Contribution of UNU/GTP training to geothermal development in Central America – Mexico

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Abstract

The Geothermal Training Programme of the United Nations University (UNU/GTP), operated with great success at the National Energy Authority of Iceland (Orkustofnun), has offered over the past 25 years, a geothermal training programme to all the Central American countries and Mexico. Of the 44 UNU/GTP Fellows trained, 31 or 70% are still active in the geothermal industry. El Salvador and Costa Rica have the highest retention with 16 and 9 active Fellows, respectively. Around 10% occupy leading positions in governmental institutions, and all have contributed significantly to domestic geothermal industries and the energy sector. UNU/GTP Fellows are leading specialists, 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/GTP 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/GTP 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.

Keywords: *United Nations University, Geothermal Training Programme, Central America, Mexico, Geothermal Utilization.*

1 Introduction

Over the past 25 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 have been 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 22% by the year 2002. 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 has

been, or is, currently under way. Feedback from the trainees and their institutions has also contributed to modifications and improvements to the training courses (http://www.os.is/unugtp/)

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 areas of geothermal exploration and development. Professionals employed in the respective domestic geothermal industries with at least one year of practical experience attend a six-month course in Iceland. Some 44 professionals from five Central American countries and Mexico (Figure 1) have benefited so far from the UNU/GTP (Table 1).

Figure 1: Location map of Central American countries and Mexico

Table 1: Areas of training.

FELLOWS OF THE UNU GEOTHERMAL TRAINING PROGRAMME IN ICELAND 1979-2003										
Country	Geological exploration	Borehole geology	Geophysical exploration	Borehole geophysics	Reservoir engineering	Fluid chemistry	Environmen. studies	Geothermal utilization	Drilling technology	Total
Guatemala		1			1	1				3
El Salvador	1	1	2	2	4	4	2	1	3	20
Honduras		1	1							2
Nicaragua					3	1				4
Costa Rica	2	2	2		2	1	1	1		11
Mexico	1		1		2					4
Total	4	5	6	2	12	7	3	2	3	44

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 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/GTP Fellows trained in Iceland, El Salvador has the highest number of participants with 20 (45%), followed by 11 participants from Costa Rica (25%)

(Table 1). In general, a high percentage of Fellows have remained in the energy industry. Of the 44 UNU/GTP Fellows, some 31 or 70% are still active in the geothermal industry in Central America and Mexico. El Salvador and Costa Rica have the highest retention with 16 and 9 active Fellows (Figure 2). Honduras, which has not developed its geothermal resources during the last 25 years, has the smallest number of Fellows with none currently working in the geothermal industry.

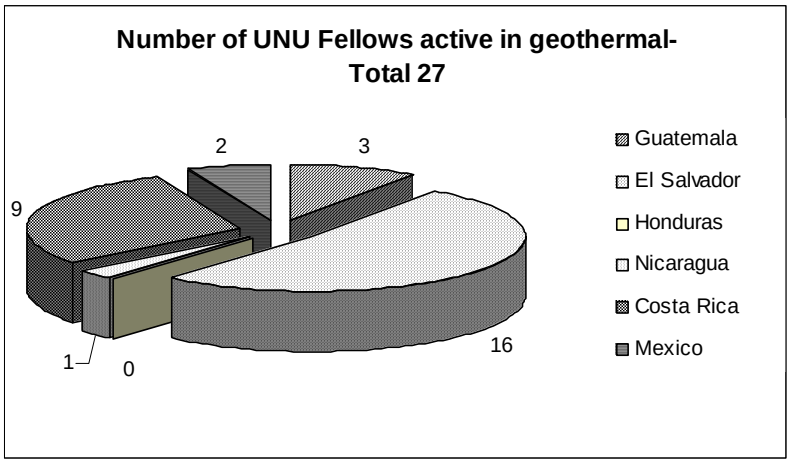

Figure 2: Number of UNU/GTP Fellows active in geothermal.

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 25 years, Mexico has made only limited use of the UNU/GTP. Mexico's Centro de Capacitación (Training Center) in Morelia-Michoacán, part of Comisión Federal de Electricidad (CFE) offers geothermal training courses aimed at Latin America. Short training courses are offered throughout the year covering the Geosciences, Economics, Reservoir Engineering and Engineering Technology.

3 Academic background of UNU/GTP Fellows from Central America and Mexico

UNU/GTP 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 – Figure 3). Geologists are in the majority with 32% (or 10) of the 31 currently active UNU/GTP 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 chemistry, chemical and mechanical engineering with 17% (5 each). The engineers work in diverse areas such as drilling technology, geothermal utilization, engineering of geothermal processes and environmental studies, while the chemists are working in chemical work (Figure 3).

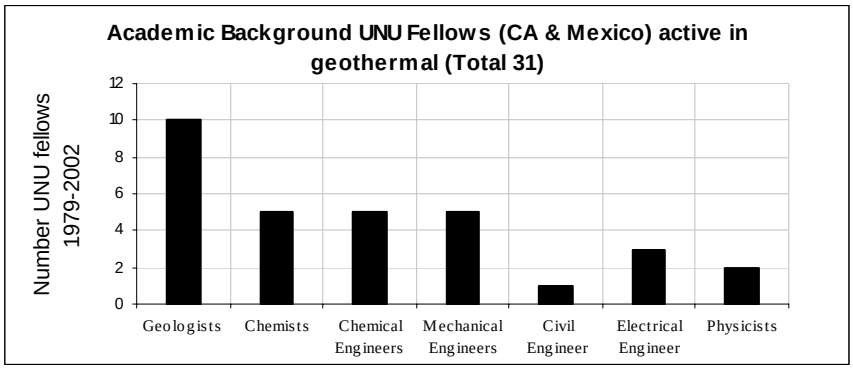

Figure 3: Academic Background UNU/GTP Fellows (Central America & Mexico).

The UNU/GTP, combined with practical experience in geothermal resources, has allowed the professionals to become geothermal specialists (Figure 4). Most professionals have moved to the Reservoir Engineering stream, 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, drilling technology, and environmental studies continue to attract professionals.

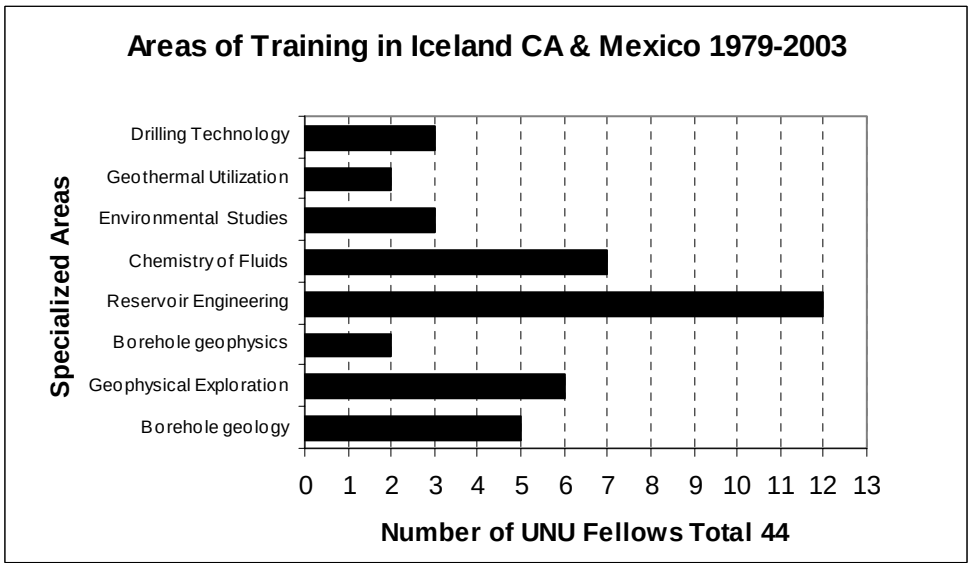

Figure 4: Areas of Training in Iceland.

4 Benefits to the area

Former UNU/GTP Fellows are leading specialists in their countries Around 70% of all the trainees are still working in the geothermal sector in Central America and Mexico, with 10% occupying leading positions in governmental institutions. The 44 UNU/GTP Fellows 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).

In Costa Rica, UNU/GTP 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. A UNU/GTP Fellow from Nicaragua, former staff of INE (Instituto Nacional de Energía), has recently moved on to obtain a PhD in Japan.

In El Salvador, UNU/GTP Fellows have assumed senior roles in LaGeo S.A de C.V.), such as heads of reservoir engineering and facilities engineering, drilling superintendent of a newly formed drilling company within LaGeo (Santa Barbara), or have taken on leadership roles in state institutions (SNET – Servicio Nacional de Estudios Territoriales) tasked with natural disaster management.

5 UNU/GTP Fellows personal achievements

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

MEXICO (****)

Name/University Degree	UNU/GTP Fellow Year	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

NICARAGUA (**)

Name/University Degree	UNU/GTP Fellow Year	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- Reservoir Engineering (1993-2002) Japan (2003) PhD

COSTA RICA (***)

Name/University Degree	UNU/GTP Fellow Year	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	Geological institute Not at ICE
Osvaldo E. Vallejos Mecánica Engineer	1996	Reservoir Engineer	Reservoir Engineering	Reservoir Engineering
Antonio Yock Fung Chemist	1998	Head of Geosciences Area	Geothermal Utilization	Head of Geosciences
Hartmann G Sequeira Civil Engineer	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 Chavarria R. Geologist	2003	Borehole Geology	Borehole Geology	

EL SALVADOR

Name/University Degree	UNU/GTP Fellow Year	Area of work before Iceland (CEL/GESAL/LaGeo)	Training in Iceland	Area of Work/Current Position
J.Luis Zuñiga Engineer	1980	Geophysics	Geophysical exploration	Consultant
Carlos R. Pullinger Geologist	1991	Geology	Geological exploration	SNET National Service Territorial Studies.
Jaime A. Arévalo M. Mechanical Engineer	1992	Drilling Department	Drilling Technology	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 Engineering	Reservoir Engineering	Geochemist/Reservoir Engineering
Julio Quijano Electrical Engineer	1994	Reservoir Engineering	Reservoir Engineering	Reservoir Engineering
Guido G. Molina Mechanical Engineer	1995	Drilling Department	Drilling Technology	Berlin Central Power Plant Coordinator-Exploitation Group
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	Facilities System. Manager of GESAL /Shell Joint Venture
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 Manage.	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	Drilling Technology	Production Chemistry / Scale Inhibition
Maria Inés Magaña Chemist	1999	Laboratory Chemist	Chemistry of Thermal Fluids	Chemist
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 E. Jacobo H. Chemist	2003	Chemical Laboratory	Chemistry of Thermal Fluids	

GUATEMALA (*)

Name/University Degree	UNU/GTP Fellow Year	Area of work before Iceland (INDE)	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 the General Manager of INDE
Nestor Renato Rodas Geologist	1996	Geology	Borehole Geology	Geology Group INDE
Francisco Alberto Asturias	2003	Geology	Reservoir Engineering	

Note: (*) Grajeda, C., 2003, Personal communication; (**) Porras, E., 2003, Personal communication; (***) Vallejos, O., Castro, S., Yock A., 2003, Personal communication; (****) De León , J., 2003, Personal communication.

6 Geothermal resources in Central America and Mexico and UNU/GTP Fellows' contributions

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

6.1 Guatemala

In 2003, Guatemala now has two geothermal power plants installed. The first is a privately operated 5 MW backpressure unit in the Amatitlán Caldera Project, which has been in operation for three years, with the goal to install a condensing 25-30 MWe plant. The second is a privately owned and operated 28 MWe power plant, which came on line in 1999, and is located in the Zunil I geothermal field. 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, which is 3.68% of the country's installed capacity with 216 GWh of power generated, equivalent to 3.7% from a total of 9 production wells in Zunil I, and 4 in Amatitlán (Huttrer, G., 2000; Roldan Manzo, A.R. and Palma Ayala, J.C., 2000).

One of the UNU/GTP Fellows is currently planning to work in a Global Environment Facility (GEF) program to be implemented by INDE. This is 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. Currently, the Totonicapán Geothermal Field is the subject of an International Atomic Energy Agency (IAEA) study.

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 thirty years have gone by and no additional studies have been performed. Some attempts have been made by the ENEE-Empresa Nacional de Energía Eléctrica to obtain financing to continue with the studies (Castillo et al., 2000).

In 1980 and 1988, two UNU/GTP 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.

6.3 El Salvador

Since 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 for a long time due to the civil war in the 1980s. The Ahuachapán power plant was under the administration of Comisión Ejecutiva Hidroeléctrica del Rio Lempa (CEL). In this time, an over exploitation of the field caused a pressure decline and the average generation was 40-45 MWe.

During the 1990s, exploration studies were executed in the southern zone at Ahuachapán - Chipilapa (east of Ahuachapán, 1990), Berlin - Chinameca (1993-

1994), and Coatepeque (1990). In 1992, a backpressure 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 water was established. As a result of all these activities, in the year 1999, a new condensing power plant was commissioned with an installed capacity of 56 MWe. At the same time, 10 new wells were being drilled in order to increase the installed capacity in Ahuachapan to 95 MWe as part of the Ahuachapán Rehabilitation Project. UNU/GTP Fellows actively participated in all these activities, such as well picking, technical design, borehole geology, development strategies, well testing and numerical modelling for the Berlin condensing power plant and Ahuachapán Rehabilitation Project.

The geothermal resources division within CEL was spun off into a new company named Geotérmica Salvadoreña S.A. (GESAL S.A. de C.V.) by the end of 1998, with CEL as the major shareholder. Recently on July 2003 GESAL changed its name to LaGeo S.A. de C.V. During the years 2000 to 2003, the participation of all 15 UNU/GTP Fellows in LaGeo has been increasing, and they have taken leading positions within several projects such as:

- Establishing business units within GESAL.
  i. Laboratory of Chemistry Analysis. The laboratory offers technical services to external parties in El Salvador and other countries in Central America. To achieve this, the laboratory is in the process of getting accreditation under the Quality System of CONACIT (Consejo Nacional de Ciencia y Tecnología) and trains staff in accordance with Norm ISO/IEC 17025. One UNU/GTP Fellow is the head of this project.
  ii. Santa Barbara Drilling Company - a newly established drilling company majority owned by LaGeo with one UNU/GTP Fellow as the superintendent.
- Hot Fractured Rock / Enhanced Geothermal System Project is a joint venture with Shell where the production capacity is planned to be augmented by 5 MW through a massive hydraulic stimulation of a low permeability well. All members of the reservoir engineering group and the LaGeo project chief are former UNU/GTP Fellows who will develop and implement new activities 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.
- Berlin's new development and the Cuyanausul project are executed jointly with LaGeo´s recently acquired strategic partner, ENEL Green Power Company of Italy, with the goals to build a third power generation unit of 28.5 MWe in Berlin, and to develop 10 MWe in Cuyanausul. UNU/GTP Fellows supplied the database for ENEL, and are working closely together with their technical staff in updating the geothermal and numerical modelling, location and designs of wells, and other projects.
- Chemical stimulation in Berlin. As part of the operations and management plan of the Berlin Field, several injection wells were chemically stimulated to maintain peak production while minimizing the production of steam. Two production wells were successfully stimulated and one production well was shut in and a second production

well is now used as a pressure monitoring well. The UNU/GTP Fellows participated actively in leading this project.

- Other projects: Feasibility of a Binary Power Plant in Berlin; injection augmentation in Ahuachapán; exploration projects in Apastepeque Obrajuelo.
- UNU/GTP Fellows are also working outside El Salvador, specifically in Nicaragua's San Jacinto - Tizate Geothermal Field where LaGeo has been in charge of changing the technical design of 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.

6.4 Nicaragua

The Instituto Nicaragüense de Energía (INE) commissioned the first single-flash unit of 35 MWe in the Momotombo Geothermal Field in 1983. 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. Since then, power generation was raised to the presently utilized capacity of 35 MWe (Huttrer, G., 2000). Several activities have been performed such as drilling of new wells, and chemical stimulation of wells. The only active UNU/GTP Fellow, a reservoir engineer, 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.

6.5 Costa Rica

Since 1994, when the first power plant was commissioned (55 MWe), the installed geothermal power generation capacity has grown to 142.5 MWe. Costa Rica plans to have an installed capacity of 161 MWe by the end of 2003 (Huttrer, G., 2000). All technical work within the disciplines of geothermal investigations are being executed by UNU/GTP Fellows trained in the last twelve years (1990-2002). Particularly in the Miravalles geothermal field, UNU/GTP 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 programs and environmental communication. The implementation of the ISO 14000 standards is also in progress.

In parallel with the expansion of the Miravalles field in the last decade, the geothermal areas of Tenorio and Rincón de la Vieja geothermal have also been explored with the participation of UNU/GTP Fellows. Recent drilling campaigns have taken place in Las Pailas (SE of Volcán Rincón de la Vieja) and Borínquen (NW of Volcán Rincon de la Vieja) areas, with the UNU/GTP Fellows in charge of borehole geology. UNU/GTP Fellows are integrating new information and developing conceptual models of the fields. Once new wells are drilled, they have continuously monitored the production and thermohydraulic conditions. The contribution of UNU/GTP Fellows has helped Costa Rica to gain a leading position in the utilization of geothermal energy in Central America.

7 Conclusions

UNU/GTP Fellows not only transferred knowledge acquired in their respective training courses, and implemented their learnings in geothermal resource development, but have also been able to successfully share best industry practices through the UNU/GTP 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/GTP 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/GTP 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/GTP 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/GTP Fellows have proven to have the skills and competencies that enable them to develop in new areas and directions such as natural disaster management.

8 Acknowledgements

I would like to give my sincere congratulations to all the UNU/GTP Fellows who have continuously contributed in the development of geothermal resources in each of their countries. I would like to greatly express many thanks, especially to Carolina Grajeda from Guatemala; Enrique Porras from Nicaragua; Osvaldo Vallejos, Sergio Castro and Antonio Yock from Costa Rica; and Jesus de Leon from Mexico, who willingly and promptly shared the information required for this paper. Also to Dr. Ingvar B. Fridleifsson, Director of the UNU/GTP at Orkustofnun, my sincere thanks for allowing me to share what Central America and Mexico UNU/GTP Fellows are currently doing in the geothermal industry.

9 References

Castillo, G.E., and Salgado, R.M. (2000). Honduras Country Update Paper. *Proceedings World Geothermal Congress 2000*, Japan, pp. 123-124.

Castro, S. (2003). Recent work in Costa Rica. Personal communication via email.

Grajeda, C. (2003). Recent work in Guatemala. Personal communication via email.

Huttrer, G. (2000). The Status of World Geothermal Power Generation 1995-2000. *Proceedings World Geothermal Congress 2000*, Japan, pp. 23-37.

Lund, J. (2000). World Status of Geothermal Energy Use Overview 1995-1999. *Proceedings World Geothermal Congress 2000*, Japan, pp. 4105-4111.

Porras, Mendieta E. (2003). Recent work Nicaragua. Personal communication via email.

Roldan Manzo, A.R., and Palma Ayala, J.C. (2000). Geothermal Power Development in Guatemala 1995-1999. *Proceedings World Geothermal Congress 2000*, Japan, pp. 407-412.

United Nations University Geothermal Training Programme website: http://www.os.is/unugtp/

Vallejos, O. (2003). Recent work in Costa Rica. Personal communication via email.

Yock, A.(2003). Recent work in Costa Rica. Personal communication via email.