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Advancing Geothermal Development in East Africa: Lessons Learned During the 2015 – 2018 EAGER Programme

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ABSTRACT

The challenges facing geothermal energy project development in East Africa are broadly divided into five categories: securing financing, mitigating resource risk, determining the role of geothermal within the overall energy mix, establishing suitable business models (public vs. private), and developing technical and project management capacity. Between 2015 and 2018, the EAGER facility sought to assist government agencies by addressing gaps in the overall process of geothermal development that had not been covered by other development assistance. This paper sets out the key lessons learned emerging from the facility's work.

1. Introduction

The East Africa Geothermal Energy Facility (EAGER) is an independent advisory facility implemented between May 2015 and November 2018 and funded by the UK Department for International Development (DFID). EAGER is a demand led facility, designed to respond to client governments' requests for assistance related to addressing barriers to geothermal development in Ethiopia, Kenya, Rwanda, Tanzania, and Uganda through bespoke technical advisory assignments staffed by expert consultants. The target countries were selected during the programme's planning phase based on the geothermal landscape, gaps in donor assistance and requests by the client governments[1]. The main lessons from this programme are set out in the following sections: policy, legal and regulatory barriers, risk sharing models, risk-based exploration planning, the characteristics of the western rift, commercial analysis, geothermal in power markets, economic development, geodata and capacity building needs. This paper builds on a presentation made in January 2018[2].

2. Policy, Legal and Regulatory Barriers

EAGER's initial mandate was to focus on strengthening legal and regulatory frameworks for geothermal development. However, a number of other barriers – as discussed in later sections

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[1] For more information on EAGER, please visit www.eagerfacility.com

[2] Sussman, 2018

– needed to be addressed and an early lesson was that these could progress in parallel with any policy, legal and regulatory development, without a delay in development activities in the short to medium term in any of the jurisdictions.

Within the legal and regulatory frameworks EAGER observed two specific areas where early clarity is beneficial. The first of these is clarity on (and separation of) roles: policy, regulation of the multiple public interest issues and development. Good governance in this area is critical as overlapping mandates can have the potential to cause confusion and/or conflict of interest for government entities engaged in both the regulation and development of geothermal.

The second is the form of technical regulation that combines effective obligations on developers with flexibility with regard to technological change. Within any regulatory framework for geothermal a decision is required on the rules to apply for the supervision of technical performance regarding safe and environmentally acceptable working practices, with particular reference to drilling. The options to mandate safe procedures are: inclusion in the law, in regulations or in licences, or some combination of these. The options in terms of the procedures themselves are: to define them in the form of detailed regulations, to mandate a specific Code of Practice, or to allow regulatory and licensee discretion by referencing best international practices. Each jurisdiction will adopt different approaches but in principle, the preferred option is to allow some flexibility in laws and regulations to adapt to technological advances without the need to amend those laws and regulations.

Key lessons:

- Development can continue while legal and regulatory frameworks are resolved.
- Clarity on roles and mandates is critical for an effective policy and regulatory regime.
- Technical regulations should allow for flexibility for technological change.

3. Risk Sharing Models

EAGER reported on international experience on public and private models of geothermal development at the 6th ARGeo conference in November 2016[3]. Five generic exploration and development models ranging from fully public to fully private represent a range of risk sharing options on a prospect by prospect as well as portfolio (multiple prospect) basis. Ethiopia has opted for the fully private sector model at existing concessions but is considering alternative models in the future. After initially applying the fully public model to develop two geothermal fields in Kenya, the government has recently opted for a range of models, including fully private and steam supply by government entities in particular. In Uganda, the fully private model has failed to enable progress as experienced international developers were unwilling to take the early stage risk and local developers proved short on technical and financial capacity. Both Tanzania and Uganda, while keeping options open as to the optimal business model for any one site, have recognized the need for government agencies to undertake more of the exploration work, at least through to the test drilling stage.

An important lesson from this experience is that options for the business model should be factored in at an early stage of exploration planning, with an initial commercial evaluation incorporating both the risks (i.e., the probability of low temperature gradient holes or dry wells) and the costs, especially the capital and financing costs and who meets those costs.

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[3] Lonsdale et al

Policymakers in East Africa are understandably interested in how to leverage infrastructure funding (e.g. government capital, donor grants, multilateral and unilateral concessional loans) to keep the price of heat and power to consumers low. This interest, combined with the need to manage early stage risk and finance exploration, has significant implications for the choice of risk sharing model, and for the capacity building required in government geothermal agencies. Where government funding is considered desirable, the geothermal sector is also competing with other energy sources in power markets for infrastructure funding that can provide the best economic return to the country.

Key Lessons:

- Risk sharing models (level of public and private sector participation in development) should be determined as early as possible in the development process.

4. Risk Based Exploration Planning for Deep-Circulation Geothermal Systems

The focus on early stage risk mitigation in geothermal projects in East Africa is primarily either on cost reduction (e.g., through GRMF) or on insurance against well failures rather than on adapting exploration approaches to the local resource type. Prior to the EAGER project, efforts to reduce exploration risks through surface exploration surveys focused on targeting >230°C volcano-hosted geothermal reservoirs rather than on acquiring geoscience surveys and integrating their results in conceptual models directed at targeting geothermal reservoirs heated to <180°C by deep-circulation, like those typical of the western branch of the East African Rift System (EARS). Since the risk of dry holes is greater for deep-circulation systems, and resource, market, and exploration risks are poorly understood, the efforts should be focused on mitigating those risks prior to utilizing insurance and exploration cost reduction mechanisms such as GRMF. Lower cost options such as temperature gradient holes (TGH) and slim holes can help to refine conceptual models and well targets to reduce the risk of failure.

EAGER has identified an iterative planning process for fault-controlled deep-circulation prospects that is consistent with experience in private sector exploration planning in the US Basin and Range region, which has about 20% of the operating geothermal fields worldwide.

Prior to considering test drilling, this process requires integrating the results of structural geologic mapping with transient electromagnetic (TEM) and magnetotelluric (MT) techniques, and geochemistry to develop viable alternative conceptual models. These conceptual models, built using multiple 2D cross-sections and maps to enable quick revision as new data are gathered and interpreted, are critical to making informed decisions, including prioritizing multiple prospect areas and whether to drill at all. EAGER has formulated a summary exploration process (Table 1) for deep-circulation fault-controlled systems. This process includes TGH as a means of reducing risk to establish the potential resource size and location before more expensive slim hole or production drilling costs are incurred. TGH are not typically utilized in volcanic systems, where resources tend to be hotter and/or deeper, exceeding the well-management capabilities of small truck-mounted drilling rigs.

Table 1: Steps in Exploration Planning for a Fault-Controlled System

No.	Activity	By
1	Conduct desktop studies and short reconnaissance visits to develop inventory of potential geothermal prospects in the country. Compile subsurface temperature data on a regional basis with a particular focus on legacy exploration and drilling data from petroleum, mining and water resources as well as geothermal exploration.	Geologist, geochemist
2	Based on initial fluid and gas geochemistry results and reconnaissance field data, identify local power market, transmission and direct use options, and conduct preliminary economic analysis (financial model) to select priority prospects for further exploration.	Geologist, geochemist power expert, direct use expert, finance expert
3	For identified prospects, compile all existing surface and subsurface geoscience data, including legacy exploration and drilling data from petroleum, mining and water resources as well as geothermal exploration, including relevant data in subsequent interpretations.	Geologists, perhaps geochemists and/or geophysicists
4	Conduct geologic/structural mapping and additional geochemical sampling at priority prospects, integrate with existing data.	Geologists, geochemists
5	Plan and conduct geophysical surveys appropriate to the models developed by geologists and geochemists and the logistics of the site, possibly including MT, TEM, gravity, magnetic and other surveys. Integrate these data with existing reflection seismic, aeromagnetic and similar geophysics data sets that may be available.	Geophysicists, in consultation with the geoscience team
6	Compile, analyze and interpret data and develop preliminary conceptual models representative of the uncertainty of the assessment.	Geoscience team
7	Using conceptual models, assess possible/probable resource area(s) and capacity, review prospect economics; locate TGHs or slim holes as appropriate dependent on resource risk analysis	Geoscience team and finance
8	Undertake the environmental and social impact assessment (ESIA) and obtain necessary approvals prior to drilling	Environmental/Social expert
9	Identify and hire TGH drilling expert (if this expertise does not exist in-house) to assist and direct drilling process, measurements and interpretation of TGH data	Management
10	Prepare a drilling program for TGH and conduct drilling risk assessment	Geoscientists and drilling expert
11	Conduct drilling tendering process; prepare and negotiate contracts; identify internal and external personnel needs and responsibilities; establish costs; prepare health, safety and environmental (HSE) documents and conduct training for relevant staff	Drilling team and consultant
12	Drill and measure TGH, then revise conceptual models using TGH results	Drilling contractor, drilling consultant, geoscientists
13	Assuming positive TGH results, determine locations for slim holes or full-size wells to confirm resource size and characteristics	Geoscientists
14	Revise economic model; prepare for and conduct PPA negotiations, plan direct use (if applicable), engage with economic development teams in local government; undertake full feasibility study, and prepare project development and business plan.	Commercial team, finance expert
15	Tender for larger drilling rig for slim holes or full-size wells depending on resource risk analysis, and include sufficient lead time for materials and equipment procurement	Drilling team
16	Drill test well(s); if successful, re-assess technical data and refine power and direct use plans accordingly.	Drilling contractor, drilling team, geoscience team

No.	Activity	By
17	Implement power generation and direct use plans.	Business development team
18	Drill and test production and injection wells.	Drilling contractor, drilling team, geoscientists, reservoir engineer
19	Determine optimal heat and power operations and agree on operating procedures with power and heat customers	Steamfield and power engineers

Other risk mitigation features include:

1. EAGER's detailed structural geology field work at five geothermal prospects in the western arm of the EARS in Uganda and Tanzania produced mechanically consistent structural models for each prospect that were more aligned with the geophysics and geochemistry than the previous regional and lineament analyses. This work resulted in modifications to and improved confidence in TGH targets and resource capacity assessments at each prospect. Research conducted over the last two decades in the US Basin and Range has demonstrated the reliability of the type of detailed structural analysis proposed in step 4 for predicting the location of permeable deep-circulation geothermal reservoirs and reducing the risk of drilling impermeable production wells[4]. Because this type of structural analysis requires far more field mapping expertise and analytical structural training than is available in East Africa, extended international training may be required to supplement introductory mentoring. However, local geologists who participated in the field mentoring are aware of what is involved and can assess the reliability of new structural studies and appreciate the limitations of applying regional lineament analyses to local geothermal prospects, as has been previously done at geothermal prospects throughout the EARS.

2. Similar structural analyses have been successfully used to characterize volcano-hosted geothermal prospects and more detailed analyses are being tested for assessing the permeability distribution in volcano-hosted geothermal reservoirs. The detailed structural mapping identified important features that led to significantly different structural models in all study areas and, when integrated with geochemistry and MT-TEM resistivity results, led to either significantly different conceptual models (e.g., Songwe and Katwe) or significantly improved confidence in particular model variations (e.g., Panyimur, Kibiro and Buranga), generally leading to somewhat higher resource estimates and increased confidence in TGH targets over a larger area for these prospects.

3. The early alignment of technical and commercial analysis is a necessary step for government agencies seeking to prioritize and undertake exploration work. A potentially large, high enthalpy volcanic resource will have low priority if it is remote from demand or a robust transmission grid (high market risk), while a low enthalpy resource with low drilling costs close to demand for both heat and power can have a high priority given economic development and time to market criteria.

Key Lessons:

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[4] Omenda et al, 2016

- An iterative planning and conceptual modeling process that is flexible enough to incorporate data and resource information throughout the exploration phase is optimal for deep-circulation geothermal systems and is an important element of the risk management process.
- In deep-circulation systems, lower cost options such as TGH and slim holes can help to refine models and well targets to reduce the cost of failure.

5. The Western Branch of the East African Rift System

In 2016, the exploration analysis approach to the western branch of the EARS began to change[5]. A separate EAGER paper[6] sets out what has been learned in EAGER activities since the last ARGeo conference[7]. As proposed by Alexander et al. (2016), most geothermal prospects along the western branch of the EARS are fault-controlled, similar to the large number of operating and drilled fields in the US Basin and Range region and western Turkey. These geothermal systems are typically smaller than those in the volcano-hosted systems of the eastern branch of the EARS, although it is likely that there are also fault-controlled systems in the far northern and southern sectors of the eastern branch (e.g., Tendaho, Ethiopia, Magadi, Kenya, and Lake Natron, Tanzania).

Experience from the Basin and Range region of the US and from Turkey has shown that low enthalpy geothermal resources can be economically viable. High enthalpy resources have been the focus in East Africa to-date. The key aspects of fault-controlled systems that can lead to this outcome in East Africa include: shallower reservoirs and lower drilling costs; local markets for power and direct use linked to economic development initiatives; and use of standard binary wellhead generation technology, which can shorten development timescales.

Based on EAGER's broad experience with fault-controlled systems and active involvement conducting structural mapping and interpreting geophysical survey results in the western branch of the EARS[8] with TGDC (Tanzania) and GRD (Uganda)[9], this new understanding has implications for both geotechnical analysis and the identification and prioritization of prospects (e.g., Songwe, Kibiro and Panyimur).

Key Lessons:

- Low enthalpy resources can be as economically viable as high enthalpy resources.

6. Commercial Analysis of Prospects

When analyzing the commercial viability of a geothermal prospect, an integrated and iterative approach involving technical, commercial, regulatory, and policy considerations is required. Key factors to consider include technical viability, competitive positioning of geothermal, power and energy demand, and other policy priorities in the energy and infrastructure sectors.

Experienced private sector geothermal developers set development priorities by conducting early commercial and financial analysis based on a wider set of criteria than a preliminary

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[5] Omenda et al, 2016
[6] Sussman, 2018
[7] Hinz et al, 2015
[8] Hinz et al, 2018
[9] Mawejje et al., 2018; Lugaizi et al., 2018; Isabirye et al., 2018; Natukunda and Bahati, 2018

geotechnical opinion and a reference point of MW of electrical capacity based on – often optimistic – analogues.

EAGER has developed a sophisticated financial model that can analyse one or more geothermal prospects and that can be used for business planning and commercial analysis based on the costs and timing of the prospect development process[10]. Most publicly available and consultant-provided financial models require the modeler to input the key technical assumptions that will affect the viability of the project. These assumptions include the potential capacity of the reservoir (MW), the well cost, and the average flow rate for production wells. The accuracy and quality of these assumptions are only as good as the modelers and their technical team, who often have limited or inapplicable experience (for example, resource data from a volcano-hosted system is unlikely to be useful when modeling a fault-controlled system). The model therefore includes look-up data tables derived from a wide range of geothermal systems worldwide from which the modeler and technical support team can calculate the system MW capacity and number of production and injection wells required based on the estimated reservoir temperature, permeability, liquid level, and anticipated depth of drilling. This allows a more objective comparison of greenfield prospects under consideration for drilling.

One key EAGER learning from the use of this model in East Africa has been that by directly involving both technical and financial team members in developing the model input values, the results tend to be more robust and management is not dependent upon the experience and knowledge of a single modeler to assess project economics. The financial model calculates both a project’s net present value (NPV) and internal rate of return (IRR) for the five different business models mentioned above. This allows a government to compare the costs and benefits of exploring and developing a particular resource alone, in concert with the private sector (PPP), or turning over the prospect to the private sector from the initial exploration phase. A simpler model may be more appropriate for an initial appraisal or a pre-feasibility study, with the more sophisticated model used at the full feasibility stage. The latter model is based on the use of geothermal energy primarily for electricity generation but allows for direct use income.

The cost of getting the geothermal energy to market should also be estimated at an early stage. Physically this is the cost of transmission connections to access the power market, plus the need to factor in any uncertainty regarding the size of the baseload power market and the competitive position of geothermal in that market. In addition, direct use options should be evaluated at an early stage. If there is unlikely to be local demand for heat and power and if the cost of getting power to the grid is high, then it is important to consider the financial consequences in prioritizing prospects for development. The evaluation of direct use revenue streams will need to be modelled separately as the investment and income will be specific to the application, and the potential market (e.g., crop drying, fisheries, dairy, spas).

An important factor in both the technical and commercial evaluation of prospects is that the assumptions can change through the exploration cycle. The process is iterative because of the uncertainties of the resource and the market for the energy.

Key Lessons:

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[10] EAGER developed two papers on the principles and the use of financial modeling for business planning. These papers can be accessed on www.eagerfacility.com.

- When analyzing the commercial viability of a geothermal prospect, an integrated and iterative approach involving technical, commercial, regulatory, and policy considerations is required.
- Both technical and commercial personnel should be involved in the analysis of the commercial viability of the resource in the context of the proposed direct use application(s).

7. Geothermal in Power Markets

It has perhaps been an assumption in the geothermal sector that there will always be a paying demand for any power produced by geothermal, and that barriers are entirely political or regulatory. However, power markets are changing both internationally and in East Africa thanks to technological change. Utilities, as the buyers of electricity on the grid, face increased risks in the changing market and this will impact on their power procurement strategies and therefore on the market for geothermal energy.

In the five countries covered by EAGER, demand profiles typically show peaks in the evening after sunset, while having low levels of demand during the middle of the day and at night. Tariffs for industrial and commercial customers may reflect this structure to some extent, but generally do little to encourage a reduction in the peak and an increase in the night time load. This is important for geothermal as it has been marketed to-date as baseload generation, but its market size depends on the willingness of end customers (typically the industrial sector) to operate at night, and on the success of the industrial growth strategies of countries. Its market is therefore restricted.

If geothermal is to operate flexibly, it will incur increased costs and will have to spread its capital costs over a lower level of output. However, there is also a market issue as power procurement strategies may not currently reflect the real value of flexible generation, especially as this value will inevitably increase as more variable or intermittent renewables come on line. In some countries it is likely that baseload PPAs may result in obligations on the utility buyer to pay for electricity from a number of energy sources at night when there is inadequate demand, as the agreements will have been awarded on the basis of the lowest price per kWh assuming baseload operation.

The disruption of renewables and small scale energy solution affects both supply and demand in power markets. End customers may choose to reduce grid demand by installing their own solar panels. Off-grid customers may prefer to install off-grid solutions rather than incur the costs of a grid connection. On the supply side, variable renewables such as solar and wind have to date been granted dispatch rights and so other forms of generation are constrained off if there is insufficient demand. For geothermal this becomes important if competing energy sources with dispatch priority such as wind take up a proportion of the baseload at night.

In the longer term the baseload market will also see competition from energy storage. Batteries do not yet have the scale and cost to compete at grid level, but solar power developers in particular are looking at how they can move into the peak demand period and eventually into baseload through demand responsive storage.

A further point affecting power markets is that the increase in market share of variable renewables has resulted in higher system operations costs to ensure the quality and reliability of supply. Traditional evaluations of generation based on the levelized cost of energy are changing to an evaluation based on an optimized system. This will have limited impact on geothermal as a baseload source of power but will increase the value of flexible plants, especially as markets will emerge in the services needed (ancillary services). These costs will vary between markets, and each country has its own market.

Private sector developers are responding to this uncertainty by looking at smaller projects in MW terms but with shorter development times. In sub-Saharan Africa they also recognize the need to consider value added services and local economic development in order to reduce and diversify risk.

The response of the geothermal sector to these rapid changes in power markets does not have to be negative. Firstly, geothermal remains in a strong competitive position regarding the baseload market, in terms of reliability, scalability and low emissions. It does not face the same issues of resilience (and therefore hidden cost) of other energy sources, notably hydro in East Africa. With effective industrial development the baseload market can grow. Secondly, geothermal has the added advantage of being able to help stimulate local economic development through use of heat for direct use as well as power. Thirdly, smaller geothermal projects can support minigrids or local grid stability without exposing utility buyers to the risk associated with large generation projects reliant on guaranteed grid demand. Smaller projects may be able to take advantage of standard wellhead generators to reduce costs and development timescales.

Key Lessons:

- Changing power markets, driven by the low costs of solar and wind and the needs of utilities to balance supply and demand, mean that the geothermal sector has to consider how it can hold its position as a baseload supplier and how the baseload part of the power market can be developed. The promotion of time of use tariffs in Kenya since December 2017 is an indication of how the market can change and can enable power generation from geothermal energy.

8. Geothermal Resources and Economic Development—Potential for Direct Use

The primary focus of geothermal development in East Africa has been on power generation into the grid and therefore on MW of electrical capacity, but actual production remains restricted to the Olkaria field in Kenya. Kenya has also been successful in its development of direct use applications for commercial and industrial uses. Worldwide the direct use of geothermal energy has increased more rapidly than its use for power generation. According to Lund and Boyd (2015)[11], direct use had increased globally by 45% from 2010 to a capacity of over 70GWt. On this basis, there is clearly a scope to view geothermal energy as more than just for grid level power generation.

In countries with rapidly growing populations, such as those in East Africa, local economic development is important for slowing down and diversifying urbanization. In addition, much local economic activity is dependent on energy sources such as diesel or biomass, leading to problems of emissions and de-forestation. Even modest power generation can support mini-grids or improve grid stability and performance in more rural areas, while combined heat and power development represents an effective use of local resources, contributing to improved industrial performance (food processing, crop drying, fisheries), new business opportunities (tourism), and therefore to greater local employment than from large scale power generation alone.

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[11] Lund et al

In EAGER's view, taking this approach to geothermal resources would increase the potential for geothermal to contribute to economic development and allow low enthalpy resources to be considered a higher priority where there is local demand for both power and heat. To this end, EAGER has carried out pre-feasibility studies in Tanzania and Uganda, which have demonstrated clear potential for direct-use applications to contribute to local economic development through, *inter alia*, improved crop drying processes, fish farming, and tourism.

Key Lessons:

- Direct use geothermal (or combined power and direct use) can have a significant positive impact on local economic development in communities in East Africa.

9. Geodata

The realization of value from geothermal energy is dependent on understanding the resource by way of the data. The requirement of government geothermal agencies is the standard acquisition, secure storage, manipulation and interpretation of data through data integration to support expert decision-making for exploration and development. Another key requirement is to enable the effective award and regulation of concessions to private sector developers. The accurate evaluation of geothermal resources is dependent on reliable and consistent data, which is updated speedily as new data is acquired.

Geothermal data in East Africa has been collected over decades, and by a wide range of international and national experts. However, EAGER experience has shown that field intelligence and decision-making expertise from subject matter experts (e.g., geologists, geophysicists, and reservoir engineers) is often not sufficiently linked with government officials, policymakers, regulators and other stakeholders associated with geothermal activities. In addition, there are no standards for data transfer and the data tends to be unstructured, not codified, and in multiple formats.

The proprietary nature of much of the data collected is another potential problem, due to different formats, different emphases, issues related to the non-transparency and so forth. The key to a successful geothermal power development is to disseminate data and decision-making capability more widely while ensuring that truly confidential data obtained from developers is treated appropriately. The goal should be to improve the capacity and decision-making capability of in-country stakeholders by providing them with access to data management systems based on best practices and tailored to their specific geothermal development requirements.

The geotechnical elements of EAGER's work have focused on Tanzania and Uganda, and the findings from geology and geophysics have been captured digitally. EAGER has established data transfer standards for this newly acquired data and has allowed for both the official UTM Arc60 datum in addition to the WGS84 datum, which is now most commonly used in the field.

While geographical data is necessarily held in a Geographical Information System (GIS), the geothermal sector has typically relied on spreadsheets for data storage and manipulation. This approach can lead to problems of inconsistency and security. Historically more sophisticated databases have been costly to acquire, implement, and operate but developments in information technology have now made a relational database economic for government agencies.

The tool that best fits the purpose of managing critical information is a publicly-licensed, open source, extended object-relational operational database management system (RDBMS) that includes processing data warehoused “in the cloud”. Factors to consider in selecting an RDBMS include: operating system, licensing costs, interface, database scale, and storage needs for data types other than tabular. Compatibility with current systems is an essential guiding factor in selecting an RDBMS. Additionally, developer experience (i.e., human resource capacity) with the selected system or vice-versa (selecting the developer based on familiarity and experience with an explicit RDBMS) should weigh heavily in the selection process. A true RDBMS is holographic: it allows the geothermal data to be customized in multiple ways, for example: by concession area, by field or reservoir, by political subdivision, or other means.

Key Lessons:

- The realization of value from geothermal energy is dependent on understanding the resource by way of the data.
- Standardized collection, formatting, and storage, as well as the ability to manipulate and interpret data is critical to advancing and de-risking exploration and attracting the private sector.

10. Capacity Building in Government Agencies

EAGER staff dedicated considerable time to developing workshops and conducting training on the technical aspects of surface and subsurface exploration and creating financial models that consider both technical and economic risks. Because it can take 5-10 years to explore and develop a geothermal project, it has become increasingly difficult for agencies to rely on short-term international consultancy studies, as longer-term plans and decisions need to be based on continuous data acquisition and interpretation.

Geothermal experience and skills are limited in East Africa except for Kenya. The existing skills are primarily geotechnical: geology, geophysics, and geochemistry. Whilst geotechnical skills may be appropriate for surface studies and surveys, it needs to be supplemented with additional skill sets when either government-sponsored development or the award and regulation of concessions are required. In general, decisions on risk sharing business models lead to a greater role for government and fewer “greenfield” private sector developments, and the greater the role of government relative to the wider skill base required.

The level of human resource capacity in government agencies is a factor in determining the institutional structure for developing and regulating geothermal development. If policy making, regulation and development are seen as three separate activities then the existing human resources may need to be split three ways. Over time the buyer of power from a private sector geothermal plant will also need sufficient understanding of resource and steamfield management and geothermal power plant optimization to manage the PPA.

Even if a “greenfield” private sector approach is preferred, government agencies should have a sufficient technical and commercial skill base in order to evaluate proposals and the proposed electricity price. Commercial skills such as business planning, finance, legal, and project management need to be developed in parallel with the geotechnical capacity. Once a developer advances to the drilling phase then a government agency must be able to undertake technical “supervision” as a regulatory activity, to ensure compliance (e.g. with the African Union Code of Practice for Geothermal Drilling).

When a government agency undertakes a drilling programme, the skill base must increase further as both drilling engineering and skilled procurement need to be integrated into the organization. If the agency acquires its own rigs then by default it becomes a rig operator, which requires different management and business skills. The scale of the agency’s activity rises again under a steam supplier model to include reservoir engineering, steamfield management, infrastructure, construction, and operation.

Tapping international expertise to fill the gap in geothermal skills can be helpful. In particular, coaching and mentoring - in order to improve skills while doing (on the job training) - has had a tangible impact on strengthening target geothermal agencies’ capacity. This approach is also more practical than some longer-term, off-site training programmes that take critical personnel out of the country and away from the projects, effectively delaying those projects until the staff return. Where external skills are essential, such as on the procurement and management of drilling, then a clearly defined cooperation with an in-house drilling engineer and a project manager will facilitate skills transfer.

In summary, depending on the business model chosen, government agencies will need human resource development plans (and budgets) to cover a significant ramp up in skills and activities over a two to three-year period. The core skills are: drilling engineering, monitoring and management, geothermal resource assessment, business planning and financial forecasting, generic project planning and management applied to the specific conditions and requirements of geothermal development projects, negotiation and management of drilling service contracts, environmental engineering, monitoring and management, community relations development, reservoir engineering, and field operations.

Key Lessons:

- Government agencies will need to increase their technical, management, and financial capabilities commensurate with the business model(s) chosen for geothermal development.
- 3rd party consultants can be used both as stop-gap measures, and to provide on-the-job training and mentoring to government personnel.

11. Conclusion

The EAGER programme has identified a range of issues that can enhance and hold back geothermal development. It has also identified several key risks that need to be managed through improved policies, skills, data analysis, interpretation and storage, and decision making. By addressing these gaps, the risk profile of geothermal projects can be improved, and this can complement the available financial risk management mechanisms.

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