Supplementary Specifications

for the application of the

United Nations Framework Classification

for Resources (Update 2019)

to

Geothermal Energy Resources

Done in Geneva on 25 October 2022

Supplementary Specifications for the application of the United Nations Framework Classification for Resources (Update 2019) to Geothermal Energy Resources

Document prepared by the United Nations Framework Classification for Resources Ad Hoc Committee of the International Geothermal Association

Summary

This document supersedes and replaces the Specifications for the Application of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009) to Geothermal Energy Resources, which were released on 30 September 2016.

This document outlines the Supplementary Specifications for the Application of the United Nations Framework Classification Resources (Update 2019) (UNFC (2019)) to geothermal energy resources. Its intended use is in conjunction with UNFC (2019). Given the updates incorporated in UNFC (2019), there is no longer a requirement to use this document in conjunction with the Specifications for the Application of UNFC-2009 to Renewable Energy Resources, which were also released on 30 September 2016, as they are no longer in use.

Preface

At the fifth session of the Expert Group on Resource Classification (now the Expert Group on Resource Management) in April 2014, the Task Force on Application of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009) incorporating Specifications for its Application (as set out in United Nations Economic Commission for Europe (ECE) Energy Series No. 42, ECE/ENERGY/94) to Renewable Energy was requested to provide at least one draft renewable commodity-specific specification for review at the sixth session. To this end, the Task Force called upon the expertise of the International Geothermal Association (IGA) to provide specifications for the Application of UNFC-2009 to geothermal energy resources using the full granularity of UNFC-2009.

Through a Memorandum of Understanding[1] that was signed in September 2014, ECE and IGA agreed that their goals in the area of geothermal resources were mutually supportive. It was also agreed that the IGA represented the best platform and international umbrella to develop specifications and guidelines for the Application of UNFC-2009 to geothermal energy and to maintain evergreen texts in a manner consistent with their proper application through regular and periodic review under the aegis of the Expert Group.

Following the Memorandum of Understanding, on 15 October 2014, IGA issued a call for volunteers interested in joining a Working Group to draft the geothermal specifications for UNFC-2009. A twelve-member Working Group was appointed on 15 January 2015.

The Geothermal Working Group developed a set of draft specifications for the Application of UNFC-2009 to geothermal energy resources, which were presented to the Expert Group on Resource Classification (now called the Expert Group on Resource Management) at its seventh session, 26-29 April 2016, for review (document ECE/ENERGY/GE.3/2016/6). The Expert Group requested that the draft specifications be issued for public comment, following which the document approval procedure agreed upon at the fifth session of the Expert Group should be followed (ECE/ENERGY/GE.3/2014/2, paragraph 97). The draft specifications were issued for public comment on the ECE website from 6 June 2016 to 4 August 2016. The Geothermal Working Group reviewed all the comments received and produced a revised set of specifications in response. The ECE Committee on Sustainable Energy endorsed the Specifications at its twenty-fifth session in Geneva on 30 September 2016.

On 30 December 2019, ECE issued the United Nations Framework Classification for Resources (UNFC) Update 2019 (UNFC (2019)), prompting the need for an update of the Specifications, as well as additional Guidance to facilitate implementation and uptake of the Specifications.

At the 74th meeting of IGA's Board of Directors on 1 November 2020, Motion 74-2 was adopted to set up a dedicated UNFC Committee as an Ad Hoc Committee, with Gioia Falcone as the Chair.

Growing awareness and interest in renewable energy resources, including geothermal resources, has highlighted a need to normalize the way in which renewable energy potentialis reported. The renewable energy industry has become a fully commercialized sector, in which several oil and gas majors have already started to play a significant role following the established local and international geothermal developers. These playershave voiced a need for a common platform to assess and compare in a transparent way the potential of their renewable and non-renewable energy portfolios. A common assessment andcomparison framework for renewable and non-renewable energy resources is also needed byinvestors, regulators, governments and consumers as a foundation for a comprehensive overview of current and future energy sustainability scenarios at project, company, country,region or world level. With no globally agreed geothermal standards, guidelines or codes existing prior to the development of this document and its 2016 pre-cursor, it is hoped that the inclusion of geothermal energy, including not only power generation but also cascaded projects and direct use within UNFC, will facilitate the improvement of global communication in the geothermal sector as part of the larger energy sector.

[1] https://unece.org/DAM/oes/MOU/2014/MoU-UNECE_IGA.pdf

Acknowledgements

The development of this document was undertaken by the IGA UNFC Ad Hoc Committee of expert volunteers led by Gioia Falcone (Chair), with Graeme Beardsmore, Paolo Conti, Robert Hogarth, Sulamith Kastl, Harmen Mijnlieff, Annamária Nádor, Christopher Schifflechner and Greg Ussher.

The efforts made by the Renewable Energy Working Group of the Expert Group on Resource Management, chaired by Jeremy Webb, in reviewing this document are greatly appreciated. The review of the document by Claudio Virues, Alberta Energy Regulator, Canada, is acknowledged.

Further acknowledgements go to the Technical Advisory Group of the Expert Group on Resource Management and to the former Chair of the Technical Advisory Group, Alistair Jones, for their input in addressing technical issues that emerged during the activities of the IGA UNFC Ad Hoc Committee.

Satinder Purewal, Co-Chair, Technical Advisory Group, Barbara Pribyl, Chair, Petroleum Working Group of the Expert Group on Resource Management, Harikrishnan Tulsidas, ECE, and Charlotte Griffiths, ECE, are thanked for the final review of the document.

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I. Introduction

1. This document supersedes and replaces the Specifications for the Application of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009) to Geothermal Energy Resources, which were released on 30 September 2016. It includes an updated version of the decision trees to aid the classification of geothermal projects, according to UNFC (2019).

2. This document outlines the Supplementary Specifications for the Application of the United Nations Framework Classification for Resources (Update 2019) (UNFC (2019)) to geothermal energy resources. Its intended use is in conjunction with UNFC (2019). Given the updates incorporated in UNFC (2019), there is no longer a requirement to use this document in conjunction with the Specifications for the Application of UNFC-2009 to Renewable Energy Resources, which were also released on 30 September 2016, as they are no longer in use.

3. This document is intended for a broad audience, including (i) policymakers and those responsible for government and regulatory resource management, (ii) company internal resource management, and (iii) financial reporting, especially for users that wish to facilitate the realization of the Sustainable Development Goals (SDGs). The SDGs were adopted by the United Nations in 2015 as a universal call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity.

4. The 17 SDGs are integrated – they recognize that action in one area will affect outcomes in others and that development must balance social, economic and environmental sustainability. Ensuring sufficient, reliable, affordable, and environmentally responsible supplies of energy and raw materials for sustainable development is a key challenge for all countries. UNFC is a tool for the effective management of national resource endowments needed for realizing the SDGs. UNFC aims to provide necessary specifications and guidelines for optimizing the sustainable management and development of resources, with positive impacts on society, the environment, local economies and employment.

A. Geothermal Energy Sources

5. In the geothermal energy context, the Source is the thermal energy contained in rocks, sediments and/or soils, including any fluid contained underground or naturally discharging at the ground surface, which is available for extraction and/or conversion into energy products. This source is termed the **Geothermal Energy Source.** The Geothermal Energy Source might change over time due to influx to, outflux from, or internal generation of energy within the underground. In Cascaded Projects (see section D), the Geothermal Energy Source may be the thermal energy output (wholly or in part) from an upstream Project drawing on the same original Geothermal Energy Source.

1. Known versus Potential Geothermal Energy Sources

6. (Refer to UNFC (2019) p1; Chapter I. Application 4th paragraph; Annex I Glossary of terms, p16, Known Source).

7. A Known Geothermal Energy Source is one where one or more wells or thermal springs have established, through testing, sampling and/or logging, the existence of a significant quantity of recoverable thermal energy. In this context, “significant” means suitable for providing heat at rates sufficient to support the Project. In the context of ground source heat pump (GSHP) Projects or thermal springs, the Geothermal Energy Source shall be considered Known.

8. A Potential Geothermal Energy Source is one where the existence of a significant quantity of recoverable thermal energy has not yet been demonstrated by direct evidence (e.g., well drilling and associated well testing/sampling/logging of sources for Projects that are expected to require wells for the planned thermal energy use, or surface discharges of thermal waters in the case where a Project plans to use natural thermal discharges), but is inferred to exist based primarily on evidence from geophysical measurements, geochemical

sampling and other surface measurements, airborne measurements or other indirect methods.

B. Geothermal Energy Products

9. (Refer to UNFC (2019) p1; Chapter I. Application 3rd paragraph; Annex I Glossary of terms, p16, Product).

10. A **Geothermal Energy Product** is an energy product that is sold, used, or otherwise delivered by a Project associated with (at least) one Geothermal Energy Source. Examples of Geothermal Energy Products are electricity and heat (for Geothermal Heating and Cooling). Other products, such as inorganic materials (e.g., silica, lithium, manganese, zinc, sulphur), gases (e.g., carbon dioxide) or water without surplus energy content, which are delivered by the same Project might be classified according to other relevant UNFC Specifications, but do not qualify as Geothermal Energy Products. However, where these other products are sold or delivered, the revenue streams should be included in the Project's economic evaluation.

11. Although thermal energy injected and stored underground in addition to the natural thermal energy accumulation (e.g., in boreholes, aquifers, caverns, pits or abandoned mines) does not qualify as a Geothermal Energy Product *per se*, its combination with thermal energy production can influence the economic viability of the Project and should therefore be included in the Project's economic evaluation. Its impact should also be quantified in the reporting of production rates of Geothermal Energy Products over time, taking into account variability of the production and storage components (e.g., seasonally).

12. Where a Project is producing energy product(s) from multiple sources, including at least one Geothermal Energy Source (a 'hybrid project'), the quantity of Geothermal Energy Product shall be estimated in terms of the contributions of the various sources to the final energy product(s) for the Project. The Evaluator shall disclose the method for estimating the quantity of Geothermal Energy Product as part of the final energy product for the Project.

C. Geothermal Energy Resources

13. (Refer to UNFC (2019) p3; chapter III. Classes 2nd paragraph; "Product Available").

14. **Geothermal Energy Resources** are the cumulative quantities of Geothermal Energy Products that will be extracted from the Geothermal Energy Source from the Effective Date of the evaluation forward (till the end of the Project Lifetime/Limit), measured or evaluated at the declared Reference Point(s).

15. For national resource reporting, the aggregation of individually reported resource estimates from commercial, non-commercial and/or governmental organizations may not cover the total national Geothermal Energy Resources. The creation of notional or hypothetical 'standard' Prospective Projects (with associated Reference Point) may allow an estimate and classification of all the nation's Geothermal Energy Resources, including those not yet linked to defined Projects. These notional Projects could be adequately classified as E3.2, F3.3, G4.

D. Project Definition

16. (Refer to UNFC (2019) p1; Chapter I. Application 4th paragraph; UNFC (2019), Annex I Glossary of terms, p17, Project; p16 Identified Project).

17. The resource classification process consists of defining a Project associated with (at least) one Geothermal Energy Source, estimating the quantities of energy that can be sold, used or otherwise delivered as Geothermal Energy Products over the Project's Lifetime, and classifying the Geothermal Energy Resource based on the criteria defined by the E, F and G Categories.

18. The Project is the link between the Geothermal Energy Source(s) and quantities of Geothermal Energy Products and provides the basis for the evaluation of environmental-socio-economic viability, technical feasibility, degree of confidence and decision-making. In

the context of geothermal energy, the Project includes all the systems and equipment connecting the Geothermal Energy Source to the Reference Point(s) where the Geothermal Energy Products are sold, used, or otherwise delivered. Including, for example, production and injection wells, ground or surface heat exchangers, connecting pipework, energy conversion systems, additional energy influx, and any necessary ancillary equipment. In the early stages of evaluation, a Project might be defined only in conceptual terms, whereas more mature Projects will be defined in sufficient detail to justify the environmental-socio-economic viability and technical feasibility.

19. The scope of a defined Project will be that for which a particular investment decision is made and which will have a substantive change/increment in the quantities of resources that will be produced. This provides for the separate consideration of multiple Projects that may draw on a common Geothermal Energy Source but be developed in incremental phases. Each phase would proceed or not based on a separate major investment decision and possibly with separate energy sales agreements or environmental permits. An example could be where an identified high-temperature hydrothermal reservoir is gradually developed through sequential Projects comprising separate power plants and associated well fields to ultimately use much of the available Geothermal Energy Source.

20. Periodic investment to (for example) maintain the supply of geothermal fluid to a Project during its lifetime would normally be anticipated and committed (in principle) as part of the original investment decision and is regarded as a 'business as usual' capital expenditure. In this context, regular additional well drilling to sustain production is considered part of the original Project, so it would not normally require a new Project definition. An exception would be if the original Project design was substantially changed or enhanced.

21. A Project downstream from another Project, drawing on the same original Geothermal Energy Source, where the thermal energy output (wholly or in part) from the upstream project represents the Geothermal Energy Source for the downstream project, is defined as a Cascaded Project. Cascaded Projects are sequentially linked according to decreasing temperature demand. An example could be Geothermal Heating and Cooling after geothermal electricity production.

E. Reference Point

22. (Refer to UNFC (2019) Part II p14; Section F Reference Point).

23. The Reference Point is a defined location in the physical or conceptual structure of the Project where the Geothermal Energy Product is measured or estimated. The Reference Point is typically the point of sale to third parties or where custody is transferred to the entity's downstream operations.

24. Where a Project produces multiple Geothermal Energy Products, e.g., electricity and heat, or has multiple sales, use or delivery points, there may be more than one Reference Point (see Section J). Geothermal Energy Products of the same type may be aggregated across different Reference Points as long as they are considered part of the same Project with the same E-F classification.

25. An Intermediate Node might be necessary to reference where a relevant quantity, different from the Geothermal Energy Source, enters the Project or occurs in between the energy process. Depending upon the specific Project, it could be necessary to report additional energy and/or mass fluxes associated with Intermediate Nodes in order to provide a clear description of the Project operation. For instance, for Geothermal Heating and Cooling with GSHPs, both heat transfer at the evaporator/condenser section and driven energy at the compressor/sorption unit should be disclosed. Other examples include systems in which geothermal apparatus works together with other energy sources (e.g., backup fuel-based technologies. or hybrid systems). In general, these additional quantities should be disclosed together with a clear description/definition of the Intermediate Node.

F. Project Lifetime/Limit

26. (Refer to UNFC (2019) Part I p3 2nd paragraph; Part II p14; Section F Reference Point).

27. The estimated Geothermal Energy Resources for a Project shall be limited to quantities that will be produced during the Project Lifetime.

28. The Project Lifetime will be the minimum of the economic limit, design life, contract period and entitlement period, as defined below. Because of its importance in estimating energy quantities, the Project Lifetime and its basis shall be disclosed in association with any reported quantities.

29. The 'economic limit' is defined as the time at which the Project reaches a point beyond which the subsequent cumulative discounted net operating cash flows or financial benefit from the Project would be negative. All cash flow evaluations shall include meeting corporate and/or regulatory environmental and social obligations and abandonment, decommissioning and restoration costs. For a Geothermal Energy Project, the economic limit may be the time when the expected extraction rate declines to a level that makes the Project uneconomic or when it is uneconomic to invest in further Project infrastructure, refurbishment or maintenance of existing equipment, such as additional wells, heat exchangers, turbines, or treatment systems for the geothermal fluid.

30. The 'design life' of a Project is the expected operating life of major physical infrastructure as defined during the technical and economic assessment of the Project. The replacement of significant project components will constitute a new Project, and a new evaluation and estimation of Geothermal Energy Resources shall be performed.

31. The 'contract period' for a geothermal Project is the term of all existing, or reasonably expected, sales contracts for the Geothermal Energy Products. The contract period should not include contract extensions unless there is a reasonable expectation of such extensions based upon the historical treatment of similar contracts.

32. The 'entitlement period' is the term of all licences and permits which provide rights to access the Geothermal Energy Source, extract the Geothermal Energy Resources and deliver the Geothermal Energy Products into the market. The entitlement period should not include licence extensions unless there is a reasonable expectation of obtaining such extensions based upon the historical treatment of similar licences issued by the issuing authority.

33. The Geothermal Energy Source and existing or planned Project infrastructure may be expected to last much longer than the Project Lifetime, but any future extracted quantities beyond those estimated for the Project would be assessed and classified as subsequent or additional Projects.

G. Access to Source

34. (Refer to UNFC (2019) Part I p4; Chapter VII).

35. A reporting entity gains and secures access to a Geothermal Energy Source through licences and permits, or other similar contracts, generally issued by the applicable government authorities. These licences and permits typically allow the entity, subject to applicable regulations, to explore the Geothermal Energy Source and, where applicable, to develop, operate a Project or Projects and transport Geothermal Energy Products into the market.

H. Access to Market

36. (Refer to UNFC (2019) Part I p4; chapter VII).

37. A geothermal Project gains access to an energy market through the application of processes and technologies, the development of infrastructure and policy settings that provide support and opportunity for a financial reward through the subsequent sale, use or delivery

of the Geothermal Energy Product(s) to target markets and product users. Market access may or may not be supported by entitlements of the Geothermal Energy Product(s) to relevant tariff and non-tariff measures, incentives and certifications as set by the country's governing bodies. Geothermal Energy Products may alternatively be used locally or within another process associated with the Project. In this case, the rights to use or deliver the Geothermal Energy Product and the expected continuity of demand over the Project Lifetime should be considered in the classification.

I. Intermittent or Variable Extraction

38. When estimating Geothermal Energy Resources associated with a Project, future production scenarios are assumed (either explicitly or implicitly). Such scenarios are generally based on the combined assessment of the future energy production capacity of the Project, sustainability of the source, as well as time-varying energy demand by users or customers. They describe expected 'yearly load hours' and anticipated production rates and should include operational and maintenance downtime. Depending on the market or the nature of the off-take of the Geothermal Energy Product(s), the Project may deliver at a constant base rate or with periodical variation between no (or minimum) production and maximum production, for example, the seasonal delivery of heat to a district heating system, or seasonal variations in agriculture direct uses, and for projects with both production and underground storage of thermal energy varying annually or seasonally.

39. Reduced or halted production due to a force majeure event (e.g., typhoon, landslide, flooding, earthquake, volcanic eruption) or unexpected operational issues are generally not included in the production forecast. If production is halted for an extended period of time (>1 year), then the classification of the Geothermal Energy Resources should be reviewed, and an updated resource assessment prepared, which discusses and explains the likelihood of restarting production.

J. Projects with Multiple Energy Products

40. (Refer to UNFC (2019) Part II p13; Chapter IV, Section D).

41. Where a Project produces more than one Geothermal Energy Product (e.g., heat and electricity), the corresponding Geothermal Energy Resources shall be estimated and classified separately but included in a single report for the Project. Quantities of different Geothermal Energy Products cannot be aggregated.

42. When a Project requires significant input energy fluxes (e.g., electrical energy to drive heat pump compressors or well production/injection pumps), these quantities should be estimated and reported along with, but separately to, the Geothermal Energy Products unless they are generated by the project itself and consumed in the project operation, in which case they can be classified separately as E3.1. Any energy or mass quantity that is considered relevant within the Project may be explicitly identified as separate and reported, together with its Intermediate Node. These quantities are not separately classified but are considered within the classification of the estimated Geothermal Energy Resource.

43. Quantities estimated at different Intermediate Nodes or Reference Points in the same Project can be aggregated. The Evaluator shall ensure coherence of the aggregation. UNFC, Part II, Section II provides additional guidance on the issue of aggregation of estimated quantities. In general, aggregated quantities must have the same nature (e.g., heat or electricity). For example, similar applications (e.g. estimates of heat delivered from a single borehole along two different pipes to two different heat exchangers could be aggregated, but heat delivered to one of those heat exchangers cannot be aggregated with heat delivered to a room via a GSHP downstream from the second heat exchanger).

K. Corporate versus National Resource Reporting

44. (Refer to UNFC (2019) Part I, p1; Chapter I. Application 4th paragraph; Part II p12;

Chapter II).

45. UNFC is designed to evaluate and classify resources associated with ***single*** projects. For reporting corporate or national Geothermal Energy Resources, the estimated quantities of the ***single*** projects may need to be aggregated.

46. UNFC (2019), Part II, Section IV J provides guidance on the issues of national resource reporting and aggregation of estimated quantities.

L. E-Axis Categories

47. (Refer to UNFC (2019) Part I, Annex I, p6 E Axis – Environmental-Socio-Economic Viability; Part I, Annex I, p8 Definition of Sub-categories; Ref to UNFC (2019) Part II p14; Chapter IV, Section H).

48. Annex I provides the definition of E-axis categories and subcategories with additional geothermal energy context.

49. Annex II includes an E-axis decision tree to aid E classification. A loop is introduced because there is potentially a suite of issues pertaining to the 'license to operate' in the environmental, social, economic, legal, etc. domains, which need to be assessed and resolved. There will usually be multiple contingencies, and the overall project E-classification should be that of the lowest ranking one.

1. Considerations for the use of 'Foreseeable Future'

50. The Foreseeable Future is a period of time that a Project can make a realistic projection of the occurrence of future conditions, events or other factors that determine the environmental-socio-environmental viability or technical feasibility of a Project. In the geothermal context, the Foreseeable Future is within a maximum of five years from the Effective Date of evaluation and is in terms of when the (irreversible) commitment to building the Project will be made.

2. Treatment of Policy Support

51. It is recognized that:

- A variety of policy support mechanisms, regulatory instruments, and financial incentives (e.g., feed-in tariffs, premiums, grants, tax credits etc.) may exist worldwide to reflect the value that off-takers or the state place on geothermal energy
- Some energy subsidies may be available on a project-by-project basis, while others may be available to all such renewable/geothermal energy projects in the market
- Energy subsidies are typically phased out over time or once the qualifying renewable energy sources reach a certain share of overall energy production and market maturation.

52. Thus, when using the Sub-category E1.2, the type of *government subsidies and/or other considerations* that make extraction and sale viable shall be disclosed, together with their anticipated future availability as at the Effective Date.

M. F-Axis Categories

53. Refer to UNFC (2019) Part I, Annex I, p6 F Axis – Technical Feasibility and Maturity; Part I, Annex I, p8-9 Definition of Sub-categories; Part II p14; Chapter IV, Section I).

54. Annex I provides the definition of F-axis Categories and Sub-categories with additional geothermal energy context.

55. Annex II includes an F-axis decision tree to aid F classification and lists a typical suite of issues pertaining to the 'technical' evaluations that are performed and documented. There will usually be multiple contingencies, and the overall project F-classification should be that of the lowest ranking one.

1. Distinction between and considerations for F1, F2 and F3

56. A Geothermal Energy Resource associated with a Project based on a Potential Geothermal Source shall be classified as F3. The F3 Category has three Sub-categories (see UNFC (2019) Annex II).

57. The F3.1 Sub-category relates to projects that are ready to be tested by well drilling or other means of directly testing the characteristics and viability of the Source.

58. For any direct use of waters already naturally flowing at the surface, F3.1 may be applied until such time as sufficient studies are in place regarding the specific Project concept to consider applying an F2 classification.

59. The F3.2 Sub-category relates to projects that are considered to need further indirect methods for investigation or other technical feasibility assessments before proceeding to well drilling (or another direct testing of the Source).

60. The F3.3 Sub-category relates to "the earliest stages of studies." These can include notional estimates of Geothermal Energy Resources for national resource reporting (see section K).

61. If the result of test drilling or other attempts to secure direct evidence of the Geothermal Energy Source is “dry,” “unsuccessful,” or “inconclusive,” the Geothermal Energy Resource shall be classified as F3.

62. Note that, by definition, energy estimates associated with Potential Sources are also classified as G4 under the 'G' Category (see section A.1).

63. No particular considerations apply to F1 and F2 in the geothermal context.

2. Category F4 – New Technologies

64. The F4 Category is provided for situations where a notional Project is defined based on technology that is yet to be demonstrated as technically feasible. The F4 Sub-category definitions enable the identification of the current status of the development of the technology.

65. F4 shall not be reported without specifying one of the three F4 Sub-categories.

3. Remaining Quantities of Product

66. In the geothermal context, heat is an intrinsic parameter of the entire Earth, and the lateral/depth boundary, reference temperature limits and recharge rate of any potential Source are arbitrary or poorly defined. Therefore, neither F4 nor any other classification shall be applied to any estimates of ‘heat in place’ or ‘heat remaining in place’ or similar. The F4 Category may be applied only to a Geothermal Energy Resource that could be produced from a notional Project based on technology that falls under one of the F4.1, F4.2 or F4.3 Sub-categories. The intent is to avoid reports and classification statements of vast quantities of heat in place while enabling the potential gains from new technologies to be expressed for particular conceptual developments.

67. Where a particular identified Geothermal Energy Source is not expected to be fully utilized by a proposed Project, the remaining potential may be addressed with a separate conceptual Project that has a different E-F-G Classification reflecting the lesser maturity and definition of the Project.

4. Definition and Use of F-axis Sub-categories

68. See sections M.1 to M.3 for definitions and use of F-axis Sub-categories.

N. G-Axis Categories

69. (Refer to UNFC (2019) Part I, ANNEX I, p7 G Axis – Degree of Confidence; Part I, Annex II, p9 G Axis – Degree of Confidence; Part II p15; chapter IV, section M).

70. Annex I provides the definition of G-axis Categories and Sub-categories with additional geothermal energy context.

71. Annex II includes a G-axis decision tree to aid G classification.

72. The G-axis Categories are intended to reflect all significant uncertainties impacting the estimated Geothermal Energy Resources quantities that are forecast to be produced by the Project. For Geothermal Projects, this can typically include uncertainty in the final capacity (maximum production rate), the capacity factor (reflecting the daily or annual usage variations), efficiency and possible changes in the Geothermal Energy Source over the Project Lifetime. It is recommended that a production profile indicating the annual production of Geothermal Energy Products over time be disclosed to demonstrate how the Project enables the rate of production over the Project Lifetime.

73. The rate of production of Geothermal Energy Products (for example, in terms of MW thermal or electrical) is often a key parameter of any geothermal project, and in turn, this is of importance for markets and regulators. Therefore, these rates and how they may change over the Project Lifetime should be included within the information reported as the basis for estimating the Geothermal Energy Resource.

74. For Projects that combine thermal energy production and underground storage, the storage impact on the production rates of Geothermal Energy Products over time should be quantified.

1. G Category for Known and Potential Geothermal Energy Sources

75. Estimated Geothermal Energy Resources associated with Known Geothermal Energy Sources shall be classified and reported using the 'G' categories, G1, G2 and G3.

76. Estimated Geothermal Energy Resources associated with Potential Geothermal Energy Sources shall be classified and reported using the 'G' Category G4 or its Sub-categories G4.1, G4.2 and G4.3.

2. Probability of Discovery for Potential Geothermal Energy Sources

77. For Potential Geothermal Energy Sources (to be reported using the G4 Category or its Sub-categories G4.1, G4.2 and G4.3), the Probability of Discovery should also be reported.

78. The Probability of Discovery is the chance that further exploration, drilling, and well testing of a Potential Geothermal Energy Source will result in the confirmation of a Known Geothermal Energy Source. This will typically be assessed considering the key factors that are required to achieve a discovery which may include temperature, permeability and fluid chemistry or other relevant parameters that are important for the type of Project planned to evaluate the technical feasibility of the Project.

79. The quantities reported in the 'G' Category G4 or its Sub-categories G4.1, G4.2 and G4.3 are 'un-risked' in that they are the quantities that may be expected to be reported for the project once Known, regardless of the level of Probability of Discovery.

O. Evaluator Qualifications

80. (Refer to UNFC (2019), Part II p15; Chapter IV, Section L).

81. Evaluators shall possess an appropriate level of expertise and relevant experience in the estimation of Geothermal Energy Resources associated with the type of Geothermal Energy Source and Project under evaluation.

82. Relevant government, industry, or financial reporting regulations may require an Evaluator to have specific qualifications and/or experience. In addition, regulatory bodies may explicitly mandate the use of a ‘competent person’, as defined by regulation, with respect to corporate reporting.

83. Any public report detailing Geothermal Energy Resources shall disclose the name of the Evaluator, including qualifications and experience, state whether the Evaluator is an employee, officer or owner of the entity preparing the report, and, if not, name the Evaluator's

employer and state its relationship to the reporting entity.

84. Estimation of Geothermal Energy Resources is very commonly a team effort involving several technical disciplines. It is, however, recommended that only one Evaluator sign the Geothermal Energy Resource report and that this person be responsible and accountable for the whole of the documentation. It is important in this situation that the Evaluator accepts overall responsibility for a Geothermal Energy Resource estimate and supporting documentation prepared in whole or in part by others and is satisfied that the work of the other contributors is acceptable.

85. Recommendations are provided separately for organizations or entities such as national governments, financial institutions and companies who wish to establish appropriate quality assurance mechanisms, qualification criteria and/or disclosure obligations that can be adopted in circumstances where competency requirements are considered desirable. The recommendations are available on the ECE website and should be read in conjunction with the Guidance Note on Competency Requirements for the Estimation, Classification and Management of Resources.[2]

P. Units

86. (Refer to UNFC (2019) Part II p15; Chapter IV, Section M).

87. Estimated quantities shall be reported in Joule (J) or multiples of the Joule. However, it is recognized that there are traditional measurement units that are widely used and accepted in the geothermal energy sector; such units can therefore be added in parenthesis next to the Joule value.

Q. Reporting a Project Classification

88. (Refer to UNFC (2019) Part II p15; Chapter IV, Section N).

89. An individual Project classification should be supported by a Project description and summary of the key elements of the Project upon which the classification is based. This should include a description of:

- The Geothermal Energy Source including the state of knowledge about the Source and uncertainties about its characteristics
- The physical Project including technology to be used for transferring subsurface energy to the surface and for any energy conversion. Conversion efficiency should be stated for any energy conversions
- Any additional energy or mass inputs into the system at an Intermediate Node
- The Geothermal Energy Product (electricity, heat etc.)
- The Reference Point(s) where the product is sold, used or transferred
- The Project Lifetime and what are the key factors that limit that lifetime
- The expected Project capacity factor considering daily or annual variability and possible trends of production over the lifetime
- The basis for calculating the expected resource quantity, including the basis for the G1, G2, G3 (or G4.1, G4.2, G4.3) range
- The Project's access to the Source, including licences, permits, and ownership
- The environmental and social impact of the Project, including the status of necessary environmental permits
- The status and conclusions of technical feasibility studies for the Project and any associated technical preparations and contracts for the design, supply or construction of the Project.

[2] https://unece.org/sites/default/files/2022-03/ECE_ENERGY_GE.3_2022_4.pdf

- The proposed timeline or project schedule for the Project – at least for the next development or evaluation phase and including any pending key decision points.
- Access to the market or other off-take agreements necessary for the products to be used or sold.
- The economic viability of the Project and whether any subsidies are required

90. The final classification should include brief reasons for the selection of the E and F Categories that are applied and state the E, F Categories, along with the G1, G2, G3 estimates.

Annex I

E/F/G Table

UNFC Category	*UNFC Definition*	*UNFC Supporting Explanation*	*UNFC Sub-Categories*	*UNFC Sub-Category Definition*	*Additional Geothermal Energy Context*
E1	*Development and operation are confirmed to be environmentally-socially-economically viable.*	*Development and operation are environmentally-socially-economically viable on the basis of current conditions and realistic assumptions of future conditions. All necessary conditions have been met (including relevant permitting and contracts) or there are reasonable expectations that all necessary conditions will be met within a reasonable timeframe and there are no impediments to the delivery of the product to the user or market. Environmental-socio-economic viability is not affected by short-term adverse conditions provided that longer-term forecasts remain positive.*	***E1.1***	*Development is environmentally-socially-economically viable on the basis of current conditions and realistic assumptions of future conditions.*	E1.1 is provided to differentiate projects that are environmentally-socially-economically viable without subsidies. Use of E1 is acceptable if the use of subsidies is not clear or it is inappropriate to make this differentiation.
			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.*	This includes subsidies needed for present or future operation. If subsidies were used in the past (e.g. to drill a well), they are no longer relevant to the classification of the Geothermal Energy Resource.
E2	*Development and operation are expected to become environmentally-socially-economically viable in the foreseeable future*	*Development and operation are not yet confirmed to be environmentally-socially-economically viable but, on the basis of realistic assumptions of future conditions, there are reasonable prospects for environmental-socio-economic viability in the foreseeable future.*	*No Sub-categories defined*	-	In the geothermal context, the Foreseeable Future is within a maximum of five years from the Effective Date of evaluation and is in terms of when the (irreversible) commitment to build the project will be made.

UNFC Category	*UNFC Definition*	*UNFC Supporting Explanation*	*UNFC Sub-Categories*	*UNFC Sub-Category Definition*	*Additional Geothermal Energy Context*
E3	*Development and operation are not expected to become environmentally-socially-economically viable in the foreseeable future or evaluation is at too early a stage to determine environmental-socioeconomic viability.*	*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;* *or,* *environmental-socio-economic viability cannot yet be determined due to insufficient information.* *Also included are estimates associated with projects that are forecast to be developed, but which will be unused or consumed in operations.*	***E3.1***	*Estimate of product that is forecast to be developed, but which will be unused or consumed in operations.*	For example, quantities produced and used internally (e.g. parasitic use, such as well pumping, power conversion loss, etc.). This classification is for the products that are unused, whereas the main project will require its own classification which may lie elsewhere on the E axis. Reporting of E3.1 is optional.
			E3.2	*Environmental-socio-economic viability cannot yet be determined due to insufficient information.*	For example, prior to-successful exploration well drilling (if a drilled well is 'dry' or unsuccessful, but further drilling is planned, this sub-category is still appropriate). Or, Where there is an active effort to obtain approval, the outcome is unknown or unclarified.
			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.*	Uneconomic sites, for example sites far from transmission and/or demand Or Where there is an active effort to obtain approval, the likelihood of receiving approval is low.

UNFC Category	*UNFC Definition*	*UNFC Supporting Explanation*	*UNFC Sub-Categories*	*UNFC Sub-Category Definition*	*Additional Geothermal Energy Context*	
F1	*Technical feasibility of a development project has been confirmed.*	*Development or operation is currently taking place or, sufficiently detailed studies have been completed to demonstrate the technical feasibility of development and operation.* *A commitment to develop should have been or will be forthcoming from all parties associated with the project, including governments.*	***F1.1***	Production is currently taking place [a]	F1.1 is useful to distinguish a project that is operating from a project that is 'under construction' which is a typical example of an F1.2 Category	F1 alone can be used for an operating project or one already committed and under construction. Any adverse operational issues (e.g. chemistry, gas content, scaling, corrosion) can be managed. Consideration needs to be given however if there are any major issues arising that may substantially impact future technical viability in which case a lower category may be considered
			F1.2	Capital funds have been committed and implementation of the development is *underway*.		
			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*	F1.3 may be used for projects that have fully proven technical feasibility, but may be awaiting other approvals that are expected to be forthcoming in a short timeframe (Justified for Development).	
F2	*Technical feasibility of a development project is subject to further evaluation.*	*Preliminary studies of a defined project provide sufficient evidence of the potential for development and that further study is warranted. Further data acquisition and/or studies may be required to confirm the feasibility of development.*	***F2.1***	Project activities are ongoing to justify development in the *foreseeable future*.	For direct use and electricity projects that rely on wells, at least one well has been drilled indicating the potential for production. But further drilling or technical evaluations are required to confirm project technical viability. For GSHP Projects and balneology pools, technical studies are still ongoing (no drilling needed)	
			F2.2	Project activities are on hold and/or where justification as a development may be subject to *significant delay*.	This may apply, for example, where additional drilling is identified as needed to complete the technical feasibility, but funding for such drilling is still unconfirmed.	
			F2.3	There are no plans to develop or to acquire additional data at the current time due to limited potential.	This may apply, for example, where drilling has found unfavourable characteristics of the geothermal energy source.	

UNFC Category	*UNFC Definition*	*UNFC Supporting Explanation*	*UNFC Sub-Categories*	*UNFC Sub-Category Definition*	*Additional Geothermal Energy Context*	
F3	*Technical feasibility of a development project cannot be evaluated due to limited data.*	*Very preliminary studies of a project, indicate the need for further data acquisition or study in order to evaluate the potential feasibility of development.*	***F3.1***	Site-specific studies have identified a potential development with sufficient confidence to warrant further testing.	Use of F3.1 provides clarity that all necessary surface based exploration studies have been completed and the next phase of data collection is the drilling of exploration wells (for geothermal projects that will rely on wells).	F3 may be used in general for projects that need drilling to prove the source and where drilling has not yet been successful in confirming the required characteristics of the geothermal energy source.
			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.	Use of F3.2 is appropriate when further studies such as surface based exploration or pre-feasibility studies for the total Project are required before proceeding with any exploration 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.	Use of F3.3 is appropriate when detailed local exploration studies have not been made of a Project location and potential is based on regional geothermal potential studies. F3.3 can also be used for inventory assessments of development potential based on regional studies.	
F4	*No development project has been identified.*	*Remaining quantities of product not developed by any project. These are quantities which, if produced, could be bought, sold or used (i.e. electricity, heat, etc., not wind, solar irradiation, etc.).*	***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.	F4 alone may not be used for geothermal Projects. The F4.1, F4.2 and F4.3 subcategories may only be applied for projects that are proposing technology that is not yet demonstrated as technically feasible. The quantities should be in terms of product (heat, electricity etc) that the theoretical production process would deliver, not the heat in place. F4 or sub-categories is not to be used for 'heat in place' or 'remaining heat in place' estimates, and the quantities must be associated with a proposed production technology, the technical status of which is stated by the F4.1, 4.2, 4.3 sub-categories.	
			F4.2	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.		

[a] Successful sustained operation of the Project up to Reference Point. For power projects, this typically includes wells and plants. For Geothermal Heating and Cooling projects without GSHPs, this might include wells and typically includes piping and ancillary equipment up to the heat delivery point.

UNFC Category	*UNFC Definition*	*UNFC Supporting Explanation*	*UNFC Sub-Categories*	*UNFC Sub-Category Definition*	*Additional Geothermal Energy Context*
G1	*Product quantity associated with a project that can be estimated with a high level of confidence.*	*Product quantity estimates may be categorized discretely as G1, G2 and/or G3 (along with the appropriate E and F Categories), based on the degree of confidence in the estimates (high, moderate and low confidence, respectively) based on direct evidence.* *Alternatively, product quantity estimates may be categorized as a range of uncertainty as reflected by either (i) three specific deterministic scenarios (low, best and high cases) or (ii) a probabilistic analysis from which three outcomes (P90, P50 and P10) are selected. In both methodologies (the 'scenario' and 'probabilistic' approaches), the estimates are then classified on the G Axis as G1, G1+G2 and G1+G2+G3 respectively.* *In all cases, the product quantity estimates are those associated with a project.* *Additional Comments:* *The G-axis Categories are intended to reflect all significant uncertainties (e.g. source uncertainty, geologic uncertainty, facility efficiency uncertainty, etc.) impacting the estimate forecast for the project. Uncertainties include variability, intermittency and the efficiency of the development and operation (where relevant).* *Typically, the various uncertainties will combine to provide a full range of outcomes. In such cases, categorization should reflect three scenarios or outcomes that are equivalent to G1, G1+G2 and G1+G2+G3.*	***none***	-	The estimates of G1, G2, G3 (or G1, G1+G2 and G1+G2+G3) should reflect the degree of confidence in the quantities of Geothermal Energy Products that are expected to be produced over the Project Lifetime. This should include allowance for uncertainty about the final net maximum production rate from the overall production facility, uncertainty about what capacity factor will be achieved on a daily or annual basis, and any possible degradation in production due to changes in the energy source of production facilities over time. All these factors should be reported in the classification text that supports the G1, G2, G3 (or G1, G1+G2 and G1+G2+G3) estimates. Uncertainty in how large a production facility may be when finalized after additional drilling and feasibility studies will be represented (e.g. this could reflect uncertainty regarding whether a project is 50 or 100 MW in the early stages of project definition) These quantities are what the proposed or existing Geothermal Energy Project will produce, not the potential of the Geothermal Energy Source. The production profile of Geothermal Energy Products, and the Project Lifetime should be indicated to support each estimate. The production profile may show energy production as GWh per year or similar units.
G2	*Product quantity associated with a project that can be estimated with a moderate level of confidence.*		***none***	-	
G3	*Product quantity associated with a project that can be estimated with a low level of confidence.*		***none***	-	

UNFC Category	*UNFC Definition*	*UNFC Supporting Explanation*	*UNFC Sub-Categories*	*UNFC Sub-Category Definition*	*Additional Geothermal Energy Context*
G4	*Product quantity associated with a Prospective Project, estimated primarily on indirect evidence.*	*A Prospective Project is one where the existence of a developable product is based primarily on indirect evidence and has not yet been confirmed. Further data acquisition and evaluation would be required for confirmation.* *Where a single estimate is provided, it should be the expected outcome but, where possible, a full range of uncertainty should be calculated for the prospective project.* *In addition, it is recommended that the chance of success (probability) that the prospective project will progress to a Viable Project is assessed and documented.*	***G4.1***	Low estimate of the quantities.	For example, delineation by surface surveys; evidence of rock-water interactions, spring analysis, temperature gradient, regional heat-flow maps, etc. As for G1,2,3, these estimates should reflect the degree of confidence in the quantities of Geothermal Energy Products from the Project, not just reservoir potential. Given the early nature of exploration, the size of any production facility may be quite uncertain but should consider local market conditions, including demand, and the likely size of the most viable portion of a potential energy source. For GSHP projects, G4 does not apply.
			G4.2	Incremental amount to G4.1 such that G4.1+G4.2 equates to a best estimate of the quantities.	
			G4.3	Incremental amount to G4.1+G4.2 such that G4.1+G4.2+G4.3 equates to a high estimate of the quantities.	

Annex II

Decision tree to aid the classification of geothermal projects according to UNFC (2019)

1. The decision trees[3] provided in this document aim to assist with the classification of a geothermal Project according to UNFC (2019).

2. For each of the three UNFC (2019) axes (E, F and G), a separate decision tree is provided. By following the arrows from decision box to decision box, the user will end up in a box giving the most suitable classification at the highest hierarchical level for the given axis.

3. 'End boxes' have a green color fill. In some cases, the end box is red suggesting that there may be insufficient information to classify the Project.

4. The arrows connecting the boxes are colored: red represents the direction for decision NO; green represents the direction for decision YES; with a blue arrow, no decision has to be made (passing information only).

5. For the E Axis, a loop is introduced because there is potentially a suite of issues pertaining to the 'license to operate' in the environmental, social, economic, legal, etc. domains, which need to be resolved. There will usually be multiple contingencies and the overall project E-classification should be that of the lowest ranking one.

6. Project activities as used in the F-axis classification definitions are related to the 'technical' evaluations that are performed and documented. For geothermal application these technical studies include:

   (a) Geological studies;

   (b) Geophysical studies;

   (c) Geochemical studies;

   (d) Geomechanical studies;

   (e) Reservoir/subsurface modelling studies;

   (f) Well/borehole drilling and completion studies;

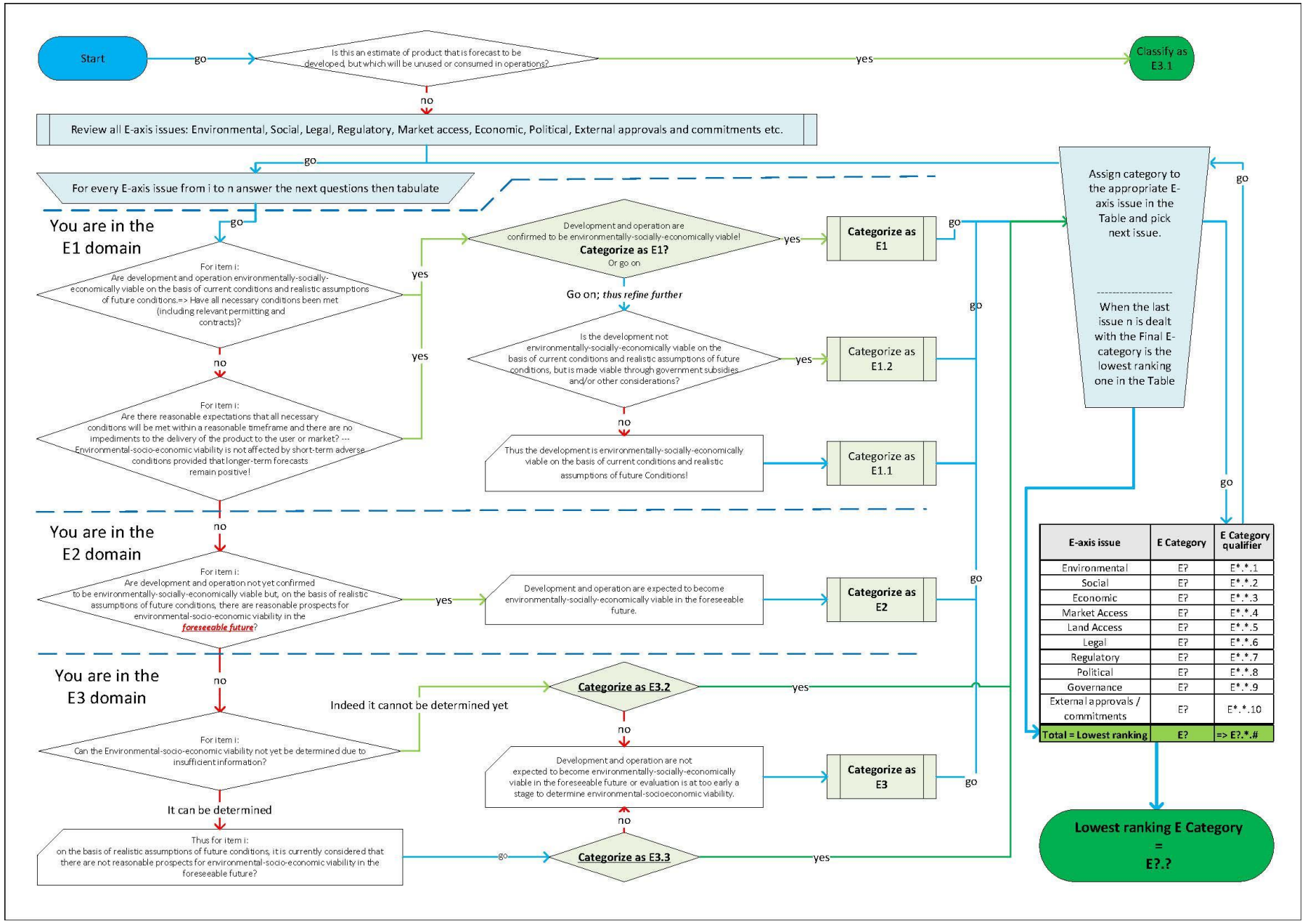
   (g) Surface equipment/infrastructure studies;

   (h) Siting/logistics.

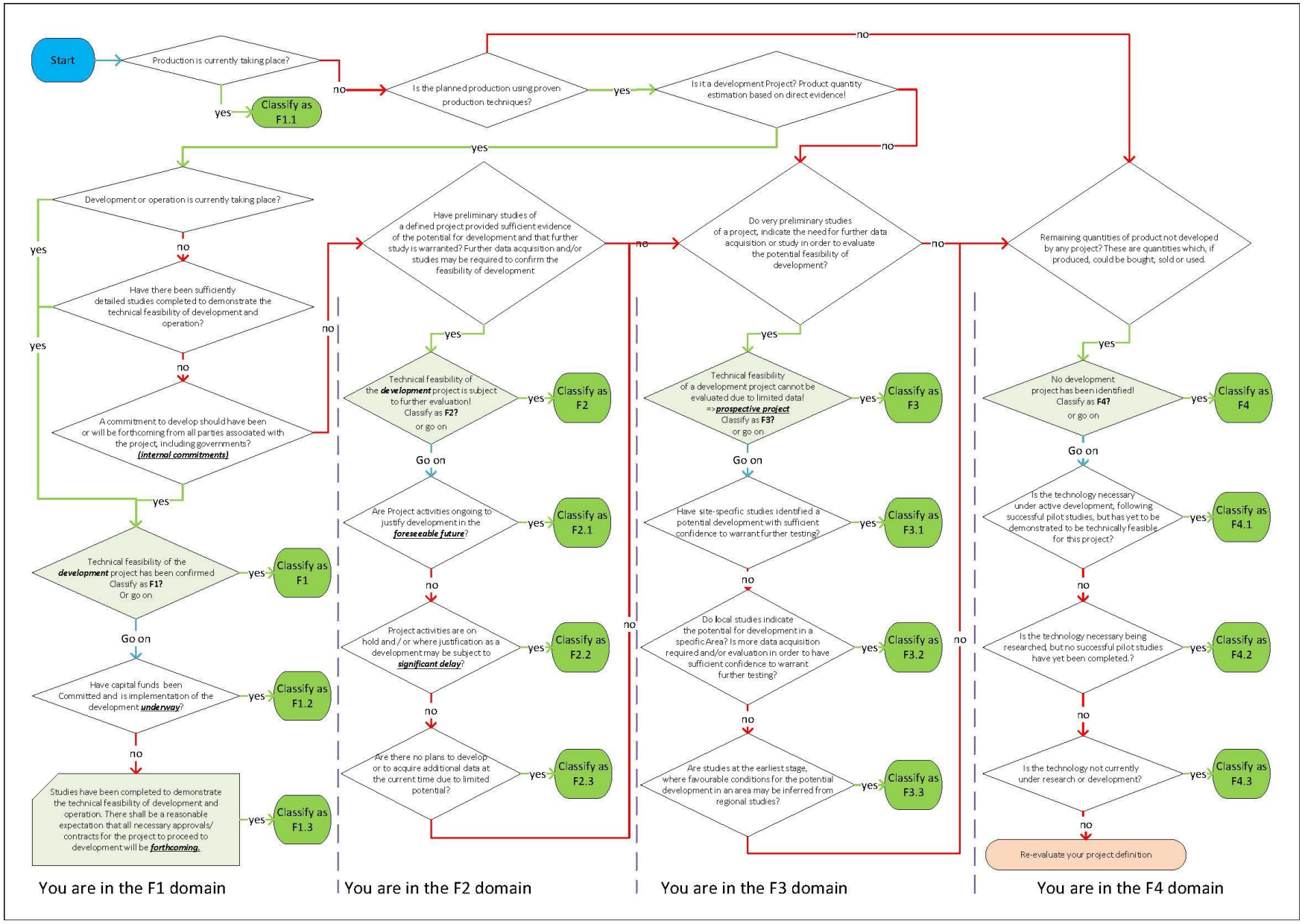
7. The studies with the lowest maturity define the final score.

[3] The decision trees were developed by Harmen Mijnlieff with contributions from the IGA UNFC Ad Hoc Committee.

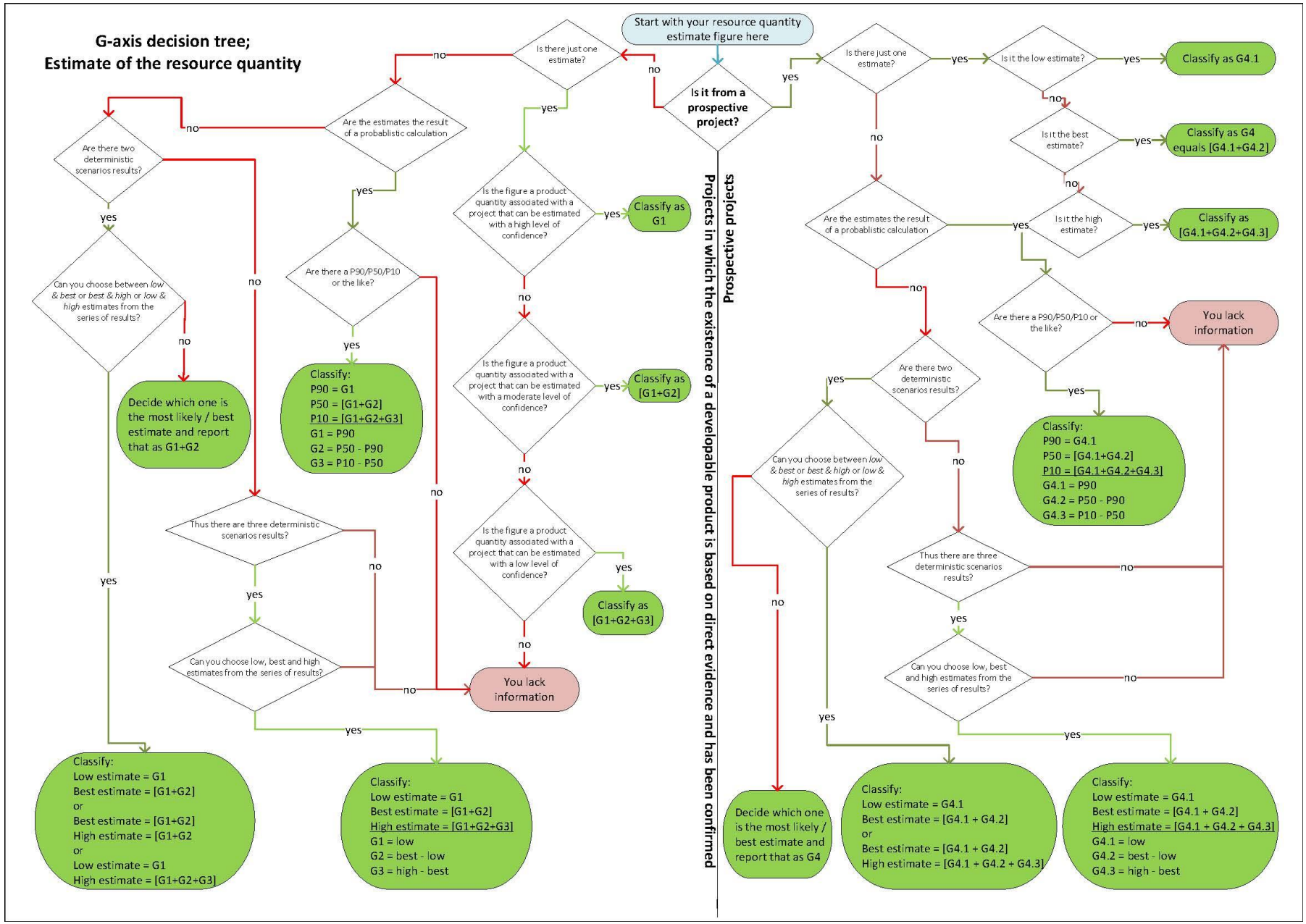
E – axis decision tree



F – axis decision tree



G – axis decision tree



Annex III

Glossary of Terms Relevant in the Geothermal Context[4]

Term	*Definition*
Cascaded Project	*A Project downstream from another Project drawing on the same original Geothermal Energy Source, where the thermal energy output (wholly or in part) from the upstream project represents the Geothermal Energy Source for the downstream project. Cascaded Projects are sequentially linked according to decreasing temperature demand.*
Foreseeable Future	*Within a maximum of five years from the Effective Date of evaluation and is in terms of when the (irreversible) commitment to build the project will be made.*
Geothermal Energy Product	*An energy product that is sold, used, or otherwise delivered by a Project associated with (at least) one Geothermal Energy Source. Examples of Geothermal Energy Products are electricity and heat. Other products, such as inorganic materials (e.g., silica, lithium, manganese, zinc, sulphur), gases (e.g., carbon dioxide) or water without surplus energy content, which are delivered by the same Project do not qualify as Geothermal Energy Products.*
Geothermal Energy Resource	*The cumulative quantities of Geothermal Energy Products that will be extracted from the Geothermal Energy Source, from the Effective Date of the evaluation forward (until the end of the Project Lifetime/Limit), measured or evaluated at the declared Reference Point(s).*
Geothermal Energy Source	*The thermal energy contained in rocks, sediments and/or soils, including any fluid contained in the underground, or naturally discharging at the ground surface, which is available for extraction and/or conversion into energy products. This source is termed the Geothermal Energy Source. The Geothermal Energy Source might change over time due to influx to, outflux from, or internal generation of energy within the underground. In Cascaded Projects, the Geothermal Energy Source may be the thermal energy output (wholly or in part) from an upstream Project drawing on the same original Geothermal Energy Source.*
Geothermal Heating and Cooling	*The use of a Geothermal Energy Source for any purpose other than electricity generation. Geothermal Heating and Cooling encompasses applications such as Agriculture and Food Processing, Industrial Process Heat, Health, Recreation & Tourism, Heating services for buildings, Cooling and dehumidification services, and others.*
Intermediate Node	*A point other than the Reference Point within the Project, where a relevant quantity of energy and/or mass enters the Project and affects the overall energy conversion or delivery process.*
Probability of Discovery	*The chance that further exploration, drilling and well testing of a Potential Geothermal Energy Source will result in the confirmation of a Known Geothermal Energy Source.*
Thermal Spring	*A spring discharging at a temperature above the mean air temperature of the location.*

[4] These terms are in addition to the Glossary of Terms included in Annex I of Part II of UNFC (2019) incorporating Specifications for its Application (ECE Energy Series No. 61).