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UNFC Resource Classification Applied to Real World Geothermal Projects: Outcomes from an Education and Implementation Pilot Program

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ABSTRACT

The Expert Group for Resource Management of the United Nations Economic Commission for Europe endorsed the Geothermal Specifications for the application of the United Nations Framework Classification (UNFC) to geothermal energy resources in September 2016. In 2018 and 2019, the International Geothermal Association (IGA), International Renewable Energy Agency (IRENA) and the Energy Sector Management Assistance Program of the World Bank Group (ESMAP), with the support of the United Nations Economic Commission for Europe (UNECE), jointly ran a program of workshops and implementation trials across three regions to train local geothermal professionals on how to use UNFC to classify Geothermal Energy Resource estimates for portfolios of real-world geothermal projects.

We report the key outcomes from that program. These include an assessment of the level of effort required to train professionals with no previous experience of applying UNFC; identification of fundamental UNFC concepts that required the most explanation and translation for geothermal professionals (for example, definitions of 'Project' and 'Geothermal Energy Resource'); observations of the key data requirements to allow project classification (for example, status of the license to operate, maturity of subsurface and engineering studies, and availability of an energy production profile for the project lifetime). Additionally, we gained an appreciation for the interdisciplinary human effort required to rigorously classify and report Geothermal Energy Resources; identified different perspectives that different stakeholders bring to the classification process; developed an understanding of where additional written aids (for example, worksheets and checklists) and guidelines could assist geothermal professionals to apply UNFC; and built an appreciation of the value of joint IGA-IRENA-ESMAP-UNECE programs of this nature to incentivize the uptake of renewable energy.

1. INTRODUCTION

1.1 Introduction

There is significant inconsistency in the way geothermal energy resources are estimated and reported around the world. This lack of consistency contributes to the challenge of improving investor confidence in geothermal energy. A common assessment and comparison framework would allow consistent reporting of geothermal energy resources around the world, but any such framework must be flexible enough to compare scenarios at project, company, regional, or national level. It must also be transparent, so that investors, regulators, governments and consumers can have confidence in reported assessments. Finally, it should be consistent with frameworks used for other energy resources, so that meaningful comparisons can be made across a range of energy options.

Many approaches have been proposed on classifying geothermal resources. These have been based on accessibility or discovery, tectonic settings, temperature/use/status, or by potential, or heat-in-place, or by electric power generation potential, or exergy, or by geological confidence. Falcone et al. (2013) and Falcone and Beardsmore (2015) provided overviews of classification schemes previously proposed for geothermal energy. The broad range of geothermal exploitation, however, burdened each of these classification systems with drawbacks and limitations, leaving the door open for ambiguity and subjectivity. The United Nations Framework Classification (UNFC) overcomes many of the shortcomings of previously proposed classification schemes and provides a harmonized framework for classifying geothermal energy resources.

One aim of the International Geothermal Association (IGA), as defined in its Charter, is "to encourage, facilitate and, where appropriate, promote the coordination of activities related to worldwide research, development and application of geothermal resources." This aim includes developing and trialing quantification and classification guidelines for geothermal energy resources. In a 2014 'Memorandum of Understanding' (MoU), the United Nations Economic Commission for Europe (UNECE) and the IGA agreed that their goals in the area of geothermal resources were mutually supportive, and agreed to establish a relationship to provide the commodity-specific specifications for the application of UNFC to geothermal resources. This paper gives a brief description of UNFC applied to geothermal energy resources, and reports on a program to trial the classification of real geothermal energy projects according to UNFC in three different regions around the world in 2018 and 2019.

1.2 A brief overview of UNFC

During the 1990s, the UNECE took the initiative to develop a uniform system for classifying and reporting reserves and resources of solid fuels and mineral commodities in response to the wishes of UN member countries. The result was UNFC-1997, which was endorsed by the United Nations Economic and Social Council (ECOSOC) in 1997. The UNFC developed through several iterations under the guidance of the Expert Group on Resource Management (EGRM) to a more effective version of the classification scheme, UNFC-2009, which was formally adopted in 2013 (ECE, 2013). UNFC-2009 initially only related to the classification of hydrocarbon

and mineral resources. The numerical suffix was formally dropped from the title of UNFC-2009 after specifications were formally adopted for the application of UNFC to injection projects for geological storage (ECE, 2016a) and to renewable energy resources (ECE, 2016b). Through the 2014 MoU, the IGA and the UNECE agreed that their goals were aligned with respect to promoting the development of the global geothermal sector. It was also agreed that the IGA provided the best platform and international umbrella to develop specifications and guidelines for the application of the UNFC to geothermal energy, and to maintain evergreen the texts in a manner consistent with their proper application through regular and periodic review. Thus, in 2016 the geothermal energy sector became the first renewable energy sector to develop a commodity-specific text for UNFC—the UNFC Geothermal Specifications (ECE & IGA, 2016)—complemented by dedicated case studies (UNECE, 2017). At the time of writing, the UNFC is the only tool that applies equally to oil and gas, mineral resources, nuclear fuel resources, renewable energy, injection projects and anthropogenic resources.

Readers are referred to the formal United Nations documents cited above for a comprehensive description of UNFC principles and details of its application to different commodities. In order to understand the application of UNFC to geothermal energy resources, however, it is necessary to understand several key UNFC concepts. Firstly, a '**Geothermal Energy Source**' is the thermal energy contained in a body of rock, sediment and/or soil, including any contained fluids, which is available for extraction and conversion into energy products. Heat and electricity are the two possible '**Geothermal Energy Products**'. A '**Geothermal Energy Project**' operates for a defined '**Project Lifetime**' and includes all the systems and equipment connecting the Geothermal Energy Source to a '**Reference Point**' at which the Geothermal Energy Products are sold, used, transferred or discarded. The Geothermal Energy Project therefore includes all equipment and systems required for the extraction and/or conversion of geothermal energy, including production and injection wells, ground or surface heat exchangers, connecting pipework, energy conversion systems, and any necessary ancillary equipment. A Geothermal Energy Project provides the basis for investment evaluation and decision-making.

A key definition in UNFC is that the '**Geothermal Energy Resource**' is the cumulative quantity of heat or electrical energy estimated to be produced by the Geothermal Energy Project over its lifetime. For a geothermal plant that is already built and operating, or at an advanced stage of development, the Geothermal Energy Resource is limited by the capacity, capacity factor, and lifetime of the plant; not just by the amount of heat that can be extracted by existing and proposed wells within the production plan for the project. For an exploration project still at an early stage of assessment, the Geothermal Energy Resource must still be estimated as the predicted production from a Geothermal Energy Source by a notional Geothermal Energy Project described at least in conceptual terms (ECE, 2013; ECE, 2016b; ECA & IGA, 2016; Falcone and Conti, 2019). The definition of the Geothermal Energy Project, therefore, is a fundamental prerequisite to quantifying the Geothermal Energy Resource.

Once quantified, a Geothermal Energy Resource is classified under UNFC according to the status of the Geothermal Energy Project. Therefore, the definition of the Geothermal Energy Project and related mass and energy balances are the fundamental starting points for resource classification. Resource estimates are classified under UNFC according to three fundamental criteria combined within a three-dimensional system (Figure 1).

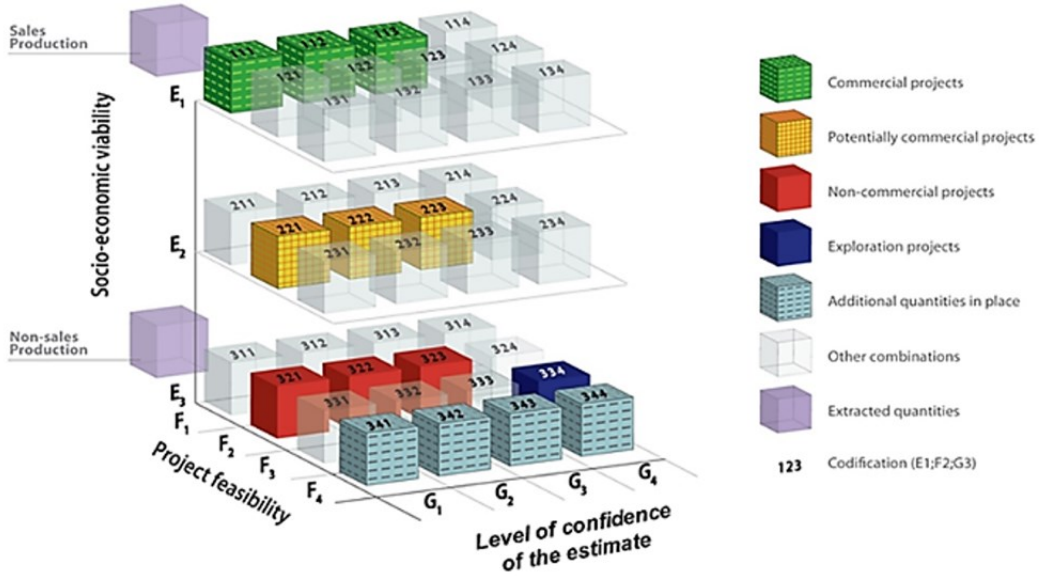


Figure 1. UNFC categories and examples of classes (see legend). After ECE (2013).

The first criterion (the **E-axis**) defines three possible categories (E1, E2 and E3) for the degree of favorability of social and economic conditions for establishing the commercial viability of the Geothermal Energy Project, including consideration of market prices and relevant legal, regulatory, environmental and contractual conditions. E1 is the most favorable rating, and E3 the least favorable. The second criterion (the **F-axis**) defines four possible categories (F1 to F4) for the maturity of studies and commitments necessary to implement development plans, and parallels standard value chain management principles. A normal project would move through categories from F4 to F1 as it progressed from early exploration before a productive geothermal reservoir has been confirmed, to a plant that is producing and selling electricity (or heat).

The third criterion (the **G-axis**) defines three categories (G1 to G3 for a 'Known' Geothermal Energy Source, and G4.1 to G4.3 for a 'Potential' Geothermal Energy Source) designating the level of confidence in the quantification of the Geothermal Energy Resource quantities, encompassing uncertainties in the geological knowledge, energy conversion efficiency, and predicted future production profiles. G1 (and G4.1) designates highest confidence, and G3 (and G4.3) lowest confidence.

The UNFC Geothermal Specifications also incorporate the primary UNFC concept of reporting the 'probability of discovery' (POD) for projects based on a 'Potential' Geothermal Energy Source—where the existence of a significant quantity of recoverable thermal energy has not yet been demonstrated by direct evidence, but is assessed as potentially existing based primarily on evidence from geophysical measurements, geochemical sampling and other surface or airborne measurements or methods. POD is an estimate of the chance that future exploration drilling will find such favorable Geothermal Energy Source conditions and is an important indicator for considering how much Geothermal Energy Resource may actually be realized from future exploration and development on one or a collection of projects.

A three-digit code incorporating E, F and G-axis values is required to fully classify a Geothermal Energy Resource estimate. The UNFC texts define sub-categories for many of the categories, and several unique category combinations can optionally be grouped together into 'classes' (e.g. Figure 1).

1.3 Joint IGA-ESMAP-IRENA-UNECE pilot program

As described above, a working relationship was established between the UNECE and the IGA in 2014 to develop specifications and guidelines for the application of UNFC to geothermal energy and so allow a meaningful comparison of geothermal resource estimates around the world and with other energy resources. The result was the UNFC Geothermal Specifications, approved by the UNECE in 2016. In January 2018, three partners—World Bank Energy Sector Management Assistance Program (ESMAP), International Renewable Energy Agency (IRENA), and IGA—embarked on an 18-month pilot program to promote and apply the UNFC Geothermal Specifications to the classification of geothermal energy resources in three regions around the word. The goals were to build capacity through technical training of local stakeholders, to create local ownership of the classification process on the ground, to apply UNFC classification to as many geothermal projects as possible, and to learn how the UNFC Geothermal Specifications might be further improved. The program was generously supported in-kind by the UNECE from Geneva, which delivered supporting material and documents to local program partners, and assisted in campaigning for the program through its local channels. The three regions selected for the pilot program were the island of Flores in Indonesia, a collection of Eastern Caribbean Islands (including St Lucia, Dominica, St Vincent, St Kitts and Nevis), and Ethiopia in East Africa.

The key message for each region was that the UNFC Geothermal Specifications provide a harmonized framework to qualify estimates of geothermal energy extractable by a project based on key elements of economic viability, technical feasibility and confidence, in a globally consistent and informative manner for prospective users of the information. Promoting standardization in this context is critical for investors, regulators, governments and consumers as a foundation for informed prospecting and evaluation of development opportunities at project, company, and national level.

The following sections report on the activities carried out in each region, the results in terms of capacity-building and resource classifications, and the main lessons learned with respect to building awareness and acceptance of the UNFC Geothermal Specifications.

2. PILOT PROGRAM WORKSHOPS

2.1 Indonesia

The program partners selected Indonesia as the first of three regions for the UNFC pilot program. The location took advantage of an opportunity to run UNFC training sessions in partnership with the annual ITB International Geothermal Workshop (IIGW) in Bandung, 21st and 22nd March 2018, when many stakeholders from the Indonesian geothermal sector gathered. The UNFC sessions comprised three parts: a 20-minute presentation in the Plenary session of the IIGW on Wednesday 21st March, a half-day Short Course as part of the IIGW program on Thursday 22nd March, and a full-day Workshop after the IIGW on Friday 23rd March. The IGA initially proposed two full days for the Workshop, but shortened it to one day, since a venue for two full days could not be found in such short notice. The Indonesian Geological Agency (Badan Geologi) provided the Workshop venue and issued invitations to key stakeholders. Badan Geologi also proposed that the classification exercise focus on geothermal projects on Flores Island in East Indonesia, as the Government of Indonesia recently declared Flores a 'Geothermal Iconic Island.' The project partners accepted the selection of Flores for the pilot program to align with the Indonesian government priorities.

The in-country program ran according to schedule. Eight volunteer representatives from the IGA and one from IRENA travelled to Indonesia to participate in the three-day program. Jacobs contributed some additional trainers supported by the Government of New Zealand through its 'GEOINZ' program. The volunteers conducted the training and shared their experiences with the participants. The audience for the Plenary presentation on 21st March comprised the full cohort of several hundred registrants to the IIGW conference. Participants in Short Course on 22nd March comprised 83 IIGW registrants, representing the IGA, development companies, government regulators, students, teachers, service companies, and foreign visitors. There were approximately 30 participants in the full day workshop on 23rd, comprising representatives from the Indonesian Geothermal Association (INAGA), government geologists and regulators, students, project developers, and the IGA experts.

Of particular educational value were three case studies presented during the Short Course, which assisted with relaying UNFC concepts to the participants using real geothermal examples. However, given the limited prior knowledge about UNFC, the majority of the available time in both the Short Course and Workshop was spent on explaining the E, F and G axes and other UNFC concepts, and on facilitating a dialogue between all participants representing different companies and organizations. One of the unexpected challenges involved obtaining a definitive list of geothermal project areas on Flores. Four different sources listed between 17–24 Flores Island geothermal project areas.

No geothermal energy resource classification was completed on site. Program partners and Indonesian stakeholders continued to discuss the UNFC via telecommunications after completing the in-country program. At the time of writing in mid-2019, however, only one geothermal energy project has been classified for Flores Island. The Mataloko Geothermal Project was selected for the first UNFC classification, partly on the basis of it having been discussed in some detail during the Workshop at Badan Geologi, and partly because the project developer, Perusahaan Listrik Negara ('PLN'), has already financially committed to the project development. Three other geothermal project areas (Atadei, Wae Sano, and Oka Ile Ange) have been selected for subsequent classification.

2.2 East Caribbean

The program partners selected a set of Eastern Caribbean islands as the second of the three regions for the UNFC pilot program. Conversations began in April 2018 between the IGA and the Program Coordinator of the Sustainable Energy Unit of the Organization of the Eastern Caribbean States (OECS) Commission. Building on the experience gained at the Indonesian workshop, the IGA took part in many conference calls with the OECS between April and September 2018 to discuss the value that UNFC might provide to the OECS geothermal sector. The most important message from the IGA was that UNFC would neither verify nor contradict existing geothermal resource quantifications, but would provide a standardized way of reporting each geothermal project such that it could be directly compared with other energy projects. The OECS subsequently hosted a UNFC event in St Lucia and invited all parties with a significant stake in geothermal development across the OECS islands.

The event spread over a three-day program that took place from 5th to 7th December 2018 at the Harbor Hotel in Castries, St Lucia. The first day was devoted to a 'Geothermal Round Table', intended to get all players together in one room in order to get full endorsement for the technical training on Day 2 and Day 3. The Geothermal Round Table brought together key experts and decision-makers in geothermal energy from the region to help advance and initiate a regional cooperation for geothermal energy. The discussions focused on the status of the OECS geothermal projects and the opportunities, challenges and underlying risks they present, with a view to highlighting risk mitigation and financing options. The round table highlighted that the states each had their own different strategies for geothermal development, but that in contrast with the situation at their last regional meeting four years earlier, each state now had a reasonably clear direction for geothermal development. The different development strategies, and the states' clarity of understanding of approach, provided the material for an interesting and productive UNFC Training Workshop on Day 2 and Day 3. The workshop introduced the UNFC classification scheme for geothermal energy projects and worked through three example projects from the region.

The Training Workshop presented the UNFC Geothermal Specifications and international application examples (i.e. case studies) and exposed participants to UNFC principles and classification methodology. It conveyed the benefits of UNFC to the future development of a geothermal market in the region. Training Workshop participants also provided valuable feedback, comments and suggestions to the IGA about the UNFC Geothermal Specifications, especially in the Eastern Caribbean context.

Four representatives from the IGA and two from IRENA participated in the event. Twenty-nine local stakeholders took part in the training. Delegates came from Anguilla, Dominica, Grenada, Montserrat, St Lucia, St Vincent, St Kitts & Nevis, the OECS, the Organization of Caribbean Utility Regulators, and the University of the West Indies.

The workshop adopted a different format and delivery approach to that used in Indonesia. The attendees self-organized into five teams, each at their own table. Some grouped by island state, while other groups were dominated by 'financiers', project developers and academia. Each group brought a different perspective to the working sessions. Formal lectures followed, introducing the UNFC Geothermal Specifications, presenting international case studies, and then focusing on how to describe a Project. The lectures were followed by a presentation by the developer from Dominica, who described their project that had been drilled and was ready for power plant tendering. The Dominica project formed the basis for each team to work through its own classification process. The attendees first worked in their teams to compile a short description of the Project, and to report back to the whole workshop for discussion. Then, to progressively classify the Project according to E, F and G axes, a short lecture on each axis was followed by the teams working to classify the Project and report back to the whole workshop. An IGA / IRENA tutor was available to work with each team, allowing them to have their own discussions, but stimulating thinking where necessary. Results from different teams were compared and discussed.

Five geothermal projects were listed as candidates for classification. Projects on the islands of St Lucia, St Vincent and Dominica were ranked highest in terms of data availability, completeness of information and by delegates from the islands. Projects on the islands of St Kitts and Nevis were ranked fourth and fifth. The Dominica project was most advanced in terms of nearing power development. The team from Dominica (including the Dominica Geothermal Development Company) described the Project, which served as the first worked example at the workshop. Representatives from St Lucia and St Vincent also gave presentations on their geothermal exploration projects, and the five teams each progressively prepared a short description and classification of these. At the time of writing in mid-2019, a UNFC geothermal resource classification has been completed for the Dominica Geothermal Project.

2.3 Ethiopia

The IGA contacted the Geological Survey of Ethiopia (GSE) and the African Geothermal Center of Excellence (AGCE) to seek support for hosting the third UNFC Workshop in Addis Ababa, Ethiopia. GSE accepted being the regional host, with assistance from AGCE. Both entities expressed a wish for a one-day Roundtable event prior to the UNFC Training Workshop, in order to capitalize on the opportunity to showcase the potential for geothermal energy in Ethiopia to the Government of Ethiopia, IRENA, World Bank, other donors, and private developers. Invitations for both the Roundtable and Training Workshop were issued in January 2019.

The three-day program took place from 5th to 7th February at the Harmony Hotel (Day 1) and the office of the World Bank (Days 2 and 3) in Addis Ababa. The Director of the GSE gave the opening speech to the Roundtable, which brought together key regional experts and decision-makers to help initiate and advance regional cooperation for geothermal energy development. The Roundtable discussions focused on the status, opportunities, challenges and underlying risks of Ethiopian geothermal energy projects, with a view to identifying options for the risk mitigation and finance.

Five IGA representatives attended the event and conducted the training, along with two from IRENA and one from the ESMAP team. Approximately 65 participants registered for the Roundtable, and 21 participants for the Training Workshop. The two-day classification workshop followed the same format as in the East Caribbean. The Aluto Geothermal Project was selected as the first for UNFC classification, based on data availability, completeness of information, and the expertise of participants present. Private developer Hotspur presented its exploration project, the Fantale Geothermal Project, which served as a second worked example by the teams on Day 2. The classification for Aluto was completed in the months following the in-country event and, as of mid-2019, remains the only completed classification for Ethiopia.

3. RESULTS AND LESSONS LEARNED

3.1 Indonesia

Eighty-three (83) individuals registered for the Short Course on 22nd March 2018 (including the IGA/IRENA team), representing a overview of the major players in Indonesian geothermal sector. The IGA trainers were able to expose participants to the basic concepts of UNFC and observed a high level of interest and engagement by all. The full-day Workshop at Badan Geologi on 23rd March, however, had only ~30 attendees (including IGA trainers), of whom a high proportion had not attended the previous day's Short Course. Many of the Workshop group, therefore, had never been exposed to even the basic UNFC concepts. This disconnect between the training day and the hands-on Workshop could be attributed to a failure by the IGA to convey to Badan Geologi (responsible for invitations to the full-day Workshop) the importance of the previous day's training.

Unfortunately, little progress was made towards classifying any geothermal energy resources during the Workshop at Badan Geologi. The primary reason was because the 'geothermal resource' values associated with the geothermal areas were presented as single values in units of installed power capacity, which is inconsistent with the UNFC definition of a 'Geothermal Energy Resource' being the expected lifetime electrical energy to be produced by a 'Project.' Furthermore, the resource quantification methods by which sustainable power generation were estimated were opaque and the companies responsible for the developments were mostly unrepresented at the Workshop. Participants present at the Workshop had no knowledge of, or access to, project information critical to a UNFC classification, such as project lifetime, status of licenses and financial commitments, off-take agreements, and drilling plans.

A positive outcome from the Workshop was that INAGA (which was represented) facilitated contact after the Workshop between IGA and PLN, Indonesia's state-owned electricity company tasked with developing the majority of geothermal areas on Flores. PLN had not been represented at the Workshop, but has since provided a dedicated staff member who has become an engaged and determined proponent of UNFC. The program partners consider this to be a good result of capacity-building in the region.

Discussion about whether the Mataloko project was based on a 'known' or 'potential' Geothermal Energy Source resulted in useful exposure for the 'probability of discovery' (POD) concept, how it is applied, and some of the challenges in determining whether a Geothermal Source is 'known' (proven by drilling) or not. A shallow productive well had already been drilled in the Project area, but the defined Project relied on further drilling to develop a deeper, as yet unproven, reservoir. The consensus was that the deeper reservoir was not yet 'known' in the UNFC sense. This example will be applicable to many projects that have been drilled, but with inconclusive results.

Another positive outcome was the assembly of a team of nine voluntary ITB faculty and students to attempt UNFC classifications for several of the Flores geothermal project areas. This exercise, carried out in the months after the Workshop, exposed the students to the challenge of assembling all the necessary data and information to deliver informed classifications, and gave them valuable practical experience. Despite their enthusiasm and efforts, however, they were ultimately unable to deliver classification reports due to their lack of access to critical information held by the project developers.

Critically, the workshop stimulated considerable interest within Indonesia, and the Government of New Zealand's 'GEOINZ' program has continued to provide training through Jacobs to embed UNFC concepts within Badan Geologi and the Government of Indonesia regulator, Direktorat Jenderal Energi Baru Terbarukan dan Konservasi Energi (EBTKE). Through the GEOINZ program, Jacobs has run two further UNFC training workshops with Badan Geologi and coauthored a paper with EBTKE that was delivered at the Indonesia International Geothermal Convention & Exhibition in Jakarta in 2018 on how the UNFC can be applied in Indonesia (Ussher *et al*, 2018). UNFC concepts are slowly becoming a part of the continuing discussions regarding energy assessments and regional plans in Indonesia.

An important lesson from the Indonesian event was the critical role that development companies must play in the UNFC classification process. The company tasked with developing a geothermal project holds the critical information that informs the classification process. Once a geothermal area is assigned to a company to develop, it is almost essential that the company take ownership of the resource quantification and classification process. This was a very important lesson that helped shape the planning for the second and third regional events.

We also learned that organizing an effective UNFC training event requires early, clear and consistent communication between the UNFC event conveners (i.e. the IGA) and the local host (e.g. Badan Geologi). Early communication should focus on:

- A description of UNFC and how UNFC can benefit the region;
- The objectives of the Workshop;
- Who is required at the Workshop and what is expected of participants;
- Ensuring that Workshop participants can cover all aspects of a geothermal project and can share their knowledge, experience and data with all other participants;
- Minimum data requirements to conduct a UNFC classification exercise in the classroom.

3.2 East Caribbean

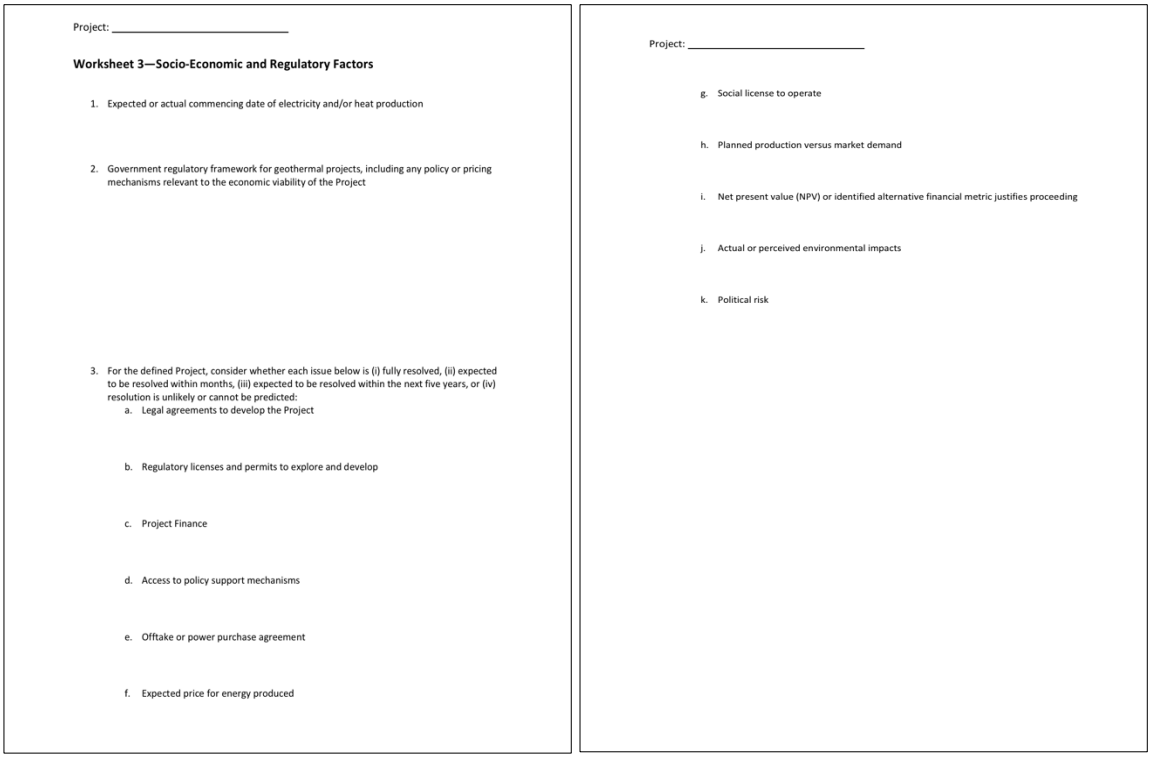
Participants in the Training Workshop were quick to grasp the process of applying UNFC to real geothermal projects. Having all geothermal stakeholders in the same room greatly facilitated discussions. Participants had come prepared and collectively brought a comprehensive understanding of all aspects of their own geothermal projects, which allowed the fine details of projects to be confidently explored. Discussions on the first day focused on E-axis and F-axis topics and resulted in identifying which 'E' and 'F' categories were most appropriate for classifying the Dominica Geothermal Project. Day 2 of the Training Workshop concentrated mainly on the G-axis, with the Dominica Geothermal Project again providing the main focus of discussions. Therefore, the Dominica Geothermal Project was effectively classified according to UNFC by the end of the Training Workshop, although a formal written document for the classification was only completed afterwards.

The modified workshop structure (relative to Indonesia), with teams seated together with a tutor and able to discuss, support and challenge each other while doing classifications, proved effective in terms of minimizing lecture time while maximizing attendee engagement and discussion. Interspersing short lectures with exercises throughout the day was also effective in maintaining engagement and ensuring that each element was reinforced with 'hands on' exercises. The format stimulated considerable discussion about the true status of Projects, and particularly the real limiting factors to development, usually related to elements on the E-axis. This discussion developed a more common understanding across all disciplines about the conditions needed for a geothermal project to proceed through to development and operation.

It was significant from a capacity building perspective that geothermal energy is relatively new to the Eastern Caribbean region. Delegates from all stages of the geothermal value chain were present in the classroom and for some of them, especially delegates from utility companies, many of the terms and definitions used by the geothermal sector were completely new. Initial discussions, therefore, focused on defining and clarifying terminology, both basic geothermal terminology as well as UNFC terminology. This took longer than expected, but was highly valued by the participants. A key learning from this is that the IGA should be clear and consistent with geothermal energy and UNFC definitions and terminology in all communications, not just in UNFC classrooms.

Participants expressed appreciation for the value of the UNFC classification exercise in providing a methodical framework to discuss the status of the regional geothermal projects. The event provided the first opportunity for many stakeholders to learn about all elements of the projects in detail.

Participants were, in general, disconcerted by the amount of material to read, understand and negotiate when dealing with the UNFC scheme. Worksheets developed by the IGA after the Indonesian UNFC workshop to provide off-line guidance and facilitate collection of relevant information (e.g. Figure 2) assisted the participants to work through the process to complete a UNFC classification in a methodical manner. The worksheets were seen as a valuable tool. The 'decision trees' presented in the UNFC Geothermal Specifications (ECE & IGA, 2016) to help with selecting appropriate categories from the 'E', 'F' and 'G' (e.g. Figure 3) were also seen as crucial by the Training Workshop participants. Participants suggested that the worksheets and decision trees could be offered in interactive digital form. Such applications could be used to analyze how decisions impact the UNFC classification, to save different versions of classifications, and to allow dynamic updates to classifications as more data become available or when there is a material change in the status of a project



Project: _____

Worksheet 3—Socio-Economic and Regulatory Factors

1. Expected or actual commencing date of electricity and/or heat production

2. Government regulatory framework for geothermal projects, including any policy or pricing mechanisms relevant to the economic viability of the Project

3. For the defined Project, consider whether each issue below is (i) fully resolved, (ii) expected to be resolved within months, (iii) expected to be resolved within the next five years, or (iv) resolution is unlikely or cannot be predicted:
   a. Legal agreements to develop the Project
   b. Regulatory licenses and permits to explore and develop
   c. Project Finance
   d. Access to policy support mechanisms
   e. Offtake or power purchase agreement
   f. Expected price for energy produced

Project: _____

g. Social license to operate

h. Planned production versus market demand

i. Net present value (NPV) or identified alternative financial metric justifies proceeding

j. Actual or perceived environmental impacts

k. Political risk

Figure 2. Example UNFC worksheet prepared by the IGA

Participants called for a single, easily digestible document, preferably in digital format with clickable links, presenting all the key points for applying UNFC to geothermal energy projects. The document should explain the main purpose of the UNFC, define all terms pertaining to geothermal energy and UNFC, and present a case study to show what a UNFC classification looks like.

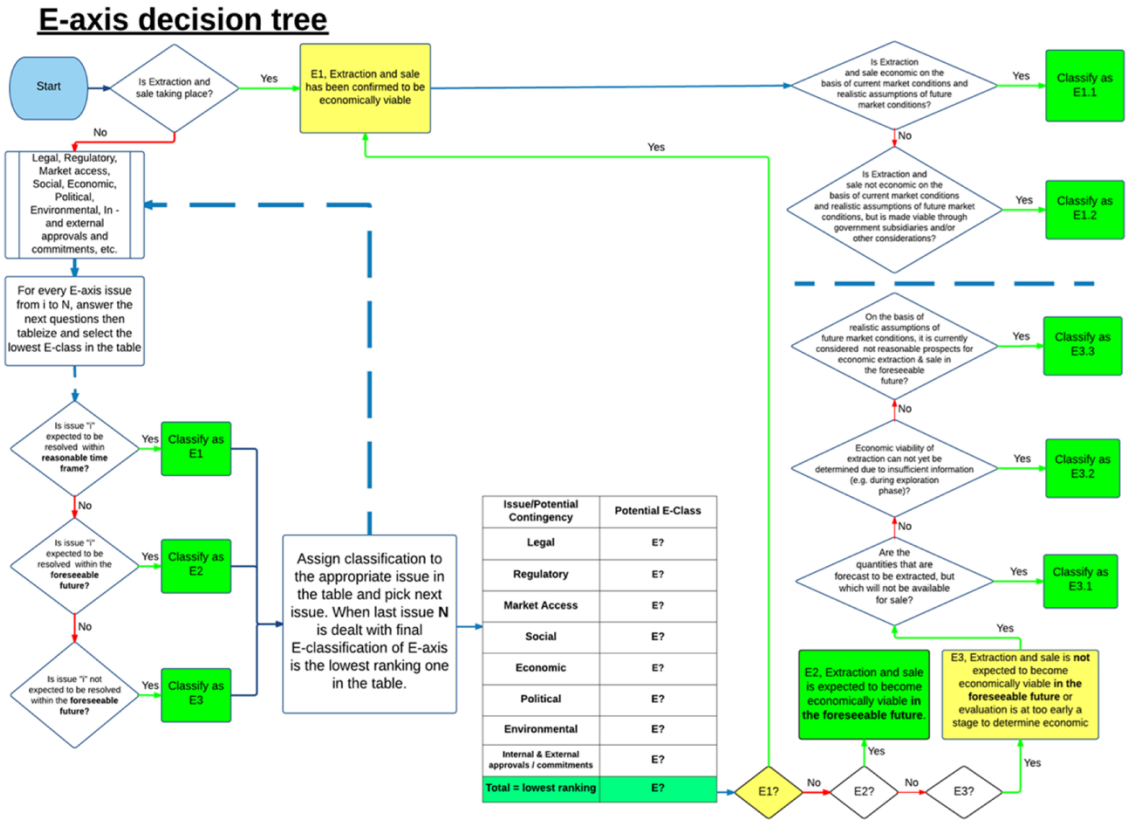


Figure 3. E-axis decision tree, as presented by ECE & IGA (2016)

3.3 Ethiopia

The Training Workshop in Ethiopia encountered many of the same issues as in the Eastern Caribbean. The first morning was predominantly spent on defining the terminology of geothermal energy and UNFC, because all elements of the geothermal value chain were represented in the classroom and for some participants, especially delegates from utility companies, many of the geothermal terms and definitions were new. The first afternoon was dedicated to a group exercise focused on Project definition and the E-axis. Training on the second day concentrated mainly on the 'F' and 'G' axes. On both days, the Aluto Geothermal Project was used as the main example. It quickly became apparent that the difference between 'prospect' and 'project' required further clarification. The event provided an excellent forum for constructive dialogue between the participants but, given that many of the participants had only superficial prior familiarity with geothermal energy and the UNFC, no classification was completed on-site.

To a large extent, the Ethiopian event reinforced the lessons learned in the Eastern Caribbean. They included a strong need for clarity and consistency on the definitions of terms used in the UNFC texts and more broadly in the geothermal energy sector. Of particular note was the UNFC definition of a Project; definition of 'Geothermal Energy Source' as opposed to 'Geothermal Energy Resource'; and the need to consider a wide range of matters affecting access to a market for energy sales.

The value of UNFC as a framework to guide discussions of the status of a geothermal project was received as most valuable as it was the first time for many stakeholders to jointly discuss the geothermal projects in Ethiopia. The training provided value in that it raised local awareness of the UNFC scheme, but did not immediately result in local capacity to carry out UNFC classifications unassisted.

As in the Eastern Caribbean, participants were overwhelmed by the number of documents and papers with which they were confronted. The feeling was magnified by the generally lower level of English proficiency relative to the Eastern Caribbean, which increased the challenge of comprehending the training material (all in English). Participants again expressed a desire for an easily digestible document explaining the main purpose of the UNFC, including a table listing all relevant definitions and terms, and presenting a case study of a UNFC classification.

4. CONCLUSIONS AND NEXT STEPS

Indonesia was the first country selected for the UNFC pilot program. Lessons learned in Indonesia were transferred to the next two workshops in the Eastern Caribbean and Ethiopia, where a new format was tested and further lessons were learned. Lessons learned in the East Caribbean were also transferred to Ethiopia. The learnings can be summarized as follows:

- All stakeholders displayed a high level of interest in UNFC and an appreciation that UNFC could provide a useful, global, harmonized classification framework for geothermal energy;
- Clear communication from the UNFC workshop organizers to the local host on the ground is necessary to implement a successful workshop on the ground;
- The IGA's local affiliated organizations (e.g. INAGA, the Ethiopian Geothermal Association, and the IGA East African Regional Branch) can play a vital role in connecting the IGA to UNFC stakeholders (the Eastern Caribbean region has no regional IGA affiliate);
- Collaboration with other assistance programs (such as the 'GEOINZ' program in Indonesia) has the potential to leverage this type of training and accelerate the implementation of the UNFC classification;
- Hardly any participant in any of the workshops had read the UNFC texts prior to the workshops. Reading the texts should be strongly encouraged as a prerequisite for future workshops;
- Existing additional UNECE guidance on project definition, evaluator qualifications, competent persons, and social & environmental considerations should be highlighted and made available to course participants;
- Follow-up work in the three regions is necessary to continue the exercise. There is an opportunity to train local representatives (nominated by affiliate organizations) to themselves become local UNFC trainers and technical advisors;
- The concepts presented in the UNFC framework are new to most people and require much more than a day or two of training to fully understand. We consider that a minimum of five days of face-to-face training is needed for participants to exit with the confidence to independently prepare their own classification reports;
- The UNFC concepts of a 'Project', 'Project Lifetime', 'Geothermal Energy Source' and 'Geothermal Energy Resource' must be clearly explained and consistently reinforced because they form the foundation of the Resource quantities being classified. This should draw on additional guidance already offered by the UNECE on the definition of a 'Project';
- Remote communication of complex concepts across distance, time zones, cultures and languages is extremely challenging, but providing clear and timely advice to local 'champions' who take ownership of implementing UNFC is the key to developing momentum for the adoption of UNFC in a region;
- It is very important to identify, educate and engage with appropriate 'Evaluators' right from the start of the classification process. Evaluators are usually from development companies, but could be government employees for classifying geothermal areas prior to development rights being granted to companies;
- The Geothermal Energy Resource must be quantified in a way that is consistent with UNFC classification. If a development company knows its project intimately, then it is not a major job for someone understanding UNFC to guide an Evaluator from that company to estimate the Geothermal Energy Resource to be produced over project lifetime and to classify the Resource according to UNFC;
- Preparation of a real project classification report would take a competent team at least two weeks to gathering data and models, QC the data and models, perform the resource estimate and classification, writing the report, and have it signed off. Two weeks is a typical time frame for earth resource assessments in general, including oil & gas and mineral resources.

The IGA recognizes the need to produce an easily digestible digital document explaining the main purpose of the UNFC, including a table listing all relevant definitions and terms, with due reference to existing UNECE documentation including the existing case studies. This is an important outcome from the three regional events and the IGA has formally commenced a process to write those guidelines.

The collaboration between IGA, ESMAP, IRENA and UNECE on this program has been seen by all partners as a success and a model for future collaborations in the geothermal energy sector.

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