UNFC-2009 AND GEOTHERMAL RESOURCE CLASSIFICATION

Malcolm A Grant[1] and Greg N H Ussher[2]

[1]MAGAK, 14A Rewi Rd, Royal Oak, Auckland, New Zealand

[2]Jacobs , 12 Nicholls Lane, Parnell, Auckland, New Zealand

malcolm@grant.net.nz

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ABSTRACT

UNFC-2009 is the United Nations Framework Classification (2009 version) and provides a system for classification of resources. It has been developed under UNECE (United Nations Economic Commission for Europe), and covers mineral and petroleum resources. It has been decided to extend the coverage to renewable energy resources. As part of this process, UNECE and IGA have agreed that IGA develop and maintain geothermal specifications. A Working Group of 12 has been appointed, two of whom are the authors of this paper.

The UNFC-2009 framework is significantly different from the resource estimates familiar in geothermal, which have a simple grading relating to how reliably the resource is defined: proven/probable/possible and a secondary category as either resource or reserve that reflects modifying factors relating to the economic and social feasibility of development. A UNFC estimate is allocated a grade along 3 axes, so that the system allows much greater (more "granular") precision in the definition of the status of a resource. The three axes, EFG, roughly correspond to economic/social, technical feasibility, and confidence in knowledge of the resource. A UNFC estimate is also project based, meaning that it relates to a proposed or existing development (or just a development concept), and is not simply used for estimating energy that may theoretically be available for identified resources, meaning that specifying how the energy is to be extracted from the reservoir forms an integral part of estimating energy potential.

The IGA's support for the UNFC-2009 geothermal classification, the wider acceptance and use of UNFC-2009 for other energy sources along with its more robust structure mean that it will most probably replace other national based standards for geothermal resource reporting once published.

Development of the geothermal specifications is however, a slow process due to the need to achieve consensus among a group with widely differing background, and the formalities of UN processes. This paper reviews the UNFC-2009 classification and the present state of geothermal specification development.

1. UNFC BACKGROUND

The text below, after ECE (2013), provides historical information on the development of the UNFC-2009:

During the 1990s, ECE took the initiative to develop a simple, user-friendly and uniform system for classifying and reporting reserves and resources of solid fuels and mineral commodities in response to the wishes of member countries to develop a standard reporting system. The result of these efforts was the creation of the UNFC-1997 that was endorsed by the United Nations Economic and Social Council (ECOSOC) in 1997.

In 2004, the classification was extended to also apply to petroleum (oil and natural gas) and uranium and renamed the UNFC-2004.

In its decision 2004/33, ECOSOC then invited the Member States of the UN, international organizations and the UN regional commissions to consider taking appropriate measures for ensuring its worldwide application. This decision provided an opportunity to harmonize existing reserves and resources classifications, in response to the integration of financial and extractive activities worldwide.

In order to facilitate worldwide application of the classification, the ECE Committee on Sustainable Energy directed the Ad Hoc Group of Experts on Harmonization of Fossil Energy and Mineral Resources Terminology (now the EGRC) to prepare and submit a revised UNFC for consideration by the Extended Bureau of the Committee. In response to that request, a stronger, simpler version of the classification was prepared. This version is the UNFC-2009.

The specifications that allow UNFC-2009 to be fully operational were developed by the EGRC between 2010 and April 2013 through an equally inclusive, transparent and robust process as that followed for the development of UNFC-2009. These specifications were agreed upon by the EGRC and subsequently by the Committee on Sustainable Energy at the end of 2013.

UNFC-2009 and the Specifications for its Application were developed by ECE, under the global mandate given by ECOSOC, and through the cooperation and collaboration of both ECE and non-ECE member countries, other United Nations agencies and international organizations, intergovernmental bodies, professional associations, the private sector and many individual experts. The development process included a survey of stakeholders' requirements and two public consultations.

The UNFC-2009 can already be used for the classification of hydrocarbon and mineral resources. It ensures alignment with widely used systems such as the CRIRSCO Template and the PRMS.

As of December 2014, the UNFC-2009 is applicable to uranium and thorium deposits via two international systems: the Red Book and the CRIRSCO Template for solid minerals. Currently, UNFC-2009 is being expanded to include renewable energy systems and injection projects, which once operational, will make it the only classification system in the world that can be applied to all energy resources.

UNFC-2009 principles

UNFC-2009 is a generic principle-based system in which quantities are classified by three fundamental criteria, which are combined in a three-dimensional system (Fig.1).

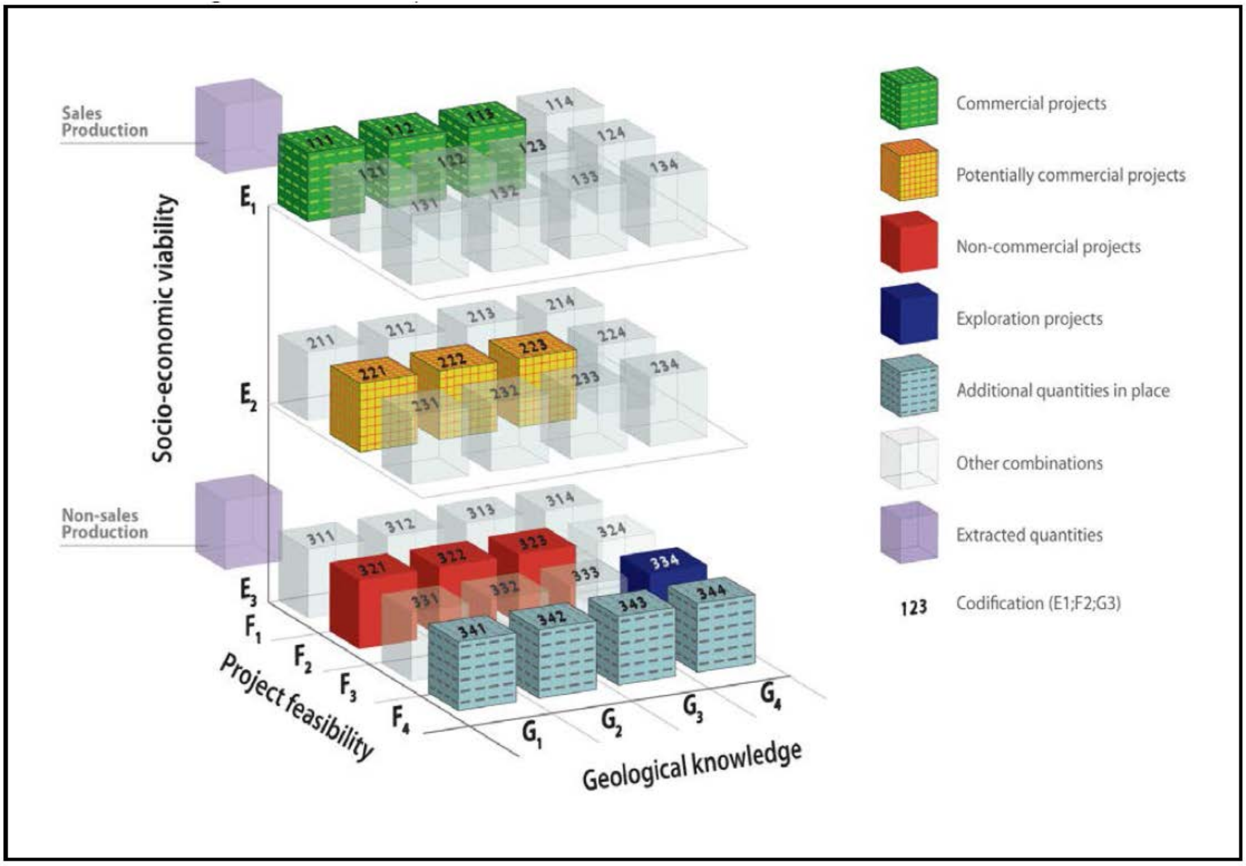

Figure 1 UNFC-2009 Categories (ECE, 2013).

The first set of categories (the E axis) designates the degree of favorability of social and economic conditions in establishing the commercial viability of the project, including consideration of market prices and relevant legal, regulatory, environmental and contractual conditions. The second set (the F axis) designates the maturity of studies and commitments necessary to implement mining plans or development projects. These extend from early exploration efforts before a deposit or accumulation has been confirmed to exist to a project that is extracting and selling a commodity, and reflect standard value chain management principles. The third set of categories (the G axis) designates the level of confidence in the geological knowledge and potential recoverability of the quantities (ECE, 2013). The assessment can reported with or without the EFG title, ie "E1F1G1" is equivalent to "111".

There are three E categories and four each for F and G categories, which are all designated by numerical codes. Each of these 11 categories has a definition and supporting explanation.

Main categories are divided into five E sub-categories and six F sub-categories. There are no sub-categories for E2, F3 and F4 and none for the G categories in the main framework. Additional F and G sub-categories are provided through the specification, which can be used in certain situations. Note that some of the combinations do not arise in practice – shown in light gray in Figure 1.

The UNFC-2009 avoids the use of commonly-used terms such as 'reserves' and 'resources', which are often misunderstood by non-experts and do not have a unique meaning.

The UNFC-2009 scheme can be divided into (Fig.2):

Principles — the classification framework

Specifications — the application rules

Guidelines — non-mandatory guidance for application

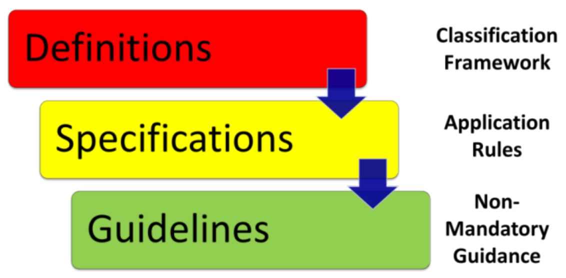

Figure 2.The UNFC-2009 scheme.

The UNFC-2009 Definition document can be downloaded at:

http://www.unece.org/fileadmin/DAM/energy/se/pdfs/UNFC/unfc2009/UNFC2009_ES39_e.pdf

2. IGA AND THE WORKING GROUP

Through an MoU that was signed in September 2014 (http://www.unece.org/fileadmin/DAM/oes/MOU/2014/MoU-UNECE_IGA.pdf), the UNECE and IGA agreed that their goals in the area of geothermal resources are mutually supportive. It was also agreed that the IGA represents the best platform and international umbrella to develop specifications and guidelines for the application of UNFC-2009 to geothermal energy, and to maintain evergreen the texts in a manner consistent with their proper application through regular and periodic review. Along with the Generic Specifications, these texts will provide the foundation and keystones for consistent application of UNFC-2009 for geothermal resources, and the meaningful comparison of geothermal resource estimates with other energy resources. This work will be overseen by the EGRC.

Following the MoU, on 15 October 2014, the IGA issued a call for volunteers interested in joining a working group (WG) to draft the geothermal specifications for the UNFC-2009. With the call still open, the IGA organized a workshop on a globally consistent classification system for geothermal energy resources (Bonn, Germany, 8-9 December 2014), hosted by IRENA and supported by ESMAP. With travel funded by ESMAP, 23 individuals took part in the workshop. The minutes and the presentations from the workshop can be found under the Resources and Reserves tab on the IGA website. IGA collected expressions of interest until 12 December 2014, with some 40 applications received. The applications were reviewed and ranked by a selection committee composed of Graeme Beardsmore (Chair of the IGA R&R Committee), Gioia Falcone (member of the IGA R&R Committee, member of the Task Force on Renewables, member of the EGRC Bureau and Leader of the WG) and Alison Thompson (IGA BoD member). On the recommendation of the selection committee, 11 invitations were issued (and accepted), resulting in a 12-member WG being appointed on 15 January 2015 (Table 1).

Since its appointment, the WG has already met regularly by teleconference to begin the process of drafting the geothermal specifications. On 4-5 March 2015, the World Bank hosted a two-day WG workshop in Washington DC. The event included a public 'open session', which was attended remotely by individuals from the IEA-GIA, the GEA, the DOE and others. The WG will also have met for 3 days from 23-25 September in Reno, following the GRC Annual Meeting.

The task of the WG is to develop the geothermal specifications as a "manual", i.e. combination of rules of application and non-mandatory guidelines/examples. This approach aims at maximizing the usability and adoption of the documents.

Table 1.The appointed members of the WG

Name	Country of residence	Affiliation
Gioia Falcone	Germany	TU Claustal (representing UNECE and IGA R&R)
Miklos Antics	France	GPC IP/Geofluid (endorsed by EGEC)
Roy Baria	UK	Mil-Tech UK Ltd.
Larry Bayrante	Philippines	Energy Development Corporation
Paolo Conti	Italy	University of Pisa (endorsed by UGI)
Malcolm Grant	New Zealand	MAGAK (endorsed by NZGA)
Robert Hogarth	Australia	Hogarth Energy Resources
Egill Juliusson	Iceland	Landsvirkjun
Harmen F. Mijnlieff	Netherlands	TNO (endorsed by Dutch Geothermal Platform)
Annamaria Nádor	Hungary	Geological and Geophysical Institute of Hungary
Greg Ussher	New Zealand	Jacobs
Kate Young	USA	National Renewable Energy Laboratory

The following is the tentative process schedule with deliverables for the WG:

Table 2. Timeline

- WG to submit draft specifications to the IGA R&R Committee for review, and implement recommendations (**~January 2016**).
- WG to submit draft specifications to the Task Force on Renewables and to the EGRC Technical Advisory Group (via the Task Force) for review, and implement recommendations (**~February 2016).**
- Following implementation of recommendations, IGA to submit a formal draft of the specifications to the UNECE at **~end February 2016**, to allow time for translations, in line with UN protocol.
- Via the UNECE Secretariat, submit the draft specifications to the EGRC at its 7th session in **April 2016**.
- After review by the EGRC, UNECE to post the draft specifications for a 3-month period of public comment (**~June/July-September 2016**)
- WG to formally address all comments and modify the draft as needed.
- Via the UNECE Secretariat, submit the modified draft specifications and the catalogue of comments and responses to the EGRC.
- If the modifications implemented following the public comment period are substantial, re-submit draft to the EGRC in **April 2017**. If the modifications are minor, the EGRC can endorse the Geothermal Specifications at an **earlier date**.

3. ADVANTAGES OF THE UNFC-2009

Clearly, the major benefit from utilising the UNFC-2009 classification is that it puts reporting for geothermal energy quantities in a common framework with oil and gas. But importantly our industry must note that other renewable energy resources incuding wind, solar and biomass that are adopting the framework. It is probable that in due course, company investors, project lenders and governments funding stimulation programs will want projects and portfolios assessed using this classification system.

The project based approach for classification means that energy assessments need to consider how the energy is proposed to be extracted and utilised. This should drive greater thought on the efficiency of energy recovery and conversion that are are intrinsic in the assessment of energy that will be produced.

The equal focus scocio-economic viability and level to which the project feasibility has been proven are particularly important in conveying how close the project is to being realised into operation. Special categories for feasibility are provided for indicating the maturity of extraction technologies that, if used correctly, will provide clear indications of barriers to be overcome before the indicated energty can be produced.

For systems yet to be drilled, and only defined by indirect means, it is recommended to indicate the probability that the potential resource will be of a commercial grade. This can provide a reality check on how likely a project truly is of a character that could be produced. Contrast this with common stored heat approaches using probabilistic parameters that almost always demonstrate a 90% probability of delivering a finite positive energy quantity, when we know that in fact many projects prove to have permeability, temperature or chemical characteristics that lead to them being abandoned as non-commercial.

4. AN EXAMPLE

To give a clearer idea of what a UNFC classification will look like, the following table recasts some of the estimates of Lawless & Lovelock (2002). Note that this revision is just an exercise in classifying the estimates, and not an endorsement of the actual values. The quantities reported are a total amount of energy – the original gave MWe for a 30-year life. The results have been rounded to one or two significant figures, as any more would overstate the precision of the estimates.

Table 3. Resource estimates, from Lawless & Lovelock (2002)

Field	Generating Capacity MWe		
	10TH	Median	90TH
Ketetahi	70	105	160
Ngawha	50	75	120

Under UNFC-2009, the corresponding estimates are:

<u>Ketetahi:</u>

- E3F3G4.1: 2000 MWe-yr
- E3F3G4.2 1000 MWe-yr
- E3F3G4.3 1600 MWe-yr

Notes. Ketetahi is not accessible due to legal constraints, being in a park. This makes it E3. It has not been drilled and there is no information about the feasibility of production, hence F3. The G4 category applies to undrilled resources, with G4.1 being the high confidence, G4.2 the medium and G4.3 the low confidence. Note that the amounts have been here listed incrementally. They can also be done cumulatively. It is also acceptable to report a single estimate, which would be the best estimate (sum of G4.1 & G4.2), which is simply G4 without any subcategory:

- E3F3G4: 3000 MWe-yr

<u>Ngawha</u>

- E2F1G1: 1700 MWe-yr
- E2F1G2 800 MWe-yr
- E2F1G3 1400 MWe-yr

It is also possible to report just a single value, the best estimate:

- E2F1G2 2500 MWe-yr

Here G2 corresponds to G1+G2 of the incremental estimates.

Given the current electricity price, production may not be currently economically viable, but it is expected to be in the forseeable future: E2. Feasibility of production and injection has been confirmed by actual drilling and operation: F1. Geological structure is known through drilling. The high confidence estimate is G1, the medium G2 and the low confidence G3.

The two fields have different classifications, due to one being drilled and with a production history, the other an undrilled field. UNFC clearly separates these different cases, whereas in Table 3 they have the same status. The greater granularity of UNFC provides for a much clearer statement of the status of a resource estimate.

In fact, Ngawha has two operating plants, a 10 MW plant comissioned in 1998, and a 15 MW plant comissioned in 2008 (Top Energy, 2015). So these could be considered a Project in their own right, possibly collectively. Provided that sufficient resource remains available to support them for a defined life (assuming say a further 30 years), that existing project could be reported as:

- E1F1G2 750 MWe-yr

That project could also report quantities that have been produced up to the assessment date. With the publication of a reservoir simulation matched to history, G2 would be upgraded to G1,

A proposed expansion at Ngawha would then have an appropriate E and F classification that reflects the state of the project maturity (economic and technical feasibility) and associated risks, and rely on an assessment of the additional resource that may be available to provide estimates of quantities to be produced (possibly using numerical similation). Insufficient information is presently available publicly for us to make an assessment for such an expansion at Ngawha. The AEE for the proposed expansion identifies proposed production wells outside the existing wellfield. As these are yet undrilled, the new project would have a classification of E2F2, plus appropriate G class.

Note that the existing plant and the expansion have different classifications. The two cannot be simply added together to produce a grand total.

Experience with trial estimates has shown that the greater granularity of UNFC resolves disputes: lengthy discussions about whether a resource may be considered proven are quickly settled with the availability of the more precise classification system. In this respect UNFC provides a clear improvement over the traditional classification of geothermal resources.

The Appendix gives a summary classification of Ngatamariki, using information publicly available in 2011. The classification applies to the project as it was conceived at that stage in 2011, after receiving resource consents and financial approval, but before construction and operation.

5. CONCLUSIONS

UNFC-2009 provides a more detailed and precise classification of resources and is likely to be a requirement for geothermal projects in the near future as investors, lenders and funders of national exploration and technology development programs require energy reporting in line with oil and gas and other renewables.

ACKNOWLEDGEMENTS

We acknowledge Gioia Falcone for her work steering the working group and drafting material which we have used here. We thank the Working Group for reviewing the Ngatamariki example attached.

ABBREVIATIONS

CRIRSCO Committee for Mineral Reserves International Reporting Standards

ECE United Nations Economic Commission for Europe

ECOSOC United Nations Economic and Social Council

PRMS Petroleum Resource Management System

REFERENCES

Lawless, J & Lovelock, B., *New Zealand's Geothermal Resource*, paper presented to NZGA conference 2002.

Top Energy, 2015. http://topenergy.co.nz/ngawha-expansion-project/background/

Far North District Counci 2015. http://www.fndc.govt.nz/services/planning-and-development/resource-consent-notices/notices/resource-consent-rc-2150191-top-energy-limited

APPENDIX: NGATAMARIKI ASSESSMENT

Project Location Ngatamariki, New Zealand

Data date: 2011

Date of evaluation: May 2015.

Quantification method: Simulation

Estimate type (deterministic/probabilistic): deterministic

NGATAMARIKI SUMMARY

Ngatamariki in New Zealand was first explored in the 1980s, then left idle until new geophysical and geochemical surveys were done in 2004, and exploration drilling resumed in 2008. The field is located in the Taupo Volcanic Zone of the North Island of New Zealand. Resource assessment and the committal to development were based upon a simulation model using natural state data and an interference test, but no production history. The field and its exploration is described in subsequent publications by Boseley et al (2010a,b) and Grant & Bixley (2011).

There is an upflow at depth of water at around 285°C, charging a liquid reservoir of neutral chloride water with good permeability. There is a limited upflow out of the reservoir top in the north-central part of the field, which discharges into a highly-permeable groundwater aquifer. A critical feature of the field that is likely to impact on reservoir management is communication between the deep high temperature reservoir and this shallower aquifer. Geochemistry shows that geothermal fluid rises from the high temperature reservoir into this aquifer where it mixes with cool groundwater, and then flows northward, feeding surface activity.

This conceptual model, with interconnected deep reservoir and shallow aquifers, was the basis of the simulation. The simulation used a single-porosity formulation. The model has a deep high temperature recharge, and outflows (represented in the model as wells) at the springs. Reservoir temperatures in all wells were matched. An interference test was conducted among the deep wells by discharging three wells for varying periods and monitoring pressure in well NM2. The model was then used to simulate the effects of production and injection over 50 years. The pressure-temperature field was used as input to compute subsidence. As there is no production history to provide calibration, the model is not fully constrained and these simulated results could be significantly in error. However the model has highlighted the significant physical processes that might control long-term reservoir behaviour. It identified the possibility of significant flow of cool fluids for the shallow cool aquifers to the deep reservoir which constrain possible development options, and management plans emphasize pressure maintenance as important.

Forecast runs showed that the project could support an 82 MWe(net) development. These results were then used to an application for support resource consents (NZ environmental allocation rights to the resource), and the decision by the developer to proceed. The proposed development required the drilling of a few additional wells, some of which were drilled at wide diameter, to take advantage of the good permeability. There would be a central group of production wells, with injection wells to the north and south field margins.

The assessment was made as of the time of grant of resource consents and internal financial approval. At this time the developer had secured land access, had drilled and tested some production wells and one injection well, all with good results. There were plans for a steamfield layout and power plant.

This assessment is made only on the basis of the information publicly available, and reported in the three references below.

References

Boseley, C., Cumming, W., Urzúa-Monsalve, L., Powell, T., & Grant, M., 2010a "A resource conceptual model for the Ngatamariki geothermal field based on recent exploration well drilling and 3D MT resistivity imaging" World Geothermal Congress

Boseley, C., Grant, M. A., Burnell, J. & Ricketts, B. 2010b. Ngatamariki Project Update. Transactions, Geothermal Resources Council, v34, pp177-182

Grant, M.A., & Bixley, P.F., 2011 "Geothermal Reservoir Engineering, 2nd Edition" Academic Press, New York.

http://www.voxy.co.nz/national/ngatamariki-consents-granted-ew-and-taupo-dc/5/48346

UNFC-2009-CLASSIFICATION AND QUANTIFICATION

Classification	Energy Quantity	Supplemental information
UNFC Class	Use energy units	Ngatamariki field area has been defined by a recent resistivity (MT) survey. By the end of 2009 the following information was available: 6 drilled wells, of which 4 were productive. One of those four producers was designated for injection. There were completion tests on all wells and production tests of the producers, plus an interference test. There was a reservoir simulation using this information. It produced a match to the initial state P&T and the interference test. There is no production history and consequently no history match. The simulation was a component of the consent applicationand modelled a development of 82MWe (net), for a period of 50 years, however the defined project was for a development of 35 years.
1.11.31+1.11.32	3000* MW_eyrs	82 MW_e for 35 years; E1.1; F1.3; G2 (ie G1+G2)
21.31+21.32	1200# MW_eyrs	82 MW_e for 15 years; E2: F1.3; G2 (ie G1+G2)

*Rounded to one significant figure. #Rounded to two significant figures

E CATEGORY CLASSIFICATION AND SUBCLASSIFICATION

Category	UNFC-2009 Definition	Reasoning for classification
E1	Extraction and sale has been confirmed to be economically viable	Well testing and simulation has shown sustained discharge is possible and flow rates are economic
Sub-category	**UNFC-2009 Definition**	At 2011 the project has eesource consents and final financial approval.
E1.1	Extraction and sale is economic on the basis of current market conditions and realistic assumptions of future market conditions	Consents were issued for 35 years, so that the project is defined for this period. The classification of E1.1 applies to the energy to produced over this period only.
Category	UNFC-2009 Definition	Reasoning for classification
E2	Extraction and sale is expected to become economically viable in the foreseeable future	The simulation showed production could be sustained for 50 years. No project is yet defined to utilise this production after 35 years. This 15 years is classified here.

F CATEGORY CLASSIFICATION AND SUBCLASSIFICATION

Category	UNFC-2009 Definition	Reasoning for classification
F1	Feasibility of extraction by a defined development project or mining operation has been confirmed	Exploration, well testing, simulation and development plans are all complete.
Sub-category	**UNFC-2009 Definition**	
F1.3	Sufficiently detailed studies have been completed to demonstrate the feasibility of extraction by implementing a defined development project or mining operation.	

G CATEGORY CLASSIFICATION AND SUBCLASSIFICATION

Category	UNFC-2009 Definition	Reasoning for classification
G2	Quantities associated with a known deposit that can be estimated with a moderate level of confidence.	Wells have been tested and a simulation completed based upon natural state and interference information. There is no production history and consequently no match to that history. Because of the lack of history confidence is moderate. If there were also a history match it would be high, ie G1.
Sub-category	UNFC-2009 Definition	
	N/A	

QUANTIFICATION

The quantification estimate derives from the reservoir simulation. This is a deterministic assessment, with a single development plan tested. Only one simulation scenario was presented. If multiple scenarios had been presented it would have been possible to define high, medium and low scenarios.

The economic assumptions are for a power station of existing standard geothermal design, supplying power into New Zealand's national grid. The developer is an electricity generator and retailer with market access.

Product type

The product produced is electricity.

Reference Point

The reference point is at the station switchyard, where power is exported into the national grid. Internal power use has already been subtracted.

SIGNATURE

I hereby declare that this project has been evaluated in accordance to the UNFC-2009 classification system. I have personal knowledge of the technical data and evaluations used, at sufficiently detailed level to be assured that the evaluation is accurate and representative. I have relied upon the accuracy of reported data as supplied.

X

Malcolm A Grant
UNFC Qualified Geothermal Project Evaluator