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A Code for Geothermal Resources and Reserves Reporting

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ABSTRACT

Geothermal companies are increasingly using both equity markets and the finance sector to raise funds to develop their projects. At the same time, the industry is pursuing new concepts such as hot rocks and engineered geothermal systems, and the large scale use of geothermal energy is a relatively new concept in many parts of the world. The industry is thus faced with the challenge of building understanding and reputation in the market place, with investors, regulators and the public. This is certainly the case in Australia, where the industry has grown rapidly from zero to almost 50 companies pursuing geothermal energy in the eight years from 2001 to 2009.

The development of a Geothermal Reporting Code and its adoption by operating companies to guide the way they report their geothermal exploration results, resources and reserves, is an important step in the growth of the geothermal energy industry.

This paper reports the development of a Geothermal Reporting Code by the geothermal industry in Australia, in a way that aligns with similar codes in the world for comparable industries. The Code covers all forms and uses of geothermal energy (except ground source heat pumps) and sets out the minimum and mandatory requirements for Public Reports, but it is not prescriptive as to how estimates of resources and reserves are made. Accompanying estimation guidelines have also been prepared but are not mandatory.

The Code was launched in Australia in August 2008, with the support of the Australian geothermal associations and, importantly, the Australian Securities Exchange (ASX). It has been developed by the Geothermal Reporting Code Committee under the auspices of the Australian Geothermal Energy Association (AGEA) and the Australian Geothermal Energy Group (AGEG). Experience with using the Code over two years will be covered in a companion paper by Lawless *et al*.

1. INTRODUCTION

The Australian geothermal sector has evolved in a way that is almost unique in the world. Historically the industry has been confined to a single small, low temperature geothermal power station in a remote community and a few community heating projects. With the appreciation of the potential of geothermal energy to replace static fossil fuel energy on a large scale from about 2000, the Australian industry has grown from zero to some 48 companies holding about 385 geothermal tenements with associated work commitments exceeding US$1bn in 2009. Ten of these companies (and all of the most active ones) are listed on the ASX and more will follow when the equity markets improve.

Utilities have played little part in the primary expansion of the Australian industry. Funding has come from stock market IPOs and subsequent issues, joint venture project buy-ins and some government grants. The reliance on stock market funding in particular has driven the Australian industry to develop a regime to make Public Reports on their value-driving assets (their geothermal resources and reserves) that is acceptable to market and investment regulators, as well being comprehendible by investors. At the same time, the reports produced under this regime need to be able to be used comparatively and numerically by non-market financiers (fund managers and banks).

The *Australian Code for Reporting of Exploration Results, Geothermal Resources and Geothermal Reserves* was developed in 2008 after widespread consultation between the industry participants, government technical authorities and investment regulators. After considering a number of possible models, it was based on the well developed Australian code for Public Reporting on minerals resources and reserves, called the "JORC" Code and maintains JORC's principals of materiality, transparency and competence in public resources reports.

The Code is a formal regime for stock-exchange listed companies to make reports to the market and also acts as a template for other entities to document their resources and reserves in a standard way that private debt and equity providers can understand and use. The code does not dictate the technical methodology used to estimate the resources and reserves. The technical person has freedom to use whatever methodology or data they think appropriate.

A crucial facet of the Code is that any Public Report by a company must be signed off by a Competent Person before the report is released. The Competent Person is usually the senior technical person responsible for writing or compiling the original resources or reserve estimate and must have at least five years of relevant experience in the type of Geothermal Play under report. The Competent Person is personally named in the Public Report and therefore must be prepared to defend his or her work if challenged by their peers.

2. STRUCTURE OF THE CODE AND RELATED DOCUMENTS

Methodologies for classifying reserves are well established in the petroleum and mineral industries. Because many of the companies active in the Australian geothermal industry have a strong mining background, and because of the simplicity and wide acceptance of the JORC code which is most commonly used for reporting of mineral reserves and resources, it was decided to model the geothermal code on that, rather than the other obvious alternative of modeling it on a petroleum reporting code such as that of SPE.

The JORC code conforms to the CRIRSCO standard (see: http://www.crirsco.com/welcome.asp) and is recognized by

both the Australian and Toronto stock exchanges. The relationship between the JORC and Australian geothermal codes is formally summarized as follows in the Code:

> This Geothermal Code is based closely on that of the Joint Ore Reserves Committee's "Australasian Code for the Reporting of Exploration Results, Mineral Resources and Ore Reserves" (the JORC Code 2004 Edition), and this has been done with the support of the JOR Committee. Nevertheless this Geothermal Code should be interpreted and applied as an independent Code.

In accordance with JORC principles, the Australian Geothermal Resources and Reserves Reporting Code ("the Code") covers a minimum, mandatory set of requirements for the Public reporting of Geothermal Resource and Reserve estimates. While it tabulates a large number of issues to be considered in reporting, it is not particularly prescriptive as to methodology in making the estimates that are reported.

The Code is accompanied by a 'Geothermal Lexicon' which provides guidance on how Geothermal Resources and Reserves can be estimated for reporting purposes. The techniques described in the Lexicon are not a mandatory part of the Geothermal Code. However, any significant deviations from the Lexicon should be disclosed and explained when reporting under the Geothermal Code.

3. CURRENT STATUS

At the time of writing (May 2009) the status of the Code was as follows. This will be expanded on in a companion paper by Lawless *et al* (this volume).

- The First Edition of the Code and Lexicon were formally launched in mid August 2008 and have been submitted to the International Geothermal Association (IGA), who have recognized the Code as appropriate and endorsed the Lexicon;
- The Code and Lexicon have also been submitted to the International Energy agency (IEA);
- Discussions have been held with the JOR Committee and agreement reached to maintain independent mineral and geothermal Codes, but with close coordination;
- The Code and Lexicon had been submitted to the Toronto Stock Exchange and Ontario Securities Commission and preliminary discussions held with the Canadian Geothermal Energy Association with the objective of aligning the forthcoming Canadian Code with the Australian one;
- 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;
- Discussions have been held with the Australian Securities Exchange (ASX). AGEA has begun the process of having the Second Edition formally incorporated into the ASX Listing Rules which in turn will bring about mandatory compliance under Australian federal law. This process will take at least a year.

The Primary Industries and Resources Department of the government of South Australia is acting as the secretariat for the Code. Copies can be obtained from:

http://www.pir.sa.gov.au/geothermal/ageg/geothermal_reporting_code

4. HOW GEOTHERMAL ENERGY REPORTING DIFFERS FROM PETROLEUM OR MINERALS

The mineral and petroleum reporting approaches include a two-dimensional classification based on:

- Reliably of the information defining the physical resource, and
- Commercial extractability of the resource.

Those distinctions are applied here to geothermal.

As mobile resources petroleum reservoirs have many similar characteristics to their geothermal equivalents but geothermal resources are subject to a variety of thermodynamic processes under extraction. Mineral resources generally have greater variability and less continuity and so require greater sampling density to assure the magnitude of contained resource.

Geothermal resources in convective hydrothermal systems further differ from both minerals and petroleum resources by being renewable through recharge, albeit usually at a slower rate than energy is extracted. The rate of this recharge can vary significantly from system to system, and can be stimulated to a varying degree by production.

Unlike most minerals and oil which have an internationally defined dollar value, electrical energy prices can vary by an order of magnitude from place to place both because of physical alternative sources of supply and regulatory policies. Therefore the "cut off grade" for geothermal resources cannot be defined as a single internationally applicable number for certain "mining criteria". It is highly country and region specific.

Furthermore, in the case of electricity generation, the "cut off grade" has to take into account the practical limitations and cost of the conversion process. It is perfectly technically feasible to generate power from fluid at 100°C or less, but it is only economic to do so in a few locations.

Geothermal projects where economics are the prime driver are typically sized to fully utilize a resource over a period of about 20 to 25 years that relates to the life of the wells and energy conversion plant, with a suitable margin for contingencies. It is therefore important to state the reserves in terms of the rate of extraction.

5. MAJOR PRINCIPLES OF THE GEOTHERMAL CODE

One of the most fundamental principles of the Code is the role of the Competent Person. The Competent Person is personally named in the Public Report and ultimately takes responsibility as to its content, having consented in writing to the form and content of the report (possibly after first requiring changes to the wording or format of the draft report to ensure its technical integrity).

A further principle in the Code is the demarcation of a reserve as opposed to resource with the taking into account of commercial viability. A '**Geothermal Resource'** is a Geothermal Play (see below) which exists in such a form, quality and quantity that there are reasonable prospects for

eventual economic extraction. A '**Geothermal Reserve'** is that portion of an Indicated or Measured Geothermal Resource which is deemed to be economically recoverable after the consideration of both the Geothermal Resource parameters and Modifying Factors.

5.1 The role of the Competent Person

The Geothermal Reporting Code states:

> A Public Report concerning a company's Exploration Results, Geothermal Resources and/or Reserves is the responsibility of the company acting through its Board of Directors. Any such report must be based on, and fairly reflect, the information and supporting documentation prepared by, or under the direction of, a Competent Person or Persons. A company issuing a Public Report shall disclose the name(s) of the Competent Person or Persons, state whether they are full-time employees of the company and, if not, name their employer. The Public Report shall be issued with the written consent of the Competent Person or Persons as to the form and context in which it appears.

The last sentence effectively means that the Competent Person must be satisfied with and consent in writing to the content of each Public Report which quotes from the original technical work. Whilst occasionally administratively burdensome, this protocol is specifically designed to prevent the over-exuberant or over-simplified portrayal of resource or reserve estimates, the quantum and quality of which may have a material impact on the value of the company doing the reporting. At the extreme, it is designed to put a brake on selective quotation of Resource and Reserve figures by companies and to give the person who will be held responsible for the work, a say in how the work is presented.

A Competent Person must have a minimum of five years experience relevant to the type of Geothermal Play under consideration and to the activity that the person is undertaking. For instance, if the Competent Person is preparing or signing off on a report on resource estimates on a particular EGS play, the five years of experience must be relevant to the estimation, assessment and evaluation of geothermal resources as well as to EGS type plays. As a general guide, persons being called upon to act as Competent Persons should be clearly satisfied in their own minds that they could face their peers and be asked to demonstrate competence in the type of Geothermal Play and situation under consideration.

In the Public Reporting of Reserves, it is likely that a number of Competent Persons will be involved, each covering different or overlapping disciplines such as geoscience, reservoir engineering, electricity generation and so on. Each will take responsibility for defined sections of the Public Report.

The Competent Person must also be a member of a recognized professional organization and be able to be held accountable to the Code of Ethics of that organization.

At the end of the day, a Public Report made by a company in relation to geothermal resources, reserves or exploration results is a document agreed by the company and the Competent Person(s) and each party can be held accountable for the content for which it is responsible.

5.2 Categories of Geothermal Reserves and Resources

Categories of Geothermal Resources and Reserves are important to provide explicit understanding of the certainty (quality and reliability) of the information that is used to define their magnitude.

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

The Geothermal Reporting Code recognizes three levels of Geothermal Resource (Inferred, Indicated and Measured) based upon increasing levels of geological knowledge and confidence.

Geothermal Reserves are estimated from Geothermal Resources by consideration and application of "Modifying Factors". These factors include capital and operating costs and energy pricing, plus the regulatory, environmental and social constraints on delivering a profitable outcome. Two categories of Geothermal Reserve are recognized (Probable and Proven) based upon the Modifying Factors being applied to either Indicated or Measured Resources respectively.

The relatively low level of confidence in Inferred Resources is such that they can never directly be converted into Reserves.

The actual category of Resource or Reserve which is ultimately defined is a matter for the Competent Person's judgment.

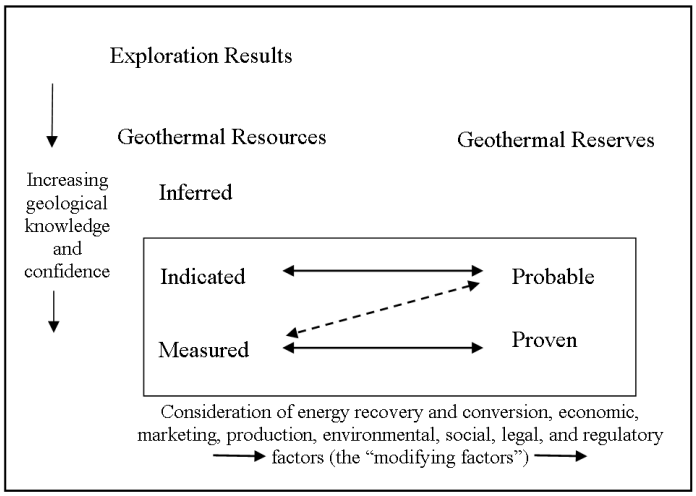

Figure 1. Relationship between Exploration Results, Geothermal Resources and Geothermal Reserves.

5.3 Categories other than Reserves and Resources

The term **Geothermal Play** is used as an informal qualitative descriptor for an accumulation of heat energy within the Earth's crust. It can apply to heat contained in rock and/or fluid. It has no connotations as to permeability or the recoverability of the energy. A Geothermal Play does not necessarily imply the existence of a Geothermal Resource or Reserve.

Exploration Results include data and information generated by exploration programs that may be of use to investors. The reporting of such information is common in the early stages of exploration when the quantity of data available is generally not sufficient to allow any reasonable estimates of Geothermal Resources.

Examples of Exploration Results include results of hot springs/fumarole sampling, surface heat flow, geochemical results and geophysical survey results, conductivity measurements, temperature measurements and temperature extrapolations (to a reasonable degree and on a rational basis).

5.4 Certainty of Data: Resources

A three stage classification (Inferred, Indicated Measured) is used to define how reliably the resource is technically defined (quality and quantity of information), and two categories (Probable, Proven) for Reserves.

The location, quantity, temperature, geological characteristics and extent of a Geothermal Resource are known, estimated or interpreted from specific geological evidence and knowledge. The term 'Geothermal Resource' covers those Geothermal Plays which have been identified and estimated through exploration and sampling and within which Geothermal Reserves may be defined by reduction of the risk after the consideration and application of the Modifying Factors.

Documentation of Geothermal Resource estimates should clearly identify any known potential risks, including geological factors such as faults which could prejudice production or sources of cool fluid intrusion which could degrade the resource.

An '**Inferred Geothermal Resource'** is that part of a Geothermal Resource for which thermal energy in place can be estimated only with a low level of confidence. It may optionally also be reported as recoverable energy and assumed electricity generation with assumptions and rate stated provided there is a reasonable basis for doing so for example, through use of close analogies. This category of Geothermal Resource is inferred from geological, geochemical and geophysical evidence and is assumed but not verified as to its extent or capacity to deliver geothermal energy. There must be a sound basis for assuming that a Geothermal Play exists, estimating the temperature and having some indication of its extent.

The Inferred category is intended to cover situations where a Geothermal Play has been identified and limited measurements and sampling completed, but where the data are insufficient to allow the extent of the Geothermal Resource to be confidently interpreted. It is based mainly on indirect measurements, for example extrapolation of temperature profiles (to a reasonable degree and on a rational basis) and other associated measurements such as conductivity and heat flow, and requires a reasonably sound understanding of the subsurface geology in three dimensions derived, for example, from geophysical surveys, to indicate temperature and dimensions.

A large fraction of the stored heat contained in the reservoir of a resource will be left in the geothermal reservoir at the time that development ceases. The amount that will be left behind may depend on technical, physical or commercial limitations.

Commonly, it would be reasonable to expect that a significant proportion of estimated Inferred Geothermal Resources would be upgraded to Indicated Geothermal Resource estimates with continued and reasonably proximate exploration such as drilling. However, due to the uncertainty of Inferred Geothermal Resource estimates, it should not be assumed that such upgrading will always occur.

Confidence in the estimate of Inferred Geothermal Resources is usually not sufficient to allow the results of the application of technical and economic parameters to be used for detailed planning. For this reason, there is no direct link from an Inferred Resource to any category of Geothermal Reserves. Caution should be exercised if this category is considered in studies of technical and economic viability.

An '**Indicated Geothermal Resource'** is that part of a Geothermal Resource which has been demonstrated to exist through direct measurements that indicate temperature and dimensions so that the thermal energy in place can be estimated with a reasonable level of confidence. It may optionally also be reported as recoverable thermal energy and assumed electricity generation with assumptions and rate stated, especially with regard to the cut-off temperature and technology pathway for conversion. It is based on direct measurements and assessments of volumes of hot rock and possibly fluid, with sufficient indicators to characterize the temperature and chemistry. Direct measurements are sufficiently spaced so as to indicate the extent of the Geothermal Resource.

A Geothermal Play can be classified as an Indicated Geothermal Resource when there has been sufficient drilling into the Play such that the nature, quality, amount and distribution of data allow confident interpretation of the geological framework, the assumption of continuity of the thermal energy distribution and a reasonable estimate of the extent of the Geothermal Play. The well locations are too widely or inappropriately spaced to confirm reservoir continuity but are spaced closely enough for continuity to be indicated.

A '**Measured Geothermal Resource'** is that part of a Geothermal Resource for which thermal energy in place can be estimated with a high level of confidence. It may also optionally be reported as recoverable thermal energy or assumed electricity generation with assumptions and rate of energy recovery stated. It is based on direct measurements and assessments of drilled and tested volumes of rock and/or fluid within which well deliverability has been demonstrated, and which have sufficient indicators to characterize the temperature and chemistry. Direct measurements are sufficiently spaced to confirm continuity.

A Geothermal Play may be classified as a Measured Geothermal Resource when the nature, quality, amount and distribution of data are such as to leave no reasonable doubt, in the opinion of the Competent Person determining the Geothermal Resource, that the thermal energy in place can be estimated to within close limits, and that any

variation from the estimate would be unlikely to significantly adversely affect potential economic viability. This category requires a high level of confidence in, and understanding of the geology and heat source.

Confidence in the estimate is sufficient to allow the application of technical and economic parameters and to enable an evaluation of economic viability that has a greater degree of certainty than an evaluation based on an Indicated Geothermal Resource.

5.5 Certainty of Data: Reserves

A '**Probable Geothermal Reserve'** is the economically recoverable part of an Indicated (usually) or, sometimes, a Measured Geothermal Resource. It will differ from Proven Reserve estimates because of greater technical uncertainty, usually in terms of factors that impact the recoverability of thermal energy such as well deliverability or longevity of the project. There will be sufficient indicators to characterize temperature and chemistry but may be less direct measures indicating the extent of the Geothermal Resource, within economically feasible drilling depth. Appropriate assessments and studies will have been carried out, and include consideration of and modification by realistically assumed drilling, economic, legal, environmental, social and governmental factors. These assessments demonstrate at the time of reporting that commercial energy extraction could reasonably be justified.

A '**Proven Geothermal Reserve'** is the economically recoverable part of a Measured Geothermal Resource. It includes a drilled and tested volume of rock within which well deliverability has been demonstrated and commercial production for the assumed lifetime of the project can be forecast with a high degree of confidence. Appropriate assessments and studies have been carried out, and include consideration of and modification by realistically assumed economic, market, legal, environmental, social and governmental factors.

Once a Geothermal Reserve has entered production and some reservoir response can be observed, classification of remaining Geothermal Reserves should become more accurate. Geothermal Reserves under production should be re-estimated with reservoir models re-calibrated to produce new estimates which are more closely linked to observed temperature and pressure changes in the reservoir, and related to the rate of energy recovery achieved.

Proven Reserves should not be solely based on the high confidence limits of a probabilistic estimate based on a larger area of resource or reserve that is not so reliably defined. If a correlation is to be made with a probabilistic estimate, Proven Reserves will be conceptually similar to a P90 limit, but this is not intended to be a rigid correlation.

5.6 Commerciality

The second main categorization based on whether the energy resource is commercially extractable or not is a little more problematical. Developers tend to closely guard their commercial information and like to maintain flexibility to develop fluid extraction and energy conversion systems to meet their business needs over the life of the project. That perspective has to be given due regard as important for project viability. However, an investor needs some certainty as to whether or not the energy is likely to be readily extractable under prevailing typical technical and market conditions (or at least those foreseeable in the short term).

Commercial viability depends on a range of technical and economic factors. The SPE Guidelines recommend the term Reserve should not be used except with reference to a specific project, and preferably where development is planned within a set time frame of around five years. However, that time frame is considered too restrictive for current geothermal projects in Australia. In the Geothermal Code, and unlike some approaches in the mineral industry, it does not mean that a full, costed and financially modeled feasibility study for the specific project under consideration has to be completed before any reserves can be declared.

If a project involves an innovative application of technology, it may be necessary for certain steps to be taken to regard the concepts involved as sufficiently proven to be able to declare a Reserve. But the level of detail required for "proof of concept" is substantially less than a full commercial feasibility study. Rather, definition of what constitutes Reserves can be done through some industry guidelines for what is commercial in the context of the conversion technology that is expected to be applied to the resource.

In order to achieve the required level of confidence in the Modifying Factors, appropriate studies will have been carried out prior to estimation of the Geothermal Reserves. The studies will have determined an exploration and development plan that is technically achievable and economically viable and from which the Geothermal Reserve estimates can be derived. These assessments demonstrate at the time of reporting that energy extraction could reasonably be economically and technically justified.

What constitutes the term 'reasonably economically and technically justified' will vary with the type of Geothermal Play, the level of study that has been carried out and the financial criteria of the individual company. For this reason, there can be no fixed definition for the term 'economically recoverable'. The term 'reasonable prospects for eventual economic extraction' implies a judgement (albeit preliminary) in respect of the technical and economic factors likely to influence the prospect of economic extraction, including the approximate exploitation parameters. The term 'Geothermal Reserve' need not necessarily signify that plant facilities are in place or operative, or that all necessary approvals or sales contracts have been received. It does signify that there are reasonable expectations of such approvals or contracts.

One element of a pragmatic approach to defining commercial viability is through the resource characteristics required for suitable productivity of wells (or injection-production couplets in stimulated systems) for the type of technology that it is assumed will be applied for energy extraction and conversion, having regard to the probable power price in that particular location.

Typical well deliverability that may be economic for the target method of extraction in the foreseeable future (10 to 20 years) is suggested as a guideline for setting the minimum grade of geothermal reservoir to be considered as any higher category than an Inferred Resource. This eliminates from consideration in Resources or Reserves those heat resources that are too deep or low grade to be considered likely to be extracted with existing or reasonably foreseeable technology.

6. CRITERIA

6.1 Resources

There must be a technically justifiable basis for defining the energy in place (the resource), which, to be placed in the Measured category, includes having an adequate number of wells to define reservoir conditions.

An assumption should be made and stated as to a minimum cut-off criterion (comparable to cut-off grade in a mineral deposit). In the case of a stored heat or other lumped parameter assessment that will be a minimum temperature below which reservoir volumes are not considered part of the resource. In the case of a numerical simulation that will probably be a minimum well deliverability based on temperature and pressure.

The cut-off grade for defining the Resource must take into account the limitations of the extraction and conversion technology and explicitly define any assumptions made. That implicitly (and preferably explicitly) includes an assumption about the energy selling price and conversion technology.

The order of magnitude (or more) difference between heat in place and the ability to extract that heat and convert into a useful form requires that the geothermal code avoid exaggerations of scale of resources that could easily mis-lead markets and investors. Indicated and Measured Resources can, therefore, be stated in terms of expected energy recovery (or optionally electricity potentially generated) provided the basis is stated as to a recovery factor and conversion efficiency to be applied, or reference made to a well-established technical path for energy conversion, even if this technology is presently un-commercial and unproven. If resources are expressed as recoverable energy or electricity to be generated, an assumption should be made and stated as to the rate of energy extraction and/or project life.

6.2 Reserves

The term Reserves is only to be used for those portions of Indicated or Measured Resources that are generally accepted to be commercially extractable with existing technology and prevailing market conditions. For a Reserve to be declared there must be a defined and proven means of extracting the energy and converting it into a saleable form. The differentiation between commercial and sub-commercial is intended to enable identification of the portion of heat that can be readily extracted using current commercial practices separately from that portion which still requires substantive improvements in technical or cost terms to be viable.

Demonstrating the well productivity that can be achieved from the resource is an essential aspect of securing a Reserve classification.

For electricity generation, an assumption must be made and stated as to conversion efficiency to be applied, or reference made to a well-established technical path for energy conversion.

Reserves are to be stated in terms of net recoverable and converted energy. If the project is for electricity generation then it should also be presented as net electrical output. An assumption should be made and stated as to the rate of energy extraction and/or project life.

With regard to the level of confirmation of commercial extractability required to be able to declare Geothermal Reserves, it is considered sufficient to establish that:

- An analysis of the economics of the project has been done to a suitable level of detail.
- The resource parameters and cut off grades (e.g. technically and economically feasible drilling depth, temperature drop in the reservoir) have been linked to the power cost or price in a technically appropriate way.
- Linkages have been made been between the technical uncertainties and the economic sensitivities.
- There is a reasonable expectation of a market for all production at the power at the price proposed, or at least the expected sales quantities of production required to justify development.
- Evidence that the necessary route to market for example transmission lines and access to the grid, are available or there is a reasonable prospect of them being developed.
- Evidence that legal, contractual, environmental and other social and economic concerns will allow for the actual implementation of the proposed scheme.

7. CONCLUSIONS

An industry largely driven by stock market listed companies requires a regime for reporting the quantum and quality of the geothermal resources and reserves to the market and the public in general. A successful such Reporting Code will not only be acceptable to the market regulators and the public, but will be able to be used by any potential finance professional to value the resources and reserves of a company for the purpose of providing debt finance or equity investment. It is therefore transferrable to markets which are not stock exchange dominated.

The Australian geothermal sector is an industry dominated by stock exchange listed companies and has developed a Geothermal Reporting Code which incorporates the fundamental principles of transparency, materiality and competence. The Code is based on the successful Australian JORC Code for minerals and sets out the minimum and mandatory requirements for Public Reports, but it is not prescriptive as to how estimates of resources and reserves are made. Accompanying estimation guidelines have also been prepared but are not mandatory.

Resources are classified in a three tier system according to the level of confidence in the aggregate of technical data going into the estimate. Portions of the highest two tiers may be converted to Reserves after the consideration of Modifying Factors which demonstrate the commerciality of that part of the Resource.

A Competent Person, defined as one who has at least five years experience in the type of Geothermal Play and the type of report is required under the Code to consent in writing to any Public Report based on their resource or reserve estimations. This places a dual onus on the reporting company and the technical person(s) to produce a Public Report that is transparent, material, competent and defendable.

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REFERENCES

Committee for Mineral Reserves International Reporting Standards: "International Reporting Template for the Public Reporting of exploration results, mineral resources and mineral reserves" (2006)

Joint Ore Reserves Committee: "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 (2004)

Lawless et al (2010) *in press* (this volume)

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

The Australian Geothermal Code Committee: "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 (2008)