The Australian Code for Geothermal Reserves and Resources Reporting: Practical Experience

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ABSTRACT

The recent trend for financing of geothermal development companies through stock market listings presents a welcome market-driven mechanism for funding the exploration and development of geothermal prospects. However, this process depends heavily upon being able to demonstrate the value added at successive stages within the long development path from exploration to power generation, and in particular for investors to have confidence in the claims made by developers about the energy resources and reserves available within each project.

In 2008 the Australian geothermal industry established a formal reporting code for geothermal Reserves and Resources. It is based largely on the JORC Code for mineral deposit, adapted for geothermal energy. The need for the Code, its principles and its course of development are described in a companion paper (Williams et al, 2010).

By the time of WGC2010, the Code will have been in operation for two years. A Code Compliance Sub-Committee has been established to review Public Reports made under the Code and report back to the governing body. This paper will describe the practical experience gained in the first two years of operation and some lessons learned.

1. INTRODUCTION

The recent trend for financing of geothermal development companies through stock market listings presents a welcome market-driven mechanism for funding the exploration and development of geothermal prospects. However, this process depends heavily upon being able to demonstrate the value added at successive stages within the long development path from exploration to power generation, and in particular for investors to have confidence in the claims made by developers about the energy resources and reserves available within each project. Similar requirements apply, in fact, to all forms of capital market financing. A standardised and trusted approach to geothermal energy resources and reserves classification and estimation is required for the stability of our industry.

Although geothermal energy extraction and electricity generation there-from is a mature industry, with a history of over 100 years, and more than 50 years experience of large scale commercial generation, to this date there has not been a universal or even widely agreed code for reserves and resources reporting. In part that has been because the parties responsible for project development have often been large utilities, or government agencies, who are not raising funding through stock market listings.

That situation has changed in recent years. Increasing incentives being applied to renewable energy and improvements in technology have extended the resource base of commercial projects to lower temperatures, thereby greatly increasing their geographical distribution. That in turn has brought new companies into the geothermal industry, particularly in Australia and Canada, many of whom have a background in mining or petroleum exploration and who are now raising capital on stock markets. The companies are well aware that having an agreed and reliable geothermal reporting code is in their best interests.

The recently formed Australian Geothermal Energy Group (AGEG) took the initiative of producing such a Code (AGEG 2008), which was later taken up by AGEA (Australian Geothermal Energy Association). This paper presents the outcome of that process, which at the time of writing (May 2009) is well on its way to formal acceptance by the Australian Securities Exchange (ASX). The Listing Rules of the ASX are regulated by the Australian Securities and Investment Commission (ASIC) and therefore have the force of federal law.

The structure and status of the Code are described in detail in a companion paper (Williams *et al.* 2010). The following section is a much more abbreviated description.

2. ESSENTIAL FEATURES OF THE CODE

After considering a number of models, the 'Geothermal Code Committee' chose to base the new Australian Geothermal Reporting Code on the JORC mineral code model (JORC 2006), for four main reasons:

- It had been developed and revised over at least 20 years and found to be very robust;
- Australian regulators were accepting of it; and
- Mineral sector investors around the world were familiar with it and it has been formally accepted for use in some overseas jurisdictions.
- It was desirable to minimize the introduction of new terminologies and concepts.

A code based on hydrocarbon reporting, such as the SPE regime could have been adopted, but it was considered that it was less well known in Australia and probably too complex and difficult to adapt to the particular circumstances facing the industry in Australia at the time..

The scope of the new Geothermal Code was uniquely designed to accommodate all forms of geothermal energy generation, including 'conventional' geothermal plays. Geothermal heat pump operations are not included in the Code for a number of reasons, including the lack of ability to obtain a tenement and therefore ownership over the 'resource'. However, the Code is applicable to use in higher-temperature direct use applications.

The classification regime for geothermal energy resources under the Geothermal Code is illustrated in Figure 1.

The Geothermal Code recognizes three levels of Geothermal Resource (Inferred, Indicated and Measured) based upon increasing levels of geological knowledge and confidence, which directly affect the assessment of the probability of occurrence.

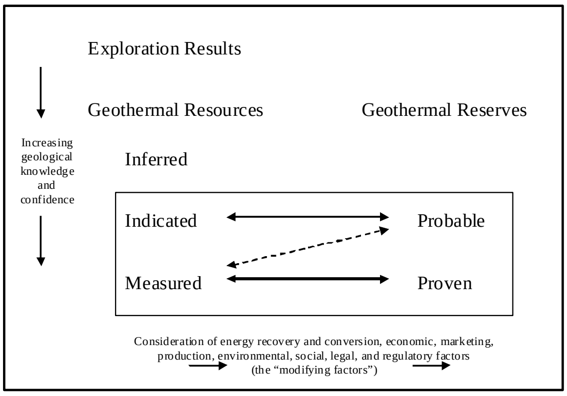

Figure 1. Relationship between Exploration Results, Geothermal Resources and Geothermal Reserves.

Geothermal Reserves are further estimated from Geothermal Resources by consideration and application of 'Modifying Factors' which directly affect the likelihood of commercial delivery. Two categories of Geothermal Reserve are recognized (Probable and Proven) based upon confidence in both the underlying Geothermal Resource estimate and the Modifying Factors.

3. METHODS OF RESOURCE ASSESSMENT

At different stages of a geothermal development the methods used to assess the geothermal Resources and Reserves will vary according to the available information. A variety of methods has been previously used for assessing energy that can be extracted, all of which have been applied deterministically or through some form of probabilistic approach. These are shown in Figure 1. In our opinion:

- Equating available energy output to surface heat flow only is likely to lead to an unrealistically low number.
- The method using summation of well outputs alone is not at all definitive and only has any useful application for resource assessment if sensibly combined with well decline analysis based on a suitable history of well performance.
- The areal energy density analogy method has usefulness for the early stages of exploration, but should not be used for anything more definitive than Inferred Resources.
- Well decline analysis is likely to be useful only in special circumstances, in projects with a long production history.
- Only the volumetric methods and reservoir simulation are adequate for the purpose of defining Indicated or Measured Resources and Proven or Probable Reserves.

However, using an overly-complicated method too early in the process can lead to spurious precision. It is perfectly possible to carry out a numerical reservoir simulation before any data is available from drilling, but it is usually of little value for resource definition and can be actively misleading (Parini and Riedel 2000).

Wherever possible these methods should be applied (and their sensitivity tested) with consideration of the classifications of resource area as proposed above. Ideally, the industry should continue to use several methods in parallel and through sharing experience (via publication) improve understanding of when each method is applicable and obtain control on how they differ in reliability.

4. PRACTICAL EXPERIENCE

At the time of writing the Code has been in operation for almost a year. A significant number of Public Reports have been submitted by several companies. A Code Compliance Sub-Committee has been established to review and comment on the reports, with 5 permanent members (three of whom are the authors of this paper) and the ability to second other persons should any of the permanent members have to excuse themselves in any particular case because of a conflict of interest.

A number of Practice Notes were also compiled and circulated by the Geothermal Code Committee to inform AGEA members on 'best reporting practice' in respect of particular aspects of the Geothermal Code.

The Geothermal Code has been disseminated to organizations and experts around the world and feedback has been constructive and positive. A number of comments or queries have come from technical persons concerned with the possibility of their technical freedom being restricted or bringing up particular circumstances where there is ambiguity with data or interpretation, for instance which temperature(s) in and around a reservoir should be used. In nearly all cases it can be shown that the Geothermal Reporting Code in no way limits any estimation methodology or choice of data, as long as those choices are clearly stated in the Public Report and can be justified by the Competent Person, if called upon to do so.

The Competent Person must also make judgments as to the classification of the resources and/or reserves. Again, there are no 'rules' laid out but check-lists and prompts are given in the guidelines and at the end of the day, the experience of the Competent Person is relied upon, as is their preparedness to defend their choices.

In discussing and reporting geothermal reserves and resources, the term 'estimation' is preferred over terms such as 'measurement' to emphasize that the computation is not exact.

From the use and discussion in Australia and internationally, a number of improvements in the

Geothermal Code have been identified and a Second Edition of the Code is scheduled for November 2009. The Geothermal Code is stated to be a 'living document' and changes are expected into the future.

In general the level of compliance has been high and industry members have demonstrated a willingness to participate. Issues that have arisen are in the following categories:

- Lack of appreciation of the reporting protocol, such as the need to include the Competent Person's statement with every Public Report including quarterly and annual summary reports. While this may appear onerous to some, it is simply following common practice in the Australian mineral industry. These matters should improve with greater familiarity.

- The amount of technical detail required in Public Reports; some reports have been very brief whilst some companies released the entire original internal technical report on the resource estimation. Ultimately it is up to the Competent Person to agree to the content of any Public Report based on their work. A very brief report will likely not contain enough information to allow the confidence on the 'bottom line' figure to be assessed, while a full report is unlikely to be comprehended by the target audience of investors. In early reports, as an education exercise, the Geothermal Code Committee has suggested more information is better than less, and a resources or reserve report of between 10 and 20 pages would be adequate, with the length of reports probably decreasing over time. Some example reports are available on the website.

- A lack of understanding of the difference between Cut Off and Base Temperatures, and the need to take (and define) both the technology pathway and economic practicalities into account when defining them, even at the stage of Inferred Resources.

- Very large numbers being quoted for energy in place in Inferred Resources, which could be misleading to investors if recovery factors and conversion efficiencies are not considered. At the same time, it would be undesirable to be too definitive about possible recovery factors at the stage of Inferred Resources. This is especially the case for EGS projects, where the resources may be extremely large and there is a lack of worldwide experience in actual long term recovery factors. Perhaps the best approach is to require a sound theoretical justification for any recovery factors adopted and provide some default criteria in the Lexicon.

- A related issue is a lack of distinction between thermal and electrical energy. Energy in place is required to be reported in thermal units. $PJ_{(thermal)}$, whereas recovered and converted energy is reported in MW-years $_{(electrical)}$ or equivalent. A few parties have failed to distinguish between these, thus blurring the size of the likely recovery and conversion factors.

- The lack in Australia of a incorporated professional geothermal body with an enforceable code of ethics, to which Competent Persons can belong. At present this is being pragmatically accommodated by requiring Competent Persons to belong to "a" professional body, without it being explicitly geothermal. In practice this means that most CP's are referring to their membership of the established mineral industry bodies such as AusIMM, which have a vigorously enforce code of ethics. Hopefully this situation will be tightened up as the Australian geothermal industry develops and a suitable body is incorporated, which will presumably be AGEA..

For advanced projects with some production history, and especially where there is evidence for heat and fluid recharge, the Code requires an estimate of heat in place as well as recoverable energy. While it is possible to estimate heat in place, it is not as meaningful in those cases as applying dynamic reservoir modelling. Using heat in place as the basis for resource estimation tacitly assumes that the ultimate end point or failure mode of the project will be heat depletion. Experience in 'conventional' geothermal projects of long duration suggest that other factors may be more significant, such as pressure or fluid depletion, reinjection short circuiting, or ingress of cool groundwater. This is not an issue for the geothermal projects in Australia so far, but it will rapidly become an issue as Australian companies take up advanced projects offshore.

5. CONCLUSIONS

Good progress has been made in Australia towards developing and formalizing a Reporting Code for Geothermal Reserves and Resources. It has drawn upon the JORC principles of Transparency, Materiality and Competence. A key distinction is that Reserves represent energy which is considered to be commercially recoverable now, whereas Resources require further work to be classified as Reserves. The code relies upon a two dimensional classification taking into account levels of geological knowledge and confidence and Modifying Factors which directly affect the likelihood of commercial delivery.

Because this is a new initiative and because geothermal technology is rapidly evolving, especially in the field of EGS, the Code does not attempt to be prescriptive regarding methodologies for resource assessment but embedded guidelines and a Lexicon are provided to assist with that.

It is hoped that once the Code becomes formally accepted in Australia it will become the basis for a more uniform international approach to the issues.

Although primarily a tool for the protection of small investors on public markets (in the case of Australia), codes with international recognition such as SPE and JORC free up cross border capital by allowing the resource and reserve assets of a company in one jurisdiction to be assessed and valued on a standard template by investors anywhere in the world, either public or private.

It is hoped that in co-operation with other national or international geothermal organizations, the Geothermal Reporting Code might form the basis of a uniform, or at least a harmonized international geothermal reporting code, which will greatly assist cross-border investment and understanding. It would also provide a consistent, robust basis for making investment and policy decisions in countries with more centrally-directed energy industries.

ACKNOWLEDGEMENTS

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REFERENCES

Joint Ore Reserves Committee, 2004. "Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves; The JORC Code 2004"

The Australasian Institute of Mining and Metallurgy, the Australian Institute of Geoscientists and the Minerals Council of Australia

The Australian Geothermal Code Committee, 2008. "Australian Code for Reporting of Exploration Results, Geothermal Resources and Geothermal Reserves; The Geothermal Reporting Code 2008 Edition" Australian Geothermal Energy Group and the Australian Geothermal Energy Association.

Parini, M.; Riedel, K.; 2000: Combining probabilistic volumetric and numerical simulation approaches to improve estimates of geothermal resource capacity. World Geothermal Congress: 2785-2790.

A F Williams, A. F; Lawless, J. V.; Ward, M.A.; Holgate, F. L.; Larking A.; 2009: A Code for Geothermal Resources and Reserves Reporting. World Geothermal Congress 2010 (in press, this volume).

Table 1: Methods of Resource Assessment and their Applicability

Method	**Applicable to:**					**Can be used to define:**	
	Early Exploration (pre drilling)	**Exploration**	**Delineation**	**During production**	**Expansion Phase**	**Resources**	**Reserves**
Surface heat flow	Yes but low confidence	Yes but low confidence	Largely redundant	Redundant	Redundant	Yes, Inferred, to a minimum	No
Sum of existing well outputs	N/A	No, does not directly indicate resource capacity	No, does not directly indicate resource capacity	No, does not directly indicate resource capacity	No, does not directly indicate resource capacity	No, except for very short term	No
Analogy based on area	Yes, but low confidence	Yes, but low confidence	Largely redundant	Redundant	Redundant	Yes, Inferred, but low confidence	No
Stored heat	Yes, but low confidence	Yes, preferred method	Yes,	Largely redundant	Largely redundant	Yes, Inferred, Indicated or Measured if backed up by well deliverability	Yes, Probable or Proven if backed up by well deliverability
Lumped parameter models	Yes, but not advisable	Yes, but not advisable	Yes	Yes in some cases	Yes in some cases	Yes, Inferred, Indicated or Measured if backed up by well deliverability	Generally no
Decline curve analysis	No	No	No	Yes	Yes	Yes, Inferred, Indicated or Measured, but not favoured	Generally no
Numerical simulation models	Yes, but not advisable	Yes, but not advisable	Yes, but low confidence	Yes, preferred method	Yes, preferred method	Yes Inferred, Indicated or Measured	Yes, Probable or Proven if backed up by well deliverability