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Estimating Indicative Transaction Value of Geothermal Reserves Based on a Method from the Petroleum Industry

Elliot Yearsley, Principal Consultant

116 Davy Street, Booragoon, WA, Australia 6154

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ABSTRACT

Geothermal reserves, and the transaction value of those reserves, have historically been under reported in the public domain. However, reporting of reserves and transaction values is common in the petroleum industry, and this larger data base can be used as a model to apply a similar method for estimating the indicative transaction value of geothermal reserves, in combination with accepted principles for reporting reserves in the geothermal industry.

The purpose of this paper is to provide a practical method that can be easily adapted to geothermal reserves that will be used in electrical power production. This method applied to geothermal reserves derives from cross referencing public domain information from both petroleum and geothermal sources as well as the author's 35 years experience in petroleum and geothermal reservoir engineering and management.

1. Introduction

Guidelines for evaluating and reporting petroleum reserves were developed over many decades and definitions were formally introduced in 1987. Today there is widespread acceptance of the Petroleum Resources Management System (PRMS), first issued in 2007. The reporting of petroleum reserves as defined in the PRMS, and transaction values underpinned by those reserves, has become commonplace in the petroleum industry.

The geothermal industry is generally not recognized for the same level of transparency in terms of reporting reserves or transaction values. Part of the reason for this is the sheer difference in size between these two industries, and that geothermal reserves are more difficult to define, but a contributing factor has been the lack of a widely recognized geothermal reserves reporting system. This is changing slowly as several geothermal reporting codes have been introduced, including the Australian Geothermal Reporting Code (2008), the Canadian Geothermal Code (2010), and the UNECE Reporting Code (2016).

The method presented in this paper for estimating indicative reserves-based transaction values based on analogues in the petroleum industry is not intended to replace discounted cash flow analysis or financial models, but can nonetheless be useful as a point of reference for comparisons, particularly when the specific inputs required for discounted cash flow analysis are unknown or a full financial model is not yet accurate or warranted.

2. Definitions

The PRMS defines *reserves* as those quantities of petroleum anticipated to be commercially recoverable by application of development projects to known accumulations under defined conditions. Reserves are further categorized in accordance with their level of certainty, including *proved reserves* which can be estimated with reasonable **certainty** to be commercially recoverable (i.e. 90% certainty or P90 reserves), and *probable* which are those additional reserves less likely to be recovered than *proved reserves* but have a reasonable **chance** of being recovered (i.e. 50% probability or P50 reserves). The combination of proved plus probable reserves are often referred to as **2P** reserves, and can also be subdivided into developed or undeveloped.

Each of the geothermal reporting codes are slightly different but the Australian code can serve as a useful comparison to the PRMS for purposes of this paper. The Australian code defines *proven geothermal reserves* as the drilled and tested volume of rock within which well deliverability has been demonstrated. These reserves can be considered to have a high degree of **certainty** (i.e. 90% certain). *Probable geothermal reserves* are the economically recoverable portion of the resource indicated by direct measurements of temperature where deliverability has been inferred. These reserves can be considered to have a reasonable **chance** of being recovered (i.e. 50% chance), and are often referred to as P50 reserves.

Resources are also defined in the PRMS and in the Australian code. In the PRMS resources are deemed not yet commercial, and can be “contingent” (on either technical or commercial factors) or “prospective” (not yet drilled). The Australian code describes geothermal resources as having a reasonable prospect for eventual economic extraction, which require “modifying factors” to become reserves (e.g. the resolution of technical or commercial issues). Although the parallels are not exact, *measured resources* in the Australian code are similar to contingent resources in the PRMS, and *inferred resources* in the Australian code are similar to prospective resources in the PRMS.

3. Converting Geothermal Energy to Oil Equivalent

To apply the petroleum transaction analogue method to geothermal reserves, it is useful to convert geothermal energy to oil equivalent, which Sanyal and Sarmiento (2005) have previously done. These authors use a conversion of one million kilowatt hours (kWh) to 1,500 barrels (Bbls) of oil, or 1.5 Bbls per megawatt hour (MWh). This conversion has been checked by this author and found to be a reasonable approximation using an efficiency of 42% for the conversion of heat rate to electrical energy in a thermal power plant. Table 1 compares the conversion used by Sanyal and Sarmiento to an average heat content for oil and the unit conversion of 1 MWh to oil equivalency for a typical thermal power plant.

Table 1: Conversion of geothermal energy to oil equivalent

Source	kWh	MWh	Bbls oil	Bbls per MWh	Thermal efficiency
Sanyal and Sarmiento (2005)	1,000,000	1,000	1,500	1.5	42%
Heat content of oil (Energy Information Agency)	1,600	1.6	1.0	0.6	100%
Conversion of oil to energy (U.S. Dept. of Energy)	1,000	1.0	1.6	1.6	39%

Sanyal and Sarmiento state that their conversion factor is based on both the energy content and the price of the two resources. At the time of their publication in 2005 those authors reference an oil price of \$40/Bbl. At one million kWh to 1,500 Bbls, this oil price translates to \$0.06/kWh, which those authors considered a realistic price level for wholesale geothermal power at the time. The average price of both resources has increased slightly since then, and this price relationship remains roughly in line with energy content for a long-term oil price range of \$50-\$60/Bbl compared to current wholesale geothermal power prices. Power prices vary widely, but for reference a recently quoted power price of \$0.082/kWh for a major geothermal project in Java (Think GeoEnergy News, April 26, 2019) would correspond to an oil price of ≈\$55/Bbl using the relationship suggested by Sanyal and Sarmiento.

4. Reporting Reserves

Petroleum reserves are generally stated in volumes as stock tank barrels of oil, or for natural gas in standard cubic feet (or cubic meters) which can be converted to barrels of oil equivalent (BOE). A widely used conversion for natural gas to BOE is 6,000 standard cubic feet to one stock tank barrel of oil, although the precise conversion depends on the composition and use of the natural gas. Geothermal reserves used for power production are (or should be) stated in energy units, such as Gigawatt hours (GWh), which represent the electricity that can be generated from the geothermal fluid over some specified period. For new projects this period is usually implied to be 30 years but can be stated otherwise. In both petroleum and geothermal reservoir engineering *reserves* refer to those volumes (petroleum) or energy (geothermal) that can be recovered applying proven production methods in commercial use.

The power plant capacity of a geothermal project (usually stated in Megawatts), planned or existing, is often confused with reserves. Although plant capacity is a convenient identifier of the size of a project, one of its disadvantages as a measure of reserves is that plant capacity by itself does not address the concept of *remaining reserves* from a reference point in time, but must be coupled with a timeframe for sustainable capacity (see for example Yearsley, 1994).

Plant capacity can also be overestimated, overbuilt, or underbuilt, whereas reserves represent an evaluation of the reservoir capacity to deliver energy from the geothermal fluid over a stated period of time (with certain assumptions regarding operation of the plant such as specific steam consumption and capacity factor). As conditions change during the operating life of a geothermal project, remaining reserves (including allowance for recharge) should ideally be updated from time to time (many petroleum operating companies publish annual reserves updates), even if plant capacity remains the same. After production is established, reserves updates are best accomplished through reservoir modelling. Sanyal (2003) has pointed out that geothermal reservoir numerical simulation is at least as reliable as its petroleum counterpart.

5. Transaction Values

Transactions of upstream petroleum assets are usually reported in the public domain with the transaction price and sometimes also state the reserves associated with the transaction. Given the large volume of oil and gas deals, statistically significant data can be found, and one recent source from Gbakon and Abiola (2018) indicates an aggregate deal value of US$10.65/BOE for global transactions of proved reserves (see Appendix I for discussion on oil and gas deal metrics).

Few transactions in the geothermal industry are reported in the public domain that contain both the transaction value and reserves, but one recent large transaction may provide a useful reference. In 2017 a consortium led by Star Energy purchased the Chevron geothermal assets in Java, Indonesia and the Philippines for a reported US$3 billion (the Philippines portion was later divested). The Indonesian portion of the transaction contained the producing Salak and Darajat geothermal fields which were estimated to represent two thirds of the total US$3 billion price, or approximately US$2 billion. These projects have been in operation for over 20 years and have a good track record for delivering the installed capacity. Assuming these projects continue to fulfill the existing electricity supply contracts (to 2039), reserves can be estimated for this transaction in terms of barrels of oil equivalent (BOE) using a similar method to that employed by Sanyal and Sarmiento (2005).

Applying a conversion of 1.5 BOE per MWh used by those authors, and the average valuation of US$10.65/BOE given above, the indicative value of the Salak and Darajat geothermal reserves can be estimated, as presented in Table 2.

Table 2: Salak and Darajat reserves and indicative value

Field	**Installed capacity** (MW net)	**Contract years** remaining[1]	**Est. remaining reserves** (GWh)[2]	**MMBOE** (at 1.5 BOE/MWh)	**Indicative value at $10.65/BOE** (US$MM)
Salak	377	22	67,000	100	1,068
Darajat	260	22	47,000	71	752
Total	**637**	**22**	**114,000**	**171**	**1,820**

1 From the transaction year of 2017.

2 Using historical plant capacity factors for these projects.

The estimated indicative value of US$1.82 billion by the method shown in Table 2 is in reasonable agreement with the reported transaction value of US$2 billion, which suggests that a useful correlation exists between petroleum and geothermal reserves and indicative valuation. This transaction represents an average value of US$0.016/kWh of reserves ($1.82 billion divided by 114,000 GWh), or roughly 20% of the wholesale geothermal power price of $0.082/kWh referenced above. This ≈20% ratio of the transaction value of developed reserves to long-term oil prices also commonly occurs in oil and gas transactions.

6. Extending the Method to Undeveloped Reserves and Resources

It follows from the definitions in the PRMS and geothermal reporting codes that proved (developed) reserves, as the most certain, should have the most value, undeveloped reserves next, and resources the least value. This value hierarchy is borne out in the transaction history in the petroleum industry, and should have a similar relationship in the geothermal industry.

A rule of thumb used by the author based on experience (and supported by proprietary data bases in the petroleum industry) is that approximately 50-60% of the proved (developed) reserves value, or roughly $5-$6/BOE, is appropriate as an indicative range for transactions of undeveloped reserves. This discount from developed reserves includes the average cost of development and the risk of reservoir performance.

Contingent resources, as defined in the PRMS, are valued somewhat lower still, in the author's experience in the range of 5-15% of the developed reserves value ($0.5 - $1.5/BOE), reflecting resource risk, development cost, and the risk of development timing.

7. Discussion

Indicative valuations are approximations intended for comparative purposes to understand transaction value in the context of reserves (or resources). The method presented here is based on petroleum industry analogues that have found widespread use and acceptance. Notwithstanding differences between the petroleum and geothermal industries, there are also underlying fundamental similarities as both are resource-driven businesses whose *ultimate value lies in their reserves*.

The first step in applying this method for estimating indicative transaction value for both petroleum and geothermal reserves is the proper analysis and statement of reserves and resources as specified in the PRMS and the corresponding geothermal reporting codes. In addition, it is suggested that greater transparency, more frequent reserves updates, and third-party reserves assessments will benefit the geothermal industry as they have the petroleum industry.

Clearly there is a more statistically significant data base for understanding petroleum reserves values compared to geothermal reserves, and the author has no doubt that as more data becomes available indicative valuation ranges for geothermal reserves will shift and can also be divided into more specific categories based on region, power price and other factors. However, the introduction of this method is intended to provide a starting point for discussion within the geothermal industry, hopefully leading to common ground and greater transparency.

7. Conclusions

A method for estimating the indicative transaction value of geothermal reserves has been presented. This method is based on petroleum industry analogues, public domain information, and the author's experience in both the petroleum and geothermal industries.

This indicative valuation method of either petroleum or geothermal reserves is not intended to replace discounted cash flow analysis or financial models, but does present a quick method for understanding and comparing the indicative transaction value of reserves.

Although in need of more data to make the valuation ranges for geothermal reserves more statistically robust, this indicative valuation method presents an opportunity for dialog in the geothermal industry to record and collate this data to be used in the future.

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APPENDIX I: OIL AND GAS DEAL METRICS

There are several sources of information for oil and gas deal metrics, starting with the public domain which includes press releases, annual and quarterly reports, and publications in professional journals. Beyond this, there are also proprietary sources that include paid subscriptions such as provided by Wood Mackenzie, IHS and Deloitte.

The challenge for petroleum transactions and reserves data is not the volume (which is sufficient), rather it is how best to collate and interpret the data. The reference used here is a recent Society of Petroleum Engineers paper by Gbakon and Abiola (SPE No. 193484-MS) that collated 6,444 transactions between 2001 and 2017. Of these 1,757 also reported the reserves associated with the sale. That paper outlines various types of deals and factors that affect transaction price, including offshore versus onshore, regional differences, and the effect of oil price. The resulting average of US$10.65/BOE represents all deals that had reserves posted with the transaction price.

To obtain enough meaningful data in the public domain on transaction values per BOE to some extent sacrifices detail on proved reserves versus 2P reserves. In practice, developments comprise mostly of proved reserves, and conversely proved reserves underpinning transactions reported in the public domain are usually developed (unless otherwise noted). The critical distinction is between developed and undeveloped reserves, as the latter category still requires development capital (although there are cases where undeveloped reserves are lumped together with developed reserves in the public reporting).

Contingent resources must also factor in resource risk and development timing (including the risk of no development), and are therefore valued correspondingly lower. For purposes of indicative valuation, contingent resources are often undifferentiated (i.e. 1C and 2C resources as defined in the PRMS are lumped together), but are separate from prospective resources which carry the most risk.

Another challenge in interpreting petroleum transaction data is the variation in oil price over time. However, the long-term data indicate that while deal volume increases with oil price, aggregate transaction metrics remain remarkably stable with a slight long-term upward trend approximating U.S. inflation rates. For example, data from the Scotia Group provided by Schiozer et al. (2006) indicate an average transaction valuation of US$7.34/BOE culled from over 6,000 upstream petroleum transactions between 1979 and 2004. The difference between the average $/BOE deal metric of $7.34 and the $10.65 derived from the later data set represents roughly a 3% per annum increase between the two published dates of 2006 and 2018.