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GEOTHERMAL – OPPORTUNITIES TO SUPPORT DELIVERING THE ENERGY FOR THE FUTURE

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ABSTRACT

Opportunities to deliver geothermal energy projects require a strong and well managed approach in order to unlock the potential for this long term sustainable energy resource. Successful geothermal developers have recognised that expertise in exploration, development and sustainable management of reservoirs must be combined with comprehensive risk management, a procurement approach seeking the maximum performance and best total cost of ownership based on economic fundamentals and sound and focused project delivery disciplines.

Key success factors related to the procurement and project delivery of geothermal developments include:

- Internal organisational or contracted in expertise in exploration, development and sustainable management of reservoirs in order to manage risks and achieve the required performance.

- Ability to manage the development risk either by balance sheet funding or project finance, which has implications for the procurement model employed and the financial backing required for geothermal exploration, development and ongoing operations.

- Best total cost of ownership (life cycle) economic performance is achieved through specification, design and constructing for station operability and maintainability, while matching the most economically efficient technology available to the geothermal resource and the capacity proven at the time of project commitment.

- Procurement and project delivery disciplines and the careful selection of project participants and incorporation of incentives and penalties provides a level playing field for competitive technologies, energy delivery, the shortest possible project construction time and achieving the required performance and quality specification.

- Effective organisational and project leadership for developing significant infrastructure projects in line with the above, particularly in managing multiple stakeholder interests, contributions from external and internal experts, the challenge of managing and developing organisational capability in the midst of project delivery, collaboration of virtual teams working in different locations or time zones. Real success may be gauged not only by the outcomes of the individual project, but in the track record achieved, the attraction of world class expertise and the organisational development and learning that is developed over time.

By a holistic consideration of economic value, focused on managing risk and matching the project procurement and delivery approach to the geothermal resource, significant economic value is unlocked by development projects. This paper notes the potential opportunities and risk mitigation strategies in procurement and project delivery that will assist in best providing the energy of the future from geothermal resources.

1. INTRODUCTION

1.1 Geothermal Opportunities

Opportunities to deliver geothermal energy projects require a strong and well managed approach in order to unlock the potential for this long term sustainable energy resource. Successful geothermal developers have recognised that expertise in exploration, development and sustainable management of reservoirs must be combined with comprehensive risk management, a procurement approach seeking the maximum performance and best total cost of ownership based on economic fundamentals and sound and focused project delivery disciplines. Examples from geothermal developments are presented to illustrate successful approaches to risk management, procurement and delivery of geothermal development projects.

1.2 Characteristics of Geothermal Energy

Geothermal is an obvious and economically favourable energy source for the future with an exciting convergence of sustainable, renewable energy with reliable, base load production that is not subject to the unpredictable variations of climate (wind, rainfall).

Geothermal reservoirs provide sustainable energy over extended time frames when well managed, with New Zealand resource management consent (permitting) requiring sustainable operation to be demonstrated by reservoir modelling for 50 years. Varying carbon emissions are produced by the use of geothermal fluids (the degree of carbon emissions is reservoir dependent) but the electrical energy produced has (i) less of a carbon impost than gas or coal fired thermal plant and (ii) is without the non-renewable aspects of fossil fuelled generation.

1.3 Geothermal Energy – Direct, Co-generation, Industrial Synergies

Geothermal has also been used as a direct energy source for clean steam and heat when industrial users are co-sited with a geothermal resource. Examples are the long term use of geothermal energy from the Kawerau field by industrial users such as Norske Skog Tasman and SCA, and the supply of geothermal steam by Contact Energy from the Tauhara field to the Carter Holt Harvey timber processing plant in Taupo.

Co-generation has an obvious economic advantage where industrial users are sited on a geothermal reservoir given multiple value streams are being provided from common infrastructure and industrial land zoning is less prone to resource consenting issues (Armstrong, Wilson, Whaley, 2001). However, careful management of industrial stakeholders and thorough geoscience modelling of subsidence is advised, as opposition may result with regard to that issue. Geothermal co-generation offers an industrial user electricity from the power plant, clean steam from the steam separation system or lower grade process heat to reduce the cooling system parasitic load required by the power plant process. A further synergy with industrial users and power plant developers is the opportunity via long term power purchase agreements or similar contractual instruments (e.g. contract for differences or power price hedge contracts) to secure long-term power price certainty for the industrial user, and to secure the project revenue stream for the power plant developer.

1.4 Geothermal Generation and the Role of Transmission as a Connection to Market

Electricity generation has been the most common use for geothermal resources worldwide, and a long history exists in New Zealand dating back to the development of the Wairakei field in the 1950s. Access to transmission and an economic connection to demand is an essential enabling factor in geothermal generation development.

Depending on the scale of generation development this may be via a distribution, sub-transmission or transmission connection, but it is most common that due to minimum economies of scale, a sub-transmission or transmission connection is favoured (Armstrong, Wilson, Whaley). In cases with smaller modular generation units, co-siting with a large industrial user may allow direct supply. However, technical and cost difficulties with electrical fault level and interaction with the industrial motor loads typically rule this out for large generators. Transmission is the most common connection method, but in some cases sufficient sub-transmission capacity is available (limitations are local demand and network capacity to support the magnitude of generation proposed). In all cases a detailed connection study is advised, in order to avoid technical issues or external network constraints impacting on the production of the generator. The base load production characteristic of geothermal power plants is particularly susceptible to economic value erosion by transmission constraints.

A significant risk to the project programme is the need for easements and resource management consents for the transmission connection, requiring positive engagement with landowners and compensation for land taken if this is to be completed in a timely manner. This is best managed by a proactive approach to both land access negotiations for easements and resource management consenting, preferably with a significant lead time ahead of grid-on date to allow for delays. Similarly, achieving transmission connection and commissioning of new generation power plant requires a focused and well prepared approach to expedite grid connection and commissioning of new power stations. In New Zealand Transpower (NZ transmission grid owner and NZ Electricity Market system operator) has very detailed connection and commissioning requirements and has many grid development priorities competing for limited resources.

The cost of the transmission connection may be a factor in determining the viability of the generation development, if the connection to the transmission grid is remote from the geothermal resource. The key factors are distance, economically optimised operating voltage (linked to cost and transmission losses), the degree of redundancy in transmission circuits required and the connection configuration to the grid. Line routes have the added cost of compensation for the transmission corridor easement by negotiations with landowners. The economic signal to the project is to (i) maximise the scale of the initial development to offset the transmission connection cost and (ii) ensure that the initial installation is economically future-proofed with sufficient capacity and allowance for expansion that is foreseeably required in subsequent stages or ideally, the ultimate expected capacity of the resource.

2. SUCCESS FACTORS FOR GEOTHERMAL DEVELOPERS

Successful geothermal developers have recognised that expertise in exploration, development and sustainable management of reservoirs must be combined with comprehensive risk management, a procurement approach seeking the maximum performance and best total cost of ownership based on economic fundamentals and sound and focused project delivery disciplines. With the right contacts and business relationships, significant projects or business opportunities can result from bringing stakeholders together in areas of mutual interest. This section will focus on the key success factors in effectively managing risk to the developer in terms of organisational capability for project delivery.

2.1 Geothermal Developer Organisational Capability

Organisational or contracted in expertise in project development and delivery, allied with strong operational experience to inform technology equipment and functional specifications is essential to manage risks and achieve the exacting goal: best total cost of ownership (life cycle) economic performance from the available resource, sustained over the long term (Armstrong, 2009). Where significant sequential developments are planned, it is beneficial for owner-developers to build internal project procurement and delivery capability. Lessons learnt from operations and through sequential project delivery can therefore be incorporated into improved specifications and project delivery approaches. Organisational capability can be built starting from a base of geothermal operations and maintenance capability, or in the case of a start-up developer, provide the internal expertise necessary for ongoing operations. In either case it is normal for external expertise to be sought to supplement internal capability, for specialist advice or to augment areas of internal weakness.

2.2 Effective Leadership is Essential

Effective organisational and project leadership is essential for developing significant infrastructure projects in line with the above objective, particularly in managing multiple stakeholder interests, contributions from external and internal experts, the challenge of managing and developing organisational capability in the midst of project delivery, collaboration of virtual teams working in different locations or time zones. Real success may be gauged not only by the outcomes of the individual project, but in the track record achieved, the attraction of world class expertise and the organisational development and learning that is developed over time. The outcomes of a project benefit greatly from a "best for project" contractual and working relationship between quality organisations and teams (Owner and Contractors, sub-contractors) coupled with a cross-functional involvement and a strong focus on continuous improvement and innovation.

The following points briefly outline issues that contribute to project failure and contributors to project success.

2.2.1 Issues Contributing to Project Failure

- Lack of project definition at the time contract let (particularly applicable to EPC).
- Unproductive owner/contractor relationship.
- Too much project risk placed with the contractor and not covered by suppliers and subcontractors.
- Poor communication within consortium.
- Inexperience of contractor parties with geothermal projects and working together.
- Contractor underbids and/or becomes overwhelmed leading to desperation and poor performance.
- Critical equipment not operating as expected, contributing to commissioning delays or poor performance.

2.2.2 Contributors to Project Success

- Good communication and cross functional appreciation of value contribution between all parties.
- Productive relationship between Owner and Contractors, ideally in a collaborative, best for project approach.
- Design risk mitigated by Owner's high level of technical expertise, resulting in well formulated interface definitions and specifications.
- Continual owner engagement through all phases of the project.
- Appropriate economic and behavioural incentives provided for all key parties.
- Good project leadership, planning, organisation, scheduling, cost control.

2.3 Focus on Project Objectives

Focusing on the key project objectives for a geothermal development project is essential at all stages in the project, but the greatest benefit is obtained during project definition, conceptual design of the procurement and project delivery strategies. Recommended objectives to maximise the value obtained from the project are

Obtaining the best total cost of ownership (life cycle) economic performance through:

- Specification, design and constructing for station operability and maintainability;
- Shortest possible project construction time;
- Achieving the required performance and quality specification.

The lifecycle economic objective has multi-dimensional facets and involves careful consideration of a wide range of factors across many disciplines (engineering, operations, compliance, economic, commercial), within the context of a geothermal development where uncertainties related to fuel properties (enthalpy, pressure, chemistry and interactions with plant materials) make optimising difficult. An emphasis on all these objectives is important in the context of maximising output from the sustainable use of a renewable fueled power station with at least 25 years economic life and design life of many components of circa 40 years. The long term view adopted is in line with resource consents granted for 35 years and sustainable operation of the reservoir proven for at least 50 years. The reward is unlocking a developer margin through sustainable and long term utilisation of the geothermal resource.

3. PROCUREMENT APPROACHES FOR GEOTHERMAL DEVELOPMENT

The choice of procurement approach is chiefly about best managing and allocating risk related to the performance of the development. The key generation project risks to be managed are total project cost, time for completion, quality of specification, measured against the economic drivers of best total cost of ownership balanced by maximised output performance annual energy, long term availability, reliability, operability and maintainability.

3.1 Procurement Model Alternatives: EPC versus EPCM

A geothermal developer's ability to manage the development risk either by balance sheet funding or project finance has implications for the procurement model employed and the financial backing required for geothermal exploration, development and ongoing operations. The risk exposure to the developer from reservoir drilling should not be underestimated, and often is greater than the risk involved in the power plant delivery. Typically, project financed geothermal developments restrict the choice of procurement to lump-sum turnkey approaches (EPC - Engineer, Procurement, Construction), since this provides funding organisations a higher degree of certainty on cost, time and specification delivery. This is because the EPC contractor is responsible for all aspects of design, construction and procurement. However, it must be recognised the under the turnkey approach the EPC contractor has risk capped at a percentage of the contract sum; by force majeure clause, liquidated damages rates and caps, exclusion of consequential damages, test tolerances, etc. Ultimately the Owner bears the majority of lifecycle and economic risk for the project. Recent successful EPC projects include Kawerau[1], Nga Awa Purua[2], Kamojang, Stillwater, Salt Wells, Thermo. Unsuccessful EPC projects include Salton Sea Unit 5 and Darajat 3.

Balance sheet funded projects have more latitude to consider non-lump sum methods of procurement (e.g. traditional separate design, bid, build, alliances or cost reimbursable forms), and this paper will consider EPCM (Engineering Procurement, Construction Management) as one such alternative.

An EPCM contract is a professional services contract where the EPCM provider manages engineering design and procurement and the construction contracts on the Owner's behalf. There are advantages in selecting EPCM (Engineering Procurement, Construction Management) as an alternative to EPC, but it must be acknowledged that the risk allocation between the two forms is radically different (Loots, Henchie, 2007), since the Owner/Developer carries the overall responsibility for design, cost, time, quality and overall performance. Successful EPCM Projects include Salton Sea 3 and Gunung Salak, both by Unocal, an owner-developer with significant in-house project delivery capacity. The diagrams below show the difference in the contractual arrangements between EPC and EPCM.

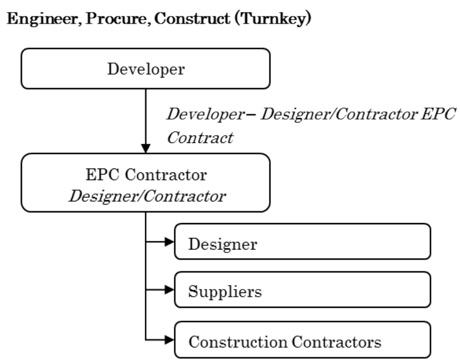

Figure 1: EPC Contractual Arrangements.

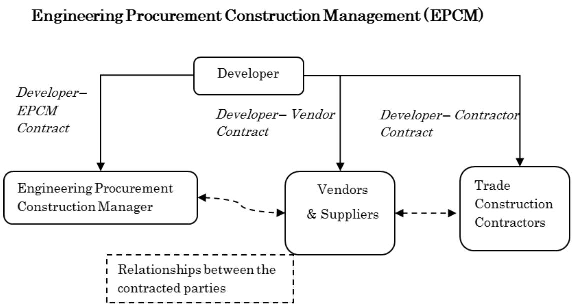

Figure 2: EPCM Contractual Arrangements.

3.2 Overview Comparison: EPC and EPCM

EPC	EPCM
Construction risk is transferred to Contractor for a premium. Schedule and performance risks capped at 10% contract value. Risk of generation forgone due to unavailability is partially mitigated by delay damages up until handover, then assumed by the Developer. Key decisions locked in contract signing Life cycle performance highly dependent on specification and quality assurance processes. Developer's lifecycle performance objective not aligned with Contractors cost minimisation objective. Less Developer resource required and simple contractual interface. Whole of plant guarantees provided by EPC wrap via LDs, plant performance. Health and safety is EPC contractor led.	Total construction risk is not contractually capped. Increased influence over design optimisation and equipment selection to achieve life cycle objectives. Greater flexibility to optimise design outcomes during project implementation. Improved knowledge transfer from design and procurement processes to the Developer builds lifecycle assessment capability. More direct access to technology vendors. Requires greater Developer resources. Developer's performance risk is partially mitigated by guarantee provisions in contracts with EPCM provider and equipment suppliers. Health and safety is Developer led, providing direct enforcement of safety requirements over all contractors.

An EPCM approach may be preferable to Owner/Developers with sufficient in-house or externally sourced expertise, given the opportunity to participate in the optimal selection of design and procurement alternatives within the delivery phase of the project. The proviso is that the selection of all project participants (EPCM provider, OEM equipment suppliers, construction contractors) is especially important to manage risk and achieve a successful outcome. As was noted earlier, the lion's share of the economic performance risk for a geothermal power plant (reservoir drilling outcomes and power plant lifecycle cost) is borne by the Owner/Developer. Therefore the capped risk protection afforded by an EPC power plant contract, while valuable, should not be overvalued in comparison to an unbundled EPCM delivery in the context of the overall risk equation for the project.

3.3 Tendered EPC Procurement Process

The tendered EPC power plant procurement approach has the advantage of maximising the economic benefit obtained

[1] Kawerau Geothermal Power Station (located in the eastern Bay of Plenty) was handed over in August 2008 at a cost of NZ$300 million and at that time, at 106MW (net), was New Zealand's largest single geothermal development in over 20 years.

[2] Nga Awa Purua Geothermal Power Station (located 15 km north of Taupo) was handed over in April 2010, at a cost of NZ$430 million and at 140MW (net), is the largest single cylinder geothermal turbine internationally.

from a competitive process, protecting an Owner/developer from direct uncapped exposure to project delivery risk and, by careful selection of power plant contractual interfaces, allows alignment of risk with those parties best placed to manage it. The following are key considerations related to the procurement approach employed:

i. An open, competitive tender process benefits from the widest practicable participation – hence engagement to invite key OEM or EPC Contractor participants to sell the project is advised, in order to avoid perceptions of Owner bias towards any particular technology or past service provider.

ii. The EPC approach is typically selected to give comfort on risk management for significant projects for Owners without significant in-house development expertise, or to satisfy project financing requirements. Selection of contract form should consider familiarity and accepted practice among the counter-parties; for example FIDIC is commonly accepted internationally.

iii. A performance based specification (outcomes and performance levels rather than prescriptive detailed specification) offers advantages in allowing scope for innovation and optimising the key design trade-offs by tenderers, and offers the owner/developer flexibility in the selection of technologies (flash, binary). A performance based approach defines the input and output interfaces and geothermal fluid characteristics and provides design limits and the required performance for the power plant and each major component/system (Gray, 2010). However, rigorous design review and HAZOP is required by experienced engineers to ensure the designs proposed are acceptable and in compliance with specifications. Specification for performance, operability and maintainability requires involvement of geothermal operations staff and engineering specialists.

iv. Power plant tender evaluation basis should be disclosed to participants. As an example, evaluation on a life cycle economic basis (total cost of ownership including O&M) may include adjustment factors specified for key variables and evaluation using a discounted cashflow model:

- Life cycle capitalised value of additional power output ($/kW) for process optimisation tradeoffs related to greater power output and levels of parasitic load within the plant.
- Production and injection fluid volumes requiring well make-up and pipework capacity.
- Time for completion.
- Generation between first commissioning and full handover.

v. Selection of key interfaces is critically important, and should be considered on a case-by case basis and include consideration of how expertise may be brought to bear to manage risk. Selecting the Power Plant scope interface to include the steam separation system[3] aligns the Contractor's ability to design to high levels of steam purity (often resourced by specialist consultancies) and the Contractor's warranty obligations for the performance of the turbine.

vi. Rigorous analysis of bids may require a team of internal and external specialists, based locally or internationally, covering the spectrum of economics, legal, commercial, risk, declared and undeclared deviations to specification, project capability & proposed trade contractors and design providers. In order to evaluate, value and process this analysis a systematic approach and well considered risk weighted evaluation framework is needed. Understanding the project capability on offer may require reference plant site visits and extensive analysis and negotiations to understand bids, resolve deviations to specification and ensure bidder's proposals were acceptable.

In summary, a competitive open tender on a life cycle economic performance basis provides the advantage of a level playing field for technologies to compete and innovation is encouraged.

3.4 Negotiated EPC Procurement Process

A negotiated procurement process may offer advantages over open tendering where:

i. A previously tendered project provides a basis to negotiate an acceptable commercial outcome. In this case normalisation for changes in scope, specification and design parameters and escalation factors (exchange rates, movements in prices of raw materials and equipment) will be required. In order to not blur the normalisation comparison between the two projects, specification changes should be carefully considered, and a separate list of potential scope changes to be priced and evaluated separately could be used to ensure departures from the first project scope may be economically evaluated.

ii. Project drivers to complete the project as soon as possible for market advantage may make negotiation more attractive.

iii. Insufficient depth of providers may make a open tendered process impractical or market dominance by a small number of providers may make the prospect of tendering costly and unattractive to bidders.

A negotiated procurement approach has the advantage of allowing an extended period of front-end engineering, giving inspection into a number of key aspects of a geothermal project:

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[3] Typical international practice has the power plant interface at the turbine inlet, which aligns the steam separation system scope with the geothermal steam field developer.

- Plant concept and process engineering to consider alternative power cycles and achieving an optimal match to the reservoir enthalpy, power plant inlet pressure and maximising utilisation of the proposed power plant equipment.

- Confirmation of the plant concept and process design early in the procurement process may allow the order of turbine and generator rotor forgings to secure these long-lead time items under a prevalent time-constrained suppliers market.

- Geotechnical investigations at the power station site may be completed as a front-end engineering activity, allowing the contractor to determine the scope required to satisfy themselves of the ground conditions before submitting their power plant tender. This provides greater transparency on ground conditions risk and may reduce risk pricing for this component. It is advisable for the Owner to engage a specialist geotechnical consultant to ensure an appropriate minimum scope is used and to review the interpretation of results.

A successful example of a negotiated EPC project is Mighty River Power's Nga Awa Purua Geothermal Power Station: delivered by Sumitomo Corporation with major equipment supply by Fuji Electric Systems, handed over in April 2010 at a cost of NZ$430 million and at 140MW (net), is the largest single cylinder geothermal turbine internationally.

3.5 Procurement and Risk Challenges May Favour Consideration of EPCM

Geothermal development provides a significant challenge to risk management in project delivery because of the interaction between reservoir characteristics, development risk, technology selection and procurement strategy. Assuming that the Owner/developer is not limited by project financing constraints and has sufficient expertise at their disposal and risk appetite for an EPCM approach, there is the potential to deliver well managed projects at lower cost and with better lifecycle economic performance than via EPC, since the EPC risk margin is avoided. However, strong project delivery discipline and careful selection of project participants for competency, capability and compatibility is needed to ensure the project outturn is below that expected of EPC.

As discussed in the previous section, similar factors that motivate the choice of a negotiated EPC process may also favour consideration of EPCM, to deal with difficult procurement situations where there are insufficient EPC providers for tendering. Use of a FEED study (concept design, technology selection and cost estimates, with the objective of identifying credible designs suitable for the resource in question) to investigate the performance and performance of technology options prior to committing to a procurement process has a number of advantages, allowing the project and reservoir specific trade-offs to be examined and valued. Since committing to an EPCM delivery may be dependent on finding compelling economic and risk management advantages over EPC, the FEED study has a strong role to play.

Other aspects relevant to considering an EPCM approach are:

- The bargaining position of EPC providers in a tight market may make the risk premium for EPC unattractive.

- Obtaining a well bounded understanding of the costs of the project prior to procurement by either EPCM or EPC is difficult. Within the P50 pricing band of +30%, -20% achievable during the tight time constraints of the FEED, it may difficult to declare a clear economic advantage within the technology options considered and to estimate the potential EPC margin that may be applicable.

- The contractual obligations and proper incentivising of the EPCM provider will require careful legal drafting. The following principal potential liabilities should be covered: performance of the design work, preparation of the budget cost estimate, preparation of the estimated duration of the work, management of the procurement and construction contractors, co-ordination of the design and construction between construction contractors. Incentivising the EPCM provider for early completion via a bonus is a common method (Loots, Henchie 2007).

- The EPCM approach may be better matched to geothermal developments given the significant reservoir parameter uncertainties that persist into the project delivery phase, until production and injection well drilling is advanced. Greater flexibility to optimise design outcomes during project implementation is provided by EPCM and within limits (e.g. delays to the project schedule and procurement of equipment) adjustment of design parameters may be more cost effectively handled under EPCM rather than EPC.

- The increased influence over design optimisation and equipment selection to achieve life cycle objectives afforded by EPCM may provide improved outcomes compared to EPC.

Case-by case evaluation of the suitability of EPCM is required, however the model does suggest advantages for geothermal development projects, having been employed successfully by Unocal in the past and more recently by Guris for the delivery of the 47 MW Germencik project (EPCM by Power Engineers Inc., Veizades & Associates, Geologica) and the Hudson Ranch 1 50 MW project by GeoGlobal Energy.

4.0 ECONOMIC MATCHING OF TECHNOLOGY TO GEOTHERMAL GENERATION OPPORTUNITIES

Selection of power plant technology matched to the resource characteristics (temperature, pressure and enthalpy) and scale of fluid take is an obvious key consideration in terms of finding the most economic power plant for each project. This section provides a general guide to matching power plant technology to the resource available, but market variances translated in to power plant price can be significant depending on factory volumes and supply side capacity. Therefore, in any individual project, completing a resource specific FEED study including procurement pricing or testing the market via open technology tender evaluated on a performance basis is an essential due diligence step before contracting for power plant.

- As a generalisation, on higher quality resources (temperature, pressure and enthalpy), where less than full injection and evaporative cooling is allowed and where developments have sufficient scale, the choice of steam flash plant is favoured in economic and efficiency terms. Care with silica deposition limits and control approaches (e.g. pH modification) is required particularly with multiple flash cycles (Gray).

- Binary plants are economically favourable for smaller scale developments and for lower enthalpy resources – up to 200°C may be used as a rule of thumb (Emerging Energy Research, 2009), however a more detailed concept study and process modelling is required on a case by case basis.

- Combined cycle power plants (e.g. Upper Mahiao, Mokai I and Mokai II projects) have thermodynamically better efficiency than binary on higher quality resources but the choice of power plant design appears driven by the EPC provider Ormat seeking to apply their OEM binary cycle bottoming units to the project and sourcing an OEM topping turbine to better exploit the steam from a higher pressure resource.

- Competition in the non-evaporative cooling and binary plant arena is limited if close to full injection of fluid to the reservoir is desired. Non-evaporative cooling applied to steam flash cycles requires air cooled heat exchangers, and is handicapped by the cost of corrosion resistant materials suitable for direct contact with geothermal fluid and a lack of proven designs. Further focus on this area is a potential opportunity, due to the environmental driver for full injection on some reservoirs.

- Development of competitive technology alternatives to flash evaporative cooling plants for smaller scale developments is an opportunity for new entrants, due to the above mentioned lack of competition in binary power plant providers who have proven operation over an extended period, a reasonable number of installed reference plants and can offer a reasonably large scale modular unit to improve economic performance.

- "Stick-built" binary power plants assembled and custom engineered from component equipment have a long history in the United States, starting with the first commercial air-cooled binary geothermal plant Mammoth 1 constructed by the Ben Holt Company and commissioned in 1984. Recent projects by ENEL at Stillwater and Salt Wells using Mafi Trench turbo-expanders have only relatively recently been commissioned (2009) so the life cycle performance and reliability of this alternative binary technology is as yet not well understood.

5.0 CONCLUSIONS

Opportunities to deliver geothermal energy projects require a strong and well managed approach in order to unlock the potential for this long term sustainable energy resource. Successful geothermal developers have recognised that expertise in exploration, development and sustainable management of reservoirs must be combined with comprehensive risk management, a procurement approach seeking the maximum performance and best total cost of ownership based on economic fundamentals and sound and focused project delivery disciplines. This paper has considered power plant procurement examples from New Zealand and internationally, to present the following conclusions:

- Geothermal is a high value energy source with great potential synergies with direct energy, cogeneration and electrical supply to industrial users co-located with the geothermal resource.

- Care is advised in ensuring programme delays do not result from transmission land access, consenting and commissioning requirements.

- Strong organisational capability and effective project leadership, bringing internal and external specialists to bear in all phases of the project are essential ingredients for the successful geothermal Owner/Developer. Emphasis on risk management, a focus on economic fundamentals and project performance starting from project definition, specification and procurement lay the foundations for every successful project. Consideration of FEED approaches recommended in order to achieve greater project definition, improved specification and reduction in risk to the project.

- Choice of procurement approach is a key instrument in best managing and allocating risk related to the performance of the development. Well delivered projects have resulted from both EPC and EPCM approaches, with EPC chiefly favoured due to project financing requirements and certainty (within liability caps) of risk outcomes borne by the EPC Contractor. The EPCM approach offers some advantages to Owner/Developers with balance sheet or alternative equity sources of funding combined with strong project delivery and geothermal expertise, given the ability to better optimise design and procurement alternatives for lifecycle economic benefit during project delivery. The EPCM approach may therefore be better matched to geothermal developments given the significant reservoir parameter uncertainties that persist into the project delivery phase, until production and injection well drilling is advanced.

- Increased competition in binary power plant would be of benefit to the market. With increased interest in geothermal generation worldwide, "stick built" binary power plants may find great application to smaller geothermal resources or where near full injection is required, as pure binary or in combined cycle application. As yet the long term performance of such technologies are unproven, however, the potential value obtained from repeated design and development of supplier relationships could be significant. Competitive advantage in binary technology development would require owner/developers in combination with skilled geothermal design, engineering and procurement providers to develop relationships with suppliers and invest in careful and economic development of this technology.

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