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Pragmatic Application of UNFC for Reporting the Maturity of Geothermal Resources

Ussher G [1]* , Falcone G [2] , Mijnlieff H [3] , Beardsmore G [4] , Conti P [5] , Lebe J [1]

[1] Jacobs, Auckland, New Zealand, [2] University of Glasgow, Glasgow, Scotland, [3] TNO, The Netherlands, [4] University of Melbourne, Melbourne, Australia, [5] University of Pisa, Pisa, Italy,

*gregory.ussher@gmail.com

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ABSTRACT

The United Nations Framework Classification (UNFC) is gradually being adopted by the geothermal sector worldwide, with notable recent examples from Africa, New Zealand and Central America, among others, underscoring its relevance. The cornerstone of UNFC is its focus on evaluating the maturity of a project, which underpins the classification of the quantities of energy resources to be produced. A concern among stakeholders, however, is the perceived complexity of the UNFC process and language for first-time users. We note that the simplified UNFC "Class" structure reflecting project maturity is a readily understood concept and could be built upon as a practical application of UNFC. We also propose that there is potential to facilitate assessments by using plain language guidance for categorizing on the E and F axes, while still adhering to the fundamental principles of UNFC. This paper presents the merits of using the Class approach that is suggested by UNFC and also we present some possible refinements for the Sub-Classes for Prospective Projects (as permitted under UNFC) to be more useful for typical deep geothermal projects and a pathway for broader application of the UNFC within the geothermal ecosystem. We also indicate how simplified language specific for the type of projects being evaluated facilitates technical assessments and enhances the value of UNFC across the full life cycle of geothermal projects. The approach we propose has been tested with actual working groups with application for geothermal inventory in Africa, New Zealand, Indonesia, Australia the Philippines and Europe. We present results that demonstrate both the effectiveness of this approach to doing assessments, and how classification results can be presented in a clear and meaningful way for users. This has been applied only to deep geothermal projects and is not modifying any standard UNFC definitions but may offer some directions for future enhancement of UNFC and broader application.

1 INTRODUCTION

The United Nations Framework Classification (UNFC) is a universal system for classifying and reporting minerals, energy, and other resources. It provides a standardized approach to ensure consistency, transparency, and sustainability in resource management. It is based on three fundamental criteria of environmental-socio-economic viability (E), technical feasibility (F), and degree of confidence in the estimate (G). By integrating environmental, social, and economic considerations, UNFC aligns with global sustainability goals, including the 2030 Agenda for Sustainable Development and the Paris Agreement. Its comprehensive framework supports decision-making processes across various sectors, facilitating efficient and responsible resource use globally. UNFC is essential for governments, industries, and stakeholders committed to sustainable resource management.

UNFC is developed and maintained by the United Nations Economic Commission for Europe (UNECE) through its Expert Group on Resource Management (EGRM), with the support of various stakeholders from governments, industry, academia and civil society. UNFC applies to a broad range of resources, including minerals, petroleum, renewable energy, nuclear fuel, injection projects for geological storage, and anthropogenic resources. In the area of renewable energy, specifications for the application of UNFC already exist for geothermal, bioenergy, solar and wind energy resources, reinforcing its role in sustainable resource management worldwide. No other system exists that encompasses such scope.

UNFC has seen significant global uptake as a standardized system for classifying and managing resources across sectors. It has been mandated under the European Union's Critical Raw Materials Act (EU CRMA) for monitoring and classifying strategic projects. In Africa, UNFC forms the basis of the African Mineral and Energy Resource Classification (AMREC), endorsed under the African Mining Vision (AMV), with the Pan-African Resource Reporting Code (PARC) aligning public reporting to UNFC standards, including for geothermal resources. Ministerial Declarations on Sustainable Resource Management by the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP) have recommended UNFC for widespread adoption in the

Asia-Pacific region. The UN Regional Economic Commissions (UN RECs) are collaborating with the UNECE to implement UNFC across all regions, supporting its integration into national resource governance frameworks.

The specifications for the application of UNFC to geothermal energy resources first became operational on 30 September 2016 (Falcone et al., 2016). They were originally developed by a working group of expert volunteers under the aegis of the International Geothermal Association (IGA). On 25 October 2022, an update was issued in the form of supplementary specifications (Falcone et al., 2022). The update was undertaken by the IGA UNFC Ad Hoc Committee of expert volunteers, with reviews and additional technical input by the EGRM renewable energy working group, the EGRM technical advisory group and additional EGRM expert individuals.

Falcone et al. (2025) identified the following key lessons learned from almost a decade of application of the UNFC Geothermal Specifications:

- UNFC classification is fundamentally an assessment of maturity of E-F-G aspects and their impact on project development.
- The primary UNFC Class representation is a powerful tool for understanding UNFC classification and for visualizing and communicating the relative maturity of projects across an inventory.
- Classification of 'prospective' geothermal projects (i.e. projects that rely on a geothermal energy source as yet unproven by drilling) would benefit from additional subclasses to represent the typically extended duration and stages of geothermal projects from early prospect identification, exploration and preparation before major investment in drilling.
- Clear and simple language that is specific to the type of geothermal source (e.g. deep hydrothermal and EGS versus shallow) would help new users more rapidly become comfortable and accurate with geothermal energy assessments and UNFC classifications.

This paper addresses these learnings by proposing some refinements for the application of UNFC to geothermal projects spanning conventional and emerging production technologies for hydrothermal systems, Enhanced Geothermal Systems (EGS) and Advanced Geothermal Systems (AGS) for heat and power.

2 UNFC KEY CONCEPTS

2.1 UNFC Nomenclature and Approach

UNFC utilizes a specific assessment framework and nomenclature (United Nations, 2022) different to that conventionally used in the geothermal (and fossil) energy industry. Some key UNFC terms include but are not limited to:

- **Projects** – defined developments or operations that can be used as a basis for environmental, social, economic, and technical evaluations and decision-making about quantities of energy that can be recovered and delivered as geothermal energy product, e.g. an electricity generation or a H&C use project;
- **Sources** – such as geothermal, solar, wind, etc. provide the general feedstock for projects from which 'products' can be developed. The term is intended in its broad sense of a naturally existing deposit and is not subject to UNFC classification (see text below);
- **Products** – electricity, heat, hydrogen, minerals, etc., are the output that can be quantified, bought, sold, or used by projects;
- **Resource** – cumulative quantities of products that will be output by a project from a source throughout the project lifetime. This energy quantity (and the related project in a broader sense) is the subject of UNFC classification;
- **Lifetime** – the future period over which a project can reasonably expect to generate products, considering economic limit, design life, contract period and entitlement period.

This language that is consistent for all UNFC applications, highlights the UNFC focus on how the (in our case, energy) product is produced from the Source by the **Project**. UNFC is not intended to guide how to assess quantities of a natural **Source** of energy, minerals or other possible commodities. But rather UNFC is intended to reflect the maturity of **Projects** that can produce the useful **Products** and hence the expected viability that (the estimated quantities of) these **Products** will actually be produced.

As applied to geothermal, UNFC is not intended for assessing energy in the ground, rather what energy can be brought from the subsurface and converted into a form to be used or sold (by the **Project**) and to indicate the viability or maturity of the proposed or possible **Project**(s) that enable that energy production.

2.2 UNFC Axes

The UNFC applies a three-axis system (United Nations, 2020) to assess energy projects. The three axes are the **E-axis** – environmental-socio-economic viability; **F-axis** – technical feasibility and maturity; and **G-axis** – degree of confidence of the estimates of Resources. Each axis is independently assessed to categorize each project into one of three E categories (E1 to E3) and four F categories (F1-F4), with the highest or most mature category being '1' on each axis. There are also subcategories such as E1.1 and E1.2 that provide a more granular categorization if appropriate.

UNFC provides standard language guidance for the categorization of projects on these axes, and there are additional commodity-specific guidance documents prepared for most commodities (including geothermal) to further assist users in the categorization process. The UNFC standard approach is to then report the E, F and G categories along with the commodity quantities expected to be produced over the project lifetime – heat or electric power in the case of geothermal.

2.3 Classes and Sub-classes

UNFC also provides for using the categorized E, F and G values to place the project into a Primary Class — **viable**, **potentially viable**, **non-viable**, or **prospective** (**Figure 1**). The class of a project will typically progress with time as the project matures, but can also regress if new challenges arise.

Total Products	Produced	Sold or used production Production which is unused or consumed in operations[a]			
		Class	Minimum Categories		
			E	F	G[b]
	The project's environmental-socio-economic viability and technical feasibility has been confirmed	Viable Projects[c]	1	1	1, 2, 3
	The project's environmental-socio-economic viability and/or technical feasibility has yet to be confirmed	Potentially Viable Projects[d]	2[e]	2	1, 2, 3
		Non-Viable Projects[f]	3	2	1, 2, 3
	Remaining products not developed from identified projects[g]		3	4	1, 2, 3
	There is insufficient information on the source to assess the project's environmental-socio-economic viability and technical feasibility	Prospective Projects	3	3	4
	Remaining products not developed from prospective projects[g]		3	4	4

a. Future production that is either unused or consumed in the project operations is categorized as E3.1. These can exist for all classes of recoverable quantities.

b. G categories may be used discretely, or in cumulative scenario form (e.g. G1+G2).

c. Estimates associated with Viable Projects are defined in many classification systems as Reserves, but there are some material differences between the specific definitions that are applied within different industries and hence the term is not used here.

d. Not all Potentially Viable Projects will be developed.

e. Potentially Viable Projects may satisfy the requirements for E1.

f. Non-Viable Projects include those that are at an early stage of evaluation in addition to those that are considered unlikely to become viable developments within the foreseeable future.

g. Remaining products not developed from identified projects or prospective projects may become developable in the future as technological or environmental-socio-economic conditions change. Some or all of these estimates may never be developed due to physical and/or environmental-socio-economic constraints. This classification may be of less value to renewable resource projects but can still be used to indicate the amount of unrealized potential. It is emphasised that the remaining products are quantities which, if produced, could be bought, sold or used (i.e. electricity, heat, etc., not wind, solar irradiation, etc.).

Figure 1: Abbreviated version of the UNFC classification with Primary Classes and grading categories for E-F-G axes (United Nations, 2020).

In addition to the primary classes of **Figure 1**, UNFC provides a set of sub-classes that align with common thinking on how projects mature (**Figure 2**). UNFC states that "While there are no explicit restrictions on the possible combinations of E, F and G Categories or Sub-categories, some may be more useful than others. For the more important combinations (Classes and Sub-classes), specific labels are provided as a support to the numerical code. This recognizes that the Classes and Sub-classes are a useful tool for combining the E, F and G Categories. There is inherent flexibility to their use, but we consider that retaining a reasonably consistent and widely recognizable Class structure is probably important for universal application of UNFC.

Our work in training and implementation to date of UNFC for geothermal projects has shown this view of UNFC to be more intuitive than just assessing the E, F and G axis categories for most people considering UNFC for the first time. Classes provide a framework for understanding the maturity of individual projects with respect to the "end game" of producing energy, and for seeing how UNFC may be practically useful in providing a view of a portfolio or inventory. We find that regulators see a major opportunity for the application of the Class / Sub-class presentation of UNFC application, and informal discussions with finance institutions has highlighted a need for this transparent presentation of project maturity.

UNFC Classes Defined by Categories and Sub-categories						
Total Products	Produced	Sold or used production				
		Production which is unused or consumed in operations				
	Class		Sub-class	Categories		
				E	F	G
	Known Sources	Viable Projects	On Production	1	1.1	1, 2, 3
			Approved for Development	1	1.2	1, 2, 3
			Justified for Development	1	1.3	1, 2, 3
		Potentially Viable Projects	Development Pending	2[b]	2.1	1, 2, 3
			Development On Hold	2	2.2	1, 2, 3
		Non-Viable Projects	Development Unclarified	3.2	2.2	1, 2, 3
			Development Not Viable	3.3	2.3	1, 2, 3
		Remaining products not developed from identified projects		3.3	4	1, 2, 3
	Potential Sources	Prospective Projects	[No sub-classes defined]	3.2	3	4
		Remaining products not developed from prospective projects		3.3	4	4

a. Refer also to the notes for Figure 2.
b. Development Pending Projects may satisfy the requirements for E1.

Figure 2: UNFC classes and sub-classes are proving more meaningful to many users than the UNFC categories (E, F, G) (United Nations, 2020) and have proven to be a valuable way of presenting consolidated regional or portfolio assessments (e.g., in Ussher *et al.*, 2023).

3 ADDITIONAL PROSPECT SUB-CLASSES

UNFC standard classes are quite granular when the classified resource is associated with a 'Known' geothermal energy sources (i.e. source where one or more wells or thermal springs have established, through testing, sampling and/or logging, the existence of a quantity of recoverable thermal energy suitable for providing heat at

rates sufficient to support the project). The granularity of 'viable' projects, for example, differentiates between 'justified for development', 'approved for development', and 'on production'.

The reference UNFC Class/Sub-class table has no granularity for 'prospective' (not yet drilled) projects. Geothermal projects, however, typically require multiple regulatory approvals and licenses and undergo multiple stages of surface exploration before drilling. At any given time, a project could be needing additional surveys or licenses, be on hold, or be ready to move onto drilling. This is important information for understanding project status or the pipeline of projects in a portfolio.

Therefore, since UNFC allows considerable flexibility for creating Classes and Sub-classes where appropriate, we have been considering some options for Sub-classes of Prospective Projects: there probably is a balance in terms of retaining some consistently within an "industry" or commodity, and probably also more broadly for all UNFC application so that users can recognize the maturity being represented. As mentioned above, users can readily relate to the Class view and this is valuable in maximizing the application and benefit from UNFC. So retaining, but expanding on, the default broad structure offered within the UNFC documentation may be beneficial.

As a minimum, we have identified additional UNFC sub-classes for 'prospective' geothermal energy projects that primarily follow the F3 sub-categories defined within UNFC (Figure 3).

One European geological survey is considering further Sub-classes for the Prospective Projects reflecting whether projects are actually defined (by a developer / operator) or just being considered theoretically possible for the purposes of conducting national geothermal resource inventory. Such a distinction is important, and reflects how suitably defined Sub-classes may be useful for application of UNFC in the national policy domain.

This paper includes some examples of where additional Sub-classes have been used in an inventory application which demonstrates the value that may be achieved by having this additional granularity for projects that are still undrilled.

	Class		Sub-class	Categories		
				E	F	G
Proven by drilling	Known Sources	Viable Projects	On Production	1.1, 1.2	1.1	1, 2, 3
			Approved for Development	1.1, 1.2	1.2	1, 2, 3
			Justified for Development	1.1, 1.2	1.3	1, 2, 3
		Potentially Viable Projects	Development Pending	2	1.3, 2.1	1, 2, 3
			Development On Hold	2	2.2	1, 2, 3
		Non-Viable Projects	Development Unclarified	3.2	2.2	1, 2, 3
			Development Not Viable	3.3	2.3	1,2,3
Un-drilled	Potential Sources	Prospective Projects	Ready to Drill	2, 3.2	3.1	4
			More Studies Required	3.2	3.2	4
			Reconnaissance	3.2	3.3	4
			Prospect Not Viable	3.3	3.3	4
		Projects Needing New Technology		3.2, 3.3	4	4

Figure 3: A modified UNFC class table (after United Nations, 2020) with additional Sub-classes for Potential Sources. An additional sub-class, separate from Prospective Projects—Projects Needing New Technology— may also be useful for Projects with an F-axis value of F4.

4 SIMPLIFIED DESCRIPTIONS FOR THE E AND F CATEGORIES

UNFC provides a set of definitions to help an assessor score components of the E-axis and F-axis at the sub-category level (United Nations, 2020). Although the definitions act as a good guideline for assessment, they are resource-agnostic and aim to cover all types of resource projects. The UNFC Geothermal Specifications already provide additional guidance on how to interpret the E-axis and F-axis definitions in a geothermal context, but we have found that new users can find the overall structure and language somewhat daunting.

Class	Subclass	UNFC Definition	Simplified, Geothermal Definition
E1	E1.1	Development is environmentally-socially-economically viable on the basis of current conditions and realistic assumptions of future conditions.	Development is currently environmentally-socially-economically viable and there are no remaining E-S-E barriers to operation
	E1.2	Development is not environmentally-socially-economically viable on the basis of current conditions and realistic assumptions of future conditions, but is made viable through government subsidies and/or other considerations.	Development is currently environmentally-socially-viable but economic viability depends on future government subsidies or similar. There are no remaining E-S-E barriers to operation.
E2	E2	Development and operation are expected to become environmentally-socially-economically viable in the foreseeable future	With economics based on drilling results (possibly including offset wells in known geological settings or other high POD cases), development and operation are expected to become environmentally-socially-economically viable in the foreseeable future (<5 years)
E3	E3.1	Estimate of product that is forecast to be developed, but which will be unused or consumed in operations.	Use only for representing production that is consumed as "parasitic load" if there is a reason to report these quantities (optional)
	E3.2	Environmental-socio-economic viability cannot yet be determined due to insufficient information.	Environmental-socio-economic viability cannot yet be determined due to insufficient information, such as project still undefined because of no positive drilling, or some E-S-E barriers to be overcome with uncertain outcome.
	E3.3	On the basis of realistic assumptions of future conditions, it is currently considered that there are not reasonable prospects for environmental-socio-economic viability in the foreseeable future.	There are not reasonable prospects for environmental-socio-economic viability in the foreseeable future. Significant barriers to be overcome with low probability of favourable outcomes in forseeable future.
F1	F1.1	Production is currently taking place.	Project is currently producing electricity or heat.
	F1.2	Capital funds have been committed and implementation of the development is underway.	Capital funds have been committed and implementation of the development is underway, e.g. power plant is under construction.
	F1.3	Studies have been completed to demonstrate the technical feasibility of development and operation. There shall be a reasonable expectation that all necessary approvals/contracts for the project to proceed to development will be forthcoming	Studies show technical feasibility and reasonable expectation for approvals/contracts for the project to build will be forthcoming soon. E.g. Feasibility Study completed, now in FEED / tendering.
F2	F2.1	Project activities are ongoing to justify development in the foreseeable future.	Project activities are ongoing to justify development in the foreseeable future. E.g. more drilling or Feasibility Study is needed and underway or planned.
	F2.2	Project activities are on hold and/or where justification as a development may be subject to significant delay.	Project activities are on hold and/or where justification as a development may be subject to significant delay. E.g. appraisal drilling is needed but funding unavailable
	F2.3	There are no plans to develop or to acquire additional data at the current time due to limited potential.	There are no plans to develop or to acquire additional data at the current time due to limited potential. E.g. drilling has shown uneconomic results.
The divide between drilled and un-drilled projects.			
F3	F3.1	Site-specific studies have identified a potential development with sufficient confidence to warrant further testing.	Site-specific studies have identified a potential development with sufficient confidence to warrant further testing. E.g ready to drill.
	F3.2	Local studies indicate the potential for development in a specific area but requires more data acquisition and/or evaluation in order to have sufficient confidence to warrant further testing.	3G studies indicate the potential of a specific area but requires more data acquisition and/or evaluation in order to warrant further survey or start drilling.
	F3.3	At the earliest stage of studies, where favourable conditions for the potential development in an area may be inferred from regional studies.	At the earliest stage of studies, where favourable conditions for the potential development in an area may be inferred from regional studies. Reconnaissance studies and initial sampling / surveys may be underway or completed.
F4	F4.1	The technology necessary is under active development, following successful pilot studies, but has yet to be demonstrated to be technically feasible for this project.	The technology necessary is under active development, following successful pilot studies, but has yet to be demonstrated to be technically feasible for this project.
	F4.2	The technology necessary is being researched, but no successful pilot studies have yet been completed.	The technology necessary is being researched, but no successful pilot studies have yet been completed.
	F4.3	The technology is not currently under research or development.	The technology is not currently under research or development, or is only conceptual.

Figure 4: An example of simplified and (deep) geothermal-specific E and F-axis sub-category definitions for geothermal project assessments, which the Jacobs team modified based on definitions in United Nations (2020). E2-E3 and F2-F3 mark the boundary between drilled and undrilled projects.

In response, we have tested using a set of descriptions of typical (deep) geothermal project stages to help assessors quickly identify E-axis and F-axis sub-categories appropriate to those stages. The intent of the descriptive terms is to facilitate reliable and more consistent selection of appropriate categories through use of language and terms that are well-understood and appropriate for the industry. In turn this can assist better communication of how UNFC can be applied so that the evaluation process itself does not cloud the end goal of achieving better transparency for companies, investors and governments about projects and their certainty for delivering energy. We developed the descriptive terms with the aim of simplifying the classification process, but rigorous classification will still need a check against the official language and guidance to confirm an assessment.

These "unofficial" definitions are presented alongside the standard in **Figure 4** (above). Jacobs' personnel tested these definitions on 16 participants at a 2-day short course during the ARGEO-C10 conference in Dar Es Salaam, Tanzania, in 2024 (Falcone et al., 2025), during an exercise to rapidly evaluate and classify all known projects in Africa. We observed a more rapid understanding and application of UNFC by the participants relative to previous workshops utilizing only the official UNFC definitions.

5 EXAMPLE APPLICATIONS

The following examples of conducting national or regional inventory demonstrate the value of applying UNFC to a portfolio of projects to provide a holistic view of the state of a market in terms of the maturity of projects being considered, developed or operating. This also demonstrates the simplicity of the UNFC Classes as a way of presenting project status and maturity. The New Zealand example conducted for the regional regulator has been the most rigorous assessment based on careful identification / definition of "Project" and consideration of E and F axes supported by a summary report for each project. This also considered the uncertainty of energy to be produced as represented in the G axis. The East Africa and Indonesia examples have been done in more cursory form based on public data and just considering best estimates of energy, but demonstrate the value of the more granular Classes and in particular the value of having subclasses in the Prospective class.

5.1 New Zealand

The Waikato Regional Council, which regulates the majority of high temperature geothermal systems in New Zealand, has run a trial application of UNFC classification to understand the resource available in their Region and is in the process of considering mandating regular UNFC reporting on projects that have Resource Consents (project already approved for development). They have trained their key technical consultant reviewers in UNFC in order to be able to review assessments made by developers / operators. Jacobs has published a comprehensive report applying UNFC for an inventory of geothermal projects in the Waikato Region in New Zealand. The progress with this initiative was reported in Think GeoEnergy (Cariaga, 2023). This assessment covered both electricity and heat production projects and potential.

The results from the Waikato Region were summarized in terms of the UNFC broad classifications of viable, potentially viable, non-viable and prospective projects and presented in **Figure 5**. This highlighted that, while the region has a substantial installed capacity and there have been recent new projects and expansions, there is a large gap in terms of any future prospects that have been tested by drilling and ready to develop (Ussher *et al.*, 2023). UNFC's focus on project maturity has proven to be highly valuable in having a view of the future pipeline of development, which was not apparent in prior approaches such as the Australian Geothermal Reporting Code.

The assessment of the Waikato Region was updated in 2024 and after just one year there was a notable change in the maturity and classification of several projects, reflecting the value of regular updating of portfolios of projects. This also demonstrated that the UNFC system has useful granularity that is sensitive to the annual changes experienced in project development, especially as projects near construction. The application of UNFC to the geothermal inventory of the Waikato Region has therefore proven highly successful, providing a concise compilation of all projects on a common assessment basis. Geothermal operators were actively engaged in the process, displaying a high level of interest and cooperation and the use of standardized templates facilitated efficient compilation of UNFC reports.

Project Class	PJ (e)		
	G1	G2	G3
Viable Projects	269.9	43.0	32.3
Potentially Viable Projects	24.4	10.4	5.8
Non-Viable Projects	10.0	5.0	5.0
	G4.1	G4.2	G4.3
Prospective Projects	147.0	57.0	80.0
Total	478.3	115.4	123.1

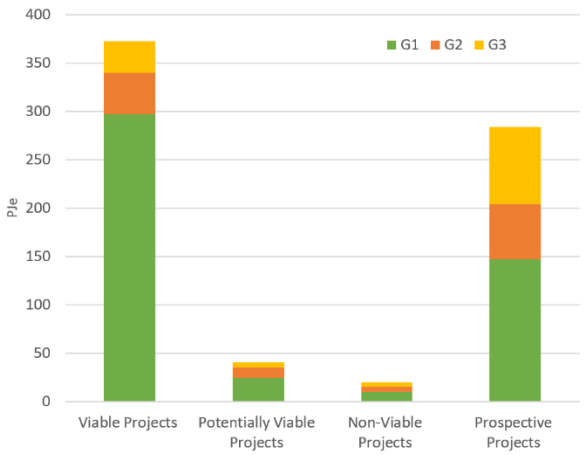

Figure 5: Example output from the Waikato Region UNFC inventory in 2023, showing the consolidation using standard UNFC categories, which provides a useful view of the geothermal pipeline (Ussher *et al.*, 2023).

5.2 East Africa 2024

In support of wider promotion of UNFC application for geothermal in Africa, the New Zealand Ministry of Foreign Affairs and Trade funded a 2-day pre-conference training and workshop at the ARGEO-C10 conference held in Dar Es Salaam, Tanzania in 2024. This workshop was led by consultant Jacobs (who have been delivering aspects of New Zealand's assistance in the region) to 16 people from across the East Africa region. In this workshop, a simplified approach for classifying projects was tested and successfully applied. This also tested an approach that extended standard UNFC maturity Categories to include more granularity for Prospective Projects that are still being explored before any deep drilling.

The outcome was that the trainees, working in small groups, quite effectively managed to classify all known geothermal projects in Africa with reasonable accuracy within a day's work. The results of this were presented to the technical sessions of the ARGEO-C10 conference. A summary is presented in **Figure 6**. Similar to the New Zealand case, this regional compilation highlighted the shortfall of projects that have been successfully drilled and ready to develop, meaning a lot more exploration drilling is needed before substantially more new generation projects can be expected in the region. This again highlights the value of UNFC and its project-oriented maturity assessment approach. This exercise also reveals that UNFC can be "demystified" and readily applied if approached appropriately.

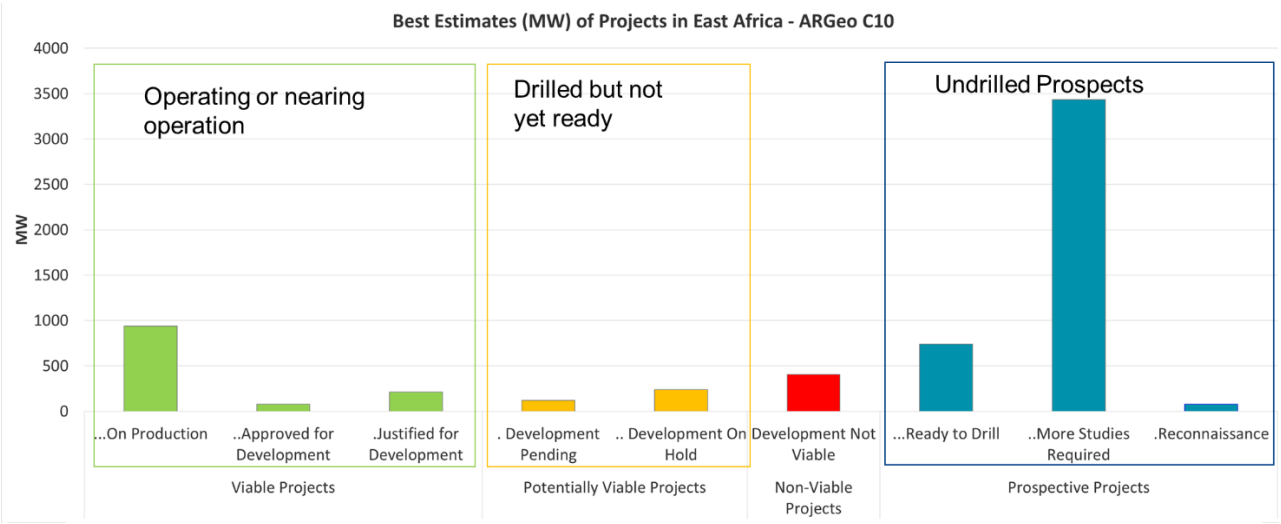

Figure 6: Results from an assessment of all known geothermal power projects and prospects in East Africa conducted by trainees in a workshop on UNFC at the ARGEO C10 conference in 2024.

5.3 Indonesia 2025

Lebe *et al* (2025) presented a compilation of all geothermal projects listed in Indonesia's latest national power plan (*Rencana Usaha Penyediaan Tenaga Listrik* or RUPTL) published by the national power company (PT PLN Persero). A total of 217 electricity-producing geothermal projects were assessed comprising the projects identified within the RUPTL for period 2025 – 2034. They also combined this with all operating projects outside of the RUPTL that hold an existing *Izin Panas Bumi* (IPB) or geothermal permit, which included all operating plants or those under construction.

All projects were assessed using the simplified E and F descriptions and combining into Classes as described in **Figure 4**. The E and F-axes were scored based on publicly available information for each project. Following UNFC practice, the results were then aggregated within classes to consolidate the results. The project class and available resource (listed as MW electric power) for each project sub-category is summarised in **Figure 7**. While UNFC strictly indicates reporting in total PJ over project life, as with the other preceding examples, MW was used as a proxy which is also more immediately recognizable and useful to the power industry.

The results show that Prospective Projects form the largest component of available geothermal power in Indonesia, forming up to 3357 MW. Most of the resource available sits within the More Studies Required category, which captures a broad range of projects including license areas where further surveys are required or currently being performed, or the projects being in ongoing licensed exploration processes, areas where preliminary surveys have been carried out by the geological survey or a development company but more information is required before decision can be made to drill. This class also includes projects where social and environmental risks currently exist but may reasonably still be resolved in the foreseeable future. Within the Prospective Project class, Reconnaissance projects constitute to over 1000 MW of geothermal resources – this sub-class covers projects where initial 3G surveys are being carried out, or very limited to no public data are available. Only about 500 MW of projects are "ready to drill" in the national pipeline.

Projects that are assessed as Viable Projects make up the second highest amount of geothermal resource in Indonesia. A total of 135 MW of projects are approved or justified for development and are expected to be producing within the foreseeable future.

The Potentially Viable projects add up to under 600 MW total and represent projects that have been drilled but encountered social, financial, permit, or technical issues that have put a temporary halt to the project, or where further drilling, studies or financing is still required to make any major capital investment decision.

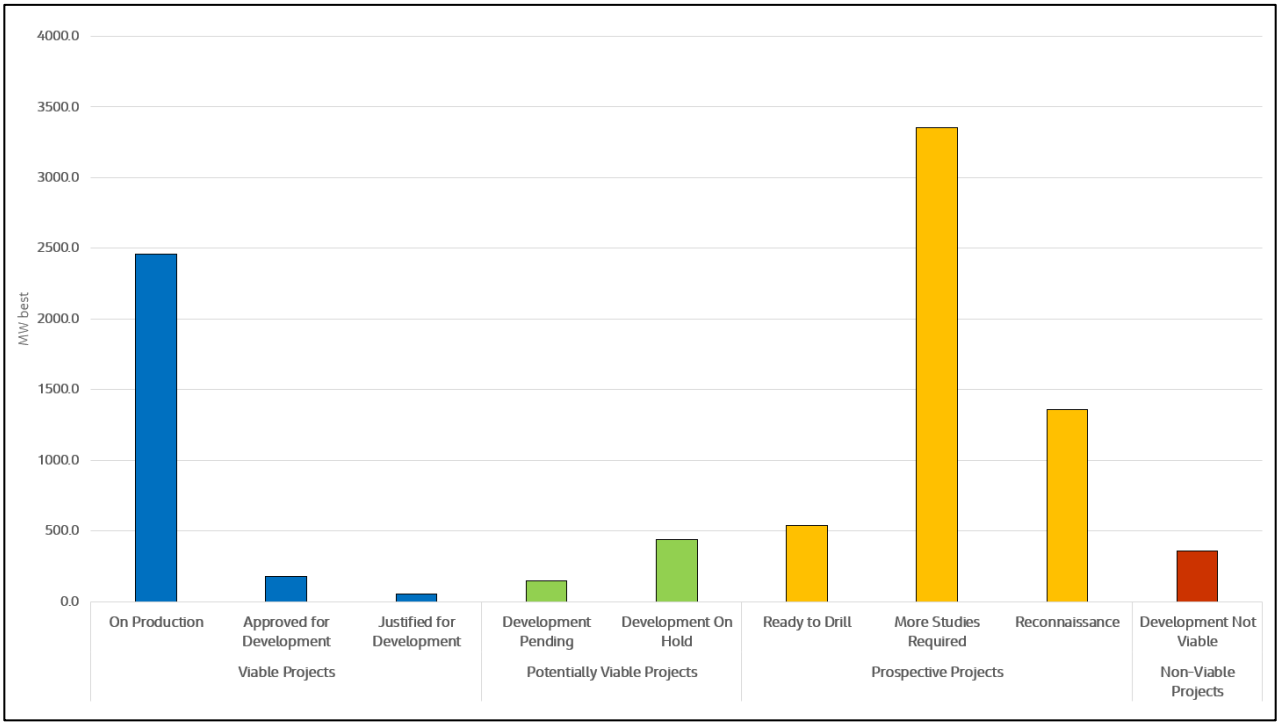

Figure 7: MW best for all electricity generation geothermal projects in the 2025 – 2034 RUPTL and operating projects as of August 2025. For viable projects, MW best represents the actual electricity generation.

The Non-Viable Projects are composed of projects situated in protected areas and national parks or other fundamental environmental or social issues, or where exploration has shown that no project can be technically viable within the foreseeable future. Changing land use classification for a national park is a significant barrier for geothermal and, despite some moves to address this, there are no strong indications that changes to the review and land use conversion process will be made in the foreseeable future.

5.4 Australia

Australia's only geothermal power plant lies idle (at the time of writing) at Winton in the state of Queensland The 310 kWe plant was constructed in 2020 to provide power to Winton Shire Council, which is also the owner of the plant. It combines two 155 kWe Organic Rankine Cycle (ORC) units intended to generate power from the town's water supply bore, which produces 1.85 ML per day (https://www.winton.qld.gov.au/water-supply/water-management-1) at 86°C under artesian pressure from the Great Artesian Basin (Beardsmore, 2024). Winton Shire Council is the only possible customer for the power plant but reportedly has no intention of bringing the plant into operation in the foreseeable future. A project to generate power from the plant, therefore, can be characterized according to our unofficial descriptions listed in **Figure 4**:

- E-axis: There are not reasonable prospects for E-S-E viability in the foreseeable future. Significant barriers to be overcome with low probability of favorable outcomes in the foreseeable future (E3.3);
- F-axis: There are no plans to develop or to acquire additional data at the current time due to limited potential (F2.3).

E3.3, F2.3 is classified as 'Non-viable development—Development not viable', an unintuitive classification for a plant that is already constructed and sitting idle. The full history of the Winton Geothermal Power Plant is not in the public domain, but factors reported by O'Neill (2023) suggest that an assessment according to UNFC principles during the feasibility stage may have classified the project E3.2, F2.2: Non-viable development—Development unclarified. Such a classification with an explicit recognition of "barriers to be overcome with uncertain outcomes" may have ultimately resulted in a more positive outcome for the project.

6 CONCLUSIONS

The use of UNFC Classes as a primary presentation of UNFC classification results has proven effective for communicating UNFC concepts and application. It is also proving to be a powerful way to present the results of inventory or portfolio assessments where users and regulators can rapidly visualize the state of an industry or sector.

UNFC provides considerable flexibility to adapt or add Classes and Sub-classes to suit user needs, but there may be value in standardizing these for an industry/commodity, or geographic region, so that there is a more universal understanding of how Classes reflect project maturity. We have indicated some options, particularly for Prospective Projects, and welcome feedback from the geothermal industry on this.

Commodity-specific descriptions for the E and F categories could assist easier and more consistent evaluation of Projects on these axes and hence placement of Projects in appropriate Classes. We have proposed a set for conventional geothermal projects, but these may need adapting for heat pump, direct use or advanced technology projects.

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