



**UNITED NATIONS
UNIVERSITY**

GEOHERMAL TRAINING PROGRAMME
Orkustofnun, Grensásvegur 9,
IS-108 Reykjavík, Iceland

30th Anniversary Workshop
August 26-27, 2008

CONTRIBUTION OF UNU-GTP TRAINING TO GEOHERMAL DEVELOPMENT IN AFRICA: UPDATE 2008

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ABSTRACT

One hundred and seven geothermal professionals from eleven African countries have been trained by the UNU-GTP for the six months in Iceland between 1979 and 2008. In addition, ten UNU-GTP Fellows have enrolled for MSc degrees and eight have already graduated. Combining the two courses about 28% of all the beneficiaries are from Africa. Kenya has benefited the most with 49 people, followed by Ethiopia with 27. About 23% of the trainees from Africa have left the industry. Kenya has retained the highest number of its professionals and has equally achieved the most in geothermal power generation. Over the 30-year period, Africa has benefited tremendously from the training. What is critically required now is to accelerate geothermal development in the continent by removing financial and political barriers so that the trained professionals can fully be utilised to achieve the intended growth. The Iceland training will still be required for some years to come, particularly in providing some assistance in formulation of a mechanism for involving the already trained professionals in training more Africans.

1. INTRODUCTION

By 2000, geothermal resources had been identified in more than 80 countries and utilisation of the resource had been recorded in 58 countries in the world. The total installed geothermal electric power by 2005 was about 8,912 MW world-wide (Bertani, 2005) and 73 TWh/a of heat energy was being used for direct heating (Lund et al., 2005). Electricity is currently generated using geothermal steam in 24 countries spread over all continents. Among the African countries, Kenya has been generating electricity since 1981 and Ethiopia started in 1998. Exploration for high-temperature resources (for electricity production) has also been conducted in Cape Verde, Djibouti, Eritrea, Tanzania, Uganda and Zambia. Rwanda, Burundi and Comoros are planning to carry out exploration in the near future. Many African countries have made some direct uses of their geothermal resources. These countries are Algeria, Egypt, Ethiopia, Kenya, Tunisia, and Zambia. Hot springs have also been identified in Burundi, Cape Verde, Madagascar, Malawi, Mozambique, Rwanda, Uganda and Zimbabwe.

In order to realise the above developments, Africa required trained manpower. The main institutions that have taken a leading role in geothermal technology training are the UNU-GTP in Iceland, the Geothermal Institute at the University of Auckland in New Zealand, the International Institute for Geothermal Research in Pisa, Italy, and Japan. By 1992, the school at Pisa had trained a total of 324 students from 68 countries in various courses. Of this total, there were 43 Africans, 119 Latin Americans, 113 Asians, and 49 Europeans (Dickson and Fanelli, 1995). On the other hand, the Geothermal Institute at Auckland University had trained 88 Africans (14%) out of a total of 638 by the

year 2002. Similarly, 64 Africans (16%) out of a total of 393 had been trained in Japan by the year 2001. The schools in Japan and Italy have closed down. The Geothermal Institute in Auckland closed down for a while and then reopened in 2006. Only the UNU-GTP has continued without interruption since it opened in 1979.

During the 30-year period 1979-2008, 402 scientists and engineers from 41 countries have completed the six-month programme in Iceland (Fridleifsson, pers. comm.). Of these, 44% are from Asia, 26% from Africa, 15% from Central and Eastern Europe and 15% from Latin America. Between 2000 and 2007, a total of 21 MSc students have been enrolled 47.5% were from Asia, 47.5% from Africa and 5% from Latin America.

2. GEOTHERMAL USES IN AFRICA

Kenya and Ethiopia are the only two countries in Africa producing electricity from geothermal steam. Kenya commissioned its first geothermal power plant at Olkaria East in 1981. The 45 MWe plant has been producing electricity in the country with an availability factor of over 95%. An independent power producer (IPP) commissioned an additional 12 MWe as a pilot plant for Olkaria III. Olkaria II (70 MWe) was commissioned between October and November 2003, and the extension of Olkaria III up to 48 MWe is expected to be commissioned in September 2008. Oserian Development Company installed a 2 MW binary plant in 2004 and 1.8 MW backpressure plant in 2008. Together these plants produce about 3 MW effective power due to lack of steam. A new geothermal strategy for Kenya requires that about 1260 MW be commissioned in the next 10 years (by 2018).

Ethiopia commissioned its first 8.5 MWe geothermal plant in 1998 at Aluto in the Lakes District (Teklemariam et al., 2000). Unfortunately, the plant has had technical problems. The plant was rehabilitated in 2007 but all the problems have not been completely resolved. Despite this, there are plans to increase the generation capacity to 30 MWe in the near future. In the long-term, Ethiopia plans to increase the geothermal capacity to 700 MWe as financing becomes available. Deep drilling in the Tendaho graben has shown temperatures of up to 260°C, and four (out of six) wells are productive. Production testing and a feasibility study are under way in Tendaho, aiming at the installation of a 5 MWe pilot plant. The present installed electric capacity in Ethiopia is about 714 MWe, mostly hydropower, and about 2260 MW more hydro is planned in the near future.

Several other African countries, particularly in the East African Rift Valley region, have significant potential for geothermal electric generation. Some exploration has been conducted for high-temperature resources in Burundi, Cape Verde, Djibouti, Eritrea, Tanzania, and Uganda. Deep drilling has only been conducted in Djibouti, where temperatures as high as 350°C have been measured in wells in the Lake Assal area. Reykjavik Energy Invest (REI) has entered into an agreement with the Djibouti government to develop this field.

Tunisia, which is one of the world leaders in the use of geothermal energy for greenhouse heating and irrigation, is currently leading in direct use in Africa with about 145 ha. of greenhouses being heated with geothermal. This development has mainly taken place in oases (Kebili, Tozeur and Gabes) in the Sahara desert (Said, 1997; Ben Mohamed, 2003). Deep drilling (2-3 km) for irrigation water in the desert oases in Tunisia has produced a large quantity of water that is far too hot to be used for irrigating the crops directly. In the Kebili area, 35 boreholes are being operated to irrigate 16,000 ha. of oases (Ben Mohamed, 2003). The hot water for irrigation of oases is initially cooled to below 45°C in multiple ponds, or by passing it through cascades in cooling towers before it is used. For greenhouses, the hot water is initially circulated through the greenhouses to keep the temperatures high during the cold nights in the desert. This circulation cools the water before it is used for irrigation. The geothermal heat can therefore be looked at as a by-product of the irrigation water. The main products in the greenhouses are tomatoes and melons for export to Europe. For centuries, Tunisia has been using hot springs for bathing and treatment of skin diseases. These bathing springs

are known as Hammams. Other uses have been for the treatment of soils in greenhouses, heating swimming pools in tourist areas and also watering cattle.

In Kenya, Oserian Development Company is using steam from a 1.28 MW well to heat fresh water through heat exchangers. The heated fresh water heats about 50 ha. of greenhouses at night where roses are grown. CO₂ from the well and some additional brought from Olkaria III is added into the greenhouses to assist in photosynthesis.

In addition to Tunisia and Kenya, many African countries make some direct use of their geothermal resources, e.g. Algeria, Egypt, Ethiopia, and Zambia. Hot springs have also been identified in Burundi, Cape Verde, Madagascar, Malawi, Morocco, Mozambique, Rwanda, Uganda, and Zimbabwe. The main recorded direct use of geothermal water is for bathing and swimming (e.g. Algeria, Ethiopia, Egypt and Tunisia) and for greenhouses (e.g. Algeria, Tunisia, Kenya). Kenya has for decades used geothermal heat to dry pyrethrum flowers and condense steam for drinking at Eburru. There are numerous opportunities for the use of geothermal resources in many countries of Africa. The key issues at hand both for the exploration and the development of the geothermal resources, are financing and technology transfer.

Financial constraint has been recognised as the biggest barrier to realising geothermal development from exploration drilling to power station construction. In a conference held in Nairobi in 2003, it was agreed that GEF co-ordinate the establishment of a risk fund that could be used to accelerate geothermal development in the countries within the East African Rift system. The initiative was called ARGeo and established a target of 1000 MW in the next 20 years. The progress of ARGeo has been very slow and no project has been financed to date.

Training will always be important to development. The UNU-GTP Fellows form a pool of people who can be used to train others. In the conference held in Nairobi in 2003, it was felt that it is an opportune time for experienced people in Africa to collaborate in both research and training through the establishment of a geothermal resource centre. The resource centre could be established in collaboration with other geothermal schools in Iceland, Japan and New Zealand. GEF and other donors would also co-fund the establishment of the centre. There is merit to continue pursuing this initiative. Following this, an annual short course was established in Kenya by UNU-GTP in collaboration with Kenya. The recent unprecedented oil price high and the growing concern for environment certainly gives geothermal the biggest opportunity for development.

3. GEOTHERMAL TRAINING IN ICELAND

The United Nations University Geothermal Training Programme (UNU-GTP) has operated in Iceland since 1979 with six months of courses for professionals from developing countries. Specialized training is offered in geological exploration, borehole geology, geophysical exploration, borehole geophysics, reservoir engineering, geochemistry, environmental studies, geothermal utilization and drilling technology. In 2000, MSc degree courses were introduced.

To date a total of 423 UNU Fellows have been trained (402 for the six months courses and 21 through MSc studies). Among the 402 UNU Fellows who attended the six months courses, one hundred and seven (107) Fellows are from eleven African countries (Table 1 and Appendix I). The means for the MSc scholarships (Table 2 and Appendix II) have been provided by the UNU-GTP through the Government of Iceland. Ten (10) MSc Fellows are from Africa (seven from Kenya and one each from Uganda, Ethiopia and Djibouti). Kenya is the leading country in geothermal research and development in Africa, and most of the geothermal specialists have been trained in Iceland. With the advanced training of the MSc students, the UNU-GTP is assisting Kenya to take its geothermal development to a much higher level.

The training activities of the UNU-GTP have expanded considerably in the last several years as in addition to training of about 30 UNU Fellows and UNU MSc students in Iceland per year, the UNU-GTP has organised annual short courses in Africa since 2005 and Central America since 2006 and is planning to start similar series in 2008 for Asian countries.

TABLE 1: Fellows of UNU-GTP from Africa 1979-2008

Country	No. trained	Retired or not in geothermal	Available
Algeria	3	3	0
Burundi	1	1	0
Djibouti	3	1	2
Egypt	4	0	4
Eritrea*	6	2	4
Ethiopia	26	11	15
Kenya	42	7	35
Tanzania	4	1	3
Tunisia	6	0	6
Uganda	11	2	9
Rwanda	1	0	1
Total	107	29	78

* Presently one person of the two is working in hydrocarbons exploration but could be available when geothermal work starts in the country.

TABLE 2: MSc Fellows from year 2000 to July 2008

Country	No. enrolled	No. graduated
Kenya	7	7
Uganda	1	1
Ethiopia	1	0
Djibouti	1	1
Jordan	1	1
China	1	1
El Salvador	1	0
Indonesia	2	0
Iran	3	2
Mongolia	2	1
Philippines	1	1
Total	21	15

4. ACTIVITIES OF FORMER UNU-GTP FELLOWS

4.1 Kenya

Forty two (42) Kenyans have been trained for six months and seven (7) have completed a MSc degree in Iceland. They come from KenGen, Ministry of Energy and the local universities but the large majority is from KenGen. Seven (7) have either retired, retrenched or are working outside the country (Appendix 1).

KenGen has been at the forefront of geothermal exploration and development in Kenya, and this is reflected by the high number of staff trained at the UNU-GTP since the Olkaria I power plant was commissioned in 1981. The first group of UNU Fellows were trained in 1982. These are Joseph Ng'ang'a in drilling, Martin Mwangi in geophysics, and Zack Muna in geochemistry. Mr. Ng'ang'a

became the Chief Drilling Engineer, Geothermal Development Manager, and is now the Deputy Managing Director in charge of Business Development. He coordinates the geothermal activities through business development. Mr. Mwangi climbed the ladder to become Chief Manager in charge of geothermal development and will be retiring in September. Silas Simiyu is currently the Geothermal Execution Manager taking over from Mr. Mwangi. Mr. Muna retired from KenGen in 2007 as Chief Geothermal Scientist in charge of all scientific work and his position has been taken by Geoffrey Muchemi as Assistant Manager.

Since then, a total of 4 geologists, 5 geochemists, 3 geophysicists, 5 reservoir engineers, 4 drilling engineers, and 4 environmental scientists have been trained from KenGen. Out of these people, 1 reservoir engineer left the company and is at Berkeley University in the USA, 1 geochemist is teaching at Moi University, and 1 geologist is teaching at Egerton University. The rest are all still working for KenGen.

When the first three people were trained in Iceland, most of the geothermal work was being done by external consultants. The drilling rate using consultants was very low and it took 6-10 months to drill a single 2000 m well. By 1990, full-time consultants and experts were phased out, and the geothermal work is now managed and performed entirely by KenGen staff. The key people in this management were trained in Iceland. The fact that one of these people is now a deputy managing director, and is in charge of business development has assisted the development of geothermal resources in Kenya. KenGen staff members have been involved in exploration work at Olkaria, Eburru, Suswa and Longonot, Menengai, Baringo, Korosi and Paka fields. They have also drilled wells in Olkaria I, II, III and Olkaria Domes and undertaken various work-over jobs. They have also been involved in Olkaria I and Olkaria II power station construction and operations.

The training received from Iceland, in various disciplines, has been very useful in the management of Olkaria I and II power stations and reservoirs in order to guarantee adequate and quality steam to the two stations. The environmental staff members of the project, who have been trained in Iceland, have been KenGen's forerunners in raising awareness in environmental matters not only within KenGen, but also in the country as a whole. They have also been instrumental in the development of KenGen's corporate environmental management policy statement and ISO 14000 certification.

KenGen staff members have also provided consultancy services within Kenya and in Zambia and Djibouti the latter being in collaboration with ISOR. They have also put proposals for work in Rwanda and the Comoros. With this experience, KenGen is co-hosting with UNU-GTP the short course for African region since 2005 where most of the lecturers are former UNU Fellows. They are also active in the ARGeo conference that is rotating around the capitals of the ARGeo countries. The last one was held in Addis Abba in 2006 and the next one will be held in Entebbe Uganda in 2008. KenGen has recently completed a power development strategy in which geothermal will be the main focus for new power increase in the country. In this geothermal strategy, about 1250 MW of geothermal are expected to be commissioned in the next 10 years and a special purpose company (GDC) for steam field development is in the formation.

The Ministry of Energy has sent four scientists for training in Iceland. Two of these retrenched in 2001. Two geophysicists are still with the Ministry of Energy. The personnel working with the Ministry provided counter-part personnel to Geothermica Italiana which was contracted by UNDP to carry out exploratory work in the Longonot, Suswa and Menengai prospects between 1988 and 1992. They were also involved in geological and geochemical exploration carried out by the British Geological Survey which covered a large area of the Rift Valley from Longonot to Lake Turkana. The British Geological Survey undertook this work in three phases from 1985 to 1992; the project was funded by the British government (Clarke et al., 1990; Dunkley et al., 1993). The Ministry staff have been involved in geothermal work jointly with KenGen at the exploration of Baringo, Korosi, and Paka. They have also been involved in coal investigation in the coastal region of Kenya.

Professors Tole and Singh came from the Faculty of Science, University of Nairobi with the aim of establishing training in geothermal technology at the local university. Professor Singh has not been active in geothermal, and is no longer teaching since December 2002. However, Professor Tole has been very active. In 1989, he became Associate Professor and moved to Moi University. Between 1990 and 1995, he was Dean of post-graduate studies, and from 1995-1996, the Dean of the School of Environmental Studies. He has co-authored about sixteen referred papers and has supervised seven post-graduate students in the field of geothermal resources. He is currently Professor of environmental geochemistry at Kenyatta University. Evan Nyaga came from Kenyatta University and is currently doing PhD in environmental studies. Two young women a geophysicist and a geochemist students (Anastasia Wanjohi and Marrieta Mutonga) from the university of Nairobi attended training in 2007.

The short courses held in Kenya for the African region since 2005 have been co-hosted by the UNU-GTP and KenGen. The lecturers have been from UNU-GTP and ISOR and former UNU Fellows from Africa and Philippines. Part of the aim of this course is to increase the cooperation between specialists in region as a means of accelerating geothermal development.

4.2 Uganda

Eleven people have undertaken the six months course and one has completed a MSc degree. These are 5 geologists, 3 geochemists, 1 reservoir engineer, 1 environmentalist and 1 geophysicist. Godfrey Bahati attained his MSc in environmental sciences and is currently the principal geochemist, based at the Department of Geological Survey and Mines in the Ministry of Energy and Mineral Development, which undertakes geothermal exploration. He is also the coordinator of the geothermal programme. Vincent Kato a senior geologist and Dan Mainza a chemist are two geochemists active on the geothermal project. James Francis Natukunda, a senior geologist, Edward Isabirye and Peter Mawejje, geologists, are project geologists under the geothermal programme in the same department. Amos Bazaale-Dolo and David Kyagulanyi are also geologists but are no longer active in geothermal work but are still in the country. Fred Alex Tugume trained as a geophysicist. He works in the Department and the geothermal project as a senior geophysicist and a project manager for Uganda National Seismology Network. He is also the manager for the Global Seismic Station established jointly by the University of California at San Diego and the Government of Uganda as an auxiliary station for the Nuclear Test Ban Treaty Organisation (CTBO). Joseph Okedi trained as a reservoir engineer at the UNU-GTP. He works as a Mining Engineer in the department and a reservoir engineer on the geothermal programme. Lastly, Catherine Nyakecho is a UNU Fellow in 2008 specialising in environmental science.

Active participation of former UNU Fellows in Uganda has been funded by several players with geological, geochemical and geophysical exploratory work done in Katwe, Buranga and Kibiro since the end of the UNDP funded geothermal exploration programme in 1994 (Bahati, 2008). Among the major activities carried out by the Government of Uganda are: the hydrological studies using isotopes in the three prospects with support from the International Atomic Energy Agency (IAEA) (Bahati et al., 2005); geophysical survey of the Katwe prospect with support from the African Development Bank (AfDB) (UAERAUS, 2004) and the Icelandic International Development Agency (ICEIDA) (Gislason et al., 2008); detailed surface analysis of the Buranga geothermal prospect, west Uganda (BGR-MEMD, 2007); and geophysical survey and temperature gradient drilling/measurement of the Katwe and Kibiro prospects with support from ICEIDA and World Bank (Gislason et al., 2008). These activities involved to a large extent the staff of the Ministry of Energy and Mineral Development. The ICEIDA and the World Bank will further evaluate the findings of surface exploration in all the three prospects, and propose a strategy for exploratory drilling at selected targets by the end of 2008 (Bahati, 2008). Mr. Bahati and his team in Uganda are organising the ARGeo conference in Entebbe to held in November 2008.

4.3 Ethiopia

Twenty six people have been trained from Ethiopia since 1983 when the first two people attended the UNU-GTP. Only fifteen of them are currently actively involved in geothermal and many are living in other countries. Four of the active people work for EEPCo and the rest for the Geological Survey of Ethiopia (GSE) and have the responsibility for exploration and drilling. Berhanu Gizaw and Kibret Beyene are senior geochemists; Meseret Teklemarian has a PhD in geochemistry and is currently the head of geothermal within the GSE. Yiheyis Amdeberhan is a senior reservoir engineer and geophysicist and Yiheyis Kebede is also a senior geophysicist.

Over the years, the UNU Fellows in Ethiopia have been involved in the Aluto-Langano field, and later Tendaho where wells have been drilled and a pilot station constructed in the former location. Two rigs owned and manned by GSE were used. In Tendaho, they worked with an Italian company. The staff is still monitoring the two reservoirs. Other exploration areas that they have been involved in are Tulu-Moye, which they explored in 1998, Corbetti and Lake Abaya, Dofan, and Fantale. In 1993, the staff were involved in isotope studies organised through a technical cooperation programme by the Ethiopian Science and Technology Commission and International Atomic Energy Agency (IAEA).

The low performance of the Aluto-Langano plant has to some extent affected the impetus of geothermal development in Ethiopia, even though GSE continues to carry out some exploration work. This, coupled with the earlier war with Eritrea and over-emphasise on hydropower may have caused many trained personnel to look for better employment outside the country. However, Ethiopia is realising that even though it has huge potential of hydropower, it is necessary to develop the geothermal resources in order to protect itself from lack of power during the dry periods. The former UNU fellows were involved in organising the successful ARGeo conference in Addis Abba in 2006.

4.4 Eritrea

Six Eritrians have been trained in Iceland. Mohammed Berhan Abdulkadir is a geophysicist and attended the UNU-GTP in 1984, as an employee of the Geological Survey of Ethiopia. Since then, he was involved in geophysical surveys at Aluto-Langano, Corbetti, Tendaho, Fentale, Tulu, Moye, Gedemsa and Dofan prospects in Ethiopia before Eritrea became independent. In the first three prospects, he was team leader of geophysical crews and in the last four years, he was the counter-part geophysicist with the Italian company Electroconsult (ELC). He later became Senior Geophysicist. After 1993, when Eritrea became independent, he joined the Department of Energy dealing in hydrocarbons and geothermal in Eritrea. He worked on geothermal until 1997 when the geothermal section was moved to the Department of Mines. He was left to work on hydrocarbons specialising in seismic data for which he has obtained an MSc degree. He is currently in USA doing a PhD degree but will be available for geothermal when activities start. Ermias Yohannes was trained in 2004 as a geochemist and is currently the head of geothermal section of the Ministry of Energy and Minerals. Kiflom Gebrehiwot and Andemariam Teklesenbet are also actively involved in the geothermal work, the latter having been in the Djibouti MT survey conducted in collaboration with ISOR. On the other side, Mohammed Omer Ibrahim is currently not working in geothermal. Eritrea have applied for funds from World Bank and ARGeo to carry out further geochemical work and a MT survey at the Alid prospect.

4.5 Djibouti

Djibouti has had two UNU Fellows already trained with a third being trained in 2008. A.E. Khairah was the first to be trained on borehole geology in 1989. He then worked for CERD which is involved in geothermal exploration until he retired in 2005. Daher Elmi Houssein was trained as a reservoir engineer in 2005 and later returned to Iceland for an MSc degree which he completed in May 2008. He has returned to work for CERD in the geothermal development, but will also pursue a PhD degree in Iceland during the next years.

4.6 Egypt

Four people have been trained in Iceland between 1990 and 2005. Three (one geologists, one reservoir engineer and one geochemist) are working for Egyptian groundwater company called REGWA and one is a geophysicist at the University of Benha. Mr. Magdy Mahgoub, was the first and was trained in borehole geology in 1990. Nowadays, he is working as a senior geologist for REGWA in the exploration department. Magda Idris is a geochemist and Sadek El-Sharkawy a reservoir engineer and are both working for REGWA. Sadek El-Sharkawy is now a manager in the geological exploration.

In 2005, Dr. Aref Lashin was trained in borehole geophysics and is currently an associate professor in the geophysics department, faculty of science at the Benha University. He was trained to be able to offer geothermal training and carry out research. Dr. Lashin has conducted some geothermal research at the coastal parts of Gulf of Suez (Lashin, 2007). He is currently working with scientists from Ain Shams University in a small joint project aiming at re-evaluating and assessing the geothermal resources in the Western Desert of Egypt (personal communication). The Egyptian geothermal resources have not be developed because of the fact that they are low-temperature resources and the availability of other energy sources readily available and competing fossil oil and coal.

4.7 Tunisia

Six Tunisians have so far been trained in Iceland in the years 1997 and 2000. Mr. Mouldi Ben Mohamed and Mondher Said have been working in the Ministry of Agriculture, Environment and Water Resources, and have been instrumental in the development of greenhouse heating using hot water in Kebili. Mr. Ben Mohamed was initially working for the Commission of Agricultural Development (CRDA) at Kebili, assisting farmers in the use of geothermal energy in greenhouse heating, and in the utilisation of geothermal in bathing and swimming pools. He is now the Deputy Director of agricultural studies and development at CRDA Manouba in the district of Tunis and is very actively involved in geothermal water use in the green houses in the whole of Tunisia which has now increased to 145 ha.

Mr. Mohamed A. Gandouzi is still the head of the Soil Division of CRDA, Kebili and is also working in the development of greenhouse heating. Mr. Mongi Elguedri is still an engineer in rural equipment in CRDA, Kebili after one year training in Japan. Mr. Aissa Agoun moved to be the head of the Water Resources Department in CRDA at Kebili. Finally, Dr. Lasaad Sbita is still teaching at the National School of Engineering in Gabes (ENIG) in the use of computers in automation.

4.8 Algeria

Four Algerians were trained at UNU-GTP between 1989 and 1994. Mr. Mahmoud Hellel, who did not complete his training due to sickness, is the only one of these who has been working in geothermal in recent years, mainly at a project on heating greenhouses in the southern part of Algeria. Unfortunately, he has now resigned due to sickness. Mr. Mohamed Abouriche passed away few years ago, while Mr. Talal Karouaz went for a diploma course at the Geothermal Institute of the University of Auckland soon after being trained at the UNU-GTP in Iceland, but did not return to Algeria. Ms. Malika Rachedi teaches at the University. However, she is not actively involved in the geothermal industry, but still keeps some interest in it.

4.9 Tanzania, Burundi and Rwanda

Tanzania has had four people trained in Iceland. George Kifua was the first one, trained in 1986 as a geophysicist. He participated in the reconnaissance surveys under the Ministry of Water, Energy and Minerals. He is now retired and working as a consultant in petroleum industry although he is still interested in geothermal industry. Jacob Mayalla, who is coordinating the geothermal development, is

a geologist trained in 2006 from Ministry of Energy and Minerals. Tarameli Mnjokava is a geochemist trained in 2007 and Gabriel Mbogoni, being trained in geological exploration in 2008, both are from the Geological Survey of Tanzania. Jacob Mayalla and the two UNU Fellows from the Geological Survey of Tanzania are currently involved in a project called “Geothermal as an alternative source of energy in Tanzania” which is a collaborative project between Ministry of Tanzania, Geological Survey of Tanzania and BGR of Germany. The one and half year project started in June 2006 and is carrying out exploration survey of the Songwe-Mbeya region.

Burundi had Mr L.Mugahaze trained as an exploration geologist in 1984 but his whereabouts is not known.

Rwanda is having their first person, Theoneste Uhorakeye, trained in 2008 in geology exploration. He is expected to be one those to spearhead geothermal work in Rwanda.

5. PROPOSAL FOR IMPROVEMENT

The UNU-GTP training programme has played a major role in geothermal manpower development for third-world countries. Some of these countries like Kenya and Ethiopia now have the capacity to carry out surface geothermal exploration, drilling and reservoir monitoring, and environmental impact assessments. However, the older staff is retiring and younger replacements are required to be engaged and trained. In addition, a requirement is envisaged for specialisation in certain aspects, for example in directional and air drilling, and reservoir simulation studies. The specialised courses may be suited to be offered through the MSc. programme that the UNU has started.

Kenya is very keen to have its people trained in various aspects of power plant design and selection, economics and financial analyses, and contract documentation and implementation. This course could be offered at an MSc degree. Although the desire is not to design power plants, this knowledge is very necessary in the critiquing process of consulting engineer's work to get the most benefit from power station projects. In this respect, Kenya has already started training people in pipeline design, contract documentation and supervision for make-up well connections. The development of expertise in the information technology in digital control systems (DCS), which have now become the industry standard in power station operations, is also critical. The use of geographical information system (GIS) is also becoming critical in any discipline that collects massive data.

On the other side, there are other countries such as Rwanda, Burundi, Uganda, Tanzania, Eritrea and Djibouti who have not attained the capacity to carry out all exploratory work. Recently, there have been signs of interest from these countries to explore and develop indigenous geothermal resources which are expected to be inspired by the establishment of the risk fund mentioned earlier and the high oil prices and environmental concerns. The UNU-GTP would therefore continue to play a major role in assisting such countries to attain the necessary capacity. This means that the UNU-GTP would continue with the type of training that it has been giving, but at the same time offering more specialized training for those countries that are already ahead.

There is a feeling that the short course started in Kenya with the assistance of UNU-GTP in 2005 should be developed into a permanent school which could host a geothermal resource centre for the East African region. The proposed centre would be used for training people and exchanging information from geothermal activities in the region.

6. CONCLUSIONS

A hundred and twenty seven (127) Africans have been trained in Iceland over the last 30 years. However, only 176.5 MWe of electric power generation and an unknown amount of direct uses have

been realised. This achievement has been realised by efforts some of which were made under very difficult circumstances by former UNU-GTP graduates. In some countries, former UNU Fellows could not be fully utilised because there was either war, poor economic environment or competing resources; and these experts have been lost to the developed countries. In several other countries, the UNU-GTP Fellows have been fully utilised and are extending their expertise to assist other African countries develop their resources. As barriers of geothermal development are removed and more countries with geothermal potential realise that it is important to have a power generation mix to overcome the severe price and weather changes, this group of trained personnel will become critically useful in the future.

UNU-GTP training has been very useful and will continue to be useful as more countries diversify their power generation mix to include geothermal as an indigenous and environmentally friendly source of energy. Some countries are already ahead of others in manpower development but will still require UNU funded training in specialised areas. This will include an expansion into areas like power station cost analysis, design, and contract management. The recent establishment of a short course based in Kenya by UNU-GTP jointly with KenGen and involving UNU Fellows from Africa is an excellent development. We propose that the UNU-GTP continues to assist in this and that it will be made a permanent school as activities in geothermal development increases in the region.

ACKNOWLEDGEMENTS

The author thanks the entire KenGen staff and various people from African countries and the UNU-GTP for providing me with some useful information used in this paper.

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APPENDIX I: UNU Fellows from 1979 to 2008

NB: Shaded area marks UNU Fellows who have retired, retrenched, deceased or are no longer active in the geothermal industry.

KENYA					
	Year	Name	Course	Current position	Organisation
1	1982	Joseph Ng'ang'a	Drilling	Deputy MD	KenGen
2	1982	Zack Muna	Geochemistry	Retired Chief Geoth. Scientist	KenGen
3	1982	Martin Mwangi	Geophysics	Chief Manager	KenGen
4	1985	Geoffrey Muchemi	Borehole Geology	Asst. Manager – Energy Development	KenGen
5	1985	Charles B. Haukwa	Reservoir Engineering	Resigned	KenGen
6	1985	Pravin S. Boghal	Geophysics	Retired	Univ. of Nairobi
7	1986	Nicholas O. Mariita	Geophysics	Geoth. Train. Officer	KenGen
8	1986	James M. Njee	Drilling	Asst. Manager – Engin. and Logistics	KenGen
9	1986	Barrack P. Ouma	Geophysics	Geophysicist	Ministry of Energy
10	1987	Hudson Andambi	Geophysics		Ministry of Energy
11	1987	Paul W. Wangombe	Geology	Retrenched	Ministry of Energy
12	1987	Augustine W. Kanyanjua	Geophysics	Retrenched	Ministry of Energy
13	1988	Mwakio P. Tole	Geochemistry	Professor	Kenyatta Univ.
14	1990	Silas M. Simiyu	Geophysics	Geo Exe. Manager	KenGen

15	1990	S.A. Onacha	Geophysics	Resigned	KenGen
16	1991	Musa Aruse	Geochemist	Lecturer	Moi University
17	1992	Otitimah Agonga	Boreh. geology	Not active in geother.	Egerton University
18	1992	Peter A. Ouma	Reservoir Engineering	Ass. Man.– Reservoir and steam fields	KenGen
19	1993	Johnson Mungania	Boreh. Geologist	Projects Dev. Officer	KenGen
20	1995	John K. Lagat	Boreh. Geologist	Senior Geologist	KenGen
21	1996	James M. Wambugu	Geochemist	Resource Assess. Off.	KenGen
22	1996	Cornel O. Ofwona	Reservoir Engineering	Reservoir Engineering Officer	KenGen
23	1997	Benjamin Kubo	Env. Scientist	Environ. & Commun. Liaison Officer	KenGen
24	1998	Joshua O. Were	Env. Scientist	Senior Environment Scientist	KenGen
25	1998	Pius W. Kollokho	Env. Scientist	Man. – EM and CDM	KenGen
26	1999	Joshua W. Odeny	Reserv. Engin.	Resigned	KenGen
27	2000	Cyrus W.Karingithi	Geochemistry	Reservoir Geochemist – Officer	KenGen
28	2000	Eustace Ndirangu	Drilling	Drilling El. Engineer	KenGen
29	2001	Gabriel Wetangula	Env. Scientist	Environm. Scientist	KenGen
30	2002	P. Ngugi	Drilling	Geoth. Plann. Officer	KenGen
31	2002	Kizito Opondo	Geochemistry	Senior Geochemist	KenGen
32	2003	Flora Mwaughanga	Env. Science	Environment Officer	KenGen
33	2003	Martha Kariuki	Res. Engineer	Steam-fields Officer	KenGen
34	2004	Pacifica Ochieng	Environm. Sci.	Environment Officer	KenGen
35	2004	Godwin Mwawongo	Res. Engineer	Geother. Projects Eng.	KenGen
36	2005	Clety Kwambai	Power Station	Snr. Mechanical Eng.	KenGen
37	2005	Peter Wameyo	Geophysics	Geophysics Assistant	KenGen
38	2006	Johnson Ndege	Power Station		KenGen
39	2006	E. Munene Nyagah	Environm. Sci.	PhD studies	Kenyatta Univ.
40	2007	Anastasia Wanjohi	Geophysics	MSc Studies/ Geophy.	Univ. of Nairobi /KenGen
41	2007	Marietta Mutonga	Geochemist	PhD studies / Geoche.	Univ. of Nairobi /KenGen
42	2008	Teresa Karani	Power Station	Electrical Engineer	KenGen
TANZANIA					
	Year	Name	Course	Current position	Organisation
1	1986	G.M. Kifua	Geology	Retired	Minstry of Water
2	2006	Jacob Mayalla	Geology	Geologist	Ministry of Energy and Minerals
3	2007	Taramaeli Mnjokava	Geochemistry	Geochemist	Geological Survey of Tanzania
4	2008	Gabriel Mbogoni	Geology	Geologist	Geological Survey of Tanzania
UGANDA					
	Year	Name	Course	Current position	Organisation
1	1990	Amos S. Bazaale-Dolo	Geological exploration	Out of service	Private practice but within country

2	1993	Godfrey Bahati	Geochemistry	Principal Chemist and Coordin. Geoth. Proj.	Ministry of Energy and Mineral Dev.
3	1994	Edward Isabirye	Borehole geology	Geologist	Ministry of Energy and Mineral Dev.
4	1995	Fred Alex Tugume	Geophysics	Senior Geophysicist	Ministry of Energy and Mineral Dev.
5	1996	David Kyagulanyi	Geological exploration	Out of service	Private practice but within country
6	2000	Vincent Kato	Geochemistry	Senior Geologist	Ministry of Energy and Mineral Dev.
7	2005	James Francis Natukunda	Geological exploration	Senior Geologist	Ministry of Energy and Mineral Dev.
8	2006	Joseph Okedi	Reservoir engineering	Mining Engineer	Ministry of Energy and Mineral Dev.
9	2006	Dan Mainza	Geochemistry	Chemist	Ministry of Energy and Mineral Dev.
10	2007	Peter Mawejje	Geological exploration	Geologist	Ministry of Energy and Mineral Dev.
11	2008	Catherine Nyakecho	Environment	Geologist	Ministry of Energy and Mineral Dev.

BURUNDI

	Year	Name	Course	Current position	Organisation
1	1984	L. Mugahaze	Geolog. Explor.	Unknown	

RWANDA

	Year	Name	Course	Current position	Organisation
1	2008	Theoneste Uhorakeye	Geothermal Utilization	Attending UNU training	Ministry of Energy

ETHIOPIA

	Year	Name	Course	Current position	Organisation
1	1983	Gabriel Gebregziabheir	Reservoir engineering	USA	
2	1983	Teshome Abera	Drilling eng.	Left geological survey	
3	1984	Ketsela Tadesse	Geophysics	Not active in geothermal	Min. of Minerals and Energy
4	1985	Abatneh Wale	Reservoir eng.		
5	1985	Meseret Teklemariam	Borhole geology	Head Geoth. Group Geol.Survey of Ethio.	Geological Survey of Ethiopia
6	1985	Berhanu Gizaw	Geochemistry		Geological Survey of Ethiopia
7	1986	Zewde Woube	Reservoir eng.	Deceased	
8	1987	Solomon Woldemichael	Geochemist	NZ	
9	1988	Narayan Eyob Easwaren	Geoth. utilizat.	USA, Banking	
10	1997	Kibret Beyene	Geochemist		Geological Survey of Ethiopia
11	1998	Yiheyis Amdeberhan	Reservoir eng.		Geological Survey of Ethiopia
12	1998	Zewde Gebregziabher	Borehole geol.	USA	
13	1999	Abraham Muluneh	Drilling		Geological Survey of Ethiopia

14	2001	Endalkachew Getaneh	Borehole geol.		Geological Survey of Ethiopia
15	2001	Yiheyis Kebede	Geophysics		Geological Survey of Ethiopia
16	2001	Merga Tassew	Geoth. utilizat.		EEPCo
17	2002	Haile Kebede	Geoth. utilizat.	Left EEPco – emigrat.	
18	2002	Muluken Tessema	Geoth. utilizat.		EEPCo
19	2002	Fessaha Tareke	Reservoir Eng.	Out of the Country	
20	2003	Yohannes Demissie	Geophysics	Left Geol. Survey	
21	2004	Akalewold Seifu	Reservoir Eng.		Geological Survey of Ethiopia
22	2004	Mulugeta Asaye	Geoth. utilizat.	MSc in Iceland	EEPCo
23	2005	Solomon Kebede	Environm. Sci.		Geological Survey of Ethiopia
24	2007	Senay Gebregiorgis	Geoth. utilizat.	Engineer	EEPCo
25	2007	Yohannes Lemma	Geophysics	Geophysicist	Geological Survey of Ethiopia
26	2008	Gezahegn Daba	Geochemistry		Geological Survey of Ethiopia
ERITREA					
	Year	Name	Course	Current position	Organisation
1	1984	Mohammed Berhan Abdulkadir	Geophysics	Currently in USA, worked in petroleum	
2	2004	Ermias Yohannes	Geochemistry	Head Geothermal Unit	Ministry of Energy and Mines
3	2004	Mohammed Omer	Geology	In Iceland, not active	
4	2005	Kiflom Gebrehiwot	Geology		Ministry of Energy and Mines
5	2007	Andemariam Teklesenbet	Geophysics	Geophysicist	Ministry of Energy and Mines
6	2008	Daniel Weldeyohannes	Geochemistry		Ministry of Energy and Mines
DJIBOUTI					
	Year	Name	Course	Current position	Organisation
1	1989	Ali Elmi Khaireh	Borehole geology	Retired and 2005	CERD
2	2005	Daher Elmi Houssein	Reservoir engineering	Researcher at Earth Science Department, Respons. Geoth. Lab.	CERD
3	2008	Mustapha Youssouf	Borehole geology	Researcher at Earth Science Department	CERD
EGYPT					
	Year	Name	Course	Current position	Organisation
1	1990	Magdy M.Mahgoub	Boreh. Geology	Senior Geologist	REGWA
2	1994	Magda Idris	Geochemistry	Senior Geochemist	REGWA
3	1995	Sadek Elsharkawy	Reservoir Eng.	Manager	REGWA
4	2005	Aref Lashin	Boreh. Geophy.	Ass. Professor, Geophysics Dept	University of Benhar
TUNISIA					
	Year	Name	Course	Current position	Organisation
1	1997	Mouldi Ben Mohammed	Geoth. Utilisat.	Deputy Director, Agricultural studies	CRDA, Manouba

2	1997	Mondher Said	Geoth. Utilisat.	Engineer	Min.of Agriculture
3	1998	Lassaad Sbita	Geoth. Utilisat.		ENIG Gabes
4	1999	Mohamed A. Gandouzi	Geoth. Utilisat.	Engineer	CRDA, Kebili
5	1999	Mongi Elguedri	Geoth. Utilisat.	Engineer	CRDA, Kebili
6	2000	Aissa Agoun	Reservoir Eng.		CRDA, Kebili
ALGERIA					
	Year	Name	Course	Current position	Organisation
1	1989	Malika Rachedi	Geoth. Utilisat.	Not Active	University
2		Mohamed Abouriche	Geology	Deceased	
3	1994	Talal Karouaz	Geochemistry	Not Active	

APPENDIX II: MSc. Fellows 2000-2008

	Name	Country	Course	Year of graduat.
1	Cornel Ofwona	Kenya	Reservoir Eng.	2002
2	Cyrus Karingithi	Kenya	Chemistry	2002
3	John Lagat	Kenya	Geology	2004
4	Gabriel Wetangula	Kenya	Environm. Sci.	2004
5	Godfrey Bahati	Uganda	Environm. Sci.	2005
6	Kizito Opondo	Kenya	Chemistry	2006
7	Joshua Were	Kenya	Environm. Sci.	2007
8	Daher Elmi	Djibouti	Reservoir Eng.	2008
9	Clety Kwambai	Kenya	Mechan. Eng.	2008
10	Mulugeta Asaye	Ethiopia	Mechan. Eng.	Studies ongoing