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GEOTHERMAL ENERGY IN THE WORLD AND THE CAPACITY BUILDING ACTIVTIES OF THE UNU-GTP

Lúdvík S. Georgsson and Ingvar B. Fridleifsson
United Nations University Geothermal Training Programme
Orkustofnun, Grensásvegi 9, 108 Reykjavik
ICELAND
lsg@os.is, ibf@os.is

ABSTRACT

The renewable energy sources are expected to provide at least 20% 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 to be in excess of 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 with 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 GWe, and less than 500 MWe have been harnessed so far. With the large untapped geothermal resources and the existing significant experience there are still ample opportunities to take geothermal to a higher level in the area. 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 GWe 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 Dominica, and are expected to continue this year in Montserrat and Dominica.

Finally, the activities of the UNU Geothermal Training Programme are described, including the 6 month training and postgraduate academic studies in Iceland with reference to Latin America. Special attention is given to the "UN Millennium Development Goals Short Courses" given almost annually in El Salvador since 2006, at first for the benefit of Central America, but more recently reaching to a large part of Latin America, and some of the volcanically active Caribbean Islands. Further development of geothermal capacity building in the region is discussed.

1. INTRODUCTION

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 is 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.

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 furthermore strong financial backup for the project is necessary.

Here, the role of geothermal energy in the world's energy mix is presented with some emphasis on its utilization in Latin America and the Caribbean region. Then capacity building activities will be discussed. The operations of the United Nations University Geothermal Training Programme (UNU-GTP) will be introduced and the need for further geothermal capacity building in the region discussed.

2. THE NEED FOR MORE ENERGY

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). And 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, now at 7 billion people, is expected to continue to increase to the end of the 21st century, and possibly double through the century. To provide sufficient commercial energy (not to mention clean energy) to the people of all continents during this century is thus 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 (WEA, 2000). 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 certainly 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 necessary to assist them in developing their renewable energy resources further so they are not compelled to meet the fast growing energy demands by fossil fuels.

3. WORLD ENERGY SOURCES

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 will 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 proposed level to which these energy sources can be expected to replace coal. In all the scenarios, the renewables are though expected to become 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 general energy consumption and the energy needed to replace coal.

But are these scenarios realistic? Table 1 (WEA, 2000) shows that there is no question that the technical potential of renewable energy resources is sufficiently large to meet future world energy requirements. The question is, however, how large a part of it can be harnessed in an economical, environmentally and socially acceptable way. This will probably vary between the energy sources. It is worth noting, 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 / 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 (>10 MW) 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 (<10 MW), 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 14,000 TWh 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 the 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. 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 are commonly operated at capacity factors in excess of 90%.

TABLE 3: Electricity from renewable energy resources in 2005

	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 also 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 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% in the 5-year period 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.

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

The largest geothermal electricity producer is the USA, with almost 15,000 GWh/yr, 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 of 10,300 GWh/yr means that geothermal supplies 17% of the total produced electricity. The same applies to Kenya, the total production of 1,430 GWh/yr puts the country in 9th place with regard to world production but 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 16 countries highest in direct use of geothermal energy.

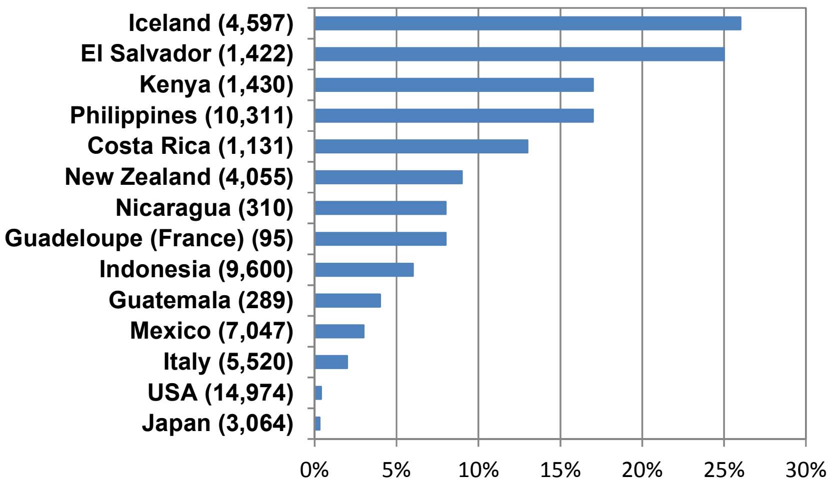

FIGURE 1: The fourteen countries with the highest % share of geothermal energy in their national electricity production. Numbers in parenthesis give the annual geothermal electricity production in GWh in 2009 (based on Bertani, 2010)

4. 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; see also Table 4). In each of the 4 countries there are geothermal power plants in operation in two geothermal areas. The photo in Figure 2 is taken at the Ahuachapán geothermal power plant in El Salvador, while Figure 3 shows the Las Pailas binary power plant in Costa Rica. The electricity generated in the geothermal areas is in all cases replacing electricity generated by imported oil. The geothermal potential for electricity generation in Central America has been estimated some 4 GWe (Lippmann 2002), but less than 0.5 GWe have been harnessed so far. Exploration and production drilling has been ongoing in several new fields in the region with positive results, most recently in the San Vicente field in El Salvador.

FIGURE 2: Some lecturers and participants in the Short Course IV in 2012 visiting the Ahuachapán geothermal power plant in El Salvador

FIGURE 3: The Las Pailas binary geothermal power plant in Costa Rica

South America also hosts vast sources of geothermal energy that are largely unexploited. 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. Despite this, the only geothermal power plant which has been operated on the continent is the 0.7 MW binary demonstration unit in the Copahue field in Argentina, which was decommissioned in 1996 (Bertani, 2010). However, all of these countries have some history of geothermal exploration, and the interest has recently been reinvigorated with the changes in global energy prices and the increased emphasis on renewables to combat global warming (Haraldsson, 2013).

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 from its geothermal resources. St. Lucia, Nevis and most recently Dominica have drilled exploration wells to analyse the resource for commercial exploitation. The recent most significant progress was the drilling of 3 deep vertical exploration wells in Dominica in 2012 (Maynard-Date, 2012; George, 2012). Further progress is expected in 2013 with the first deep exploration well being drilled in Montserrat, and additional trial wells in Dominica.

4. THE UNU GEOTHERMAL TRAINING PROGRAMME IN ICELAND

4.1 Introduction

The UNU Geothermal Training Programme (UNU-GTP) was established in Iceland in 1978. Its 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 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 (in 2008) (Fridleifsson, 2010).

During 1979-2012, 515 scientists and engineers from 53 countries have completed the annual six month courses. They have come from countries in Asia (40%), Africa (32%), Latin America (16%), Central and Eastern Europe (12%) and Oceania (0.4%). Since 2000, 33 have graduated with MSc degree (end of 2012). In January 2013, seven pursued their MSc and three 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 that have each been a week, and more than 500 scientists/engineers have now been trained at the Short Courses, which have extended over 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 now become an important part of the UNU-GTP operations (Georgsson, 2010, 2012a, b).

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. And now, the Inter-American Development Bank (IDB) with the support of the Nordic Development Fund (NDF) is working towards establishing a model for a sustainable post-graduate university programme to be established in El Salvador for the benefits of the Latin American countries, with the cooperation of amongst others the UNU-GTP, 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 6 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 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 4 shows the recently revised 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	Chemistry of Thermal Fluids	Environmental Science	Geothermal Utilization	Drilling Technology
1 2 3 4 5 6	Introductory Lecture Course Main aspects of geothermal energy exploration and utilization Practicals and short field excursions								
7 8 9 10	Field geology Lithological, tectonic & hydrothermal mapping Temperature surveying	Sample preparation Cutting analysis Petrography - Lithological & alteration logs	Thermal methods - Magnetics Gravity - Seismic methods Resistivity of rocks - Resistivity methods: DC, TEM & MT	Well logging & testing - theory & practises Logging and testing demonstrations Reservoir physics & well/reservor modelling Monitoring response to exploitation		Sampling of fluid & gas - Wet steam wells - Analytical methods Thermodynamics - Data processing and interpret.	EIA project planning Chemistry - Physics Biology - Monitoring Revegetation - Safety	Thermal design of power plants & source systems - Direct use of geothermal heat - Scientific modelling of utilization systems	Drilling equipment & procedures - Well design Rig operations - Safety Management - Cementing
11 12	Excursion to some of the main geothermal fields of Iceland, geothermal power plants and direct use facilities								
13 14	Gradient wells Remote sensing - GIS	XRD - Fluid inclusions Logging software	Processing & modelling resistivity data - GPS	Resource management & reinjection Data processing & software applications		Water-rock interaction Corrosion & scaling	Gas dispersion & abatem. Corrosion & scaling	Power plant components - Control systems - Corrosion & scaling	Completion - Testing Problems - Drilling software
15 16 17 18 19 20 21 22 23 24 25 26	**Project and report writing**	**Project and report writing**	**Project and report writing**	**Project and report writing**	**Project and report writing**	**Project and report writing**	**Project and report writing**	**Project and report writing**	**Project and report writing**

FIGURE 4: Approximate time schedule and contents of the 6 month specialized courses at UNU-GTP

The largest groups of UNU Fellows have come from China (80), Kenya (72), El Salvador (34) and Philippines (33). Figure 5 shows the UNU Fellows who completed the 6 months training in 2012.

For the past several 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 three 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 2010-2012, with the largest group to date trained in 2012, including 33 UNU Fellows, 11 of whom were mainly financed through other agencies. Especially Kenya has utilized this opportunity as possible. Figure 6 shows the development of the training capacity of the UNU Geothermal Training Programme in Iceland from the beginning in 1979 to 2012. For a more detailed description of the general operations of the UNU-GTP see Fridleifsson (2010) or the UNU-GTP webpage, *www.unugtp.is*.

FIGURE 5: UNU Fellows in Iceland for the 6 month training in 2012

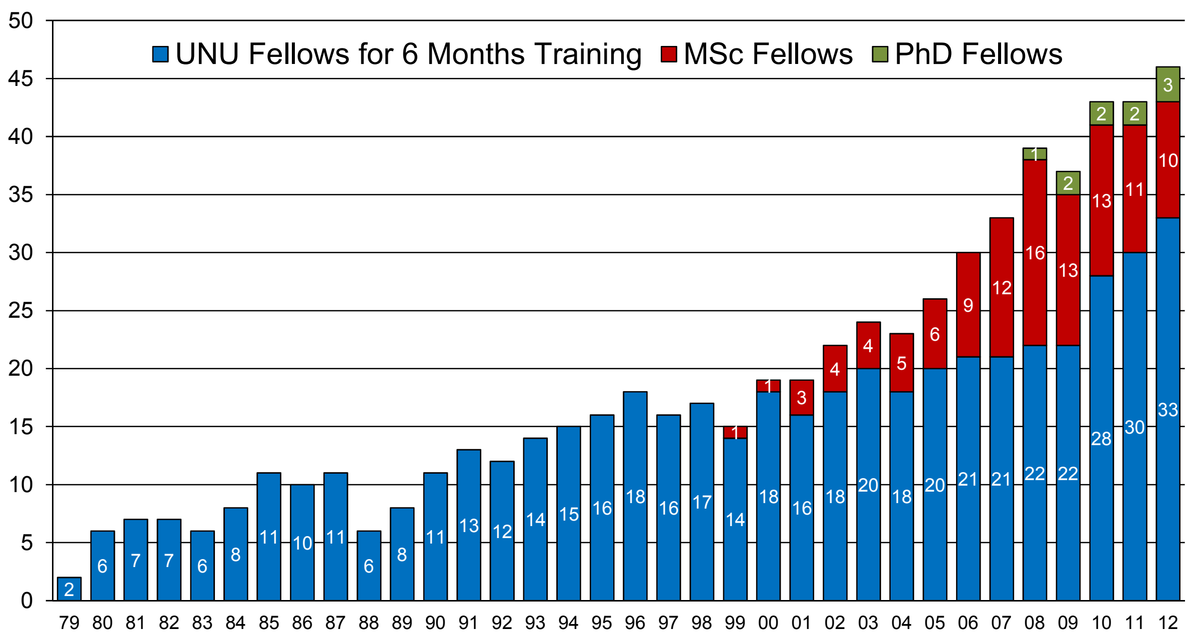

FIGURE 6: The gradual development of the training capacity of the UNU Geothermal Training Programme in Iceland from 1979 to 2012

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, 33 former UNU Fellows (China 2, Costa Rica 1, Djibouti

1, El Salvador 4, Eritrea 2, Ethiopia 2, Indonesia 4, Iran 3, Jordan 1, Kenya 8, Mongolia 1, Philippines 2, Rwanda 1 and Uganda 1) have completed an MSc degree in geothermal science and engineering (December 2012) through the UNU-GTP MSc programme, with 5 or 15% from Latin America. At the beginning of 2013, 7 are doing their MSc studies in Iceland, 1 of whom comes from El Salvador, and 1 from Nicaragua. 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-GTP Fellowships funded by the Government of Iceland.

Finally, three former UNU Fellows, all coming from Africa, have now (end of 2012) been admitted to PhD studies at the University of Iceland on UNU-GTP Fellowships, with the first ones starting in the academic year 2008-2009. On February 15, 2013 a new milestone was reached in the operations of the UNU-GTP with the first one of these defending her PhD thesis. Dr. Pacific F.Achieng Ogola from Kenya was in fact the first person from Africa to graduate with a doctoral degree from the UI.

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 Millennium 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 gradually developed into a more general course on geothermal exploration: "*Short Course on Exploration for Geothermal Resources*", which is now 3½ week long.

Participation in the Short Courses in Kenya has increased 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 two decades. New countries have also been added to those invited most years, and in many cases, they have been participating for the first time in geothermal meetings in the UNU-GTP events. In total, 19 countries of Africa have now participated, the majority of them on a fairly regular basis. The highest number of participants in a single event is 61 in the 2012 Short Course, and the total number of participants in the Workshop/Short Courses is now over 360 persons. 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 or being groomed for geothermal work, who are given an introduction to state-of-the-art exploration techniques for geothermal resources and the possible development of this valuable renewable energy source.

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 building of facilities which can make this possible, and if current plans hold, this should turn into a reality soon. For a further description of the UNU-GTP Workshops and Short Courses in Africa see Georgsson (2010; 2011; 2012a) or the UNU-GTP webpage (*www.unugtp.is*).

4.4.2 The Central-American Series of Millennium Short Courses

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. And Mexico has certainly been one of the world's largest producers 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, especially in El Salvador and Costa Rica. Hence, Central America was selected as the region for the second Series of Millennium Short Courses, with LaGeo S.A de C.V. in El Salvador chosen as a cooperation partner 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 of courses, as it has certainly proven to be.

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 said "*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 7 shows most of the participants of the workshop.

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 event to another. The first one was titled "*Short Course on Geothermal Development in Central America: Resource Assessment and Environmental Management*", a week-long event held in El Salvador in late November 2007 (Fridleifsson et al., 2007). Regional participants were 45 + 17 lecturers, with additional international lecturers coming from Iceland, Kenya and the Philippines (Tables 5 and 6).

FIGURE 7: Participants in the first UNU-GTP Workshop in Central America in 2006

TABLE 5: Participants in the Millennium Short Courses in Central America 2007-2012

Country	2007	2009	2011	2012	Total
Bolivia				1	**1**
Chile				5	**5**
Colombia			5	2	**7**
Costa Rica	6	7	6	1	**20**
Dominica		2	2	2	**6**
El Salvador	22	9	23	28	**82**
Ecuador			1	2	**3**
Guatemala	1	1	2	1	**5**
Honduras	2	2	5	2	**11**
Mexico	1		3	6	**9**
Nevis		2	2	1	**5**
Nicaragua	13	7	13	11	**44**
Others		2		3	**5**
Total	**45**	**32**	**62**	**65**	**203**

TABLE 6: Lecturers in the Millennium Workshops and Short Courses in El Salvador in 2006-2012

Short course / Workshop	Total	Home country	Neighb. countries	Intern.	Iceland	UNU-Fellows
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
El Salvador 2012	26	10	8	3	5	11

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 in 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 consisted of 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. The third Short Course was the "*Short Course on Geothermal Drilling, Resource Development, and Power Plants*", a week long course given in January 2011. Here, 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 saw continue in last year's event, the week long *Short Course IV on Geothermal Development and Geothermal Wells*" (Georgsson et al., 2012) and progressing even further with the current event. Tables 5 and 6 show the number of participants and lecturers. Figure 8 shows the participants of the Short Course in 2012.

FIGURE 8: Participants and lecturers in the El Salvador Short Course in 2012

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, production monitoring, environmental aspects, and even techniques for direct use. However, participation can also be expected to cover a wider geographical 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 be expected to become a significant factor in the Short Courses in the near future. Similarly, participation from South America is also expected to increase, 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 the possibility to be selected for training in Iceland. There are now many examples of good participants in the Short Courses being selected for the 6 month training in Iceland. And in a few cases it has even led to MSc studies in Iceland, 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 are the customer-designed Short Courses in developing countries, given for the first time in 2010. This new service of the UNU-GTP was 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 2010-2012, 9 such Short Courses or Advanced Training have been held for five different customers in three continents. The contents have varied from general geoscientific courses to more specialized ones, such as on geothermal drilling, as well as scaling and corrosion in geothermal installations. Similarly, the length has varied from one week to 6 months, based on the need and target. An example is the week long "Short Course on Geothermal Exploration and Development" held in El Salvador in 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 UNU-GTP Millennium Short Courses.

4.6 The strength of the internet

Open publications has always been the motto of the UNU-GTP, which is in line with the general policies of the United Nations University, supporting free access of scientific material for the developing nations. The reports of the UNU Fellows in Iceland have been distributed free of charge to geothermal institutions worldwide, and the same has applied to publications of study material. The annual report book "Geothermal training in Iceland" is also sent to all active former UNU Fellows, and to geothermal institutions worldwide. With the coming of the internet, from the early 2000s, the reports have also been published open-file in a pdf-version at UNU-GTP's website. More recently, all older reports have also been made available there. The same applies to the UNU-GTP Workshops and Short Courses, and the UNU-GTP Anniversary Publications. Papers written for these events and published in books and/or on CDs, are all also available for downloading at the website: *www.unugtp.is.*

It is safe to say that with all the material now accessible on the UNU-GTP website, the UNU-GTP has created one of the largest open databases in the world available on geothermal exploration, development and utilization. This is easy to verify by searching for material on geothermal on the internet, through one of the large search machines, where material published by the UNU-GTP will inevitably score high in possible views. It is therefore interesting to look at some statistics in this. Table 7 shows the most viewed publications in 2012 and their numbers of views. The Short Courses in El Salvador are obviously attracting much attention as papers presented there are in 3 of the 4 top seats. The number of views can also be considered very high for such specialized literature.

Additionally, it is interesting to see the geographic distribution of the website's visitors who viewed the publications of the UNU-GTP (including the website of Orkustofnun (*www.os.is*)). With 23,698,449 visits, Iceland was at the top, but Figure 9 shows the number of visits from other countries. Here it must be noted that for this purpose, it is only possible to see which countries view publications on the UNU-GTP and Orkustofnun websites, but not which publications are being viewed. What is unexpected here are the high number of visits from countries that are not known for access to significant amount of geothermal resources, like the Netherlands and Germany. However, here another factor must be considered which is how "computerized" the country is, and how general access is to the internet. This would be expected to increase the share of the developed countries, which the figure seems to support.

TABLE 7: Most viewed publication of the UNU-GTP on the internet in 2012

No.	No. views	Title and author of publication	Publication year and type/event
1	365,303	*Piping design: the fundamentals*, by José Luis Henriquez and Luis Agurirre	2011 - ESSC
2	114,520	*Absorption refrigeration system as an integrated condenser cooling unit in a geothermal power plan*, by Tesha	2009 – MSc thesis
3	85,575	Gravity and magnetic methods, by José Rivas	2009 - ESSC
4	42,226	*Geothermal power plant cycles and main components*, by Páll Valdimarsson	2011 - ESSC
5	29,473	*Analysis of management methods and application to maintenance of geothermal power plants*, by Clety Kwambai Bore	2008 – MSc thesis
6	22,885	*East African Rift System –an overview,* by Kristjan Saemundsson	2010 - KSC

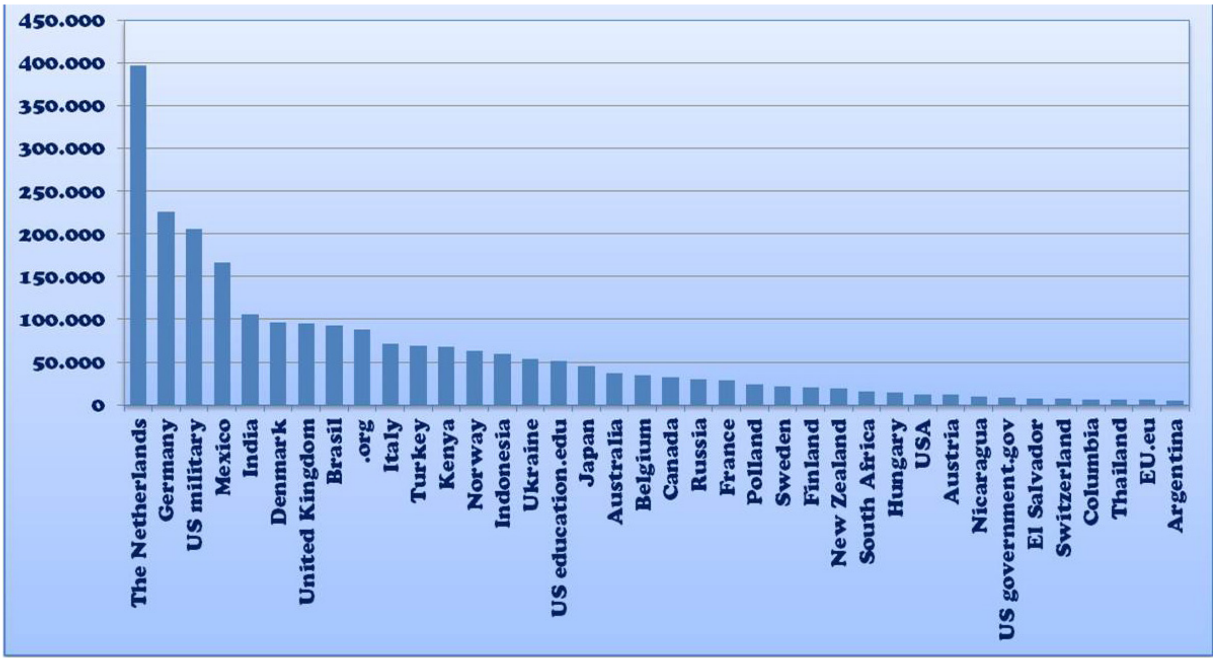

FIGURE 9: Number of views of the UNU-GTP and Orkustofnun websites by country (made by M. Ómarsdóttir)

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 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 for 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. When considering the wealth of these resources, it can be argued that it is surprising, how slow the development has been in S-America and the Caribbean region.

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. This we will continue to do both through offering UNU Fellowships for 6 month training and postgraduate academic studies in Iceland, and through Short Courses in the region itself. Here, we especially hope to be able to intensify our effort with regard to countries in the early stages of development.

A *Geothermal Diploma Course* in Spanish and open for all the C-American countries has been given twice in El Salvador in the last 4 years with both financial and educational support from Italy (Caprai et al., 2012). This initiative has now come to an end. However, the Inter-American Development Bank (IDB) with the support of the Nordic Development Fund (NDF) has now pledged support for the continuation of this, and is working towards establishing a model for a sustainable post-graduate university programme, which could even progress to an MSc programme, to be established in El Salvador for the benefits of the Latin American countries, with the cooperation of amongst others the UNU-GTP, LaGeo, and Salvadorian universities. This can prove an important basis for taking geothermal development in the region to a new level. The annual UNU-GTP Short Course could be foreseen to become an integral part of this diploma course. Hopefully, we will see the realisation of this in 2014.

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