Australian Code for Reporting of Exploration Results, Geothermal Resources and Geothermal Reserves

The Geothermal Reporting Code

Second Edition (2010)

Australian Code for Reporting of Exploration Results, Geothermal Resources and Geothermal Reserves

The Geothermal Reporting Code

Second Edition (2010)

Effective November 2010

Prepared by:

The Australian Geothermal
Reporting Code Committee (AGRCC)

A Joint Committee of the Australian Geothermal Energy Group (AGEG) and the Australian Geothermal Energy Association (AGEA)

All correspondence regarding the Geothermal Reporting Code should be addressed to:

Chairman, Australian Geothermal Reporting Code Committee
C/- Alexandra Long
Secretariat Executive – Australian Geothermal Energy Group (AGEG)
Primary Industries and Resources SA
GPO Box 1671, Adelaide SA 5001

Email: alexandra.long@sa.gov.au
Telephone: 08 8463 7022 (w) or 0418 684 186 (m)

GA10-4784

Contents

Preface to the Second Edition

Following the launch of the First Edition of the Geothermal Reporting Code in August 2008, it became mandatory for Members of the Australian Geothermal Energy Association (AGEA) to report their Exploration Results, Geothermal Resources and Geothermal Reserves under the Geothermal Reporting Code.

In the ensuing six months, a number of issues became apparent in the use and interpretation of the Geothermal Reporting Code. Most significant amongst these were:

- That the definition of an Inferred Geothermal Resource was allowing large estimates of stored heat to be reported. Whilst derived by legitimate methodologies, it was perceived that these large figures may not be properly understood by non-technical people and may result in a diminution of credibility of the industry;
- The units of energy described in the First Edition were not always consistent or practical; and
- Companies were misunderstanding the requirements in respect of Competent Persons and the circumstances requiring a Competent Person sign-off on a Public report.

In addition, a number of inconsistencies and other issues were identified which needed correction.

The Geothermal Reporting Code Committee consulted with industry and received feedback from companies and practitioners both in Australia and overseas. The Second Edition of the Geothermal Reporting Code addresses the issues identified above. In some cases definitions and meanings have been changed (for example, the re-defining of Geothermal Resources as *recoverable* energy, rather than energy in place) whilst in others, aspects of the Geothermal Reporting Code that were already in place have been made more explicit (for example, the obligations in respect of Competent Person sign-offs).

Introduction

The Australian Geothermal Reporting Code Committee (AGRCC), sponsored by the Australian Geothermal Energy Group and the Australian Geothermal Energy Association, was established in 2007 to produce and maintain a methodology for Public Reporting of Exploration Results and the assessment of Geothermal Resources and Geothermal Reserves that will promote transparency, consistency and confidence. The methodology will:

1) Provide a basis that is satisfactory to investors, shareholders and capital markets such as the Australian Securities Exchange, in the same way that there are recognised Reporting Codes for mineral deposits and petroleum fields.

2) Be applicable to the type of geothermal projects that are likely to be undertaken in Australia, given that many of the Australian Geothermal Plays currently under investigation are different in geological nature from most of those which have so far
been commercially developed in other countries.

3) At the same time, be applicable to Geothermal Plays in other countries, since companies making public reports in Australia are increasingly active globally. This includes established projects with a production history as well as greenfield sites.

This document is the outcome of the work conducted by the AGRCC. It is based on extensive discussions, public presentations and review of earlier drafts.

This document is the Australian Code for Reporting of Exploration Results, Geothermal Resources and Geothermal Reserves (the "Geothermal Reporting Code"). It covers a minimum, mandatory set of requirements for the public reporting of Exploration Results, Geothermal Resources and Geothermal Reserves. A companion document, the Geothermal Lexicon, provides guidance on how Geothermal Resources and Geothermal Reserves can be estimated for reporting purposes. The techniques described in the Lexicon are not a mandatory part of the Geothermal Reporting Code. However, any significant deviations from the Lexicon must be disclosed and explained when reporting under the Geothermal Reporting Code.

Reference in the Geothermal Reporting Code to a Public Report or Public Reporting is to a report or reporting on Exploration Results, Geothermal Resources or Geothermal Reserves, prepared for the purpose of informing investors or potential investors and their advisors. This includes a report or reporting to satisfy regulatory requirements.

It is anticipated that the reporting of Exploration Results and Geothermal Resource and Geothermal Reserve assessments will principally be undertaken by companies operating geothermal tenements. Reports may also be issued by other entities, for example, non-operating joint venture companies and government geoscience agencies.

The Geothermal Reporting Code is intended to be a living document. Once established, however, it will require a formal process to change. The process to review and up-date the Geothermal Reporting Code is managed by the AGRCC, in consultation with key stakeholders. The process for managing the Geothermal Reporting Code is anticipated to evolve over time as its practical application progresses.

The Geothermal Lexicon is more discursive, less formal and will be subject to more frequent revisions for clarity and as concepts evolve.

Acknowledgement

This Geothermal Reporting Code is based closely on the Joint Ore Reserves Committee's "Australasian Code for 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 Reporting Code should be interpreted and applied independently.

Format

In this edition of the Geothermal Reporting Code, important terms are highlighted in **bold** text. Guidelines are placed after some Reporting Code clauses using indented *italics*. They are intended to provide assistance and guidance to readers. They do not form part of the Geothermal Reporting Code, but should be considered persuasive when interpreting the Geothermal Reporting Code.

Governing Principles

The main principles governing the operation and application of the Geothermal Reporting Code are transparency, materiality and competence.

a) **Transparency** requires that the reader of a Public Report is provided with sufficient information, the presentation of which is clear and unambiguous, to understand the report and is not misled.

b) **Materiality** requires that a Public Report contains all the relevant information which investors and their professional advisors would reasonably require, and reasonably expect to find in the report, for the purpose of making a reasoned and balanced judgement regarding the Exploration Results, Geothermal Resources or Geothermal Reserves being reported.

c) **Competence** requires that the Public Report be based on work that is the responsibility of suitably qualified and experienced persons who are members of recognised, relevant professional organisations and subject to accountability and a professional Code of Ethics.

Scope

Geothermal Energy is the energy in the form of heat beneath the surface of the solid Earth.
The Geothermal Reporting Code is relevant to all forms of geothermal energy (including naturally permeable aquifers, engineered geothermal systems and both magmatic and non-magmatic heat sources) and all forms of end-use applications of geothermal energy (including both electricity generation and direct use projects). Ground source heat pumps operating at low source temperatures are excluded from coverage by the Geothermal Reporting Code. In this context "geothermal energy" is taken to include only thermal energy from the Earth to which legal rights of extraction can, in principle, be obtained. In most jurisdictions that will apply only above a certain minimum temperature.

> *The Geothermal Reporting Code is a required minimum standard for Public Reporting of geothermal-related Exploration Results, Geothermal Resources and Geothermal Reserves. Companies are encouraged to provide information in their Public Reports which is as comprehensive as possible.*
>
> *Public Reports include any form of publication of Exploration Results, or Geothermal Resource and/or Reserve estimations. They include but are not limited to:*
>
> - *Company annual reports, quarterly reports and other reports to the Australian Securities Exchange, and/or other organisation as required by law.*

- *Company information in the form of postings on company web sites*
- *Briefings and presentations for shareholders, stockbrokers and investment analysts.*
- *Reports if they have been prepared for the purposes of informing investors, including: environmental statements, information memoranda, expert reports, and technical papers.*
- *Any document (including web pages) that quotes from or contains a reference to Exploration Results, Geothermal Resources or Geothermal Reserves extracted from a previous Public Report.*

All such Public Reports must include a statement of consent by the Competent Person.

For companies issuing concise annual reports, or other summary reports, inclusion of all information that is material to the reporting of Exploration Results, Geothermal Resources and/or Geothermal Reserves is recommended. In cases where summary information is presented it should be clearly stated that it is a summary, and a reference attached giving the location of the Geothermal Reporting Code-compliant Public Report(s) or Public Reporting on which the summary is based.

It is recognised that companies may be required to issue reports into more than one regulatory jurisdiction, with compliance standards that may differ from this Geothermal Reporting Code. It is recommended that such reports include a statement alerting the reader to this situation.

The term 'regulatory requirements' is not intended to cover reports provided to State and Federal Government agencies for statutory purposes, where providing information to the investing public is not the primary intent. If such reports become available to the public, they would not normally be regarded as Public Reports under the Geothermal Reporting Code.

Reference in the Geothermal Reporting Code to "documentation" is to internal company documents prepared as a basis for, or to support, a Public Report.

It is recognised that situations may arise where documentation prepared by Competent Persons for internal company or similar non-public purposes does not comply with the Geothermal Reporting Code. In such situations, it is recommended that the documentation includes a prominent statement to this effect. This will make it less likely that non-complying documentation will be used to compile Public Reports.

While every effort has been made within the Geothermal Reporting Code and Lexicon to cover most situations likely to be encountered in Public Reporting, there may be occasions when doubt exists as to the appropriate form of disclosure. On such occasions, users of the Geothermal Reporting Code and those compiling reports to comply with the Geothermal Reporting Code should be guided by its intent, which is to provide a minimum standard for Public Reporting and to ensure that such reporting contains all information which investors and their professional advisors would reasonably require, and reasonably expect to find in the report, for the purpose of making a reasoned and balanced judgement regarding the Exploration Results, Geothermal Resources or Geothermal Reserves being reported.

Competence, Responsibility and Accountability

A Public Report concerning a company's Exploration Results, Geothermal Resources and/or Geothermal 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 the Competent Person is a full-time employee of the company, and, if not, name the Competent Person's employer. The report shall be issued with the written consent of the Competent Person or Persons as to the form and context in which it appears.

Appropriate forms of compliance statements may be as follows (delete bullet points which do not apply):

- *If the required information is in the report:*

  "The information in this report that relates to Exploration Results, Geothermal Resources or Geothermal Reserves is based on information compiled by (insert name of Competent Person), who appears on the Register of Practicing Geothermal Professionals maintained by the Australian Geothermal Energy Group Incorporated at the time of the publication of this Report".

- *If the required information is included in an attached statement:*

  "The information in the report to which this statement is attached that relates to Exploration Results, Geothermal Resources or Geothermal Reserves is based on information compiled by (insert name of Competent Person), who appears on the Register of Practicing Geothermal Professionals maintained by the Australian Geothermal Energy Group Incorporated at the time of the publication of this Report".

- *If the Competent Person is a full-time employee of the company:*

  "(Insert name of Competent Person) is a full-time employee of the company".

- *If the Competent Person is not a full-time employee of the company:*

  "(Insert name of Competent Person) is employed by (insert name of Competent Person's employer)".

- *For all reports:*

  "(Insert name of Competent Person) has sufficient experience which is relevant to the style and type of geothermal play under consideration and to the activity which he/she is undertaking to qualify as a Competent Person as defined in the Second Edition (2009) of the 'Australian Code for Reporting Exploration Results, Geothermal Resources and Geothermal Reserves'. (Insert name of Competent Person) has consented in writing to the inclusion in the report of the matters based on his/her information in the form and context in which it appears".

Documentation detailing Exploration Results, Geothermal Resource and/or Geothermal Reserve estimates, on which a Public Report on Exploration Results, Geothermal Resources and/or Geothermal Reserves is based, must be prepared by, or under the direction of, and signed by, a Competent Person or Persons. The documentation must provide a fair representation of the Exploration Results, Geothermal Resources and/or Geothermal Reserves being reported.

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 person is undertaking and must appear on the Register of Practicing Geothermal Professionals maintained by the Australian Geothermal Energy Group at the date of publication of the Public Report in question. If the Competent Person is preparing a report on Exploration Results, the experience must be relevant to geothermal exploration. If the Competent Person is estimating, or supervising the estimation of, Geothermal Resources, the experience must be relevant to the estimation of Geothermal Resources. If the Competent Person is estimating, or supervising the estimation of Geothermal Reserves, the experience must be relevant to the estimation of Geothermal Reserves.

The key qualifier in the definition of a Competent Person is the word 'relevant'. Determination of what constitutes relevant experience can be a difficult area and common sense has to be exercised. The key word 'relevant' also means that it is not always necessary for a person to have five years experience in each and every type of Geothermal Play in order to act as a Competent Person if that person has relevant experience in other system types.

In addition to experience in the type of Geothermal Play, a Competent Person taking responsibility for the compilation of Exploration Results, Geothermal Resource or Geothermal Reserve estimates should have sufficient experience in the data gathering and analytical techniques relevant to the Geothermal Play under consideration to be aware of problems which could affect the reliability of data. Some appreciation of heat extraction and energy conversion techniques applicable to that type of Geothermal Play is also important.

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. If doubt exists, the person should either seek opinions from appropriately experienced colleagues or refer the client to other persons with that experience or should decline to act as a Competent Person.

Estimation of Geothermal Resources may be a team effort (for example, involving one person or team collecting the data and another person or team preparing the estimate). Estimation of Geothermal Reserves is very commonly a team effort involving several technical disciplines. It is recommended that, where there is clear division of responsibility within a team, each Competent Person and his or her contribution should be identified, and responsibility accepted for that particular contribution. If only one Competent Person signs the Geothermal Resource or Geothermal Reserve documentation, that person is responsible and accountable for the whole of the documentation under the Geothermal Reporting Code. It is important in this situation that the Competent Person accepting overall responsibility for a Geothermal Resource or Geothermal Reserve estimate and supporting documentation prepared in whole or in part by others, is satisfied that the work of the other contributors is acceptable.

Persons acting as Competent Persons are accountable for their work, and in being enrolled on the Register of Practicing Geothermal Professionals of AGEG, they agree to be bound by the accountability procedures of AGEG. Procedures for making complaints against the work of a Competent Person, the mechanisms for having the complaint heard and assessed, and the mechanism for enforcing sanctions against the Competent Person (if appropriate) are detailed in Annex 1 to the Geothermal Reporting Code. Annex 1 may be modified from time to time independently of the Geothermal Reporting Code and the current version is as published on the web sites of AGEG and AGEA.

Categories of Geothermal Resources and Geothermal Reserves

Categories of Geothermal Resources and Geothermal 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 used by the Geothermal Reporting Code is illustrated in Figure 1. Some explanation and definition of the categories is given below and summarised in Table 1. More background is given in the Geothermal Lexicon.

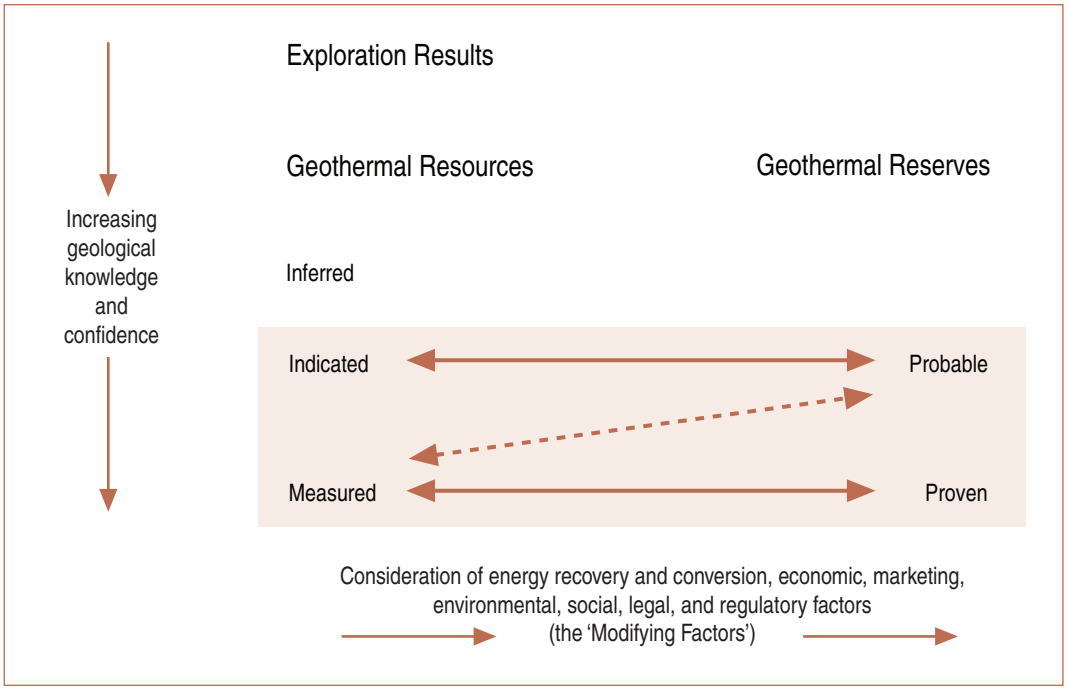

Figure 1. Relationship between Exploration Results, Geothermal Resources and Geothermal Reserves. The Geothermal Reporting Code recognises three levels of Geothermal Resource (Inferred, Indicated and Measured) based upon increasing levels of geological knowledge and confidence which directly affect the assessment of the probability of occurrence. Geothermal Reserves are further estimated from Geothermal Resources by consideration and application of "Modifying Factors" which directly affect the likelihood of commercial delivery (e.g. production, economic, marketing, legal, environmental, land access, social and governmental factors). Two categories of Geothermal Reserve are recognised (Probable and Proven) based upon confidence in both the underlying Geothermal Resource estimate and the Modifying Factors. General relationships and pathways between the various Geothermal Resource and Reserve categories that are permitted under the Geothermal Reporting Code are as shown.

Reporting Terminology

Public Reports dealing with Exploration Results, Geothermal Resources and/or Geothermal Reserves must use only the categories set out in Figure 1.

> *Figure 1 sets out the framework for Geothermal Resource and Geothermal Reserve estimates to reflect different levels of geological confidence and different degrees of technical and economic evaluation. Geothermal Resources will usually be estimated by a geologist on the basis of geoscientific information with some input from other disciplines. Geothermal Reserves, which are a modified sub-set of the Indicated and Measured Geothermal Resources, require consideration of the Modifying Factors affecting extraction and energy conversion, and should in most instances be estimated with input from a range of disciplines.*

Neither Geothermal Resources nor Geothermal Reserves are precise calculations.

> *To emphasise the imprecise nature of Geothermal Resource and Reserve estimates, the final results should always be referred to as 'estimates' and not as 'calculations'.*

Geothermal Resources and Geothermal Reserves must only be reported in units of **Recoverable Thermal Energy** in the play i.e. as Petajoules (PJ_{th}) or $Megawatt_{thermal}$-years (MW_{th}-years) relative to defined **Base** and **Cut-off Temperatures**. If the thermal energy is envisioned to be converted into electricity, then an estimate of the **Recoverable Electrical Energy** may additionally be stated using units of PJ_e or MW_e-years. In all cases the subscript 'thermal' / 'th' or 'electrical' / 'e' must be used to distinguish thermal from converted electricity energy and all recovery and **Conversion Factors** used must be stated separately and clearly in close proximity to the energy figure.

Geothermal Reserves should be associated with an identified development plan for all or part of the Geothermal Resource. For example, those Geothermal Reserves to be transformed into electrical energy may additionally be reported as either the net rate of generation for the life of the project (e.g. x MW_e for y years) or the net total production over the life of the project (e.g. GWh_e). In the case of advanced projects with a production history where assessment is based on dynamic reservoir simulation and energy extraction is expressed as an energy rate (MW_e or MW_{th}) over a defined time period, Recoverable Thermal Energy need not be stated, provided clear criteria are given for the eventual termination of the project.

> *Should a figure for Thermal Energy in Place be included in a Public Report, it must not be done in a way which might imply that the in-place figure is a Geothermal Resource.*
>
> *The net transformed electrical energy will usually be that energy which is available for sale at the output terminals of the power station.*

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 Geothermal Reserve and quantitative amounts of energy should not be reported against it.

The term '**Modifying Factors**' is defined to include energy recovery and conversion, production, economic, marketing, environmental, social, legal, land access and regulatory factors.

Reporting – General

1. Public Reports concerning a company's Exploration Results should include appropriate data presented in a way that has no implication regarding commerciality and should not include any assessment of energy quantum.

2. Public Reports concerning a company's Geothermal Resources may include an estimate of **Thermal Energy in Place** in PJ_{th} or MW_{th}-years but this figure must not be described as a "resource" and if stated, must be clearly differentiated from any Geothermal Resource figure. The Geothermal Resource is the estimated **Recoverable Thermal Energy**. It must be stated in terms of Recoverable Thermal Energy using units of PJ_{th} or MW_{th}-years relative to defined Base and Cut-off Temperatures. If there is a reasonable basis for doing so, convertibility into electricity may be assessed and an additional estimate of the recoverable, converted electrical energy may be stated using units of PJ_e or MW_e-years. The recovery and conversion factors used must be separately stated alongside the Geothermal Resource estimate, whenever it is quoted in a Public Report.

3. Public Reports concerning a company's Geothermal Reserves must be an estimate of Recoverable Thermal Energy, under the same conditions and parameters as for Geothermal Resources in (2) above. Given that the reporting of Geothermal Reserves requires consideration of Modifying Factors, it is expected that the use of the thermal energy will have been determined. In this case the quantum of converted energy may additionally also be reported, for example, y MW_e for x years or GWh_e over the economic life of a power generation project. The recovery and conversion factors used must be separately stated alongside the Geothermal Reserve estimate, whenever it is quoted in a Public Report.

4. A company must disclose any relevant information concerning a Geothermal Reserve that could materially influence the economic value of that Reserve to the company. A company must promptly report any material changes in its Geothermal Resources or Geothermal Reserves.

5. Companies must review and publicly report on their Geothermal Resources and Geothermal Reserves at least annually.

Table 2 provides a list of the main criteria which should be considered when preparing reports on Exploration Results, Geothermal Resources and Geothermal Reserves. These criteria need not be discussed in a Public Report unless they materially affect estimation or classification of a Geothermal Resource or Geothermal Reserve.

It is not necessary, when publicly reporting, to comment on each item in Table 2, but it is essential to discuss any matters which might materially affect the reader's understanding or interpretation of the results or estimates being reported. This is particularly important where inadequate or uncertain data affect the reliability of, or confidence in, a statement of Exploration Results or an estimate of Geothermal Resources or Geothermal Reserves; for example, poor repeatability of down hole measurements etc.

If there is doubt about what should be reported, it is better to err on the side of providing too much information rather than too little. Uncertainties in any criteria that could lead to under- or over-statement of Geothermal Resource or Geothermal Reserve estimates should be disclosed in accordance with the governing principles of Transparency, Materiality and Competence.

Reporting of Exploration Results

6. Exploration Results include data and information generated by exploration programmes. The Exploration Results may or may not be part of a formal declaration of Geothermal Resources or Geothermal Reserves.

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.

If a company reports Exploration Results they must not include any assessment of the quantum of contained or recoverable energy but should state whether or not the actual reservoir rocks have been measured or sampled and if so should include temperature measurements and depth of the measurements. Where Exploration Results include modelled or extrapolated data, the rationale for prediction should be discussed and the input data presented alongside the modelled results together with an indication of their reliability or accuracy. Public Reports of Exploration Results must not be presented so as to unreasonably imply that potentially economically extractable energy has been discovered.

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

Reports of borehole temperature measurements should state the duration of time elapsed since either the end of drilling and/or the end of the most recent circulation in the hole prior to the recording of the temperature values so as to give some indication of whether or not the measurements reflect the true formation temperature.

7. Public Reports of Exploration Results must contain sufficient information to allow a considered and balanced judgement of their significance. Reports must include relevant information such as exploration context, type and method of surface sampling, type and method of geochemical analysis, type and method of geophysical surveys, land tenure status plus information on any of the other criteria that are material to an assessment. Where analytical or measurement results are reported, the report must include all results, along with sample type, location, analytical methods, etc. Reporting of selected information such as measurements from isolated drill holes or surface samples, without placing them in context or perspective is unacceptable.

8. It is recognised that it is common practice for a company to comment on and discuss its exploration in terms of target size and type. Any such information relating to exploration targets must be expressed so that it cannot be misrepresented or misconstrued as an estimate of Geothermal Resources or Geothermal Reserves. The terms Resource(s) or Reserve(s) must not be used in this context. Any statement referring to a potential quantity of Thermal Energy in Place or Recoverable Thermal Energy of the target must be expressed as ranges and must include (1) a detailed explanation of the basis for the statement, and (2) a proximate statement that the potential quantity of recoverable energy is conceptual in nature, that there has been insufficient exploration to estimate a Geothermal Resource and that it is uncertain if further exploration will result in the determination of a Geothermal Resource.

Reporting of Geothermal Resources

9. A '**Geothermal Resource**' is a Geothermal Play which exists in such a form, quality and quantity that there are reasonable prospects for eventual economic extraction. If there is no reasonable prospect for eventual economic extraction then the energy in question should not be included in estimates of Geothermal Resources. The location, quantity, temperature, geological characteristics and extent of a Geothermal Resource are known, estimated or interpreted from specific geological evidence and knowledge. Geothermal Resources are sub-divided, in order of increasing geological confidence, into Inferred, Indicated and Measured categories.

   Portions of a Geothermal Play that do not have reasonable prospects for eventual economic extraction must not be included in a Geothermal Resource. If the judgement as to 'eventual economic extraction' relies on untested technology, practices or assumptions, this is a material matter which must be disclosed in a public report (e.g. recovery of supercritical geothermal water).

   If the reporting of Geothermal Resources includes estimates of end-use energy, for example electricity that may be generated, the report must refer to reasonable and defendable factors pertaining to energy conversion related to the likely end-use.

The term 'Geothermal Resource' covers those Geothermal Plays which have been identified and estimated through exploration and sampling and within which Geothermal Reserves may eventually be estimated by reduction of the risk after the consideration and application of the Modifying Factors.

The term 'reasonable prospects for eventual economic extraction' implies a judgement (albeit preliminary) by the Competent Person in respect of the technical and economic factors likely to influence the prospect of economic extraction, including the approximate conversion type and efficiency, and exploitation parameters. In other words, a Geothermal Resource is not an inventory of all heated areas drilled or sampled, regardless of ***Base*** *or* ***Cut-Off Temperature***[1]*, likely dimensions, location or extent. It is a realistic inventory of those Geothermal Plays which, under assumed and justifiable technical and economic conditions, might, in whole or in part, be developed.*

To arrive at "reasonable and defendable factors pertaining to reservoir recovery and the efficiency of energy conversion", the factors discussed in the Geothermal Lexicon should be used. If other factors are used, a clear supporting explanation must be provided as to the source of the factors and the reason they have been used.

Where considered appropriate by the Competent Person, Geothermal Resource estimates may include a small proportion of the Geothermal Play below the selected Cut-Off Temperature providing that the total Geothermal Resource retains reasonable prospects for eventual economic extraction.

Documentation of Geothermal Resource estimates should clearly identify any known potential risks, for example geological factors such as faults, which could prejudice production or be sources of cool fluid intrusion which could degrade the Geothermal Resource. Public Reports should include commentary on the matter if considered material by the Competent Persons compiling the Public Reports.

Any material assumptions made in determining the 'reasonable prospects for eventual economic extraction' should be clearly stated in the Public Report. Interpretation of the word 'eventual' may vary depending on the context of the envisaged end-use.

Any adjustment made to the data for the purpose of making the Geothermal Resource estimate, for example by interpolation or extrapolation, should be clearly stated and described in the Public Report.

Certain reports (e.g. inventory well reports, exploration reports to government and other similar reports not intended primarily for providing information for investment purposes) may require full disclosure of all potential thermal energy extraction, including some Geothermal Plays that do not have reasonable prospects for eventual economic extraction. Such estimates of extraction would not qualify as Geothermal Resources or Geothermal Reserves in terms of this Geothermal Reporting Code and this should be clearly stated in the respective reports.

10. An '**Inferred Geothermal Resource**' is that part of a Geothermal Resource for which Recoverable Thermal Energy (in units of PJ_{th} or MW_{th}-years) can be estimated only with a low level of confidence. Assumptions made in making the estimate must be stated, especially in respect of the **Base and Cut-off Temperatures** and the technology pathway for usage. If there is a reasonable basis to do so, convertibility into electricity can be assessed and an additional estimate of the recoverable, converted electrical energy may be stated using units of PJ_e or MW_e-years. The recovery and conversion (if used) factors used must be separately stated alongside the Geothermal Resource figure, whenever it is quoted in a Public Report. 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.

1 *See the Geothermal Lexicon for definition and discussion*

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 rock properties 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.

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

Confidence in the estimate of Inferred Geothermal Resources is usually not sufficient to allow the application of technical and economic parameters 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.

Consideration of the 'technology pathway for usage' at the Inferred Geothermal Resource level does not imply actual knowledge or consideration of detailed technology. It is sufficient to consider this in terms of 'ORC binary plant', 'reverse refrigerant plant' or 'flash steam plant', for example.

11. 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 Recoverable Thermal Energy (in units of PJ_{th} or MW_{th}-years) can be estimated with a reasonable level of confidence. Thermal Energy in Place has been estimated through direct measurements and assessments of volumes of hot rock and fluid with sufficient indicators to characterise the temperature and chemistry. Direct measurements are sufficiently spaced so as to indicate the extent of the Thermal Energy in Place. Assumptions made in making the estimate must be stated, especially in respect of the Base and Cut-off temperatures and the technology pathway for usage. If there is a reasonable basis to do so, convertibility into electricity can be assessed and an additional estimate of the recoverable, converted electrical energy may be stated using units of PJ_e or MW_e-years. The recovery and conversion (if used) factors used must be separately stated alongside the Geothermal Resource figure, whenever it is quoted in a Public Report.

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.

An Indicated Geothermal Resource has a lower level of confidence than that applying to a Measured Geothermal Resource, but has a higher level of confidence than that applying to an Inferred Geothermal Resource. Confidence in the estimate is sufficient to allow the application of technical and economic parameters, and to enable an initial evaluation of economic viability.

Consideration of the 'technology pathway for usage' at the Indicated Geothermal Resource level does not imply actual knowledge or consideration of detailed technology. It is sufficient to consider this in terms of 'ORC binary plant', 'reverse refrigerant plant' or 'flash steam plant', for example.

12. A '**Measured Geothermal Resource**' is that part of a Geothermal Resource which has been demonstrated to exist through direct measurements that indicate at least reservoir temperature, reservoir volume and well deliverability, so that Recoverable Thermal Energy (in units of PJ_{th} or MW_{th}-years) can be estimated with a high level of confidence. The Thermal Energy in Place has been demonstrated to exist through 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 characterise the temperature and chemistry. Direct measurements must be sufficiently spaced to confirm continuity. Assumptions made in making the estimate must be stated, especially in respect of the Base and Cut-off temperatures and technology pathway for usage. If there is a reasonable basis to do so, convertibility into electricity can be assessed and an additional estimate of the recoverable, converted electrical energy may be stated using units of PJ_e or MW_e-years. The recovery and conversion (if used) factors used must be separately stated alongside the Geothermal Resource figure, whenever it is quoted in a Public Report.

    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 Recoverable Thermal Energy 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.

    Consideration of the 'technology pathway for usage' at the Measured Geothermal Resource level does not imply actual knowledge or consideration of detailed technology. It is sufficient to consider this in terms of 'ORC binary plant', 'reverse refrigerant plant' or 'flash steam plant', for example.

13. The choice of the appropriate category of Geothermal Resource depends upon the quantity, distribution and quality of data available and the level of confidence that attaches to those data. The appropriate Geothermal Resource category must be determined by a Competent Person or Persons.

    Geothermal Resource classification is a matter for skilled judgement and Competent Persons should take into account those items in the Geothermal Lexicon which relate to confidence in Geothermal Resource estimation.

    In deciding between Measured Geothermal Resources and Indicated Geothermal Resources, Competent Persons shall consider, in addition to the phrases in the two definitions relating to reservoir continuity in Clauses 11 and 12, the phrase in the guideline to the definition for Measured Geothermal Resources which states that: '... any variation from the estimate would be unlikely to significantly affect potential economic viability'.

    In deciding between Indicated Geothermal Resources and Inferred Geothermal Resources, Competent Persons shall take into account, in addition to the phrases in the two definitions in Clauses 10 and 11 relating to reservoir continuity, the definition for Indicated Geothermal Resources which states that these are 'that part of a Geothermal Resource which has been demonstrated to exist through direct measurements that indicate temperature and dimensions so that Recoverable Thermal Energy (in units of PJth or MWth-years) can be estimated with a reasonable level of confidence.' This contrasts with the definition for Inferred Geothermal Resources which states that these are '…that part of a Geothermal Resource for which Recoverable Thermal Energy (in units of PJth or MWth-years) can

be estimated only with a low level of confidence' and which 'is inferred from geological, geochemical and geophysical evidence and is assumed but not verified as to its extent or capacity to deliver geothermal energy'.

The Competent Person should take into consideration issues of the type of heat extraction (e.g. pumped or non-pumped) and Cut-off Temperature when assessing continuity. The Cut-off Temperature chosen for the estimation should be realistic in relation to the technology pathway for the Recoverable Thermal Energy2.

14. Geothermal Resource estimates are not precise calculations, being dependent on the interpretation of limited information on the location, depth and extent of the body of heat and on the available geoscientific results. Reporting of Thermal Energy in Place and Recoverable Thermal Energy figures should reflect the relative uncertainty of the estimate by rounding off to appropriate significant figures and, in the case of Inferred Geothermal Resources, by qualification with terms such as 'approximately'.

In most situations, rounding to the second significant figure should be sufficient. For example: 31 MW_{th} and 6.5 MW_e. There will be occasions, however, where rounding to the first significant figure may be necessary in order to convey properly the uncertainties in estimation. This would usually be the case with Inferred Geothermal Resources.

To emphasise the imprecise nature of a Geothermal Resource estimate, the final result should always be referred to as an estimate not a calculation.

Competent Persons are encouraged, where appropriate, to discuss the relative accuracy and/or confidence of the Geothermal Resource estimates. Where a statement of the relative accuracy and/or confidence is not possible, a qualitative discussion of the uncertainties should be provided. Use of probabilistic estimates is encouraged.

15. Public Reports of Geothermal Resources must specify one or more of the categories of 'Inferred', 'Indicated' and 'Measured'. Categories must not be reported in a combined form unless details for the individual categories are also provided.

Public Reporting of Thermal Energy in Place (which may be stated, but not described as a 'resource') and Recoverable Thermal Energy outside the categories covered by the Geothermal Reporting Code is not permitted unless the situation is covered by Clause 8, and then only in strict accordance with the requirements of that clause.

Estimates of Thermal Energy in Place and Recoverable Thermal Energy outside of the categories covered by the Geothermal Reporting Code may be useful for a company in its internal calculations and evaluation processes, but their inclusion in Public Reports could cause confusion.

16. The word 'Reserve' or 'Reserves' must not be used in describing Geothermal Resource estimates as the term implies technical feasibility and economic viability and is only appropriate when all relevant Modifying Factors have been considered. Reports and statements should continue to refer to the appropriate category or categories of Geothermal Resources until technical feasibility and economic viability have been established to an appropriate level of confidence. If re-evaluation indicates that the Geothermal Reserves are no longer viable, the Geothermal Reserves must be reclassified as Geothermal Resources or removed from Geothermal Resource/Geothermal Reserve statements.

[2] *Refer to the Geothermal Lexicon for a discussion of this point*

It is not intended that re-classification from Geothermal Reserves to Geothermal Resources or vice versa should be applied as a result of changes expected to be of a short-term or temporary nature, or where company management has made a deliberate decision to operate on a non-economic basis. Examples of such situations might be energy price fluctuations expected to be of short duration, drilling emergencies of a non-permanent nature, transmission line failure etc.

Reporting of Geothermal Reserves

17. 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. These assessments demonstrate at the time of reporting that energy extraction could reasonably be economically and technically justified.

    'Modifying Factors' are described at Figure 1.

    The term 'economically recoverable' implies that heat extraction of the Geothermal Reserve has been demonstrated to be viable under reasonable financial assumptions. 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'.

    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 Reserves can be derived. It may not be necessary for these studies to be at the level of a final feasibility study.

    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. The Competent Person should consider the materiality of any unresolved matter that is dependent on a third party on which exploration and development is contingent.

    If there is doubt about what should be reported, it is better to err on the side of providing too much information rather than too little.

    Any adjustment made to the data for the purpose of making the Geothermal Reserve estimate, for example assumptions made regarding temperature measurements, should be clearly stated and described in the Public Report.

18. A '**Probable Geothermal Reserve**' is the economically recoverable part of an Indicated or in some circumstances, a Measured Geothermal Resource. It will differ from Proven Geothermal Reserves because of greater 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 characterise 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, which include consideration of and modification by realistically assumed drilling, economic, legal, environmental, social and governmental factors. These assessments will demonstrate at the time of reporting that commercial energy extraction could reasonably be justified.

A Probable Geothermal Reserve has a lower level of confidence than a Proven Geothermal Reserve but is of sufficient quality to serve as the basis for a decision on the development of the Geothermal Resource. It is 'more likely than not' that the Geothermal Reserve estimate is correct, reflecting a greater than 50% chance of occurrence.

19. 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. These assessments must demonstrate that, at the time of reporting, extraction of the geothermal energy could reasonably be economically justified.

A Proven Geothermal Reserve represents the highest confidence category of Geothermal Reserve estimate. The type of Geothermal Play or other factors could mean that Proven Geothermal Reserves are not achievable in some parts of a Measured Geothermal Resource.

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.

20. The choice of the appropriate category of Geothermal Reserve is determined primarily by the relevant level of confidence in the Geothermal Resource and after considering any uncertainties in the Modifying Factors. Allocation of the appropriate category must be made by a Competent Person or Persons.

The Geothermal Reporting Code provides for a direct two-way relationship between Indicated Geothermal Resources and Probable Geothermal Reserves, and between Measured Geothermal Resources and Proven Geothermal Reserves. In other words, the level of geological confidence for Probable Geothermal Reserves is similar to that required for the determination of Indicated Geothermal Resources, and the level of geological confidence for Proven Geothermal Reserves is similar to that required for the determination of Measured Geothermal Resources.

The Geothermal Reporting Code also provides for a two-way relationship between Measured Geothermal Resources and Probable Geothermal Reserves. This is to cover a situation where uncertainties associated with any of the Modifying Factors considered when converting Geothermal Resources to Geothermal Reserves may result in there being a lower degree of confidence in the Geothermal Reserves than in the corresponding Geothermal Resources. Such a conversion would not imply a reduction in the level of geological knowledge or confidence.

A Probable Geothermal Reserve derived from a Measured Geothermal Resource may be converted to a Proven Geothermal Reserve if the uncertainties in the Modifying Factors are sufficiently reduced. No amount of confidence in the Modifying Factors for conversion of a Geothermal Resource to a Geothermal Reserve can override the upper level of confidence that exists in the Geothermal Resource. Under no circumstances can an Indicated Geothermal Resource be converted directly to a Proven Geothermal Reserve.

Application of the category of Proven Geothermal Reserve implies the highest degree of confidence in the estimate, with consequent expectations in the minds of the readers of the report. These expectations should be borne in mind when categorising a Geothermal Resource as Proven.

21. Geothermal Reserve estimates are not precise calculations. Reporting of the economically recoverable portion of a Geothermal Resource should reflect the relative uncertainty of the estimate by rounding off to appropriate significant figures. Refer also to Clause 14.

    To emphasise the imprecise nature of a Geothermal Reserve, the final result should always be referred to as an estimate not a calculation.

    Competent Persons are encouraged, where appropriate, to discuss the relative accuracy and/or confidence of the Geothermal Reserve estimates. Where a statement of the relative accuracy and/or confidence is not possible, a qualitative discussion of the uncertainties should be provided (refer to Table 2).

22. Public Reports of Geothermal Reserves must specify one or both of the categories of 'Proven' and 'Probable'. Reports must not contain combined Proven and Probable Geothermal Reserve figures unless the relevant figures for each of the categories are also provided.

    Public Reporting of the economically recoverable portions of Geothermal Resources outside the categories covered by the Geothermal Reporting Code is not permitted unless the situation is covered by Clause 8, and then only in strict accordance with the requirements of that clause.

    Estimates of the economically recoverable portions of Geothermal Resources outside of the categories covered by the Geothermal Reporting Code may be useful for a company in its internal calculations and evaluation processes, but their inclusion in Public Reports could cause confusion.

    When revised Geothermal Reserve and Geothermal Resource statements are publicly reported they should be accompanied by reconciliation with previous statements. A detailed account of differences between the figures is not essential, but sufficient comment should be made to enable significant changes to be understood by the reader.

23. In situations where figures for both Geothermal Resources and Geothermal Reserves are reported, a statement must be included in the report which clearly indicates whether the Geothermal Resources are inclusive of, or additional to the Geothermal Reserves.

    Geothermal Reserve estimates must not be aggregated with Geothermal Resource estimates to report a single combined figure. The resulting total is misleading and is capable of being misunderstood or of being misused to give a false impression of a company's prospects.

    In some situations there are reasons for reporting Geothermal Resources inclusive of Geothermal Reserves and in other situations for reporting Geothermal Resources additional to Geothermal Reserves. It must be made clear which form of reporting has been adopted. Appropriate forms of clarifying statements may be:

        'The Measured and Indicated Geothermal Resources are inclusive of those Geothermal Resources modified to produce the Geothermal Reserves.' or

        'The Measured and Indicated Geothermal Resources are additional to the Geothermal Reserves.'

In the former case, if any Indicated and Measured Geothermal Resources have not been modified to produce Geothermal Reserves for economic or other reasons, the relevant details of these unmodified Geothermal Resources should be included in the report. This is to assist the reader of the report in making a judgement of the likelihood of the unmodified Geothermal Resources eventually being converted to Geothermal Reserves.

Inferred Geothermal Resources are by definition always additional to Geothermal Reserves.

24. Table 2 provides, in a summary form, a list of the criteria which should be considered when preparing reports on Exploration Results, Geothermal Resources and Geothermal Reserves. These criteria need not be discussed in a Public Report unless they materially affect estimation or classification of the Geothermal Reserves. Changes in economic, title or political factors alone may be the basis for significant changes in Geothermal Reserves and should be reported accordingly.

Table 1. Summary of Resource and Reserve Classification

This Table should be used only as a guideline for those preparing reports on Exploration Results, Geothermal Resources and Geothermal Reserves. For full formal definitions of Geothermal Resources and Geothermal Reserves, please refer to the Geothermal Reporting Code text.

	Exploration Results	Geothermal Resource			Geothermal Reserve	
		Inferred	Indicated	Measured	Probable	Proven
Commerciality	No implications regarding commerciality.	Commerciality not yet established. Probably feasible with current or future technology, prevailing and/or more favourable market conditions.			Commercial. Feasible with existing technology and prevailing market conditions.	
Definition	Data from exploration that is of material value to Geothermal Resource estimation, but which in itself is insufficient to define a Geothermal Resource category.	The Recoverable Thermal Energy within an area/volume that has enough direct indicators of Geothermal Resource character or dimensions to provide a sound basis for assuming that a body of thermal energy exists, estimating temperature and having some indication of extent.	The Recoverable Thermal Energy within a more reliably characterised volume of rock than the Inferred Geothermal Resource. Sufficient indicators to characterise temperature and chemistry, although with few direct measures indicating extent.	The Recoverable Thermal Energy within a drilled and tested volume of rock within which well deliverability has been demonstrated, with sufficient indicators to characterise temperature and chemistry and with sufficient direct measurements to confirm the continuity of the reservoir.	That part of an Indicated Geothermal Resource for which commercial production for the assumed lifetime of the project can be forecast, or: That part of a Measured Geothermal Resource for which commercial production for the assumed lifetime of the project cannot be forecast with sufficient confidence to be considered a Proven Geothermal Reserve. The chance of occurrence is 'more likely than not'.	Applies directly to production satisfying all Modifying Factors. Directly related to that part of a Measured Geothermal Resource for which commercial production for the stated lifetime of the project can be forecast with a high degree of confidence.
Correlation with Probabilistic Estimates					~P50	~P90
Required		1. Recoverable Thermal Energy 2. Major assumptions and recovery factor(s)	1. Recoverable Thermal Energy 2. Major assumptions and recovery factor(s)	1.Recoverable Thermal Energy 2. Major assumptions and recovery factor(s)	1. Recoverable Thermal Energy 2. Major assumptions and recovery factor(s)	1. Recoverable Thermal Energy 2. Major assumptions and recovery factor(s)

	Exploration Results	Geothermal Resource			Geothermal Reserve	
		Inferred	Indicated	Measured	Probable	Proven
Optional, in addition		3. Thermal Energy in Place (***must not be described as a 'resource'***) 4. Total assumed electricity generation 5. Assumed electricity generation over a period And if so: 6. Major assumptions and conversion factor(s)	3. Thermal Energy in Place (***must not be described as a 'resource'***) 4. Total assumed electricity generation 5. Assumed electricity generation over a period And if so: 6. Major assumptions and conversion factor(s)	3. Thermal Energy in Place (***must not be described as a 'resource'***) 4. Total assumed electricity generation 5. Assumed electricity generation over a period And if so: 6. Major assumptions and conversion factor(s)	3. Thermal Energy in Place (***must not be described as a 'resource' or a 'reserve'***) 4. Total assumed electricity generation 5. Assumed electricity generation over a period And if so: 6. Major assumptions and conversion factor(s)	3. Thermal Energy in Place (***must not be described as a 'resource' or a 'reserve'***) 4. Total assumed electricity generation 5. Assumed electricity generation over a period And if so: 6. Major assumptions and conversion factor(s)
Units	As appropriate	1. PJ_{th} or MW_{th}-years 2. As appropriate 3. PJ_{th} or MW_{th}-years 4. PJ_e or MW_e-years 5. x MW_e for y years 6. As appropriate	1. PJ_{th} or MW_{th}-years 2. As appropriate 3. PJ_{th} or MW_{th}-years 4. PJ_e or MW_e-years 5. x MW_e for y years 6. As appropriate	1. PJ_{th} or MW_{th}-years 2. As appropriate 3. PJ_{th} or MW_{th}-years 4. PJ_e or MW_e-years 5. x MW_e for y years 6. As appropriate	1. PJ_{th} or MW_{th}-years 2. As appropriate 3. PJ_{th} or MW_{th}-years 4. PJ_e or MW_e-years 5. x MW_e for y years 6. As appropriate	1. PJ_{th} or MW_{th}-years 2. As appropriate 3. PJ_{th} or MW_{th}-years 4. PJ_e or MW_e-years 5. x MW_e for y years 6. As appropriate

Table 2. Assessment and Reporting Criteria

These tables are a checklist and guideline which those preparing reports on Exploration Results, Geothermal Resources and Geothermal Reserves should use as a reference. They are for guidance only and are not formally part of the Geothermal Reporting Code

The checklist is not prescriptive. It is to identify parameters and assumptions used in geothermal exploration/development and to consider each of these from the viewpoint of the disclosure required for transparency and materiality. Relevance and materiality are overriding principles that determine what information should be publicly reported. It is, however, important to report any matters that might materially affect a reader's understanding or interpretation of the results or estimates being reported. This is particularly important where inadequate or uncertain data affect the reliability of, or confidence in, a statement of Exploration Results or an estimate of Geothermal Resources or Geothermal Reserves.

The order and grouping of criteria in Table 2 reflects the normal systematic approach to exploration and evaluation. Criteria in the first group 'Pre-Drilling Exploration Technical Data' may apply to all succeeding groups. In the remainder of the tables, criteria listed in preceding groups would often apply to succeeding groups and should be considered when estimating and reporting. Thus data required in A may also be relevant to B and data in A & B may be relevant to C but that in C, for instance, may not be required for B. In Item D a distinction is made between parameters more relevant to naturally convective hydrothermal reservoirs and deep sedimentary aquifers, and those more related to Hot Rock situations (Enhanced Geothermal Systems (EGS) may draw on both).

A. Pre-Drilling Exploration Technical Data

Parameters listed in this group may be required in all succeeding groups

Parameter / Data	Considerations
Geological maps and interpretation	• Nature and quality of available mapping (e.g. scale, completeness, age, authors, 2D, 3D etc.) including basis for interpretation and any implications for likely Geothermal Resource types • Description of any relevant Geothermal Plays previously recorded in the vicinity or same geological province
Data location and spacing	• Adequacy of base maps • Methodology and quality of sample location (e.g. GPS etc.) • Datum and projection used along with any relevant parameters (locations should be reported using recognised co-ordinate systems and not local grids wherever possible) • Spacing of available data points • Extent of data interpolation/extrapolation including explanation of techniques applied
Evidence for past or present water/rock interaction	• Location and description of observed hydrothermal alteration and mineralisation
Hydrology	• Nature and quality of near-surface hydrological data and the basis for interpretation including indicators of deeper hydrology
Sampling techniques	• Nature and appropriateness of geological, geochemical or fluid sampling procedures including collection, steps taken to ensure samples are representative, sample identification and preservation

Parameter / Data	Considerations
Analytical techniques	• Identification and experience of analytical laboratory • Nature, quality and appropriateness of laboratory techniques and related quality control procedures (e.g. in determination of petrographic, geochemical, fluid or gas analysis, physical rock properties, isotope, age data etc.) • The level of analytical uncertainty and whether acceptable levels of accuracy and precision are considered to have been established
Temperature measurement and geothermometry	• Nature and quality of available surface temperature data (e.g. ambient, 1m probe, aerial infra red scans, existing shallow wells etc.) • Nature, quality and appropriateness of techniques used to determine temperatures from fluid or rock chemical geothermometry, including source of fluids, level of uncertainty in measurement and key assumptions made • Nature of thermal features used to determine temperature and their relation to chemical sampling
Temperature gradient	• Nature, quality and appropriateness of calculations used to determine temperature gradient including the nature and source of surface temperature data and the associated level of uncertainty • Depth intervals of determined gradients
Thermal conductivity (K)	• Whether determined analytically, modelled or assigned • Where determined analytically, identification and experience of analytical laboratory and nature, quality and appropriateness of analyses used (e.g. number and frequency of samples, technique used to determine K, type of samples (e.g. core etc.), sample preparation (e.g. sample dimension, polish etc.) and analytical specifications (e.g. orientation of samples, wet or dry analysis, temperature at which K was determined etc.)) • Where modelled, the nature, quality and appropriateness of the model used, the source and quality of input parameters, corrections applied and/or key assumptions made • Where assigned, the basis for interpretation including key assumptions and data sources • The estimated level of uncertainty
Heat flow	• Whether based upon measured or assumed parameters • Where based on measured data, the nature and quality of the measurements (temperature and thermal conductivity), including characteristics of any thermal features from which they were derived, frequency and distribution of the samples, method/s used for depth matching temperature and thermal conductivity data, assumptions made and any evidence of temporal change • Where reliant upon assumed or assigned data, then the basis for interpretation, including key assumptions and data sources • In all cases nature, quality and appropriateness of the model/s used (e.g.1D, 2D or 3D modelling), corrections applied and key assumptions made regarding physical conditions, vertical heat flow, topographic models etc. • The estimated uncertainty including key assumptions made
Heat generation determination	• Basis for the identification of significant sources of subsurface heat generation • Nature, quality and appropriateness of model used to calculate heat generation capacity and the level of uncertainty in the results
Geophysical techniques	• Nature, quality and appropriateness of any geophysical techniques used to describe or define geothermal anomalies including uncertainty and key assumptions made before, during and after interpretation, modelling, calibration of rock properties especially with drill hole data, contractors used and available survey parameters (e.g. resistivity, seismic, gravity, magnetic, MT) for both regional and local surveys

Parameter / Data	Considerations
Data integrity and verification	• Measures taken to ensure data have not been corrupted between initial collection and use in models/calculations • Data validation process • The verification of significant results by application of alternative techniques and/or independent personnel

B. Tenement, Environmental and Infrastructure Data

Parameters listed in the preceding group apply where relevant. Parameters listed in this group may be required in all succeeding groups. Information in this group in particular may require updating and re-issuing at later stages in the development process.

Parameter / Data	Considerations
Tenement and land tenure status	• Type, reference name/number, location and ownership including agreements or material issues with third parties such as joint ventures, partnerships, overriding royalties, native title interests, historical sites, wilderness or national park and environmental settings • The security of tenure held at the time of reporting along with any known impediments to obtaining a licence to operate in the area
Terrain, geotechnical issues and access	• Identification of significant geotechnical, geohazard or access issues which could affect future drilling locations or sterilise sectors
Environmental issues	• Identification of significant environmental issues (for example, water requirements, induced seismicity) which could affect future drilling locations or sterilise sectors
Land use issues	• Identification of significant land use conflicts which could affect future drilling locations or sterilise sectors
Infrastructure	• Proximity to and quality of relevant infrastructure and water supply, in particular transmission lines when the project is being considered for electricity generation
Exploration by other parties	• Acknowledgment and appraisal of exploration by other parties to the extent the data are available

C. Subsurface and Well Discharge Data

Parameters listed in the preceding group apply where relevant. Parameters listed in this group may be required in all succeeding groups

Parameter / Data	Considerations
Drilling data	• Type of drilling used (e.g. core, rotary etc.) including basic spud/collar details (e.g. date drilled, depth etc.) • Availability of drilling records and data from rig instrumentation (e.g. ROP, WOB, circulation losses, mud logging, drilling breaks, well kicks etc.) • Nature and quality of directional survey data • Type of completion used and related details (e.g. depth to casing etc.)
Well sample recovery	• Nature and quality of down-hole samples (e.g. cuttings, core, fluids etc.) and sampling intervals including the basis for determination of sampling depths and measures taken to ensure samples are representative

Parameter / Data	Considerations
Geological log	• The nature and scale of logging as well as the basis for geological interpretation and identification of alteration zones (e.g. qualitative vs. quantitative logs, lithology, palaeontology, palynology, mineralogy, fluid inclusions, Vitrinite reflectance etc.) • Whether there is any evidence from mineralogy indicating acid or high-gas fluids
Downhole temperature pressure and flow logs	• Nature (e.g. continuous log, maximum recording thermometer, injectivity test, Pressure Build Up etc.), quality (e.g. tool precision, operating parameters, time allowed, resolution, type and frequency of calibration) and appropriateness (e.g. tool operating parameters relative to hole conditions, tool resolution, processing or corrections required and/or applied) of instrument/s used • Characteristics and quality of measurement(s) (depth, frequency, timing, precision, accuracy etc.) including level of uncertainty • Appropriateness of interpretation with consideration for all significant influences (e.g. presence of local aquifers or known fluid circulation, well status at time of logging (e.g. shut in, flowing, injection rate etc.)) • Nature and quality of any temperature correction/s applied or justification for neglecting correction (e.g. length of time elapsed between drilling and temperature measurement) • If no corrections are applied and the measured temperature is likely to be affected by the drilling thermal anomaly this must be clearly stated
Other downhole logging	• Nature (e.g. FMI, Gamma, calliper etc.), quality (e.g. tool precision, operating parameters, resolution, type and frequency of calibration) and appropriateness (e.g. tool operating parameters relative to hole conditions, tool resolution, processing or corrections required and/or applied) of instrument/s used • Nature and quality of measurement(s) (depth, frequency, timing) • Appropriateness of interpretation with consideration for all significant influences (e.g. hole condition, temperature, formation invasion etc.)
Aquifers	• Location of permeable zones/aquifers, their significance and relationship to structures and stratigraphy • Nature, quality and appropriateness of model/s used to determine adjusted heat flow
Depth of reservoir	• Depth of anticipated reservoir development
Injection tests	• Nature and quality of injectivity tests conducted across permeable zones • Nature (e.g. calculated or observed, flow versus wellhead pressure) and appropriateness of determined injection capacity of well including key assumptions and temperature data • Any evidence of temporal change
Multi-well tests	• Nature (e.g. circulation, interference, tracer etc.) and quality of well tests and measurements, including duration and sampling methods where relevant • Appropriateness of test interpretation including any corrections or omissions and any evidence of temporal variation
Well discharge testing	• Nature (e.g. James method, separator and orifice plates, Tracer Dilution Flow Test etc.) and duration of tests (including completeness of the measurement suite over the wellhead pressure discharge curve) • Quality and reliability of monitoring equipment • Characteristics observed over time including any chemical and/or physical indications of dilution by drilling fluids, stability, multi-zone behaviour, possible scaling or dry-out, tracer returns.

D1. Naturally Convective Systems and Hot Sedimentary Aquifer Resource Parameters

Parameters listed in the preceding groups apply where relevant. Parameters listed in this group apply to all succeeding groups where relevant.

Parameter / Data	Considerations
Flow rate	• Nature (e.g. individual vs. interference, duration, depth etc.), quality and appropriateness of techniques used to record flow rates in wells together with key assumptions made • Where rates are derived from individual well tests these must be detailed individually and must not be summed except with suitable acknowledgement of possible interference • Magnitude and uncertainty of temperature and pressure drawdown observed during flow tests, in relation to chemical indications of stability and long term trends
Pressure data	• Nature, quality and appropriateness of techniques used to determine reservoir pressures including multi-well correlations, fluids and key assumptions made
Recharge	• What allowance (if any) has been made for heat and fluid recharge, and the basis thereof
Water saturation and enthalpy	• Nature and appropriateness of techniques used to determine in-situ water saturation • Nature and quality (e.g. accuracy) of measurements of well discharge enthalpy including consideration of how they relate to in situ saturation
Scaling, gas content (composition) and acidity	• Data on reservoir fluid chemistry and its impact on the reservoir, wells and surface facilities • Nature and appropriateness of tests carried out to determine surface and down hole scaling potential of fluids including the basis for interpretation of test results • Nature and appropriateness of tests run, models applied or analogies used as evidence for possible offset of scaling by methods of downhole or surface inhibition
Reservoir properties	• Nature, quality and appropriateness of methods used to determine reservoir properties (rock types, porosity, permeability, anisotropy, specific permeable structures etc.) • Basis for interpretation of temperature and pressure profiles
Conceptual model: nature of the system	• Nature, quality and appropriateness of integrated geo-hydrological reservoir model including analogies used and key assumptions made • Whether the fluid is naturally convecting • If the project is based on a laterally extensive aquifer, what are its hydrological properties outside the concession area • Interpretation of physico-chemical reservoir processes
Numerical modelling	• Nature of numerical simulation modelling, including model structure, key parameters, boundaries and relationship to conceptual modelling • Results of natural state modelling • Results of history matching (if any) • Results of forecast runs including descriptions of scenarios modelled • Sensitivity analysis and the effects of alternative interpretation
Data extrapolation	• The extent of data interpolation/extrapolation including explanation and justification of techniques applied

D2. Hot Rock Resource Parameters

Parameters listed in the preceding groups including D1 apply where relevant. Parameters listed in this group apply to all succeeding groups where relevant.

Parameter / Data	Considerations
Lithology	• Nature, condition and volume of reservoir target
Fluid conditions	• Whether any naturally occurring fluids exist in the target reservoir rocks and if so what is their chemistry • Whether external water sources will be required as the medium to remove the heat contained in the rocks
Stress condition	• Nature, quality and appropriateness of available stress measurements • Number, spacing and depth of available stress measurements
Natural fractures	• Nature, quality and appropriateness of data (orientation, location, frequency) regarding the natural fracture network including knowledge of flowing fractures, their depth and relevance to the reservoir development • Fracture character including aperture, width, mineral content and surrounding cataclastic zone
Reservoir stimulation	• Nature, location and frequencies of reservoir stimulation events • Corresponding pressure/flow data, including basis for interpretation and displaying temporal variations • Quality and reliability of monitoring equipment
Micro-seismic monitoring	• Nature, quality and appropriateness of seismic network used to monitor reservoir stimulation (e.g. instrumentation, distribution, locational accuracy, sensitivity, resolution, check shot etc.) • Volume estimation of the derived reservoir including key assumptions made and estimation of uncertainty • Evidence for achievement of stimulated reservoir volume

E. Reporting of Exploration Results

Parameters listed in the preceding group apply where relevant. Parameters listed in this group may be required in all succeeding groups

Parameter / Data	Considerations
Diagrams	• Where possible, maps and sections (with scales) and tabulations of intercepts should be included for any material discovery being reported if such diagrams significantly clarify the report. • Diagrams and maps should be presented using recognised coordinate systems with datum, projection and all relevant parameters declared on the map face
Balanced reporting	• Where possible reporting should be comprehensive • Where comprehensive reporting of all Exploration Results is not practicable, representative reporting should be practiced to avoid misleading reporting of Exploration Results
Other substantive exploration data	• Other exploration data, if meaningful and material, should be reported including (but not limited to): geological observations; geophysical survey results; geochemical survey results; groundwater; geotechnical and rock characteristics; potentially deleterious or contaminating substances
Audits or reviews	• The results of any audits or independent reviews of exploration data, models or interpretations
Further work	• The nature and scale of planned further work (e.g. tests for lateral extensions or depth extensions or large-scale step-out drilling).

F. Estimation and Reporting of Geothermal Resources

To be considered in conjunction with previous tables when reporting results of Geothermal Resource assessment

Expected use	• Nature of the anticipated Geothermal Resource exploitation including any assumptions made
Data integrity	• Source and reliability of all relevant Geothermal Resource data • Measures taken to ensure data described has not been corrupted between initial collection and use in models/calculations • Data validation process
Data interpretation	• Confidence in (or conversely the uncertainty of) any interpretation of geological, geophysical or geochemical data to be used in the Geothermal Resource estimation • The effect, if any, of alternative interpretation/s upon Geothermal Resource estimation
Well deliverability	• Must be demonstrated if Geothermal Resource/s to be regarded as Measured • Whether the project will rely on pumping or self-discharging wells • Information on expected parasitic power requirement for production or injection pumps
Estimation and modelling techniques	• The nature and appropriateness of the estimation technique(s) applied and key assumptions made • The availability of previous production records and whether such data is considered • Any assumptions regarding the correlation of variables • The process of validation, the checking process used and the reconciliation of model to measured data and the verification of significant results by application of alternative techniques and/or independent personnel
Cut-off parameters	• The basis for any adopted cut-off temperatures, flow rates or quality parameters (e.g. reservoir porosity, well deliverability etc.) applied, preferably related to a known technology pathway
Recovery factors	• Must be explicitly stated and justified
Conversion efficiency	• If used, expected conversion efficiency for converting heat into electricity • Methodology used for determination of conversion efficiency including an explanation of the technology pathway and justification of any assumptions made
Dimensions	• The extent and variability of the estimated Geothermal Resource expressed as surface area and depth below surface including a explanation of the basis for any interpretations of reservoir geometry
Geothermal Resource Life	• The expected life of the Geothermal Resource based upon available modelling and anticipated development • Nature, quality and appropriateness of methods used for Geothermal Resource-life modelling including key assumptions • Estimation of deleterious elements (e.g. short circuiting, scaling etc.)
Classification	• The basis for the classification of the Geothermal Resource into varying confidence categories • Whether appropriate account has been taken of all factors • Whether the results appropriately reflect the views of the Competent Person
Third party involvement	• Acknowledgement of possibly conflicting developments by other parties
Audits or reviews	• The results of any audits or reviews of the Geothermal Resource estimate
Balanced and impartial reporting	• Where possible reporting should be comprehensive • Where comprehensive reporting of all Geothermal Resource estimation is not practicable, representative reporting should be practiced to avoid misleading reporting of Geothermal Resource estimation

Discussion of relevant accuracy/confidence	• Where appropriate a statement of the relative accuracy and/or confidence in the Geothermal Resource estimate using an approach or procedure deemed appropriate by the Competent Person. For example, the application of sensitivity analysis, probabilistic analysis or use of scenario trees, or, if such an approach is not deemed appropriate, a qualitative discussion of the factors which could affect the relative accuracy and confidence of the estimate • The statement should specify whether it relates to the whole or partial Geothermal Resource and, if partial, clearly state the extents along with assumptions made and procedures used • These statements of relative accuracy and confidence of the estimate should be compared with production data, where available
Qualifications and accountability	• A statement of the qualifications, experience and accountability of the Competent Person making the assessment

G. Estimation and Reporting of Geothermal Reserves

To be considered in conjunction with previous tables when reporting results of Geothermal Reserves assessment

Resource assessment for conversion	• Description of Geothermal Resource estimate to be used as a basis for conversion to a Geothermal Reserve, including data sources and justification for all assumptions made • Clear discrimination between Geothermal Resources reported as additional to Geothermal Reserves and those included within the Geothermal Reserves
Study status	• The type and level of study undertaken to enable the Geothermal Resource to be converted to Geothermal Reserve
Plant when related to electricity generation	• Technology to be used and demonstration of technical viability if novel • Expected capacity and life of associated power plant development • Expected plant factor including key assumptions in determination
Environmental and land use	• Identification of any significant environmental factors or land use conflicts which sterilise sectors or impact on project economics including, but not limited to: - Third party development - Emissions to air or water - Subsidence - Effect on groundwater - Effects on natural thermal activity or ecosystems - Changes in surface heat flow, induced hydrothermal eruptions - Induced seismicity - Effects on tourism, bathing or other land uses
Cost and revenue factors	• The derivation of, or assumptions made, regarding projected capital and operating costs • The assumptions made regarding revenue • The allowances made for royalties payable
Market assessment	• Location of the Geothermal Resource relative to the expected market • Market capacity vs. price • Where applicable, the electricity price used, including the basis for assuming this value, its estimated uncertainty and the effects of any uncertainty upon the Geothermal Reserve estimation
Other	• The effect, if any, of natural risk, infrastructure, legal, social or governmental factors on the likely viability of the project • The status of titles and approvals critical to the viability of the project

Classification	• The basis for the classification of the Geothermal Reserve into varying confidence categories • Whether appropriate account has been taken of all factors • Whether the results appropriately reflect the views of the Competent Person
Audits or reviews	• The results of any audits or reviews of the Geothermal Reserve estimate
Discussion of relative accuracy/confidence	• Where appropriate a statement of the relative accuracy and/or confidence in the Geothermal Reserve estimate using an approach or procedure deemed appropriate by the Competent Person. For example, the application of sensitivity analysis, probabilistic analysis or use of scenario trees, or, if such an approach is not deemed appropriate, a qualitative discussion of the factors which could affect the relative accuracy and confidence of the estimate • The statement should specify whether it relates to the whole or partial Geothermal Reserve and, if partial, clearly state the extents along with assumptions made and procedures used • These statements of relative accuracy and confidence of the estimate should be compared with production data, where available
Qualifications and accountability	• A statement of the qualifications, experience and accountability of the Competent Person making the assessment

H. Additional Factors: Existing Developments

To be considered in conjunction with previous tables. The purpose of this section is to account for previous Geothermal Resource extraction and to use production data to better characterise future Geothermal Reserve estimation.

Production data	• Production data on past total heat and fluid extraction and reinjection • Pressure, temperature, enthalpy and chemical historical trends both for individual wells and the whole Geothermal Resource, together with any interpretations in terms of reservoir processes and the hydrogeological conceptual model • Any assessments of heat and fluid recharge
Reservoir monitoring	• Methods used and an assessment of data quality for reservoir monitoring, including but not limited to: - Surface and downhole pressure and temperature measurements - Fluid flows and enthalpy measurements - Tracer tests - Well output tests - Thermal activity and heat flow monitoring - Ground deformation monitoring - Microgravity monitoring - Environmental monitoring
Production history	• History of Geothermal Resource usage including numbers and locations of wells used for production and reinjection, especially in relation to observed reservoir changes
Numerical modelling	• Numerical simulation modelling should be used at this stage as soon as sufficient production history is available to do so in meaningful fashion • Good history matchings should be achieved for credibility • Should include a detailed description of all scenarios modelled and bear a close relationship to the actual existing or proposed development scheme
Development scenarios	• Future Geothermal Resource usage scenarios