Joint resource calculation according to the UNFC in the case of complex geothermal energy utilisation

The United Nations Framework Classification for Resources (UNFC) is a multi-sectoral framework designed to integrate the assessment of energy (e.g., geothermal) and mineral resources (e.g., lithium) within a unified model. This approach accounts for technological maturity, societal acceptance, policy constraints, and financial risk factors across all project components. While CRIRSCO-, PERC-, and JORC-compliant reporting focus specifically on minerals – essential for capital market disclosures – the UNFC offers superior interoperability for multi-resource developments and facilitates the classification of currently non-viable resources.

To mitigate the redundancy of dual assessments, a 'bridging' document has been established (UNECE, 2024; CRM-geothermal Deliverable D4.1; Falck & Correia, 2025). A primary advantage of the UNFC is its capacity for joint assessment in co-production scenarios, which is fundamental to the CRM-geothermal context. In such cases, the volume of mineral raw materials cannot be definitively quantified a priori, as extraction yields depend on fluid flow rates and solute concentrations, both of which exhibit temporal variability.

Challenges in Fluid-based Extraction

Although hydrocarbon classification schemes share commonalities with these objectives, the UNFC standards for oil and gas do not yet fully encompass the extraction of minerals from liquids. This is particularly evident in petrothermal reservoir systems, where insufficient natural fluid requires artificial circulation (Figure 1).

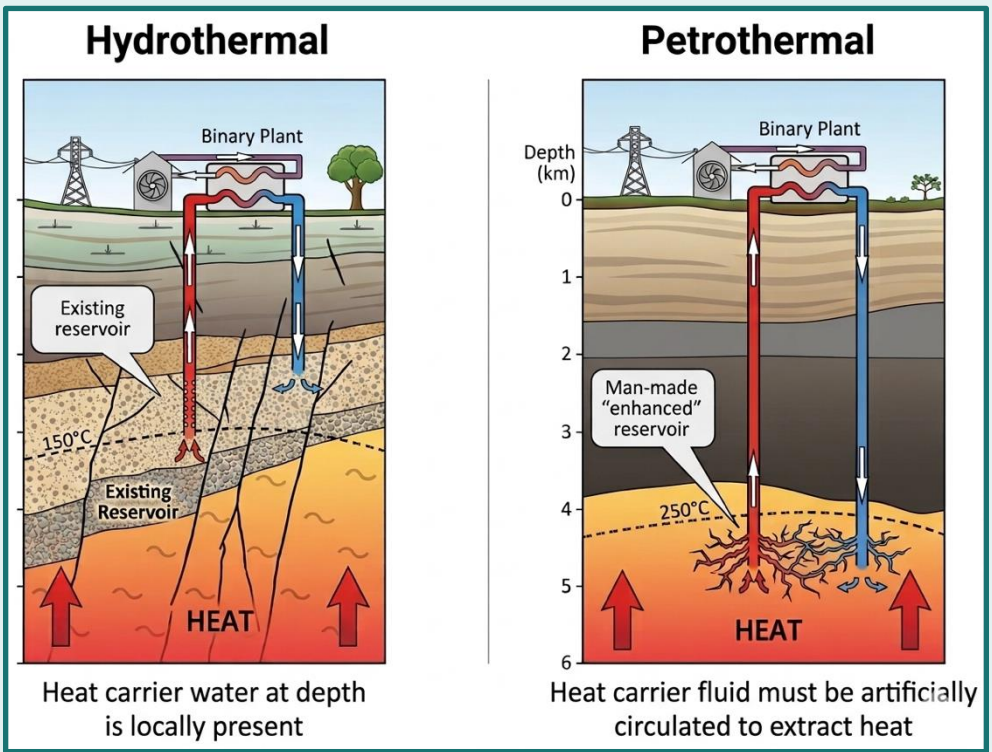

Figure 1: Differences between hydrothermal and petrothermal systems.

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In these systems, the in situ leaching period is relatively brief (days to weeks). Conversely, hydrothermal systems involve fluid-rock interactions occurring over geological timescales. In hydrothermal scenarios, it is critical to model the timing of reinjected water arrival at the production well. Even in the absence of thermal breakthrough, the lithium concentration in reinjected water is typically significantly lower than that of formation water residing in the reservoir for millennia. Furthermore, kinetic processes—not just thermodynamic equilibrium – must be integrated into the analysis. Lithium enrichment may exceed reinjection values through:

- mixing and dilution with regional groundwater;
- the dissolution of minerals within fracture networks.

Given the time-dependent nature of these phenomena, a kinetic component is essential for accurate resource modelling.

Strategic Benefits of the UNFC Framework

The UNFC framework offers several strategic benefits for integrated geothermal and critical raw materials (CRM) projects (Figure 2). First, it enables a comprehensive resource classification approach by allowing the simultaneous evaluation of geothermal potential and CRM availability. This helps clarify the interdependencies and synergies within integrated projects, such as the recovery of lithium from geothermal brines.

In addition, the framework supports strategic planning through a harmonised classification system that helps governments and project developers align initiatives with national raw materials strategies, renewable energy objectives, and climate commitments, including targets linked to the EU Green Deal.

Figure 2: Strategic benefits of UNFC for complex geothermal energy utilisation.

The framework also contributes to risk management and investment de-risking. By explicitly incorporating uncertainty and Environmental, Social, and Governance (ESG) considerations into its E, F, and G axes, the UNFC enhances both project robustness and investor confidence.

Finally, UNFC improves investor transparency by establishing a common reporting standard that facilitates comparability across projects. This is particularly important for hybrid developments whose financial viability depends on multiple outputs, such as electricity generation and lithium extraction.

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Methodology and Conclusions

Hydrodynamic and transport modelling provide the foundational tools for the evaluation of multi-resource projects under the UNFC code. A joint assessment must quantify each commodity separately while simultaneously gauging the environmental, social, and technical feasibility of the integrated system (Figure 3). Methodologically, the "lowest common denominator" principle applies: the overall project classification is governed by its least favourable component. From an economic perspective, the project's viability must be assessed holistically; for example, a project may remain feasible if heat and power generation are profitable, even if lithium extraction is currently sub-economic.

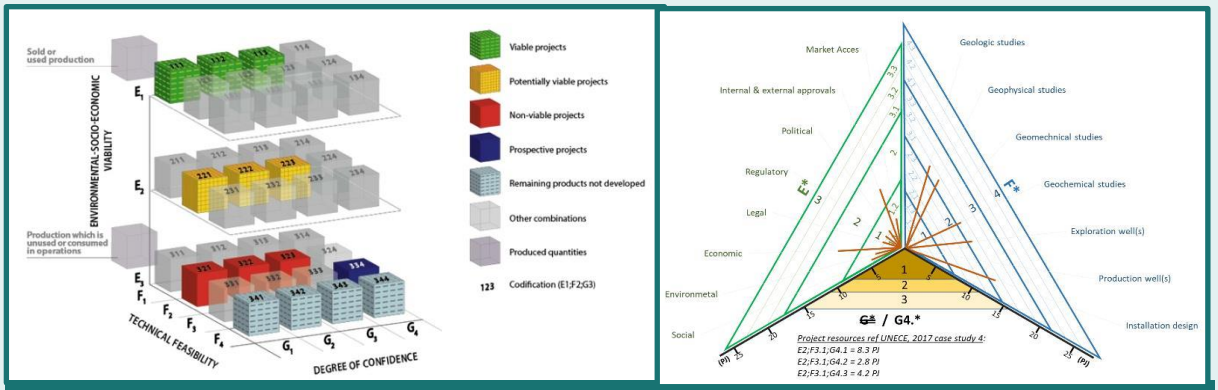

Figure 3: UNFC-2009 classes (left) and a referred project's „UNFC fingerprint" (Mijnlieff et al. 2019)

Finally, the availability of extensive datasets – particularly from geothermal and hydrocarbon exploration – enables the application of machine learning and advanced petrophysical analytics. The rapid integration of artificial intelligence into reservoir modelling is expected to catalyse a significant breakthrough in the practical implementation of UNFC joint evaluations.

More information:

Deliverable 2.5: Report on resource calculation according to the UNFC

Deliverable 4.1: ESG due diligence of the combined extraction of CRMs and energy, incl. UNFC/UNRMS compatible reporting and policy recommendation

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