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GEOTHERMAL ENERGY IN THE WORLD WITH SOME EMPHASIS ON THE STATUS IN LATIN AMERICA AND CAPACITY BUILDING

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ABSTRACT

The renewable energy sources are expected to provide some 20-40% of the world primary energy in 2050. 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. Based on the World Energy Assessment Report update on the status in 2001 (WEA, 2004), the primary energy consumption in the world was assessed as 400 EJ, with about 80% coming from fossil fuels, but only 14% from renewable energy sources. The contribution of the renewables is discussed and their possibilities. Their current share in the energy production is mainly from biomass and hydro, followed by wind and geothermal energy. In a future envisioned through depleting resources of fossil fuels and environmentally acceptable energy sources, geothermal energy with its large technical potential is expected to play an important role.

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, while hydro stations provide 46% of the electricity for the four countries, and wind energy 2%. The geothermal potential for electricity generation in Central America has been estimated some 4,000 MWe, and less than 500 MWe have been harnessed so far. With the large untapped geothermal resources and the significant experience in geothermal as well as hydro development in the region, Central America can become an international example of how to reduce the overall emissions of greenhouse gases in a large region. South America also hosts vast resources of geothermal energy that are largely unexploited, estimated to be in the range of 4-9 GWe. Exploration and development is now on-going in countries like Bolivia, Chile, Colombia and Ecuador. Similarly, the 11 volcanic islands of the Eastern Caribbean have an estimated power potential of 16,000 MWe collectively, according to USDOE studies. Production is still limited to Guadeloupe, with 15.7 MWe, but exploration wells have been drilled in St. Lucia, Nevis and are now on-going in Dominica.

Finally, attention is given to the capacity building operations of the UNU Geothermal Training Programme with special reference to Latin America, both through the geothermal training in Iceland, and short courses in the region.

1. INTRODUCTION

Amongst the top priorities for the majority of the world´s population is access to sufficient affordable energy. There is a very limited equity in the energy use in the different parts of the world. Some 70% of the world´s population lives at per capita energy consumption level below one-quarter of that of W-Europe, and one-sixth of that of the USA (WEC, 1993). Two billion people, a third of the world´s population, have no access to modern energy services. A key issue to improve the standard of living of the poor is to make clean energy available to them at prices they can cope with. World population is expected to double by the end of the 21st century. To provide sufficient commercial energy (not to mention clean energy) to the people of all continents is an enormous task.

The renewable energy sources are expected to provide 20-40% of the primary energy in 2050. The technical potential of renewable energy sources is estimated 7600 EJ/year, and thus certainly sufficiently large to meet future world energy requirements. The question is how large a part of the technical potential can be harnessed in an economical, environmentally and socially acceptable way.

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 in e.g. Central America and the East African Rift Valley, the majority of the grid connected electricity is already provided by hydro and geothermal energy. It is very important to assist them in developing their renewable energy resources further so they do not need to meet the fast growing energy demands by fossil fuels.

Geothermal energy is foreseen to play an important role in an energy future where the emphasis is no longer on fossil fuels, but on energy resources that are at least semi-renewable and long-term environmentally acceptable, especially with regard to emission of greenhouse gases and other pollutants. For developing countries which are endowed with good geothermal resources, it is a reliable local energy source that can be used to replace energy production based on imported (usually) fossil fuels. The technology is proven and cost-effective. For developing countries that have good resources and have acquired the necessary local expertise it has become very important. A good example of this is Kenya, as well as the Philippines, El Salvador and Costa Rica, where geothermal energy has become one of the important energy sources providing for 10-20% of the electricity production. Iceland should also be mentioned as the only country where geothermal energy supplies more than 60% of the primary energy used. This is done through direct use for space heating, bathing, etc., and through production of electricity.

Geothermal systems can be classified into a few different types, but with reference to variable geological conditions each one is in principle unique, so that good knowledge is needed through exploration. Furthermore, development of a geothermal system for electrical production is a capital intensive undertaking, and thus requires financial strength, or at least access to good financing. Thus, for developing geothermal resources, good training and expertise are needed for the exploration and development work, and strong financial backup for the project.

Here, the role of geothermal energy in the world’s energy mix is presented with some emphasis on Latin America and the eastern Caribbean region. Finally, the United Nations University Geothermal Training Programme (UNU-GTP) is introduced, and its capacity building operations, also with some emphasis on Latin America.

2. WORLD ENERGY SOURCES

The scarcity of energy resources forecasted in the 1970s did not occur. With technological and economic development, estimates of the ultimately available energy resource base continue to increase. Economic development over the next century will apparently not be constrained by geological resources. Environmental concerns, financing, and technological constrains appear more likely sources of future limits (Fridleifsson, 2002).

In all scenarios of the World Energy Council (WEC), the peak of the fossil fuel era has already passed (Nakicenovic et al., 1998). Oil and gas are expected to continue to be important sources of energy in all cases, but the role of renewable energy sources and nuclear energy vary highly in different scenarios and the level to which these energy sources can be expected to replace coal. In all the scenarios, the renewables are though expected to become very significant contributors to the world primary energy consumption, providing at least 20% of the primary energy in 2050 and 30% in 2100. They are expected to cover a large part of the increase in the energy consumption and to replace coal.

It is a very legitimate question to ask whether these scenarios are realistic. Table 1 shows the technical potential of renewable energy resources (WEA, 2000). There is no question that the technical potential of the renewables is sufficiently large to meet future world energy requirements. The question is, however, how large a part of the technical potential can be harnessed in an economical, environmentally and socially acceptable way. This will probably vary between the energy sources. It is worth noting, however, that the present annual consumption of primary energy in the world is more than 400 EJ (Table 2).

TABLE 1: Technical potential of renewable energy sources
Source: World Energy Assessment (WEA, 2000)

	EJ per year
Hydropower	50
Biomass	276
Solar energy	1,575
Wind energy	640
Geothermal energy	5,000
TOTAL	**7,600**

Table 2 shows the world primary energy consumption in 2001 (WEA, 2004). Fossil fuels provide 80% of the total, with oil (35%) in first place, followed by coal (23%) and natural gas (22%). The renewables collectively provide 14% of the primary energy, mostly in the form of traditional biomass (9%) and much less by large (>10MW) hydropower stations (2%) and the “new renewables” (2%). Nuclear energy provides 7% of the world primary energy.

TABLE 2: World primary energy consumption in 2001
Source: World Energy Assessment (WEA, 2004)

Energy Source	**Primary energy EJ**	**Percentage %**
Fossil fuels	**332**	**79.4**
Oil	147	35.1
Natural gas	91	21.7
Coal	94	22.6
Renewables	**57**	**13.7**
Large hydro (>10 MW)	9	2.3
Traditional biomass	39	9.3
“New renewables” (biomass, geothermal,solar, small hydro (<10MW), tidal, wind)	9	2.2
Nuclear	**29**	**6.9**
Total	**418**	**100**

If we only look at the electricity production, the role of hydropower becomes much more significant. The world electricity production was about 14,000TWh in 1998 as compared with 6,000 TWh in 1973 (WEA, 2000). Most of the electricity was produced by coal (38%), followed by hydro (18%), nuclear (17%), natural gas (16%) and oil (9%). Only 2% of the electricity was provided by the "new renewables" (small hydro, biomass, geothermal, wind, solar and tidal energy).

Table 3 shows the installed capacity and electricity production in 2005 for renewable energy sources, namely hydro, biomass, wind, geothermal, and solar energy (from Fridleifsson et al., 2008). The data for the table is compiled from "Tables" in the 2007 Survey of Energy Resources (WEC, 2007). It should be noted that the installed capacity for biomass is not given in the "Tables", but reported as "In excess of 40 GW" in the text. The capacity factor for biomass is thus uncertain. No figures are given for the installed capacity and electricity production of tidal energy in the survey. The table clearly reflects the variable capacity factors of the power stations using the renewable sources. The capacity factor of 73% for geothermal is by far the highest. Geothermal energy is independent of weather conditions contrary to solar, wind, or hydro applications. It has an inherent storage capability and can be used both for base load and peak power plants. The relatively high share of geothermal energy in electricity production compared to the installed capacity (1.8% of the electricity with only 1% of the installed capacity) reflects the reliability of geothermal plants which can be (and are in a few countries) operated at capacity factors in excess of 90%.

TABLE 3: Electricity from renewable energy resources in 2005
Compiled from Tables in 2007 Survey of Energy Resources (WEC, 2007)

	Installed capacity		**Production per year**		**Capacity factor %**
	GWe	**%**	**TWh/yr**	**%**	
Hydro	778	87.5	2,837	89	42
Biomass	40*	4.5	183	5.7	52*
Wind	59	6.6	106	3.3	21
Geothermal	8.9	1.0	57	1.8	73
Solar	4	0.4	5	0.2	14
Total	**890**	**100**	**3,188**	**100**	**41****

* Capacity factor is uncertain; **Weighted average.

Table 3 serves to demonstrate that renewable energy sources can contribute significantly more to the mitigation of climate change by cooperating than by competing. It underlines that geothermal energy is available day and night every day of the year and can thus serve as a supplement to energy sources which are only available intermittently. It is most economical for geothermal power stations to serve as a base load throughout the year, but they can also, at a cost, be operated to meet seasonal variations and as peak power.

Geothermal energy is one of the renewable energy sources that can be expected to play an important role in an energy future where the emphasis is no longer on fossil fuels, but on energy resources that are at least semi-renewable and long-term environmentally acceptable, especially with regard to emission of greenhouse gases and other pollutants. For developing countries which are endowed with good geothermal resources, it is a reliable local energy source that can at least to some extent be used to replace energy production based on imported (usually) fossil fuels. The technology is proven and cost-effective. For developing countries that have good resources and have acquired the necessary local expertise it has become very important. A good example of this is Kenya, as well as the Philippines, El Salvador and Costa Rica, where geothermal energy has become one of the important energy sources providing for 10-20% of the electricity production. With Kenya's Vision 2030, geothermal is scheduled to become Kenya's main source of electricity, with plans to for 5000 MWe on-line in the two next decades (Ngugi, 2012). Iceland should also be mentioned as the only country where geothermal energy supplies more than 60% of the primary energy used. This is done through direct use for space heating, bathing, etc., and through production of electricity (Ragnarsson, 2010).

In 2009, electricity was produced from geothermal energy in 24 countries, increasing by 20% from 2004 to 2009 (Bertani, 2010). Table 4 lists the top sixteen countries producing geothermal electricity in the world in 2009, and those employing direct use of geothermal energy (in GWh/year). Figure 1 shows the top fourteen countries in the world with the highest percentage share of geothermal in their national electricity production.Special attention is drawn to the fact that El Salvador, Costa Rica and Nicaragua are among the seven top countries, and that Guatemala is in tenth place (Figure 1).

TABLE 4: Top sixteen countries utilising geothermal energy in 2009;
data on electricity from Bertani (2010) and on direct use from Lund et al. (2010)

Geothermal electricity production		**Geothermal direct use**	
	GWh/yr		**GWh/yr**
USA	14,974	China	20,932
Philippines	10,311	USA	15,710
Indonesia	9,600	Sweden	12,585
Mexico	7,047	Turkey	10,247
Italy	5,520	Japan	7,139
Iceland	4,597	Norway	7,001
New Zealand	4,055	Iceland	6,768
Japan	3,064	France	3,592
Kenya	1,430	Germany	3,546
El Salvador	1,422	Netherlands	2,972
Costa Rica	1,131	Italy	2,762
Turkey	490	Hungary	2,713
Papua – New Guinea	450	New Zealand	2,654
Russia	441	Canada	2,465
Nicaragua	310	Finland	2,325
Guatemala	289	Switzerland	2,143

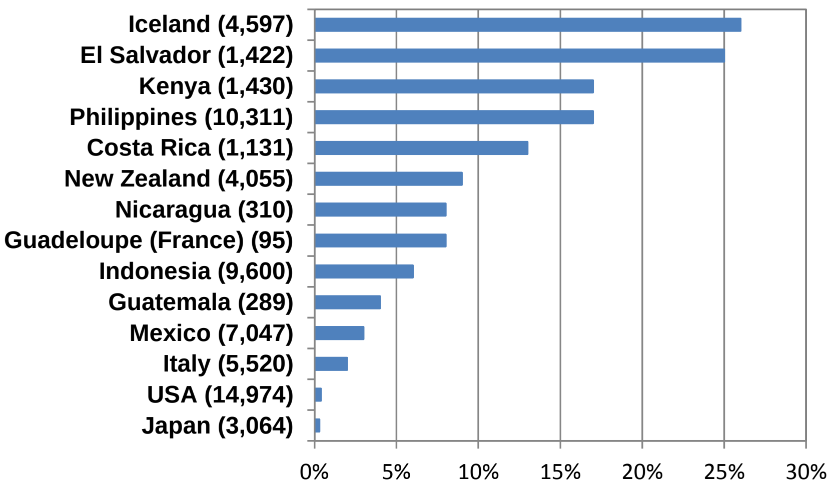

FIGURE 1: The fourteen countries with the highest % share of geothermal energy in their national electricity production. Numbers in parenthesis give the annual geothermal electricity production in GWh in 2009 (Bertani, 2010)

The largest geothermal electricity producer is the USA, with almost 15,000 GWh/a, but amounting to only 0.5% of their total electricity production. It is different for most of the other countries listed in Table 4, with geothermal playing an important role in their electricity production. That certainly applies to the fourth country on the list, the Philippines, where the production of10,300 GWh/a means that geothermal supplies 17% of the total produced electricity. The same applies to Kenya, the total production of 1,430 GWh/a puts the country in 9th place with regard to world production and constitutes 17% of the total electricity production in Kenya. For direct use (Lund et al., 2010), China heads the list followed by the USA, Sweden and Turkey. No Central American country is on the list of the 16countries highest in direct use of geothermal energy.

3. GEOTHERMAL ELECTRICITY IN LATIN AMERICA AND EASTERN CARIBBEAN

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). Figure 2 shows the Berlin geothermal power plant in El Salvador. 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. The geothermal potential for electricity generation in Central America has been estimated some 4 GWe (Lippmann 2002), and less than 0.5 GWe have been harnessed so far. With the large untapped geothermal resources and the significant experience in geothermal as well as hydro development in the region, Central America can become an international example of how to reduce the overall emissions of greenhouse gases in a large region (Fridleifsson, 2007; Fridleifsson et al., 2008). Similar development can be foreseen in the East African Rift Valley, as well as in several other countries and regions rich in high-temperature geothermal resources.

FIGURE 2: The Berlín geothermal power plant in El Salvador (Henriquez, 2008)

South America also hosts vast sources of geothermal energy that are largely unexploited (Haraldsson, 2011). In 1999, the Geothermal Energy Association estimated the continent´s potential for electricity generation from geothermal resources to be in the range of 4-9 GWe based on available information and assuming technology available at the time (Gawell et al., 1999). These resources are largely the product of the convergence of the South American tectonic plate and the Nazca plate that has given rise to the Andes mountain chain, with its countless volcanoes. High-temperature geothermal resources in Bolivia, Chile, Colombia, Ecuador and Peru are mainly associated with the volcanically active regions, although low-temperature resources are also found outside them. All of these countries have some history of geothermal exploration, which has been now been reinvigorated with recent changes in global energy prices and the increased emphasis on renewables to combat global warming (Haraldsson, 2011).

The 11 volcanic islands of the Eastern Caribbean lying on the inner arc have an estimated power potential of 16,310 MWe collectively, according to USDOE studies. Guadeloupe as of 2004 has an operating facility of 15.7 MWe and is the only island in the region harnessing power for its geothermal resource. St. Lucia, Nevis and most recently Dominica have drilled exploratory wells to analyse the resource for commercial exploitation. The current most significant progress is the drilling of 3 deep vertical exploration wells in Dominica. The first of these wells was completed in late January, 2012 and drilling of the second well has started (Maynard-Date 2012).

4. THE UNU GEOTHERMAL TRAINING PROGRAMME IN ICELAND

4.1 Introduction

The UNU Geothermal Training Programme (UNU-GTP) was established in Iceland in 1978. The mandate 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. The UNU-GTP also organizes Workshops and Short Courses on geothermal development in Africa (started in 2005), Central America (started in 2006) and China (started in 2008)(Fridleifsson, 2010a; 2010b).

During 1979-2011, 482 scientists and engineers from 50 countries have completed the annual six month courses. They have come from countries in Asia (41%), Africa (30%), Latin America (16%) and Central and Eastern Europe (13%). Since 2000, 28 have graduated with MSc degree (end of 2011). In 2011, eleven pursued their MSc and four PhD studies at the University of Iceland.

The UNU-GTP Short Courses are a special 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 3 workshops (1 week), and more than 400 scientists/engineers have now 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. An offspring of the Millennium Short Courses has been the possibility of UNU-GTP to offer customer-designed geothermal short courses, which has become an important part of the UNU-GTP operations in the past two years(Georgsson, 2010a; 2011).

Since the start of the Workshops/Short Courses in 2005/6, the long term aim has been that the courses would develop into sustainable regional geothermal training centres. This is foreseen to happen in Kenya for the benefit of the African countries. The Inter-American Development Bank (IDB) is now working towards establishing a model for a post-graduate University programme to be established in El Salvador for the benefits of the Latin American countries, with the cooperation of a.o., the UNU-GTP, The Nordic Development Fund (NDF), LaGeo and Salvadorian universities.

4.2 The 6-month geothermal training in Iceland

The main emphasis of the 6 month 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, *Geological exploration*, *Borehole geology*, *Geophysical exploration*, *Borehole geophysics*, *Reservoir engineering*, *Environmental studies*, *Chemistry of thermal fluids*, *Geothermal utilization* and *Drilling technology*. Each participant is meant to follow only one line of training, but within each line there is a considerable flexibility to allow for the needs of the individual.

The basic set-up of the 6-month training includes a 5 week introductory lecture course which aims to provide the individual with background knowledge on most aspects of geothermal energy resources and technology. It is followed by lectures and practical training in the field that individual is specializing in (6-7 weeks), Excursions are arranged to some of the main geothermal fields under exploration and utilization in Iceland, with seminars held and case histories presented on each field (2 weeks). The final phase is the execution of an extensive research project (10-12 weeks), under the guidance of an expert supervisor, which is concluded with a research project report. The trainees are encouraged to work on geothermal data from their home country if available. The reports are published in the annual yearbook "Geothermal Training in Iceland" (edited by Lúdvík S. Georgsson, international publishing code ISBN 978-9979-68). All research reports are also available on the home page of the UNU-GTP (*www.unugtp.is*). Figure 3 shows the approximate time schedule and contents of 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
1–5	**Introductory Lecture Course All main aspects of geothermal energy exploration and utilization Practicals and short field excursions**								
6–10	Field Geology Maps and photos Structural 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, reservoir physics and stimulation, tracer tests, and computer programs		EIA planning Chemistry Physics Biology Revegetation Health & safety	Sampling of fluids and gas Scaling and corrosion Analytical methods Thermodynamics Geothermometers	 Heat transfer & fluid flow Control systems	Drilling equip. & 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	Aquifer modelling	Data processing techniques	Logging methods Data eval.	Responses to exploitation	Gas dispersion and abatement	Water rock interaction	Design of plants and systems	Cementing Completion
15–26	**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**

FIGURE3: Approximate time schedule and contents of the 6-month specialized courses at UNU-GTP

The largest groups of Fellows have come from China (78), Kenya (62) and El Salvador (32). Figure 4 shows the UNU Fellows that completed the 6 months training in 2011.

FIGURE 4: UNU Fellows in Iceland for the 6 month training in 2011

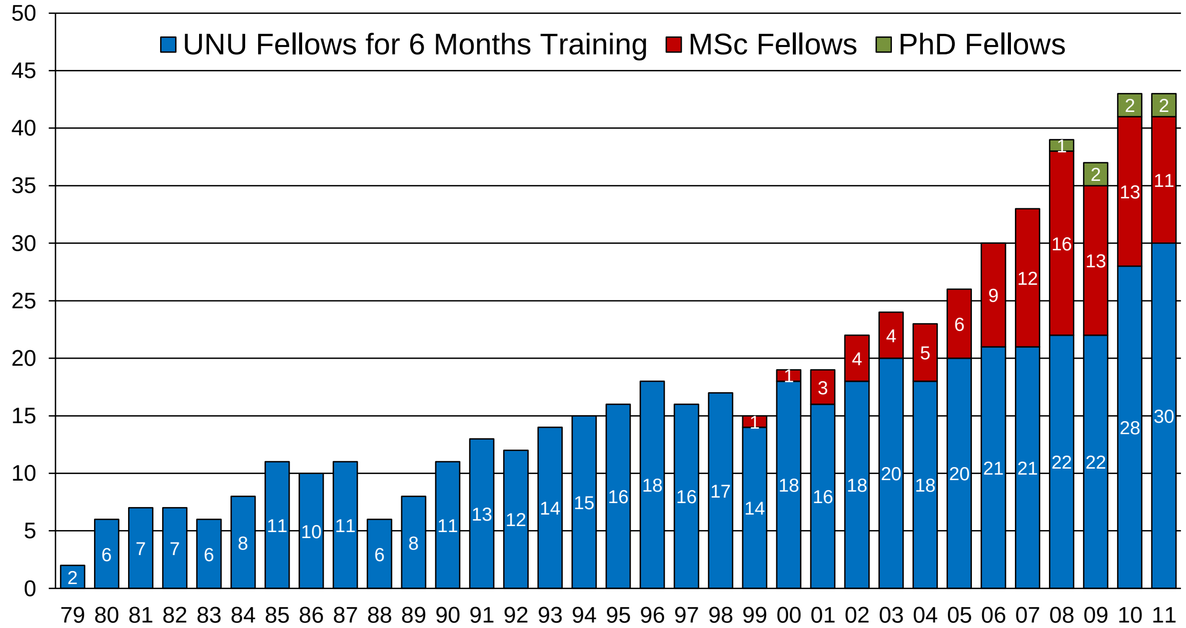

FIGURE 5: The gradual development of the training capacity of the UNU Geothermal Training Programme in Iceland from 1979 to 2011

For the past few years, regular funding of the UNU-GTP has allowed financing of six months training of about 20 UNU Fellows per year, with extra 1-3 Fellowships per year being financed through other sources, at least partially. However, the last two years have seen a dramatic increase in this. Improved set-up and new facilities in Iceland have made it possible for UNU-GTP to accept additional fellows if financed through external sources. This is reflected in the large groups in 2010 and 2011, with the largest group to date trained in 2011, including 30 UNU Fellows, 8 of whom were mainly financed through other agencies. Figure 5 shows the development of the training capacity of the UNU Geothermal Training Programme in Iceland from 1979 to 2011. For a more detailed description of the general operations of the UNU-GTP see Fridleifsson (2010b) or the UNU-GTP webpage, *www.unugtp.is*.

4.3 The MSc and PhD programme

The aim of establishing an MSc programme in cooperation with the University of Iceland (UI) was to go a step further in assisting selected countries to strengthen their specialist groups even further and increase their geothermal research capacity, through admittance and support for postgraduate academic studies. The six months training at the UNU-GTP fulfils 25% of the MSc programme credit requirements (30 of 120 ECTs). Since 2001, 28 former UNU Fellows (China 1, Costa Rica 1, Djibouti 1, El Salvador 3, Eritrea 1, Ethiopia 2, Indonesia 4, Iran 3, Jordan 1, Kenya 7, Mongolia 1, Philippines 2, and Uganda 1) have completed an MSc degree in geothermal science and engineering (December 2011) through the UNU-GTP MSc programme, with 4 or 14% from Latin America. At the end of 2011, 8 are doing their MSc studies in Iceland, 2 of whom come from El Salvador. The MSc theses have been published in the UNU-GTP publication series, and can also be obtained from the UNU-GTP webpage (*www.unugtp.is*). All of the MSc Fellows have been on UNU Fellowships funded by the Government of Iceland.

Furthermore, four former UNU Fellows, all coming from Africa, have now (end of 2011) been admitted to PhD studies at the University of Iceland, with the first two admitted in the academic year 2008-2009. The two first ones are on UNU Fellowships while the other two are funded through other sources in Iceland.

4.4 Workshops and Short Courses

The Short 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 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.

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*).

4.4.1 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 electric power. Cooperation was sought with Kenya, which has been the leading African country in geothermal development.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 the Kenyan geothermal companies.

The first event in Africa, "*Workshop for Decision Makers on Geothermal Projects and their Management*", was held in Kenya in November 2005. At the Workshop, high-level decision makers from five countries met to learn about and discuss the main phases of geothermal development and what kind of manpower, equipment, and financing was 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 ten 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. During the last 6 years, the annual Short Course in Kenya has gradually developed into a more general course on geothermal exploration: "*Short Course on Exploration for Geothermal Resources*", which has become3½ week long (Georgsson, 2010a; 2010b; 2011).A special addition in November 2008 was the "*Short Course on Geothermal Project Management and Development*" (Georgsson et al., 2008). This three day event, given in Entebbe, Uganda was mainly aimed at high level managers/employees in ministries/energy companies/research institutions in East Africa.

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 productionfrom 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. The highest number of participants in a single event is 58 for the 2011 Short Course, and the total number of participants in the Workshop/Short Courses is now more than 300 persons. Similarly, the number of lecturers has increased with the length of the Short Courses as can be seen from Table 5, which also shows that most of the African lecturers/supervisors are former UNU Fellows trained in Iceland.

TABLE 5: Lecturers in the UNU-GTP Workshops and Short Courses 2005-2011

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
Kenya 2011	36	27	5	0	4	27
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	25	12	6	1	6	14
China 2008	32	16	6	4	6	11

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, 271 Africans (including Yemen) participated in the Short Courses during 2006-2011 compared to a total of 62 UNU Fellows from the region being trained for 6 months in Iceland during the same period.

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 should become a reality soon.

For a further description of the UNU-GTP Workshops and Short Courses in Africa see Georgsson (2010a; 2011) or the UNU-GTP webpage (*www.unugtp.is*).

4.4.2 Short Courses in Central America

Similar to East Africa, in Central America geothermal resources are now playing 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. And Mexico has certainly one of the largest producer of geothermal electricity for many years. 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 6 shows most of the participants of the workshop.

FIGURE 6: 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. So the topics have differed from one to another. The first one was titled "*Short Course on Geothermal Development in Central America: Resource Assessment and Environmental Management*",a week-long event, and held in El Salvador 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 5 and 6).

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., 2009). 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. The Short Course reached a broader audience than the first two with participation from the East Caribbean Region. Similarly, with the next event, "*Short Course on Geothermal Drilling, Resource Development, and Power Plants*", a week long course given in January 2011, the UNU-GTP reached for the first time to countries in South America (Georgsson et al., 2011). The topic also proved 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. This is a trend we are seeing continuing with the current event.Figure 7 shows the participants of the Short Course in 2011.

TABLE 6: 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	23	**54**
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**	**62**	**139**

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 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 is also expected to increase in these Short Courses, as interest in the development of high-temperature resources in this part of the world grows.

From a more general perspective, 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

FIGURE 7: Participants and lecturers in the El Salvador Short Course in 2011

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., 2008; 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 within the region.

4.5 Customer-designed Short Courses

The latest capacity building service of the UNU-GTP has been 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 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.

In 2010 and 2011, 6 such Short Courses have been held for five different customers in three 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. An example of this is the week long "Short Course on Geothermal Exploration and Development" held in El Salvadorin November 2011. The Short Course was sponsored by the Organization of American States (OAS) for the benefit of three South-American countries, Ecuador, Colombia and Peru, all of which have consequently been invited to send participants to the current UNU-GTP event.

5. DISCUSSION

One of the major concerns of mankind today is the ever increasing emission of greenhouse gases into the atmosphere and the threat of global warming. It is internationally accepted that a continuation of the present way of producing most of our energy by burning fossil fuels will bring on significant climate changes, global warming, rises in sea level, floods, draughts, deforestation, and extreme weather conditions. One of the key solutions to avoid these difficulties is to reduce the use of fossil fuels and increase the sustainable use of renewable energy sources. Geothermal energy can play an important role in this aspect in many parts of the world.

Using indigenous renewable energy resources is an important issue and a possible solution for many countries, not least from the third world. This applies very much to the Latin America and the eastern Caribbean Islands. The volcanic systems of Central America and along the Andes mountain chain, as well as the volcanoes of the eastern Caribbean Islands, are a powerful heat source to the numerous high-temperature geothermal systems found in the region. These renewable energy resources have the potential to supply clean and sustainable energy to countries in dire need for energy and at the same time reduce their dependence on fossil fuels.

Capacity building and transfer of technology are key issues in the sustainable development of geothermal resources. Many industrialised and developing countries have significant experience in the development and operations of geothermal installations for direct use and/or electricity production. It is important that they open their doors to newcomers in the field. We need strong international cooperation in the transfer of technology and the financing of geothermal development in order to meet the Millennium Development Goals and the threats of global warming. The UNU-GTP is intent on assisting the Latin American and Caribbean countries in geothermal capacity building as best it can, so geothermal power can play a bigger role in the energy future of the region.

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