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# Geothermal industry statistics: a revised model for data collection and reporting

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## ABSTRACT

Geothermal statistics are subject to fragmentation and inconsistencies between different energy entities due to varied data collection and reporting methods. Such incomplete and inaccurate data contribute to an imprecise reflection of geothermal industry. One of the key industry reporting organizations – the International Geothermal Association (IGA) – compiles data that are further used in most of the global energy reports. The data collection and reporting methods employed by the IGA were last updated in the year 2000 and no longer reflect current industry trends and usage. To ensure good data quality and cohesive information globally the International Geothermal Association revised its framework for data reporting for both the power and heating and cooling. The new data model is the result of two expert groups active from January to November 2021. This paper briefly describes the approach used and introduces new standard for collecting and reporting geothermal statistics. The approach is based on a three-level pyramid model that describes the *W's* of geothermal utilization: the "what", the "who" and the "how". It serves the goal of specifying the process of data collection, unifying industry nomenclature, and making the data reporting more systematic, transparent, and consistent.

## 1. INTRODUCTION

Geothermal statistics suffer from fragmented data and inconsistencies between various data collecting entities (Ketilsson *et al*., 2015a; Booshehri *et al*., 2021). The study of Krieger, Kurek and Brommer (2022) shows that various methods of data collection lead to discrepancies in reported values or even their misrepresentation. Comprehensive research by Ketilsson, Sigurðsson and Bragadottir (2015b) also indicates that data gathered by renewable organizations are often unreliable. Both studies argue the differences between data as reported by energy entities are beyond acceptable levels to reflect real market trends: in some cases, the values reported by these entities for one country differentiate by as much as 500% (Krieger, Kurek and Brommer, 2022). These discrepancies usually arise from inconsistent data sources, opaque data collection methods, and varying data reporting systems.

To better support the development of the geothermal industry, data standardization is a priority (Kurek, 2023). The existing discrepancies have influence over global energy reports, where geothermal energy tends to be underrepresented, highly irregular, and at times even conflicting. Data also effects the decisions by policy makers, as they do not get a clear and transparent overview of the geothermal energy market. This in turns hampers political and economical support for the sector.

This paper addresses the issue of data quality in geothermal industry by introducing a new approach for data revision, which results in a coherent model for data collection and reporting as implemented by the International Geothermal Association (IGA). The IGA data serves as a key reference to many international organizations (Hervey *et al*., 2014). This is because among other energy entities the IGA provides the largest dataset in terms of countries covered – 91 in total. The organization also consecutively and comprehensively reports on heating and cooling sector, which is the most disputed in terms of data reporting. In addition, the International Geothermal Association is the leading world authority on the geothermal industry and many renewable energy organizations and scientific institutions reference its data. The IGA provides a continuous dataset since 1980s. However, its data collection and reporting methods were established in the late 1990s and updated only once in 2000. Due to the emergence of new technologies and applied uses of geothermal resources, the system demanded a revision. This revision is also prompted by the need for targeted geothermal policymaking, which is impractical to achieve without reliable data (Fan and Nam, 2018; Kabeyi, 2019; Liu *et al*., 2021).

This paper is divided into three parts. First, we describe the existing approach used by the International Geothermal Association, outlining the process of data collection for World Geothermal Congress (WGC) World and Country Updates. Second, the process of data revision is discussed. This involved extensive work of geothermal industry experts within independent groups under the IGA umbrella. Lastly, a new approach using the three-tiered *pyramid model* is introduced. The results are a new data system with updated categories, quality standards, and a process for data collection. The key expert recommendations for future data systems are also included. The last section captures key outcomes and results obtained outlining a way forward for the clear, consistent, and comprehensive geothermal data framework.

## 2. INTERANTIONAL GEOTHERMAL ASSOCIATION DATA COLLECTION

In practical terms, the "IGA dataset" is composed of the data reported in the WGC Country Updates by the designated country experts. Since 1985, the IGA has collected geothermal Country Updates through authors' contributions, however the first completed WGC proceedings are available from 1995 onwards.

Currently, Country Updates are submitted every three years (before 2020, every five years) and are compiled into the online Geothermal Paper Database (International Geothermal Association, 2023). Usually, the templates for Country Updates are sent to representatives in different countries reporting to the IGA. These templates consist of eight tables, which include:

- Table 1 "Present and planned production of electricity" (*power data*)
- Table 2 "Utilization of geothermal energy for electric power generation" (*power data*)
- Table 3 "Utilization of geothermal energy for direct heat excluding heat pumps" (*heating and cooling data*)
- Table 4 "Geothermal ground-source heat pumps" (*heating and cooling data*)
- Table 5 "Summary table of geothermal direct heat uses" (*heating and cooling data*)
- Table 6 "Wells drilled for electrical, direct and combined use of geothermal resources" (*operational data*)
- Table 7 "Allocation of professional personnel to geothermal activities" (*other data*)
- Table 8 "Total investments in geothermal" (*other data*)

In 2000, revisions were made to calculations of installed power and energy used.

The data in the subsets available within one Country Update might occasionally contradict each other. For example, the data on greenhouse utilization in WGC2020+1 Country Update for China, Georgia, and Slovenia is reported differently in Table 3 and Table 5. The values diverge to the degree that they imply differing growth trends: in one subset, data shows growth in the sector while in the other, decline. Also, the values from one report to another may not always be comparable with each other due to rotation of country authors and as a result their reporting methods. Indeed, most of the Country Updates have different authors, so that consecutive data reporting is not always preserved. When analyzed for consistency in terms of continuity of authorship from 2000-2020 only 50% of all Country Updates are consistent, i.e., there are more than three reports in a row submitted by the same author or a group of authors. Some examples of the most consistent authorship include Bulgaria, Chile, Ecuador, Greece, India, Mexico, Nepal, Poland, Portugal, Slovakia, and the USA. Although there is no obligation to manage the Country Updates by the same person, geothermal industry could benefit from the the consistent and continuous authorship.

Since the year 1995 the number of countries reporting their data via Country Updates have gradually increased: 47 in 1995, 61 in 2000, 68 in 2005, 68 in 2010, 75 in 2015 and 85 in 2020. The data from these Country Updates are extracted to build two combined World Updates – one for power and one for heating and cooling. However, the data between them do not always coincide, i.e., not all Country Updates are used for the World Updates. Usually, about 85% of data in World Updates come from Country Updates. Additional data are often acquired via personal communication, but the exact sources are rarely disclosed. In some instances in the case of missing data, previous Country Updates are taken as a reference. Occasionally, countries included in one World Update are not included in the next. Additionally, final installed capacity values might differ between the Country and World Updates. Some examples include China, France, Iceland, Mongolia, and Slovenia (for heating and cooling data). Although the discrepancy is within 1-5 MWt range, this contributes to a lack of consistency between the datasets within one organization.

As we can see, the existing data collection methods employed by the IGA are in need of revision to address inconsistencies and discrepancies in reporting. The importance is amplified by the fact that World Updates are extensively used as a key reference by other global energy organizations. This creates a snowball effect, where poor quality national geothermal data is transferred further to the global energy reports.

## 3. IGA DATA EXPERT WORK

To address these issues, two expert groups were formed in 2021 as external IGA advisory – one for power and one for heating and cooling data set. During their work data collection, reporting, and the methodology of the International Geothermal Association was revised. The groups also provided recommendations on data standards for the IGA.

The work started in January 2021 with concept building, data curation and expert outreach. Working groups were set up in March 2021 and their work was finalized in November 2021. The revisions included updates on energy definitions, categories, direct use classification, calculations, sources, and methods for data collection and reporting on geothermal energy statistics. The final outcomes were published on the IGA website in February 2022 (International Geothermal Association, 2022).

The work from both groups was led by the IGA Education and Information Committee with Adele Manzella as the chairperson and Margaret Krieger as a coordinator and data analyst. The international experts contributing to power group included: Jem Austria (Energy Development Corporation, Philippines), Greg Bignall (G&A Geothermal Advice Limited, New Zealand), Guido Cappetti (Enel Green Power, Italy), Füsun Tut Haklıdır (Istanbul Bilgi University, Türkiye), William Harvey (Reykjavik University, Iceland), Eylem Kaya (University of Auckland, New Zealand), Alexander Richter (Iceland Renewable Energy Cluster, Iceland). The expert for heating and cooling group included Mar Alcazar (RIGS: Red Iberoamericana de Geotermia Somera, Argentina), Paolo Conti (University of Pisa, Italy), Thomas Garabetian (EGEC, Belgium), Maria Guðmundsdóttir (Orkustofnun, Iceland), Marek Haito (Polish Geothermal Society, Poland), Martin van der Hout (Strategic Consultant to the IGA, the Netherlands), Katarzyna A. Kurek (Wageningen University and Research, The Netherlands), Wietze Lise (Principal Consultant at MRC Turkey, Türkiye), Jim Lovekin (GeothermEX, USA), Angela Prieto (Sigma Prima Geoengineering, Columbia) and heating and cooling liaison Arlene Anderson on behalf of the U.S. Department of Energy, Systems Analysis & Low-Temperature Geothermal Program.

## 4. IGA DATA MODEL

To approach the revision of data systematically and consistently, a revision model, named a pyramid model, was created. It was inspired by *Simple Rules* strategy for decision-making and problem solving (Sull and Eisenhardt, 2015). When this pyramid model was built, the following guidelines were taking into account: 1) data revision process should be simple and limited to a certain number of values (or data categories); 2) the model should reflect the needs of the industry; 3) it should be applicable and easy to work with; and 4) it should be flexible enough to allow for new technologies and innovations. Additionally, a few principles were embedded into the model and the process of data revision:

- Timing: each group met once a month at the same time for one hour.
- Coordination: the expert activities were coordinated with rules and objectives explained and established at the beginning of every meeting.
- Priority: a minimum goal of one revised data category was set for every meeting.
- Stopping: when the discussion stalled, and no positive outcome was achieved within 10 min it was interrupted by the coordinator. In such instances, the group was asked to either delay a decision until the next meeting or come to an agreement by voting by absolute majority.

Expert groups followed this systematic approach for the evaluation of data collection methods employed by the IGA. Such approach and principles ensure that the data revision process remains simple and flexible.

The data revision itself consisted of three parts (where each represents the pyramid level): the revision of data categories (the “what” of data), the discussion about data sources (the “who” of data), and the brainstorming session about the process of data collection and data standards (the “how” of data). In this pyramid, one layer builds on the next one complimenting the understanding of the data structure and the process for its collection and reporting. The description of each level and the outcome of experts’ revision follow below.

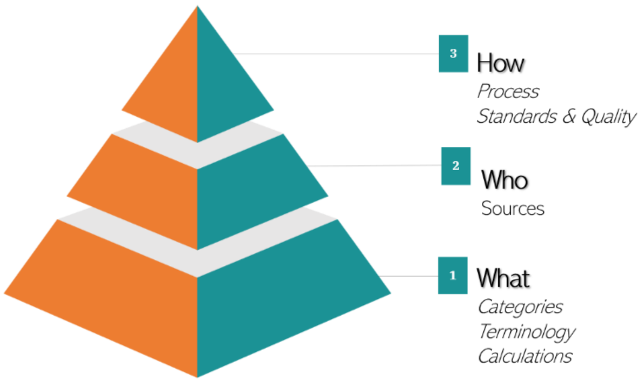


**Figure 1: Three-layered pyramid model.**

### 4.1. What

Data categories, or the “what” of the model, is the first fundamental layer of the pyramid. At this stage the revision of existing data categories, terminology, and calculations are carried out. For **power dataset** the categories were revised and grouped into three parts, *geothermal field*, *plant* and *unit* statistics. For example, the categories collected for the *geothermal field* include its location, field name and field operator, depth of a deepest production well, etc. Some new categories include the classification of geothermal systems into hot water, two-phase liquid dominated, and two-phase vapour dominated as per Kamila *et al.* (2021) and differentiation between reservoir engineering systems (hydrothermal, EGS, closed loop). *Geothermal plant* categories include plant name and operator, and a new data entry option that allows industry experts to indicate if the plant uses co-production or is a part of a CHP or a hybrid energy system. Finally, *geothermal unit* consists of generating unit name and its type, year commissioned, its status, turbine manufacture, installed capacity, and produced energy both gross and net.

For the **heating and cooling dataset**, the revision started with the discussion about the appropriate name for the sector as this has had some variation in previous reporting. The names, “heating and cooling”, “direct use”, “thermal” and “heat” have been used previously to describe geothermal heat production. The decision to choose heating and cooling as opposed to any other name was based on a few principles that were agreed upon within an expert group. These are: 1) inclusivity – the name to reflect both high and low enthalpy, shallow and deep resources; 2) comprehensiveness – the name to include geothermal heat pumps within its scope; and 3) clarity – the name to be understood by the larger (non-geothermal industry) audience. Much like the power dataset, the categories for heating and cooling are grouped together in three parts, *geothermal field, application,* and *technology*. *Geothermal field* includes data categories that address location and the type of a geothermal system, such as field name, type of geothermal system, number of wells drilled over the reporting period (with separate reporting for exclusively heating and cooling wells and for those using CHP), average depth of wells under operation, etc. *Geothermal application* reflects the type of geothermal heating and cooling use. The uses were majorly revised and now include only five application types: (I) agriculture and food processing, (II) industrial process heat, (III) health, recreation and tourism, (IV) heating and cooling for buildings, and (V) other uses. One significant change here included the removal of geothermal heat pumps (GHPs) from application types. Previously, the use of GHPs was reported as a stand-alone category for a type of application on par with greenhouse heating, bathing and swimming, etc. In a new classification GHPs are defined as a type of installation within *geothermal technology* dataset, which also includes heat exchanger, direct use of the fluid, district heating and cooling, combined power and heat, energy storage and other types of technologies used in heating and cooling energy production.

The complete list with revised categories can be found online on the IGA website (International Geothermal Association, 2022).

### 4.2. Who

Data sources, or "who" of the data model, is the second layer and involves identifying relevant geothermal data sources. It addresses important questions as "Who should contribute to the data collection?", "Who are the main data stakeholders?", "Are these individual experts, geological surveys, or government representatives?", etc. It serves to establish clear information sources that would promote a reliable and transparent data and make data reporting more transferable between data experts.

The key recommendation emerging from experts is that organizations like the IGA should strive to collect the data from the most reliable and relevant sources, such as official national agencies maintaining the database on capacity and energy production. If country experts are involved in the process of data collection (such as authors of Country Updates), they are required to use one of the following national sources (from the most to least preferable as assessed by the expert groups):

- Government statistical agencies
- Energy authorities
- Operators and owners of geothermal facilities
- Licencing organization
- Geological surveys
- Other data energy entities

Expert interviews with the current and past Country Update authors are recommended to collect and record the sources used for reporting. Geothermal National Associations are to be involved in this process and to play a coordination role and if necessary, to appoint their national data experts.

### 4.3. How

Data process, or the "how" of a data model is a final top layer of the pyramid, which ensures the appropriate quality of submitted data. It introduces data standards for its collection and reporting. "How do we ensure that data is transparent, reliable, and consistent?", "How often should the data be collected?" and "What are the procedures for data collection?" – are the questions addressed here.

First, digital geothermal data platform is to be established. It should be open and accessible at no cost, and hosted by the International Geothermal Association. The categories identified in the first layer should be embedded into the platform with logical connections between them. All data entries, submission, and retrieval should be performed digitally. Data sources should be transparent and clearly indicated in the database. The data should be submitted on a continuous yearly basis to assure the consistent and up-to-date access to information. To eliminate data gaps, the new emerging geothermal markets with no geothermal energy use so far should also be included. Trusted and independent peer reviewers should be appointed to ensure the data quality. These reviewers could rotate to ensure the better understanding of data standardization from various stakeholders.

A dedicated digital training session should be offered to industry experts who will be implementing and reporting with this new model. This would facilitate a better understand on how to locate and catalogue geothermal uses in their respective countries. Digital education materials should supplement the dissemination of information on importance of data quality, its consistency and transparency.

## 5. KEY OUTCOMES AND DISCUSSION

The revision of IGA model for collecting and reporting on geothermal data was completed in November 2021 and the outcomes were published on the IGA website in February 2022. This new model was envisioned to be used for the World Geothermal Congress 2023. The approach to and the results of data revision are also proposed for reference to other organizations. The revised data system is expected to support the process of harnessing, storing, and sharing coherent geothermal statistics. It represents a system of guidelines and addresses major questions in geothermal data reporting: what data to collect, who to ask for the data and how to collect it.

This revised model is a first step toward data systematization. As a next step it is advised to establish a digital, open, high-quality database of geothermal statistics. A prerequisite for its successful functioning is an extensive network of experts, who would be willing to contribute their time and skills to global data collection and curation. One of the reasons for inconsistent values are experts relying on their professional experience, which may differ country to country. To eliminate discrepancies, industry experts should rely on a unified approach for data collection and reporting. Training of industry experts who are involved in the data reporting is recommended. The training should explain new data collection methods, processes, and quality standard. If an expert can no longer contribute to the data collection, they should appoint a possible successor so to mitigate some risk of loosing the knowledge acquired. If possible, they should help train the new successor. Of course, testing this model and its reliability together with experts is an important part of this process. To achieve the best results, the industry network should be diverse in terms of gender and geography.

Overall, the data acquired this way should be as transparent and reliable as possible. A consistent data collection system mitigates the risk of under- or over-reporting and misrepresenting the geothermal industry nationally and globally. For industry organizations like the IGA, a systemized dataset serves as an advocacy tool to argue for better geothermal initiatives in both economic and political sectors and represent the true state-of-the-art in the geothermal industry and help public engagement.

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