Presented at SDG Short Course IV on Exploration and Development of Geothermal Resources,
organized by UNU-GTP and KenGen, at Lake Bogoria and Lake Naivasha, Kenya, Nov. 13 – Dec. 3, 2019.

UNITED NATIONS UNIVERSITY
UNU-GTP
Geothermal Training Programme

KenGen

GEOTHERMAL ENERGY IN THE WORLD AND THE UN SUSTAINABLE DEVELOPMENT GOALS

Lúdvík S. Georgsson and Ingimar G. Haraldsson
United Nations University Geothermal Training Programme
Orkustofnun, Grensasvegi 9, Reykjavik
ICELAND
lsg@os.is, ingimar.haraldsson@os.is

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 over 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 2019, on the current world energy status and future energy scenarios, the primary energy consumption in the world was assessed as 565 EJ in 2015, with about 82% 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 is expected to play an important role. Africa is currently a region where access to energy is limited, but WEC has predicted an annual growth rate of 5% in the next decades, considerably higher than for other regions.

This paper provides an overview of the energy utilization in the world and the operations of UNU Geothermal Training Programme in Iceland are presented, with emphasis on East Africa. Utilization of geothermal energy in Africa is reviewed and examples are presented from the region, as well as from Iceland where geothermal energy plays a larger role than in any other country in the world.

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 on a long-term basis, especially with regard to emission of greenhouse gases and 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 developed the necessary local expertise it has become very important. A good example is Kenya (Mangi, 2018), as well as El Salvador and Costa Rica (OLEDA, 2018), where geothermal energy has become one of the important energy sources providing between 17 and 29% of generated electricity. Iceland should also be mentioned as the only country where geothermal energy supplies more than 60% of the primary energy used (61% in 2017), as a result of direct uses such as heating and bathing, and through the production of electricity (Ragnarsson, 2018).

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

Here, the role of geothermal energy in the world's energy mix is presented with some emphasis on E-Africa, and examples are given on its use in Africa and Iceland. An introduction to United Nations University Geothermal Training Programme is also given, and reference taken in the UN Sustainable Development Goals.

2. THE UNU GEOTHERMAL TRAINING PROGRAMME

United Nations University Geothermal Training Programme (UNU-GTP) has operated in Iceland since 1979 offering six-month annual courses for professionals from developing countries. From being one of four geothermal schools established in the 1970s, UNU-GTP is now the only international graduate programme offering extensive specialized geothermal training in all main fields of geothermal exploration and development. The aim is to assist developing countries with geothermal potential in capacity building in order to make the countries self-sufficient in expertise for geothermal development. This is done through offering university graduates engaged in geothermal work an opportunity for intensive work-related training. The training is conducted in English and is to some extent tailor-made to suit the needs of the home country. UNU Fellows generally receive scholarships financed mainly by the Government of Iceland. Since 2000, cooperation between UNU-GTP and the University of Iceland (UI) has opened up the possibility for some UNU Fellows to extend their studies to MSc level, with the six months training adopted as an integral part (30 out of 120 ECTS). A similar contract was made with Reykjavík University (RU) in 2013. In 2008, the cooperation with UI was expanded to include PhD studies, with the first PhD Fellows accepted in the academic year 2008-2009 and the first one graduating in 2013. This has also been extended to Reykjavik University, with the first PhD Fellow accepted in 2018.

As a contribution to the UN Millennium Development Goals and through the funding of the Icelandic Government, UNU-GTP expanded its activities to giving annual workshops/short courses in Africa (started in Kenya in 2005), Central America (started in El Salvador in 2006), and Asia (given in China in May 2008). The courses have been organised in cooperation with local national energy companies responsible for geothermal development (in Kenya these have been KenGen and GDC). A part of the objective is to increase geothermal cooperation within the region, and to reach out to countries with a potential and interest in geothermal development which have not yet received quality training. The courses have made it possible for UNU-GTP to reach out to an increasing number of geothermal scientists and engineers. In 2016, these short course series were redeveloped in line with the new UN Sustainable Development Goals. These series have also been an important factor contributing to UNU-GTP being able to offer customer-designed courses, lasting from one to 12 weeks, modelled to the demands of a paying customer. This has become an important part of UNU-GTP's operations in this decade, serving several customers in 4 different continents.

As outlined in more detail in Section 6, the East-Africa region has been a major cooperating partner of UNU-GTP from the starting years. Amongst the 718 graduates of UNU-GTP (1979-2019), 281 or 39% have come from 18 African countries. Most of these come from East Africa. By far the largest number has come from Kenya (134). This is followed by Ethiopia (45), Djibouti and Tanzania (19), Uganda

(17), and Rwanda (12). Former UNU Fellows are at the forefront of geothermal research and development in most of these countries. The political and economic situation in some of the countries has, however, delayed geothermal development, with some of the professionals trained at UNU-GTP having left their jobs in the geothermal sector and even immigrated to other countries. Africa has also received the majority of UNU-GTP MSc Fellowships and PhD Fellowships, with 40 MSc Fellows, or 60% of a total of 67, who have graduated from the UNU-GTP supported MSc programmes. In addition, 7 out of 8 UNU Fellows who have embarked on PhD studies to date on a UNU-GTP Fellowship are Africans. The first one defended her dissertation in February 2013, the first African to do so in Iceland, with two more having since defended their dissertation, or being on the verge of it (Dec. 2019), and thus receiving a PhD degree. All are Kenyans.

FIGURE 1: The group of UNU Fellows who attended the 6-month training in Iceland in 2019 in Ásbyrgi, Öxarfjördur, NE-Iceland

Figure 1 shows the group of UNU Fellows that attended the 6-month training in Iceland in 2019, 24 UNU Fellows, including 5 Kenyans, 2 Ethiopians, 2 Tanzanians, 1 Djiboutian and 1 Nigerian. For more general information on UNU-GTP, see e.g. Georgsson, 2018; Georgsson et al., 2018, and Haraldsson and Georgsson, 2018, or the UNU-GTP web page *www.unugtp.is*.

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 association 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 PJ/a (Lund and Boyd, 2015).

Amongst the top priorities for the majority of the world´s population is access to sufficient affordable energy. The current status shows a very limited equity in energy use in 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). A key issue to improve standard of living is to make clean energy available to everybody at affordable prices.

Today´s energy consumption still relies on fossil fuels. Table 1 shows the use of primary energy in 2015 based on a report by the World Energy Council (WEC, 2019). The total use of primary energy is assessed to have been about 565 EJ, with 82% 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 increasing role in the 21st century. The technical potential of the renewable energy sources is certainly large enough (WEA, 2004).

TABLE 1: World primary energy consumption in 2015 (WEC, 2019)

Energy source	Primary energy (EJ)	Share (%)
Fossil fuel	**462**	**81.9**
Oil	179	31.7
Gas	123	21.8
Coal	160	28.4
Renewables	**77**	**13.6**
Biomass	55	9.7
Hydro	13.7	2.4
Other renewables	8.1	1.4
Nuclear	**26**	**4.6**

In its report, WEC (2019) puts forward three scenarios for the energy utilization development until 2060. One of these is named *Modern Jazz,* which demonstrates a market-led, digitally disrupted world with faster-paced and more uneven economic growth. The second is named *Unfinished Symphony,* a strong, coordinated, policy-led world with long-term planning and united global action to address connected challenges, including decarbonisation. The third is named *Hard Rock,* a fragmented world with inward-looking policies, lower growth and less global cooperation.

According to *Modern Jazz,* total use is predicted to increase to 677 EJ in 2060, which is an increase of 20%. 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 640 EJ which is an increase of only 13%. The share of renewables is predicted to reach about 35%. Fossil fuels are still responsible for a big part of the energy production, however, with their share lowering to about 50%. Finally, *Hard Rock* to some extent shows the opposite and outlines a scenario illustrating the free market more or less in control. Total utilization is predicted to reach 774 EJ, which is an increase of 37%. Fossil fuels will continue to dominate with 70% of the production while the share of the renewables is predicted to reach only 23%. Positive is the general prediction of considerably improved energy efficiency (WEC, 2019). On the other hand, a harsh reality is that no scenario is expected to achieve the targets of the Paris Agreement to keep global warming to within 2°C (WEC, 2019).

Table 2 shows the production of electric energy in 2015 and how it is predicted to develop to 2060, according to the three different scenarios (WEC, 2019). Here, the share of the renewables is expected to increase even more. According to the table, other renewables, which include wind, geothermal, solar and others are only contributing 7% of the total electrical energy production in 2015. In 2060, in *Modern Jazz* this is expected to increase to about 38.5% and in *Unfinished Symphony* to about 47%, while *Hard Rock* shows only an increase to about 25.5%. The future of other renewables appears bright.

Table 3 shows similar information but here the distribution is on regional scale, and it is based on 5 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 a dark continent in more than one respect. The good news, however, is that the annual growth rate (AGR) for Africa for the period to 2050 is predicted to be very good, about 5%, which is higher than for all other regions, and considerably higher than for most. This is good news for Africa.

TABLE 2: Electrical production by energy source 2015-2060 (WEC, 2019)

Energy source	**2015**		**2060 – MJazz**		**2060 – USym.**		**2060 - HRock**	
	TWh	**%**	**TWh**	**%**	**TWh**	**%**	**TWh**	**%**
Coal	9,341	39	2,403	4	1,219	2	8,137	19
Gas	5,561	23	21,372	37	14,749	25	11,070	25.5
Hydro	3,903	16	6,540	11.5	7,660	13	6,786	16
Nuclear	2,571	11	4,811	8	7,818	13	5.394	12.5
Oil	990	4	526	1	92	0.2	594	1.5
Oth. renewabl.	**1,705**	**7**	**22,246**	**38.5**	**27,543**	**47**	**11,033**	**25.5**
Total	**24,072**		**57,898**		**59,082**		**43,012**	

TABLE 3: Electrical production by 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 & Caribbean	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, at the start of the century wind energy surpassed geothermal and has now left it far behind, and in the last few years solar energy has also jumped past geothermal, based on the continuous lowering of the costs of solar panels. The total electricity production from renewable energy sources (Table 4) was assessed as 5,608 TWh/a in 2015 (WEC, 2019). Of this, 70% came from hydropower, 15% from wind, 9.4% from biomass, 4.6% from solar, while geothermal contributed to 1.4%. With its huge technical potential (WEA, 2004), geothermal energy is definitely one of the energy resources contributing to a greener future.

TABLE 4: Electricity from renewables in 2015-2016 (WEC, 2013**; 2019*)

	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	3,903	69.6	6,540	22.7	7,660	21.8	6,786	38.1	**39**
Biomass	527	9.4	2,567	8.9	2,872	8.2	2,017	11.3	**54**
Wind	540	15.0	9,523	33.1	10,786	30.6	4,443	24.9	**21**
Solar	256	4.6	8,821	30.6	11,773	33.4	3,943	22.1	**10**
Geothermal	**80**	**1.4**	**599**	**2.1**	**859**	**2.4**	**365**	**2.0**	**72**
Other	2	0	736	2.6	1253	3.6	265	1.5	**10**
Total	**5,608**	**100**	**28,786**	**100**	**35,203**	**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 shows statistics for 2016, compiled from data presented in a report by

IRENA (2018), with some reference also taken from older IRENA data in Taylor et al. (2015). According to these, the renewables are definitely competitive, showing the electrical energy cost (excluding outliers) to be in the range of 2-15 UScents/kWh for hydro, and 4-9 UScents/kWh for biomass. It is slightly higher for geothermal, 4-12 UScents/kWh, with similar numbers for wind, 4-20 UScents/kWh, depending somewhat on if it is onshore or offshore, with the latter seemingly at least 50% more expensive. The costs for solar PV have gone down dramatically in the last few years with the lowering of the prices for solar panels, and are at 8-25 UScents/kWh, while they may be more than double that for thermal solar, which is opposite to what it was traditionally. The upfront installation cost is also assessed to be fairly similar for the different energy sources, 500->3000, 500-8000 and 1340-6000 USD/kW, for hydro, biomass and wind, respectively, with the higher values for wind relating to offshore power production. Geothermal (2000-5000 USD/kW) and solar (1000-5500 USD/kW, with higher values for thermal solar) are more expensive to install. This high upfront cost is the main disadvantage of geothermal. On the other hand, a big advantage of geothermal energy compared to other renewables is its high capacity factor, being independent of weather conditions or daylight, contrary to solar energy, wind energy, or hydropower. Table 4 shows the capacity factor to be 72%, but the reliability of geothermal plants is such, that they can often be operated at capacity factors up to 80-95%. Thus, geothermal power plants are very good for providing base load. This last fact is not illustrated in Table 4 or 5.

TABLE 5: Levelized cost of electricity (LCOE) and installation costs in 2016 from renewable energy sources (IRENA, 2018; referring also to Taylor et al., 2015)

Source	**LCOE in 2016 (USD/kWh)**		**Installation cost 2016 (USD/kW)**	
	Assessed range	**Average**	**Assessed range**	**Average**
Biomass*	0.04 – 0.09	-	500 – 8,000	-
Geothermal	0.04 – 0.12	0.07	2,000 – 5,000	3,500
Hydro	0.02 – 0.15	0.05	500 – >3,000	1,780
Solar – Photovoltaic (util.scale)	0.08 – 0.25	0.12	1,000 – 5,500	1,500
Solar – Concentrating**	0.20 – 0.32	0.27	2,550 – 9,000	-
Wind – Onshore	0.04 – 0.13	0.07	1,000 – 3,000	1,400
Wind – Offshore	0.09 – 0.25	0.14	2,000 – 6 ,000	4,500

* Difficult to assess average – depends much on type of fuel; ** Depends a lot on use of storage.

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 ten 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 United States, with almost 16,600 GWh/a, but this still amounts only to half a percent of the country's total electricity production (Bertani, 2015). It is different for most of the other countries listed in Table 6, with geothermal playing an important role in their electricity matrix. That certainly applies to the 2nd country on the list, the Philippines. With 1,870 MWe on-line, geothermal contributed to 14% of the electricity requirements (Bertani 2015). Table 6 also shows recent addition in the production capacity (numbers in red), with a large increase manifested for selected countries (Richter, 2019). Turkey has taken the biggest jump, with geothermal power on-line increasing from 397 MWe in 2014 to 1345 MWe in 2019. Indonesia has also taken a similar jump, having now reached 2nd place through their increase from 1340 MWe to 1919 MWe in 2019. Kenya, the only African country seen in the table, also shows a healthy increase. The power production capacity is now more than 850 MWe, which puts the country in 7th place, above Iceland. In Iceland, the geothermal electricity production amounted to about 27% of the produced electricity in 2017 (Ragnarsson, 2018). The last 3-4 years have also seen new countries added to the list of producers, like Chile and Croatia.

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 Africa it is not surprising that no African country is seen among the top ten countries in direct use of geothermal energy.

TABLE 6: Top ten countries in electricity production from geothermal energy in 2014 (Bertani, 2015), and those leading direct use (Lund and Boyd, 2015); red numbers are recent updates (Richter, 2019)

Geothermal electricity production			**Geothermal direct use**	
Country	**MWe**	**GWh/a**	**Country**	**GWh/a**
USA	3,450 – 3,650	16,600	China	48,435
Philippines	1,870	9,646	USA	21,075
Indonesia	1,340 – 1,919	9,600	Sweden	14,423
Mexico	1,017 – 951	6,071	Turkey	12,536
New Zealand	1005 – 980	7,000	Iceland	7,422
Italy	916 – 944	5,660	Japan	7,259
Iceland	665 - 755	5,245	Germany	5,426
Kenya	**594 – 850**	**2,848**	Finland	5,000
Japan	519 – 542	2,687	France	4,408
Turkey	397 – 1,345	3,127	Canada	3,227

Focussing on energy use in the East African region, Tables 7-8 show interesting numbers. They are based on statistics from OECD/IEA and the World Bank published in 2019. Table 7 shows the total primary energy supply (TPES) in four of the East African countries in 2017. It shows well how important biomass and waste are in the region, accounting for 64-88% of the total supply in the respective countries, and how small the share of the other renewable energy sources still is. Fossil fuel supplies energy for some of the electricity and of course the transport sector. Geothermal is though certainly making a breakthrough in Kenya.

TABLE 7: Total Primary Energy Supply (TPES) in selected East African countries in 2017 (calculated from OECD/IEA, 2019)

	Fossil	**Hydro**	**Geoth./ sol./wind**	**Waste/ biomass**
Eritrea	23%			77%
Ethiopia	9%	3%		88%
Kenya	20%	1%	15%	64%
Tanzania	17%	1%		82%
Total	**14%**	**2%**	**5%**	**79%**

Finally, Table 8 demonstrates some difference in electricity production per capita between three East African countries, varying between 100 and 2000 kWh/capita (in 2017), compared to the average value for the OECD countries, about 8000 kWh/capita. The numbers show clearly the need for improvement in the region, if living standards are to be improved significantly.

TABLE 8: Statistics on selected East African countries in 2017 (OECD/IEA, 2019; World Bank, 2019)

	Population[1]	**GDP[1] USD[2]/capita**	**TPES[3] kWh/capita**	**Electricity[3] kWh/capita**
Ethiopia	106 million	768	4,652	100
Kenya	50 million	1,569	5,815	200
Tanzania	55 million	974	4,652	100
OECD	**1,296 million**	**38,431**	**47,683**	**8,000**

1: World Bank (2019); 2: Current (2017); 3: OECD/IEA (2019)

4. UTILIZATION OF GEOTHERMAL ENERGY IN AFRICA

As seen in Section 3, the East African countries have similar energy production and consumption characteristics. Traditional biomass represents by far the largest part of primary energy produced (Table 7). The extensive use of combustible waste and biomass causes deforestation and contributes to environmental degradation. All the East African countries import petroleum products, mainly for transport and some for electricity production, which is not desirable with respect to the environment and global warming in particular. Instead local renewable energy sources should be preferred, at least as far as their availability allows. For the countries surrounding the East African Rift System (EARS) (Figure 2) with its volcano-tectonic activity, their high-temperature geothermal resources have the potential to play a much bigger role and even become one of the most important resources for electricity production (Teklemariam, 2008). Renewable energy sources (hydro, wind, solar, geothermal) have only accounted for a small portion of the total primary energy production (TPES), averaging only 7% in 2017 when looking at numbers for selected countries in E-Africa (Table 7).

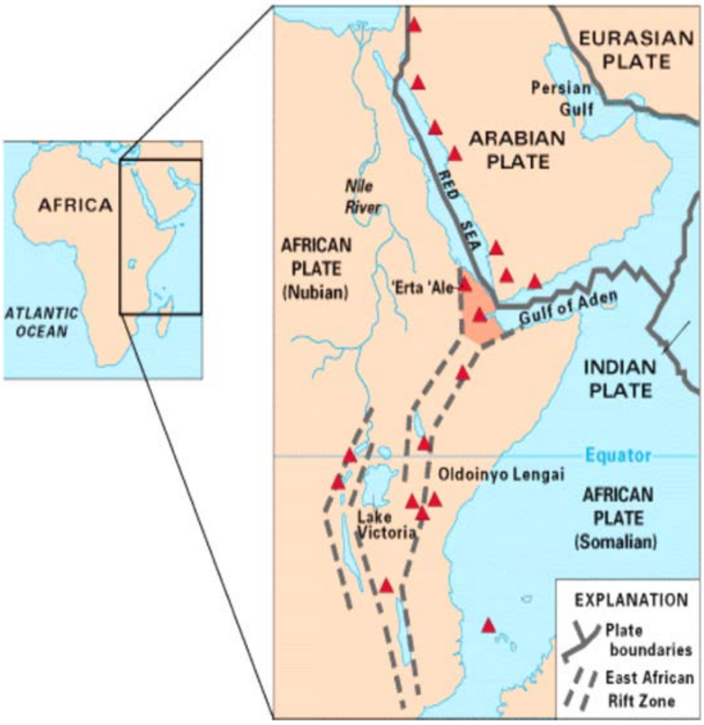

FIGURE 2: The Great East African Rift System (Teklemariam, 2008)

Geothermal can also be expected to play an important role in the countries of North Africa. However, the geothermal resources in this part of Africa are of the low-temperature type, and thus the practical utilization is mainly limited to direct uses, such as space heating, agriculture, aquaculture, spas and recreation, etc. Electrical production through binary stations might though be possible at a few locations.

With the technology of today, East Africa has high potential to generate energy from geothermal power. Despite that, Kenya is still the only country harnessing this resource to a significant extent. It has the richest potential, evaluated at more than 7000 MWe (Simiyu, 2010). But more importantly, Kenya put forward a very ambitious plan to reach a total of 2000 MW of geothermal power on-line in 2018 and the even more ambitious 5000 MWe in 2030 (Simiyu, 2010; GoK, 2014). This may have proved to be overly ambitious, but still illustrates the strong intentions of the Government of Kenya. Since the early 1980s, Kenya slowly increased its total geothermal power generation from 15 MWe to 202 MWe at the Olkaria geothermal area in 2010. The year 2014 saw a major increase in KenGen's geothermal electrical production in Olkaria with two additional 140 MWe power plants coming on-line (Figure 3 shows the Olkaria IV power plant), which together with smaller units (wellhead generators and enlargement of the ORPower4 power plant) took Kenya's production capacity to 594 MWe at the end of 2014. With the enlargement of Olkaria IAU (83 MWe), and building of Olkaria V (160 MWe) coming on line in 2019, Kenya is reaching more than 850 MWe. GDC has also been drilling with 3-4 rigs in the Menengai geothermal area, and after some disappointments in the early phases, seems to be getting promising results, with e.g. the directional well MN-1A, and is now ready for development together with IPPs.

It should also be mentioned that at Lake Naivasha, Kenya, geothermal water and carbon dioxide from geothermal fluids are used in an extensive complex of greenhouses for growing roses (Figure 4). Using

FIGURE 3: The Olkaria IV power station in Kenya, opened in mid-2014, with an installed capacity of 140 MWe from two 70 MWe turbines

geothermal heating to improve the quality of the products started in 2003. The Oserian farm is still (2019) the biggest geothermal greenhouse farm in the world, with 50 ha. of greenhouses being heated with geothermal to produce high quality cut flowers (Lagat, 2010).

FIGURE 4: Roses grown in a greenhouse heated with geothermal at the Oserian farm, Kenya

Olkaria is also the location of a new geothermal spa (Figure 5), built by KenGen, to some extent modelled after the Blue Lagoon in Iceland (Mangi, 2015). There is not much spa or public bathing tradition in Kenya, but the Olkaria Spa may certainly create an interest in this and

FIGURE 5: The geothermal spa in Olkaria, Kenya

has been quite popular among tourists in the Naivasha area.

In Ethiopia, the Aluto-Langano pilot power plant, built in 1998 for producing 7.2 MWe on-line, had a major problem in operation for its first years, with only partial production for a few months after its opening. Mechanical problems in the plant and limited steam supply were a difficult problem to overcome. This led to no or low production for long periods of time (Teklemariam, 2008). After restoration, the plant was running smoothly and producing 3 MWe for several years, but has now been shut down. Additional wells have been drilled and more are scheduled to get more steam. The plan is not only to get the pilot plant back on-line, but also for an extended plant, scheduled to produce 75 MW of electricity, with the assistance of World Bank and JICA. Furthermore, Reykjavik Geothermal has announced large production plans for the Corbetti and Tulu Moye geothermal fields, which seem to be reaching a drilling stage in the very near future, with bureaucratical problems having finally been solved.

Geothermal exploration and research have recently been undertaken in Djibouti, Uganda, Tanzania, Eritrea, Zambia, Malawi, and in Rwanda. The ambitious exploration drillings in Karisimbi in Rwanda, unfortunately were not successful, with the two deep exploration wells not confirming the existence of a geothermal reservoir. This is a lesson to learn from for the countries bordering the western part of the EARS, emphasizing that much more exploration is needed there. The big question with the western rift is whether its potential is mainly confined to intermediate- and low-temperature activity, which would see its possibilities for electrical production limited quite much. Djibouti has also been drilling deep exploration wells, with some results.

The advantages of, and barriers to, the utilization of geothermal energy resources in the East African region have been summarized by Teklemariam (2008):

- The region has a large untapped geothermal resource potential;
- The geothermal resources are indigenous, reliable, environmentally clean, economically viable, and renewable;
- Development of geothermal resources is constrained by:
  i. the risks that are associated with resource exploration and development,
  ii. the financial risks that are associated with investment in power development projects,
  iii. lack of appropriate investment and institutional settings in many East African countries;
- Diversified use of geothermal energy augments energy supply from hydropower plants and improves the generation mix. It avoids vulnerability to drought and oil price fluctuations.

To light up East Africa by geothermal electricity, investors and financial assistance from international agencies are necessary, and the human capacity to deal with the exploration and development needs to be built up further.

FIGURE 6: A geothermal green house in Tunisia, the hot water flows through plastic pipes at the ground surface

In North Africa, low-temperature geothermal waters for direct use have been utilized successfully in Tunisia where hot water intended for irrigation is cooled down in greenhouses thus allowing production of quality products, such as cucumbers and melons, mainly for export to Europe (Figure 6). In 2014, the total area heated in geothermal greenhouses in Tunisia had reached 244 ha, making it one of the largest producers in the world from geothermally heated greenhouses. Extensive use of geothermal water for bathing can be added to this as an important cultural habit with roots stretching back some thousands of years. Direct use of geothermal energy is also recorded for Algeria, and Morocco has been exploring for geothermal resources. Tunisia provides the example for the other countries of North Africa to follow (Ben Mohamed, 2015).

5. EXAMPLES OF USES OF GETHERMAL ENERGY IN ICELAND

Iceland is a unique country with regard to utilization of geothermal energy, with 61% of its primary energy consumption in 2017 coming from geothermal energy (Ragnarsson, 2018). Direct use plays the most important role here with more than 90% of houses in the country heated by geothermal energy, 12 months of the year. Other uses include greenhouses, fish farming, industry, snow melting, swimming pools, etc., but even so only a fraction of the potential is used. Electrical production from geothermal power plants has increased rapidly in the last 3 decades, amounting to about 30% of the total electrical production in 2018 (Orkustofnun, 2019). With the Theistareykir power plant in N-Iceland coming on line in 2017-2018, the total installed capacity reached about 754 MWe (Figure 7).

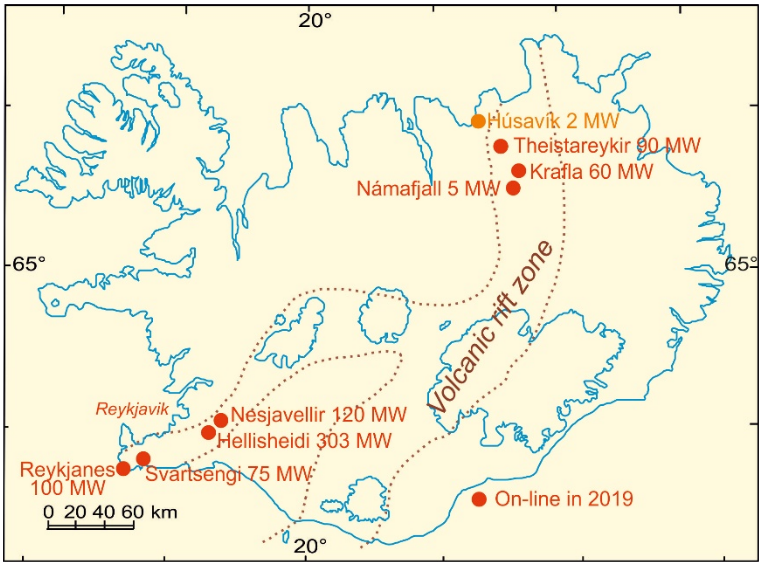

FIGURE 7: Geothermal power plants in Iceland in 2019

It can be said that geothermal utilization is a way of life in Iceland. Reykjavik Energy supplies the capital, Reykjavik, and its surroundings, in total almost 230,000 people or 64% of the population with hot water for heating through 12 months of the year, making it the largest geothermal municipal heating service in the world. Geothermal swimming pools are found in almost every village and small town in Iceland. The most famous bathing place is, however, the Blue Lagoon (Figure 8), a by-product of the Svartsengi power plant and located in a hostile lava field, 5-10 km from the nearest towns. It has become a landmark for Iceland and a must for any tourist to visit. To this can be added benefits such as snow-melting of pavements around houses, not forgetting the use of geothermal water for heating of greenhouses and for fish farming.

FIGURE 8: UNU Fellows bathing in the Blue Lagoon in 2003

6. UNU-GTP CONTRIBUTION TO GEOTHERMAL TRAINING FOR AFRICA

6.1 The 6-month training

The first Africans attended the 6-month training programme in 1982 when 3 out of 7 participants were Kenyan employees of the East African Power and Lighting Company Ltd. Kenya was a natural first beneficiary country as the first steps were being taken towards geothermal electricity generation at Olkaria I during this time. In the following year, the first Fellows from Ethiopia (Geological Survey of Ethiopia) attended. Over the period 1979-2019, a total of 276 Fellows from Africa (Figure 9) have attended the 6-month training programme in Iceland and 5 undertook similar training in Kenya in 2013, carried out by the UNU-GTP. The 281 African 6-month Fellows account for 39% of the total number of 718 Fellows (Table 9; Figure 9).

TABLE 9: Number of UNU Fellows from Africa attending the 6-month training in Iceland over the period 1982-2019

Country	Total number	Women	Years attended
Algeria	4	2	1989, 1994, 2009
Burundi	2	0	1984, 2013
Comoros	2	0	2010, 2015
D.R. Congo (DRC)	1	0	2015
Djibouti	19	4	1989, 2005, 2008, 2009, 2010, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019
Egypt	4	1	1990, 1994, 1995, 2005
Eritrea	7	0	1984, 2004, 2005, 2007, 2008, 2010
Ethiopia	45	4	1983, 1984, 1985, 1986, 1987, 1988, 1997, 1998, 1999, 2001, 2002, 2003, 2004, 2005, 2007, 2008, 2010, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019
Kenya	134	34	1982, 1985, 1986, 1987, 1988, 1990, 1991, 1992, 1993, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019
Malawi	4	1	2012, 2013, 2015, 2017
Morocco	1	0	2011
Nigeria	1	0	2019
Rwanda	12	4	2008, 2009, 2010, 2011, 2012, 2013, 2014, 2016
Sudan	1	0	2014
Tanzania	19	7	1986, 2006, 2007, 2008, 2009, 2011, 2012, 2014, 2015, 2016, 2017, 2018, 2019
Tunisia	6	0	1997, 1998, 1999, 2000
Uganda	17	3	1990, 1993, 1994, 1995, 1996, 2000, 2005, 2006, 2007, 2008, 2009, 2011, 2012, 2013, 2016
Zambia	2	0	2009, 2018
Total:	**281**	**60**	(All years)

Although UNU-GTP emphasizes the training of women, the pool of candidates for 6-month studies has tended to be male dominated, especially in earlier years. This is reflected in 21% of candidates from Africa having been female from the beginning (60/281). Looking specifically at the last decade (2010-2019), it can be observed that the ratio has increased to 29% (47/162).

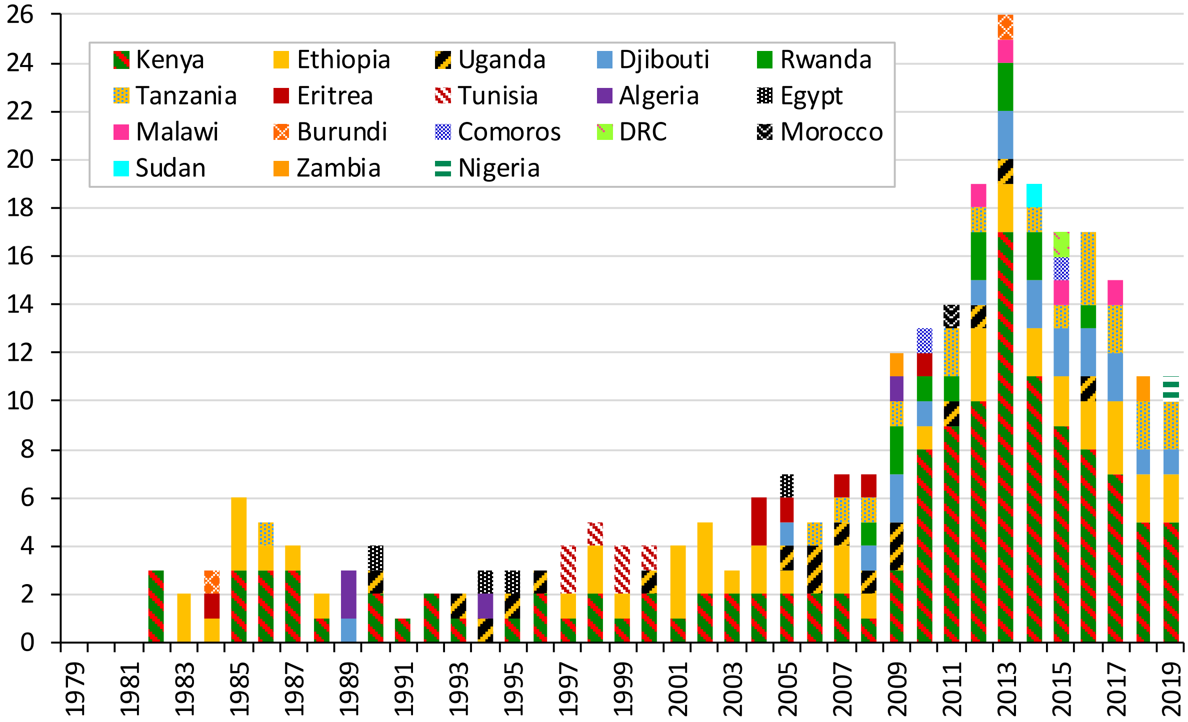

FIGURE 9: Number of African UNU Fellows attending the 6-month training in Iceland over the period 1979-2019 (partially same information as in Table 9)

6.2 MSc and PhD studies

The first Africans to be supported by UNU-GTP for MSc studies, embarked on their studies at the University of Iceland in the autumn of 2000. Since then, the majority of MSc students have come from Africa. As mentioned in Section 2, a total of 40 African Fellows had completed their MSc degrees in late 2019, 24 from Kenya, 4 from Ethiopia, 3 from Tanzania, 2 from each of Djibouti, Eritrea, Malawi and Rwanda, and 1 from Uganda. This includes 8 women. This is close to 60% of the total number of 67 graduates who have received UNU-GTP MSc Fellowships. Six African Fellows continued working on their MSc degrees in late 2019, 4 of whom embarked on the studies in the fall of 2019.

Seven former 6-month Fellows from Africa have been awarded with PhD Fellowships by UNU-GTP as of 2019 (out of a total of 8), six are from Kenya and 1 from Tanzania. Three have defended their dissertations (2 women and 1 man), whereas four continue to work on their degrees (all men).

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

The *Workshop for Decision Makers on Geothermal Projects and their Management* was held in Kenya in 2005 as a contribution towards realizing the objectives of the UN Millennium Development Goals (MDGs) (Georgsson, 2010). It was followed up by annual Short Courses focusing on surface exploration for geothermal resources, held in Kenya in cooperation with Kenya Electricity Generating Company Ltd. (KenGen) and later Geothermal Development Company Ltd. (GDC) over the period 2006-2015. An addition was the *Short Course on Geothermal Project Management and Development*, held in

Uganda in 2008, which was also a part of the MDG Short Course Series for Africa. The Workshop and Short Courses were attended by 554 participants from 21 countries in Africa, in addition to Yemen, over the period 2006-2015. The publishing of papers in association with the courses has allowed UNU-GTP to build an extensive collection of lectures and papers on geothermal development, which have contributed to the possibility of offering tailored training. The papers have been published on CDs and are openly available on UNU-GTP's website: *www.unugtp.is*. For further information on the MDG Short Course Series, see Haraldsson (2018), and Haraldsson and Georgsson (2018).

6.4 Customer-designed short courses

Since 2010, UNU-GTP has conducted various short courses and long-term training efforts in cooperation with local partners in 4 continents. As of end of year 2018, 24 trainings of short, medium and long duration had been conducted for African countries: 12 in Kenya for Kenyans and/or participants from neighbouring countries, 5 in Ethiopia, 3 in Djibouti, 3 in Rwanda, and 1 in Iceland. (Table 10). These trainings have ranged from a 2-day workshop for decision makers intended to provide

TABLE 10: Trainings and workshops for African countries supported by MFA – ICEIDA

Name	Year	Host country	Beneficiary countries	No. part.	No. women
SC on Deep Geothermal Exploration	2013	Rwanda	Rwanda	20	3 (15%)
SC Geotherm. Devel. for Dec. Makers	2013	Kenya	Burundi, DRC, Rwanda	13	1 (8%)
SC Geotherm. Devel, for Dec. Makers	2013	Kenya	Malawi, Tanzania, Zambia	23	2 (9%)
WS for Geothermal Developm. Donors	2014	Iceland	African countries[1]	48	12 (25%)
SC on Well Design and Geothermal Drilling Technology	2015	Ethiopia	Ethiopia	30	1 (3%)
SC on Preparations of Bankable Geothermal Documents	2015	Ethiopia	Ethiopia	25	6 (24%)
SC on Geothermal Project Management	2015	Ethiopia	Ethiopia	25	3 (12%)
SC on Geothermal Project Management	2015	Kenya	Kenya	26	7 (27%)
SC on Preparation of Bankable Docum. for Geothermal Projects	2015	Djibouti	Djibouti	18	2 (11%)
SC on Geothermal Project Management	2015	Djibouti	Djibouti	16	2 (13%)
SC on Well Design and Geothermal Drilling Technology	2016	Djibouti	Djibouti	23	2 (9%)
SC on Borehole Geophysics for Geothermal Development	2016	Ethiopia	Ethiopia	27	4 (15%)
SC on Project Management for Geothermal Development	2016	Ethiopia	East Africa	34	6 (18%)
Introd. SC on Geoth. Project Managem.	2017	Kenya	Kenya	16	4 (25%)
SC I on Management and Financing for Geothermal Project Development	2018	Rwanda	East Africa	25	6 (24%)
SC II on Low-Temperature Geothermal Systems and Direct Use Applications	2018	Rwanda	East Africa	24	8 (33%)
			Total:	**393[2]**	**69[2] (18%)**

1: Participants came from Burundi, Comoros, Democratic Republic of the Congo, Djibouti, Eritrea, Ethiopia, France, Germany, Iceland Kenya, Rwanda, Uganda, United States and other countries, representing geothermal companies and institutions in Africa, development donors (AfDB, African Union, ARGeo-UNEP, BGR, ICEIDA, IRENA, JICA, KfW, NDF, World Bank, USAID-Power Africa), and private enterprises.;
2: Some individuals participated in more than one training.

overview and serve as a platform for discussion, to in-depth training of experts leading to certification equivalent to the 6-month studies in Iceland.

Some of the training has been called for by geothermal companies in order to strengthen employee skill sets, while others have been implemented in response to requests from development donors. The Icelandic Ministry for Foreign Affairs (MFA) – ICEIDA has specially supported several trainings for Africa, often in cooperation with the Nordic Development Fund (NDF), as shown in Table 10.

7. UN SUSTAINABLE DEVELOPMENT GOALS AND THE 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, KenGen and GDC, 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;
- Geothermal resources can be utilized in a sustainable manner, 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 on average 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 course series in Kenya and El Salvador have been changed to reflect support of the SDGs. The courses continue to rest on the solid foundations of the MDG Short Courses and the structure remains to a great extent the same as before, although some changes in approach and content have been introduced to better reflect the SDGs. *SDG Short Course I on Exploration and Development of Geothermal Resources*, organized by UNU-GTP, KenGen and GDC, was held by Lake Bogoria and Lake Naivasha during November 10-30, 2016 and SDG Short Courses II and III followed in 2017-2018 (Table 11; Figures 10-11) (Haraldsson, 2018; Georgsson and Haraldsson, 2018).

TABLE 11: SDG Short Courses for Africa in 2016-2018

Name	Dates	No. countries	No. particip.	No. women
SDG Short Course I on Exploration and Development of Geothermal Resources	10-30 Nov., 2016	16	61	21 (34%)
SDG Short Course II on Exploration and Development of Geothermal Resources	9-29 Nov., 2017	17	63	22 (35%)
SDG Short Course III on Exploration and Development of Geothermal Resources	7-27 Nov. 2018	14	32	11 (34%)
	Total:	**19[1]**	**156**	**54 (35%)**

1: Cameroon, Comoros, Djibouti, Democratic Republic of Congo (DRC), Egypt, Eritrea, Ethiopia, Kenya, Madagascar, Malawi, Morocco, Mozambique, Nigeria, Rwanda, Sudan, Tanzania, Uganda, Yemen, and Zambia.

FIGURE 10: SDG Short Course III in Kenya in 2018. Clockwise from top left: Lecture by Dir. Lúdvík S. Georgsson, field guidance by Geologist Victor Otieno, control room lecture by Eng. George Ngomi, examination.

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.

FIGURE 11: Participants, lecturers and organizers of SDG Short Course III in Kenya

8. AFRICAN GEOTHERMAL CENTRE OF EXCELLENCE

The establishment of an African geothermal training centre has been discussed for some time and its structure and functions are currently being carved out under the auspices of an interim coordination unit that is to pass the programme on to more permanent hosts (Georgsson, 2018). UNU-GTP is prepared to contribute to such a centre as it has done in the case of the Geothermal Diploma Course for Latin America held annually in El Salvador (Georgsson and Haraldsson, 2018).

9. THE GEOTHERMAL FUTURE

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, 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.

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.

Geothermal energy is now on the threshold of becoming a major energy source in the energy market in East Africa. It certainly is in Kenya, which has set itself very ambitious goals to reach in the coming decades, by declaring that geothermal is to become its main source of additional electricity in the near future through Kenya Vision 2030 (GoK, 2014). From the current availability of geothermal electricity with 850 MWe on-line (Mangi, 2018), the long-term plans are to reach 5000 MWe on-line from geothermal by the year 2030. This may be an overly optimistic goal, but still shows the burning ambition of the Government of Kenya, which is to be admired and supported.

Other countries in the region are following in Kenya's footsteps, with increasing speed in actions. Ethiopia, Djibouti, Tanzania, Eritrea and Uganda are taking significant steps through new projects, partially in cooperation with foreign companies or investors, in exploration and development of their geothermal sources. The time has, however, come to take it one step further, to significant energy production. That should be the hallmark of the next decade in East Africa.

The Geothermal Training Programme looks forward to see geothermal turn on the lights in the East African countries, and is determined to provide the training opportunities which the region needs, both in Iceland and hopefully also through a future training centre in Kenya in cooperation with the Geothermal Developing Company (GDC), Kenya Electricity Generating Co. (KenGen), and the African Union.

In the near future, UNU-GTP will operate under a new identity, with the Government of Iceland, through the Ministry for Foreign Affairs (MFA), and United Nations University (UNU) having decided to discontinue their cooperation from the start of 2020. Instead MFA has sought cooperation with UNESCO. This has resulted in a new institution being formed in Iceland, which is expected to become a UNESCO Category 2 Centre, and act as an umbrella over the 4 UNU programmes located in Iceland. The name of this institute will be GRÓ under the auspices of UNESCO. So, in future the Geothermal Training Programme will become *GRÓ GTP under the auspices of UNESCO*. It should be stressed that the government of Iceland is fully committed to the future support of GRÓ GTP.

REFERENCES

Ben Mohamed, M., 2015: Geothermal energy development: the Tunisian experience. *Proceedings of the Word Geothermal Congress 2015, Melbourne, Australia*, 8 pp.

Bertani, R., 2015: Geothermal power generation in the world, 2010-2014 update report. *Proceedings of the World Geothermal Congress 2015, Melbourne, Australia,* 19 pp.

Georgsson, L.S., 2018: Forty years of geothermal training in Iceland – History, status and future direction. *Papers presented at "40th Anniversary Workshop of the United Nations University Geothermal Training Programme", Reykjavík, Iceland*, 19 pp.

Georgsson, L.S., and Haraldsson, I.G., 2018: The role of geothermal energy and capacity building in achieving the UN sustainable development goals in Latin America and the Caribbean. *Papers presented at "SDG Short Course III on Geothermal Reservoir Characterization: Well Logging, Well Testing and Chemical Analysis", organized by UNU-GTP and LaGeo, Santa Tecla, El Salvador*, 22 pp.

Georgsson, L.S., Haraldsson, I.G. and Ómarsdóttir, I., 2018: Capacity building in geothermal: update and summary of UNU-GTP's activities for geothermal development in Africa. *Proceedings of the ARGeo-C7 Conference, Kigali, Rwanda,* 13 pp.

GoK, 2014: *Kenya Vision 2030*. Government of Kenya, website: *www.vision2030.go.ke/.*

Haraldsson, I.G., 2018: The UN Sustainable Development Goals Short Courses for Africa, Latin America and the Caribbean *Papers presented at "40th Anniversary Workshop of the United Nations University Geothermal Training Programme", Reykjavík, Iceland,* 11 pp.

Haraldsson, I.G., and Georgsson, L.S., 2018: UNU Geothermal Training Programme in Africa: Short Courses held in support of the UN Sustainable Development Goals and the ICEIDA/NDF Geothermal Exploration Project. *Proceedings of the ARGeo-C7 Conference, Kigali, Rwanda,* 13 pp.

IRENA, 2018: *Renewable power generation costs in 2017*. International Renewable Energy Agency, Abu Dhabi, report, 160 pp.

Lagat, J., 2010: Direct utilization of geothermal resources in Kenya. *Proceedings of the World Geothermal Congress 2010, Bali, Indonesia*, 7 pp.

Lund, J.W., and Boyd, T.L., 2015: Direct utilization of geothermal energy 2015, worldwide review. *Proceedings of the World Geothermal Congress 2015*, *Melbourne, Australia*, 31 pp.

Mangi, P.M., 2015: Project review of geothermal spas´ construction in Kenya and Iceland. Report 21 in: *Geothermal training in Iceland*. UNU-GTP, Iceland, 443-474.

Mangi P.M., 2018: Geothermal development in Kenya - country updates. *Proceedings of the ARGeo-C7 Conference, Kigali, Rwanda,* 14 pp.

OECD/IEA, 2019: *Statistics*. Organization for Economic Cooperation and Development / International Energy Agency, website: *www.iea.org/statistics*

Orkustofnun, 2019: Energy statistics in Iceland 2018. Orkustofnun – National Energy Authority, Reykjavik, 14 pp, website: *orkustofnun.is/gogn/os-onnur-rit/Orkutolur-2018-enska.pdf.*

Ragnarsson, Á, 2018: Geothermal country update for Iceland. *Proceedings of the ARGeo-C7 Conference, Kigali, Rwanda,* 13 pp.

Richter, A., 2019: *Recent information on increase in geothermal power production*. Think GeoEnergy Magazine.

Simiyu, S.M., 2010: Status of geothermal exploration in Kenya and future plans for its development. *Proceedings of the Word Geothermal Congress 2010, Bali, Indonesia*, 11 pp.

Taylor, M., Daniel, K., Ilas, A., and Young So, E., 2015: *Renewable power generation costs in 2014*. International Renewable Energy Agency – IRENA, Abu Dhabi, 164 pp.

Teklemariam, M., 2008: Overview of geothermal resource utilization and potential in the East African Rift System. *Proceedings of the 30th Anniversary Workshop of UNU-GTP, Reykjavik, Iceland*, 9 pp.

UN, 2015a: *Unanimously adopting historic Sustainable Development Goals, General Assembly shapes global outlook for prosperity, peace.* United Nations, website: *www.un.org/ press/en/2015/ga11688.doc.htm.*

UN, 2015b: *Sustainable Development Goal 7*. United Nations, website: *sustainabledevelopment.un.org/sdg7*

UN DESA, 2017: *World population projected to reach 9.8 billion in 2050, and 11.2 billion in 2100.* UN Department of Economic and Social Affairs, news brief, 1 pp, webpage: *www.un.org/development/desa/en/news/population/world-population-prospects-2017.html*

WEA, 2004: *World energy assessment: overview 2004 update*. Prepared by UNDP, UN-DESA and the World Energy Council. United Nations Development Programme, New York, United States, 85 pp.

WEC, 2013: *World energy scenarios – composing energy futures to 2050*. World Energy Council, in partnership with Paul Scherrer Institute, London, United Kingdom, 281 pp.

WEC, 2019: *World energy scenarios, 2019.* Prepared by the World Energy Council, London. Website: *www.worldenergy.org/publications/entry/world-energy-scenarios-2019-exploring-innovation-pathways-to-2040.*

World Bank, 2019: *World Bank open data*. World Bank Group, website: *data.worldbank.org/*