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THE ROLE OF GEOTHERMAL ENERGY AND CAPACITY BUILDING IN ACHIEVING THE UN SUSTAINABLE DEVELOPMENT GOALS IN AFRICA

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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 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 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 is expected to play an important role. Africa is currently an energy depleted region, but in the WEC report an annual growth rate of 5% is predicted in the next decades, considerably higher than for other regions which is good news for Africa.

This paper gives 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 other pollutants. For developing countries which are endowed with good geothermal resources, it is a reliable local energy source that can at least to some extent be used to replace energy production based on imported (usually) fossil fuels. The technology is proven and cost-effective. For developing countries that have good resources and have acquired the necessary local expertise it has become very important. A good example is Kenya, as well as the Philippines, El Salvador and Costa Rica, where geothermal energy has become one of the important energy sources providing 10-25% of the electricity production. Iceland should also be mentioned as the only country where geothermal energy supplies almost 70% of the primary energy used (69% in 2014), both through direct use for heating, bathing, etc., and through production of electricity (Ragnarsson, 2015).

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 is needed through exploration. Furthermore, development of a geothermal system for electrical production is a capital intensive undertaking, and thus requires financial strength, or at least access to good financing. Thus, for developing geothermal resources, good training and expertise are needed for the exploration and development work, and strong financial backup for the project.

Here, the role of geothermal energy in the world's energy mix is presented with some emphasis on 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 recently established 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 giving university graduates engaged in geothermal work intensive on-the-job training. The training is conducted in English and is 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.

As a contribution to the UN Millennium Development Goals and through the funding of the Icelandic Government, UNU-GTP has 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 are now 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. More recently, this has 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 the last 5-6 years, serving several customers in 4 different continents.

East-Africa has always been a major cooperating partner of UNU-GTP. Amongst the 647 graduates of UNU-GTP (1979-2016), 244 or 38% have come from seventeen African countries. Most of these come from East Africa. By far the largest number has come from Kenya (117). This is followed by Ethiopia (38), Uganda (17), Djibouti (15), Tanzania (13), and Rwanda (12). Former UNU Fellows lead the 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. Twenty four, or 53%, out of the forty five UNU MSc-Fellows who have graduated from the MSc programme (at the end of 2015) are from Africa, 15 from Kenya, 2 from Eritrea, Ethiopia and Rwanda, and 1 from each of Djibouti, Tanzania and Uganda. Currently, 7 Africans are pursuing their MSc studies in Iceland, coming from Djibouti, Kenya and Malawi. Finally, the first four UNU PhD-Fellows are Kenyans, with the first one defending her dissertation in February 2013, the first African to do so in Iceland. Kenya has been the leading country in E-Africa in geothermal research and development, and many of its specialists have been trained in Iceland. Figure 1 shows the group of UNU Fellows that attended 6-month training in Iceland in 2016: 34 UNU Fellows, including 8 Kenyans, 3 Tanzanians, 2 Djiboutians, 2 Ethiopians, and 1 from each of Rwanda and Uganda.

FIGURE 1: The group of UNU Fellows that attended the 6 months training in Iceland in 2016, at Theistareykir high-temperature field in NE-Iceland, a drillrig is seen in the background

For more information on UNU-GTP, see e.g. Georgsson et al., 2014a and b; and Georgsson et al., 2015a and b) or its 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 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).

At present, 1.1 billion people of the 7.4 billion people living on our planet (2015) have not access to electricity (WEC 2016). UN predicts the world population to grow to about 10.2 billion by 2060. 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.

Today´s energy consumption still relies on fossil fuels. Table 1 shows the use of primary energy in 2014 based on a new 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).

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 2050, 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 renewables is predicted to reach about 37%. Fossil fuels are still responsible for a big part 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
Oth. renewabl.	**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 a dark continent in more than one way. The good news, however, are that the annual growth rate for Africa for the period to 2050 is predicted to be very good, about 5% (AGR), which is higher than for all other regions, and considerably higher than for most. This is good news for Africa.

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 & 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, 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 the 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, 2013**; 2016*)

	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 for base load. This last fact is not illustrated 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 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 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 in-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. Here, we should also see a big increase for 2016 as the new power plants which came on-line in 2014, were only producing for a minor part of that year. 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 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)

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

Focussing on energy use in the East African region, Tables 7-8 show interesting numbers. They are based on statistics from OECD/IEA published in 2016. Table 7 shows the primary energy consumption in four of the East African countries in 2013. It shows well how important biomass and waste are in the region, accounting for 70-90% of the total consumption in the respective countries, and how small the share of the other renewable energy sources is still. Fossil fuel supplies energy for some of the electricity and of course the transport sector. Geothermal is though certainly making a breakthrough in Kenya, something which should be considerably clearer in a year or two.

TABLE 7: Total primary energy supply (TPES) in selected East African countries in 2013 (calculated from OECD/IEA, 2016)

	Fossil	**Hydro**	**Geoth./ sol./wind**	**Waste/ biomass**
Eritrea	23%			77%
Ethiopia	6%	2%		92%
Kenya	18%	2%	8%	72%
Tanzania	15%	1%		84%
Total	**11%**	**1%**	**2%**	**86%**

Finally, Table 8 demonstrates the huge difference in electricity production per capita between the East African countries, varying from 60 to 170 kWh/capita (in 2013), compared to the average value for the OECD countries, about 8100 kWh/capita. The numbers show clearly the need for improvement in the region, if living standards are to be improved significantly (see also Georgsson, 2014b).

TABLE 8: Statistics on selected East African countries in 2013 (OECD/IEA, 2016)

	Population	**GDP $[1]/capita**	**TPES kWh/capita**	**Electricity kWh/capita**
Eritrea	5.0 million	508	1,861	60
Ethiopia	94.6 million	423	5,815	70
Kenya	43.7 million	1,073	5,699	170
Tanzania	50.2 million	761	5,582	100
OECD	**1261.9 million**	**37,058**	**48,962**	**8,110**

1: 2010 USD

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 category of 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 in times of environmental awareness and high oil prices. Instead local renewable energy sources should be preferred, at least as far as conventional resources allow. 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. Renewable energy sources (hydro, geothermal, wind, solar, etc.) have only represented a small portion of the total primary energy production, averaging 2% for hydropower, wind, geothermal and solar production combined (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, i.e. space heating, agriculture, aquaculture, recreation, etc., Electrical production through binary stations might though be possible at a few locations.

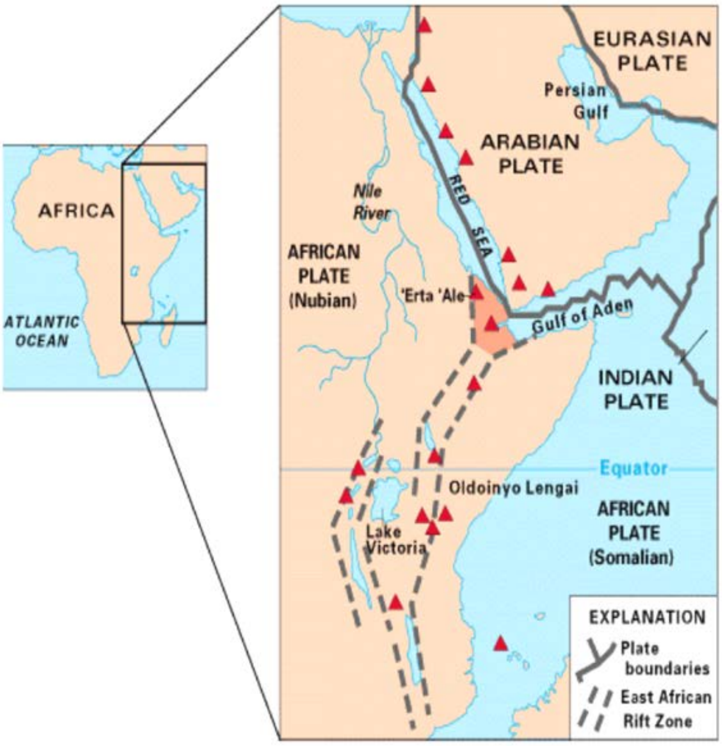

FIGURE 2: The Great East African Rift System (Teklemariam, 2008)

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 has 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 be overly ambitious, but still illustrates the strong intentions of the Government of Kenya. Since the early 1980s, Kenya has slowly been increasing 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. This is a dramatic rise and a proof of Kenya's great determination in reaching set goals. 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.

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

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 geothermal heating to improve the quality of the products started in 2003. The Oserian farm is still (2016) 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 in the tradition of the Blue Lagoon in Iceland (Mangi, 2013). There is not much spa or public bathing tradition in Kenya, but it may create a new interest in this and will certainly be popular among tourists in the Naivasha area.

FIGURE 5: The new geothermal spa in Olkaria, Kenya

In Ethiopia, the Aluto-Langano pilot power plant, built in 1998 for producing 7.2 MWe on-line, had 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. Drilling is now being prepared to get more steam, not only to get the pilot plant back on-line, but also for an extended plant, scheduled to produce 75 MWe of electricity, with the assistance of World Bank. Furthermore, Reykjavik Geothermal has announced large production plans for the Corbetti geothermal field, which are expected to be realised in the very near future.

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.

The good possibilities in 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 an indigenous, reliable, environmentally clean and economically viable, renewable energy resource;
- 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; and
    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.

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 green-houses 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, but Tunisia provides the example for the other countries of North Africa to follow (Ben Mohamed, 2014).

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

5. EXAMPLES OF USES OF GETHERMAL ENERGY IN ICELAND

Iceland is a unique country with regard to utilization of geothermal energy, with more than two thirds (68%) of its primary energy consumption in 2013 coming from geothermal energy (Ragnarsson, 2015). Direct use plays the most important role here with 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 recent years, amounting to about 29% of the total electrical production in 2013. In 2014, the total installed capacity was about 665 MWe (Figure 7).

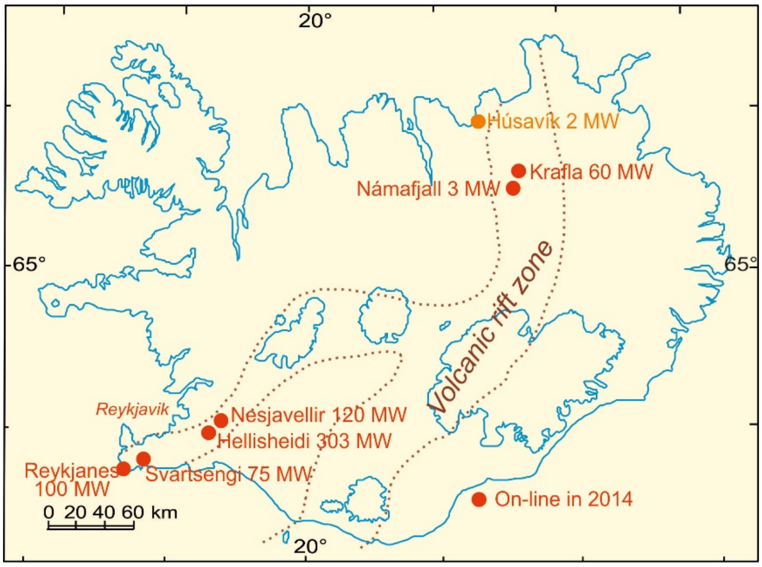

FIGURE 7: Geothermal power plants in Iceland in 2014

It can be said that geothermal energy is a way of life in Iceland. Reykjavik Energy supplies the capital, Reykjavik, and its surroundings, in total just over 200,000 people, 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 in Olkaria during this time. In the following year, the first Fellows from Ethiopia (Geological Survey of Ethiopia) attended. Over the period 1979-2016, a total of 239 Fellows from Africa (Figure 9) have attended the 6-month training programme in Iceland and 5 undertook training in Kenya in 2013. The total of 244 African 6 month Fellows accounts for close to 38% of the total number of 647 Fellows (Table 9; Figure 9).

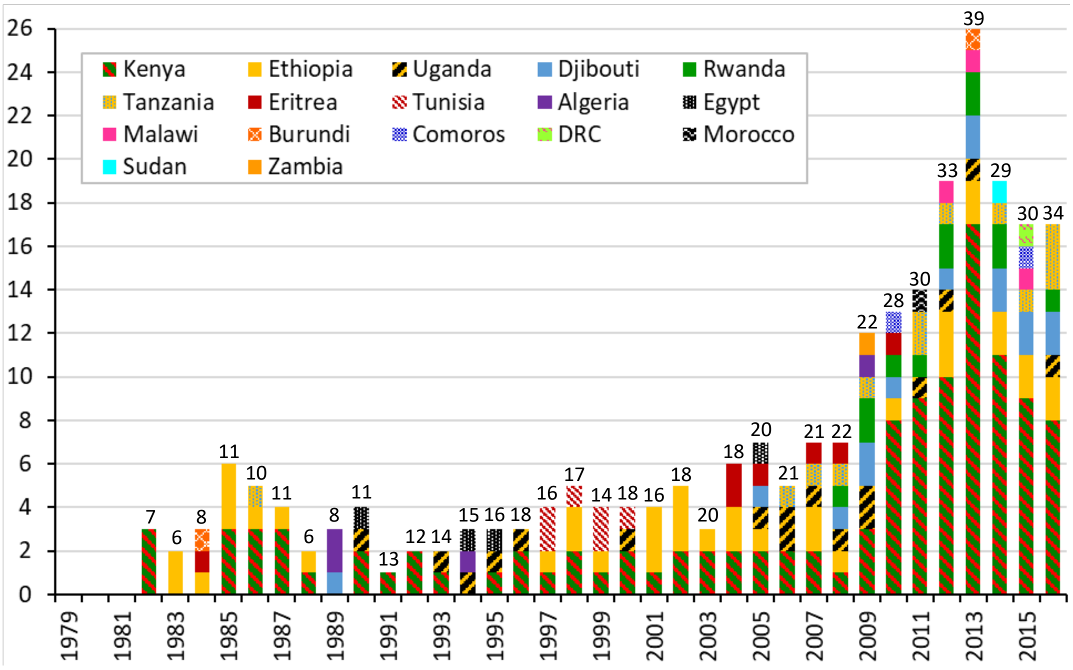

FIGURE 9: Number of African UNU Fellows attending the 6-month training in Iceland over the period 1979-2016 (partially same information as in Table 9); numbers on top of columns indicate the total number of Fellows in each year's class

TABLE 9: Number of Fellows from Africa attending the 6-month training in Iceland over the period 1982-2016

Country	Total number	Women	Years attended
Algeria	4	2	1989, 1994, 2009
Burundi	2	0	1984, 2013
Comoros	2	0	2010, 2015
Democratic Republic of the Congo (DRC)	1	0	2015
Djibouti	15	2	1989, 2005, 2008, 2009, 2010, 2012, 2013, 2014, 2015, 2016
Egypt	4	1	1990, 1994, 1995, 2005
Eritrea	7	0	1984, 2004, 2005, 2007, 2008, 2010
Ethiopia	38	4	1983, 1984, 1985, 1986, 1987, 1988, 1997, 1998, 1999, 2001, 2002, 2003, 2004, 2005, 2007, 2008, 2010, 2012, 2013, 2014, 2015, 2016
Kenya	117	29	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
Malawi	3	0	2012, 2013, 2015
Morocco	1	0	2011
Rwanda	12	4	2008, 2009, 2010, 2011, 2012, 2013, 2014, 2016
Sudan	1	0	2014
Tanzania	13	4	1986, 2006, 2007, 2008, 2009, 2011, 2012, 2014, 2015, 2016
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	1	0	2009
Total:	**244**	**49**	(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 about 20% of candidates from Africa having been female from the beginning (49/244). Looking specifically at the last decade (2007-2016), it can be observed that the ratio has increased to 28% (43/151).

6.2 MSc and PhD studies

The first African to be supported by UNU-GTP for MSc studies, embarked on his studies at the University of Iceland in 2001. Since then, the majority of MSc students have come from Africa. A total of 24 African Fellows had completed their MSc degrees at the end of 2015, including 2 women: 1 from Djibouti, 2 from Eritrea, 2 from Ethiopia, 15 from Kenya, 2 from Rwanda, 1 from Tanzania, and 1 from Uganda. This was close to 53% of the total number of 45 graduated MSc Fellows. Nine African Fellows continued working on their MSc degrees in 2016, with 4 more commencing their studies.

Four former 6 month students have been awarded with PhD Fellowships, all from Kenya. Two have defended their dissertations (both women), whereas 2 are working on their degrees (both men).

6.3 Workshops and Short Courses held in support of the U.N. 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 as shown in Table 10. The *Short Course on Geothermal Project Management and Development*, held

TABLE 10: Workshop and Short Courses held in Africa in support of the Millennium Development Goals 2006-2015. All of the short courses were held in Kenya, except for the latter course in 2008, which was held in Uganda.

Name	Dates	No. countries	No. particip.	No. women
Workshop for Decision Makers on Geothermal Projects and their Management	14-18 Nov, 2005	5	30	
Short Course I on Surface Exploration for Geothermal Resources	13-22 Nov, 2006	6	23	
Short Course II on Surface Exploration for Geothermal Resources	2-17 Nov, 2007	11[1]	30	6 (20%)
Short Course III on Surface Exploration for Geothermal Resources	24 Oct – 17 Nov, 2008	11[1]	37	6 (16%)
Short Course on Geothermal Project Management and Development	20-22 Nov, 2008	10[1]+2[2]	24	2 (8%)
Short Course IV on Surface Exploration for Geothermal Resources	1-22 Nov, 2009	11[1]	45	9 (20%)
Short Course V on Surface Exploration for Geothermal Resources	29 Oct – 19 Nov, 2010	13[1]	56	13 (23%)
Short Course VI on Surface Exploration for Geothermal Resources	27 Oct – 18 Nov, 2011	15[1]	58	10 (17%)
Short Course VII on Surface Exploration for Geothermal Resources	27 Oct – 18 Nov, 2012	14[1]	61	17 (28%)
Short Course VIII on Surface Exploration for Geothermal Resources	31 Oct – 23 Nov, 2013	18[1,3]	70	20 (29%)
Short Course IX on Surface Exploration for Geothermal Resources	2-23 Nov, 2014	18[1]	58	15 (26%)
Short Course X on Surface Exploration for Geothermal Resources	9-30 Nov, 2015	18[1]	62	19 (31%)
	Total:	**22[1]+2[2]**	**554**	**116+ (~23%)**

1: Incl. Yemen; 2: One from Germany, another from Italy; 3: One represented the African Development Bank.

in Uganda in 2008, was also a part of the MDG series of short courses 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 participation is broken down by country in Table 11. 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 customer designed training. The papers have been published on CDs and are openly available on UNU-GTP's website: *www.unugtp.is.*

TABLE 11: Participants in the Millennium Workshop and Short Courses in Africa 2005-2015

	2005	**2006**	**2007**	**2008**	**2008[1]**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**Total**
Algeria			1					1					**2**
Burundi				2	1	2	2	1	2	2	1	1	**14**
Cameroon										1	1	1	**3**
Comoros			2			2	3	2	1	1	2	1	**14**
D.R. Congo				1	1			1	3	3	2	2	**13**
Djibouti		2	1	2	3	2	2	3	2	3	2	3	**25**
Egypt			1									1	**2**
Eritrea	2	3	2	2	1	2		2		2	1	2	**19**
Ethiopia	5+2[2]	3	1	2	3	3	1	3	3	3	3	3	**35**
Kenya	6+9[2]	10	13	18		21	31	30	28	32	30	28	**256**
Malawi							3	3	2	3	1	2	**14**
Morocco							1						**1**
Mozambique							1	1	2	1	1	1	**7**
Niger										1			**1**
Nigera									2	2	1	1	**6**
Rwanda			2	2	1	3	3	4	6	3	2	2	**28**
Sudan									2	3	2	1	**8**
Tanzania	2	2	2	2	4	3	3	2	3	2	3	7	**35**
Uganda	4	3	3	2	5	3	2	2	3	2	3	3	**35**
Zambia				2	2	2	3	2		3	1	2	**17**
Zimbabwe											1		**1**
Yemen			2	2	1	2	1	1	2	2	1	1	**15**
Others					2					1			**3**
Total	**30**	**23**	**30**	**37**	**24**	**45**	**56**	**58**	**61**	**70**	**58**	**62**	**554**

1: Held in Uganda. All other courses held in Kenya (Table 10).; 2: Added number shows lecturers

The last course in the MDG Short Course series was *Short Course X on Surface Exploration for Geothermal Resources*, held in November 2015 (Figure 10).

FIGURE 10: Participants and organizers of Short Course X on Surface Exploration for Geothermal Resources by wellhead units in Olkaria

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 2015, 17 training programs of short, medium and long duration had been conducted in African countries: 11 in Kenya for Kenyans and/or participants from neighbouring countries, 3 in Ethiopia, 2 in Djibouti, and 1 in Rwanda. In addition, a workshop was held in Iceland in 2014 for African countries. These programmes have ranged from a 2-day workshop for decision makers intended to provide 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 International Development Agency (ICEIDA), often in cooperation with the Nordic Development Fund (NDF), has supported several trainings within the framework of the Geothermal Exploration Project, as shown in Table 12.

TABLE 12: Trainings and workshops for African countries supported by ICEIDA as part of the Geothermal Exploration Project

Name	Dates	Host country	Beneficiary countries	No. part.	No. women
Short Course on Deep Geothermal Exploration	25-29 Jun, 2013	Rwanda	Rwanda	20	3 (15%)
Short Course on Geothermal Development for Decision Makers from Burundi, DRC and Rwanda	25-28 Sep, 2013	Kenya	Burundi, DRC, Rwanda	13	1 (8%)
Short Course on Geothermal Development for Decision Makers from Malawi, Tanzania and Zambia	26-30 Nov, 2013	Kenya	Malawi, Tanzania, Zambia	23	2 (9%)
Workshop for Geothermal Development Donors	27-28 May, 2014	Iceland	African countries[1]	48	12 (25%)
Short Course on Well Design and Geothermal Drilling Technology	12-24 Jan, 2015	Ethiopia	Ethiopia	30	1 (3%)
Short Course on Preparations of Bankable Geothermal Documents	26 Jan – 3 Feb, 2015	Ethiopia	Ethiopia	25	6 (24%)
Short Course on Geothermal Project Management	9-20 Feb, 2015	Ethiopia	Ethiopia	25	3 (12%)
Short Course on Geothermal Project Management	18-28 May, 2015	Kenya	Kenya	26	7 (27%)
Short Course on Preparation of Bankable Documents for Geothermal Projects	5-10 Sep, 2015	Djibouti	Djibouti	18	2 (11%)
Short Course on Geothermal Project Management	12-21 Sep, 2015	Djibouti	Djibouti	16	2 (13%)
			Total:	**244[2]**	**39[2] (16%)**

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.

7. THE UN SUSTAINABLE DEVELOPMENT GOALS AND THE NEW UN 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 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.

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. AFRICAN GEOTHERMAL CENTRE OF EXCELLENCE

The establishment of an African geothermal training centre has been discussed for some time and preparations are currently underway to make it a reality. 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, 2016).

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 player in the energy market in East Africa. Kenya 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. From the current availability of geothermal electricity with 677 MWe on-line (Omenda and Mangi, 2016), the long-term plans are now to reach 2000 MWe on-line from geothermal by the year 2018, and 5000 MWe by the year 2030. These may by overly optimistic goals but still show the burning ambition of the Government of Kenya, which is to be admired and supported.

Other countries in the region are slowly following in Kenya's footsteps. Ethiopia, Djibouti, Tanzania, Eritrea, Uganda and Rwanda 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 the energy production. That should be the hallmark of the next decade in East Africa.

The UNU-GTP 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 UNU-GTP training centre in Kenya in cooperation with the Geothermal Developing Company (GDC), Kenya Electricity Generating Co. (KenGen), and the African Union.

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