experience in geothermal development and a thorough knowledge of the energy sector in Nicaragua was contracted for the assignment. The mid-term evaluation assessed the progress achieved and identified difficulties during the implementation of the GCBP with the purpose of updating the project plan.

Following the mid-term evaluation, the SC decided to modify the GCBP to improve implementation efficiency and overall project effectiveness and added a representative from MARENA in the SC Minister and the CC. At the SC meeting on December 3rd, Thorleifur Finnsson, ICEIDA Advisor, took over as a representative on behalf of ICEIDA in the Steering Committee

2010

There was a change in the project management in January, as Magdalena Pérez left MEM-DDG and Mario Gonzáles took over her position as a head of MEM-DDG and as project coordinator on behalf of MEM. Mr. Roberto Araquistáin, vice minister of MEM and Mrs. Engracia Merlo GCBP coordinator from MARENA took seat in the SC, and Mrs. Engracia Merlo took also seat in the CC.

Main activities for Component 1 "Technical Assistance".

At MEM-DDG:

- Technical assistance and training of MEM-DDG staff in the interpretation and evaluation of existing exploration data on geothermal fields, as well as the interpretation of exploration data in areas in which concessions have been granted (geology, geochemistry and geophysics).

- Further, technical assistance for the evaluation of data from the drilling of geothermal wells and reservoir engineering.
- Technical assistance and accompaniment continued for the MEM-DIG in the holding of geothermal exploratory investigations in high- and low-enthalpy areas through a number of field trips for in situ training.
- The installation and implementation of a Data Management System. To that end, a high-capacity server was installed at MEM-DIG including the software needed for the design, installation and management of a database containing all available information and data from the various areas of geothermal exploration and operation in Nicaragua. A system was designed with the assistance of Icelandic experts working in tandem with Nicaraguan technicians.
- Special attention was given to the continuity of technical assistance in calibrating the laboratory equipment and the start-up of a system by which to validate the processes and methods of geochemical analysis of water and gas samples.
- Further, the process of accreditation of the MEM-GeLab got underway with participation of experts from ISOR and the LaGeo of El Salvador.
- One MEM-DDG geologist attended the UNU-GTP in Iceland with ICEIDA support.

At MARENA:

- Technical assistance consisted mainly of the onset of an extensive study titled “Forest Fragmentation in Protected Areas within Geothermal Concession Zones” which includes maps displaying the state of conservation of forests located within protected areas with geothermal potential.
- Work also continued at MARENA on the preparation of standard ToR for EIA for geothermal exploration and exploitation.
- Four workshops were held on environmental legislation for staff at the MARENA territorial delegations, as well as at the environmental units at the mayor’s offices in those municipalities in which geothermal projects are located. The workshops were held in several towns in Nicaragua, with a total participation of over three hundred attendants.

Component 2 “Training and Strengthening of Capacities”.

This year the main objective was the training of staff at government institutions charged with monitoring and following up on geothermal projects.

- Seminars and workshops were held on the following subjects: geothermal well geology; geophysical methods used in geothermal exploration; geothermal geochemistry; analysis and management of data bases; risk analysis; and entrepreneurial coaching. Forty professionals from both the public and the private sectors participated in these courses and seminars.
- A number of MEM staff members continued to receive training in acquisition of the English language.

- A seminar entitled “Current and Future Situation Regarding Geothermal Energy in Nicaragua”, with the participation of staff from the main concessionaries of geothermal projects in Nicaragua, alongside staff from MEM.

Component 3 “Infrastructure and Equipment”.

Procurement continued of the equipment at the GeLab, for the running of all necessary geochemical analysis for geothermal development and monitoring and training of staff to carry out these analyses continued.

2011

To ensure that the objectives of Component 1 “Technical Assistance” and Component 2 “Training and Capacity Strengthening” could be successfully meet, the decision was made to carry out the technical assistance and training jointly.

Main work undertaken at MEM:

- Technical assistance and training in the interpretation and evaluation of earlier data concerning the production of chemical data for geothermal fields.
- Practical course for the interpretation of geochemical data.
- Training course in the design and efficiency of turbines.
- Field training for the research unit at the MEM Geothermal Directorate by means of field trips for the purpose of carrying out geological and geochemical exploration in low-enthalpy areas.
- Training in geothermal petrography held at the LaGeo laboratory in El Salvador.
- Technical assistance and training for the evaluation and interpretation of drilling data from geothermal wells and for reservoir engineering.
- Work continued on the design, training and capacitation in the Data Management System, which was installed in the year 2010 in order to store and manage all the information and data gathered on the geothermal areas being explored and exploited in the country.
- Continuation of the process of validating chemical analyses and accrediting the GeLab with the assistance of the Salvadoran geothermal company LaGeo.
- An environmental engineer from MEM-UGA attended UNU-GTP in Iceland.
- The engagement of a consultant for the drafting of a Business Plan for the MEM-GeLab for the purpose of providing the guidelines necessary to ensure the sustainability of the Laboratory over time and its operation as an efficient and competitive business unit.
- MEM-GeLab moved in the organizational chart from MEM-DDG.
- MEM sent a staff member to the United Nations University Geothermal Training Programme in Iceland.

Main activities undertaken at MARENA:

- The study titled “Forest Fragmentation in Protected Areas with Geothermal Potential” was concluded, with an atlas of maps and a GIS analysis which displays the status of forest conservation in each of the 11 areas in which high-enthalpy geothermal fields have been located as defined in the Nicaragua Geothermal Master plan from 2001

- Work also continued on the preparation of standard ToR for EIA for geothermal exploration and exploitation. Revisions of the ToRs were completed in June 2011.
- Guidelines were drafted to demonstrate the concession process for private developers of geothermal fields.

The GCBP supported also a module on the "Use of Geothermal Energy" taught at UNAN-León by two Icelandic experts. The module was a part of a course on Renewable Energy for master students, which is supported by The Spanish Agency for International Development Cooperation (AECID).

The procurement part of the third GCBP component "Infrastructure and Equipment" was concluded upon procurement of all equipment necessary for the proper functioning of a geochemical laboratory at MEM-GeLab. Training of staff of GeLab continued and accreditation process was started.

2012

In 2012, the Geothermal Capacity Building Project (GCBP), financed by ICEIDA in Nicaragua concluded its implementation phase in accordance with a five-year plan reflected in the GCBP Document (2008). Hence, this was the last year for implementing the activities described in the work plan. These activities were carried out as scheduled, together with the Ministry of Energy and Mines (MEM) and the Ministry of the Environment and Natural Resources (MARENA), and according to the aforementioned Project Document.

For the purpose of ensuring that during this final year there would be compliance with and strengthening of the project's main objective which was to enhance the use of geothermal resources in Nicaragua by building capacities at the government institutions involved in their development. The main activities for 2012 were the consolidation and strengthening of Component 2 activities ("Training and Capacity Building").

The activities undertaken at MEM were as follows:

- Technical assistance and training in the interpretation and evaluation of the historical production and chemical data for the Momotombo well field.
- A practical course on the interpretation of geochemical data in the different fields under exploitation in Nicaragua.
- On-site training for the Research Unit at the Geothermal Directorate at MEM, by means of field trips to carry out geological and geochemical explorations in low-enthalpy areas.
- Work continued on the design, training and use of the Data Management System which was set up in 2011 for the purpose of storing and managing the information and data from geothermal areas under exploration or already operating in the country.
- The accreditation process of the Geochemical and Geothermal Laboratory at the National Accreditation Organization began.
- MEM sent a staff member from the GeLab to the United Nations University Geothermal Training Programme in Iceland.

The activities undertaken at MARENA were as follows:

- Edition and publication of eleven (11) volumes of the study titled “Forest Fragmentation in Protected Areas with Geothermal Potential”. These include maps and analyses gathered using a Geographic Information System (GIS) and showing the state of conservation of the forests in each of the ten (10) areas with geothermal potential, located in the Nicaraguan Pacific volcanic mountain range and defined as having geothermal potential in the Nicaragua Geothermal Master Plan.
- Publication of the Procedures Guide for Geothermal Developers, including the Standard Terms of Reference for the Environmental Impact Evaluations (EIA). These are now official and following these procedures is mandatory in order to be eligible for concessions allowing the exploration and exploitation of geothermal resources.
- Work continued on the preparation of the Nicaragua Mandatory Technical Standards (NTONs) for the development of geothermal projects. The proposal was worked on jointly by staff from MEM and MARENA. During 2013 an effort will be made to reach consensus with private developers. Both ministries are working on a process intended to conclude with the NTONs adoption and publication this same year whereupon they too will become official.

As part of the technical assistance component, cooperation continued with the Master’s Degree Programme in Renewable Energy offered at the National Autonomous University of Nicaragua in León (UNAN-León). A module titled “Uses of Geothermal Energy” was prepared and taught by an Icelandic expert. This Master’s Programme at UNAN-León is financed mainly by the Spanish International Cooperation Agency (AECID).

Component 3 of the Programme, titled “Infrastructure and Equipment”, was successfully concluded in the year 2009 upon procurement of all the equipment necessary for the proper functioning of the Geochemistry and Geothermal Laboratory. Related monitoring activities are now being carried out by the Geothermal Directorate at the Ministry of Energy and Mines.

In November the Final Evaluation of the GCBP took place. A team of Icelandic consultants and experts were engaged by ICEIDA headquarters in Reykjavik and visited Nicaragua for the purpose of carrying out an in situ investigation. The Final Report was finished in June, 2013.

APPENDIX II: OVERVIEW OF VISITS AND INTERVIEWS BY EFE TEAM

Following is an overview of visits and interviews by the EFET during the extension of the EFE.

ICEIDA - Nicaragua; Gioconda Guevara.

MEM; Mrs. Lorena Lanza vice-minister of MEM, Mario González, Luís Molina, Ernesto Ramón Martinez, Francisco Ruiz, Juana Ruiz, Roberta Quintero, Azucena del Carmen Espinales Martinez, Isaura Porras Cruz.

MARENA; Roberto Araquistáin Cisneros, Luis Fiallos P., Engracia Merlo. Petrona Gago, Liliana Díaz.

MINREX; Francis Rodríguez, Elieth Blandford Archibold.

UNAN-LEÓN; Leonardo Mendoza, Jorge Cisne, Maritza Vargas.

POLARIS; José Antonio Rodríguez, Magdalena Pérez.

GEONICA; Víctor Valencia, Guillermo Chávez.

ICEIDA - Iceland; Engilbert Gudmundsson, Sighvatur Björgvinsson, Gísli Pálsson, Geir Oddsson

ICEIDA Advisors; Þorkell Helgason, Þorleifur Finnsson

ISOR; Thráinn Fridriksson, Benedikt Steingrímsson, Halldór Ármannsson, Sigurdur Gardar Kristinsson.. The EFET did not have the opportunity to talk to Ana Maria Gonzáles (El Salvador), Roberto Renderos (El Salvador) due to Season Vacations.

National Planning Agency of Iceland; Thóroddur F. Thóroddsson

Environment Agency of Iceland; Helgi Jensson, Sigurrós Friðriksdóttir

APPENDIX III: OVERVIEW OF RESOURCE SIZE ESTIMATES IN NICARAGUA AND PROPOSED DEVELOPMENT STRATEGY

Below some information is given that is relevant for geothermal development in Nicaragua including both information on resource size estimates and development strategy.

Nomenclature

The terminology of the United States Geological Survey, as given in Mineral Commodity Summaries (2011) p. 193-195 is considered both concise and very useful for any studies on sub-surface resources and their exploitation This terminology is specifically developed for sub-surface mineral resources but it is equally useful for geothermal energy because it is also a sub-surface resource. By the USGS terminology, it should be clear what is meant by various terms used for the exploration, development and use of geothermal resources (see Table III.1). For experts, management and Government alike, the use of the USGS terminology is superior to that mostly practiced by the geothermal industry. As an example: what does geothermal potential mean precisely? In what way should the number 1200 MW_e potential be understood? If geothermal manifestations are known within a volcanologically active region, is that a proof of a high-enthalpy geothermal reservoir? The terminology should reflect to what extent statements are based on data (hard facts).

Table III.1 Definition of terms that describe the level of certainty about the size and grade of specific deposits of subsurface resources. From USGS, Mineral Commodity Summaries (2011), pp. 193-195 (a).

TERM	DEFINITION
Undiscovered resources (b)	Resources, the existence of which are only postulated, comprising deposits that are separate from identified resources. Undiscovered resources may be postulated in deposits of such grade and physical location as to render them economic, marginally economic, or subeconomic. To reflect varying degrees of geologic certainty, undiscovered resources may be divided into two parts, hypothetical and speculated resources
Hypothetical resources	Undiscovered resources that are similar to known mineral bodies and that may be reasonably expected to exist in the same producing district or region under analogous geologic conditions. If exploration confirms their existence and reveals enough information about their quality, grade, and quantity, they will be reclassified as identified resources.
Speculative resources	Undiscovered resources that may occur either in known types of deposits in favorable geologic settings where mineral discoveries have not been made, or in types of deposits as yet unrecognized for their economic potential. If exploration confirms their existence and reveals enough information about their quantity, grade, and quality, they will be reclassified as identified resources.
Identified resources (c)	Resources whose location, grade, quality, and quantity are known or estimated from specific geological evidence. Identified resources include economic, marginally economic, and sub-economic components. To reflect

	varying degrees of geologic certainty, these economic divisions can be subdivided into measured, indicated, and inferred.
Demonstrated - measured	Quantity is computed from dimensions revealed in outcrops, trenches, workings, or drill holes; grade and (or) quality are computed from the results of detailed sampling. The sites for inspection, sampling, and measurements are spaced so closely and the geologic character is so well defined that size, shape, depth, and mineral content of the resource are well established
Demonstrated - indicated	Quantity and grade and (or) quality are computed from information similar to that used for measured resources, but the sites for inspection, sampling, and measurement are farther apart or are otherwise less adequately spaced. The degree of assurance, although lower than that for measured resources, is high enough to assume continuity between points of observation
Demonstrated - inferred	Estimates are based on an assumed continuity beyond measured and (or) indicated resources, for which there is geologic evidence. Inferred resources may or may not be supported by samples or measurements
Reserve base	That part of an identified resource that meets specified minimum physical and chemical criteria related to current mining and production practices, including those for grade, quality, thickness, and depth. The reserve base is the inplace demonstrated (measured plus indicated) resource from which reserves are estimated. It may encompass those parts of the resources that have a reasonable potential for becoming economically available within planning horizons beyond those that assume proven technology and current economics. The reserve base includes those resources that are currently economic (reserves), marginally economic (marginal reserves), and some of those that are currently subeconomic (subeconomic resources). The term "geologic reserve" has been applied by others generally to the reserve-base category, but it also may include the inferred-reserve-base category; it is not a part of this classification system
Reserve	That part of the reserve base which could be economically extracted or produced at the time of determination. The term reserves need not signify that extraction facilities are in place and operative. Reserves include only recoverable materials; thus, terms such as "extractable reserves" and "recoverable reserves" are redundant and are not a part of this classification system.

aDefinitions given by the USGS are more detailed than those given in Table 2.2. They are, however, adequate for the purpose of this report. [b]Undiscovered resources are divided into two classes, hypothetical and speculative resources, depending on the degree of geologic certainty. [c]Identified resources are also for the most part divided into three classes, measured, indicated and inferred. Reserve conforms with the term "proven resource."

METHODOLOGY FOR GEOTHERMAL DEVELOPMENT

The resource size estimate of 1200 MW_e should be classified as an estimate of the size of geothermal resources that are undiscovered by the terminology of the USGS (see Table above). The development strategy, described below, represents a methodology as how to identify and prove an economically useful geothermal reservoir particular area at minimum risk cost.

The methodology described here for the development of geothermal resources and the key to success involves systematic collection of data on any prospective geothermal field and skillful (not routine) interpretation of these data. The development work is divided into four main phases and the results of a previous phase form the basis whether or not to embark on the next phase. The phases are:

- Surface exploration - (Anomaly)
- Exploration drillings - (Indicated Deposit)
- Drilling of step-out wells - (Proven Deposit)
- Drilling of appraisal wells to quantify the characteristics of a wellfield - (Economic Deposit).

The terms in parenthesis are commonly used by the mining industry.

It is further advisable to develop any geothermal field in steps, erect a relative small power plant and enlarge it at a later date or build a new one on the basis of results of reservoir monitoring studies that show how the reservoir has responded to the production load. Full exploitation of a particular geothermal field may take 10 years, or more, depending on its size. The above described approach also has the advantage that all parties involved in the development should easily envisage at any time at what development stage the project is, geoscientists, engineers, management, as well as politicians.

The first phase in the development of a geothermal field involves surface exploration:

- geological mapping
- sampling and analysis of geothermal fluids
- resistivity surveys
- sometimes other geophysical surveys and
- hydrological balance studies.

The surface exploration results form the basis for decision to embark on exploration drilling or, if the exploration results are taken to be negative, to halt the project. The siting of the first exploration well(s) should be based on the surface exploration results. The outcome of well tests should be used to revise, as necessary, a) interpretation of surface exploration data but also b) used to site new wells and revise their design (diameter, depth, etc.), if considered feasible. Exploration wells should be regarded as successful, if temperatures are sufficiently high, permeability satisfactory, the fluid with acceptable chemical composition and the steam yield 8-10 kg/s (4-5 MW_e) if the intention is to use steam.

If the drillings of an exploration well(s) is not considered successful, two options exist, either to terminate the project or drill more exploration wells in different sector or sectors of the geothermal field. If, on the other hand, exploration wells are successful, the next phase involves

drilling of step-out wells in the vicinity of successful exploration well(s) with the purpose of exploring the size of the favorable geothermal “anomaly” discovered by the exploration drillings. There are no fixed rules as to how far step-out wells should be drilled from a successful exploration well, yet a distance of 1-2 km is common. Having delineated a prospective wellfield by step-out wells, continued drillings should be within the prospective wellfield (also termed production field) in order to quantify the production characteristics of the underlying reservoir.

Initial exploration drilling plans often assume the drilling of 2-4 wells. It may be expensive to drill one well only, at least if the drill rig needs to be transported to a distant location and if some road building is required for access to the prospective geothermal field, the cost of environmental impact studies and piping of water and/ or electric cables is required for the drillings. Drilling of more than one well in one step (prepare two or more drill pads in the beginning) means that 2-3 exploration wells have been drilled before the drilling results can be made use of for siting a new well.

If confidence is limited in a geothermal field, as based on surface exploration data interpretation, it may be justified to drill relatively shallow slim-holes. Otherwise, all wells should be designed as production wells and the purpose of drilling every such well is to prove steam. It varies how much steam needs to be proved before a pre-feasibility study should be carried out on the economy of the prospect to be followed by decision on the erecting a power plant. Sometimes the figure is 50% proved steam, sometimes as much as 80%.

When a decision has been taken to build a power plant, drillings continue until sufficient steam has been proved. It is common to prove about 10% excess, or an excess that equals that of the best production well. This is needed because steam flow from wells is expected to decline with time, especially during the early period of their production history.

Geothermal reservoirs represent a thermal and permeability anomalies at their depth in the crust. Production from any such reservoir in excess of natural heat loss is therefore expected to enhance recharge of colder groundwater into the reservoir. The most important monitoring studies of geothermal reservoirs under production involve measuring pressure decline in monitoring wells, decrease in steam yield of wells and changes in fluid chemistry. In particular, mobile chemical components, like chloride, are useful to map cold groundwater recharge. Chloride concentrations are very low in groundwater but high in geothermal water. A decline in chloride concentrations in well discharges is thus an indication of cold recharge. In the long run, such recharge may cause considerable cooling of the reservoir but early on the recharging water will gain temperature by flowing through the hot reservoir rock before entering wells.

Decline in steam output of wells calls for drilling of make-up wells. It is very important to have a proven wellfield at the beginning where make-up wells could be drilled. To save as much as possible on drilling costs, it should always be considered to use wells that are poor producers for injection. Their injectivity may not be good in the beginning but could improve with time due to contraction of the rock in receiving aquifers as a result of cooling.

Table III.2 Division of geothermal development projects into phases

PHASE	ACTION	POSITIVE RESULT
1	geothermal exploration	indicated reservoir
2	exploration drillings	inferred reserve
3	drilling of step-out wells	reserve base
4	drilling of appraisal wells	reserve
5	preliminary design and feasibility study	
6	decision to erect geothermal plant	

The last column in the Table refers to success.

Drilling and flow tests by themselves do not provide sufficient information to characterize a geothermal reservoir. Various tests are needed as summarized in Table III.3.

Table III.3 Well testing and other well measurements.

	MEASUREMENT/DATA COLLECTION	RESULT
1	*Circulation losses during drilling*	Possible aquifers
2	*Drill cores*	Rock porosity
3	*Completion tests*	Permeability, depth of possible aquifers
4	*Temperature logging during heat-up*	Aquifers, temperature at different depths
5	*Pressure logging during recovery*	Aquifer in well connected to the formation
6	*Flow tests*	Steam flow, discharge enthalpy
7	*Samples of water and steam*	Producing aquifers, scaling, corrosion
8	*Lithology study*	Lithological section
9	*Hydrothermal alteration*	Formation temperatures, history of geothermal system

During drilling it is important to take cores at regular intervals to determine the porosity of the rocks and therefore the quantity of water stored in a specific volume of rock. It is also valuable to report circulation losses during drilling. Other gathering of data from wells that should be upon and after well completion is summarized in Table III.3.

When a potential wellfield has been delineated by drilling of step-out wells and later proved by drilling and testing of appraisal wells, a figure should be produced for the amount of fluid stored

in the reservoir below the wellfield. It is common to assume that a wellfield of 1 km^2 needs to be proved for 15 MW_e power generation (To generate 1 MW_e from geothermal steam using condensing turbines requires a steam flow of 1.8-2.0 kg/s). If it is assumed that the porosity is 10%, the reservoir temperature 250°C on average and the reservoir thickness 1.5 km, the amount of fluid below each square km of wellfield suffices to produce 15 MW_e over a period of 24 years. For 10% porosity and 250°C, the amount of heat stored in the reservoir rock is ~85% of the total in the reservoir, 15% in the rock. If the reservoir temperature is 300°C, the corresponding period would be 35 years. It is difficult to predict how much of the heat in the rock can be made use of. If it is assumed to be 25 and 50%, respectively, 1 km^2 of wellfield would last

APPENDIX IV: UNU-GTP FELLOWS SUPPORTED BY GCBP

Fellows attending the UNU-GTP in Iceland during the period of ICEIDA support.

FELLOW AND HOME INSTITUTION	YEAR	REPORT TITLE
Jorge Cisne UNAN-León	2006	Sampling and analyses of geothermal steam and geothermometer applications in Krafla, Theistareykir, Reykjanes and Svartsengi, Iceland. http://www.os.is/gogn/unu-gtp-report/UNU-GTP-2006-09.pdf
Irene Chow UCA	2007	Gaussian modeling of the dispersion of hydrogen sulphide from Hellisheidi power plant, Iceland. http://www.os.is/gogn/unu-gtp-report/UNU-GTP-2007-05.pdf
Francisco Ruíz MEM geoth.	2008	Geochemical interpretation of the Masaya-Granada-Nandaime chemical data, Nicaragua. http://www.os.is/gogn/unu-gtp-report/UNU-GTP-2008-26.pdf
Juana Ruíz MEM geoth.	2009	Reassessment of the production capacity of two geothermal fields in Nicaragua. http://www.os.is/gogn/unu-gtp-report/UNU-GTP-2009-24.pdf
Roberta Quintero MEM geoth.	2010	Borehole geology of well SJ9-2, San Jacinto - Tizate geothermal field, NW-Nicaragua. http://www.os.is/gogn/unu-gtp-report/UNU-GTP-2010-27.pdf
Manuel Vanegas UNAN-León	2010	Chemical assessment of water prospects for direct applications in Nicaragua. http://www.os.is/gogn/unu-gtp-report/UNU-GTP-2010-31.pdf
Mariela Arauz MEM environ.	2011	Environmental monitoring of geothermal projects in Nicaragua. http://www.os.is/gogn/unu-gtp-report/UNU-GTP-2011-06.pdf
Isaura Porras MEM geoth.	2012	Chemical evolution of the Momotombo reservoir and silica and calcite scaling potential of the fluid. Not yet published.

The tasks identified to fulfill the objective to build up infrastructure at MEM and MARENA needed for the development and use of geothermal resources are presented in Annex V, of the GCBP-FPD. Inspection by the EFET shows that all these tasks have been fulfilled.

APPENDIX V: DEVELOPMENT STATUS OF GEOTHERMAL AREAS UNDER EXPLORATION OR PRODUCTION

Momotombo

The re-assessment of the Momotombo geothermal field is the subject of a special ISOR-MEM report to which both Icelandic and Nicaraguan experts contributed (Egilsson et al., 2012). The fundamental outcomes of the report include updated volumetric evaluation of the geothermal reservoir using the Monte Carlo probabilistic method assuming a certain heat recovery factor followed by estimation of its production capacity. The main outcomes are:

1. It seems clear that ideas of 50-80 MW_e production from the current geothermal reservoir (wellfield?) are not realistic. A more realistic scenario is considered to be 30-35 MW_e.
2. Updated volumetric assessment also suggests a production capacity in this range.
3. Cold recharge into the reservoir is from the southeast.
4. The present development is such that production capacity is not expected to exceed 30 MW_e.

The report is of high quality for what it stands for but it only deals with the topic of reservoir engineering in the sense that these words are used by the geothermal industry. For training purposes it would have been important to revise the conceptual model as a whole. The term conceptual model means a construct and implies an attempt to incorporate all available data into a single model and if successful a concept (understanding) has been developed for the reservoir characteristics. Thus a comprehensive conceptual model would include lithology, hydrothermal alteration, fluid chemistry, cold recharge as indicated by decline in chloride concentrations in addition distribution of temperature and pressure (and decline), changes in well discharge enthalpy and steam yield of wells. The decline of chloride, which is a measure of fast cold recharge (see Arnórsson, 1998) can be made use of to estimate extraction of heat from the reservoir rock by the incoming cold ground water.

The points discussed above are included here because they have a bearing on general objectives of training, namely to bring together experts who specialize in different disciplines, yet they have a common goal and inter-disciplinary teamwork tends to be more fruitful than work that involves isolated contributions from different disciplines.

Managua – Chiltepe

MEM got the task to evaluate whether or not wells should be drilled on the Managua-Chiltepe slope. In 2006 GeoNica was awarded concession to develop the field. The concession area was 100 km^2. The report issued by MEM granting GeoNica concession to develop this geothermal field is professional and quite satisfactory.

GeoNica´s first task was to carry out an exploration survey and propose sites for two exploration wells. First, GeoNica carried out EIA in 2007. They submitted their report on the results of exploration in 2008 and received a licence to drill in the same year.

Iceland GeoSurvey (ISOR) reviewed the report written by GeoNica on the results of surface exploration which included a proposal of a location and target depth of a single exploration well, rather than two (Hersir and Ólafsson, 2009a). In the GeoSurvey report of Hersir and Ólafsson

(2009a) the view is expressed that a different site for the first exploration hole was preferred. The report evaluation of Hersir and Ólafsson (2009) should have been carried out by MEM experts or at least a group of expert from both MEM and ISOR.

One slim hole was drilled in 2009 to about 1100 m depth. The highest temperature recorded was only 80°C (not a high temperature field, at least where the hole was drilled) but interpretation of the gas content of steam from the only fumarole sampled in the area was taken to indicate subsurface temperatures of 280-290°C. After seeing the negative results from the first exploration well, GeoNica turned in their licence to MEM in 2010. For this reason work expected to be carried out by MEM for monitoring and evaluating the development phase of GeoNica at Managua – Chiltepe was never realized as well as later design of power plant and surface equipment.

El Hoyo – Monte Galán

MEM granted GeoNica exploration licence at El Hoyo – Monte Galán geothermal field in April 2006, or at the same time as Managua – Chiltepe. As at Managua – Chiltepe, the consession area was 100 km^2. The concession included surface exploration followed by the drilling of two exploration ells. The report issued by MEM granting GeoNica concessions to develop El Hoyo – Monte Galán geothermal field is professional and quite satisfactory.

GeoNica submitted a report on surface exploration in March 2009. In this report 6 sites for exploration wells were proposed. As for Managua – Chiltepe, ISOR experts evaluated the report submitted by GeoNica on the results of the surface exploration (Hersir and Ólafsson, 2009b) and later two well reports compiled by GeoNica on the results of the two exploration wells drilled in the area (Mortensen and Egilsson, 2012).

Warm water springs seem to be rather abundant in the area. Water geothermometers indicate subsurface temperatures of 150-200°C. Gas samples give calculated gas geothermometer temperatures of 80-287°C. According to gas geothermometer interpretation by ISOR experts, temperatures as high as 275-300°C can be expected at La Hoyo – Monte Galán.

In 2009-2010 two wells, about 2000 m deep, were drilled. GeoNica produced two reports describing the drilling operations results of these drillings. The first well had a maximum temperature of almost 200°C but insignificant permeability and was not productive. The only circulation loss reported was at 103 m depth. Maximum temperature was slightly below 200°C at ~300 m depth which is to be compared with an estimate of 300°C based of surface exploration data. The second well which was drilled about 1400 west of the first one was significantly cooler, with maximum measured temperature of about 150°C at well bottom and also unproductive although extensive circulation losses occurred in the production section below 1175 m. Both wells may not have recovered thermally when the temperture runs were taken in which case reservoir temperature are higher than the temperature logging data indicate. The presence of hydrothermal alteration minerals in drillcuttings, such as epidote, indicates temperatures in excess of about 230°C. Thus, the drilling results have proved sufficiently high temperatures for the reservoir to be exploited for power generation but the low permeability is discouraging.

GeoNica revised their plan in the light of the poor outcome of the drilling of the first two wells and decided to drill 3 slim holes of 500 to over 1,000 m depth. The highest measured

temperature was 124°C although extrapolation of gradient in one well indicated 200°C. Thus, the results from the slimholes were not only negative with respect to permeability but also with respect to temperature.

ISOR reviewed the reports written by GeoNica on the results from the first two wells drilled at El Hoyo – Monte Galán (Mortensen and Egilsson, 2012). A part of the review included a three day visit to Nicaragua (21-23 July, 2010) and had meetings with MEM staff as well as GeoNica.

San Jacinto – Tizate

At present Triton Power (now RAM Power) operates a 72 MW_e power plant at San Jacinto. A total of 15 wells have been drilled of which 3 are used for injecting spent fluid. Seven wells are productive and connected to the power plant. The average yield of all drilled wells is close 5 MW and 6 MW if the three injection wells are excluded. This proves that permeability is good at San Jacinto. Reservoir temperatures range from 250°to 315°C. Part of the reservoir is two-phase but part liquid water. The field is elongated in a N-S direction, probably about 1 by 7 km, i.e. 7 km^2. This relatively small size gives an indication of its generating capacity. The wellfield (production area) at Casita is about 2.5 km^2. Mendieta (2009) is a potential of 225 MW_e for the Casita field based on estimation by the volumetric method. If the lateral extent of the field is truly 7 km^2, the volumetric estimate seems excessive. Both the relatively small size and shape of the geothermal field (reservoir) call for careful chemical monitoring to identify recharge of colder groundwater (is manifested by decrease in chloride of well discharges) into the reservoir that inevitably will occur as a consequence of pressure drawdown caused by the production load. Decrease in chloride may be regarded as a precursor of intense cold recharge. This is mentioned here to support MEM and because this is not mentioned in the two ISOR reports, discussed below.

ISOR has prepared two expert reports on the San Jacinto Project (Steingrimsson, 2011; Ingimundarson and Thórhallsson, 2009). The first deals with current status and future plans for monitoring and development but the subject of the second involves technical feasibility of the power plant, now already in operation. The reports form part of the contribution of ISOR to the GCBP.

Casita – San Cristóbal

Developments in this geothermal field are not included in Appendix I of the Final Project Document of GCBP. Yet, ISOR has produced a report on this field and MEM has been involved in following up of the concession holder, Triton Power (RAM Power), for their investigations in this area. They carried out surface exploration in the area and submitted a report on this work in June, 2005. The ISOR report is a part of the institutional support to MEM in Nicaragua under the auspices of GCBP. For these reasons, progress made during the development of the geothermal resource in the Casita area will be incorporated into the present report. The Casida concession was awarded to Triton Power (RAM Power) in 2002. This company re-assessed the geothermal potential of the area as part of their investigations in 2004 and carried out a structural geology study in 2002. The report of June 2005 describes work performed on surface exploration. A summary of the findings is given below which is based on an ISOR report (Hersir et al., 2009).

The Casita volcano is built up of andesitic volcanic with a large central crater (eruptive feature) or a caldera (summit collapse due to rapid emptying of a magma chamber). Normal faults seen as topographic features pass through the summit of the volcano. Likely they represent

permeability anomalies. Surface thermal activity in the area is widespread. The manifestations consist of fumaroles and steaming ground.

The relatively intense surface activity is considered to be a good indication of a high-temperature geothermal resource. The gas content of fumarole steam indicates sub-surface temperatures in excess of 250°C. Warm to hot springs are abundant. They are considered to represent steam-heated water and do not, therefore, give an indication of sub-surface temperatures. The lateral extent of the reservoir, as based on the results of MT-soundings and the distribution of surface geothermal manifestations is ~20 km^2. The power capacity of the reservoir is estimated to be 120-330 MW_e for 20 years, or 24-66 MW_e for a 100 year exploitation period. Two drilling targets are considered to be of greatest interest, 1) a possible vapor-dominated zone below the Casita Ridge and 2) liquid-dominated reservoir under the vapor zone. In their evaluation report, ISOR supports the four proposed exploration wells sites.

In 2009 MEM licenced Trinto Power to drill exploration wells at Casita. One slimhole has been drilled to almost 900 m depth. It encountered a 230°C steam zone and the well was productive. This was not unexpected.

As deduced from the extent of surface manifestations and MT-soundings, the lateral extent of the reservoir seems to be of the order of 4 km^2. If this is correct the estimated capacity of the reservoir is rather excessive. Information obtained during the visit of the EFET to Nicaragua was that another estimate was 85 MW potential with 90% probability.

Triton Power (RAM Power) has applied to MEM for an exploitation licence for a 33 MW_e power plant (three 11 MW turbines). Presently MEM is evaluating the application.