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GEOTHERMAL CAPACITY BUILDING FOR THE LATIN AMERICAN COUNTRIES

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ABSTRACT

The renewable energy sources are expected to provide 20-40% of the world primary energy in 2050, depending on scenarios. A key element in the mitigation of climate change is capacity building in renewable energy technologies in the developing countries, where the main energy use growth is expected. Central America is one of the world´s richest regions in geothermal resources. Geothermal power stations provide about 12% of the total electricity generation of the four countries Costa Rica, El Salvador, Guatemala and Nicaragua. The electricity generated in the geothermal fields is in all cases replacing electricity generated by imported oil. Hydro stations provide 46% of the electricity for the four countries, and wind energy 2%. With an interconnected grid, it would be relatively easy to provide all the electricity for the four countries by renewable energy. El Salvador and Costa Rica are among the leading geothermal countries in the world. International geothermal schools and leading universities offering geothermal science and engineering in their curricula conduct their teaching and supervision mostly in English. A description is given of the activities of the UNU-GTP with its mandate to assist developing countries with significant geothermal potential to establish groups of specialists in geothermal exploration and development by offering six month specialized training for professionals employed in geothermal research and/or development. The UNU-GTP also organizes Workshops and Short Courses on geothermal development in Africa (started in 2005), Central America (started in 2006), and in Asia (started in 2008). Since the start of the Workshops/Short Courses in 2005/6, the long term aim has been that the courses would in the future develop into sustainable regional geothermal training centres. This is well on the way in Kenya for the benefit of the African countries. This has also been discussed from time to time in El Salvador by UNU-GTP and LaGeo. A regional training centre teaching/supervising geothermal science/engineering in Spanish would open the doors for a large number of professionals from Latin American countries to seek advanced training and conduct research. Advancement in geothermal development in Latin American countries would not be as hampered by traditional language skills as at present. Establishing a regional geothermal training centre hosted by a leading geothermal company such as LaGeo, and a capable university in El Salvador, would be an important step for Latin America for the promotion of the utilization of renewable energy sources.

1. INTRODUCTION

The renewable energy sources are expected to provide 20-40% of the world primary energy in 2050, depending on scenarios. The main growth in energy use will be in the developing countries. It is thus very important to support developing countries with fast expanding energy markets, such as China and India, to try as possible to meet their growing energy demands by developing their renewable energy resources. In some countries, e.g. in Central America and Kenya in the East African Rift Valley, the majority of the grid connected electricity is already provided by hydro and geothermal energy. It is very important for the international community to assist the countries in these regions in developing their renewable energy resources further rather than to guide them to meet the fast growing energy demands by fossil fuels. A key element in the mitigation of climate change is capacity building in renewable energy technologies in the developing countries, where the main energy use growth is expected (Fridleifsson, 2010a).

The Government of Iceland and the United Nations University (UNU) decided in 1978 to establish the UNU Geothermal Training Programme (UNU-GTP), with Orkustofnun (the National Energy Authority of Iceland) as the host institution. The mandate (*www.unugtp.is*) is to assist developing countries with significant geothermal potential to establish groups of specialists in geothermal exploration and development by offering six month specialized training for professionals employed in geothermal research and/or development. More recently, the UNU-GTP also offers a few successful candidates the possibility of extending their studies to MSc or PhD degrees in geothermal sciences or engineering in cooperation with the University of Iceland (Fridleifsson, 2010b).

During 1979-2010, 452 scientists and engineers from 47 countries have completed the annual six month courses. They have come from countries in Asia (42%), Africa (29%), Central and Eastern Europe (14%), and Latin America (15%). Since 2000, 25 have graduated with MSc. In 2010, thirteen pursued their MSc and four PhD studies at the University of Iceland.

The UNU-GTP also organizes Workshops and Short Courses on geothermal development in Africa (started in 2005), Central America (started in 2006), and in Asia (started in 2008) (Fridleifsson et al., 2008). This is a contribution of the Government of Iceland to the Millennium Development Goals of the United Nations. A part of the objective is to increase the cooperation between specialists in neighbouring countries in the field of sustainable use of geothermal resources. About 200 scientists/engineers and decision makers have participated in the workshops (1 week), and about 300 scientists/engineers have been trained at the Short Courses (1-3½ weeks). Many former UNU Fellows are lecturers and co-organizers of the UNU-GTP Workshops and Short Courses (Georgsson, 2010a).

Since the start of the Workshops/Short Courses in 2005/6, the long term aim has been that the courses would in the future develop into sustainable regional geothermal training centres. This is well on the way in Kenya for the benefit of the African countries. This has also been discussed from time to time in El Salvador between UNU-GTP and LaGeo. The initiative of the University of El Salvador (UES) and LaGeo in 2010 to develop the first Diploma Course in Geothermal Energy for Central American students, triggered the cooperation of the Inter-American Development Bank (IDB) and the UNU-GTP in evaluating the possibility of formally supporting the establishment of a postgraduate course (which might lead to a MSc degree) at the University of El Salvador or another qualified university in the region. The Nordic Development Fund (NDF) has also participated in meetings on this. The postgraduate course would be open to qualified graduates from primarily Latin American countries. Lectures/tuition would be primarily in Spanish, but to some extent in English.

As mentioned above, the long term aim has been that the Short Courses would in the future develop into sustainable regional geothermal training centres. The backbone of such a training centre in El Salvador would be LaGeo with its geothermal experts, research and exploration facilities, as well as several geothermal fields and power stations in operation.

The purpose of the present paper is to describe the contents of the 6 month specialized training of the UNU-GTP in Iceland. Some of this could be used as a model for the forthcoming Regional Training Centre and Diploma/MSc course. Similarly, a summary will be made on the UNU-GTP Millennium Workshops and Short Courses. A lot of teaching material has been prepared for the Workshops and Short Courses, which could be modified and used in the Diploma/MSc course in El Salvador.

The 6 month specialized training of the UNU-GTP is evaluated as 30 ETC units, and thus accounts for 25% of the MSc degrees (120 ETC) at the School of Engineering and Natural Sciences of the University of Iceland. An agreement on a Masters programme for graduates of the UNU-GTP was signed between the UNU-GTP and the University of Iceland in May 2000.

2. GEOTHERMAL TRAINING IN ICELAND

The approximate time schedule of the six month specialized courses is shown in Table 1. All participants attend an introductory lecture course (5 weeks, three lectures per day) which aims to provide background knowledge on most aspects of geothermal energy resources and technology, and to generate an appreciation for the interrelationship between the various disciplines necessary in geothermal projects from the initial exploration to the stages of implementation and utilization. Participants have to take two written tests during the introductory lecture course. The introductory course is followed by lectures and practical training in the respective specialized fields (7 weeks), and the execution of a research project (12 weeks) which is concluded with an extensive research project report. Excursions are also arranged to the main geothermal fields under exploration and utilization in Iceland. Seminars are held and case histories studied on each field.

TABLE 1: Approximate time schedule for the six month specialized courses at UNU-GTP in Iceland

Week	Geological Exploration	Borehole Geology	Geophysical Exploration	Borehole Geophysics	Reservoir Engineering	Environmental Studies	Chemistry of Thermal Fluids	Geothermal Utilization	Drilling Technology
1 2 3 4 5	Lecture course on all main aspects of geothermal energy exploration and utilization, practicals and short field excursions								
6 7 8 9 10	Field geology Maps and photos Structure analysis Hydrogeology	Drilling Petrological logging Alteration Mineralogy	Resistivity methods Thermal methods Magnetics Gravity	Course on well logging and reservoir engineering including: Logging and well testing practises Reservoir physics Reservoir simulation Tracer tests Computer programs		EIA Project planning Chemistry Physics Biology Monitoring Revegetation Health and safety	Sampling of fluids and gas Scaling and corrosion Analytical methods Thermodynamics Geothermometers	Heat transfer and fluid flow Control systems	Drilling equipment Drilling procedures Well design Safety Management Rig operations
11 12			Excursion to the main geothermal fields of Iceland						
13 14	Field work in deeply eroded strata	Aquifers Modelling	Data processing techniques	Logging methods Data evaluation	Responses to exploitation	Gas dispersion and abatement	Water rock interaction	Design of plants and systems	Cementing Completion
15 16 17 18 19 20 21 22 23 24 25 26	Project and report	Project and report	Project and report	Project and report	Project and report	Project and report	Project and report	Project and report	Project and report

The main emphasis of the training is to provide the participants with sufficient understanding and practical experience to permit the independent execution of projects within a selected discipline in their home countries. Nine specialized lines of training are offered (Table 1). Each participant is meant to follow only one line of training, but within each line there is considerable flexibility. A detailed description can be found on the home page of the UNU-GTP (*www.unugtp.is*).

The following lines of specialized training are offered:

Geological exploration offers practical training in basic geological and geothermal mapping, which is commonly the first step in the geothermal exploration of an area. Participants should have a degree in geology.

Borehole geology gives training in making geological logs, analyses of drill cuttings and cores. The identification of alteration minerals (microscope and x-ray diffraction) and the interpretation of the alteration mineralogy form an integral part of the course. Participants should have a degree in geology.

Geophysical exploration is practical training in conducting geophysical surveys of geothermal areas and/or interpretation of such data. Emphasis is on the application of computers in the interpretation. Participants should have a degree in physics, geophysics or engineering.

Borehole geophysics covers the essentials of geophysical measurements in boreholes used for geothermal investigations, with an emphasis on temperature and pressure measurements. Participants should have a degree in physics, geophysics or engineering.

Reservoir engineering covers the methodology needed to obtain information on the hydrological characteristics of geothermal reservoirs and to forecast the long term response of the reservoirs to exploitation. Participants should have a degree in engineering, physics, geophysics, mathematics or hydrogeology.

Environmental studies cover environmental impact assessments (EIA), laws and policies, the planning and execution of EIA projects and environmental auditing. Scientific methods suitable for environmental monitoring and modelling are assessed and biological impact, pollution and occupational safety considered. Participants should have a degree in science or engineering.

Chemistry of thermal fluids gives an insight into the role of thermal fluid chemistry in geothermal exploration and exploitation, including sampling, analysis of major constituents and the interpretation of results. Participants should have a degree in chemistry, geochemistry or chemical engineering.

Geothermal utilization deals with the civil, mechanical and chemical engineering aspects of geothermal fluids in pipes, equipment and plants. Insight is also given into electrical and control engineering aspects related to geothermal utilization. The feasibility of projects and environmental factors are also considered. Participants should have a degree in engineering.

Drilling technology provides engineers with the information and on-site training necessary to prepare them for the work of drilling engineers or supervisors. The course deals with the selection of drilling equipment, well design and casing programs, cementing techniques, and the cleaning and repairs of production wells. Participants should have a degree in engineering.

Most of the teaching is done by tutorials and practical work where the teacher works with two or three trainees, and use is made of available textbooks and articles in journals. In some instances, however, text material and manuals have been made for the training. Some of the teaching material has been published in reports, and is available from the UNU-GTP (and on www.unugtp.is). UNU Fellows have, in many cases, used teaching material from the UNU-GTP to train colleagues in their own institutions.

A significant part of the practical training is done in connection with the research projects of the Fellows. In many cases, the participants bring with them data from geothermal projects in their home countries. The project topic is always selected with respect to the conditions of the home country of the participant. All project reports are published by the UNU-GTP. Since 1994, the reports have been published in the annual yearbook "Geothermal Training in Iceland" (edited by Ludvik S. Georgsson, international publishing code ISBN 978-9979-68). Copies can be obtained upon request. The books are mailed regularly to former UNU Fellows, universities and leading geothermal research institutions in over 50 countries. All research reports from 1979-2008 are also available on the home page of the UNU-GTP (*www.unugtp.is*).

On some occasions, UNU Fellows from a given country (e.g. Costa Rica, El Salvador, Kenya, Philippines) have conducted multidisciplinary research (geology, geophysics, chemistry, reservoir engineering, environmental impact studies) over several years on data from the same area in their home countries under supervision of Icelandic specialists. All the countries mentioned above obtain 15-22% of their electricity from geothermal steam. In 2009, 15 of the 22 research projects dealt at least partly, with geothermal areas in the home countries of the Fellows, while 17 of 28 did so in 2010.

Table 2 lists the countries of origin of the participants who have completed six month training during 1979-2010, and their specialized courses. The largest groups of Fellows have come from China (75), Kenya (53), Philippines (31), El Salvador (30), Ethiopia (27), and Indonesia (27). Eighteen other countries have sent 5-20 participants. Figure 1 shows the UNU Fellows that completed the 6 months training in 2010.

TABLE 2: Fellows of the UNU Geothermal Training Programme in Iceland 1979-2010

Country	Geological exploration	Borehole geology	Geophysical exploration	Borehole geophysics	Reservoir engineering	Chemistry of therm.	Environmen. studies	Geothermal utilization	Drilling technology	Total
Albania								2		**2**
Algeria	1		1			1		1		**4**
Azerbaijan							1			**1**
Bulgaria				1	2	2				**5**
Burundi	1									**1**
China		3	1	2	27	15	10	15	2	**75**
Comoros			1							**1**
Costa Rica	2	2	2		2	3	2	4		**17**
Djibouti		2			2	1		1		**6**
Dominica						1				**1**
Egypt		1		1	1	1				**4**
El Salvador	1	1	2	2	5	4	4	7	4	**30**
Eritrea	2		2		1	2				**7**
Ethiopia		3	5	1	5	4	1	6	2	**27**
Georgia								1		**1**
Greece			1					2		**3**
Guatemala		1			1	1				**3**
Honduras		1	1							**2**
Indonesia		5	3	2	6	1	2	7	1	**27**
Iran	1	3	1	1	2	1	3	7	1	**20**
Jordan	1			1	1	2		1		**6**
Kenya	1	6	11		7	9	9	3	7	**53**
Latvia								1		**1**
Lithuania					1			1		**2**
Macedonia						1				**1**
Mexico	1		1	1	3					**6**
Mongolia	1		1		1	2		4	1	**10**
Nepal						1		1		**2**
Nicaragua		1			4	4	1			**10**
Pakistan	1	1			1	1				**4**
Philippines		4	5	4	9	6		3		**31**
Poland		1		1	5	1		6		**14**
Romania						1		4		**5**
Russia	1				2	5	1			**9**
Rwanda	1		1		1			1		**4**
Serbia				1	1	1				**3**
Slovakia				1	1					**2**
St.Kitts & Nevis					1					**1**
Tanzania	3		1			1				**5**
Thailand		1		2		1		1		**5**
Tunisia					1			5		**6**
Turkey		1			1	4	1	3		**10**
Uganda	4	1	2		1	4	1			**13**
Ukraine					2					**2**
Vietnam	1		1		1	1			1	**5**
Yemen	2	1				1				**4**
Zambia								1		**1**
Total	**25**	**39**	**43**	**21**	**98**	**83**	**36**	**88**	**19**	**452**

3. WORKSHOPS AND SHORT COURSES

3.1 Introduction

The courses/workshops are set up in a selected country in the target region through cooperation with local energy agencies/utilities and/or earth science institutions, responsible for exploration, development and operation of geothermal facilities in the respective countries. In implementation, the

FIGURE 1: UNU Fellows in Iceland for 6 months training in 2010

first phase has been a week long workshop during which decision makers in energy and environmental matters in the target region have met with the leading local geothermal experts and specially invited international experts. The status of geothermal exploration and development has been introduced and the possible role of geothermal energy in the future energy mix of the region discussed. The purpose has, on one hand, been to educate key decision makers in the energy market of the respective region about the possibilities of geothermal energy, and increase their awareness of the necessity for more effort in the education of geothermal scientists in the region, and, on the other hand, to further the cooperation between specialists and decision makers in the different countries. Similarly, the decision makers have been informed about the planning of geothermal projects, the needs for different types of surface exploration, environmental issues, exploration drilling, well testing, feasibility studies, banking matters, power plants etc. The aim is to create an understanding of the various components associated with geothermal development, including the scientific/engineering language used by scientists, engineers and bankers.

The workshop is followed by "annual" specialized Short Courses for earth scientists and engineers in surface exploration, deep exploration, production exploration, environmental studies and production monitoring etc., in line with the type of geothermal activity found in the respective region, and the needs of the region. Material presented and written for these events has been published on CDs and is also available on the website of the UNU-GTP (*www.unugtp.is*).

3.2 The African series of Short Courses

During the planning of the first Workshop, the priority region was East Africa with its huge and to a large extent unused potential for geothermal power development, and urgent need for development. Cooperation was sought with Kenya, which has been the leading African country in geothermal development, and KenGen - the Kenya Electricity Generating Company, which has been the main authority in charge of that development. The Lake Naivasha area in the southern part of the Kenyan rift was chosen as the main site for the Short Courses, due to the vicinity of the active Olkaria high-temperature geothermal system and its geothermal power plants. In 2009, the recently formed Geothermal Development Company – GDC in Kenya, which has taken over many of the responsibilities of KenGen as well as staff members, came in as an additional cooperation partner. The cooperation has generally meant that the costs of all invited foreign participants (travels and

accommodation) and non-local lecturers (salaries, travels and accommodation) are covered by the UNU-GTP and the Icelandic Government, while the costs of the local Kenyan participation and some of the local arrangements are born by KenGen, and from 2009 also by GDC.

The first event in Africa, "*Workshop for Decision Makers on Geothermal Projects and their Management*", was held in Kenya in November 2005. The 5 day Workshop was held after six nations in East Africa with good geothermal potential had decided to join forces and increase their cooperation in geothermal research and development within the so-called African Rift Geothermal Facility (ARGeo). Here the UNU-GTP had accepted to play a leading role in guiding and implementing the capacity building component of ARGeo, and the Workshop was intended to be the first step in that process. At the Workshop high-level decision makers from five of the six ARGeo countries met to learn about and discuss the main phases of geothermal development and what kind of manpower, equipment, and financing is needed for each phase, and analyse what was available in the region (Fridleifsson et al., 2005).

The result of the Workshop was that the Short Courses in East Africa should to begin with focus on surface exploration which was the field acutely needed for most countries in the region. The first Short Course was the 10 day "*Short Course on Surface Exploration for Geothermal Resources*" held in November, 2006. The purpose was to give "a state of the art" overview of the methods used in surface geothermal exploration, and discuss the status and possibilities of geothermal development in East Africa (Georgsson and Simiyu, 2006). During the last 5 years, the annual Short Course at Naivasha has gradually developed into a more general course on geothermal exploration. In 2007, a few days of field work and demonstrations were added at the start of the course. This part has been held at Lake Bogoria in the Central Kenyan rift and has been entirely handled by the KenGen/GDC staff. And in 2008, 4 days of project work were added at the end of the Short Course, which at that time had become 3½ week long. This model was followed in 2009 and 2010. Table 3 gives an overview of the events to date. The topic of the Short Courses has also gradually broadened by adding varying types of lectures to its content, including environmental science, resource assessment, project planning, drilling technology, well logging, well siting and an introduction to geothermal power plants, as can be seen from the published CDs (Georgsson et al., 2007; 2008a, 2009a, 2010). As an example, Table 4 shows the set up of the "*Short Course IV on Exploration for Geothermal Resources"* held in November 2009 (Georgsson, 2010b).

TABLE 3: UNU-GTP Workshops and Short Courses held in East Africa 2005-2010 as a part of the UNU Millennium Development goals

Event	Main site	Dates	Duration (days)
Workshop for Decision Makers on Geoth. Projects & their Man.	Naivasha	Nov. 14-18, 2005	5
Short Course on Surface Exploration for Geothermal Resources	Naivasha	Nov. 13-22, 2006	10
Short Course II on Surface Exploration for Geothermal Resourc.	Naivasha	Nov. 2-17, 2007	16
Short Course III on Exploration for Geothermal Resources	Naivasha	Oct. 24 - Nov. 17, 2008	25
Short Course on Geothermal. Project Management & Developm.	Entebbe	Nov. 20-22, 2008	3
Short Course IV on Exploration for Geothermal Resources	Naivasha	Nov. 1-22, 2009	22
Short Course V on Exploration for Geothermal Resources	Naivasha	Oct. 29 - Nov. 19, 2010	22

A special addition in November 2008 was the "*Short Course on Geothermal Project Management and Development*". This three day event, given in Entebbe, Uganda, was co-organized by the UNU-GTP, KenGen and the Ministry of Energy and Mineral Development (DGSM) in Uganda, and mainly aimed at high level managers/employees in ministries/energy companies/research institutions in East Africa (Georgsson et al., 2008b).

Participation in the Short Courses in Kenya has increased with every year, not least due to the big pressure on capacity building in Kenya itself, which is needed for its intended fast-tracking of geothermal development in the next few years, with plans to increase geothermal power production

TABLE 4: The structure of "Short Course IV on Exploration for Geothermal Resources " held at Lake Bogoria and Naivasha, Kenya, November 2009

Dates	Programme	No. lectures	Prac-ticals	Lecturer/Supervisor		
				Local	Neighb.	Iceland
1. Nov.	Arrival at Lake Bogoria					
2. Nov.	Introductory lectures	8		8		
3.-6. Nov.	Site visits to geothermal areas and geothermal field work		X	8		
7. Nov.	Site visit and drive to Lake Naivasha		X			
8. Nov.	Geothermal energy, power plants, drilling, etc.- Lectures	5		4		2
9. Nov.	Geothermal activity and geology – Lectures & mapping	6	X	3		1
10.-11.No.	Geophysics – Lectures & interpret.	14	X	3		2
12. Nov.	Chemistry of thermal fluids – Lectures and interpretation	8	X	2		1
13. Nov.	Practical sessions in geophysics and chemistry		X	4		2
13. Nov.	Hydrology, resource assessment, logging and well siting	4		4		
14. Nov.	Excursion – Olkaria geothermal field, power plant and drilling rigs			2		4
15. Nov.	Environmental science – lectures and measurements	5	X	6		1
16.-17. No.	Status of geothermal in E-Africa – Planning projects	15	X	3	5 (+ 5)*	
18. Nov.	Case examples	5	X	1		3
19.-21. No.	Project work in groups		X	7		3
22. Nov.	Project presentations, course review, closing ceremony	(8)	X	1		1
23. Nov.	Departure participants – Instructors assessment meeting					

* Trainees from countries outside ARGeo gave lectures on geothermal in their countries, shown in parentheses

from the current 200 MWe electric to at least 1500 MWe by 2020 (Simiyu, 2010). New countries have also been added to those invited most years, and in many cases, they have been participating for the first time in UNU-GTP events. In total, 17 countries have now participated, the majority of them on a fairly regular basis. Yemen has been included despite being on the other side of the Red Sea and thus in Asia, as it has common geological features with East Africa. The highest number of participants in a single event is 56 for the 2010 Short Course, and the total number of participants is now reaching close to 250 persons (Table 5). Similarly, the number of lecturers has increased with the length of the Short Courses as can be seen from Table 6, which also shows that most of the African lecturers/supervisors are former UNU Fellows trained in Iceland.

The Short Courses in East Africa have certainly proven to be a valuable addition to the capacity building activities of the UNU-GTP in Africa. They are now established as a good first training opportunity for young African scientists and engineers engaged in geothermal work. They have been given an introduction to state-of-the-art exploration techniques for geothermal resources and the possible development of this valuable renewable energy source. In total, 213 Africans (including Yemen) participated in the Short Courses during 2006-2010 compared to a total of 48 UNU Fellows from Africa (including Yemen) being trained for 6 months in Iceland during the same period.

TABLE 5: Participants in the Workshop and Short Courses in East Africa 2005-2010

Country	Kenya 2005*	Kenya 2006	Kenya 2007	Kenya 2008	Uganda 2008	Kenya 2009	Kenya 2010	Total
Algeria			1					**1**
Burundi				2	1	2	2	**7**
Comoros			2			2	3	**7**
Congo				1	1			**2**
Djibouti		2	1	2	3	2	2	**12**
Egypt			1					**1**
Eritrea	2	3	2	2	1	2		**12**
Ethiopia	5+2	3	1	2	3	3	1	**20**
Kenya	6+9	10	13	18		21	31	**108**
Malawi							3	**3**
Morocco							1	**1**
Mozambique							1	**1**
Rwanda			2	2	1	3	3	**11**
Tanzania	2	2	2	2	4	3	3	**18**
Uganda	4	3	3	2	5	3	2	**22**
Zambia				2	2	2	3	**9**
Yemen			2	2	1	2	1	**8**
Others					2			**2**
Total	**30**	**23**	**30**	**37**	**24**	**45**	**56**	**245**

* The second number shows African lecturers, most of whom also participated fully in other parts of the Workshop

TABLE 6: Lecturers in the UNU-GTP Workshops and Short Courses 2005-2010

Short course / Workshop	Total	Home country	Neighbour. countries	Internat.	Iceland	UNU-Fellows
Kenya 2005	16	9	2	1	4	8
Kenya 2006	20	11	5	0	4	15
Kenya 2007	25	16	4	0	5	18
Kenya 2008	28	19	5	0	4	23
Uganda 2008	15	1	7	2	5	8
Kenya 2009	35	27	4	0	4	26
Kenya 2010	34	27	3	0	4	23
El Salvador 2006	25	8	9	5	3	9
El Salvador 2007	16	3	5	3	5	7
El Salvador 2009	19	12	4	0	5	11
El Salvador 2011*	29	14	6	3	6	17
China 2008	32	16	6	4	6	11

*Not confirmed numbers

Furthermore, the Short Courses have become a new channel to the more advanced training in Iceland with the strongest participants showing their ability and strength, and thus opening the possibility to be selected to go for training in Iceland. There are now many examples of good participants in the Short Courses being selected for the 6 months training in Iceland. And in four cases it has even led to MSc studies in Iceland (Georgsson et al., 2008c; Fridleifsson and Georgsson, 2009), first of whom completed his MSc in April 2010.

The Short Courses have also been an important element towards increased cooperation between the countries in East Africa. Here, Kenyans have mainly been in the role of the donors/contractors, while countries like Rwanda, The Comoros and Zambia, have utilized their knowledge and contracted them

for local exploration projects. Similarly, geothermal exploration projects financed by ICEIDA, e.g. in Djibouti and Eritrea, have been carried out partly with the assistance of a multinational group including experts from their neighbouring countries.

The UNU-GTP foresees a further development of the Short Courses in Africa, and expects that in the near future they will develop into a permanent regional school for geothermal training. The Kenyan cooperation partners are now preparing the building of facilities which can make this possible, and if current plans hold, this could become a reality in the year 2012.

For a further description of the UNU-GTP Workshops and Short Courses in Africa see Georgsson (2010a and 2010b) or the UNU-GTP webpage (*www.unugtp.is*).

3.3 Short courses in Central America

Similar to East Africa, in Central America geothermal resources play an ever increasing role in the power production of countries like El Salvador, Costa Rica, Nicaragua and Guatemala, with considerable untapped potential in several of the countries. The UNU-GTP has since its early years supported this region through training of many staff members of geothermal institutions in the region, especially in El Salvador and Costa Rica. Hence, Central America was selected as the region for the second Millennium Series of Short Courses. Two partners for cooperation could be foreseen, ICE in Costa Rica and LaGeo S.A de C.V. in El Salvador, with the latter chosen for this task. LaGeo (with its predecessors) has been responsible for geothermal development in El Salvador since the 1970s and has all the know-how necessary to be an active and strong partner in hosting this series.

The "*Workshop for Decision Makers on Geothermal Projects in Central America*" was held in San Salvador in late November 2006 (Fridleifsson and Henriquez, 2006). The fifty participants in the 6 day event were mainly from the four countries in Central America most active in geothermal development, i.e. Costa Rica, El Salvador, Guatemala, and Nicaragua, and some of them were from the highest level. The Workshop was a sound success. In its conclusions, it says "*the importance of local geothermal energy resources and their possible potential in increased power production in the region is emphasized, along with the minimal environmental impact of geothermal, and the need for increased training and regional technical cooperation in this field."* Figure 2 shows most of the participants of the workshop.

FIGURE 2: Participants in the first UNU-GTP Workshop in Central America in 2006

With geothermal development in Central America at a more advanced stage compared to East Africa, it has not been necessary to put the same emphasis on surface exploration in the Short Courses. One of the topics that were discussed during the Workshop was that environmental legislation and development of National Parks covering many of the volcanic systems and thus geothermal systems could be a barrier to further development of this environmentally benign and renewable energy resource. Thus the first Short Course was on one hand aimed at this problem and on the other on project management. The "*Short Course on Geothermal Development in Central America: Resource Assessment and Environmental Management*" was a week long event, and held in Santa Tecla in late November 2007. In addition to lectures (Fridleifsson et al., 2007) and discussions of the subjects, there were practical exercises on reservoir resource assessment of geothermal fields in several countries, and in environmental management planning for specific geothermal fields. Local participants were 45 + 8 lecturers, with additional international lecturers coming from Iceland, Kenya and the Philippines (Tables 6 and 7).

TABLE 7: Participants in the Short Courses in Central America 2007-2011

Country	2007	2009	2011*	Total
Colombia			5	**5**
Costa Rica	6	7	6	**19**
Dominica		2	2	**4**
El Salvador	22	9	~20	**~51**
Ecuador			1	**1**
Guatemala	1	1	2	**4**
Honduras	2	2	5	**9**
Mexico	1		3	**4**
Nevis		2	2	**4**
Nicaragua	13	7	13	**33**
Others		2		**2**
Total	**45**	**32**	**~59**	**~136**

* Scheduled participation - not confirmed

For various reasons, the third event in Central America was delayed to 2009. The two week long "*Short Course on Surface Exploration for Geothermal Resources*" was held in October 2009 in El Salvador. It was a shorter version of the courses that had been held in East Africa 2007-2009, with the main emphasis on geophysics and chemistry of thermal fluids, and aimed at young earth scientists in the region (Georgsson et al., 2009b). The last day was co-participation in the "Central American Geothermal Workshop", a cooperative event between LaGeo, the International Geothermal Association (IGA) and UNU-GTP, intended to highlight geothermal development in Central America. Figure 3 shows the participants of the Short Course, while Figure 4 is from a field work session. The Short Course reached a broader audience than the first two with participation from the East Caribbean Region where high-temperature geothermal systems associated with active volcanic system are found. Similarly, with the current "Short Course on Geothermal Drilling, Resource Development, and Power Plants", the UNU-GTP is for the first time reaching to countries in South America. The current topic has also proven to be very interesting to many private companies in the geothermal business in the region, reflected in their increased participation, even at their own cost.

The Short Courses in El Salvador have brought new and important components to geothermal development in Central America. They have not only increased the available training capacity for the region, but also furthered cooperation between the countries of the region in geothermal development. The geothermal development in Central America is on average at a higher level than in East Africa, which means that the future need in capacity building is more varied. We foresee the need for Short Courses covering topics ranging from surface exploration to development, field management, and production monitoring. However, participation can also be expected to cover a wider area where geothermal resources have not been developed to the same extent. Many of the small nations of the

FIGURE 3: Participants and lecturers in the El Salvador Short Course in 2009

Eastern Caribbean region have important geothermal resources to be developed. Participants from this region can become a significant factor in the Short Courses in the near future. Similarly, participation from South America can also be expected to these Short Courses in increasing numbers, as interest in the development of the high-temperature resources in this part of the world grows.

3.4 Customer-designed Short Courses

The latest capacity building service of the UNU-GTP has been to offer customer-designed Short Courses in developing countries, done for the first time in 2010. This new service of the UNU-GTP has been triggered by an urgent need for training in countries planning fast-tracking of geothermal development, while it has also been an offspring of the regular training and Short Courses and the material prepared there. This has proven a good opportunity for some countries/ institutions in need of a rapid capacity building process, beyond what UNU-GTP can

FIGURE 4: Participants in the 2009 Short Course in El Salvador doing geophysical field work

service under its conventional operations, and which have themselves the strength or the support of external sources (e.g. multilateral or bilateral aid agencies) to finance such events. The paying customer defines the outline of the Short Course, while UNU-GTP is a guarantee of the quality of the contents. The first such courses have been held in 2010 for four different customers in two countries. The contents have varied from general geoscientific courses to geothermal drilling, as well as scaling and corrosion in geothermal installations, and the length has varied from one to eleven weeks.

4. REGIONAL GEOTHERMAL TRAINING CENTRE FOR LATIN AMERICA

There are several good reasons for establishing a regional geothermal training centre for Latin America. A few will be listed here, but more can be added, discussed, and debated at the Short Course in El Salvador 16-22 January 2011.

1. There are several large and small countries in Latin America which are richly endowed with geothermal resources, but no serious exploration or development has been undertaken. Many of the countries have developed their hydro resources to some extent, but most are dependent on fossil fuels, irrespective of whether they have to import their oil/gas/coal.
2. Central America is one of the world´s richest regions in geothermal resources. Geothermal power stations provide about 12% of the total electricity generation of the four countries Costa Rica, El Salvador, Guatemala and Nicaragua, according to data provided from the countries (CEPAL, 2010). The electricity generated in the geothermal fields is in all cases replacing electricity generated by imported oil. Hydro stations provide 46% of the electricity for the four countries, and wind energy 2%. With an interconnected grid, it would be relatively easy to provide all the electricity for the four countries by renewable energy.
3. El Salvador and Costa Rica are among the leading geothermal countries in the world.
4. International geothermal schools and leading universities offering geothermal science and engineering in their curricula conduct their teaching and supervision mostly in English.
5. A regional training centre teaching/supervising geothermal science/engineering in Spanish would open the doors for a large number of professionals from Latin American countries to seek advanced training and conduct research. Advancement in geothermal development in Latin American countries would not be as hampered by traditional language skills as at present.
6. Establishing a regional geothermal training centre hosted by a leading geothermal company such as LaGeo, and a capable university in El Salvador, and in cooperation with the United Nations University, would be an important step for Latin America for the promotion of the utilization of renewable energy sources.
7. The renewable energy sources are expected to provide 20-40% of the world primary energy in 2050, depending on scenarios. A key element in the mitigation of climate change is capacity building in renewable energy technologies in the developing countries, where the main energy use growth is expected.

As mentioned in the Introduction of this paper, the long term aim has been that the Workshops/Short Courses would in the future develop into sustainable regional geothermal training centres. This is well on the way in Kenya for the benefit of the African countries. This has also been discussed from time to time in El Salvador between UNU-GTP and LaGeo. The initiative of the University of El Salvador (UES) and LaGeo in 2010 to develop the first Diploma Course in Geothermal Energy for Central American students, triggered the cooperation of the Inter-American Development Bank (IDB) and the UNU-GTP in evaluating the possibility of formally supporting the establishment of a postgraduate course (which might lead to a MSc degree) at the University of El Salvador or another qualified university in the region. The postgraduate course would be open to qualified graduates from primarily Latin American countries. Lectures/tuition would be primarily in Spanish, but to some extent in English.

The matter is open for debate, preparations, negotiations, commitment, and execution.

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