A brief glossary of Polish and the UNFC-2009 classifications and nomenclature of geothermal resources assessment

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ABSTRACT

As widely known there is no standard international terminology in use throughout the geothermal community, which would facilitate mutual comprehension between estimated resources. The differences can be seen even when existing definitions of geothermal energy and geothermal resources are taken into consideration. These differences result mainly from on how the geothermal energy is meant, who is the ownership of geothermal resources, and what kind of legislation governs the aspects related with the use of geothermal resources.

Most of the concepts regards classification and assessment of geothermal resources, which assume geothermal as mineral, and refers to the classification and terminology derived from the mining industry, including mineral and fossil fuels (coal, petroleum etc.). Difficulties with interpretation of the results and comparison of geothermal resources assessment are growing when data from the Eastern Europe countries are considered.

The article will provide a guideline to understand the principles of geothermal resources classification, and methodology of its assessment, which are being use in Poland, in regards to the concepts of a new United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009.

Additionally the article highlights the possibility to adopt the principles of classification and methodology of geothermal resources assessment used in Poland to the classification rules of the UNFC-2009. The article is an attempt to begin a formal discussions, in order to meet the main objectives of UNFC-2009 and provides standardization of existing national system and criteria for evaluation of geothermal resources and reserves and to enable comparison of various existing classifications - according to uniform rules.

1. INTRODUCTION

Assuming that launching of geothermal power plant in Larderello, Tuscany-Italy (in 1911 year), can be recognized as the beginning of world's industrial use of geothermal energy it is obvious that for over 100 years none uniform standards of geothermal resources classification, assessment and reporting, which would facilitate mutual comprehension between estimated resources has been developed.

Lack of global standardisation can be caused even by different understanding of the principles, which regards e.g. definition of "geothermal energy" and "geothermal resources". An overview of legal and regulatory frameworks and law acts regards geothermal energy over the world and particularly in Europe indicates that they can vary in many respects between countries, and even within them (Haraldsson 2012).

The differences can be seen when existing definitions of geothermal energy and geothermal resources are to be taken into consideration. These differences result mainly from on how the geothermal energy is meant, who is the ownership of geothermal resources, and what kind of legislation governs the aspects related with the use of geothermal resources. From this point of view existing definitions can be classified into three categories (Haraldsson 2012):

- a part of mineral estate, handled by mineral legislation (usually geological/mining law);
- as water resources, handled by water or geological legislation;
- resources unique in themselves.

Most of the concepts regards classification and assessment of geothermal resources, which assumed geothermal as mineral, refers to the classification and terminology derived from the mining industry, including mineral and fossil fuels, coal and petroleum as well. These methods usually describe the quantity or volume of valuable materials in the earth, that can be excavated on the surface with intrinsic economic interest. Specificity of geothermal phenomena itself

imply that when terminology applies to mineral resources is used, several assumptions e.g.: extraction processes, recoverability, etc. (see Muffler & Cataldi, 1978) must be taken into consideration.

In such context the activity undertaken by joint effort of the Economic Commission for Europe (UNECE) and the Working Group of IGA experts are highly desirable.

Geothermal community expects that an uniform criteria of classification, assessment and reporting of geothermal resources and reserves, which consider market and economic conditions, would facilitate international communication and cooperation.

UNFC-2009 has been developed to meet, to the extent possible, the needs of applications pertaining to international energy and mineral studies, government resource management functions, corporate business processes and financial reporting standards (ECE 2013).

2. LEGAL ASPECTS OF THE UNFC-2009 IMPLEMENTATION IN POLAND

Due to significant strong market position of conventional sources of energy and other mineral resources sector in Poland, especially coal and hydrocarbons, the level of UNFC-2009 standards unification is much higher then e.g. geothermal.

As formally declared Poland in 2010 has confirmed its commitment to The United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (www.unece.org). According to aforementioned declaration the data presented in the 2010 edition of the publication entitled: "Mineral Resources of Poland" issued by The Polish Geological Institute-National Research Institute (PGI-NRI) and the Ministry of Environment, was prepared according to the UNFC-2009 standards. Together with the Polish Geological Institute-National Research Institute, and in cooperation with the Polish Ministry of the Environment (Department of Geology and Geological Concessions), UNECE co-organized a workshop in Warsaw, 21-22 June 2010 on "UNFC-2009 – Theory and Practice". The event was sponsored by KGHM Polish Copper S.A. and the Polish Oil & Gas Company, recognized as the largest players in the Polish mining mineral resources scene.

Moreover, so far there not any guidelines exist for use of the UNFC-2009 in the field of geothermal energy.

Application of UNFC-2009 by The Member States of The United Nations, international organizations and the regional commissions are recommended by the European Economic and Social Committee (ECOSOC) by decision taken on 42-nd meeting (decision 2004/233 of 16.07.2004).

3. THE MAIN CONCEPT OF THE UNFC-2009

The United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009) is a universally applicable scheme for classifying/evaluating energy and mineral reserves and resources - it is the successor to UNFC-2004. Designed as an all-encompassing framework, it enables the incorporation and unification of existing national systems, while allowing their classification units and glossary to be retained (ECE 2013).

Geothermal specifications were prepared by a dedicated Working Group led by Professor Gioia Falcone of Cranfield University, United Kingdom (formerly employed at Clausthal University of Technology, Germany). In order to present and illustrate the principles of classification and facilitate understanding of the rules adopted in the framework of UNFC-2009 uses 12 examples of applications of classification, based on geothermal projects located in: Australia, Germany, Hungary, Italy, The Netherlands, New Zealand, the Philippines and Russia (ECE 2013).

The United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009) differs from other systems as it classifies estimated resource quantities using three axes: socio-economic variability (E), project feasibility (F) and geological knowledge (G). The first set of categories (the E axis) designates the degree of favourability of social and economic conditions in establishing the commercial viability of the project, including consideration of market prices and relevant legal, regulatory, environmental and contractual conditions. The second set (the F axis) designates the maturity of studies and commitments necessary to implement mining plans or development projects. These extend from early exploration efforts before a deposit or accumulation has been confirmed to exist through to a project that is extracting and selling a commodity; they reflect standard value chain management principles. The third set of categories (the G axis) designates the level of confidence in the geological knowledge and potential recoverability of the quantities (ECE 2013). Additionally, the categories E, F, G, depending on the degree of recognition, can be divided into classes and sub-classes marked with appropriate symbols (e.g.: 3,4,1) (Falcone 2015a). Combinations of these criteria create a three-dimensional system as shown in Fig. 1.

Detailed information can be found in: Falcone (2015a, 2015b) (ECE 2013).

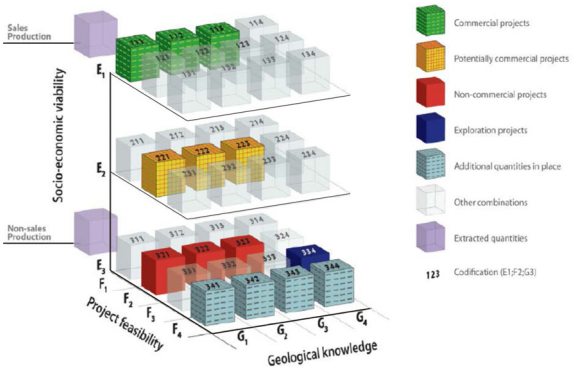

Figure 1: The United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (ECE 2013).

Specifications for the application of The United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC) to geothermal energy resources were released for public comment from 6-th of June, until 4-th of August 2016.

3. POLISH CLASSIFICATION OF GEOTHERMAL RESOURCES

The country is characterised by significant low-enthalpy geothermal potential, where space heating represents the most important type of direct uses (Górecki (ed.) and Hajto et al. 2006a, 2006b). Geothermal waters of diversified reservoir temperatures, from 20 to 80-90°C, in some cases even over 100°C occurs within the sedimentary-structural basins filled with Mesozoic sediments. The main geothermal aquifers of regional importance in Poland are connected with the Lower Cretaceous and Lower Jurassic sandstones, which extent occupy ca. 80% of the Polish territory. Geothermal resources are related directly to petrophysical and hydrogeological parameters of aquifer rocks, mainly with the: porosity, permeability and hydraulic conductivity what implies "volume" method of geothermal waters and energy resources and reserves calculation.

In Poland the legal regulations of classification and assessment methodology of geothermal waters and their accumulated energy have not been established, as yet. The EU experts used the classification based upon the McKelvey's diagram (1972), which refers to classifications and terminology derived from the mineral industry (Haenel and Staroste 2002). Classification, according to the McKelvey's diagram was modified in order to include traditional terminology and definitions applied in Poland. In regards to specific geological and hydrogeological conditions, mentioned above, volume "heat in place" method of geothermal resources was employed. The methodology is based on assumptions developed by (Nathenson and Muffler 1975, Gringarten and Sauty 1975, Muffler and Cataldi 1978) and strongly concerns both the economic and ecological aspects of geothermal energy assessment. The horizontal axis represents the accuracy of geological recognition, whereas the vertical one displays the depth of occurrence and the economic efficiency of geothermal energy use. Classification of geothermal resources being in use in Poland is shown on figure 2.

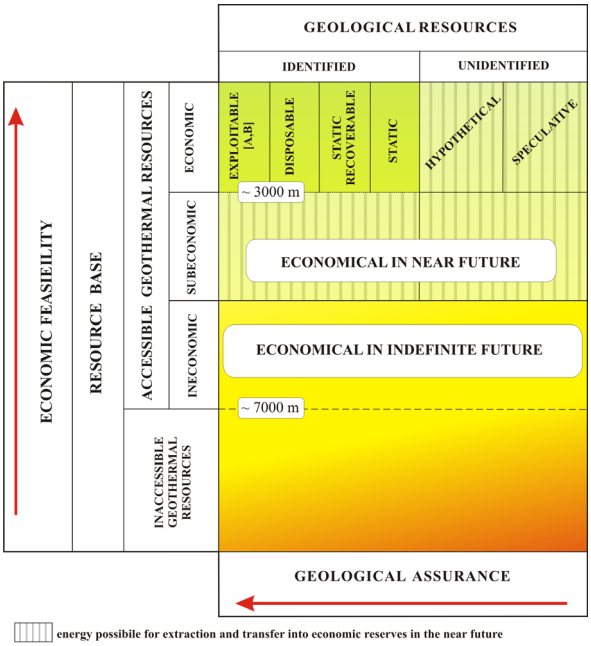

Figure 2: McKelvey diagram presenting classification of geothermal resources – modified in accordance to the Polish geothermal classification and nomenclature.

Additionally the method of calculation of hydrogeological parameters enables estimation of potential discharge from hypothetical wells. Calculations include technological aspects related to exploitation, among the other assumptions regarding exploitation system (single well, doublet). The methodology takes also into account the level of geological confidence (hydrogeological and thermal parameters) of the study area, which enables estimation of resources according to the classification as: accessible, static, static-recoverable, disposable and exploitable resources and reserves.

Developed computer-aided methodology of economic effectiveness evaluation by analysis of *the power factor* – Gosk (1982) enables preliminary assessment of geothermal energy utilization on a regional scale and indicates areas where geothermal waters exploitation may be profitable. The methodology allows to interpret data in the three-dimensional network which enables to conduct the geostatistical analysis and objectivisation the results of calculation.

A detailed description of the concept of economic evaluation of regional geothermal resources potential by analysis of the "power factor" was presented in several publications, including: Hajto (2011), Hajto and Gorecki (2010), Hajto and Górecki (2013) and others.

Method of regional geothermal resources estimation used in Poland allows to interpret the data as a 3D grid models, where a single grid node can be identified with a hypothetical installation (geothermal project),

indicated - due to the UNFC-2009 specifications, as key element of regional resources estimation concept. Total resources in respective class: accessible, static, static-recoverable, is aggregation of resources, calculated for a single block (a hypothetical project), with taking into account the calculation (balance) area (e.g. aquifer extent, an administrative units, e.g.: municipality boundaries, country's borders, etc.).

The method of disposable waters and energy resources estimation, whose definition is given in Table 1, takes into consideration that the number of installed geothermal doublets (~projects) per surface area of geothermal reservoir is limited due to technological (hydrogeological) working conditions of the doublet system, e.g.: interference radius of the wells. To simplify it can not be possible to run a number of geothermal doublets in a defined area. The use of specialized software allows to perform geostatistical analysis and objectify the calculation results.

In the concept of Polish classification, the reserves of geothermal waters and energy represent the highest category of geothermal resources, which are estimated in the way of detailed hydrogeological studies. The exploitable resources are assessed basing upon the results of all hydrogeothermal studies and tests made in exploration and production wells, and are determined for a single production well or for a cluster of wells.

Distribution of geothermal resources used in Poland together with definitions of the main classes and their reference to the UNFC-2009 classification are shown in Table 1.

Table 1: Polish classification of geothermal resources in relation to the resource categories of the UNFC-2009.

Classes of geothermal resources (Poland)	The UNFC-2009		
	E	**F**	**G**
exploitable geothermal waters and energy reserves (a) /proven reserves/	**1**	**1.2-1.3**	**1**
disposable geothermal waters and energy reserves (b) /economically feasible/	**3.1 (2)***	**2.1-2.2**	**1-3**
static-recoverable geothermal waters and energy resources (c) /technical potential/	**3.2-3.3**	**2.1-2.3**	**1-3**
static geothermal waters and energy resources (d) /potential resources/	**3.2-3.3**	**2.2-2.3**	**1-3**
accessible geothermal energy resources (e) /theoretical potential/	**3.2-3.3**	**3-4**	**3-4**

* *conditionally (with the full acceptance of regional method of disposable reserves calculation)*

Explanations to table 1.

(a) exploitable geothermal waters and energy reserves – amounts of free (gravitational) geothermal water, which can be produced at given geological and environmental settings with intakes of optimum technical and economic parameters, expressed in m^3/h, with relevant drawdown, recalculated into J/year or TOE/year. The exploitable resources are assessed basing upon the results of all hydrogeothermal studies and tests made in exploration and production wells, and are determined for a single production well or for a cluster of wells;

(b) disposable geothermal waters and energy reserves – the amounts of free (gravitational) geothermal water within the horizon or other calculation unit, which can be developed under given conditions but without detailed localization as well as technical and economic specification of an intake, expressed in m^3/h, J/year or TOE/year. Estimation of disposable reserves should be preceded by parametric/economic evaluation of given geothermal reservoir.. The disposable reserves constitute a part of assessed static-recoverable resources, which utilization would be economically effective;

(c) static-recoverable geothermal waters and energy resources – constitute a part of the static resources diminished by the recovery factor Ro, expressed in m^3 or km^3, recalculated into the energy units Joules. The static-recoverable geothermal waters and energy resources are a part of static resources of given groundwater reservoir or horizon, which can be produced with the given exploitation systems: one well, doublet, etc.;

(d) static resources of geothermal waters and energy – the amounts of free (gravitational) geothermal water hosted in pores, fractures or caverns of given hydro geothermal horizon, expressed in m^3 or km^3, recalculated into the energy units Joules. These resources are calculated if the recognition of continuous groundwater reservoirs or horizons is possible in the given area. Basing on determined properties of groundwater horizons: lithology, thickness, porosity and permeability, the identification of producing reservoirs and horizons, due to e.g. borehole geophysics measurements is possible;

(e) accessible geothermal energy resources – mean the amount of thermal energy accumulated in the Earth's crust down to certain depth (3 000 m) or to the top surface of crystalline basement, referred to the mean annual temperature of the Earth's surface and expressed in [J].

4. CONCLUSIONS

In Polish legislation, including Geological and Mining Law (Journal of Laws 2011 no. 163 item. 981, consolidated text: Journal of Laws 2015 no 0 item 196), no regulations applicable to classification of geothermal resources exist.

The concepts and definitions of: static, disposable and exploitable resources has been regulated, but they only apply to groundwater resources, not to geothermal energy accumulated in these waters. An official reports, aiming summary on resources and reserves of mineral deposits in Poland, issued periodically by the Polish State Geological Survey (Polish Geological Institute-National Research Institute), including "The balance of mineral resources deposits in Poland..." e.g. latest released in 2015 (Szuflicki, Molan, Tymiński (ed.), et.al. 2015) doesn't contain an information on geothermal energy resources. The "Balance…" provides an information regarding the use of groundwaters in operating installations, where thermal waters are used for heating, curative and other purposes.

Unfortunately, regional estimates of geothermal resources commissioned by the Ministry of the Environment (geothermal Atlases) are not included in that reports, but at least some of selected items, would enrich the scope of information and the knowledge on domestic geothermal energy resources.

Preliminary analysis indicates that appropriate counterparts of Polish geothermal classification with the UNFC-2009 can be found under adoption of certain theoretical assumptions.

Difficulties to identify the clear relationship between both of the classifications arising, by the fact that the Polish classification is generally based on regional analysis of mathematical models and assessment of economic indicators, e.g. *the power factor*, which by definition merely reflect the approximate value of real quantities describing the various parameters of particular geothermal projects, including an important, from the point of view of the UNFC-2009 economic parameters. Aforementioned assumptions should be taken into consideration, when appropriate assessment by UNFC-2009 classification is performed.

To conclude it should be emphasis that there is a need to modify the manner of geothermal resources reporting in Poland, to concerns not only the sustainability of geothermal waters itself, but also the resources of energy accumulated in these waters - expressed in Joules.

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