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Developing Engineers to Compliment Geothermal Expansion in East Africa

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ABSTRACT

Kenya has established a road map on how to become a middle income economy by the year 2030. One of the challenges for this vision is the unavailability of energy mainly electricity to power the vision. There was therefore need for a strategic plan to accelerate development of power generation facilities to avail power to support industrial and infrastructural development. Kenya has in the past heavily depended on hydroelectricity which comprises of 2/3 of the total amount of electricity available on the national grid. This mode of power generation has in the recent past been adversely affected by long dry spells due to climate change, leading to high dependency on diesel plants whose electricity is more costly and contributes to climate change. In view of the above, Kenya has had to explore other modes of power generation such as wind, solar and geothermal. More focus has however shifted to geothermal exploitation because previous studies had shown the resource available stands at over 7000MW. The geothermal power generation mode has also been found to be sustainable and environment friendly. Geothermal exploitation is a highly specialized sector that requires highly specialized human resources mainly scientists and engineers. Kenya has made milestones in training scientists who are directly participating in geothermal exploitation both in the Geothermal Development Company and Kenya Electricity Generating Company as well as offering consultancy to other East African countries. This paper highlights the need, how and to what level the engineers can also be trained to enable them play a critical role in geothermal development in Kenya and beyond.

1. INTRODUCTION

Engineers can be divided into three levels: Class A, Class B and Class C levels. Class A engineers are able to design a system or component and manufacture or construct it. Class B engineers are able to design a system or component and hand it over for manufacture or construction. Class C engineers can only coordinate activities that require engineering understanding. There are many engineers employed in the geothermal sector in Kenya but almost all of them are in the class C level. They have not been trained well enough to be able to either design or install any geothermal exploitation facility. Given the resolve by the Government of Kenya through the Ministry of Energy to maximally exploit the geothermal resources, there is need to develop engineers just as scientists, to at least class B level. They should be able to design power generation facilities and other direct use application facilities.

2. NEED STATEMENT

Geothermal development can be classified into two main phases: phase one – the resource development phase in which the scientists and some engineers (reservoir and drilling) have been sufficiently trained to handle geo-scientific exploration, drilling and reservoir measurements; and phase two – the resource utilization phase which involves conversion of the geothermal resource into useful applications such as power generation and direct uses. The second phase requires engineers who can design and supervise installation of the various facilities for power generation and direct application of geothermal resources. Kenya has so far not exploited this idea because it has mainly relied on external consultants to design and supervise construction of its geothermal power plants. Exploitation of the geothermal resource in Kenya is going to be a long-term endeavour if the entire 7000MW is to be exploited. To reduce the costs and time of development occasioned by use of consultants, it would be better to train local engineers to conceptualize, design and supervise the construction of geothermal projects. The trained engineers will also be available to offer consultancy services to other East African countries. This is not to say that external consultants will completely be ruled out of geothermal projects in Kenya and East Africa because given the current activities, the projects will require that both local and external consultants complement each other.

3. SCOPE OF TRAINING

The main scope of the training is to equip the engineers with skills to enable them design, procure and supervise construction of geothermal power plants, wellhead generators and direct use systems. At the end of the training the engineers should be able to produce preliminary and detailed design drawings using relevant software, extract bills of quantities and prepare tender documents to procure contractors who can supply and construct power plants together with the steam gathering systems and direct use systems. The engineers should also undergo contract management courses to enable them supervise geothermal projects effectively.

3.1 Geothermal Power Plants

There are various components involved in developing geothermal power plants, including: mechanical, electrical and instrumentation works. In mechanical works, identified mechanical engineers should be trained on how to conceptualize and formulate the thermodynamic cycles for power plants, identify the various parts and components of the power pants and their auxiliaries, size them, represent them in drawings, extract bills of quantities for the various components and use them to formulate tenders. They should be trained on the various computer softwares that are used to produce drawings for use by contractors in constructing the power plants. They should also be introduced to various standards that govern the choice of materials and procedures of power plant construction.

In electrical works, identified electrical engineers should be trained on the various electrical components of the power plants including how to: size and specify them, produce preliminary and detailed design drawings, extract bills of quantities and prepare tender documents to procure electrical contractors. Civil and structural engineers on the other hand should also be identified and trained on design and supervision of power plant platforms and anchorages of the various components of the power plant; electrical and electronics to design and supervise power plant communication systems for automated operation as well as monitoring of the power plant.

3.2 Steam Gathering System

A geothermal power plant cannot be complete without a steam gathering system, also known as the steamfield. This comprises of the wellhead assembly, wellhead silencers, cyclone separators, steam and brine pipelines together with their fittings. All these components form a system that transports steam from the wells to the power plant and brine from the separators to the hot-reinjection wells. The selected engineers should be trained on how to formulate the process flow, size the various steamfield components including the pipe supports, produce detailed design drawings, bills of quantities and tender documents to procure contractors who can install the steam gathering systems.

3.3 Wellhead Generators

It has been established that the time taken to develop conventional power plants after drilling the wells is too long. For instance, drilling wells for the 280MW project in Olkaria started in 2007 and construction of the power plants will be completed in 2014 - a 7-year lead time. During this period steam in the drilled wells is idle and therefore time for power generation is lost yet the demand for electricity remains high. This situation led to the formulation of modular power plants otherwise known as wellhead generators which can be hooked on to a well so as to generate power while awaiting construction of a conventional power plant. Kenya Electricity Generating Company has already installed a pilot plant at Olkaria which is generating 5MW while Geothermal Development Company is putting up another one in Menengai. The contracts to develop these units were on the basis of design and construct. To accelerate development of these units - now that drilling of geothermal wells in Kenya is a continuous process - training of engineers who can formulate appropriate thermodynamic cycles for power plants for various wells is necessary. They should also be trained on how to: identify various components that form the wellhead units, size them and produce detailed design drawings. From the designs they should be able to produce tender documents and procure for contractors to supply and install the units while they supervise.

3.4 Direct Uses

Apart from power generation, geothermal resources have other numerous direct uses. These applications include the use of brine in spurs, heating of homes, cooling, heating of green houses, use of gases in green houses, use of geothermal heat to dry agricultural products, use of condensate for irrigation, etc. The main challenge is transporting the resource either in form of heat or water to the place where it is required and also designing systems that will utilize the resource. Engineers should therefore be trained on how to design systems, procure materials and even construct the systems. There is minimum direct utilization of geothermal resources in Kenya mainly because of lack of expertise in terms of formulation and development of the requisite systems. Only Oserian Development Company has been able to exploit these resources by taking advantage of their proximity to Olkaria geothermal project. Local communities in Eburu have demonstrated direct uses of geothermal resources by distilling vapour from fumaroles to get drinking water and using geothermal heat to dry pyrethrum. These direct applications can only be fully harnessed if engineers are trained on how to develop more modern systems of directly utilizing geothermal resources.

4. METHODOLOGY

This section proposes various methods and modes of training engineers so as to attain the required knowledge and skills in design and supervision of geothermal projects. The modes will have to encompass theoretical studies in a class set-up in which the trainees will be introduced to various engineering and scientific principles and parameters applied in design of various geothermal utilization facilities. Trainees will also be introduced to various components that form the various systems and how to size and specify them. At this stage they will also be introduced to the various computer software used design. Another mode will be attachment and mentorship - once the trainees have gone through class work they will be attached to on-going projects during their design stage for practical lessons. This will help them to convert the acquired theoretical knowledge into practical work. Trainees will also be required to go for industrial visits to factories that manufacture various geothermal power plant parts. This will enable them to understand the importance of every part, the various available options, how to specify them and their costs.

4.1 Geothermal Institutions

There are already established institutions that offer valuable and specialized geothermal courses; key among them being United Nations University in Iceland and Auckland University in New Zealand. They have played a great role in developing most of the leading geothermists in the fields of exploration, drilling and reservoir measurements around the world. The courses in these institutions are mainly centred on the above fields with a very small component of geothermal utilization. Due to their experience, these institutions can be engaged to develop a structured and specialized course that comprehensively covers design of various geothermal utilization systems to be offered to the engineers. Apart from UNU and Auckland Universities, other institutions can be identified around the world to offer the training. Geothermal Development Company and Kenya Electricity Generating Company being the leading stakeholders in the geothermal sector in Kenya can also jointly or independently set up a Geothermal Training Institute and scout for experts around the world to offer the required training to engineers.

4.2 Consulting Firms in Geothermal Projects

Geothermal institutions can only offer theoretical knowledge that should be tempered by practical knowledge to make engineers effective. Practical skills can mainly be acquired by attaching the trainees to consultants working on on-going projects. The trainees will be required to work on a project with the consultants so that they can be taken through various considerations and steps on how to come up with designs of various geothermal systems. Some of the leading firms with experience in design and supervision of geothermal projects include SKM, WESTJEC, Green Energy and Geothermal Development Associates. A strategy should be designed on how to engage these firms to offer attachments and mentorship programmes to the trainees.

4.3 Manufacturers of Equipments for Geothermal Systems

After the trainees have gained both theoretical and practical knowledge, they need to know the available equipment, materials and control systems for construction of geothermal utilization facilities available on the market. These will enable them to easily specify them and prepare bills of quantities. It is very important to know the items one wants to procure and install and this information is mainly available at the manufacturing plants. The trainees can also obtain catalogues and brochures with useful information from the manufacturers. Some of the factories the trainees can visit include manufacturers of turbines and generators, cooling towers, condensers, control systems and auxiliaries for power plants. They should also visit manufacturers of pipes and their fittings and separators for the steamfield. Direct uses projects are not as complicated as power plants and therefore, engineers can adopt already locally available technologies like irrigation, heating and cooling to come up with projects on direct utilization of geothermal resources.

5. BUDGET AND TIMELINES

Design of power plants is a highly specialized assignment due to the many and critical components involved. The team to be trained should therefore be dedicated and have great interest in design of systems using engineering and scientific principles. The budget and timelines are based on similar trainings.

For purposes of ascertaining a reasonable budget and timelines, we use a team of participants comprising 10 engineers, i.e., 2 mechanical engineers, 3 electrical and electronics engineers, 2 instrumentation engineers and 2 civil structural engineers (Table 1). It is proposed that they undergo a joint theoretical course and finally split into various specialties during attachments and mentorship. It is also assumed that mentorship/attachments and industrial visits will run concurrently.

Table 1: Budget Estimates and Timelines

Item	Description	Cost (USD)	Time (Months)
1	Theoretical course (tuition + accommodation)	500,000	3
2	Attachments / mentorship and industrial visit (travel costs and accommodation)	1,500,000	12
TOTAL		**2,000,000**	**15**

This budget and timelines assume that the trainees will have mastered the principles of design of power plants together with steamfields. The trained team must be deployed on various projects where they will be engaged full time - they may encounter challenges but will be able to contact their mentors in such cases. The same team will be used as mentors for the successive teams that will want to train in design of various geothermal utilization facilities.

6. BENEFITS

There are many benefits that can be derived from developing the local engineers' capacity to formulate, design and supervise construction of geothermal utilization systems especially power plants now that geothermal exploitation will be a long-term endeavour in Kenya and East Africa. Some of the benefits are outlined below.

6.1 Reduction of Cost in Developing Geothermal Utilization Facilities

The cost of consultancy in engineering projects has always been put at between 5% and 15%. It is therefore reasonable to argue that using local consultants will reduce the cost of development by 10%. For instance, the cost of consultancy for a steamfield contract for 280MW project at Olkaria is approximately Ksh 1.6 Billion while the cost of constructing one is Ksh 14 Billion. It therefore means that for the entire 280MW project whose total cost of construction is Ksh 82 Billion, the country would save up to Ksh 8 Billion if the designs are done locally.

6.2 Shortens Project Duration

Using local consultants will eliminate the time period spent on procuring external consultants. The procurement process in Kenya is quite tedious and long especially for contracts involving large sums of money. Once a project has been initiated the local consultants will immediately commence working on designs then move on to procurement of supply and installation of the designed systems.

6.3 A Source of Revenue

Once the engineers are competent and experienced in designing and developing geothermal utilization systems, they will be able to offer consultancy services to projects in other countries or other private developers thereby bringing in revenue to their companies and countries.

6.4 Refurbishment of Old Power plants
From the experience of Olkaria I geothermal power plant, it has become evident that the power plant efficiency has deteriorated to a level that operational and maintenance costs are high compared to the revenue generated. This is because the plant is aged - it is over 30 years old. However the wells that supply steam to the plant are still producing steam and reports of investigation by Westjec indicates that the steamfield infrastructure is still intact. It is therefore necessary for the plant to be refurbished in an effort to increase its efficiency and modernize it. The trained engineers would be of great value in determining whether the plant can be refurbished, and if so then play a critical role in, redesigning it and procuring contractors to refurbish the plants.

6.5 Installation of Wellheads
Wellheads are gaining a lot of interest amongst geothermal developers due to their ability to utilize steam shortly after drilling as compared to the conventional power plants. The biggest challenge has been formulating the appropriate units for various types of wells. This problem can be solved by the trained engineers through advising management on the appropriate units, designing them and formulating good tenders to procure construction of the units.

6.6 Expansion of Direct Uses of Geothermal Resources
Direct uses for geothermal resources have not been exploited to any meaningful level. This is mainly because of the challenges involved in delivering the resource to the required place of use given that the resource is mainly found in remote areas. The trained engineers should be able to overcome this challenge and deliver the resource to where it is required and design systems that will utilize the resource.

6.7 Improvement of Operation and Maintenance of Power Plants
The engineers who will have designed the power plants will be available for consultation by the operational team whenever there is a problem. The team will also help in the procurement of proper spares and will easily maintain contacts with suppliers and manufacturers whose information will be vital in the operation and maintenance of the power plants.

6.8 Effective Supervision of Projects
As pointed out earlier in this paper, the trained and experienced engineers will not totally replace external consultants. There are projects which will still require external consultants but the engineers will be involved as client's representatives on a knowledgeable position. In current projects, client's representatives have insignificant knowledge in power plant installation and therefore play peripheral roles in the implementation of projects.

7. CHALLENGES
Several challenges are expected during the implementation of any capacity building efforts. Some of these are discussed in the following sections.

7.1 Financing
As presented in Table 1, it is evident that the cost of training is quite high and could have a significant impact on individual company's balance sheet if they were to sponsor the training. It is however possible to devise strategies for funding the trainings, some of which include donors: joint sponsorship by major companies involved in the geothermal sector and inclusion of training components in major geothermal contracts.

7.2 Duration
The time required for training the engineers to the required level of skills and knowledge is quite long compared to other trainings. The engineers will therefore be out of their normal duties for a long and this may affect the delivery of services. This can however be solved by distributing the duties to other engineers left behind and in the worst case scenario, recruiting a new team of engineers.

7.3 Failure to Deliver
Designing and construction of power plants is a complex exercise that requires the highest level of concentration and commitment. There is therefore the possiblity that even after going through the proposed programme, the engineers can fail to acquire the necessary skills and knowledge and still remain unreliable when called up to execute a project. This can be overcome by first vetting the engineers to ensure that only the best are selected for the programme/training. Experts can also be called upon to design a programme that guarantees well developed engineers capable of applying the knowledge and skills acquired.

7.4 Sourcing of Trainers
Experts in design of power plants are few and engaged most of the time. It might not be easy to engage them on long-term basis to attend to the trainees. This can be solved by proper negotiation with the consultants before engaging them.

7.5 Fear of Loss of Jobs
Some of the experts to be engaged might feel that they will lose contracts to local engineers and therefore offer sub-standard training. The experts should however be assured that geothermal projects in Kenya will be many, will not all be handled by local engineers and that there will be arrangements where they can complement each other.

8. RECOMMENDATIONS
Stakeholders in the geothermal sector will face several challenges in their resolve to train local engineers to become experts in the design and installation of geothermal utilization facilities. We recommend the following:

1) Develop strategies for attracting funding for the training programme including approaching

donors and encouraging joint sponsorship by various stakeholders in the sector.

2) Approach various institutions offering geothermal courses and experts in power plant developments to assist in developing a curriculum that will produce competent engineers.
3) Develop a procedure for vetting and selecting candidates for the training.
4) Developing a system that will enable the trained engineers to practice what they will have learnt even after completion of the training programme - to avoid forgetting.
5) Develop partnerships and memoranda between companies already involved in geothermal exploitation and consulting firms to facilitate mentorship programmes for engineers.
6) Develop good relationships between geothermal developers and manufacturers of geothermal power plants so that engineers can continuously receive product information required in design and specifications.

9. CONCLUSION

Geothermal exploitation in Kenya and some East African countries has started in earnest and it will take a long time to exploit the entire capacity. This therefore calls for the development of highly specialized experts especially engineers to take a lead in the installation of geothermal utilization facilities. The benefits outlined in the paper present an opportunity for Kenya and East Africa to develop their own engineers so as to fast track geothermal exploitation at home and also export the knowledge to the rest of the world.