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ABSTRACT

Overcoming technical challenges associated with geothermal development – from frisky production wells to fine adjustments of reinjection chemistry – are essential to project success. Effective project management may play a less visible but equally important role in determining the positive impact of a plant. By tuning parameters of the project structure, both the overall quality and contributions to the well-being of the local population can be maximized. This paper covers the factors inherent to geothermal resources that can provide opportunities and challenges for home-country financial, engineering, operational, and supplier participation, despite the highly specialized equipment and folk wisdom required for certain aspects. We discuss strategies to support effective inclusion of in-country resources in project design, procurement, construction, and operation, with the aim of keeping these projects financially attractive, locally rewarding, and successful in the long-term. The Olkaria II Unit 3 project, constructed a decade after commissioning of Units 1 and 2, provides an interesting contrast of two sets of plants very similar technically but executed under different project structures. Other illustrative examples from the Americas, Europe, and Asia regarding local content considerations are provided. Among other factors, we propose that geothermally appropriate and clear divisions of responsibilities between local and foreign parties, integration of local entities throughout all project phases, and specialized knowledge transfer are all shown to assist in project execution and maximize long term benefits to the plant and community. Sections of this paper were originally presented at the 2010 World Geothermal Congress (Wallace et al, 2010) and have been updated with perspectives gained following the recent successful completion of the Olkaria II project.

Introduction

Some things to keep in mind while reading this paper:

- Geothermal Plants are Unique: Hardly any two geothermal plants or projects are truly alike, and this sets them apart from breeds such as gas turbines or diesel generators which can be more standardized. Geothermal resources may contain difficult-to-handle constituents, and conditions change over time. If the resource causes problems, the owner is in no position to upgrade the fuel specification or order a better batch from the supplier.

- A Zillion Parts: Even comparatively small plants are complicated. Each one has a zillion parts and problems inevitably arise during design, shipment, construction, and maintenance. These parts also come from a zillion places. Luckily, geothermal artists have a great capacity for providing solutions. It is essential for projects to have access to a good, practical experience base to avoid serious disruption in the plant’s ability to enter service and continue to serve its owners and power consumers.

- Building Value at Home: Geothermal power plants can be long-term partners for the communities that host them, and not just a distantly owned drive-by industrial facility that shuts down when the tax credits run out. The aim of this paper is to highlight ways that a geothermal plant can be developed to conserve capital and knowledge within the plant’s home region. Ownership and mastery of geothermal technology in the local setting is the best way to bring reliable geothermal power to more and more people who can benefit from it.

This paper discusses characteristic challenges posed by geothermal plant development. It draws on our history with projects around the world, and on the experience of others involved in development as well.

Capable project management is an essential characteristic for successful completion and long-term harmony of a geothermal
these challenges throughout each of three phases of a project: and this paper will explore those possibilities. We will discuss participation and knowledge transfer than for conventional plants, these challenges also represent an opportunity for greater local present new challenges for decision makers. However, some of these challenges are high priority to improve energy security and economy in the face of climate and oil price fluctuations.

Olkaria II Unit 3 is a 35 MW flash unit similar to Units 1 and 2. After decades of operations Kenya has built up significant human capital and experience in this field, and thus when KenGen and the owner’s engineer SKM approached the tender for the third unit some managerial and logistical aspects were modified to improve the process. Mitsubishi Heavy Industries (MHI) acted as the prime contractor, with engineering services provided by POWER Engineers and local contractor services provided by H. Young, similar to the team assembled for Units 1 and 2. The plant was successfully commissioned in 2010. The following observations on project structures – successes and trials - are based on this and similar projects over the past decades.

Project Delivery Methods – EPC? D/B/B?

Project structure is a key cost driver, but not one that shows up on the equipment list. A popular method for constructing plants has been the Engineer, Procure and Construct (EPC) delivery method, where a single contractor is responsible for delivering a “turnkey” product to the owner in accordance with tender specifications (Grimmitt and Vera, 2007). This prime contractor, MHI for Olkaria II, assembles the requisite engineering and construction teams, which perform the detailed design, procurement, construction, and commissioning. The prime contractor provides a single interface with the owner. The contractor may assume liability in the form of liquidated damages for schedule, workmanship, and performance guarantees. This structure is attractive to financiers because a single fixed price is agreed upon and the number of interfaces between the owner and contractor is minimized. As the Olkaria II project was conducted with financing in part from the World Bank, the EPC fixed-price structure was considered the most appealing, and all three Units were contracted under this structure.

Design/Bid/Build (D/B/B) is a competing delivery method. In D/B/B, the owner retains the services of an engineer, who performs the detailed design and then provides tender documents to contractors; one or many. Since the owner and their engineer
have performed the detailed design, they shoulder most of the performance risk, so long as the workmanship of the contractors is acceptable. The owner may in some cases place purchase orders for major equipment such as the turbine and condenser. The Germencik project in Turkey, with Gurmat as the owner and POWER Engineers as their engineer, was executed under a modified D/B/B approach.

An advantage of the EPC approach is the fixed up-front price, which has considerable appeal to owners and financiers, especially under conditions of high volatility in commodities. A disadvantage to the owner may be higher total project costs from the contractor, to compensate for more performance risk and markups on much of the equipment. The EPC contractor may also have cause for significant change orders if the tender document is not well defined. The preparation of tender documents for an EPC bid can take some time, and the detailed design of a plant which repeats the features of the tender specification represents a redundant element. Thus the project timeline can be lengthier than for D/B/B. Since the EPC contractor is undertaking most of the detailed design, owner input to the process is less and thus control over design features, if desired, is weakened and limited to the EPC tender documents. If the owner may be indecisive or tempted to indulge in costly features, relaxing their effort using EPC may benefit them. The owner may also learn a great deal from moving through the EPC process with an experienced contractor.

An advantage of the D/B/B approach, since the owner shoulders additional risk, is that the quoted cost from the contractor may be lower. Since there is only a single detailed design cycle, there may be a shorter schedule, resulting in an earlier online date and lower project cost. Preliminary project estimates based on D/B/B may thus be apparently less expensive than for EPC. This may introduce a pitfall, if financiers insist on a later switch to EPC that drives project costs above levels previously approved. Thus the project delivery method and consequences of switching should be carefully considered very early. The D/B/B approach requires the owner to use a more sophisticated engineering firm, whereas for the EPC approach a smaller supervisory team may be sufficient for the owner. Table 1 summarizes some of the tradeoffs between EPC and D/B/B structures.

Table 1. Summary of EPC and D/B/B Characteristics.

<table>
<thead>
<tr>
<th></th>
<th>Engineer/Procure/Construct (EPC)</th>
<th>Design-Bid-Build (D/B/B)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Familiar style?</strong></td>
<td>Recently very popular because of risk management concerns.</td>
<td>The traditional project structure for utilities.</td>
</tr>
<tr>
<td><strong>Essentials?</strong></td>
<td>Single contractor delivers “turkey” project and guarantees performance.</td>
<td>Owner contracts with engineer for design, and then bids supply and construction.</td>
</tr>
<tr>
<td><strong>Price and risk advantage?</strong></td>
<td>EPC if well defined will limit price risk, though the EPC entity charges more to cover risk.</td>
<td>D/B/B can deliver low price if the project goes predictably; if not, cost increases pass to owner.</td>
</tr>
<tr>
<td><strong>Schedule performance</strong></td>
<td>Can be slower than D/B/B due to EPC specification and wary contract development.</td>
<td>D/B/B can be quicker because of less internal contractual friction and only one major engineering activity, so long as the owner respects the schedule.</td>
</tr>
<tr>
<td><strong>Owner control of design and construction outcome</strong></td>
<td>Limited; the EPC entity has principal control.</td>
<td>High – the owner has continual involvement through their engineering arm executing the detailed design.</td>
</tr>
<tr>
<td><strong>Contracting simplicity for owner</strong></td>
<td>Simple – one EPC entity for the owner to contract with.</td>
<td>Sometimes complex, with separate contracts for engineer, constructors, equipment, etc.</td>
</tr>
<tr>
<td><strong>Overall contracting style</strong></td>
<td>Potentially competitive: a zero-sum game can emerge between owner and EPC contractor.</td>
<td>Potentially more cooperative, without an EPC contract to separate and pit the interests of owner and contractors.</td>
</tr>
<tr>
<td><strong>Neocolonial complications?</strong></td>
<td>EPC contracts tend to attract large firms confident enough to take on the schedule and performance risks. Such firms may not be highly sensitive to the appeal of local technology transfer and local involvement. However, such firms may also be relatively bankable by commercial lenders or non-governmental organizations (NGOs).</td>
<td>A D/B/B project, typically with home-country ownership or direction, can potentially be managed by the owner with a high interest in local involvement and technology transfer. Such an approach may not inspire bankers or NGOs with confidence, however.</td>
</tr>
<tr>
<td><strong>Owner management style required</strong></td>
<td>Hands off. What you get is what you get.</td>
<td>Demand for owner attention and management may be bottomless.</td>
</tr>
</tbody>
</table>

Speed is also useful in estimating. Bidding cycles are always compressed, and the speed to execute accurate estimates is highly valued, as the gap between project authorization and the execution of an EPC contract must be minimized to reduce vulnerability to commodity prices or other economic fluctuations. This is espe-
cially true for geothermal plants with large investments in copper and stainless steel, which have been particularly volatile of late (Stundza, 2008).

The size of tasks may be a challenge for individual local firms. If splits in scope are made, they should be reviewed carefully in order to minimize the number of interfaces. Consider two options:

- Complete project civil design/construction by contractor A
- Complete project structural design/construction by contractor B
- Complete project mechanical design/construction by contractor C
- Complete project electrical design/construction by contractor D
- Complete project instrumentation and control design/construction by contractor E

Option 1 is to award contracts based on discipline specialization. This allows smaller firms to bid on more manageable work packages that may be better suited to their fields. This was the approach generally used for the Bouillante and Olkaria II Unit 1 and 2 projects.

This may be perceived as more hospitable to participation by small local contractors, but in our opinion, this option can create management and construction challenges due to the extremely high number of interfaces between firms, requiring additional coordination by the owner. For example, the coordination of hundreds of pipe supports designed by the mechanical contractor with the design of steel by the structural contractor.

While Olkaria II Units 1 and 2 were successfully completed under this approach, a different tendering strategy was chosen by KenGen and SKM for Unit 3. Consider the alternative presented in Option 2, which is scope divided by physical divisions.

- Substation design/construction by contractor A, handling civil, mechanical, electrical, and instrumentation/controls tasks
- Power Plant design/construction by contractor B, handling civil, mechanical, electrical, and instrumentation/controls tasks
- Auxiliary building design/construction by contractor C, handling civil, mechanical, electrical, and instrumentation/controls tasks
- Steamfield design/construction by contractor D, handling civil, mechanical, electrical, and instrumentation/controls tasks

Option 2 requires multidisciplinary firms, but it may still be possible to keep the work package scopes manageable by dividing the project into separate physical aspects. Separating steamfield and powerhouse is one natural division, and perhaps other aspects such as administration buildings, water treatment facilities, pumphouses or injection piping can be partitioned as well. Ideally, the minimum number of firms necessary participates in design and construction, but scope is divided as needed to suit the size of available organizations. Dividing packages by geography or physical layout areas rather than discipline allows for more efficient organization. This Option 2 approach to minimizing interfaces is more reflective of what was used for Olkaria II Unit 3, and in our opinion was a great improvement.

These considerations need to be evaluated by the owner during the initial project estimation and selection of project delivery methods, since an EPC consortium made up of these firms will build their estimates according to these divisions of responsibility. Similarly, although the selection of contractors, in the case of a D/B/B approach, may be made later in the project than would be required in an EPC project, the detailed design performed by the owner should consider these factors to produce biddable work packages reflective of the capabilities of local firms.

Note that other project delivery methods exist, such as Build-Operate-Transfer (BOT) and Build-Own-Operate (BOO), where a developer, perhaps foreign, may retain control and operate the plant for some period of time after commissioning. Paradoxically in some cases this may offer greater local benefits if the expense and complexity of the O&M infrastructure is unduly costly for the scale of the projects envisioned, unless managed by a foreign firm with an existing support network.

**Project Execution**

Assuming a wise choice of project delivery method and a motivated team of contractors, what are challenges and opportunities that a geothermal project may present for local participation during the execution phase? First, please note that these considerations are highly site-specific; they may or may not be applicable to a given project. The wide variety of countries and resource types where geothermal power may be utilized makes it difficult to offer standardized approaches.
Most geothermal sites generate power from naturally occurring fluids (steam, hot water or brine) that contain proportions of various solids such as silica, or non-condensable gases such as hydrogen sulfide. The interaction of these compounds often creates scale-prone, corrosive, and erosive environments, requiring time-tested and site-specific selections of materials for specialized components such as control valve internals, pump seals and bearings, and other wetted parts. The selection of proper materials is essential for providing a robust plant design. This is not to say that materials selection for geothermal applications is arcane or mysterious, since conventional wisdom on materials is widely available among geothermal plant engineering specialists and many industry suppliers, but it is critical to plant well-being and productivity.

When the engineer works with manufacturers to select the proper equipment, it is important to keep the local representatives aware of the need for specialized options and site support. This can result in some tension if a local manufacturer’s representative, who is not familiar with geothermal projects, attempts to propose unsuitable equipment that is more locally common, say for mining or other industries.

At times there can be a competition between the local representative and the home office of the manufacturer to decide who will handle the order and produce the documentation, as there often is a commission involved, perhaps several percent of the contract price. We have often encountered significant delays in bidding, contract negotiation, and obtaining equipment design documents, for example on miscellaneous pump or control valve procurement, as various parties of the same manufacturer but located in multiple locations in Europe, the U.S., and Asia would vie for control of the contract.

Any long-term successful project also requires the solid support of the local equipment representatives for commissioning and aftermarket support – we have often wistfully hoped that skilled responsive representatives would be available locally rather than need to be flown from Europe or the U.S. However, during the design phase, the demands on the equipment supplier to be familiar with geothermal applications, and to produce very detailed CAD drawings of site-specific equipment that will be referred to over the life of the plant, may be beyond the capabilities of the local representative. Overzealous local representatives taking on too much scope may discover after the initial document reviews that their lack of access to resources will cost the project weeks or months in resubmittals as the factory scrambles to fill the design void.

We suggest that this coordination between manufacturers and their local representatives through the various phases of the project be encouraged and clarified with a win-win structure very early in the equipment bidding phase so that a quality product can be delivered, while also ensuring that the local representative is a good partner for long-term service needs of the plant. Neither party should feel excluded.

Procurement of bulk materials such as carbon, galvanized, and stainless steel piping and structural members offers a good opportunity to maximize local content. What can be sourced in the home country? If not available locally, do local suppliers have a good relationship with an adjacent (Gulf country?) distributor, and can they obtain these at globally competitive prices and within a tight schedule? Local firms with these logistical links in place have more reliable information for preparing the initial bid and permit smoother project execution.

For the Olkaria II project, much of the carbon steel piping supports and some vessels were able to be sourced through Kenyan firms, resulting in cost and schedule savings. Conversely, the fact that the appropriate grades of stainless steel, certain structural members, and pipe support specialty components were not locally available was identified early and allowed appropriate arrangements and lead times in the schedule for those to be procured overseas.

Skilled local contractors can serve an important role early in the project if their wisdom can be tapped during the design phase. For the Darajat III project in Indonesia, constructability reviews held between designers and contractors identified a potential improvement in the cooling tower.

During work on the previous unit, the extensive labor involved with the cast in place concrete cooling tower contributed to significant costs and may have been a factor in a fatality during construction. The construction manager suggested that a preset design would be possible, which would allow less formwork and less labor activity required in the dangerous area high above grade.

The cooling tower manufacturer agreed to adjust their design to accommodate this, at a modest cost due to the early notice. The tower was constructed efficiently and safely using this new technique. Having local participants integrated into the design decisions via formally structured events like constructability reviews allows opportunities for material, labor, or safety improvements applicable to local conditions to be identified sufficiently early to be acted upon.

Geothermal projects often require significant permitting efforts due to land and water use concerns, air quality monitoring, wildlife and access issues, fire safety, and other aspects of interest to local administrators. A local engineering firm familiar with the process and able to smoothly coordinate with the prime contractor and local agencies is a valuable resource.

For the Miravalles III project in Costa Rica, a local firm was contracted that was able to take the construction documents generated by the EPC contractor and transform those into the appropriate format and Spanish language for permitting packages. Firms with capabilities such as these are valued partners and should be identified early in the project.

**Geothermally-Appropriate Divisions of Responsibility**

A key tool to aid cooperation between contractors is to identify the division of responsibilities for all phases from project estimation, design, procurement, and construction. A matrix identifying these should be exhaustively detailed, and preparation of this is a way of thinking in advance of ways that the best strengths of in-country participants can be best applied in project execution.

In our experience – which is happily extensive, but still not comprehensive or authoritative in all cases – certain kinds of project activities seem to fall most handily, productively and accountably onto the hands of particular kinds of project enti-
ties. Table 2 and the following discussion recount some of our observations and experience with responsibility divisions from past geothermal projects.

**Prime Contractor Areas**

There are some components where it is generally efficient that the prime contractor retains responsibility for the design and procurement. These include:

- Design/supply of key power block components: turbine, large equipment foundations, circulating water system including condenser; cooling tower, large pumps, and switchgear. These products are often sourced internationally or from the prime contractor directly, if they happen to be an equipment supplier such as Mitsubishi Heavy Industries or Fuji. The specialized knowledge for interconnection based on past experience is essential and it may invite lengthier engineering than warranted, construction delays, or serious operational difficulties if this is outsourced.

- Powerhouse layout and conceptual design. Useful to be done by the prime contractor, since they will have a better recognition of space requirements for overhaul or maintenance.

- Specialty (engineered) pipe supports or items such as spring cans, snubbers, or expansion joints. These are often not available locally, or the relationships of stress analysis and the need for specific products instead of less expensive substitutes may not be appreciated by local firms.

- Plant control system. A note to owners: the geothermal development process consumes significant time for resource exploration, tender specification preparation, bidding negotiation and other phases. Advances in electronics technology can outstrip the pace of power projects. Commonly control system specifications are obsolete, through no fault of the owner, by the time the detailed design is performed, and adherence to the specifications may not be appropriate or even possible. During the Olkaria II and Miravalles III projects we encountered this; in the first case for aspects of the steamfield controls, and in the second for the plant control system. In both cases constructive discussions between the owner and contractor regarding the latest state of the art equipment helped bridge the gap between the obsolete specification requirements and the currently available commercial solution (McAuliffe and Cole, 2001). This is a common occurrence and should be anticipated.

- Control valves and manual valves. Due to special materials which may be required, these may be unique to a country without previous geothermal projects. In such a case, it may be advisable for these to be sourced internationally by specialists experienced with the particular application.

- Field fabricated tanks; sometimes vessels if shops are qualified to the ASME or PED certifications.

- Procurement of carbon steel steamfield and plant piping.

- Powerhouse detailed design such as cladding, architecture, and plumbing. Local firms often have a better grasp of local codes and standards, aesthetics, and materials, fixtures and fittings available locally and economically. They may be well suited to take a powerhouse conceptual layout and transform it into a detailed design. At the Germencik project in Turkey, local designers performed the complete conceptual and detailed design and procurement for admin and warehouse facilities – a successful illustration of the “Option 2” slicing of the plant contracts.

- Bulk pipe supports, bolting, electrical bulks. These are good candidates for local sourcing, so long as the potentially corrosive aspects of the geothermal fluids and the needs for specialized coatings in some cases are taken into account. In many cases steel must be galvanized and copper wiring must be supplied tinned, for protection from atmospheric H.S. At Olkaria II a significant local effort was used to galvanize fittings and steel used on the project. Identifying the availability of hot-dip galvanizing facilities in advance is helpful. As existing industries strain hard to provide these services, this may be a business opportunity.

- Pipe fabrication and testing. For Olkaria II H Young was able to fabricate much of the large-bore stainless piping in house, resulting in better QA than field fabrication. It is important at an early stage to identify between the designer and fabricator the level of detail required on design drawings and check that segregations of shop and field fabrication are appropriate.

- Structural steel. For the Germencik project, at the initial design stage the local contractor provided the designer with a detailed list of structural shapes available economically in the local market. The designer then based most selections from the list, minimizing use of difficult-to-obtain shapes.

- Security. A strong security presence at the site is essential for maintaining site safety and preventing losses of essential material or equipment that may take months to replace. At the Olkaria II project many of the site guards were hired from the surrounding Maasai communities, and they proved to be excellent at strictly regulating access to the site.

**The Grey Area**

Several pieces of equipment fall into a grey area, where either the prime or local contractors may take responsibility for design and procurement, but some caution should be observed. These include:

- Heating, ventilation, and air conditioning systems (HVAC). Local contractors may have performed this type of design, and local materials may be available. However, all parties need to recognize that the HVAC systems - components and redundancy - are the principal line of defense against the
Knowledge transfer opportunities for laborers, operators, and maintenance personnel should be well defined from the start of the project. This training should be closely synchronized with the construction schedule: too early and suitable hands-on training will be unavailable; too late and valuable opportunities during commissioning will be lost. In addition to site training of operators, the training program should include provisions for specialized courses on major equipment such as the turbine, generator, and control system at the manufacturer’s locations. These training programs can frequently be augmented by site visits with free training and a dose of marketing given by equipment representatives, and owners should make the most of such opportunities.

### Long Term Relationships

Geothermal plants have closer relationships with adjacent communities compared to conventional power plants. The underground resource is never perfectly characterized, and will change over time as fluid is withdrawn and injected. It is likely that additional wells will be drilled or plants added as more data are gathered, resulting in additional jobs for the local workforce. Natural degradation of piping over time due to corrosive/erosive effects of geothermal fluid may result in more frequent small upgrade and maintenance projects than for conventional fossil plants. The changing nature of the resource may provide opportunities to modify non-condensable gas extraction systems, such as at Miravalles (Moya and Sánchez, 2005), or fluid injection strategies such as at the Geysers (Stark et al, 2005). The dynamic nature of a geothermal field means there is considerable value in the relationships between owners and local contractors continuing long after commissioning.

A positive relationship an owner can maintain with the local community may extend to the expansion of the plant into a “resource park” that provides other services, such as district heating, recreation, and health opportunities, exemplified at the Svartsengi plant (Thorolfsson, 2005). Plant tours, energy education programs, and cooperative research programs with local universities are a way to motivate general technical aptitude in students, build capacity of future employees, and foster good relationships with the community.

Some of the most important keys to long-term success are local champions. These are something international prime contractors cannot build; as it is essential to have more than a figurehead several thousand kilometers away or a temporary foreign consultant. Project champions need to be national, local, and committed to the project success, armed with sufficient authority and resources.

Despite good technology, over time challenges inevitably develop, and without champions the best designed and constructed plants will suffer from the ravages of nature. Such individuals ideally have a solid technical
background, and can build on their education during the design, construction, and commissioning processes. Champions can gain additional expertise through opportunities such as Iceland’s remarkable United Nations University (UNU) Geothermal Programme, which offers specialized training in geothermal exploration, drilling, reservoir engineering, and utilization, tailored for the individual and country (Fridleifsson, 2005). With scores of graduates from the UNU, Kenya and their subsequent geothermal successes provide a prime example of the value of such programs. Compact, professional-accessible geothermal programs are too rare, and increases in enrollment and additional programs will be sorely needed if there is to be considerable expansion of geothermal into new regions. Attendees at these institutions should be prepared to help disseminate knowledge upon their return to their team and encourage other new entrants to the geothermal field.

Conclusions

Geothermal projects offer many ways to build relationships between the plant and local communities, and specific strategies have been presented to structure and maintain these. It is possible to neglect these concepts and build a technically superior plant, but foregoing these opportunities will result in lower long-term reliability and community benefits. Key strategic decisions must be made early in the plant development process. Essential considerations include project structures that offer avenues for greater local participation, discussions that result in comprehensive and achievable division of responsibilities, continuous knowledge transfer, and the importance of local champions. Geothermal plants offer reliable renewable energy, with users secure in the knowledge that, unlike many other industrial facilities, it cannot be moved with economic winds of fate. A well executed geothermal project should be a source of pride, benefit, and responsibility for the community as a valued local asset.

References


