UNITED NATIONS UNIVERSITY
UNU-GTP
Geothermal Training Programme
Orkustofnun, Grensasvegi 9,
IS-108 Reykjavik, Iceland

40th Anniversary Workshop
April 26 2018

GEOTHERMAL DEVELOPMENT IN KENYA: UPDATE AND THE ROLE OF UNU-GTP IN CAPACITY BUILDING

Peketsa Mangi
Kenya Electricity Generating Company Ltd - KenGen
P. O Box 785-20117
Naivasha
KENYA
pmangi@kengen.co.ke

ABSTRACT

Currently, Kenya has an installed capacity of 690 MWe, with KenGen contributing 533.5 MWe while the rest is by IPPs. Capacity building has been a key contributor to the success of geothermal development in Kenya. The major player in capacity building has been Iceland's United Nations University Geothermal Training Programme (UNU-GTP), which has been building staff competencies in the areas of geothermal expertise though annual shortcourses, 6-month trainings, MSc and PhD since its inception in 1978. To-date 321 Kenyans have undergone the 3-weeks short course since it was initiated in 2005. A total of 124 have undertaken 6-month training in Iceland, and 21 have graduated from the MSc programme, in the specialized areas of Geothermal Geology, Geological Exploration, Borehole Geology, Geophysical Exploration, Borehole Geophysics, Reservoir Engineering, Chemistry of Thermal Fluids, Environmental Science, Drilling Technology, Geothermal Utilization, and Project Management and Finances. For the PhD programme, five Kenyans have been awarded fellowships by UNU-GTP for studies in Environmental Sciences, Geophysics and Geology. The continuous collaborative capacity building between the Icelandic UNU-GTP and Kenyan institutions has contributed to accelerated geothermal development, further aided by deliberate Kenyan Government strategic initiatives and policies implementation. In 2013, the Government of Kenya came up with an initiative dubbed the 40-months challenge through which the Country was to add 5,000 MWe with geothermal contributing 1,646 MWe.

1. INTRODUCTION

The success story of geothermal development in Kenya has been made possible from the support of the Government and financial partners. Also crucial to the success has been capacity building endeavours in the fields of exploration, development, utilization and management for sustainability. The journey of geothermal development in Kenya has not been a smooth one as it has had several instances of pitfalls. However, the resilience shown by the geothermal players to soldier on, creating a better understanding of the geothermal resource through capacity building of staff on geoscientific exploration techniques is what has yielded the positive results.

The major player in capacity building has been UNU-GTP in Iceland that specializes in capacity building for geothermal exploration and development for professionals from developing countries. UNU-GTP has been training Kenya geothermal staff since 1982 through provision of scholarships and institution sponsored programmes. This capacity building effort in key areas of resource exploration and

assessment, drilling, power plant development, operation and management, reservoir monitoring, and geothermal research has thus contributed to the success of geothermal development

The contribution of the Kenya Government has been immense in terms of providing the necessary regulatory and policy framework. Such enablers include Government of Kenya (GOK) support to geothermal power development, which has had a prominent place in Kenya's overarching development plans such as the Vision 2030, past initiative to develop up to 5,000+ MWe by 2016 in which geothermal power was expected to have contributed about 1,646MWe. Under this programme, KenGen was expected to commission 700 MWe of geothermal power by 2018, of which over 360 MWe has already been commissioned, while an additional 300 MWe will be commissioned by 2019. In addition, the KenGen G2G strategy revolves around aspirations of increasing capacity by +2500 MW by 2025, with geothermal contributing about 2000 MWe.

2. UNU-GTP CAPACITY BUILDING OF KENYA GEOTHERMAL PROFESSIONALS

UNU-GTP was established in late 1978. Kenyans have almost from its start benefitted from the various types of trainings facilitated for geothermal development. These include the regular annual Short Courses Series, which have been held for East Africa in Kenya from 2005 (Georgsson and Haraldsson, 2016). The start was through the week-long "Workshop for Decision Makers on Geothermal Projects and their Management", being continued through annual Short Courses 3-3½ week long. The Short Course Series was run under a UN Millennium Development Goals title since 2006, but in 2016, this was replaced by the Sustainable Development Goals (SDGs). To date, 321 Kenyan trainees have benefitted from the 3-weeks short course on exploration and development of geothermal resources (Figure 1). The annual Short Courses, first aimed only at surface exploration, but gradually extended to about 3½ week events that cover most aspects of surface geothermal exploration, drilling and an introduction to development.

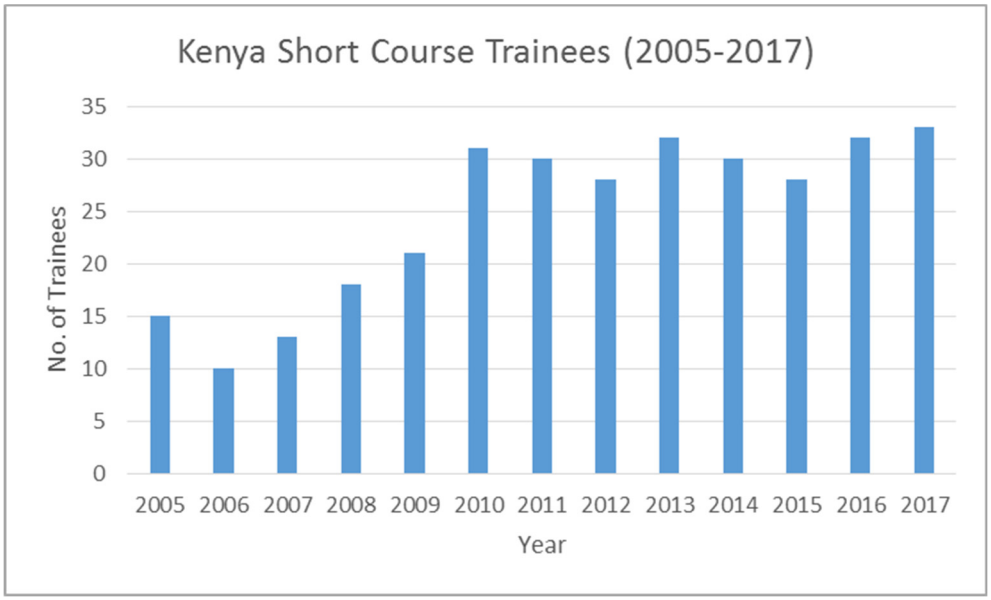

FIGURE 1: Number of Kenyan participants in the annual Kenyan Short Course Series

The Figure 1 shows that the number of the short course participants from Kenya has been on steady rise since its inception in 2005. It also indicates that from 2011, an average of 30 Kenyans per year have attended the course.

Apart from the regular annual 3-weeks short courses, Kenya geothermal staff have underwent the specialized 6-months UNU-GTP training in Iceland. The areas of specialization are namely: Geothermal

Geology, Geological Exploration, Borehole Geology, Geophysical Exploration, Borehole Geophysics, Reservoir Engineering, Chemistry of Thermal Fluids, Environmental Science, Drilling Technology, Geothermal Utilization and Project Management and Finances. Figure 2 shows the number of staff trained as per the area of specializations, while Figure 3 shows training of MSc graduates.

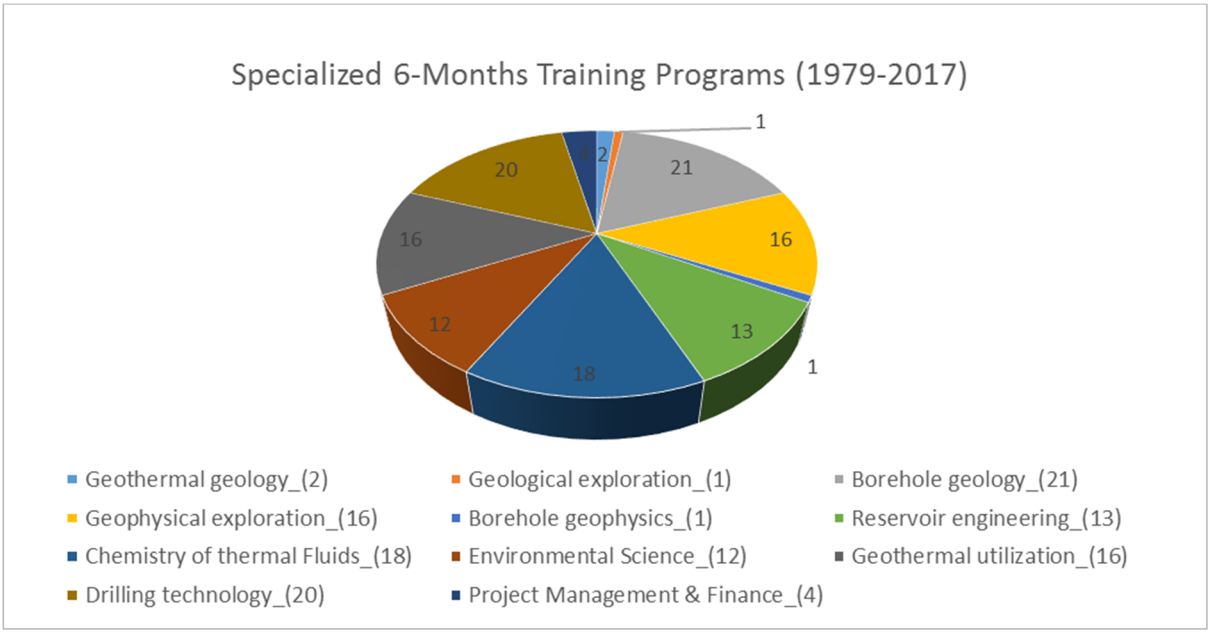

FIGURE 2: Number of Kenyans participating in the different lines of 6-month specialized training

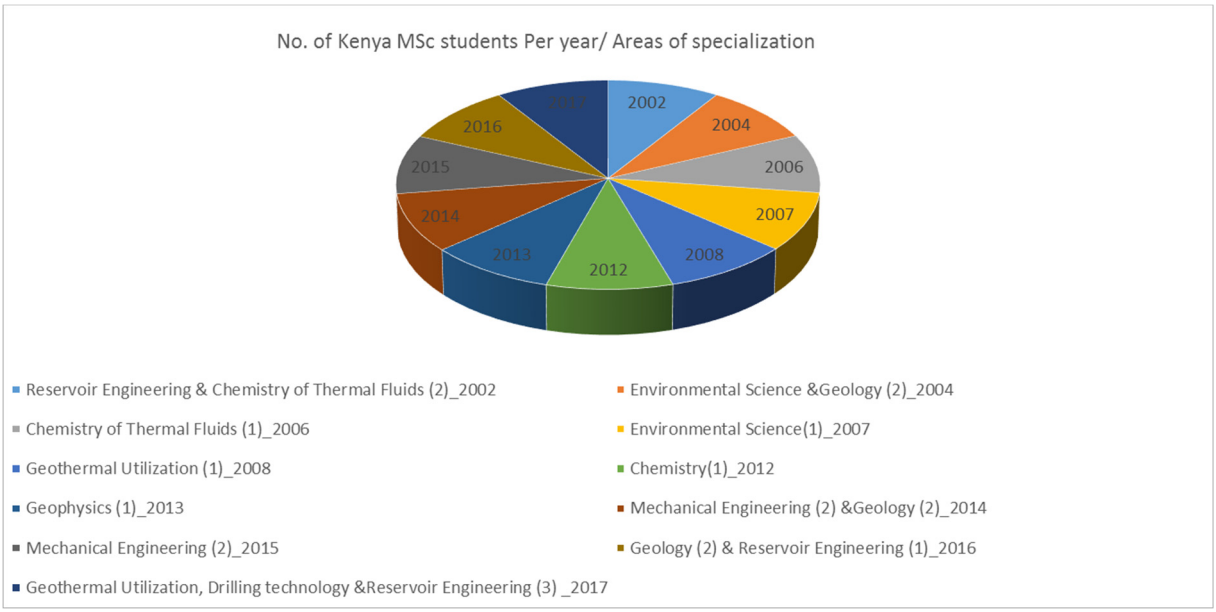

FIGURE 3: MSc graduates from Kenya who have undergone their studies in Iceland in 2000-2017

A total of 124 staff from Kenya have been trained from the year 1979 to 2017 in the 11 specialized areas. The areas of specialization that have over 15 trained personnel are Borehole geology with 21 staff and is followed closely by drilling technology (20), chemistry of thermal fluids (18), geothermal utilization (16) and geophysical exploration (15). It should be noted that of the 21 Borehole geologists trained in Borehole geology, 5 were trained in Kenya while 16 underwent their training in Iceland.

UNU-GTP has also from the year 2002-2017 graduated twentyone (21) Masters of Science UNU fellows from Kenya in the specialized areas of borehole/structural geology, geochemistry of thermal fluids,

geothermal utilization, reservoir engineering, geothermal utilization, drilling technology, environmental management and project management. Figure 3. shows the number of graduates per area per year and specialization. Analysis of the data shows that geology is leading area of specialization with a total of 6 who have graduated from the year 2002-2017. In addition to the number of graduates since 2017, three (30 are currently undergoing MSc training in specialized areas of chemistry, drilling technology and electrical engineering applications for power plant operations.

UNU-GTP has also been generous to Kenya and it is in this context that five PhD fellowships have been awarded to Kenyan since 2009 in the environment, geophysics and geology fields of expertise. To-date two candidates have graduated in the fields of environment while three are ongoing.

UNU-GTP has also offered customer-designed hands-on trainings for KenGen and Geothermal Development Company (GDC) staff. As examples the following can be mentioned: in 2010-2011, about 40 KenGen staff were given a 3-month introduction to geothermal technology; and in 2012-2013, five KenGen borehole geologists received an in-house training on borehole geology, a programme which was equated with the 6-month programme in Iceland. The UNU-GTP 6-month and MSc and PhD Fellowships have mainly been financed by the Icelandic Government, while some have been sponsored through local institutions or companies (Georgsson, 2016).

3. GEOTHERMAL DEVELOPMENT JOURNEY IN KENYA

The GOK current strategy is to generate more power to cater for the country demand growth estimated at 8% per year. According to Vision 2030, more than 8000 MWe will be required by 2030. Most of this power is expected to be generated from renewable sources, with geothermal contributing the largest share. In the light of this ambitious strategy, preliminary and detailed geoscientific studies and assessment of geothermal resource potentials have been undertaken in geothermal prospects within the Kenya Rift that includes Olkaria, Akiira, Eburru-Badlands, Elementaita, Longonot, Menengai, L. Magadi-Shombole, Suswa, Baringo, Arus-Bogoria, Paka, Chepchuk, Silali, Emuruangogolak, Namarunu and Barrier geothermal prospects. In addition, preliminary and detailed geoscientific studies and assessment of geothermal resource potential have been undertaken in other areas such as Homa Hills, Chyulu Hills and Mwananyamala in coastal region of Kenya.

Kenya was the first African country to develop commercial geothermal energy utilization. Exploration for geothermal resources in Kenya began in 1952. Surface exploration (geological and geophysical) was carried out within the Kenyan Rift between 1952 and 1956. It was done by a consortium of companies which included the East African Power & Lighting Company, Ltd. (EAPL), Power Securities Corporations, Ltd., Associated Electrical Industries Export, Ltd., and Babock and Wilcox, Ltd. The study revealed that the central Kenyan Rift Valley, in particular Olkaria area, could contain geothermal energy resources. This findings resulted in the siting and drilling of two geothermal wells (X1 and X2) in 1956. The two wells were drilled to a depth 950 and 1200 m, respectively, and recorded a maximum downhole temperature of 235°C. The drilling operations were contracted to East African Drilling Company, Ltd. Attempts to discharge these wells proved futile and further work was finally stopped in March, 1959. This dented a blow to interest in geothermal development. Additionally, the 1960's intense development of hydropower kept the interest in geothermal resource low.

High cost of hydropower development and its unreliability saw the shifting of power generation focus back to geothermal. In 1967, a Wenner configuration resistivity survey was carried out in the Rift valley from Lake Hannington (currently known as Lake Bogoria) in the North and Olkaria in the South. This work showed a number of resistivity anomalies and favoured exploratory drilling. The search for geothermal resources was further compounded by the 1970's World oil crisis. This crisis greatly affected the world economy at that time when there was overreliance on fossil fuel. Owing to these challenges, a joint Geothermal Project by the United Nations Development Program (UNDP) and the Government of Kenya (GoK), represented by East African Power and Lighting Company Ltd. (EAPL) was initiated

in the early 1970's. This project led to more geoscientific work being carried out between Olkaria and Lake Bogoria, and at Eburru in 1971 and 1972. The work mainly consisted of geological mapping, hydrogeological surveys, gravity studies and infra-red imagery surveys.

By 1972, the resource within Olkaria was the most prospective and hence a decision was taken to concentrate geothermal development at Olkaria area (80 km^2). A technical review meeting at the end of 1972 recommended drilling of four deep (~ 2200 m) exploratory wells in Olkaria area. In 1973, drilling of the four wells commenced with funds from UNDP. By 1976, six wells (well OW-1 to OW-6) had been drilled. These wells were drilled by a rig owned by the East Africa Power Lighting Comp., a company owned by the then East Africa Community's three countries (Kenya, Uganda and Tanzania).

Feasibility study done by SWECO, Stockholm and VIRKIR Consulting Group, Ltd. on reservoir assessment on steam utilization for power generation, effluent disposal by product use and environmental impact of the development provided promising results (Sweco-Virkir, 1976). The study recommended the development of a 2x15 MWe power station. After the completion of the feasibility study, UNDP pulled out of the project. Active drilling for a 30 MWe power plant continued in which Geothermal Energy New Zealand, Ltd. (GENZL) was engaged to supervise all drilling operations. In late 1977, the EAPL evolved to Kenya Power Company (KPC) following the breakup of the East African Community. KPC later assumed all the responsibility to develop geothermal resources in Kenya.

Additional wells were thereafter drilled to provide enough steam for the generation of electricity, and in June 1981 the first 15 MWe generating Olkaria I Unit 1 power plant was commissioned. By the end of 1984, a total of 33 wells had been drilled in the Olkaria East production field, and three 15 MWe units commissioned by early 1985, with the second 15 MWe unit coming on-line in November 1982 and the third unit in March 1985, raising the total to 45 MWe. KPC – later KenGen – was responsible for the development and operation of this first geothermal steam plant in Africa, the Olkaria I power plant with an installed capacity of 45 MWe (3×15 MW). In 1988 exploration drilling was undertaken in Eburru geothermal prospect in which 6 wells were drilled. It was in 1998 that independent power producer (OrPower) was issued with geothermal license to develop Olkaria III, an undertaking which has developed into a 160 MWe power plant based on binary technology. Drilling for Olkaria II was carried out through the 1990s in the Olkaria Northeast production field. The power plant was commissioned in the year 2003, comprising Units I and II, both of 35 MW capacity and a combined output of 70 MW. The third unit was added in 2010, also with an installed capacity of 35 MW taking the total installed capacity to 105 MW (3×35 MW).

Major strides in geothermal development initiatives in Kenya took place from 2009-2010, after GDC as a government Special Purpose Vehicle (SPV) was formed and has been key in the development of Menengai geothermal field as well as in exploration of other geothermal prospects such as Suswa, Baringo, Arus Bogoria, Paka-Silali, Emuruangogolak and Namarunu. During this period, Geothermal Resources Licences were issued to the following Companies; WalAM Geopower, Inc. (IPP) for exploration and development of Suswa geothermal field. In July 2009, the Kenya Ministry of Energy awarded Africa Geothermal International, Ltd., (AGIL) an independent power producer (IPP) geothermal resource licence for the Longonot geothermal prospect. Other IPPs that have been granted geothermal license for exploration and development are Marine Power Generation in Akiira geothermal field and OlSuswa Energy for exploration and development of Barrier geothermal field. During the period of 2011-2017, AGIL completed geoscientific studies of Longonot geothermal prospect with the siting of 7 exploration wells with plans for drilling underway. In 2015, Marine Power Generation through Akiira One Geothermal, Ltd., drilled 2 exploration wells in Akiira field using the KenGen rig and KenGen expertise. OlSuswa Energy, Ltd. is scheduled to undertake geoscientific studies of Barrier geothermal field using the expertise of KenGen geoscientific team having awarded KenGen the contract.

Through Joint Geophysical Imaging (JGI) techniques, Olkaria Domes potential was established from the drilling of 3 exploration wells in 1999. Drilling at Olkaria by KenGen and the Great Wall Development Company (GWDC), funded by Chinese government, resulted in actualization of the 300

MWe development at Olkaria in 2014. Then, KenGen commissioned two (2) power plants (Olkaria IV, and Olkaria IAU (Units 3&4)) with an installed capacity of 150 MWe each, which was one of largest single geothermal power plant developments implemented in the world over a period of 36 months. Also, in order to quickly recoup revenue from high costs of geothermal development, KenGen invested in Well Head Technology where a so-called wellhead unit is installed on an individual well. The wellhead technology has injected additional 81.1 MWe from Olkaria geothermal field from the 15

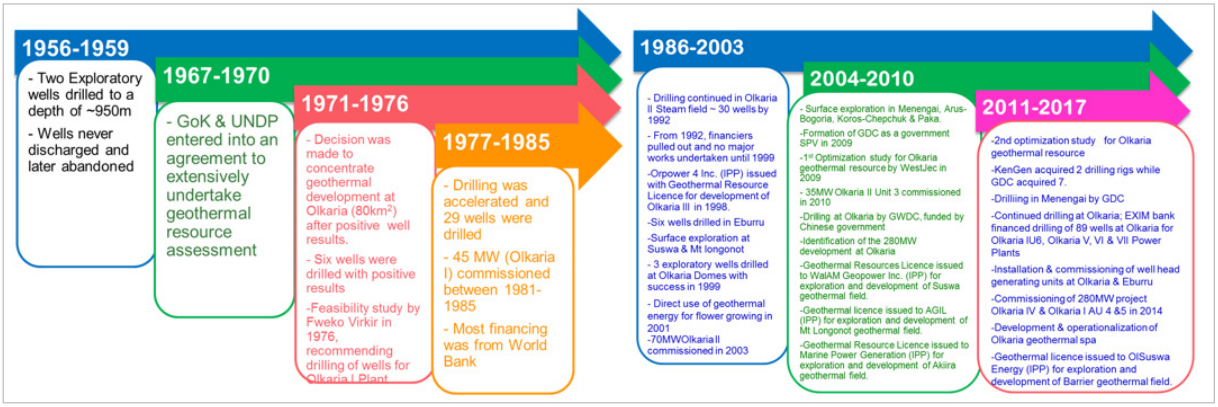

FIGURE 4: Summary of geothermal development history for Kenya (KenGen, 2017)

wellhead units which had been commissioned in 2017.

Since its formation GDC has been carrying out drilling in Menengai geothermal field and over 40 wells have been drilled, with proven steam potential of 105 MWe. Three IPPs, namely Sosian Energy, Ormat Technology and Mauritius based Quantum Power will each develop 35 MWe.

Besides use of geothermal in electricity generation, geothermal direct uses have also been developed. An example can be taken from the Oserian Development Company, which grows cut flowers for export and is utilizing steam in the green houses: to heat fresh water through heat exchangers, enrich CO_2 levels and to fumigate the soils utilizing H_2S. The heated fresh water is then circulated through greenhouses (Simiyu, 2010).

KenGen in April 2011 – July 2013 constructed geothermal spa, which has become a tourist attraction in the region. In Menengai geothermal field, four demonstration units have been set up, including geothermally powered dairy unit, geothermally heated aquaculture ponds, geothermally heated green house and geothermally powered laundry unit. In Eburru geothermal field geothermal direct uses include drying of pyrethrum as well as production of drinking water from fumarole condensation.

Summary of major developments and initiatives in the development of geothermal resources in Kenya is highlighted in Figure 4.

3. UNU-GTP CONTRIBUTION IN GEOTHERMAL DEVELOPMENT

The GOK current strategy is to generate more power to cater for the country demand of which 80% is expected to be from geothermal resources. To speed up this, the GOK has provided targets of realization of geothermal power from energy institution lead by KenGen and GDC. In the light of this ambitious strategy, the KenGen has in the past carried out preliminary and detailed geoscientific studies and assessed the geothermal resource potential of Olkaria, Eburru, Menengai, Suswa, Baringo, Arus Bogoria, Paka-Silali, Emuruangogolak, Namarunu with siting of exploration target wells.

From 2010, UNU-GTP has also been able to offer customer-designed training and courses in line with the needs of clients from developing countries which have been supported by local or external financial mechanisms. This has become an increasing part of their operations, and several countries of Africa

have benefitted from this. An important part has been the ”Geothermal Exploration Project in E-Africa”, aimed at 13 countries and mainly financed through ICEIDA of Iceland and the Nordic Development Fund (NDF). Under this programme, UNU-GTP has had the task of geothermal capacity building and strengthening of institutional build-up with regards to geothermal expertise. Examples of activities include Workshops for Decision-Makers for various countries of E-Africa and a Workshop for Geothermal Development Donors held in Iceland. Furthermore, new course material has been developed, such as in project management, and for preparations of bankable documents for geothermal projects.

UNU-GTP has also offered advisory services in support of establishment of Africa Geothermal Centre of Excellence (AGCE) in Kenya with assistance of UNEP - Africa Rift Geothermal (ARGEO) in collaboration with regional and international stakeholders.

3.1 UNU-GTP contributions: case study of KenGen

Over the years, KenGen through UNU-GTP has developed a wealth of expertise in geothermal resource exploration and development through hands-on experience, training and career development of its staff and have in return promoted research, technology and innovation in geothermal energy. This has allowed the company to keep in tandem with latest technological developments in geothermal industry. KenGen is also a corporate member of the African Rift Geothermal Project (ARGeo) and a member of International Geothermal Association (IGA), Geothermal Resource Council (GRC), Geothermal Association of Kenya (GAK) and Geological Society of Kenya (GSK). KenGen is also a key sponsor of the UNU-GTP Short Course series that has been held annually in Kenya, since its inception in 2006.

Through UNU-GTP training programmes, KenGen has well established expertise in; Geology, Geochemistry, Geophysics, Geomatics/GIS, Civil and Infrastructure Engineering, Environmental Management and Stakeholder Engagement, Drilling operations and Services, Reservoir and Steamfield Management as well as Power Plants Installation and Operation. Geology team has grown to become well experienced and skilled in geothermal surface exploration, well siting and well design, borehole geology, geothermal mineralogical studies including petrography, fluid inclusion and XRD analysis.

Geochemistry team has expertise in geochemical exploration in geothermal prospects, fluid chemistry, chemical analysis of alteration hydrothermal deposits and environmental chemistry monitoring. The team is also mandated in power plant chemistry monitoring. Geophysics team has expertise in geothermal exploration surveys using MT, TEM, seismic, gravity, and magnetic techniques. Geophysics team is also active in monitoring of geothermal exploitation using gravity and seismic techniques to establish if there is subsidence associated with abstraction or micro-earthquakes related to reinjection.

The KenGen Reservoir and steamfield staff have been trained by UNU-GTP in Iceland, including the latest Petrel training that has enabled our staff to carry out 3D-conceptual modelling. This has made them effective in reservoir management. The reservoir team can effectively carry out scientific assessment such as heat loss surveys and geothermal reservoir size estimation, numerical and conceptual modelling and simulation. Also key responsibility of the Section is well measurements and tests necessary for evaluating geothermal reservoir characteristics of a field and also management of the steamfield infrastructure.

The Company has the required tools and equipment for the tasks which include temperature and pressure tools, calibration machines for the instruments, truck mounted logging units, winches, truck mounted crane, recovery tubes, test separators, and pressure monitoring tools. The Section also carries out deviation surveys and Static Formation Temperature Tests (SFTT) and completion tests after drilling. It has expertise in interference tests, discharge tests, and design of re-injection schemes. The Section besides managing the reservoir and steamfield of Olkaria and Eburru wells, it has also offered consultancy services to external customers such as Akiira Geothermal Company in carrying out well completion tests and tests of its drilled wells.

4. CONCLUSIONS

Kenya currently has an installed geothermal capacity of over 690 MWe. Acceleration of geothermal development in Kenya has largely been achieved through investing in human capital through capacity building of geothermal staff. The contribution of UNU-GTP of Iceland towards these achievement cannot be overemphasized. Enabling environment through support Government of Kenya in terms of policy formulation and enactment that triggers geothermal development and financial support from development partners have been key ingredients to success story of geothermal development in Kenya.

ACKNOWLEDGEMENTS

Special thanks go to the Ms Málfrídur Ómarsdóttir UNU-GTP for providing the training data that has been used in this paper.

REFERENCES

Georgsson, L.S., 2016: Taking African geothermal knowledge to a higher level – training activities of UNU-GTP for Africa. *Proceedings of the 6th African Rift Geothermal Conference*, Addis Ababa, Ethiopia, 10 pp.

KenGen, 2017: *BoC presentations*. KenGen, internal report (unpublished).

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.

Sweco-Virkir., 1976: *Feasibility report for the Olkaria geothermal project*. United Nations – Government of Kenya, report.