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UNU FELLOWS IN CENTRAL AMERICA AND MEXICO 1979-2008

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ABSTRACT

The Geothermal Training Program of the United Nations University (UNU-GTP), operated with great success at Orkustofnun – the National Energy Authority of Iceland, has over the past 30 years offered a geothermal training program to all Central American countries and Mexico. Of the 59 UNU Fellows trained (including UNU Fellows trained in 2008), 47 or 80% are still active in the geothermal industry. El Salvador and Costa Rica have the highest retention with 24 and 13 active fellows respectively. Around 60% occupy leading positions in governmental institutions, and all have contributed significantly to domestic geothermal industries and the energy sector. The UNU Fellows are leading specialists who have stepped out of traditional boundaries as implementers of know-how, and have assumed roles in the development and implementation of new geothermal practices and technologies in their home countries. UNU Fellows not only transfer knowledge acquired in their respective training courses, and implement their learning in geothermal resource development, but have also been able to successfully share best industry practices through the UNU Fellows network. Additionally, fellows successfully collaborate with third parties, research institutions, and consultants, contributing to the region's success in attracting international investors in the geothermal energy sector.

1. INTRODUCTION

Over the past 30 years, geothermal energy development in Central America and Mexico has substantially increased due to the world´s recent emphasis on the sustainable development of energy with clean resources. Nevertheless, this progress could not be possible without the competent training of regional geothermal experts through the UN University (UNU). During those years, geothermal resources were explored and developed which resulted in the construction of numerous geothermal power projects. For example, in El Salvador alone, the contribution of electricity generated from geothermal resources increased from 14% to some 24% by the year 2008. The continued success of the utilization of geothermal energy sources depends not only on public and private investments and the presence of geothermal resources, but also on development of knowledge and skills required for the successful development of a geothermal industry.

The training made available to Central American countries and Mexico, by the United Nations and countries with a long tradition of geothermal energy utilization such as Iceland, New Zealand, Japan, and Italy, has greatly contributed to the growing importance of geothermal energy sources, not only in terms of power generation, but also in terms of sustainable development of domestic renewable resources.

The Geothermal Training Programme continues to develop technical specialists in each of the relevant disciplines for geothermal resource utilization, with priority given to candidates from countries where geothermal exploration and development have been, or are currently under way. Feedback from the trainees and their institutions has also contributed to modifications and improvements to the training courses (*www.unugtp.is*).

2. BACKGROUND AND HISTORY OF THE UNU GEOTHERMAL TRAINING PROGRAMME

The United Nations University (UNU) was founded in 1975. Since 1979, the UNU Geothermal Training Programme of the United Nations University (UNU-GTP) has been operating at Orkustofnun - the National Energy Authority of Iceland, with great success. The goal of the UNU-GTP is to assist countries with significant geothermal potential to build-up or strengthen groups of technical specialists. The areas of specialization cover most aspects of geothermal exploration and development. Professionals employed in the respective local geothermal industries with at least one year of practical experience attend a six month course in Iceland. Some 59 professionals from five Central American countries and Mexico have benefited so far from the UNU-GTP (Figure 1).

FIGURE 1: Location map of Central American countries and Mexico

Geothermal institutions nominate their candidates, graduates in science or engineering, to participate in the UNU-GTP. Recipients of the Fellowship are selected based on the role of geothermal energy within the countries' energy plans; the institutional capabilities for geothermal research and utilization in the respective countries; and the national training needs. This is complemented by approximately biennial site visits by representatives of the UNU-GTP to the countries of nominees, and personal interviews with them.

Of the UNU Fellows trained in Iceland (not including UNU Fellows in 2008), El Salvador has the highest number of participants with 25, followed by 14 participants from Costa Rica (Table 1). In general, a high percentage of Fellows has remained in the energy industry. Of the 54 (59) UNU Fellows, some 42 (47) or 78% (80%) are still active in the geothermal industry in Central America and Mexico. El Salvador and Costa Rica have the highest retention with 22 and 12 active Fellows (Figure 2). Honduras, which has not developed its geothermal resources during the last 28 years, has the smallest number of fellows with none currently working in the geothermal industry.

TABLE 1: Areas of training (UNU Fellows 2008 added in italics)

Country	**Geolog. Explorat.**	**Borehole Geology**	**Geophys. Explorat.**	**Borehole Geophys.**	**Reservoir Engineer.**	**Chem. of Thermal Fluids**	**Environ. Studies**	**Geoth. Utilization**	**Drilling Technolo.**	**Total**
Costa Rica	2	2	2		2	2	2	2+*1*		14+*1*
El Salvador	1	1	2	2	5	4	3	4+*1*	3+*1*	25+*2*
Guatemala		1			1	1				3
Honduras		1	1							2
Mexico	1		1	+*1*	2					4+*1*
Nicaragua					3	2+*1*	1			6+*1*
Total	**4**	**5**	**6**	**3**	**13**	**10**	**6**	**8**	**4**	**54+5**
MSc Fellows	El Salvador 1: Roberto Renderos from 2007									

In the last 2 years, Honduras has submitted to private companies, concessions to explore and develop the geothermal resources in three different areas. Human resources trained are therefore needed to be able to complete all the phases included in the development of geothermal resources.

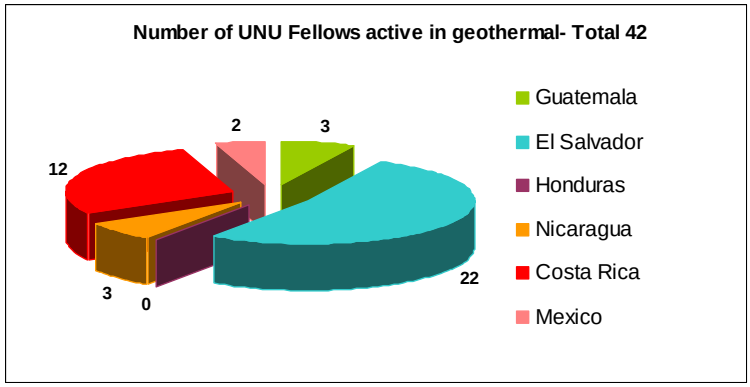

FIGURE 2: Number of UNU Fellows active in geothermal

While Mexico has the largest installed capacity (755 MW) compared to the Central American countries with 407 MW, and has made significant advances in the development of geothermal resources over the last 30 years, Mexico has made only limited use of the UNU-GTP. Mexico's Centro de Capacitación (Training Centre) in Morelia-Michoacán offers geothermal training courses aimed at Latin America. Short training courses are offered throughout the year covering Geosciences, Economics, Reservoir Engineering and Engineering Technology.

3. ACADEMIC BACKGROUND OF UNU FELLOWS FROM CENTRAL AMERICA AND MEXICO

UNU Fellows come from a wide variety of academic backgrounds ranging from geology, chemistry and physics to most of the engineering disciplines (mechanical, civil, electrical and chemical engineering). Geologists are in the majority with 31% (or 13) of the 42 currently active UNU Fellows, and are concentrated in Costa Rica. An academic foundation in geology proves to be the most versatile preparation to assume a wide variety of roles after the UNU-GTP. Geologists have joined electrical and mechanical engineers as geothermal reservoir engineers. Geologists and physicists often work in the area of geophysics. The second most prevalent academic background is chemist - chemical engineering and mechanical engineering with (12 and 8 each). The engineers work in diverse areas such as: drilling technology, geothermal utilization, engineering of geothermal processes and environmental studies (Figure 3).

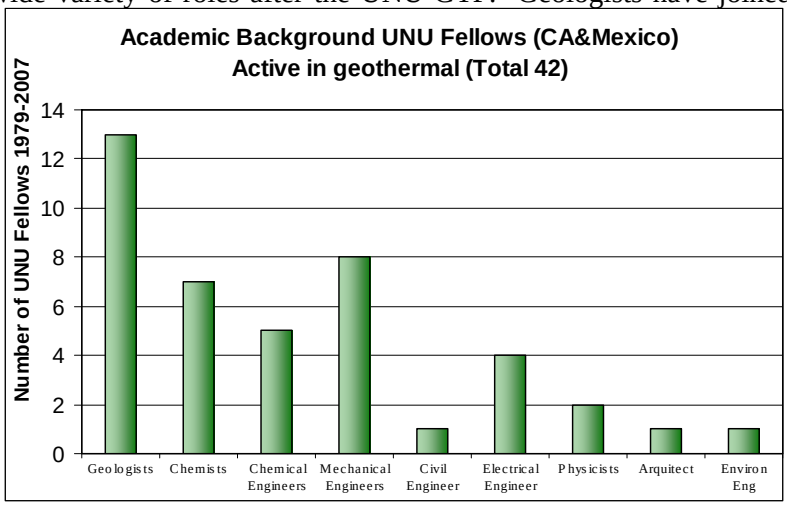

FIGURE 3: Academic background of UNU fellows (Central America & Mexico)

The UNU-GTP, combined with practical experience in geothermal resources, has allowed the professionals to become geothermal specialists (Table 2 and Figure 4). Most professionals have moved to the Reservoir Engineering stream, and are thus reflecting the advanced status of the geothermal industry with fields already operating; or are in the late development phase where there is a need for conceptual and numerical models. In addition, production chemistry plays an important role reflected in the attractiveness of the specialization in Chemistry of Thermal Fluids. Exploration continues to play an important role in Central America and Mexico, and hence disciplines such as geophysical and geological exploration,

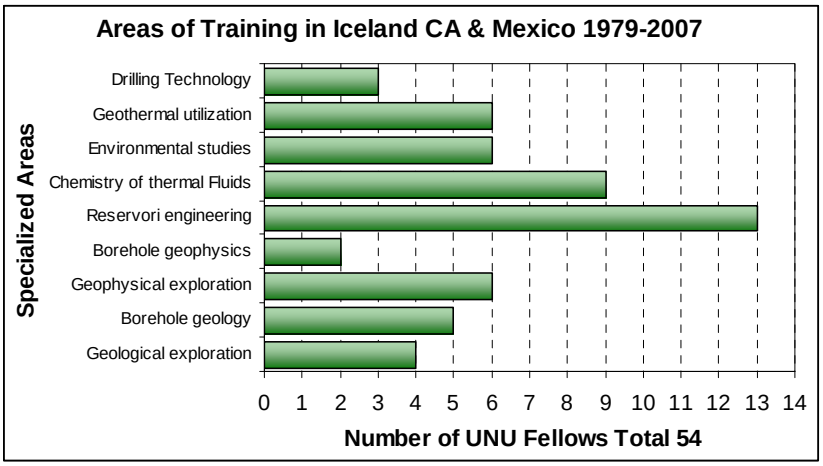

FIGURE 4: Areas of training in Iceland

TABLE 2: Areas of training in Iceland

Areas of training	%
Reservoir Engineering	24
Chemistry of Thermal Fluids	17
Geological Exploration and Borhole Geology	16
Geophysical Exploration and Borehole Geophysics	15
Environmental Studies, Geothermal Utilization and Drilling Tech.	28

drilling technology, and environmental studies continue to attract professionals. From the 54 professionals trained, 46% correspond to El Salvador, 26% to Costa Rica, 11% to Nicaragua and 6 and 7% to Guatemala and Mexico.

For an exploration work in a geothermal area in any of the Central American countries, the number of specialists required varies from 6 to 8. A geologist is needed to perform surface exploration, volcanological studies and borehole geology. A geophysicist usually performs magnetometric, gravimetric and seismic studies. The geochemist is in charge to perform studies in domestic wells and cold/hot springs, fumarolic areas and isotopic studies. The drilling specialist together with borehole geophysicist is needed while drilling wells and a reservoir engineer to make numerical simulations once several wells are drilled.

4. BENEFITS TO THE AREA

In all the Central American countries the demand for energy grows at 3-5% annually, this value more likely will be increased with the entrance in operation of the Free Trade Agreement. This implies an increment of over 100-200 MW in installed capacity, which currently now is being replaced by power stations based on oil, coal or gas. Central American countries need to look urgently for renewable sources such as geothermal and to depend less on sources with volatile energy prices that bring economic, political and social problems as well.

The geothermal industry requires necessarily the work of a multidisciplinary team, which often are specialists in very different areas. In Central America, the geothermal resources are not of common knowledge and are therefore frequently not included in the curriculum of undergraduate university studies. Therefore the geothermal specialists are technically prepared within the existing geothermal companies through development and skill programs. The skills and knowledge in geothermal is usually earned abroad in countries with extended geothermal background. In some universities Masters or PhD degrees are offered, but scholarships are often required. Iceland has for the last 30 years been one of the leading countries in the training for development of geothermal resources through the UNU-GTP based at Orkustofnun. This programme has since 1979 offered great opportunities to the Central American countries for training of geothermal specialists.

Former UNU Fellows are leading specialists in their countries. In Central America and Mexico, around 78% of all the trainees are still working in the geothermal sector with 10% occupying leading positions in governmental institutions. From the 54 UNU Fellows, 42 have contributed significantly to the domestic geothermal industries and energy sectors.

For example, in Guatemala, one UNU-GTP Fellow has assumed a leadership role in INDE (Instituto Nacional de Electrificación), specifically in the Rural Electrification Plan, and in the establishment of the Global Environmental Facility (GEF). A geologist trained in Iceland as reservoir engineer, is actually working as head of exploration in the Tecuamburro geothermal area in the Town of Viñas Santa Rosa (44 MW estimated), with ENEL, an Italian leading company in electrical energy production. The third UNU Fellow is currently working with borehole geology well studies.

In Costa Rica, UNU Fellows have assumed leadership roles in ICE (Instituto Costarricense de Electricidad) responsible for the geosciences, and have taken responsibility for implementing the ISO 14000 standards in geothermal operations. Most of the geologists have participated in exploration and borehole geology studies in geothermal areas such as Tenorio, Rincon de La Vieja (Borínquen and Las Pailas geothermal areas). Some have also assumed leading roles as head of geosciences and coordinators of reservoir engineering, geology and geothermal field operation areas. Environmental studies are executed by former UNU Fellows, gaining great experience in this topic.

A UNU Fellow from Nicaragua, now occupying management position at the Momotombo geothermal field, working also as a reservoir engineer coordinator in the Amatitlán geothermal field, Guatemala, obtained a PhD in Japan. A UNU Fellow who was recently trained in Chemistry of Thermal Fluids, now works as Director of the Geothermal Group and Renewable Energy at the University of León. His experience gained in sampling thermal fluids in Iceland has allowed him to work in different geothermal fields, such as San Jacinto Tizate in cooperation with LAGEO El Salvador as well as in the Managua-Chiltepe area. He is working in a project to transfer geothermal knowledge and skills to all the members of the group and to coordinate a geothermal diploma course in cooperation with LAGEO S.A. de C.V., El Salvador, as well as performing studies in the low- and high-enthalpy areas in cooperation with the Ministry of Energy and Mines of Nicaragua from 2009 to 2010. At the same time a former UNU Fellow is attending a postgraduate course in Norway in Environmental Impact Assessment and plans to obtain an International Master Degree in Environmental Assessment and Management of Resources.

In El Salvador, UNU Fellows have assumed senior roles in LAGEO S.A. de C.V., such as heads of exploratory studies in and outside the country, heads of reservoir engineering areas and facilities engineering, drilling superintendent of a newly formed Drilling Company within LAGEO (Santa Barbara), or have taken on leadership roles in the management of very important projects such as in Chinameca and the optimization of Ahuachapán.

5. UNU FELLOWS PERSONAL ACHIEVEMENTS

Below in Table 3 is a summary of the current roles of UNU Fellows. Most of them have been able to develop successfully their careers in their employing companies. This is also possible due to the continuous knowledge exchange and participation in congresses, geothermal research conferences, and workshops.

TABLE 3: Summary of current roles of UNU Fellows in Central America and Mexico

GUATEMALA*				
Name / University Degree	**Year of training**	**Area of work before Iceland**	**Training in Iceland**	**Area of work / Current position**
Carolina Grajeda Chemical Engineer	1992	Geochemistry	Chemistry of Thermal Fluids	Head of Restructuring Division / Technical Assistant of Manager
Nestor Renato Rodas Geologist	1996	Geology	Borehole Geology	Geology group
Francisco Asturias Geologist	2003	Borehole Geologist - Geologist	Reservoir Engineering	Reservoir Engineering. ENEL-Guatemala: Coordinator Exploration Studies -2008

EL SALVADOR

Name / University Degree	Year of training	Area of work before Iceland (CEL/LAGEO)	Training in Iceland	Area of work / Current position
J. Luis Zuniga Electrical Engineer	1980	Geophysics	Geophysical Exploration	Consultant
Carlos R. Pullinger Geologist	1991	Geology	Geological Exploration	National Service Territorial Studies (2001-2007) Project Manager of Chinameca geothermal area (2008)
Jaime A. Arevalo M. Mechanical Engineer	1992	Drilling Department	Drilling Engineering	Santa Barbara Drilling Company
Luz A. Barrios M. Geologist	1993	Geologist/XRD Lab	Borehole Geology	Geologist/Reservoir Engineering
Manuel Monterrosa Electrical Engineer	1993	Reservoir Engineering	Reservoir Engineering	Head Reservoir Engineering
Francisco Montalvo Chemist	1994	Geochemist/ Reservoir Eng.	Reservoir Engineering	Geochemist / Reservoir Engineer
Julio Quijano Electrical Engineer	1994	Reservoir Engineering	Reservoir Engineering	Reservoir Engineering
Guido G. Molina Mechanical Engineer	1995	Drilling Department	Drilling Engineering	Berlin central power plant Coordinator/Exploitation area
Pedro A. Santos Physicist	1995	Geophysics	Geophysical Exploration	Coordinator/Geophysics area
Arturo Quezada Geologist	1996	Geologist	Borehole Geophysics	Coordinator/Geology area
Jose L. Henriquez Mechanical Engineer	1997	Head Berlin geothermal field	Geothermal Utilization	Coordinator of fluid disposal system area
Marbin Martinez Chemical Engineer	1997	Chemical Engineering area	Chemistry of Thermal Fluids	Ministry of Environment and Natural Resources
Ricardo Ventura Computer Engineer	1997	Reservoir engineering	Reservoir Engineer Data base man.	Ministry of Education - Computer Programming
Ana Silvia de Arévalo Chemical Engineer	1998	Environmental Area	Environmental Studies	Coordinator - Environmental Studies
Carlos Emilio Guerra Chemical Engineer	1998	Chemical Engineering area	Drilling Technology	Production Chemistry/ Calcite Inhibition
Maria Inés Magaña Chemist	1999	Chemist / Laboratory	Chemistry of Thermal Fluids	Production Chemistry/ Calcite Inhibition
Jose Antonio Rivas Physicist	2000	Seismology/ Geophysics	Geophysical Exploration	Seismologist
Raul Edgardo López Chemical Engineer	2001	Environmental area	Environmental Studies	Environmental Studies
Roberto E.Renderos P. Chemist	2002	Chemical laboratory	Chemistry of Thermal Fluids	Head - Chemical Laboratory
Patricia Jacobo Chemist	2003	Chemical laboratory	Chemistry of Thermal Fluids	Chemical Engineering area
Anibal Rodríguez Mechanical Engineer	2005	Borehole measurements	Reservoir Engineering	Reservoir Engineering area
Blanca Minervini Architect	2005	Civil engineering Project management	Geothermal Utilization	Civil Engineering area Project Management
Kevin Padilla Chemical Engineer	2007	Environmental area	Geothermal Utilization	Environmental area - Engineering management
Manuel Rivera Electrical Engineer	2007	Ahuachapán power plant	Geothermal Utilization	Ahuachapán power plant
Juan Carlos Abrego Mechanical Engineer	2007	Engin. managem.: Fluid disposal system	Geothermal Utilization	Engineering management
Godofredo Lopez Industrial Engineer	2008	Ahuachapán power plant	Geothermal Utilization	LaGeo – UNU-GTP training in Iceland
Rosa Noemy Escobar Architect	2008	Civil engineering Project management	Drilling Engineering	LaGeo – UNU-GTP training in Iceland

NICARAGUA**				
Name / University degree	**Year of training**	**Area of work before Iceland - INE**	**Training in Iceland**	**Area of work / Current position**
Enrique Porras Mendieta Engineer	1991	Reservoir Engineering	Reservoir Engineering	ORMAT Momotombo-Amatitlán Res. Eng. (1993-2002), Japan (2003-2005) PhD. ORMAT Amatitlán Res Eng (2005-2006), ORMAT Momot. Proj. Man.(2005-2008)
Jorge Isaac Cisne Chemist	2006	University of León	Chemistry of Thermal Fluids	Professor University of León: Head of geothermal group
Irene Gilma Chow Environm. Engineer	2007	University of León	Environmental Studies	Norway: Environm. Assessment and MSc degree in EA and Res. Managem.
José Francisco Ruíz Chemical Engineer	2008	University of León	Chemistry of Thermal Fluids	INE - UNU-GTP training in Iceland
COSTA RICA***				
Name / University degree	**Year of training**	**Area of work before Iceland - ICE**	**Training in Iceland**	**Area of work / Current position**
Guillermo Lezama Geologist	1984	Geophysics	Geophysical Exploration	Coordinator geophysics area
Oscar Mora Protti Geologist	1989	Coordinator – Geology group	Borehole Geology	Borehole geology Las Pailas-Borinquen
Dagoberto Herrera Geologist	1990	Geophysics	Geophysical Exploration	Geophysics
Juan R. Vargas Geologist	1992	Field geologist	Geological Exploration	Not at ICE
Osvaldo E. Vallejos Mecánica engineer	1996	Reservoir engineer	Reservoir Engineering	Reservoir engineering
Rodolfo Bogarín Chemical engineer	1996	Coordinator Geoth. field operation	Geothermal Utilization	Not at ICE
Antonio Yock Fung Chemist	1998	Head of Geosciences area	Geothermal Utilization	Head of Geosciences
Hartmann Guido Sequeira, Civil Engin.	1999	Environmental assessment	Environmental Studies	Responsible environmental assessment
Fernando Molina Z. Geologist	2000	Borehole geology / Field work	Geological Exploration	Coordinator - geology group
Sergio Castro Geologist	2002	Borehole geology	Reservoir Engineering	Coordinator - reservoir engineering
Leyner Chavarría Rojas	2003	Borehole geology	Borehole Geology	Borehole geologist
Manuel Barrantes Geologist	2006	Environmental assessment	Environmental Studies	Environmental assessment
Alejandro Rodriguez Geologist	2006	Geochemist	Geochemist Exploration	Geochemistry
Federico Nietzen S. Bio engineer	2007	Coordinator Geoth. field operation	Geothermal Utilization	Coordinator geothermal field operation
Orlando Hernández Industrial engineer	2008	Geothermal field operation	Geothermal Utilization	ICE – UNU-GTP training in Iceland
MEXICO (****)				
Name/University Degree	**Year of training**	**Area of work before Iceland - CFE**	**Training in Iceland**	**Area of work / Current position**
Pedro Sanchez Upton Engineer	1986	Reservoir Engineering	Reservoir Engineering	Geothermoelectric Project Manager, Morelia, Michoacan
Jesús de León Vivar Engineer	1988	Reservoir Engineering	Reservoir Engineering	Cerro Prieto Geothermal Field Head/ Reservoir Engineering
Cecilia D. Lorenzo P. Geophysical Engineer	2008	Seismic monitoring	Borehole Geophysics	CFE – UNU-GTP training in Iceland

Note: * Grajeda, C., 2003, 2006, 2008, pers. comm.;
** Porras, E., 2003, 2006, 2008, Cisne, J., 2008, Chow, I. 2008, pers. comm.,
*** Vallejos, O., Castro, S., Yock, A., 2003, 2006, 2008, pers. comm..,
**** De León , J., 2003, pers. comm.

6. GEOTHERMAL RESOURCES IN CENTRAL AMERICA AND MEXICO AND UNU FELLOWS CONTRIBUTIONS

UNU Fellows are involved in the development of new fields and cooperate with third parties in the development of geothermal resources.

6.1 Guatemala

Guatemala has now two geothermal power plants installed. The first one is a privately operated 5 MW back pressure unit in the Amatitlán caldera project that has been in operation for almost nine years, with plans to install a condensing 25-30 MWe plant. The second is also a privately owned and operated 28 MWe power plant, which came on line in 1999, and is located in the Zunil I geothermal field. It should be operated by Ormat until the year 2019. Its estimated capacity is close to 50 MW. In the Zunil II geothermal field, the potential for power generation has been assessed at 40-50 MWe. At the end of 1999, Guatemala had 29 MWe on line or 3.7% of the country's installed capacity, and 216 GWh of power generated, also equivalent to 3.7%, from a total of 9 production wells in Zunil I and 4 wells in Amatitlán (Huttrer, 2000; Roldán Manzo, and Palma Ayala, 2000). In 2008, Guatemala is expected to produce 49.5 MW of geothermal electricity, having 24 MWe from Zunil I, 5 MWe from Zunil II and 20.5 MWe in Amatitlán, and the equivalent of 10 MW of direct use (Lund, 2000; Roldán Manzo, 2005).

In the year 2003, an agreement between the Guatemalan Government and IADB/GEF was signed for the development of the "Program for exploitation of the geothermal resources of Guatemala for electricity generation projects", which should be developed in the next four years after 2005. In 2004, the Guatemalan Government, published a law called "Incentives for the development of renewable energy projects", Decree No. 52-2003 to facilitate a tax exemption for the imports of machinery and equipment to be used in projects of energy based on renewable energy and ten years of income tax exemption after the initial date of production.

One of the UNU Fellows is currently working in a Global Environment Facility (GEF) programme implemented by INDE in the year 2003. It was designed to promote renewable energy such as geothermal by overcoming physical and institutional barriers for investment in the electricity sector through initiatives to increase the competitiveness of renewable energy, the development of a database, and by working on an institutional framework.

Following geochemical studies executed from 1995 to 2000, the areas of Totonicapán, Moyuta, Tecuamburro and San Marcos have been identified as potential commercial targets. The Totonicapán geothermal field was the subject of an International Atomic Energy Agency (IAEA) study. Actually ENEL an Italian company is carrying out a reconnaissance study in the Tecuamburro geothermal area with the prospect of installing a 44 MWe power plant in the town of Viñas Santa Rosa.

6.2 Honduras

Honduras does not have a geothermal power plant. Even though regional studies were performed during the seventies and eighties by the United Nations and USAID, more than twenty eight years past, no additional studies have been carried out. Some attempts were made by the ENEE - Empresa Nacional de Energía Eléctrica to obtain financing to continue with the studies (Castillo et al., 2000). Just recently three concession areas were given to private companies, to explore and develop the geothermal resources. The purpose is to install an electrical power plant. Platanares is the first geothermal area to be developed by a company named Geoplatanares. Three exploratory wells will be drilled at the beginning of the year 2009 and each down to approx. 1500 m depth. The plan is to have close to 35 MWe with 90% of probability. The contract with a specialized drilling company is already prepared, the access roads are ready and one of the three pads is already finished, waiting for all the drilling materials to arrive.

Azacualpa and Pavana will be developed by a company named GeoPower and they are now planning to drill gradient wells by the end of 2009. The government is supporting the developing of the renewable resources such as geothermal, and has recently approved a law which offers several incentives for the developing companies. The government does not develop the geothermal resources.

In 1980 and 1988, two UNU Fellows from ENEE were sent to Iceland to be trained in geophysical exploration and borehole geology. One of them moved over to the hydro department of ENEE when geothermal work slowed down in the country. There is no record on the other. With the initial activities observed by the private companies, human resources with geothermal knowledge and skills are necessary.

6.3 El Salvador

After the first power plant was commissioned in Ahuachapán in 1974, which over the subsequent 6 years was built up to the capacity of 95 MWe, El Salvador did not experience further development of its geothermal resources, during the civil war in the 1980´s. The Ahuachapán power plant was under the administration of Comisión Ejecutiva Hidroeléctrica del Rio Lempa (CEL). During this time, an over exploitation of the field caused a pressure decline and the average generation was 40-45 MWe.

During the 1990´s, exploration studies were executed to the south, at Ahuachapán - Chipilapa (east of Ahuachapán 1990), Berlin - Chinameca (1993-1994), and Coatepeque (1990). In 1992, a back-pressure power plant began operating in Berlin with steam supplied from 2 production wells. During 1997-1999, eighteen new wells were drilled and a production and injection system for the water was established. As a result of all these activities, in the year 1999 a new condensing power plant with 2 units was commissioned with an installed capacity of 56 MWe (28 MWe each unit). At the same time, 10 new wells were drilled in order to increase the installed capacity in Ahuachapan to 95 MWe as part of the Ahuachapán rehabilitation project. UNU Fellows actively participated in all these activities, such as well selection, technical design, borehole geology, development strategies, well testing and numerical modelling for the Berlin condensing power plant and Ahuachapán rehabilitation project.

By the end of 1998, the geothermal resources division within CEL was spun off into a new company named Geotérmica Salvadoreña S.A. (GESAL), which a few years later changed its name to LaGeo S.A. de C.V. and is now jointly owned by CEL and Enel Green Power of Italy. During the years 2000 to 2008, the participation of all 22 UNU Fellows in LaGeo has increased, and they have taken leading positions within several projects such as:

- Establishing business units within Lageo.
  i. Laboratory of chemical analysis. The laboratory offers technical services to external parties in El Salvador and other countries in Central America. To achieve this, the laboratory obtained its accreditation under the Quality System of CONACYT (Consejo Nacional de Ciencia y Tecnología) and staffs were trained in accordance with Norm ISO/IEC 17025. A UNU Fellow is the head of this project but is actually in Iceland now MSc studies in Geothermal Energy.
  ii. Santa Barbara Drilling Company - a drilling company which is majority owned by LaGeo and has a UNU Fellow as the superintendent. It has three drilling rigs and provides drilling services to Berlin, Cuyanausul, Ahuachapán, San Vicente and Chinameca Geothermal fields. Recently mechanical workover and cleaning jobs were performed with one rig in Momotombo geothermal field, Nicaragua. Drilling contracts were signed with Chile and several wells will be drilled in Hoyo Monte Galan and Managua Chiltepe geothermal areas in Nicaragua in the year 2009.

- Hot fractured rock / Enhanced geothermal system project was carried out in a joint-venture with Shell where plan was to increase the production capacity by 5 MW through a massive hydraulic stimulation of a low-permeability well. All members of the reservoir engineering group and

project chief were former UNU Fellows. New activities were developed and implemented in this project e.g. tracer tests for three types of di-sulfonates; detailed high-resolution pressure monitoring; streaming potential induced by fluid flow; micro-seismic monitoring; and modern logging activities. The hydraulic fracture increased injection capacity of a tight injection well, even though the energy production was not obtained due to failure in propagating fractures.

- Cuyanausul project was executed jointly with LaGeo´s strategic partner, ENEL Green Power Company of Italy, with the goal to build a 10 MWe power plant in Cuyanausul. The exploration work was performed by UNU Fellows. Two wells were drilled but the hot temperature geothermal resource was not encountered.

- Berlin's new development project was executed jointly with LaGeo´s strategic partner, ENEL Green Power Company of Italy, with the goal to build a third power generation unit of 44 MWe in Berlin. UNU Fellows supplied the database for ENEL, and are working closely together with their technical staff in updating the geothermal and numerical modelling, location, design and drilling of wells. The new condensing unit was commissioned by November of 2006. UNU Fellows were in charge of the exploitation department and borehole measurements area and both worked together with the reservoir engineering members (UNU Fellows) to build injection and production scenarios capable of sustaining the electrical generation. A new expansion project has been proposed in order to develop the south and southwest area to install the fifth unit of 28 MWe. This will be done by using the already existing pads and by building new ones. Three production wells and two injection wells are planned.

- A bottoming cycle binary plant was built to produce 9 MW from the extraction of residual heat from the separated water.

- Chemical stimulation in Berlin – Ahuachapan – San Vicente geothermal fields: As part of the operations and management plan of the Berlin field, several injection and production wells were chemically stimulated to maintain a stable generation (60 MWe). The excellent results have proved to be a cost effective technique to implement in all the production and injection wells. Seven wells in the Ahuachapan field were chemically cleaned showing excellent results. A total of 40 stimulation works have been performed in injection and production wells since the year 2000 up to 2008. From these, 12 stimulation jobs were performed by a service company and 28 were selected, designed, planned and executed by UNU Fellows. UNU Fellows participate actively in leading this project. An increase of close to 40 MWe has been experienced, and a total of 322 kg/s in injection capacity improvement.

- A project called "Optimization of Ahuachapan geothermal field" is conducted by a UNU Fellow in order to increase its power by 25 MWe. From these, 15 MWe are now actually produced by opening more production wells, without the extreme abatement of the reservoir pressure. Chemical stimulation and drilling of new wells are planned to be executed in the next year to complete the remaining 10 MWe. Two production wells at the southern and central part of the field were drilled and an output of 15 MWe was obtained. The third phase of the project is waiting, aiming to improve the efficiency of the second unit of the Ahuachapan power plant.

- Exploration projects in the east part of the country, starting with San Vicente, Apastepeque-Obrajuelo, Chinameca and Conchagua, were done under the leadership of the head geoscientists, all UNU Fellows.

- A concession awarded to Orpower 7 Inc., which later was called San Vicente 7 Inc., El Salvador, a subsidiary of LaGeo is in charge of developing the San Vicente geothermal field. The first well SV1 was drilled in the year 1979 and three exploratory wells were drilled (SV1A, SV2 and SV3) during 2005-2006. The SV1A well had high temperature but low permeability. Wells SV2 and SV3 encountered high permeability but low temperature. The project has ended

but exploratory drilling will be performed in the future but closer to the heat source of the San Vicente volcano where higher temperature and permeability is expected.

- Exploration studies were performed in the Chinameca geothermal area and the drilling of one vertical production well will start at the end of 2008. If the results are good, a deviated well will be drilled from the same pad to further develop the field towards the south and southeast.

- UNU Fellows are also working outside El Salvador, specifically in Nicaragua's San Jacinto - Tizate geothermal field where LaGeo is in charge of designing the steam gathering system, designed previously by a private company. LaGeo is responsible for the bidding document, awarding the execution of the contract and supervising the installations of the surface facilities as well as the operation of the two well head units, which started generation in the year 2005.

- UNU Fellows worked in Nicaragua in exploratory studies in two concession areas owned by LaGeo: Hoyo Monte Galan and Managua - Chiltepe. Other fellows will interact in different stages and aspects in the development of these two fields.

- In El Salvador geothermal plants actually supply 23-24% of the current electrical demand, but with all the recent projects performed, an expansion to 46% is expected by the year 2010. About 70% of this increment is under progress through the projects Optimization of Ahuachapan, the Binary cycle power plant and the expansion of Berlin geothermal power plant (40 MWe).

- Pumping stations: Former UNU Fellows worked together with the management director of the pumping stations of Berlin at the TR1 pad.

6.4 Nicaragua

In 1983, the Instituto Nicaragüense de Energía (INE), commissioned the first 35 MWe single flash unit at the Momotombo geothermal field. A similar second unit was built and installed in 1989. Power production declined to 20 MWe in the late 1980s due to a drop in production pressure and production constrained by injection. A private operator signed a contract with INE in 1999 to restore the power generation up to 70 MWe. This was the first exploitation contract. Since then, power generation has been raised to the presently utilized capacity of 35 MWe (Huttrer, 2000). In all, 11 wells are used to produce steam and 5 wells are used for reinjection.

Several activities have been performed such as drilling of new wells, workover of existing production wells, which included mechanical repairs and cementing jobs. Chemical stimulation was performed in injection wells to enhance permeability. In production wells, cleaning was done mainly to clean calcite scaling. Injection of brine of 100% is carried on to develop reservoir pressure and to avoid pollution of the Managua Lake. At the end of the year 2002, a 7.5 MW binary power plant came on line in order to increase generation (Porras, 2008).

The only active UNU Fellow, a reservoir engineer, has worked on well workovers with a service provider in the chemical stimulation program and was in charge of leading the implementation of a calcite inhibition system. Actually he is now the production manager of Momotombo geothermal field, after returning from completing his PhD studies in Reservoir Engineering in Japan.

The second concession is for the San Jacinto geothermal project and this was given to a private company named San Jacinto Power SA, a wholly owned Nicaraguan subsidiary of the Panamanian based Polaris Energy Corporation (formerly the San Jacinto Energy Corporation). Polaris has negotiated a twenty year "Take or Pay" power purchase agreement to supply 66 MWe of electricity to the Nicaraguan grid, which will require the installation of a 70-75 MWe gross power plant. San

Jacinto just finished the first drilling phase with one deviated production well SJ6-2 with 22.8 MWe with a WHP of 800 psi and 303°C at the bottom.

Two concession areas, Hoyo Monte Galan and Managua-Chiltepe were given to GEONICA, a company composed by 60% of ENEL Italian Energy Company and 40% of Lageo. The exploration studies were already finished and were performed by Lageo´s geoscientists. The Environmental Impact Studies have been submitted to MARENA (Ministry of Environment of Nicaragua) and the respective environmental permissions will soon be received in order to start with the deep exploratory drilling by October of 2008.

By June 2008, an International bidding process started for the geothermal areas of Volcan Casita - San Cristobal. The final date for submitting the offers is August 7th. The bids will be reviewed and the process will finish by the end of 2008 with the contract of the concession to explore these areas for a period of two years. Two more areas are in the waiting list for future concessions, Apoyo and Mombacho. The decision will be made by the Ministry of Energy of Nicaragua perhaps by year 2009.

6.5 Costa Rica

Since 1994, when the first power plant was commissioned (55 MWe), the installed geothermal power generation capacity has grown to 162.5 MWe (Huttrer, 2000; Mainieri, 2005). At the end of 2005, the energy produced by Miravalles geothermal system, represented 15.1% of the total energy produced in the country.

All technical work within the disciplines of geothermal investigations are being executed by UNU Fellows trained in the last fifteen years (1990-2008). Particularly in the Miravalles geothermal field, UNU Fellows are involved in the continuous update of reservoir models as the field expands, in the execution of isotope studies and in the hydraulic characterization of the field. Furthermore, environmental scientists are working with the environmental assessment of Miravalles, educational programmes and environmental communication. The implementations of Norms ISO 14000 showed excellent results.

In parallel with the expansion of the Miravalles field in the last years, the geothermal areas of Tenorio and Rincón de la Vieja have also been explored with the participation of UNU Fellows. Recent drilling campaigns have taken place in Las Pailas (southeast of the volcano Rincón de la Vieja) and Borínquen (northwest of the volcano Rincon de la Vieja) areas, with the UNU Fellows in charge of borehole geology.

All the studies in the Las Pailas field were successfully completed and the first 35 MW plant feasibility report has been already presented. Based on the national electrical development programme, this unit will be online by the year 2010. Until now, the direct use of the geothermal energy has been limited to a few swimming pools (Mainieri, 2005).

UNU Fellows are integrating new information and developing conceptual models of the fields. Once new wells are drilled, they continuously monitor the production and thermohydraulic conditions. The contributions of the UNU Fellows have helped Costa Rica to gain a leading position in the utilization of geothermal energy in Central America.

7. CONCLUSIONS

UNU Fellows not only transfer knowledge acquired in their respective training courses, and implement their learning in geothermal resource development, but have also been able to successfully share best industry practices through the UNU Fellows network. The close cooperation that is visible

particularly in Central America and the continued success of geothermal energy utilization attest to the vibrant community of geothermal experts in the region.

More importantly, UNU Fellows have stepped out of traditional boundaries as implementers of know-how and have assumed roles in the development and implementation of new geothermal practices and technologies. UNU Fellows successfully collaborate with third parties, research institutions and consultants contributing to the region's success in attracting international investors in the geothermal energy sector.

Geothermal energy will play an increasingly important role in the sustainable development of energy sources in a future carbon-constrained world where successful management of climate change will play an important role. UNU Fellows with their detailed knowledge of the resource base will continue to contribute to the development of geothermal resources not only in technical terms but also in the setting and implementation of electrification policies and plans (see Guatemala). On a wider scale, UNU Fellows have proven to have the skills and competencies that enable them to develop in new areas and directions such as natural disaster management.

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