Proceedings World Geothermal Congress 2026
Calgary, Canada, June 8 – 11, 2026

A Standard, Reliable Framework to Classify, Categorize and Disclose Each Stage of a Geothermal Project and its Geothermal Energy Resource

G. Banks[1]*, S. Gardner[2] and P. Ball[3]
Route To Reserves Consulting, Inc. and Geothermal Energy Advisors, LLC[1]*, Ryder Scott Company, L.P.[2], Geothermal Energy Advisors, LLC[3]
Route2reserves@gmail.com

Keywords: Geothermal Resource, Uncertainty, Exploration, Disclosure

INTRODUCTION

The geothermal industry needs a resource reporting and disclosure framework that is globally applicable, globally standardized, and provides instruction on the project forecasting metrics that are needed by geoscience, engineering, finance, insurance, auditing and regulatory stakeholders. Such a geothermal resources management system (GRMS) will enable stakeholders to consistently (a) define and classify each stage of maturity of any geothermal project, (b) categorize its geothermal resources, (c) objectively compare and rank geothermal projects, and (d) manage a given geothermal resource. The GRMS will need to:

- Include the earliest exploration stages (Figure 1), when the geothermal resource base is estimated and a project's uncertainty range is widest.
- Enable high levels of confidence and trust during geothermal project valuations and transactions.
- Focus on the quantification of a geothermal project's uncertainties, probability of success, risks (opportunities and threats), and value creation.
- Be technology-agnostic, i.e., as appropriate to a fracked reservoir project in a deep sedimentary basin as a project on a volcano, and incorporating hydrothermal, open-loop (EGS) and closed loop (CLG) reservoir engineering techniques.
- Parallel the widely respected Petroleum Resources Management System (PRMS) and CO2 Storage Resources Management System (SRMS) (SPE, 2018 and SPE, 2022) international standards.
- Meet national standards of public reporting and disclosure to securities and exchange commissions.

Initial versions of a GRMS have been used by these authors (e.g., Figure 1) and used to successfully evaluate clients' geothermal projects. We advocate for a geothermal industry proponent (or consortium) to commission an international standard GRMS document. Authors need to be experts in: exploration, subsurface geoscience, reservoir engineering, deep drilling, contracts, transactions, economics, underwriting, auditing, etc.

The commercial geothermal industry is more than 100 years old. It needs to rapidly expand and innovate to meet society's ever-increasing energy demands and the energy industry's technological advances. Geothermal investors, regulators, and corporate management teams need to conduct project SWOT analysis, resources and reserves classifications (reserves are a subset of resources), and related disclosures in a consistent manner. A standard geothermal framework will enable them to compare and rank geothermal opportunities, and clearly communicate the differences in terms that are well defined and understood.

The geothermal industry has created several frameworks to categorize geothermal resources (See Methods). However, none has achieved widespread acceptance and application. They provide a historical foundation for subsequent improvements. Meanwhile, the petroleum industry has a standardized and universally accepted set of guidelines, standards, and protocols to report project progress and reserves in financial statements: the PRMS by SPE (2018). The PRMS incorporates technical uncertainty and commercial maturity. It has been refined over decades of practical application. Users can clearly, consistently and transparently:

- Define and classify the geological and commercial maturity at each project stage.

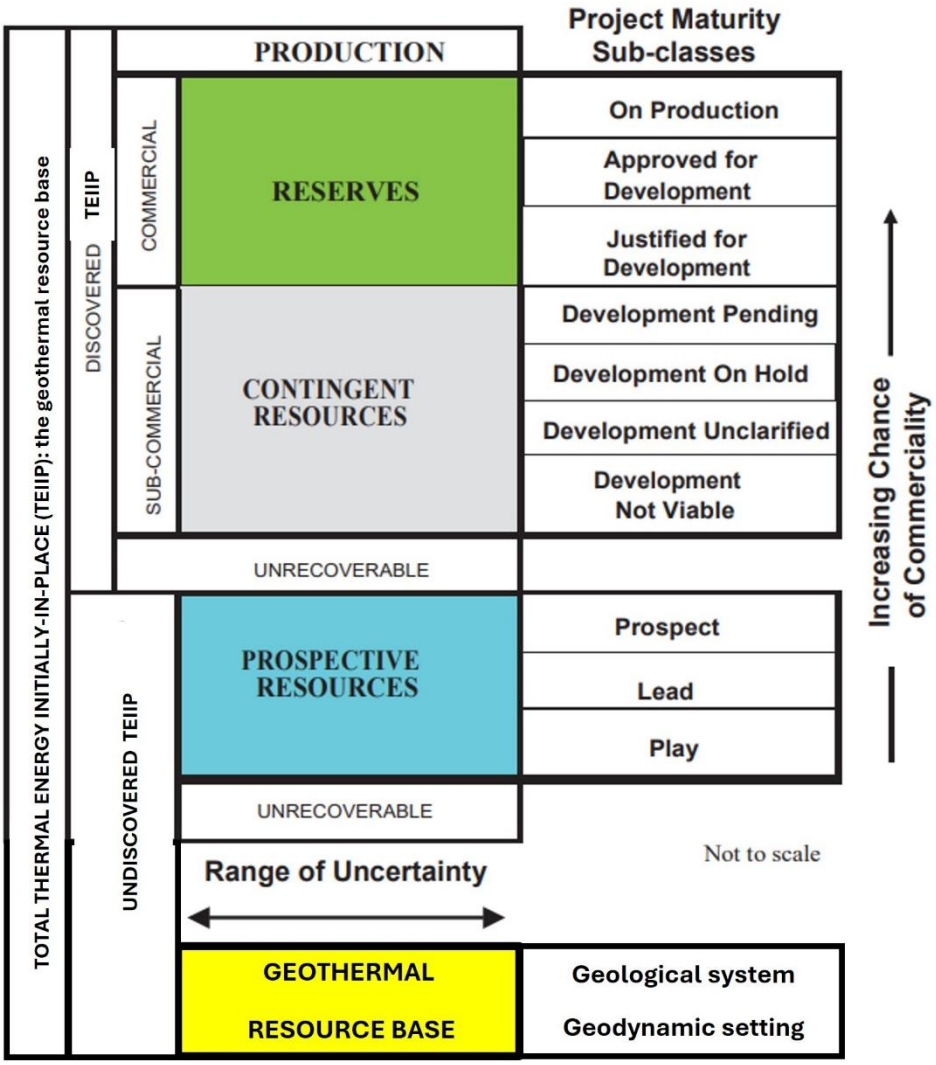


Figure 1. A geothermal resource and project maturity classification scheme based on the SPE-PRMS for hydrocarbons and modified by Geothermal Energy Advisors in 2025 for proprietary assignments for its geothermal engineering clients. Ryder Scott has independently created and successfully applied a similar scheme (Gardner and Faulder, 2024). Two consultancies developing a similar product independently demonstrates the value of adapting the PRMS.

- Classify and categorize a resource from Undiscovered to Proven Reserves stages.
- Disclose Resources and Reserves to stakeholders using clearly defined terms and categories.

The PRMS's globally accepted framework is adaptable for geothermal projects and resources. That is because the geothermal and petroleum industries are similar in several ways and aims.

- Both explore for energy held in underground fluids and geology, which is then extracted to use/sell at a profit.
- Both describe and model geology and fluid flow to 10 kilometres deep using limited information.
- Both use a project's information to predict the project's future performance and future limitations.
- Their scientists and economists need to clearly convey how their activities reduce uncertainty and financial risk at each technical and commercial readiness stage of a project, whilst the geological and commercial chance of success and expected value have increased.

Therefore, a GRMS should be based on the PRMS (SPE, 2018).

1 METHODS

As a geothermal project advances, the understanding of the project and the methods used to calculate its resources change, e.g., the resource's class and category, size, uncertainty, risk, expected value, and the next analysis to conduct. Investment, insurance, regulatory and other stakeholders need to be familiar with a geothermal project's calculation methods and their implications. The petroleum and mineral exploration industries provide their stakeholders with guidance on this (Figure 2). In contrast, the authors have not yet seen sufficient guidance in geothermal sector reporting codes. We compared geothermal resource reporting methods to generate geothermal forecasting metrics, namely: the Canadian Geothermal Code for Public Reporting, 2010 (CCPR) by the Canadian Geothermal Code Committee (2010a and 2010b), the Australian Geothermal Reporting Code, 2010 (AGRC) by the Australian Reporting Code Committee, (2010), the United Nations Framework Classification for Resources update 2019 to Geothermal Energy Resources (UNECE, 2022), and the Bridging Document between the Petroleum Resources Management System and the United Nations Framework Classification for Resources (UNECE, 2023).

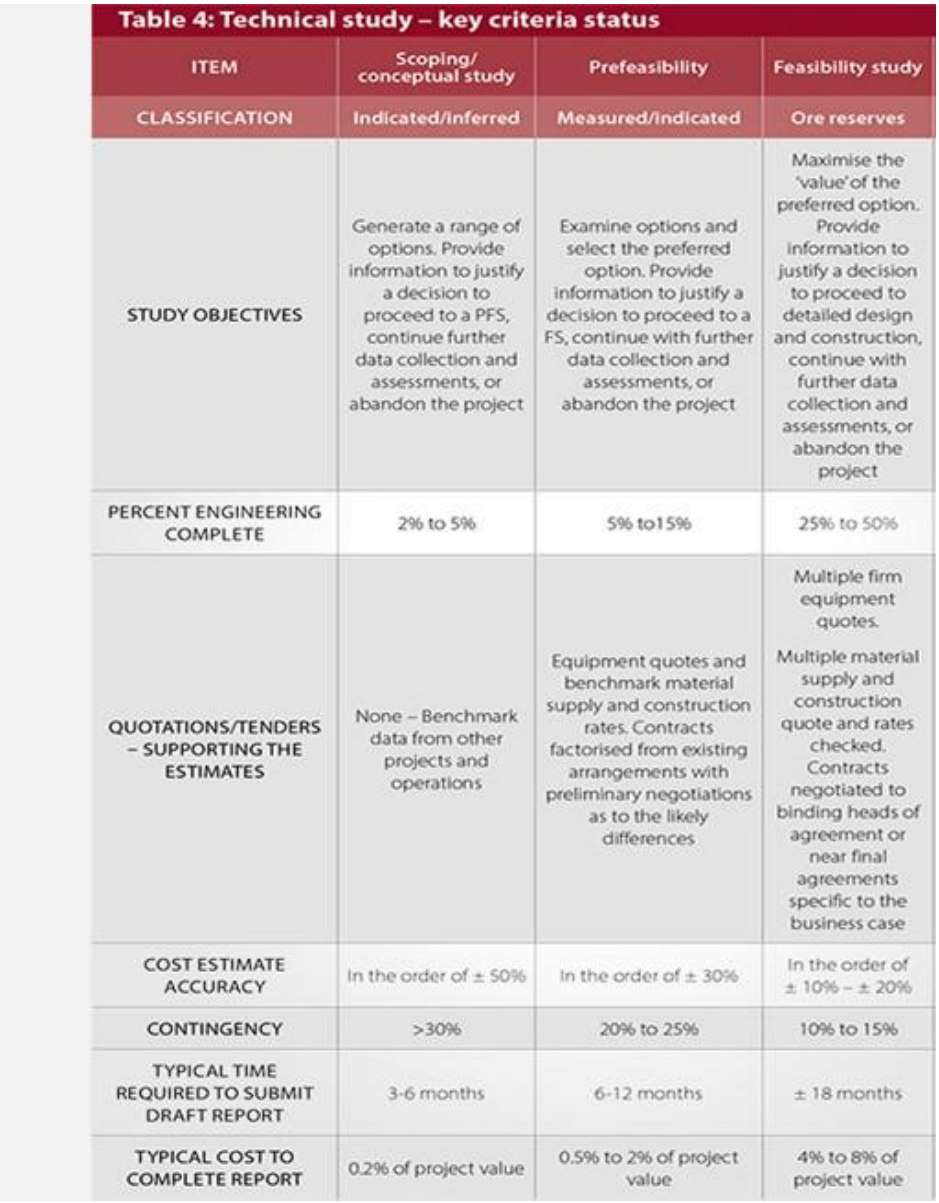


Table 4: Technical study – key criteria status

ITEM	Scoping/ conceptual study	Prefeasibility	Feasibility study
CLASSIFICATION	Indicated/inferred	Measured/indicated	Ore reserves
STUDY OBJECTIVES	Generate a range of options. Provide information to justify a decision to proceed to a PFS, continue further data collection and assessments, or abandon the project	Examine options and select the preferred option. Provide information to justify a decision to proceed to a FS, continue with further data collection and assessments, or abandon the project	Maximise the 'value' of the preferred option. Provide information to justify a decision to proceed to detailed design and construction, continue with further data collection and assessments, or abandon the project
PERCENT ENGINEERING COMPLETE	2% to 5%	5% to15%	25% to 50%
QUOTATIONS/TENDERS – SUPPORTING THE ESTIMATES	None – Benchmark data from other projects and operations	Equipment quotes and benchmark material supply and construction rates. Contracts factorised from existing arrangements with preliminary negotiations as to the likely differences	Multiple firm equipment quotes. Multiple material supply and construction quote and rates checked. Contracts negotiated to binding heads of agreement or near final agreements specific to the business case
COST ESTIMATE ACCURACY	In the order of ± 50%	In the order of ± 30%	In the order of ± 10% – ± 20%
CONTINGENCY	>30%	20% to 25%	10% to 15%
TYPICAL TIME REQUIRED TO SUBMIT DRAFT REPORT	3-6 months	6-12 months	± 18 months
TYPICAL COST TO COMPLETE REPORT	0.2% of project value	0.5% to 2% of project value	4% to 8% of project value

Figure 2. Some of the items estimated during the sequence of engineering and economic evaluations in mineral exploration. Numerical parameters are stated as ranges, which may be more representative than a single deterministic number. Stakeholders can easily envisage the project's progress and remaining tasks. (Mining Journal, online).

These geothermal reporting codes have insufficient protocols for a user to (a) define and classify the stage of maturity of a geothermal project, (b) categorize the technical uncertainty of its geothermal resources, and (c) create a multi-scenario forecast about a geothermal project's potential success/performance. For example:

- The CCPR and AGRC have not kept up to date with 2010 to 2026 engineering innovations.
- They do not contain guidance about how to progress or manage a geothermal project.
- They lack content about how to report uncertainty, probability, and risk estimates and categories. Whilst the decision tree of UNECE (2023) to characterize resources mentions a P90-P50-P10 option, and a "high", "best", "low" option, more guidance needs to be stated to allow consistency between evaluators.
- They lack content about defining geothermal exploration entities i.e., the geothermal province, system, play, lead, prospect and discovery (Ball et al., 2025a, b). These project stages may require $10s millions of expenditure to prove up a geothermal discovery/viable reservoir/aquifer. Thus, they require sufficient content in a geothermal resource reporting code.
- Some reporting codes are indifferent to how Geothermal Resources and Geothermal Reserves are estimated, as long as estimates are endorsed by a "Competent Person". Publishing a standard definition or checklist for "Competent" geothermal evaluator would be useful.

Additionally, the UNFC's guidelines are not as familiar or as widely adopted in the finance and insurance sectors of the energy industry as the PRMS is, and may not displace the more-established PRMS method.

We also reviewed how adaptable the PRMS (SPE, 2018) is for use with geothermal projects, from the perspectives of exploration geoscience, engineering, and independent Resource/Reserves evaluations. It can be adapted and be fit-for-purpose in a straightforward manner. There are more points in the Discussion section.

2 DISCUSSION

The introduction and Methods sections have outlined why the PRMS would be the optimal template for a contemporary GRMS. In addition to the benefits list in the Introduction section, the PRMS is the best template for a GRMS because it:

- Is widely used by companies worldwide for asset management, asset evaluation, and reporting of resources and reserves in the manner required by stock exchanges and regulatory bodies.
- Includes a matrix that considers the commercial maturity and the range of technical uncertainty.

When a GRMS is created, it will need to contain/enable/explain:

- Instructions how the user will disclose a geothermal project's: range of technical uncertainty, commercial maturity, risks, cash-flow forecasts, resource volume, recovery factor, resource replenishment rates, resource decline rates, expected value, return on invested capital, etc.
- Criteria/milestones that must be attained for a project to progress from one stage to the next.
- Guidance for evaluating technical uncertainty during play analysis and prospect portfolio analyses, because these tasks are the foundation for choosing a drillable prospect. How the project can create value and manage risk during the exploration stage (Banks et al., 2022).
- How to estimate the geothermal resource base, i.e. the full spectrum of estimated quantities of thermal energy available to the project: discovered and undiscovered, recoverable and unrecoverable, commercial and uneconomic, already produced and remaining. See Figure 1, as one example of a potential framework.
- Reduce the subjective nature of current geothermal resources estimation methods.
- Appropriate components of the existing geothermal resource codes. Be clear and usable to (a) new investors who have experience investing in the petroleum industry and are familiar with many common and shared activities with the geothermal industry, such as subsurface geoscience evaluation, well drilling and completions (including horizontal wells), and fluid production through surface pipelines and facilities, and (b) investors newly entering the realm of subsurface assets and development (e.g., a data center, a climate-controlled vegetable farm, a military facility, etc.).

A GRMS based on the PRMS and the CO_2 SRMS would deliver the vocabulary and metrics that geothermal geoscientists, engineers, regulators, investors, insurers, and policymakers require, i.e. uncertainty range, probability (chance, likelihood) of success/commerciality, risk (opportunities and threats), and value.

3 CONCLUSIONS

The geothermal industry needs a resource reporting and disclosure framework that is globally applicable and globally standardized. It needs to (a) detail exploration analyses and decision milestones, (b) guide forecasting metrics, (c) provide consistency for geoscience, engineering, finance, insurance, auditing and regulatory stakeholders, and (d) meet national standards of public reporting and disclosure to securities and exchange commissions.

We advocate for a geothermal industry proponent or consortium to commission an international standard GRMS document. A group is already in the early organizational phases within SPE. Authors need to be senior experts in: geothermal exploration, subsurface geoscience, reservoir/aquifer engineering, deep drilling, contracts, transactions, economics, underwriting, auditing, etc.

The Petroleum Resources Management System (PRMS) and CO2 Storage Resources Management System (SRMS) (SPE, 2018 and SPE, 2022), provide a good framework for the establishment of a Geothermal Resources Management System (GRMS) that will provide numerous advances of the variety of current geothermal resource codes.

REFERENCES

Australian Reporting Code Committee. The Geothermal Reporting Code, Second Edition, Australian Code for Reporting of Exploration Results, Geothermal Resources and Geothermal Reserves, (2010), 34 Pages.

Ball, P.J., Banks, G., Montgomery, M., and Afonso, C. Chapter 12: Global screening for superhot rock geothermal energy: geodynamic settings, prospective heat endowment and extraction techniques. *In Livescu, S., and Dindoruk, B., (eds), Geothermal Energy Engineering,* Elsevier, (2025a).

Ball, P.J., Banks, G., and Stroganov, V. The importance of geodynamic settings and exploring for geothermal energy, LATAM 2025, San Salvadore, El Salvadore, September 2025, (2025b)

Banks, G. Samis, M., and Schodde, R. How to Create Value and Manage Risk during Exploration. Training course at Prospectors and Developers Association of Canada, Toronto, Canada (2022).

Canadian Geothermal Code Committee. The Canadian Geothermal Code for Public Reporting, Reporting of Exploration Results, Geothermal Resources and Geothermal Reserves 2010 Edition, Canadian Geothermal Energy Association, (2010a). 34 Pages.

Canadian Geothermal Code Committee. The Canadian Geothermal Code for Public Reporting, Reporting of Exploration Results, Geothermal Resources and Geothermal Reserves 2010 Edition, Code Overview and Key Terms, Canadian Geothermal Energy Association, (2010b) 6 Pages.

Gardner, S. and Faulder, D. Geothermal Reserves Standards: A Study of the Applicability of the SPE Petroleum Resources Management System, a Proposed Classification Framework for Geothermal Reserves and Resources. *GRC Transactions,* Vol. 48, (2024).

Mining Journal, online. https://www.mining-journal.com/mining-journal-global-finance-report-2022/special-report/4066400/technical-glossary-technical-study-standards.

Society of Petroleum Engineers. Petroleum Resources Management System, Jun. 2018, (2018), https://info.specommunications.org/rs/833-LLT-087/images/PRMgmtSystem_V1.01%20Nov%2027.pdf.

Society of Petroleum Engineers. Extension of PRMS Principles to Non-Hydrocarbons, Aug. 2022, (2022) https://www.spe.org/en/industry/reserves/non-hydrocarbons/

Society of Petroleum Engineers. CO2 Storage Resources Management System (2025) https://doi.org/10.2118/9781959025931

UNECE. Supplementary Specifications for the application of the United Nations Framework Classification for Resources (Update 2019) to Geothermal Energy Resources, (2022), 26 Pages.

UNECE. Bridging Document between the Petroleum Resources Management System and the United Nations Framework Classification for Resources 2023 Update (2023).