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14 November 2018

Technical Project Manager (part time through until 30 June 2019)

Background:
The IGA is seeking a temporary, part time Technical Project Manager (or team) to assist the IGA to meet its responsibilities with respect to a joint IGA-ESMAP-IRENA pilot program to trial the application of UNFC Geothermal Specifications through Workshops in several regions around the world. This is a desk-top communication and data collation task. No travel is anticipated. The Technical Project Manager will liaise directly with local partners to assemble, collate and present supporting data, and help prepare subsequent reports to enable the Deliverables:

- Report summarizing activities, participants and outcomes after each Workshop;
- Summaries of geothermal resources in each region as classified under the UNFC, with supporting data for dissemination via IRENA's renewable energy atlas;
- A final report for ESMAP summarizing the key lessons learned from the pilot program.

Task description:
Specific tasks to achieve these goals include:

- Provide technical advice and feedback to local partners to gather and provide relevant geothermal project data for their region;
- Assess assembled data for completeness against the UNFC Resource Report Checklist (attached);
- Ideally assemble the data for each geothermal project into a concise package for consideration and classification during in-country Workshops;
- Provide regular (at least weekly) updates to the Chairman of the IGA R&RC.

Required skills and experience:
- Broad understanding of, and experience with, UNFC in general and UNFC Geothermal Specifications in particular;
- Good understanding of the terminology and concepts in the UNFC texts;
- Good interpersonal skills;
- Excellent written and verbal communication skills in English;
- Flexible work times;
- Rapid communication response times.

Time frame:
The estimated time commitment is 5 hours per week, beginning immediately. The actual time commitment will depend partly on the ability of the TPM to clearly communicate the

requirements to local partners, but also on the number of projects to be considered in each region, and the degree of cooperation provided by the local partners and project custodians. Most of the work will be required prior and shortly after the regional Workshops. Details are yet to be confirmed, but indicative locations and dates are:

- St Lucia (Eastern Caribbean), 5-7 December 2018;
- Addis Ababa (Ethiopia), date TBC in early 2019;
- A Central American location, date TBC in 2019.

Reporting:
The TPM will report directly to the Chairman of the IGA Resources and Reserves Committee

Remittance:
Remittance will be capped at US$5,000 per regional event, up to a maximum of three events. This amount will be payable in arrears upon receipt by IGA of funds from ESMAP after successful completion of each regional event and report.

Expressions of Interest:
Please express your interest in this position by submitting a CV directly to Marit Brommer, Executive Director of the International Geothermal Association, at iga@lovegeothermal.org before close of business in Bonn (Germany) on Friday 23rd November 2018.

Note that Officers, Directors and Committee Chairs of the International Geothermal Association or the IGA Service Company are ineligible to apply.

14 November 2018

Structure and checklist for information to support UNFC Geothermal Energy Resources classification

This document suggests a structure to summarize key information in preparation for Geothermal Energy Resources classification according to the UNFC. Adoption of this structure is not mandatory, but it provides a logical framework for gathering and presenting relevant information. The structure covers the topics and information requested in the UNFC Generic Specifications, UNFC Renewables Specifications, and the UNFC Geothermal Specifications. Individuals collating the information requested in this document are encouraged to familiarize themselves with these three UNFC documents, which can be downloaded individually from:
https://www.unece.org/energywelcome/areas-of-work/unfc-and-resource-management/unfc-documents.html

This document does not deal with the classification process itself, but only with collecting and presenting supporting information prior to classification. Where helpful, the document includes direct quotes from the UNFC family of documents. These are identified by *"italics and quotation marks inside green boxes"*. Other explanatory notes are provided as plain text in yellow boxes.

UNFC is a three-dimensional system for classifying the predicted production from a defined energy Project. The classification must consider technical, socio-economic and regulatory conditions affecting the Project, and the level of confidence in the recoverable resource estimate. A named Evaluator is to be responsible and accountable for the resulting report. Under the UNFC umbrella, the UNFC Geothermal Specifications provide a harmonized global framework for classifying estimates of **Geothermal Energy Resources**, defined as:

> *"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 Reference Point."*
>
> Geothermal Energy Products include heat and/or electricity measured in energy units.

The sections below are presented as numbered **HEADINGS** followed by dot-points listing the information required under each heading. The dot-points are not headings, but rather a checklist of items that should be covered. In all cases, *every item should be addressed with sufficient detail as justified by the stage of development of the Project*. A total of two or three paragraphs might suffice for each numbered section for very early stage exploration projects, whereas each numbered section might run to several pages for more advanced projects. The requested information can be presented as text, tables or figures as appropriate, but should be embedded into a single document.

UNFC does not require disclosure of confidential or commercially sensitive information, but the Evaluator must have unfettered access to that information to make an informed classification. There are different ways that a report can address all items on the checklist without disclosing sensitive information. Two possibilities are:

(a) Indicate that the Evaluator has considered the details and implications of each sensitive item. For example, the report could address the item, *"Net present value (NPV) or identified alternative financial metric justifies proceeding"* without disclosing financial model details by stating, *"Cash flow models with reasonable assumptions indicate positive NPV over the life of the Project."*

(b) Produce a report for a stated Evaluation Date in the past. UNFC does not require the Evaluation Date be the present day, only that the date be disclosed. For example, a report could present public domain data available on the date an exploration licence was granted. Note, however, that a back-dated report might not satisfy regulators or potential investors.

1. THE PROJECT(S)

A UNFC classification begins by defining a **Project**. A Project can be thought of as an engineering program to extract heat from a 'Geothermal Energy Source' (synonymous with 'geothermal reservoir') and use it to produce quantities of 'Geothermal Energy Product' (electricity and/or heat for sale) at a defined 'Reference Point' or points.

"Project includes all the systems and equipment connecting the Geothermal Energy Source to the Reference Point(s) where the final Geothermal Energy Products are sold, used, transferred or disposed of. The Project shall include all equipment and systems required for extraction and/or conversion of energy, including, for example, production and injection wells, ground or surface heat exchangers, connecting pipework, energy conversion systems, 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 significant detail."

Projects form the basis of financial decisions. If incremental or phased development of a geothermal site is proposed, where progress to each phase depends on the success of previous phases, each phase should be treated as a separate Project. For example, 2 x 10 MWe generators planned for a geothermal site under the same EPC, finance and licensing agreements might be treated as a single Project. However, 2 x 10 MWe generators to be constructed five years apart under independent EPC, finance and licensing agreements, especially if the second is contingent on the performance of the first, should be defined as two separate Projects.

- State the name, location (ideally with map) and owner/developer of the geothermal Project
- State the intended Geothermal Energy Product(s) (electricity and/or heat)
- State the intended audience for the report

The intended audience can influence the details of Project definition and Geothermal Energy Resource quantification. Possible audiences include central energy planning agencies interested in projections of potentially dispatchable energy, shareholders interested in predicted Project revenue, internal managers interested in allocating company resources, or others.

- State the purpose of the Project

The purpose of a Project influences the Project's size relative to the quantified potential of a geothermal reservoir. Stating the purpose of the Project, therefore, provides a clear and explicit link between the assessment of a Geothermal Energy Source, the choice of Project parameters, and the subsequent quantification of the Geothermal Energy Resource. Purposes could include, but are not limited to, "Provide incremental capacity to the grid to meet projected growth in base load demand over the Project Lifetime", "Generate the maximum power that the Geothermal Energy Source will support", "Replace an existing energy generator scheduled for decommissioning", "Provide 100% of projected heat demand, with surplus production sold as electricity."

- Describe the assumed characteristics of the Geothermal Energy Source (e.g. present a 'conceptual model' of the geothermal system)
- Mention any non-energy products (e.g. silica, lithium, manganese, zinc, sulphur, gases, water for sale) that will be extracted from the geothermal fluid as part of the same Project

Quantities of non-energy products are not classified in UNFC Geothermal Energy Resource Reports, but they should be mentioned if they affect the economics of the Project.

- State the Reference Point(s) at which the electricity and/or heat is quantified

"The Reference Point is a defined location in the production chain where the quantities of Geothermal Energy Product are measured or assessed. The Reference Point is typically the point of sale to third parties or where custody is transferred to the entity's downstream operations. Sales or production of Geothermal Energy Products are normally measured and reported in terms of estimates of remaining quantities crossing this point from the Effective Date of the evaluation."

There may be different Reference Points for each product.

- Describe any significant mass or energy fluxes, apart from the main geothermal fluid and energy flux, that will affect the overall energy conversion process

"Depending upon the specific Project, it could be necessary to report other additional quantities affecting the overall energy conversion process. For instance, in Ground Sourced Heat Pumps, both heat transfer at the evaporator/condenser section and driven energy at the compressor unit should be declared. Other examples concern those systems in which the geothermal apparatus works together with other energy sources (i.e. back-up technologies) or thermal cascading systems. In all these cases, additional points of evaluation may be necessary to provide a clear description of project operation. In general, any reported energy quantity shall be disclosed together with a clear description/definition of the corresponding point of evaluation."

- State the actual and/or planned/estimated number of production and injection wells
- State the assumed or predicted future production temperature, pressure and/or enthalpy at the well head(s)
- Describe the actual and/or planned energy conversion/utilization plant (e.g. type of power plant, nameplate capacity, layout and characteristics of the direct heating system, Ground Sourced Heat Pump technology etc)
- Define and justify the Project Lifetime

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

"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 from the Project would be negative. For a geothermal 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 extraction infrastructure such as additional wells."

"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."

"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 reasonable expectation of such extensions, based upon historical treatment of similar contracts."

"The 'entitlement period' is the term of all licenses 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 license extensions unless there is reasonable expectation of obtaining such extensions, based upon historical treatment of similar licenses issued by the issuing authority."

2. SOCIO-ECONOMIC AND REGULATORY FACTORS

- State whether electricity and/or heat production has already commenced and when
- Describe the government regulatory framework for geothermal projects, including any policy or pricing mechanisms relevant to the economic viability of the Project
- Explicitly consider each of the following factors. Disclose any outstanding issues and state whether they are likely to be resolved quickly, resolved within the next five years, or might never be resolved:

Information on the following factors could be presented under explicit subheadings

  - Legal agreements to develop the Project
  - Regulatory licenses and permits to explore and develop
  - Financing
  - Access to policy support mechanisms
  - Offtake or power purchase agreement, expected price for energy produced
  - Social license to operate
  - Planned production versus market demand
  - Net present value (NPV) or identified alternative financial metric justifies proceeding
  - Actual or perceived environmental impacts
  - Political risk

Political risk is "the risk of a strategic, financial, or personnel loss for a firm because of such nonmarket factors as macroeconomic and social policies (fiscal, monetary, trade, investment, industrial, income, labour, and developmental), or events related to political instability (terrorism, riots, coups, civil war, and insurrection)" Kennedy, C (1988). "Political Risk Management: A Portfolio Planning Model". Business Horizons, 31, 21, quoted in Wikipedia.

3. TECHNICAL STAGE OF DEVELOPMENT

- Provide a succinct history of the technical work program or field development plan up to the Evaluation Date, particularly addressing the stage of pre-drill exploration (regional studies only; geology / geophysics / geochemistry (3G) activities in progress; 3G activities competed?)
- Clearly state whether one or more wells have been drilled into the Geothermal Energy Source and, if so, whether production tests have demonstrated commercially recoverable energy.

"'Recoverable' implies that the depth and the thermal, permeability and fluid properties of the Geothermal Energy Source have been shown, or are expected, to be suitable for recovering heat at rates which have a reasonable chance of being sufficient to support a commercial project.

This is a key factor for classification of the Geothermal Energy Resource on the G-Axis. Disclose whether one or more exploration wells have penetrated the predicted geothermal reservoir. 'Dry,' 'unsuccessful' or 'inconclusive' well test results *do not* demonstrate commercially recoverable energy but should nevertheless be disclosed.

- State whether the Project will use extraction and power conversion technology that has been successfully demonstrated for analogous Projects elsewhere in the country and/or worldwide. If not, describe the proposed technology and identify components for which this Project will act as a pilot demonstration for this kind of Geothermal Energy Source (e.g. deeper, hotter/colder, more aggressive fluids, higher flow rates than previously demonstrated).
- Disclose any known, anticipated or possible technical issues that might delay or significantly impact the proposed technical development of the Project (e.g. acidity, high NCG content, scaling)
- If no plant is yet operating, describe the remaining technical steps until energy production will commence

4. RESOURCE ASSESSMENT AND CONFIDENCE LEVEL

- State the Evaluation Date

This will typically be the month and year in which the relevant data are compiled

- State whether the Geothermal Energy Source is 'Known' or 'Potential', consistent with information presented in Section 3

"A Known Geothermal Energy Source is one where one or more wells have established through testing, sampling and/or logging the existence of a significant quantity of potentially recoverable heat. In this context, 'significant' implies that there is evidence of a sufficient quantity of recoverable heat to justify estimation of the Geothermal Energy Resources demonstrated by the well(s) and for evaluating the potential for economic development."

"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. drilling and - in some cases - well testing, sampling and/or logging), but is assessed as potentially existing based primarily on evidence from geophysical measurements, geochemical sampling and other surface or airborne measurements or methods."

  - If the Geothermal Energy Source is 'Known', describe its thermal, permeability and fluid properties and the results of recoverability tests
  - If the Geothermal Energy Source is 'Potential', discuss, quantify and state the 'Probability of Discovery', which is the chance that further exploration, drilling and well testing will confirm a Known Geothermal Energy Source.

"This probability is the chance that further exploration, drilling and well testing 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 energy extraction planned."

Probability of Discovery (PoD) is a percentage between 0 % and 100 %. It is usually estimated subjectively as the product of the perceived chance that exploration drilling will discover a geothermal reservoir with sufficient temperature (A %), permeability (B %) and chemical properties (C %) for commercial development: PoD = A x B x C.

- Describe the method, assumptions and results for estimating the energy recoverable from the Geothermal Energy Source.

Common tools include the volumetric (stored heat) method, dynamic reservoir models and power density, based on discrete scenarios or probabilistic (Monte Carlo) modeling constrained by geophysical measurements, geochemical sampling and other surface or airborne measurements or methods. Assumptions might include physical limits, recharge rate, cut-off parameters, reservoir properties, power density etc. Ideally a range of possible solutions should be considered.

"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."

"Where applicable, conversion factors (e.g., if quantities are converted from thermal energy to electricity) shall be disclosed."

- Describe future production profiles and estimates of cumulative quantities of Geothermal Energy Product predicted to be produced by the defined heat/electricity Project over the Project Lifetime.

"When estimating Geothermal Energy Resources associated with a Project, future production scenarios are assumed (either explicitly or implicitly). Such scenarios 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."

"Assumed future production scenarios are generally based on estimated future annual energy production rates. These should include the seasonal swing in energy production and load hours. Taking into account the expected (seasonal) variability of future production within a given year, it is possible to report the cumulative energy produced in the subsequent reported years."

"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 a resource report prepared which discusses and explains the likelihood of restarting production."

Sum the expected variable production over each future year and report the cumulative energy to be produced over the remaining Project Lifetime. A range of production profiles with different likelihoods should be considered to produce 'low', 'best' and 'high' estimates of cumulative production. Quantities predicted for 'Potential'

Geothermal Energy Sources are 'un-risked'. That is, they are the expected quantities for the Project once the Geothermal Energy Source is 'Known', regardless of the 'Probability of Discovery'.

Uncertainties in future production profiles due to demand-side factors such as the impact on predicted network load factor of independent future production elsewhere on the grid should be disclosed. If such uncertainties are relevant to the intended audience of the report, then the uncertainties should also be factored into the quantification of the Geothermal Energy Resource.

- Declare which of 'incremental', 'scenario' or 'probabilistic' approach was used to produce 'low', 'best' and 'high' estimates of cumulative future production

"There are three established approaches to determining appropriate estimates."

"The 'incremental' approach, which is based on estimates for discrete portions of the Renewable Energy Source and/or the Project, where each estimate is assigned on the basis of its level of confidence (high, moderate and low) reflecting available knowledge regarding potential recoverability."

"The 'scenario' approach, which is based on three discrete scenarios that are designed to reflect the range of uncertainty in the possible outcomes (low, best and high estimates) of the Project extracting energy from the Renewable Energy Source as a whole."

"The 'probabilistic' approach, where multiple possible scenarios are generated (e.g. by Monte Carlo analysis) from input distributions of parameter uncertainty associated with the Project extracting energy from the Renewable Energy Source as a whole. Three specific outcomes are then selected from the output probability distribution as representative of the range of uncertainty (P90, P50 and P10 values are equated to low, best and high estimates respectively, where P90 means there is 90% probability of exceeding that quantity)."

In practice, most geothermal energy projects are assessed using either the scenario or probabilistic approach. Projects at the earliest stages of assessment, when optimal plant capacity is yet to be determined, usually rely on a probabilistic approach. A scenario approach is more appropriate for more mature Projects defined in terms of a single plant capacity.

- Disclose any possible future energy production risks beyond those that have already been disclosed in earlier sections
- Comment on the technical and economic feasibility of the future recovery of 'additional heat in place' beyond the energy predicted to be produced by the Project during its lifetime.

5. EVALUATOR

- State the name, qualifications, experience, governance, and affiliation of the Evaluator

"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 under evaluation. Relevant national, 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."

"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 of the entity preparing the report, and, if not, name the Evaluator's employer."

"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."

- State the Evaluator's relationship to the Project owner
- State how the Evaluator meets any additional requirements (if any) that might be imposed by local regulatory authorities