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

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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 Scenarios" report on the status in 2010 and predictions for 2050 (WEC, 2013), the primary energy consumption in the world was assessed to be 546 EJ in 2010, with about 80% coming from fossil fuels, but only 15% 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 13.0% of the total electricity generation of the four countries Costa Rica, El Salvador, Guatemala and Nicaragua. The geothermal potential for electricity generation in Central America has been estimated some 4 GWe, and less than 700 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, Ecuador and Peru. 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, Dominica and Montserrat.

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 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 and the current Diploma Course given at the University of El Salvador.

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. Kenya is a good example of this, as well as the Philippines, El Salvador and Costa Rica where geothermal energy is providing for 10-25% 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. Therefore, 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 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 (Fridleifsson et al., 2008).

The renewable energy sources are expected to provide 20-30% of the primary energy in 2050 (WEC, 2013). 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, e.g. in 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. THE ROLE AND POTENTIAL OF GEOTHERMAL ENERGY TODAY

Geothermal energy is a resource that has been used by mankind for washing, bathing and healing through its history. In the 20th century, geothermal gradually came on-line as an energy source for electricity production and to be used directly, besides bathing or washing, for heating of houses, greenhouse heating, aquaculture etc. According to energy reviews based on surveys for 2009, presented in combination with the World Geothermal Conference 2010, geothermal resources have been identified in over 90 countries while quantified utilization is recorded in 78 countries. Electricity is produced from geothermal energy in 24 countries. In 2009, the worldwide use of geothermal energy was estimated to be about 67 TWh/a of electricity (Bertani, 2010), and direct use 122 TWh/a (Lund et al., 2010).

Today´s energy consumption relies on fossil fuels. Table 1 shows the use of primary energy in 2010 based on a recent report by the World Energy Council (WEC, 2013). The total use of primary energy is assessed to have been about 546 EJ in 2010, with 80% of it coming from fossil fuels. With rising oil prices and with environmental concerns expected to play a bigger role, through necessary reduction in emissions of greenhouse gasses, renewable energy sources are expected to play an increasingly bigger role in the 21st century. The technical potential of the renewable energy sources is certainly large enough.

TABLE 1: World primary energy consumption in 2010 (WEC, 2013)

Energy source	Primary energy (EJ)	Share, (%)
Fossil fuel	**435**	**79.6**
Oil	172	31.5
Gas	114	20.9
Coal	149	27.2
Renewables	**81**	**14.8**
Biomass	66	12.1
Hydro	13	2.3
Other renewables	2.2	0.4
Nuclear	**30**	**5.5**

In its report, WEC (2013) puts forward two innovative scenarios for the energy utilization development until 2050. One of these is named *Jazz* where it is assumed that the forces of the market or consumer prices will be decisive in the development. The other is named *Symphony*, where it is assumed that focus will be on environmental sustainability, and thus politics will have a major say in the development.

According to *Jazz* total use is predicted to increase to 879 EJ in 2050, which is an increase of 60%. Fossil fuels are expected to be still dominating with 77% of the production while the share of the renewables is predicted to become about 20%. *Symphony* is a considerably different scenario. The total use is predicted to be 696 EJ which is an increase of only 28%. The share of renewables is predicted to reach about 30%. Fossil fuels are still responsible for the majority of the energy production, with their share, however, lowering to about 59%. Also on a positive note is the prediction of a considerably improved energy efficiency.

Table 2 shows the production of electric energy in 2010 and how it is predicted to develop to 2050, according to the two different scenarios (WEC, 2013). The share of the renewables is expected to increase even more. According to the table, other renewables, which include wind, geothermal, solar and tidal energy are only contributing 4% of the total electrical energy production in 2010. In 2050, in *Jazz* this is expected to increase to about 20% and in *Symphony* to about 32%. So the future of the other renewables appears bright.

TABLE 2: Electrical production vs. energy source 2010-2050 (WEC, 2013)

Energy source	**2010**		**2050 - Jazz**		**2050 – Symphony**	
	TWh	**%**	**TWh**	**%**	**TWh**	**%**
Coal	8,666	40	20,279	38	8,483	18
Gas	4,777	22	13,427	25	9,517	20
Hydro	3,491	16	5,789	11	7,701	16
Nuclear	2,783	13	3,279	6	6,950	15
Oil	980	5	0	0	0	0
Oth. renewabl.	**798**	**4**	**10,894**	**20**	**15,266**	**32**
Total	**21,476**		**53,647**		**47,918**	

Table 3 shows similar information but here the distribution is on regional scale. The uppermost line shows the values for Sub-Saharan Africa and it illustrates clearly how this region is starved of electrical energy. Africa is the dark continent in more than one way. For Latin America and the Caribbean the status is more positive but still a large effort is needed to fulfil the needs of the region, as seen in the fairly high prediction of increase in production during the next few decades, 2.6-3.0% annual growth rate depending on scenario.

TABLE 3: Electrical production vs. regions 2010-2050 (WEC, 2013)

	2010		**2050 - Jazz**		**2050 – Sym.**	
	TWh	**%**	**TWh**	**AGR %**	**TWh**	**AGR %**
Sub-Saharan Africa	414	1.9	3087	5.2	2836	4.9
Mid. East & N-Africa	1150	5.3	3644	2.9	3314	2.7
Lat. America & Carib	**1147**	**5.3**	**3701**	**3.0**	**3221**	**2.6**
N-America	5214	24.3	8024	1.1	8057	1.1
Europe	5104	23.8	8439	1.3	7961	1.1
S- & Central Asia	1331	6.2	8429	4.7	6560	4.1
E-Asia	6121	28.5	14298	2.1	12571	1.8
SE-Asia & Pacific	996	4.6	4024	3.6	3398	3.1
Total	**21,477**		**53,646**		**47,918**	

The use of geothermal energy has increased steadily during the last few decades, and until the start of this century it was seated as number three of the renewables with regards to electricity production. However, more recently wind energy has surpassed geothermal and has now left it far behind. The total electricity production from renewable energy sources (Table 4) was assessed as 4,289 TWh in 2010 (WEC, 2013). Of this, 81% came from hydropower, 7.9% from biomass, 8.3% from wind, 1.6% from geothermal, while solar contributed to 0.8%. With its huge technical potential, geothermal energy is definitely one of the energy resources contributing to a greener future.

TABLE 4: Electricity from renewables in 2010 (WEC, 2013)

	Installed capacity		**Production/a**		**Capacity factor**
	GW	%	TWh/a	%	%
Hydro	778	74	3,491	81	39
Biomass	71	6.5	337	7.9	54
Wind	191	17.5	358	8.3	21
Geothermal	**11**	**1.0**	**69**	**1.6**	**72**
Solar	39	3.6	34	0.8	10
Total	**1,090**	**100**	**4,289**	**100**	**37**

A comparison of energy costs between countries is difficult, because of differences in taxation and subsidies. According to the World Energy Association survey (WEA, 2004), the renewables are definitely competitive, showing the electrical energy cost to be 2-10 UScents/kWh for geothermal and hydro, 4-8 UScents/kWh for wind, 3-12 UScents/kWh for biomass, but higher for solar energy. These are not new numbers but still representative. The investment cost is also assessed to be quite similar for the different energy sources, 1000-3500 USD/kW for hydro, 500-6000 USD/kW for biomass, 800-3000 USD/kW for geothermal and 850-1700 USD/kW for wind. The advantage of geothermal energy compared to other renewables is the high capacity factor, being independent of weather conditions contrary to solar energy, wind energy, or hydropower. The reliability of geothermal plants means that usually they can be operated at capacity factors in excess of 90%. This is partly illustrated in Table 4.

In 2009, electricity was produced from geothermal energy in 24 countries, increasing by 18% from 2004 to 2009 (Bertani, 2010). Table 5 lists the top eleven countries producing geothermal electricity in the world in 2009, and those employing direct use of geothermal energy (in GWh/year). The largest electricity producer is the USA, with almost 16,600 GWh/a, but this still amounts only to half a percent of their total electricity production. It is different for most of the other countries listed there, with geothermal playing an important role in their electricity production. That certainly applies to the second country on the list, the Philippines, where the production of more than 10,000 GWh/a means that geothermal supplied 17% of the electricity produced. Three Latin American countries are seen in the table. Mexico is in 4th seat with 7047 GWh/a, but this amounts though only to 3% of the total production. While for El Salvador and Costa Rica 1422 GWh/a and 1131 GWh/a produced, respectively, amounts to 25% and 13% of the total. Here, we should even see positive changes in the new data being prepared for the World Geothermal Congress 2015. A high value is also seen for Iceland where a production of 4597 GWh/a means that geothermal supplied about 25% of the produced electricity. For direct use, China heads the list with USA and Sweden in second and third place, through rapidly increasing use of ground source heat pumps, followed by Turkey, Japan, Norway (new on the list, also through use of ground source heat pumps) and Iceland (Lund et al., 2010). With direct use of geothermal energy still insignificant in Africa it is not surprising that no Latin American country is seen among the top ten countries in direct use of geothermal energy.

TABLE 5: Top eleven countries in electricity production from geothermal energy in 2009 (Bertani, 2010), and those with direct use (Lund et al., 2010)

Geothermal electricity production			**Geothermal direct use**	
Country	**GWh/a**	**% nat. produc.**	**Country**	**GWh/a**
USA	16,603	0.5?	China	20,932
Philippines	10,311	17	USA	15,710
Indonesia	9,600	3?	Sweden	12,585
Mexico	**7,047**	**3**	Turkey	10,247
Italy	5,520	2	Japan	7,139
Iceland	**4,597**	**25**	Norway	7,001
New Zealand	4,055	10	Iceland	6,768
Japan	3,064	0.3?	France	3,592
Kenya	1,430	17	Germany	3,546
El Salvador	**1,422**	**25**	Netherlands	2,972
Costa Rica	**1,131**	**13**	Italy	2,762

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.

4. GEOTHERMAL ELECTRICITY IN LATIN AMERICA AND EASTERN CARIBBEAN

FIGURE 1: Some lecturers and participants in the Short Course IV in 2012 visiting the Ahuachapán geothermal power plant in El Salvador

FIGURE 2: The Las Pailas binary geothermal power plant in Costa Rica

Central America is one of the world´s richest regions in geothermal resources. Geothermal power stations provide 13% of the total electricity generation of the four countries Costa Rica, El Salvador, Guatemala and Nicaragua, according to data provided from the countries (CEPAL, 2014; see also Table 5). In each of the 4 countries there are geothermal power plants in operation in two geothermal areas. The photo in Figure 1 is taken at the Ahuachapán geothermal power plant in El Salvador, while Figure 2 shows the Las Pailas binary power plant in Costa Rica. The electricity generated in the geothermal areas is mainly 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 0.7 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.

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 increased emphasis on renewables to combat global warming (Haraldsson, 2013).

The 11 volcanic islands of the Eastern Caribbean lying on the inner arc of the Lesser Antilles chain 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 Dominica and most recently Montserrat 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), with two more exploration wells drilled in 2013-2014, while the first deep exploration well was drilled in Montserrat in 2013.

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. A similar agreement has now been signed with the Reykjavik University. 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) (Georgsson et al., 2015a and b).

During 1979-2014, 583 scientists and engineers from 58 countries have completed the annual six-month courses. They have come from countries in Asia (37%), Africa (36%), Latin America (15%), Central and Eastern Europe (11%) and Oceania (1%). Since 2000, 41 have graduated with an MSc degree (March 2015), and the first UNU PhD Fellow graduated in February 2013 from the University of Iceland. In March 2015, eleven pursued their MSc and two 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 750 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 et al., 2015a and b; Georgsson, 2014).

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 Nordic Development Fund (NDF) and the Inter-American Development Bank (IDB) are supporting a post-graduate diploma programme at the University of El Salvador for the benefit of the Latin American countries, run under Consejo Nacional de Energía – CNE, in El Salvador, with the cooperation of LaGeo and under the guidance of UNU-GTP.

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. After a review in late 2014, eight specialized lines of training are offered, *Geothermal Geology, Geophysical Exploration, Reservoir Engineering and Borehole Geophysics,* *Chemistry of Thermal Fluids*, *Environmental Studies*, *Geothermal Utilization*, *Drilling Technology*, and *Geothermal Project Management and Finances*. Each participant is meant to follow only one line of training, but within each line there is some 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 the individual is specializing in (6 weeks). A new feature is group work (approx. 2 weeks) carried out during the second half of the introductory lectures and into the starting phase of the specialized lectures. 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 (10-11 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" (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 recently revised time schedule and contents of the six month specialized courses at UNU-GTP in Iceland.

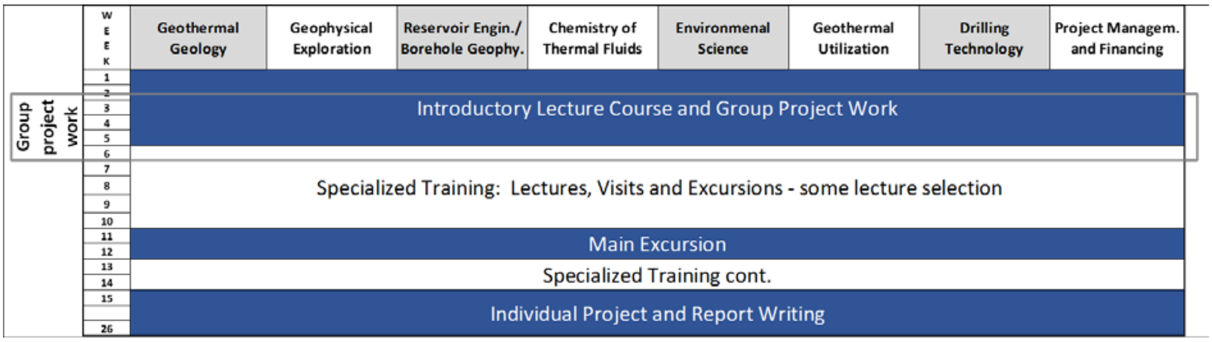

FIGURE 3: Approximate time schedule and contents of the 6-month specialized courses at UNU-GTP

The largest groups of UNU Fellows have come from Kenya (100), China (83), El Salvador (38) and Philippines (36). Figure 4 shows the UNU Fellows who completed the 6 months training in 2013.

FIGURE 4: UNU Fellows in Iceland for the 6 month training in 2013

For the past decade or so, regular funding of the UNU-GTP has allowed financing of six months training of 18-20 UNU Fellows per year, with extra 1-3 Fellowships per year being financed through other sources, at least partially. However, the last five years have seen a dramatic increase in the latter. 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 2010-2014, with the largest group to date trained in 2013, including 34 UNU Fellows, 13 of whom were mainly financed through other agencies. Especially Kenya has utilized this opportunity extensively. Figure 5 shows the development of the training capacity of the UNU Geothermal Training Programme in Iceland from the beginning in 1979 to 2014. It should be noted that the numbers for 2013, include 5 additional Kenyan borehole geologists, who got a similar training through a 3 month course and 6 month training in Kenya in 2012-2013, and have thus been given a similar status as conventional UNU Fellows.

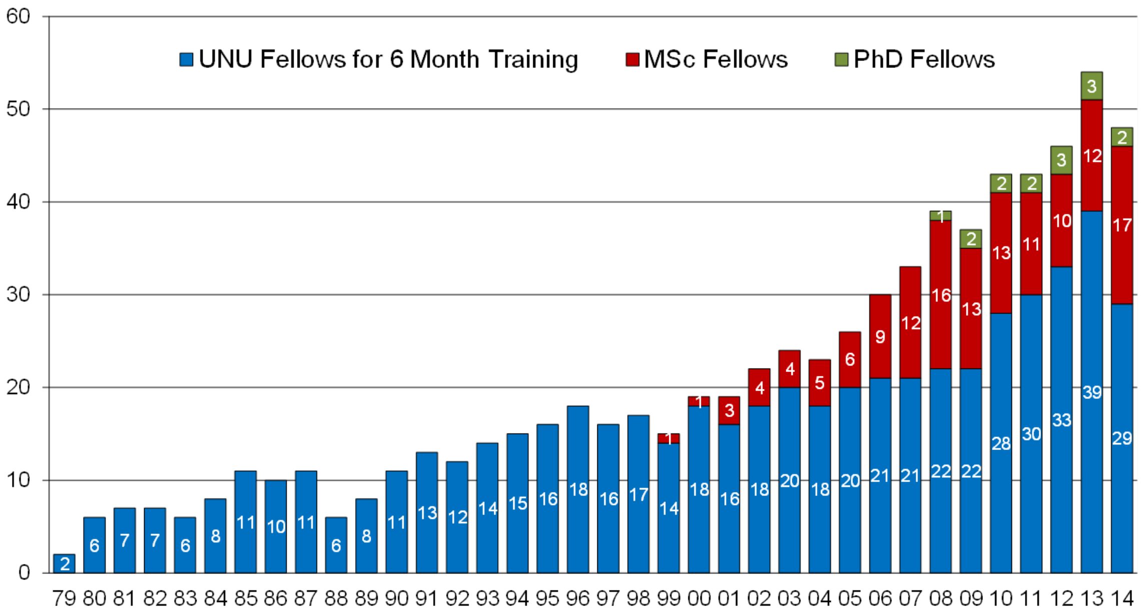

FIGURE 5: The gradual development of the training capacity of the UNU Geothermal Training Programme in Iceland from 1979 to 2014

For a more detailed description of the general operations of the UNU-GTP see Georgsson et al. (2015a) 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, 41 former UNU Fellows (China 2, Costa Rica 1, Djibouti 1, El Salvador 5, Eritrea 2, Ethiopia 2, Indonesia 4, Iran 3, Jordan 1, Kenya 14, Mongolia 1, Nicaragua 1, Philippines 2, Rwanda 1 and Uganda 1) have completed an MSc degree in geothermal science and engineering (March 2015) through the UNU-GTP MSc programme, with 7 or 17% from Central America. In March 2015, 11 are doing their MSc studies in Iceland, 1 of whom comes 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 Central American MSc Fellows have been on UNU-GTP Fellowships funded by the Government of Iceland (Georgsson et al., 2015a).

Finally, three former UNU Fellows, all coming from Africa, have 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.

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, 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

The first event in Africa, "*Workshop for Decision Makers on Geothermal Projects and their Management*", was held in Kenya in November 2005, in cooperation with the Kenya Electricity Generating Company - KenGen. 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.

The result of the Workshop was that the Short Courses in East Africa should begin with a 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 8 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 most years, 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, 22 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 70 in the 2013 Short Course, and the total number of participants in the Workshop/Short Courses is now over 490 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. For a further description of the UNU-GTP Workshops and Short Courses in Africa see Georgsson et al. (2015b) or Georgsson (2014) 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. 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.

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. 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. 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. 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 which has continued in last three events, the one week long *Short Course IV on Geothermal Development and Geothermal Wells*" in March 2012, "*Short Course V on Conceptual Modelling of Geothermal Systems*" in February 2013, and *Short Course VI on Utilization of Low- and Medium-Enthalpy Geothermal Resources and Financial Aspects of Utilization*, in March 2014. Table 6 shows the number of participants and lecturers in these events. Figure 6 shows the participants of the Short Course in 2014.

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.

TABLE 6: Participants in the Millennium Short Courses in Central America 2007-2014

Country	**2007**	**2009**	**2011**	**2012**	**2013**	**2014**	**Total**
Bolivia				1			**1**
Chile				5	5	4	**14**
Colombia			5	2	4	2	**13**
Costa Rica	6	7	6	1	2	3	**25**
Dominica		2	2	2	1	1	**8**
El Salvador	22	9	23	28	18	26	**126**
Ecuador			1	2	3	2	**8**
Guatemala	1	1	2	1	2	2	**9**
Honduras	2	2	5	2	4	1	**16**
Mexico	1		3	6	6	3	**19**
Montserrat						1	**1**
Nevis		2	2	1	2	2	**9**
Nicaragua	13	7	13	11	11	5	**60**
Peru					3	1	**4**
Others		2		3		2	**7**
Total	**45**	**32**	**62**	**65**	**61**	**55**	**320**

FIGURE 6: Participants and lecturers in the El Salvador Short Course in 2014

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 is 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.

As of March 2015, 23 such Short Courses or Advanced Training have been held for eight different customers in five 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 were consequently invited to send participants to the UNU-GTP Millennium Short Courses.

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 was given twice in El Salvador in 2010-2012, with both financial and educational support from Italy. Through funding by the Nordic Development Fund (NDF) and the Inter-American Development Bank (IDB) this was continued in 2013, with 26 participants, 10 of whom came from outside El Salvador, from all over Latin America, and again with similar participation in 2014. This course will continue for at least the next year. The long-term aim is, however, to work 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.

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