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THE ROLE OF GEOTHERMAL ENERGY AND CAPACITY BUILDING IN ACHIEVING THE UN SUSTAINABLE DEVELOPMENT GOALS IN LATIN AMERICA AND THE CARIBBEAN

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ABSTRACT

The United Nations (UN) has committed to ensuring access to affordable, reliable, sustainable and modern energy for all by 2030, as stated in Sustainable Development Goal 7. In line with this, electricity will need to be brought to about one billion people in developing and transitional countries over a short time period. It is foreseen that a large part of this energy will come from the renewables, including geothermal energy. Capacity building is a key enabler in accelerating the utilization of geothermal energy in countries of greatest need.

Based on the World Energy Council report, published in 2016, on the current world energy status and future energy scenarios, the primary energy consumption in the world was assessed as 574 EJ in 2014, with about 81% coming from fossil fuels, and only 14% from renewable energy sources. Different scenarios proposed by WEC for development to 2060 are discussed with emphasis on the potential contribution of the renewables and their prospects. The current share of renewables in energy production is mainly from biomass and hydro, but in a future envisioned through depleting resources of fossil fuels and environmentally acceptable energy sources, geothermal energy with its large technical potential, being well suited for a base load, as well as being financially competitive with the other renewable energy sources, is expected to play an important role. The status of geothermal in Latin America and the Caribbean (LAC) and its possible future role is discussed, as well as the capacity building activities of UNU-GTP with emphasis on LAC region.

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 environmentally acceptable over the long term, 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.

The pursuit of harnessing geothermal energy is thus in line with the targets of United Nations Sustainable Development Goal 7: *To ensure access to affordable, reliable, sustainable and modern energy for all.*

Geothermal development furthermore supports Goal 13 (climate action) directly when geothermal energy is used in place of fossil fuels and numerous other SDGs indirectly. Special note is taken of Goal 5 (gender equality) in UNU-GTP's operations.

For developing countries that have good resources and have acquired the necessary local expertise geothermal energy has become very important. Kenya is a good example of this, as well as the Philippines. The same can be said about El Salvador and Costa Rica where geothermal energy is providing 29 and 10% of the electricity production, respectively. Iceland should also be mentioned as the only country where geothermal energy supplies almost 2/3 of the primary energy used (62% in 2016), both through direct use for heating, bathing, etc., and through production of electricity.

Geothermal systems can be classified into a few different types but with reference to variable geological conditions each one is in principle unique, so that good knowledge is needed through exploration. Furthermore, development of a geothermal system for electrical production is a capital intensive undertaking, and thus requires financial strength, or at least access to good financing. 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 (LAC) region. Then capacity building activities will be discussed, both in general and specifically in the context of Latin America and the Caribbean. The operations of the United Nations University Geothermal Training Programme (UNU-GTP) will be introduced and placed in context with the SDGs, 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. About 1 billion people, or roughly 13% of the 7.6 billion people living in the world, have no access to electricity (WEC, 2019; UN DESA, 2017). UN predicts the world population to grow to about 9.8 billion by 2050 (UN DESA, 2017). Key issue to improve standard of living is to make clean energy available to everybody at affordable prices.

World energy consumption is expected to continue increasing and a large share of the increase is expected to come from the renewables (WEC, 2016). Providing sufficient commercial energy (not to mention clean energy) to the people of all continents during this century is thus a big task.

Today´s energy consumption still relies on fossil fuels. Table 1 shows the use of primary energy in 2014 based on a report by the World Energy Council (WEC, 2016). The total use of primary energy is assessed to have been about 574 EJ in 2014, with 81% 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 (WEA, 2004).

The renewable energy sources are expected to provide 40-60% of the primary energy in 2060 (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, 2004). 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 important to support 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 2014, presented in combination with the World Geothermal Conference 2015, geothermal resources have been identified in over 90 countries while quantified utilization is recorded in 82 countries. Electricity is produced from geothermal energy in 24 countries. In 2014, the worldwide use of geothermal energy was estimated to be about 74 TWh/a of electricity (Bertani, 2015), and direct use 588 TWh/a (Lund and Boyd, 2015).

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TABLE 1: World primary energy consumption in 2014 (WEC, 2016)

Energy source	Primary energy (EJ)	Share (%)
Fossil fuel	**465**	**81.1**
Oil	180	31.4
Gas	121	21.1
Coal	164	28.6
Renewables	**81**	**14.1**
Biomass	59	10.3
Hydro	14	2.4
Other renewables	7.6	1.4
Nuclear	**28**	**4.8**

In its report, WEC (2016) puts forward three innovative scenarios for the energy utilization development until 2060. One of these is named *Modern Jazz* which indicates a complex but competitive market landscape driven by efficiency and innovation. The second is named *Unfinished Symphony*, where the focus is on resilient, integrated, global, low-carbon energy systems. The third is named *Hard Rock*, which takes reference from a fractured world with diverse sets of economic, energy and sustainability outcomes.

According to *Modern Jazz*, total use is predicted to increase to 715 EJ in 2060, which is an increase of 25%. Fossil fuels are still expected to be fairly dominating with 63% of the production while the share of the renewables is predicted to become about 29%. *Unfinished Symphony* is a considerably different scenario. The total use is predicted to be 634 EJ which is an increase of only 11%. The share of the other renewables is predicted to reach about 37%. Fossil fuels are still responsible for the majority of

the energy production, however, with their share lowering to about 50%. Finally, *Hard Rock* shows the opposite and outlines a scenario of what may happen if the free market will be in total control. Fossil fuels will continue to dominate with 70% of the production while the share of the renewables is predicted to reach only 21%. Positive is the prediction of considerably improved energy efficiency (WEC, 2016). Table 2 shows the production of electric energy in 2014, and how it is predicted to develop to 2060, according to the three different scenarios (WEC, 2016). Here, 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 6% of the total electrical energy production in 2014. In 2060, in *Modern Jazz* this is expected to increase to about 37% and in *Unfinished Symphony* to about 47%, while *Hard Rock* shows only an increase to about 25%. The future of other renewables appears bright.

TABLE 2: Electrical production vs. energy source 2014-2060 (WEC, 2016)

Energy source	**2014**		**2060 – MJazz**		**2060 – USym.**		**2060 - HRock**	
	TWh	**%**	**TWh**	**%**	**TWh**	**%**	**TWh**	**%**
Coal	9,697	41	3,299	7	1,068	2,5	8,199	18
Gas	5,155	22	15,463	32	7,516	17	11,781	26
Hydro	3,895	16	6,558	13.5	7,100	16	6,573	15
Nuclear	2,535	11	4,908	10	7,617	17	6,661	15
Oil	1,033	4	274	0.5	76	0.2	421	1
Other renew.	**1,500**	**6**	**17,987**	**37**	**20,888**	**47**	**11,279**	**25**
Total	**23,816**		**48,491**		**44,474**		**44,914**	

Table 3 shows similar information but here the distribution is on regional scale, and it is based on 3 years older data (WEC, 2013). 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 (AGR) depending on scenario.

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

	2010		**2050 – Jazz**		**2050 – Symphony**	
	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
Latin America & Caribb.	**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
South & 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, after hydro and biomass. However, more recently wind energy has surpassed geothermal and has now left it far behind, and in the last few years solar energy has also jumped past geothermal, through the continuous lowering of the costs of solar panels. The total electricity production from renewable energy sources (Table 4) was assessed as 5,395 TWh/a in 2014 (WEC, 2016). Of this, 72% came from hydropower, 13.3% from wind, 9.1% from biomass, 3.7% from solar, while geothermal contributed to 1.4%. 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 2014 (WEC, 2016*; 2013**)

	Production/a		**MJazz – 2060 Product./a***		**USym – 2060 Product./a***		**HRoc – 2060 Product./a***		**Capacity factor****
	TWh/a	**%**	**TWh/a**	**%**	**TWh/a**	**%**	**TWh/a**	**%**	**%**
Hydro	3,895	72.2	6,558	26.7	7,100	25.2	6,573	36.8	**39**
Biomass	493	9.1	2,574	10.5	2,508	8.9	1,870	10.5	**54**
Wind	717	13.3	8,818	36	9,326	33.0	5,608	31.1	**21**
Solar	198	3.7	5,718	23.3	7,943	28.2	3,270	18.3	**10**
Geothermal	**77**	**1.4**	**638**	**2.6**	**1,111**	**4.0**	**418**	**2.4**	**72**
Other	15	0.3	239	1.0	210	0.7	113	0.7	**10**
Total	**5,395**	**100**	**24,515**	**100**	**28,223**	**100**	**17,852**	**100**	**37**

A comparison of energy costs between different energy sources is difficult, because of differences in taxation and subsidies. Table 5 is based on statistics from IRENA for 2014, compiled by Taylor et al. (2015). According to these, the renewables are definitely competitive, showing the electrical energy cost to be 2-15 UScents/kWh for hydro, and very similar for biomass, 3-14 UScents/kWh. It is slightly higher for geothermal, 7-15 UScents/kWh, with similar numbers for wind, 6-20 UScents/kWh, depending somewhat on if it is onshore or offshore, with the latter seemingly at least 50% more expensive. The costs for solar, which have gone down dramatically in the last few years with the lowering of the prices for solar panels, are 12-24 UScents/kWh, while they are roughly 50% higher for the thermal solar, which is opposite to what it used to be. The upfront installation cost is also assessed to be fairly similar for the different energy sources, 450-3500 USD/kW for hydro, 1340-2330 for onshore wind, but considerably more expensive for offshore. Geothermal (1900-5100 USD/kW) and solar (1690-4250 USD/kW) are more expensive to install. This high upfront cost is the main disadvantage of geothermal. However, the big advantage of geothermal energy compared to other renewables is the high capacity factor, being independent of weather conditions or daylight, contrary to solar energy, wind energy, or hydropower. The reliability of geothermal plants is such, that they can usually be operated at capacity factors in excess of 90%, which means that geothermal power plants are very good as base load. This last fact is not illustrated in Table 5, but can be seen in Table 4.

TABLE 5: Levelized cost of electricity (LCOE) and installation costs in 2014 (Taylor et al., 2015)

Source	**LCOE 2014 USD/kWh**	**Installation cost 2014 USD/kW**
Biomass	0.03-0.14	400-6,820
Geothermal	0.07-0.15	1,900-5,100
Hydro	0.02-0.15	450-3,500
Solar – Photovoltaic (utility scale)	0.12-0.24	1,690-4,250
Solar – Concentrating	0.19-0.39	3,550-8,760
Wind – Onshore	0.06-0.12	1,340-2,330
Wind – Offshore	0.13-0.20	2,700-6,530

In 2014, electricity was produced from geothermal energy in 24 countries, increasing by 11% from 2009 to 2014 (Bertani, 2015). Table 6 lists the top twelve countries producing geothermal electricity in the world in 2014, and those in 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 (Bertani, 2015). It is different for most of the other countries listed there, with geothermal playing an important role in their electricity matrix. That certainly applies to the second country on the list, the Philippines. With 1870 MWe on-line, geothermal contributed to 14% of the electricity requirements (Bertani 2015). Similar applies to Kenya, the only African country seen in the table, the total production of 2,848 GWh/a puts the country in 8th place with regard to total production. Three Latin American countries are seen in the table. Mexico is in 4th seat with regards to MWe on-line, but in 5th seat with regards to production with 6071 GWh/a. This amounts though to less than 3%

TABLE 6: Top twelve countries in electricity production from geothermal energy in 2014 (Bertani, 2015), and those with direct use (Lund and Boyd, 2015)

Geothermal electricity production			**Geothermal direct use**	
Country	**MWe**	**GWh/a**	**Country**	**GWh/a**
USA	3,450	16,600	China	48,435
Philippines	1,870	9,646	USA	21,075
Indonesia	1,340	9,600	Sweden	14,423
Mexico	1,017	6,071	Turkey	12,536
New Zealand	1005	7,000	Iceland	7,422
Italy	916	5,660	Japan	7,259
Iceland	665	5,245	Germany	5,426
Kenya	594	2,848	Finland	5,000
Japan	519	2,687	France	4,408
Turkey	397	3,127	Canada	3,227
Costa Rica	**207**	**1511**	Hungary	2852
El Salvador	**204**	**1442**	Italy	2412

of their total production, while for Costa Rica (11th) and El Salvador (12th) 1511 GWh/a and 1442 GWh/a produced, amount to about 15% and 24% of the total, respectively. The highest value though, is seen for Iceland where a production of 5,245 GWh/a means that geothermal supplied about 29% 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 and Iceland, based on traditional direct use (Lund and Boyd, 2015). With direct use of geothermal energy still insignificant in Latin America and the Caribbean it is not surprising that no LAC country is seen in the top twelve list in direct use of geothermal energy.

Even though the numbers in Table 6 are fairly recent, development has been quite fast in some countries, leading to noticeable changes. Since 2015, two countries are leading this race. Turkey continues its great leap forward and at the end of 2016, it was in 7th place with 700 MWe on-line, while Indonesia has been approaching the Philippines steadily and is bound to overtake them in 2018.

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

Central America is one of the world´s richest regions in geothermal resources. Geothermal power stations provide almost 9% of the total electricity generation of the five countries Costa Rica, El Salvador, Guatemala, Honduras and Nicaragua, according to data provided from the countries (CEPAL, 2018; see also Table 6). In each of Costa Rica, El Salvador, Guatamala, and Nicaragua there are geothermal power plants in operation in two geothermal areas, whereas the first geothermal power plant in Honduras started operation in 2017. The photo in Figure 1 is taken at the Ahuachapán geothermal power plant in El Salvador, while Figure 2 shows the recent 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.

FIGURE 1: Some lecturers and participants in the Short Course IV in 2012 visiting the Ahuachapán geothermal power plant 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, geothermal has been slow to take off. Until recently, the only geothermal power plant that had been operated on the continent was the 0.7 MWe binary demonstration unit in the Copahue field in Argentina, which was decommissioned in 1996. However, the 48 MWe Cerro Pabellon power plant has now been inaugurated in Chile (September 2017), setting an important example of geothermal utilization in the continent.

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

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. Three slim holes were drilled in Nevis in 2008 (Maynard-Date and George, 2013), with a full size exploration well completed in early 2018, with promising results. Three deep vertical exploration wells were drilled in Dominica in 2012 (Maynard-Date, 2012; George, 2012), with two more exploration wells drilled in 2013-2014. In 2018, the World Bank announced plans to support the Dominica geothermal project with funding of more than 17 million USD. Two wells were also drilled in Montserrat in 2013, which are considered capable of supporting the peak load of the island (Brophy et al., 2014).

5. UNITED NATIONS UNIVERSITY GEOTHERMAL TRAINING PROGRAMME

5.1 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. Moreover, 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 and Reykjavík University. The UNU-GTP has also organized Workshops and Short Courses held in support of the United Nations Development Goals, in Kenya (and Uganda) for African countries (since 2005), El Salvador for Latin American and Caribbean countries (since 2006), and China for Asian countries (in 2008) (Georgsson et al., 2015a and b). Since 2010, UNU-GTP has offered tailor-made short courses and training activities in the developing countries in response to customer demand. Former Fellows have been encouraged to participate in the quinquennial World Geothermal Congresses and have benefitted from conditional financial support from UNU-GTP.

The UNU-GTP Short Courses were started as a special contribution of the Government of Iceland to the Millennium Development Goals of the United Nations. A part of the objective was to increase cooperation between specialists in neighbouring countries in the field of sustainable use of geothermal resources. About 200 scientists/engineers and decision makers participated in the 3 Workshops that had a duration of one week, and over 880 scientists/engineers were trained at the Short Courses, which have had a duration of 1-3½ weeks. In 2016, UNU-GTP started a new series of Short Courses in support of the UN Sustainable Development Goals, in collaboration with local partners (Georgsson and Haraldsson, 2016a and 2016b). Many former UNU Fellows are lecturers and co-organizers of the UNU-GTP Workshops and Short Courses. An offspring of the 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 happening to some extent in El Salvador with the coupling of the new SDG Short Courses to the Geothermal Diploma Course for Latin America (see Section 8) and it is also possible that the SDG Short Courses in Kenya will be coupled to the African Geothermal Centre of Excellence that is currently under development.

5.2 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. 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 (see Figure 3) 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). Group work (approximately 2 weeks) is carried out during the second half of the introductory lecture period. 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

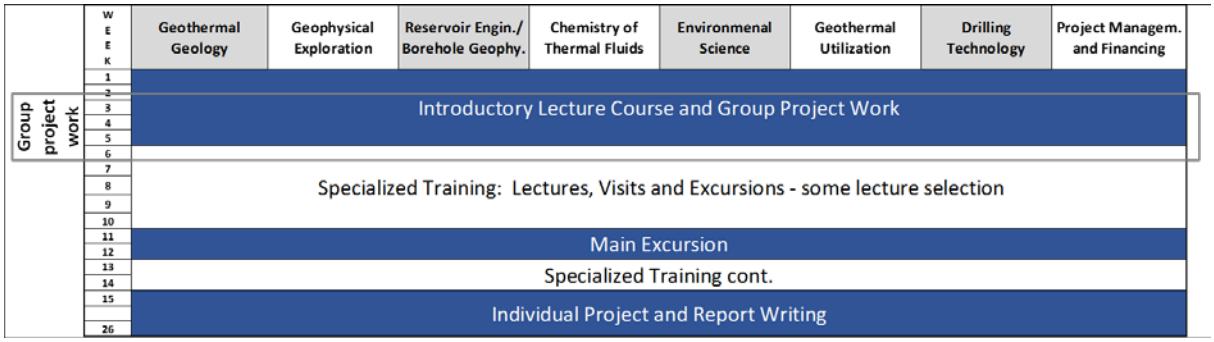

FIGURE 3: Approximate time schedule and contents of 6-month specialized courses at UNU-GTP

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 time schedule and contents of the six month specialized courses at UNU-GTP in Iceland.

The largest groups of UNU Fellows have come from Kenya (124), China (87), Ethiopia (41), the Philippines (40) and El Salvador (39). Figure 4 shows the UNU Fellows who attended the 6-month training in 2017.

FIGURE 4: UNU Fellows in Iceland for 6-month training in 2017

In the first decade of the 2000s or so, regular funding of the UNU-GTP allowed financing of six months training of 18-20 UNU Fellows per year, with 0-2 extra fellowships financed annually through other sources, at least partially. However, the years 2010-2016 saw a dramatic increase in the latter. Improved set-up and new facilities of the UNU-GTP in Iceland made it possible for UNU-GTP to accept additional Fellows if financed through external sources. This is reflected in these large groups of 2010-2016, with the largest groups to date trained in 2013, including 34 UNU Fellows, 13 of whom were mainly financed through other agencies, and again in 2016, 15 of whom were mainly financed through different funding mechanisms. 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 2017. It should be noted that in Figure 5, 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.

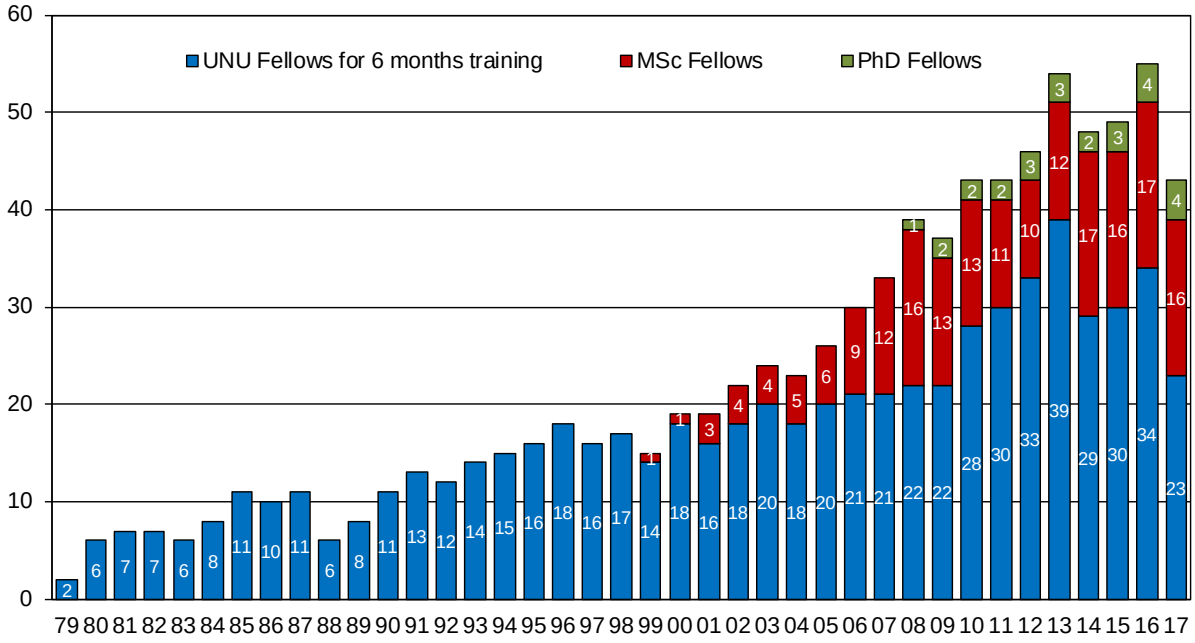

FIGURE 5: The gradual development of the training capacity of UNU Geothermal Training Programme in Iceland from 1979 to 2017

During 1979-2017, 670 scientists and engineers from 60 countries have completed the annual six-month courses. They have come from countries in Africa (39%), Asia (35%), Latin America and the Caribbean (14%), Central and Eastern Europe (11%) and Oceania (1%).

5.3 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. A similar agreement was made with Reykjavík University in 2013. The six months training at the UNU-GTP fulfils 25% of the MSc programme credit requirements (30 of 120 ECTs) at the two universities. The agreement with the University of Iceland was later extended to PhD studies, with the first PhD Fellow embarking on studies in 2008.

As of end of 2017, 56 have graduated with an MSc degree and 2 have completed a PhD degree on a UNU-GTP Fellowship. Meanwhile, 11 MSc Fellows and 4 PhD Fellows continued their studies into 2018

5.4 Workshops and Short Courses in support of United Nations Development Goals

In 2004, UNU-GTP received funding from the Icelandic Government to extend training efforts to the developing countries in order to support the objectives of the United Nations Millennium Development Goals (MDGs). This effort materialized in Workshops for Decision Makers in Kenya in 2005, El Salvador in 2006 and China in 2008. The workshops in Kenya and El Salvador later grew into a series of short courses held in support of the MDGs until 2015 and new series were started in 2016 in support of the SDGs.

In 2005, the *Workshop for Decision Makers on Geothermal Projects and their Management* was held in Kenya in cooperation with Kenya Electricity Generating Company Ltd. (KenGen). The intent was to reach out to decision makers to discuss the geothermal potential of East Africa and emphasize the important role of training for effective geothermal resource development. The workshop was followed up with a series of annual *Short Courses on Surface Exploration for Geothermal Resources* over the

period 2006-2015, intended for participants from African countries with geothermal potential. The series was held in cooperation with KenGen and later Geothermal Development Company Ltd. (GDC). The workshop and short courses were attended by 554 participants from 21 African countries, also including Yemen.

In 2006, the *Workshop for Decision Makers on Geothermal Projects in Central America* was held in El Salvador in cooperation with LaGeo S.A. de C.V., with a similar intent as the workshop in Kenya a year earlier. As in Kenya, the workshop was followed up with a series of semi-annual short courses that varied in topics from year to year (see further in Section 6.3).

In 2008, the *Workshop for Decision Makers on Direct Heating Use of Geothermal Resources in Asia* was held in China in cooperation with the Tianjin Bureau of Land, Resources and Real Estate Management and the Tianjin Bureau of Geology and Mineral Exploration and Development. The workshop was attended by 118 participants from 7 Mid- and Far-Eastern countries. Aspirations were set to follow the workshop up with a short course series similar to those in El Salvador and Kenya, but funding did not prove sufficient in subsequent years, largely due to the Financial Crisis of 2008.

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*).

5.5 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 end of year 2017, 40 such short courses and training activities have been held in 4 continents. The contents have varied from general geoscientific courses to more specialized ones. Similarly, the length has varied from 2 days to 6 months, based on the needs and targets (Haraldsson, 2018).

5.6 Support to attend World Geothermal Congresses

Since 1995, UNU-GTP has encouraged and assisted former Fellows in attending the quinquennial World Geothermal Congresses organized by the International Geothermal Association (IGA). To this end, UNU-GTP has offered partial travel grants to Fellows who submit a paper for publication in the congress proceedings. The grants have been administered by IGA.

6. UNU-GTP CONTRIBUTION TO GEOTHERMAL TRAINING FOR LATIN AMERICA AND THE CARIBBEAN

6.1 The 6-month training

The first Latin Americans attended the 6-month training programme in 1980, one from El Salvador (Comisión Ejecutiva Hidroeléctrica del Río Lempa – CEL) and another from Honduras (Empresa Nacional de Energía Eléctrica – ENEE). The first Fellow from Mexico (Comisión Federal de Electricidad – CFE) attended a year later, in 1981 (Table 7 and Figure 6). The emphasis on Central America and Mexico over South America and the Caribbean in the beginning is simple: Interest was high in the former region with electricity production from geothermal resources already under way,

TABLE 7: Number of Fellows from Latin America and the Caribbean attending the 6-month training in Iceland over the period 1980-2016

Country	Total number	Women	Years attended
Bolivia	3	0	2014, 2015, 2016
Costa Rica	18	1	1984, 1989, 1990, 1992, 1996, 1998, 1999, 2000, 2002, 2003, 2006, 2007, 2008, 2009, 2010, 2011
Dominica	1	1	2010
Ecuador	3	0	2014, 2015, 2016
El Salvador	40	10	1980, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2005, 2007, 2008, 2009, 2010, 2011 2012, 2013, 2014, 2016, 2017
Guatemala	3	1	1992, 1996, 2003
Honduras	3	0	1980, 1988, 2011
Mexico	8	2	1981, 1986, 1988, 1989, 2008, 2009, 2011, 2012
Nicaragua	13	6	1981, 1990, 1991, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013
St. Kitts and Nevis	2	1	2010, 2012
St. Vincent and the Grenadines	1	1	2014
Total:	**95**	**23**	(All years except 1982, 1983, 1985, 1987 and 2004)

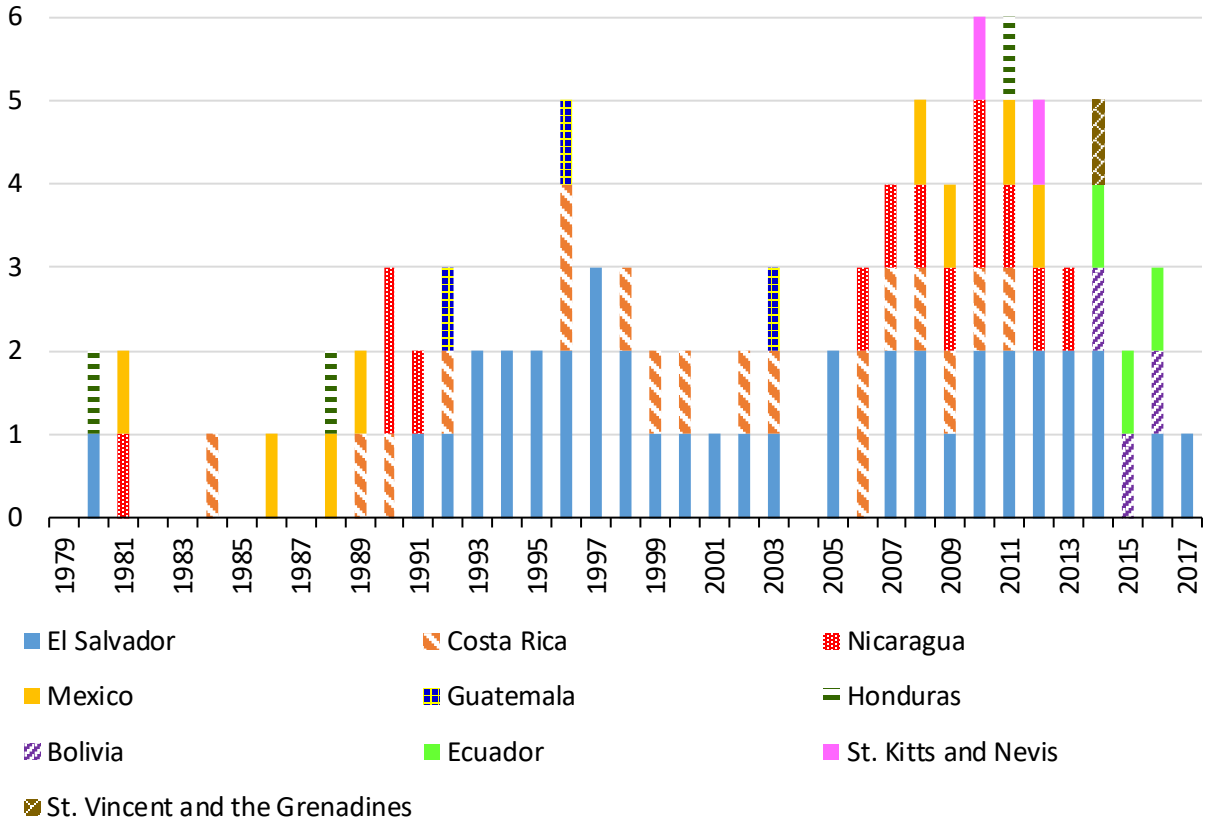

FIGURE 6: Number of UNU Fellows from Latin America and the Caribbean attending 6-month training in Iceland over the period 1979-2017 (partially same information as in Table 7)

while interest and means were more limited in South America and the Caribbean Islands. Central Americans and Mexicans have continued to attend the programme throughout the years, though emphasis on Mexico is now low, as the country is not defined as a developing country. With increased interest and drilling in the Caribbean, the first Fellows from Dominica and Nevis attended the programme in 2010 and from South America, the first Fellows came from Bolivia and Ecuador in 2014.

Although UNU-GTP emphasizes the training of women, the pool of candidates for 6-month studies has tended to be male dominated in some countries, especially in earlier years. This is reflected in about 24% of candidates from Latin America and the Caribbean (LAC) having been female from the beginning. Looking specifically at the last decade (2008-2017), it can be observed that the ratio has increased to 39% (16/41). Over the period 1979-2017, a total of 95 Fellows from Latin America and the Caribbean attended the 6-month training programme in Iceland, which is just over 14% of the total number of 670 Fellows.

6.2 MSc and PhD studies

The first Latin American student, from El Salvador, embarked on his MSc studies at the University of Iceland in 2007, supported by a UNU-GTP Fellowship. A total of 9 Latin American students had completed their MSc degrees as of end of 2017 from University of Iceland: 1 from Bolivia, 1 from Costa Rica, 6 from El Salvador, and 1 from Nicaragua. At the same time, 2 students from Latin America and the Caribbean were working on their degrees: 1 from Costa Rica and 1 from St. Vincent and the Grenadines. The extension of Fellowships to South America and the Caribbean bear witness to the increased interest in harnessing geothermal resources in those regions. Out of the 9 students who had completed, 1 was female (Nicaragua), whereas 1 of the 2 students working towards the degree is a female. No student from Latin America and the Caribbean has been enrolled in PhD studies to date.

6.3 Workshops and Short Courses held in support of UN Millennium Development Goals

The *Workshop for Decision Makers on Geothermal Projects in Central America* was followed up with a series of semi-annual short courses that varied in topics from year to year as shown in Table 8. The Workshop and Short Courses were attended by 412 participants from 15 countries in Latin America and the Caribbean over the period 2006-2015. The participation is broken down by country in Table 9.

The topics have changed from year to year in response to perceived need within the region (Table 8), which is varied within and between countries. The countries that have already been utilizing geothermal resources for electricity generation for decades can contribute to and benefit from courses addressing any topic of geothermal development, while the needs in countries that are still in the exploration and drilling phases are more geared towards the early development stages. The variation of topics has allowed UNU-GTP and LaGeo to build up an extensive collection of lectures and papers on geothermal development, which have contributed to the possibility of offering customer designed training. The papers have been published on CDs and are openly available on UNU-GTP's website: *www.unugtp.is*.

6.4 The SDG Short Course series

The new SDG Short Course series was started in 2016 in support of the UN Sustainable Development Goals (Section 7). The first event was *SDG Short Course I on Sustainability and Environmental Management of Geothermal Resource Utilization and the Role of Geothermal in Combating Climate Change*, held in El Salvador in September as an integral part of the Geothermal Diploma Course for Latin America (Section 8; Table 10). The course drew a record number of 68 participants from 14 countries, including the 30 students of the Diploma Course. Twenty-three women attended, accounting for nearly 34% of the total. An expert on climate change issues, and a former UNU Fellow, was invited as a guest lecturer from Kenya.

The second event was *SDG Short Course II on Feasibility Studies for Geothermal Projects* held in El

TABLE 8: Workshop and Short Courses held in El Salvador in support of the Millennium Development Goals 2006-2015

Name	Dates	Target region	No. countries	No. particip.	No. women
Workshop for Decision Makers on Geothermal Projects in Central America	27 Nov – 2 Dec, 2006	C-America	4	50	
Short Course I on Geothermal Development in Central America: Resources Assessment and Environmental Management	15 Nov – 1 Dec, 2007	C-America and Mexico	6	45	
Short Course II on Surface Exploration for Geothermal Resources	17-30 Oct, 2009	C-America and the Caribbean	7+2[1]	32	13 (41%)
Short Course III on Geothermal Drilling, Resource Development and Power Plants	16-22 Jan, 2011	LAC	10	62	14 (23%)
Short Course IV on Geothermal Development and Geothermal Wells	11-17 Mar, 2012	LAC	12[2]	65	15 (23%)
Short Course V on Conceptual Modelling of Geothermal Systems	24 Feb – 2 Mar, 2013	LAC	12	61	18 (30%)
Short Course VI on Utilization of Low- and Medium Enthalpy Geothermal Resources and Financial Aspects of Utilization	23-29 Mar, 2014	LAC	13[3]	55	23 (42%)
Short Course VII on Surface Exploration for Geothermal Resources	14-22 Mar, 2015	LAC	13	42	18 (43%)
		Total:	**15[4]+2**	**412[5]**	**~1/3**

1: The additional countries were Spain (1) and Switzerland (1); 2: Three participants did not represent countries, but rather international funding institutions (Inter-American Development Bank – IDB, and World Bank – WB); 3: Two participants attended from IDB; 4: Bolivia, Chile, Colombia, Costa Rica, Dominica, El Salvador, Ecuador, Guatemala, Honduras, Mexico, Montserrat, Nicaragua, Peru, St. Kitts and Nevis, and St. Vincent and the Grenadines (Table 9); 5: Some of the participants have attended more than one course.

Salvador during September 17-23 September as an integral part of the Geothermal Diploma Course for Latin America (Section 8; Table 10). In total, 66 participants took part from 14 countries in Latin America and the Caribbean and one regional institution (OECS). The wide geographical representation bears witness to the large geothermal potential found within the LAC region, most of which has still not been utilized. The Short Course was also used as a platform to launch the El Salvador chapter of Women in Geothermal (WING). This event was led by Rosa Escobar, Engineering Manager at LaGeo, with contributions by Dr. Juliet Newson, Director of the Iceland School of Energy at Reykjavík University and Magaly Flores, Manager at the Federal Commission of Electricity in Mexico. The Short Course was well attended by women overall, with 32 female participants (48.5%) and 34 male participants (51.5%). This is the largest group of women to attend the short courses to date.

6.5 Customer-designed short courses

UNU-GTP has held two tailor-made short courses in Latin America in cooperation with regional organizations and local partners. In November 2011, the *Short Course on Geothermal Exploration and Development* was held in El Salvador in cooperation with the Organization of American States (OAS) and LaGeo. The course was attended by 14 participants from Colombia (3), Ecuador (3) and Peru (3), Chile (1), Costa Rica (1), El Salvador (1), and OAS (2).

TABLE 9: Participants in the Millennium Short Courses in Central America 2007-2015

Country	2007	2009	2011	2012	2013	2014	2015	Total
Bolivia				1			3	**4**
Chile				5	5	4	3	**17**
Colombia			5	2	4	2	5	**18**
Costa Rica	6	7	6	1	2	3	2	**27**
Dominica		2	2	2	1	1	1	**9**
El Salvador	22	9	23	28	18	26	10	**136**
Ecuador			1	2	3	2	3	**11**
Guatemala	1	1	2	1	2	2		**9**
Honduras	2	2	5	2	4	1	2	**18**
Mexico	1		3	6	6	3	3	**22**
Montserrat						1	1	**2**
Nicaragua	13	7	13	11	11	5	6	**66**
Peru					3	1	2	**6**
St. Kitts and Nevis		2	2	1	2	2		**9**
St. Vincent and the Grenadines							1	**1**
Others		2		3		2		**7**
Total	**45**	**32**	**62**	**65**	**61**	**55**	**42**	**362**

In November 2014, UNU-GTP cooperated with the Mexican Centre for Innovation in Geothermal Energy (Centro Mexicano de Innovación en Energía Geotérmica – CeMIEGeo) in conducting *Short Course on Geothermal Exploration*, held in Los Azufres in Mexico. The course was attended by 42 participants from different geothermal companies, institutions and universities in Mexico (Figures 7 and 8).

TABLE 10: SDG Short Courses for Latin America and the Caribbean (LAC region)

Name	Dates	Target region	No. countries	No. particip.	No. women
SDG Short Course I on Sustainability and Environmental Management of Geothermal Resource Utilization, and the Role of Geothermal in Combatting Climate Change	4-10 Sept, 2016	LAC	14[1]	68	23 (34%)
SDG Short Course II on Feasibility Studies for Geothermal Projects	17-23 Sept, 2017	LAC	14[2]	66	32 (48%)
		Total:	**16[3]**	**134**	**55 (41%)**

1: As well as representatives from the World Bank; 2: As well as a representative from the Organization of Eastern Caribbean States; 3: Argentina, Bolivia, Chile, Colombia, Costa Rica, Dominica, Ecuador, El Salvador, Guatemala, Mexico, Montserrat, Nicaragua, Peru, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines.

FIGURE 7: SDG Short Course II in El Salvador. Group photo (left) and group work (right)

FIGURE 8: Participants of *Short Course on Geothermal Exploration* carrying out exercises in Los Azufres

7. THE UN SUSTAINABLE DEVELOPMENT GOALS AND THE NEW SDG SHORT COURSE SERIES

The United Nations Sustainable Development Summit 2015 was held during 25-27 September 2015. On the opening day of the summit, the post-2015 Sustainable Development Goals (SDGs) were unanimously adopted as targets to be reached by 2030 (United Nations, 2015a).

In response to this, UNU-GTP and its cooperating partners decided to start a new series of short courses that were to take heed of and support the goals. In particular, the courses were to support Goal 7, which has the overall aim of ensuring access to affordable, reliable, sustainable and modern energy for all, with the following stated targets (United Nations, 2015b):

- By 2030, ensure universal access to affordable, reliable and modern energy services;
- By 2030, increase substantially the share of renewable energy in the global energy mix;
- By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy; and
- By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, Small Island Developing States (SIDS), and land-locked developing countries, in accordance with their respective programmes of support.

The short courses are well suited to help fulfil the goal as:

- Geothermal energy prices compare well with other environmentally benign energy sources;
- Medium to high enthalpy geothermal resources can be used to provide reliable base load power over long periods of time to large populations;
- While the sustainability of geothermal utilization can be drawn into question, partly on account of the transient nature of the resources themselves when looking at long time spans, the resources can be utilized for extended durations provided that development is approached cautiously and resources managed well;
- Geothermal resources can be utilized to provide heat and electricity in as modern a way as any other energy resources;
- The short courses come about through international cooperation that is meant to facilitate research and transfer knowledge between countries and generations;
- The short courses are directed at the developing countries and Small Island Developing States (e.g. Caribbean Islands).

In addition, special note is taken of Goals 5 and 13:

- *Goal 5: Achieve gender equality and empower all women and girls*.
  This is in line with UNU-GTP's strategic plan. The ratio of women to the overall number of participants in short courses, 6-month studies and advanced academic studies in Iceland has been improving with time and the goal is to improve further on this. However, it must be noted that the pool of candidates is often male dominated, so even if women are given preference over men in the selection process, it can still be difficult to reach gender parity. This is counter-acted by informing cooperating entities of the emphasis placed on gender equality and the consequent importance of nominating women for training.
- *Goal 13: Take urgent action to combat climate change and its impacts*.
  It is well recognized that greenhouse gas emissions from geothermal utilization projects are significantly lower than the emissions associated with projects that make use of fossil energy. The utilization of geothermal resources therefore contributes to the mitigation of climate change when used in place of fossil fuels. Geothermal energy may also be used to help with adaptation where climate change effects are inescapable and negative.

Furthermore, it is expected that the short course series will contribute to other SDGs indirectly:

- *Goal 1: End poverty in all its forms everywhere*.
  It is expected that capacity building aimed at enhancing geothermal development will help to bring energy to more people, which in turn will increase their economic opportunities and reduce poverty. Such opportunities may arise from better and more reliable access to electricity, but also possibilities for direct utilization of geothermal resources in specific areas, such as for drying agricultural products, horticulture, aquaculture, bathing and tourism, and various industrial processes.
- *Goal 3: Ensure healthy lives and promote well-being for all at all ages*.
  It is expected that access to geothermal energy will increase opportunities for leading healthier lives. One example is the possibility of changing from biomass cook-stoves to electrical cook-stoves, with improved and more reliable access to electricity, which has the potential of improving indoor air quality.
- *Goal 8: Promote inclusive and sustainable economic growth, employment and decent work for all*.
  Economic growth is strongly linked to energy utilization: in order for an economy to grow, access to energy is of major importance. This in turn is linked to Goal 1. It is expected that capacity building aimed at enhancing geothermal development will help realize this goal.
- *Goal 9: Build resilient infrastructure, promote sustainable industrialization and foster innovation*.
  Geothermal development brings with it construction of energy utilization systems, such as power plants, and calls for a power grid to carry the electricity to consumers. The availability of energy also promotes industrialization, whether it be through utilization of electricity or heat. Geothermal power plants often bring with them new roads that are utilized by the wider population and sometimes open access to regions that were inaccessible before. There are also examples of locals benefitting from water supply systems that have been constructed for the primary purpose of supplying water for geothermal drilling and power plant operations.
- *Goal 15: Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss*.
  The utilization of geothermal energy can in some cases help reduce reliance on wood for cooking, which can decrease pressure on forests.
- *Goal 16: Revitalize the global partnership for sustainable development*.
  One of the aims of the short courses is to strengthen relationships between stakeholders in geothermal development within and between countries, for the benefit of geothermal development on national, regional and global scales. In particular, the short courses are a realization of the following target: Enhance international support for implementing effective and targeted capacity-

> building in developing countries to support national plans to implement all the sustainable development goals, including through North-South, South-South and triangular cooperation.

Consequently, the titles of the short courses in El Salvador and Kenya have been changed to reflect support of the SDGs. The new series, which were launched in 2016, continue to rest on the solid foundations of the MDG Short Courses, although some changes in approach and content have been introduced to better reflect the SDGs.

UNU-GTP has been supporting the overall aim and targets of Goal 7 in all its operations since its establishment – in Iceland and abroad. The formal recognition and adoption of the Goal by the UN system is therefore very much welcomed and the launch of the new SDG Short Courses in El Salvador and Kenya is a re-affirmation of UNU-GTP's commitment to the stated aims of the Goal, as well as support to other relevant SDGs.

8. GEOTHERMAL DIPLOMA COURSE FOR LATIN AMERICA

A Specialized Geothermal Diploma Course has been offered at the University of El Salvador for several years. The first two courses were run in 2010 and 2012, mostly for Salvadorans, with financial support from Italy, implemented in cooperation with Salvadoran and Italian partners (de Velis and Montalvo, 2011; Caprai et al., 2012; Haraldsson et al., 2013; Axelsson, 2013; Haraldsson, 2015). The Nordic Development Fund (NDF) and the Inter-American Development Bank (IDB) then pledged additional funding to secure the program over the period 2013-2015, with implementation support from Consejo Nacional de Energía (CNE) and LaGeo. UNU-GTP carried out an evaluation of the program as run in the first two years of implementation and continued to serve in an advisory role through participation in the programme's Academic Committee over the period 2013-2015. During this period 10 scholarships were reserved for Salvadorans, 10 scholarships were reserved for Latin American participants from outside of El Salvador, and up to 10 additional places were offered to participants who could attend without scholarships.

In early 2016, NDF pledged further funding to support the continuation of the Diploma Course in 2016-2017, with the Icelandic Ministry for Foreign Affairs (MFA-ICEIDA) as the implementing agency. UNU-GTP also became a direct implementing partner along with LaGeo and the University of El Salvador. In light of some changes in the implementation of the program, including added responsibility assumed by LaGeo, the name of the programme was changed to *Geothermal Diploma Course for Latin America*. The number of available scholarships and class size were unchanged from the previous funding period. In 2018, the Diploma Course is funded jointly by MFA-ICEIDA and NDF.

At this juncture it was decided to include the annual UNU-GTP / LaGeo Short Course as an integral part of the Diploma Course curriculum. Thus, in addition to participants invited specially for the Short Course from the LAC region, it would also be open to the Diploma Course students who would benefit from the topics presented, as well as from exposure to international lecturers and participants. This arrangement was run successfully in 2016 and 2017 (Section 6.4).

While the Diploma Course is carried out almost exclusively in Spanish, the Short Course is carried out in English and Spanish according to the preference of lecturers, with translation offered between the two languages for those who need it. This reflects the larger target region for the Short Course, as it includes the Lesser Antilles Islands of the Caribbean (where English is dominant) in addition to Latin America.

The coupling of the SDG Short Course series to the Geothermal Diploma Course for Latin America is well fitting in light of both undergoing critical overhaul in 2016 and the important role of UNU-GTP and LaGeo in both.

9. TRAINING NEEDS IN LATIN AMERICA AND UNU-GTP's ROLE IN TRAINING

As part of the aforementioned evaluation of the Diploma Course as implemented in 2010 and 2012, UNU-GTP carried out an assessment of training needs in Latin America. Based on three scenarios with different assumptions on the number of experts needed per MW of geothermal electricity generation, growth in capacity and workforce turnover, the training needs for Latin America were assessed at 13-45 experts per year (Haraldsson et al., 2013; Haraldsson, 2016).

Envisioned reported capacity increases at the time were found to call for the addition of close to 300 experts to the sector, although the time frame over which these additions were to be implemented was unclear. The assessment results decidedly pointed to a need for training a significant number of geothermal experts in Latin America on a yearly basis (Haraldsson, 2016).

While UNU-GTP intends to continue its support to Latin America and the Caribbean, the Geothermal Diploma Course for Latin America is seen as a programme that can increasingly respond to the basic training needs in Latin America, assuming that it will continue operating for years to come. The Diploma Course is a good choice for Spanish speakers who can carry out studies in an environment that is culturally similar to home. It is set up as a general programme where all participants attend the same lectures encompassing most aspects of geothermal development from early exploration to utilization. Some possibilities for specialization are offered through project work that is usually carried out in groups.

UNU-GTP's 6-month training in Iceland is more specialized than the Geothermal Diploma Course for Latin America and can therefore still be of value to some experts from Spanish speaking Latin America who want to delve deeper into specific subjects of interest and even have a possibility for continuing their studies at the MSc or PhD level. Also, the training in Iceland is considered more appropriate for Fellows from the English speaking Caribbean Islands due to the language of instruction.

10. 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 change, global warming, rise 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 developing and transitional countries. 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 Sustainable 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, as discussed in Sections 5, 6 and 8 above. 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 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) implementation was ensured over the period 2013-2015, and additional pledges by the NDF and the Icelandic Ministry for Foreign Affairs have ensured continuation through 2018. The long-term aim is to work towards establishing a sustainable post-graduate university programme, which could even include MSc studies, for the benefit 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 is expected to be an integral part of the *Geothermal Diploma Course for Latin America*, as it has been in 2016-2018.

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