23 May 2013

GEOTHERMAL – WHITE PAPER

Contents

A global fund to de-risk exploration drilling: possibility or pipe dream?

Installed power capacity from naturally-occurring geothermal resources represents just 6% of estimated global potential. This untapped capacity reflects in large part the high risk and cost associated with deep exploration drilling. The most promising mechanism proposed to date to reduce risk at this stage and accelerate development is to diversify risk across a large portfolio of projects via a global geothermal drilling fund. Here Bloomberg New Energy Finance in collaboration with development consultants Rinova International present the first quantitative look at the feasibility and potential impact of a *Geothermal Exploration Drilling Fund*.

- A developer must drill typically two to four deep exploration wells to confirm expected output and determine economic viability of a given resource. At $5–9m each, it costs about $10–36m just to know whether or not a resource merits development. The high cost and risk of answering this question is keeping most geothermal sites undeveloped.
- Interest in breaking this barrier is mounting. Geothermal power is increasingly cited as a means of fuelling economic growth in the developing world – an estimated 113GW of untapped potential is located in 39 developing countries. Recently, several agencies have proposed portfolio funds, but to date no publicly available study has been completed to determine the feasibility and potential impact of such a fund.
- Here we draw upon recent global historical geothermal exploration drilling data to determine whether a $500m rotating debt facility could provide affordable financing to a global portfolio of geothermal projects for the first few deep exploration wells.
- A revolving global *Geothermal Exploration Drilling Fund* (GDF) may be able to offer debt financing to exploration-phase projects at rates that are commercially viable for the fund and potentially quite attractive to developers.
- We derived these conclusions from analysis of empirical data on historical geothermal drilling success and probabilistic modelling of portfolio size and economics.
- Outcomes are most sensitive to drilling success rate and the fund's own cost of capital – ie, return required by lenders/contributors.
- A commercial financing approach using a 7% cost of capital would result in a 17% interest rate to developers, while a fund with public sector support and a 3.5% rate of return to public sector contributors could offer loans at a 14% interest rate. While these rates are high, they could be attractive, considering the total lack of access to financing at this time for early-stage drilling.
- The fund's economics are also attractive from a development perspective, with a 1:25 indirect financial leverage ratio, and 7MW of capacity indirectly resulting per million dollars of funds

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utilised. Put differently, $500m in the fund would result in approximately $9.6bn of new investment in geothermal projects.

- The fund would directly finance drilling of 473MW across a portfolio of 24 projects and, in the scenario we present here, those confirmed resources would catalyse an additional 1,927MW, bringing the total impact of the fund to 2,400MW.

1. RATIONALE

Installed power capacity from naturally-occurring geothermal resources represents just 6% of the 196GW estimated global potential. This untapped capacity reflects in large part the high risks and costs associated with exploration drilling. Generally speaking, following initial pre-feasibility surveys and exploration activities[1], a developer must confirm expected output and determine economic viability of a given resource by drilling a set of – typically two to four – production-scale wells.[2] At $5–9m each, it costs about $10–36m for a developer simply to know whether or not a resource merits development.

Given the risk, outside capital – both equity and debt – for this stage is virtually non-existent in the market. Investors would require at least venture-level returns (~40%), and that could more than double the levelised cost of electricity (LCOE) for the project.[3] Even large-cap companies financing development off their balance sheets struggle to give projects the green light at this stage. Because of this, most full-diameter test drilling activity is largely limited to two groups that typically balance-sheet finance this stage: i) the handful of well-capitalised geothermal-focused state-owned and private developers able to develop several projects simultaneously to diversify risk and absorb losses, and ii) joint ventures for single projects in which parties bear only a portion of the risk and cost burden.

Several options for reducing risk at this stage have been proposed. The most promising is to diversify resource-confirmation drilling risk across a portfolio of projects via a global and/or regional geothermal drilling fund. A few of these are already in implementation, but are relatively small and focused on a specific country or region. Geothermal is gaining attention as a means of fuelling economic growth as an estimated 113GW of untapped potential is located in 39 developing countries. Recently, several agencies have proposed global funds, but to date no publicly available study has been completed to determine the feasibility and potential impact of such a fund. Here we propose the first quantitative economic assessment of a GDF.

2. METHODOLOGY

In this analysis, we performed basic probabilistic and financial calculations to explore the feasibility of a GDF under certain conditions. We utilised a cost-based analysis, finding the costs of the fund including probable portfolio losses, then finding the necessary interest rates required to cover these costs. The resulting interest rates are used as an indicator of the viability of the fund.

1 Preliminary survey and exploration phases are when the developer completes initial data collection and desktop analysis of the site, environmental permitting, geoscientific surveys and initial [shallow] exploration drilling. For continuity, we align nomenclature in this White Paper with the geothermal development phases outlined in the *Geothermal handbook: planning and financing power generation* published in June 2012 by the Energy Sector Management Assistance Program (ESMAP) at the World Bank.

2 A production-scale well (aka full diameter well) is an exploration well that, if successful, could be used to supply steam and/or fluid to a power plant. They are typically drilled to a depth of 1,000–3,000m and have a bottomhole diameter of 250mm (8in) or larger. These wells are not to be confused with temperature gradient or intermediate depth (aka slim hole) wells that are not drilled to sufficient depth or diameter to function as production wells. They are relatively inexpensive and typically the first exploratory wells drilled at a site – outcomes at these wells are key to whether or not development proceeds to the next step, production-scale test drilling.

3 See the 30 March 2010 Research Note, *Geothermal levelised cost of electricity update*

We used a bottom-up approach to derive the number of projects and capacity directly and indirectly resulting from GDF loans.[4] Key assumptions defining the starting point of our calculation are shown in Table 1, with additional details in Appendix A:. Appendix C: outlines the basic steps in our calculation. Our probabilistic analysis derived the size and cost of a defaulted portfolio based on a set of specified drilling criteria. This formed the first segment of cost. Financing and administrative costs matching different fund structures formed the second and third components of cost.

Table 1: Selected model assumptions

Assumption	Units	Value	Comment
Maximum size	$m	500	
Fund duration	Years	10	• Rotating term – two loans periods, five years each • Principal repayments to the fund allow each dollar originally invested in the GDF to be loaned twice
Drilling success rate	%	40–90	• See Section 3 and Appendix C
Project success criteria	Number of wells	3	• Project considered successful and GDF stops providing capital upon completion of third successful well
Project failure criteria	Number of wells	2	• Loan considered defaulted and GDF stops loaning money to any project that drills two failed wells • Could also be seen as a debt forgiveness policy
Successful well cost	$m/well	8	• Based on Bloomberg New Energy Finance geothermal cost model • Relatively conservative assumption given the variability in drilling costs globally
Failed well cost	$m/well	6	• Based on Bloomberg New Energy Finance geothermal cost model • Relatively conservative assumption given the variability in drilling costs globally

Source: Bloomberg New Energy Finance, Rinova International

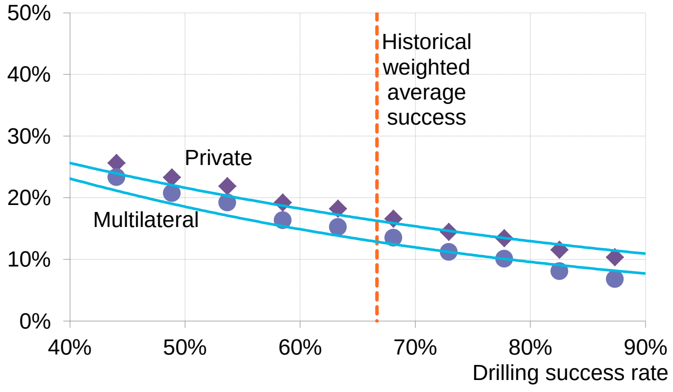
3. FINDINGS

It may be possible to offer relatively affordable debt to the market through a GDF where currently none is available. Using the parameters outlined above and in Appendix A: our probabilistic drilling model generated an outcome of 28 successful resource-confirmation drilling projects, and 10 failed projects that were treated as defaults and total losses. This corresponds to a lending portfolio of $738m in the successful portfolio and $209m in the failed portfolio.

Despite a 34% default rate, we found the GDF may be feasible under certain circumstances. We examined two scenarios in particular. In our Multilateral and Private scenarios, the GDF could offer debt financing to the market at interest rates of 14% and 17%, respectively. While these interest rates are high, they are likely much lower than comparable equity financing returns and should only be carried for a few years – repaid in full when the developer receives debt financing for plant construction.

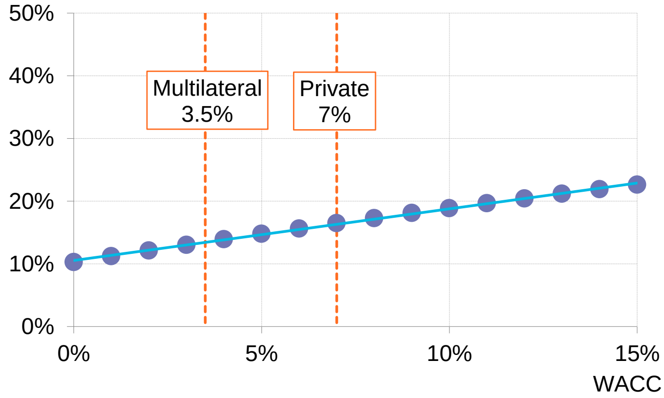
4 Instead of pre-defining a specific number of projects in the GDF portfolio and asking how much it will cost, we defined the initial size of the GDF (at $500m) and calculated how much capacity and additional investment it could leverage.

Figure 1: Interest rate sensitivity to drilling success rate (%)



Source: Bloomberg New Energy Finance, Rinova International

Figure 2: Interest rate sensitivity to GDF cost of capital (%)



Source: Bloomberg New Energy Finance, Rinova International

Drilling success rate

The outcomes we present here are most sensitive to the drilling success rate. The global *weighted average* success rate for full-diameter exploration wells is 67%. It is a bit higher than we initially expected, and nearly 50% higher than the rule-of-thumb rate broadly accepted by the industry for greenfield exploration drilling. We describe our steps in deriving the success rate in Appendix C:Appendix C:, the starting point for which is a global database of historical well success. This will accompany a report from the International Finance Corporation (IFC) of the World Bank Group, due out July 2013 and entitled *Success of geothermal wells: a global study* (data used in this study used with permission). We employed this success rate in all scenarios.

Although it might appear over-optimistic at first sight, we view the 67% rate as a rather conservative assumption, particularly as it is based on empirical data representing a large cross-section of historical geothermal drilling activities. The success rate *could* be even more favourable for the GDF, as its desirable financial offering may allow it to cherry-pick projects across the globe. In addition, we anticipate the bulk of projects chosen would be at sites expected to be high-grade geothermal resources – ie, selection could skew toward the upper-end of the resource quality banding in Table 2. Per the discussion in Section 1, as more than 90% of the estimated geothermal resource base sits untapped, it is reasonable to assume there are numerous candidate sites globally where GDF-financed drilling could see success rates above 67%. And if, for example, a GDF involved multilateral players and international cooperation, it may attract recipient-country government cooperation – such governments would presumably nominate their best candidate sites, likely resulting in better outcomes.

Cost of capital

The cost of financing for the GDF – ie, the return required by investors and/or contributors to the fund – strongly impacts the interest rate that it will be able to offer projects. A 1% increase in the weighted average cost of capital (WACC) translates to a nearly equivalent rise in the interest rate.

In our **Private Scenario** the GDF WACC is 7% (Figure 2). This scenario supposes a portion of financing at commercial rates and some with concessional pricing from a development finance agency. The financing could also include equity, which would be balanced by lower rates of debt. We assume the lenders see favourably the diversified portfolio, and price debt lower than they would to a single drilling project. This scenario results in GDF loans at a 17% rate.

We also examine a scenario with more concessional financing, at a 3.5% WACC. This **Multilateral Scenario** (Figure 2) assumes development assistance from sovereign entities, and could represent a multilateral-administered fund with concessional financing from sovereign contributors. This results in GDF loans at a 14% rate.

It should also be noted that the model assumes relatively efficient origination and processing of loans, with eight of every 10 years earning interest for a given dollar.

4. OUTLOOK

While individual loans for geothermal exploration drilling are non-existent, a GDF providing relatively affordable loans and appropriate reflows to contributors should be possible. The Private Scenario appears to be commercially viable and could operate on a revolving and profitable basis, though it would have less of a catalytic impact on project financials. In turn, the possibility for sovereign contributors to provide development assistance to a GDF, and receive a 3.5% return while still catalysing 24 geothermal projects may prove attractive. As such, a multilateral GDF could make effective use of a limited subsidy with a high impact. We note a global fund could be a highly effective means to pool sources of public assistance, with multilateral banks possibly leveraging their convening power to attract better projects and more financing.

We also note an attractive 1:25 indirect financial leverage ratio (fund size to total project financing leveraged in successful portfolio)[5] – ie, $500m in the fund would result in approximately $9.6bn of new investment in geothermal projects. The GDF would also indirectly leverage approximately 7MW of new capacity per million dollars loaned from the fund.

We expect GDF financing could also be highly attractive to project sponsors. Structured as debt, GDF investments would provide needed capital without diluting recipient equity, perhaps providing stronger incentive towards initial investment in the project. Equity dilution can be a significant deterrent for some developers as they consider options for financing subsurface development activities and is another of the numerous reasons projects stall and capacity remains untapped.

Outlined in Appendix A:, we expect GDF loans to be paid back at financial close, using a portion of the plant construction capital the developer receives at this point – just as equity may commonly get taken out at this stage in other projects. The result is that the borrower must carry this debt for only a relatively short period, a feature that could add to the attractiveness of GDF loans – already favourably priced – to potential borrowers. Also, an exit for GDF funding at this stage means the fund does not take on project risk – eg, construction, completion, off-taker, commercial. (Appendix A:).

The model can also be used to examine the outcome of other scenarios. For instance, under a slightly more pessimistic scenario, a commercial fund with a 10% WACC would need to charge 19% interest to cover its costs. Another model that has been discussed as a public support tool is a “breakeven fund” or “perpetuity fund” which would not seek to make any return for its contributors, but merely return the original principal (0% cost of capital). Our model indicates such a fund would be able to offer an 11% interest rate to projects.

This exercise gives preliminary indication of the possible viability of such an instrument with simple calculations. More tailored and extensive modelling could indicate the potential outcome of a particular set of financing sources, loan criteria, fund structure, or set of target recipient countries. It could also demonstrate the impact of GDF financing on the economics of geothermal projects, and estimate abated emissions.

[5] Actual leverage results for our Multilateral and Private Scenarios are 1:24.4 and 1:24.8, respectively.

Appendices

Appendix A: Additional modelling assumptions

- We utilised a fund size of $500m, which we found to be the minimum size to achieve meaningful portfolio diversification.
- All projects receive uniform loan terms: four years effective tenor, uniform interest rate. All loan repayment structures (to the GDF and to projects) are interest-only with a lump-sum repayment of principal at the end of the period. All projects (and the GDF) draw down exactly the amount of financing they need when it is required, and incur no commitment fees.

  Please note that we realise the tenor would vary by project, but for this modelling exercise we assume an *average* of four years. We assume drilling activities financed under the GDF will result in project sponsors receiving and/or allocating additional capital for production drilling – ie, the remaining production and injection wells required to meet desired output or, put another way, to produce steam/fluid sufficient for target power plant capacity.

  We also expect these successful projects to reach financial close, at which point the sponsor receives and/or allocates plant construction capital – typically debt, and the largest capital investment during project development. The GDF loan is paid back at financial close, just as equity may commonly get taken out at this stage in other projects. The GDF therefore is only taking on risk until financial close, and repayment of the loan is *not* dependent on income to the project. This reduces a lot of risk for the fund.
- Conservative project failure criteria assume that when drilling outcomes are poor, these compound with other risks to result in a 100% loss and no recuperation of the loan principal. However interest is paid up until the end of the effective tenor. This can also be seen as a generous forgiveness policy.

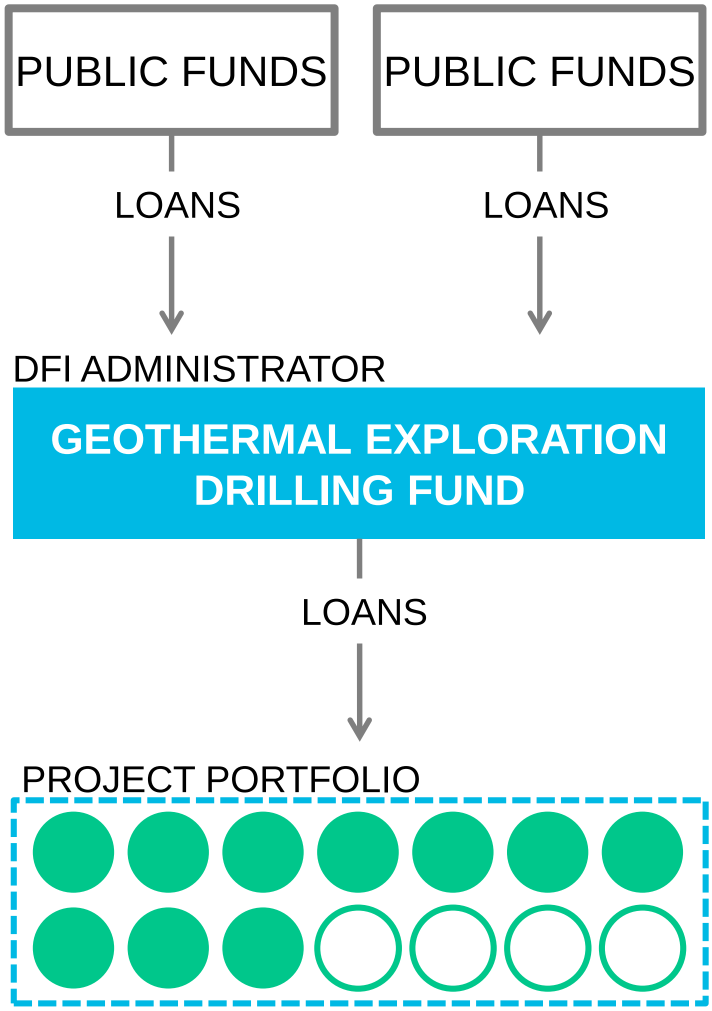
  We also employ this generous forgiveness policy to acknowledge development risk the GDF carries up to the point of financial close – ie, during development drilling. It acts as a means to account for unanticipated problems that lead to project cancellation.
- A front-end fee is paid by the fund and by all projects.
- In the Private Scenario, the fund manager earns 1% per year for their services. In the Multilateral Scenario, fund administration costs were based on administration costs for the Climate Investment Funds, adjusted for programme complexity and including implementation fees.
- The financing in this model is notionally available to government or private developers alike, and we assumed the same terms and conditions for both. We note that a government may wish to use the financing, for example, to hire a third-party contractor to complete resource confirmation then make the concession available to a private developer through competitive tender.
- Project eligibility requirements: to receive debt from GDF, each hypothetical project in this model must first complete the preliminary survey and exploration phases of the development process.[6] This includes any temperature gradient or intermediate depth (aka slim hole) wells – ie, these well types are *not* eligible and any drilling of such must be completed before a project can qualify for a GDF loan. The next development step for *all* eligible projects is production-scale test drilling (see Footnote 2 for well definitions).

[6] For continuity, we align nomenclature in this White Paper with the geothermal development phases outlined in the *Geothermal handbook: planning and financing power generation* published in June 2012 by the Energy Sector Management Assistance Program (ESMAP) at the World Bank.

- The size, number and availability of the GDF recipient projects is based on the Bloomberg New Energy Finance global database of geothermal projects.

Appendix B: Notional fund diagram

Figure 3: Multilateral scenario diagram



Source: Rinova International, Bloomberg New Energy Finance Note: DFI is development finance institution

Appendix C: Model calculation overview

The basic components and calculations we used to assess GDF feasibility and potential impact follow. Please note that for our purposes a *project* is equivalent to a *loan* from the GDF – a successful project results in a repaid GDF loan and a failed project results in a defaulted, or forgiven, GDF loan and is counted as a loss to the fund.

1. **Set well success probability –** we derived well success probability across a number of different qualities of resource from a global database of historical well success, adjusted to limit our analysis to *only* production-scale (aka full diameter) exploration wells drilled over the past three decades. The well success rate is different for different resource types; we use six resource quality levels (see Table 2). Separately, we consider the likelihood of each project drilling in each resource type. The well database and resource classifications in Table 2 are drawn from *Success of geothermal wells: a global study*, a report from the International Finance Corporation (IFC) of the World Bank due out July 2013 (data in this study have been used here with permission).

The probability of encountering each of the resource types listed in Table 2, and the well success probability at each of these, *must* be considered, in order to determine probability across the four possible outcomes – ie, well success or failure in a good or bad resource. The resulting *global weighted average* exploration drilling success probability is 67%.

Table 2: Resource quality levels

Resource level	Description
2	Very low temperature 100C to <150C
3	Low temperature 150C to <190C
4	Moderate temperature 190C to <230C
5	High temperature 230C to <300C
6	Ultra-high temperature 300C+
7	Steam field 230C to 240C

Source: Classification of Geothermal Systems, Sanyal (2005)

2. **Set project success and failure criteria –** a project succeeds if developers drill three successful wells and fails if developers drill two failed wells. This allows 16 unique configurations of well success and failure. Each configuration has a cost based on the number of successful and failed wells drilled. Loans range from $12–28m for forgiven configurations and $24–30m for successful ones.
3. **Calculate probability of each configuration and number of successful and failed projects across total fund –** combining the probabilities of well success and of resource quality we worked out how likely each possible configuration is. Across the fund, we then determined the expected total number of successful and failed projects. We also calculated the expected power production from successful projects. Our weighted average well productivity across all resource types is 6.5MW/well – or 20MW for each successful project.
4. **Determine interest rate** – After finding the size of the successful and failed portfolios, we then found the required return of the fund in order to cover (1) financing costs (2) administrative costs, and (3) losses from the failed portfolio. Income was derived from a simple cash flow model that allowed the fund to draw down debt as needed to cover expenditures, when income was not sufficient. In this model the portfolio rotates twice in a 10-year period, with a four-year effective tenor each time. Administrative costs vary according to the source of the fund's financing and resulting probable governance structure. Drilling programme funds are drawn down over two years, and loans are staggered.
5. **Perform scenario analysis** – Next, we derived financial outcomes for four funding scenarios. For all scenarios, we used the 67% global weighted average success rate for full-diameter exploration wells as described above. Our **Private Scenario** assumed fund management costs of 1% by a private manager, utilised a cost of capital of 7% and resulted in an interest rate of 17% to borrowers (Figure 2). Our **Multilateral Scenario** assumed multilateral administration, a governance structure including sovereign contributor engagement, and administration costs based on those of Climate Investment Funds, adjusted for complexity. This scenario assumed a 3.5% cost of capital and resulted in a 14% interest rate to borrowers. Secondary scenarios of a 0% cost of capital and a 10% cost of capital resulted in 11% and 19% required interest rates, respectively.

   We verified our cost-of-capital assumptions via several interviews with private and development finance organisations, each fitting the profile of a potential GDF investor/contributor.

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