Entering geothermal energy into the UNFC-2009 classification system: case studies of direct-use projects from Hungary

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ABSTRACT

The paper briefly introduces the progress made by a Working Group based on a MoU between EGRC-UNECE and IGA to elaborate the specifications and guidelines for geothermal energy in order to incorporate geothermal into the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009). Four Hungarian direct use case studies are discussed where the authors made a Monte-Carlo based resource estimation and made an tried to classify the projects according to the UNFC-2009 scheme.

1. INTRODUCTION

The growing importance and the commercialization of the renewable energy sector urge the need of a common platform to assess and compare renewable and fossil energy portfolios in a transparent way. The United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009) (ECE 2013) is a universally accepted and internationally applicable scheme for the classification and reporting of fossil energy and mineral reserves and resources.

In 2013 the Expert Group on Resource Classification of the United Nations Economic Commission for Europe (EGRC-UNECE) established a Task Force, which elaborated the Draft Specifications for the application of the UNFC-2009 to renewable energy resources (EGRC-UNECE 2014). Adding on some reviews on the existing – however no globally agreed standards, guidelines and codes on the classification and reporting of geothermal resources / reserves (Beardsmore 2013, Falcone et al 2013, Falcone and Beardsmore 2015) – the EGRC-UNECE and the International Geothermal Association (IGA) signed a Memorandum of Understanding (MoU) in 2014 to establish a Working Group (WG) to elaborate the specifications and guidelines for geothermal energy in order to incorporate geothermal into the UNFC-2009 system. After a 2 years of intensive work documented in two White Papers (www.geothermal-energy.org/reserves_and_resources.html), the WG prepared the Draft Specifications for the application of UNFC-2009 to Geothermal Energy Resources at the beginning of 2016, a 105 page document with 12 case studies and a “decision tree” assisting the interpretation of the E, F, G axes of the UNFC-2009 scheme. The document was reviewed an commented by the IGA Reserves and Resources Committee, the UNECE Task Force on Renewables, the EGRC Technical Advisory Group (TAG) and Bureau, and was also submitted to the International Energy Agency Geothermal Implementing Agreement (IEA-GIA) and to the Geothermal Energy Association (GEA) for a preliminary review. The finalized Draft Specifications (ECE/ENERGY/GE.3/2016/6) was presented at the 7th EGRC Session in Geneva in April 2016 and is now open for public comments https://www.unece.org/fileadmin/DAM/energy/se/pdfs/UNFC/UNFC2009_publcom.geoth.2016/Geothermal.Specs_for.public.comment.pdf

During the elaboration of the Draft Specifications, the WG recognized that the amplification of various case studies from all over the world representing various application schemes (EGS, hydrothermal, directs use, GSHP, electricity and heat, as well as single and aggregated projects) would help a lot in a better understanding and interpretation of the UNFC-2009 classification framework.

This paper presents one of the re-worked Hungarian case studies of the Draft Specifications (Hódmezővásárhely geothermal district heating) and introduces another three Hungarian direct-use project examples (Szentes, Miskolc, Veresegyház) representing different types of applications in various geological environments, through which the process of classification according to the UNFC-2009, its merits and difficulties are discussed.

2. THE UNFC-2009 CLASSIFICATION AND ITS APPLICATION TO GEOTHERMAL ENERGY RESOURCES

The UNFC-2009 is a universally accepted and internationally applicable system in which mineral resources-reserves / fossil energy quantities *associated with a certain* mining *project* are classified and reported on the basis of the three fundamental criteria of economic and social viability (E), field project status and feasibility (F), and geological knowledge (G), using a numerical and language independent coding scheme. Combinations of these criteria create a three-dimensional system (Fig. 1).

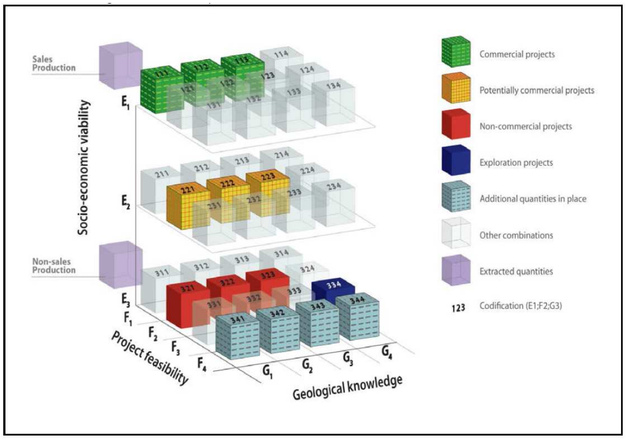

Figure 1: UNFC-2009 categories and classes (ECE, 2013)

The classification process of a geothermal project consists of (1) defining a project, (‘geothermal energy source’ is equivalent to the terms ‘deposit’ or ‘accumulation’ used for solid minerals and fossil fuels in UNFC-2009), (2) estimating the quantities of energy that can be recovered and delivered as ‘products’ (typically heat or electricity), and (3) classifying the geothermal energy resource based on the criteria defined by the E, F and G categories.

The full interpretation of the different E, F, G categories and their supplementary renewable- and geothermal context is available in the Geothermal Draft Specifications (ECE/ENERGY/GE.3/2016/6).

Geothermal energy resources are the cumulative quantities of geothermal energy products that will be extracted *from the effective date of the evaluation forward* (till the end of the project lifetime/limit), measured or evaluated at the *reference point* (a defined location in the production chain).

The **E-axis** of the UNFC-2009 scheme classifies whether extraction and sale is economically viable (E1), is expected (E2), or not expected (E3) to be economically viable in the foreseeable future. However, in addition to economic considerations, class E comprises all environmental, legal-regulatory, market access, social and political features relevant for a project. While project developers/operators have a full overview of all these aspects, an external evaluator often finds it difficult to collect and assess all these information. Furthermore, a consistent classification of the myriad of these (sometimes controversy i.e. economic-vs. environmental) aspects is a real challenge; at the moment a separate sub-group on the E axis of the EGRC-UNECE is working on accommodating all these considerations into the UNFC-2009 scheme.

Based on the concept of the “decision–tree” being part of Geothermal Draft Specifications, the WG agreed to evaluate all the E-aspects one-by-one (i.e. is issue "x" expected to be resolved / confirmed within reasonable timeframe [<1-2years] →E1; within the foreseeable future [<5 years]→E2; or beyond the foreseeable future [>5 years] →E3), then summarizing all aspects one-by-one in a table and select the lowest E-class which will characterize the given project.

The Geothermal Draft Specifications highlighted the treatment of policy support in relation to subcategory E1.2, as a variety of policy support mechanisms, regulatory instruments and financial incentives (e.g., feed-in tariffs, premiums, grants, tax credits etc.) are available to geothermal projects. It stated that the type of government subsidies and/or other considerations that make extraction and sale viable shall be disclosed, together with their anticipated future availability as at the effective date. However financial support given to a project *before* the effective date of evaluation does not make any influence on this category.

The **F-axis** mostly deals with project status and technology. Technology should be classified on the F-axis whether feasibility of extraction has been confirmed (F1), or is subject to further evaluation (F2). Exploration projects are classified as F3. The Geothermal Draft Specifications draw the attention that additional quantities in place (F4) are generally poorly defined for geothermal, mostly because of the poorly defined depth limits and recharge rate of the geothermal energy source, and because of the fact that the ‘cut-off parameter’ (e.g. temperature) below which heat extraction is no longer commercially viable is dependent upon the technology used in the project.

The **G-axis** categories are intended to reflect all significant uncertainties impacting the estimated geothermal energy resource quantities that are forecast to be extracted by the project. It differentiates between a *known geothermal energy source* (where one or more wells have established through testing, sampling and/or logging the existence of a significant quantity of potentially recoverable heat) that is classified using G1, G2 and G3 categories, and a *potential geothermal energy source*, classified and reported using the G4 category, where the existence of a significant quantity of recoverable thermal energy has not yet been demonstrated by direct evidence (e.g. drilling, well testing, etc.), but is assessed as potentially existing based on evidence from geophysical measurements, geochemical sampling and other surface or airborne measurements or methods.

Due to the fluid character and replenishment of geothermal energy source, the various uncertainties will combine to provide a full range of possible outcomes, comparable to the extraction of fluids in the petroleum sector. Therefore such categorization reflects three scenarios or outcomes that are equivalent to G1, G1+G2 and G1+G2+G3.

3. DEFINING HUNGARIAN CASE STUDIES AND DATA COLLECTION FOR PROJECT CLASSIFICATION

Due to the favourable geothermal conditions, Hungary's long-lasting traditions and advanced position in the direct use in Europe are well known (e.g. Nádor et al. 2013, Tóth 2015). Although there are about 860 active thermal water wells in Hungary, and large efforts have been done in establishing a joint national geothermal database (Nádor et al. 2016), data collection for the appropriate characterization of certain 'geothermal projects' for the UNFC-2009 faced significant difficulties.

A major problem is that the exact way of utilisation – a basic pre-requisite to define and identify a 'geothermal project' – is missing from most of the national databases. There are several reasons for this: (1) the exact way of utilisation is irrelevant for most of the authorities, e.g. it does not matter whether mining royalty is paid after a greenhouse heating or a geothermal district heating, the calculation method and rate (2% of the value of the used geothermal energy) is the same. Similarly, the water fee (to be paid after the abstracted amount of water) is irrelevant of its utilization type (irrigation, drinking, balneology, etc.). (2) The owner and status of a well is changing quite often: e.g. a small farmer company may give up business, so the well is inactive for a few years, than a new user re-starts activities perhaps for a different type of utilisation. (3) Many of the wells are of multi-purpose use. When thermal water from a single well is distributed in a cascade system (e.g. heating, domestic hot water supply, spa, etc.), it is hard to categorize the use, furthermore the different uses may, or may not be operated by the same company (i.e. local ESCO vs. spa owner).

Due to significant efforts of the Geological and Geophysical Institute of Hungary in 2015 in merging and harmonizing fragmented national databases from water and mining authorities, as well as other relevant scientific datasets, geology-related and production data, necessary for project identification and quantification of the 'Geothermal Energy Source' became available. Based on this dataset four case studies were selected to test the applicability of the UNFC-2009 classification system. Selection criteria included to represent different utilization types (district heating, thermal water town heating, direct use in the agriculture sector) with various operational practices (full / partial / no reinjection) in diverse geological settings (porous / carbonate reservoirs), as well as to have public data relevant for the classification of E and F classes. The location of the case study projects is shown on Fig. 2.

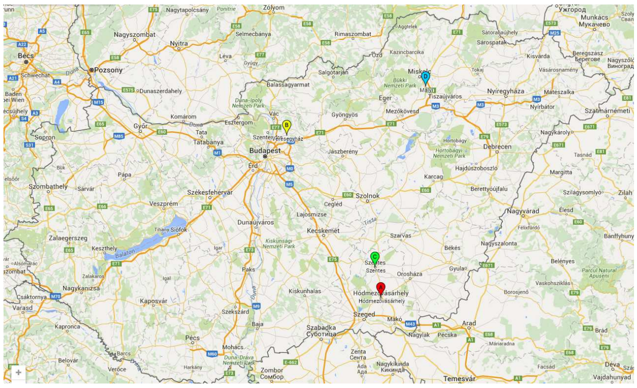

Figure 2: Location of the four Hungarian direct-use case studies (A: Hódmezővásárhely, B:Veresegyház, C: Szentes, D: Miskolc)

The quantification of the resource estimate was done by applying the volumetric method using Monte Carlo simulation for the reservoir parameters (area, thickness, temperature, porosity) as well as the recovery factor (Table 1). Assumptions about the 'area' of the reservoir were based on cumulative recharge areas of individual wells of the given project deriving from hydrodynamic modelling, whereas the 'thickness' of the reservoir was estimated on the basis on the total lengths of screened intervals. The reservoir temperature was estimated from outflow temperature and reservoir lithology, whereas porosity data came from well-data and / or analogue settings. The quantities of recoverable heat (i.e. heat energy stored in the pores) associated with high-, medium-, and low level of confidence are based on 90, 50 and 10 percentile of the resulting cumulative probability distribution respectively (Table 1).

4. UNFC-2009 CLASSIFICATION OF HUNGARIAN CASE STUDIES

4.1. Hódmezővásárhely

Hódmezővásárhely is a mid-size town with 47700 habitants situated in SE Hungary (Fig. 2), where geothermal conditions are very favourable due to high subsurface temperature and widespread distribution of Upper Miocene sandstone aquifers at a depth range of 1800-2300 m.

A Municipality owned company operates a cascade system of 10 wells (8 production and 2 reinjection) (Ádok 2012). The wells are multi-purpose and supply water for district heating, domestic hot water supply and are also used for balneological purposes. The first well was drilled in 1954 for medical and district heating purposes. The currently operating system – developed in several stages (1967, 1984, 1994-1998, 2007) – consists of several geothermal loops, which provide heating of 2725 flats and 130 public consumers. The development was partly co-financed by the ERDF-sourced Energy and Environment Operative Program.

	Input parameters					Calculated parameters			
	A	B	C	D	E	F	G	H	**I**
	Reservoir area (km^2)	Reservoir thickness (km)	Porosity (V/V)	Reservoir temperature (˚C)	Recovery factor	Total volume (km^3)	Pore volume (km^3)	Porosity heat content (PJ)	**Recoverable heat (PJ)**
Calcu-lation formula						A*B	C*F	4.187*G*(D-30)	**(H*E)**
Hódmezővásárhely									
Min	12,5	0.080	0.06	58	0.1				
Max	15,5	0.150	0.18	108	0.2				
"p90"	*12.8*	*0.087*	*0.07*	*63*	*0.11*	1.21	0.109	20.5	**2.88**
"p50"	*14*	*0.115*	*0.12*	*83*	*0.15*	1.6	0.185	38.7	**5.69**
"p10"	*15.2*	*0.143*	*0.17*	*103*	*0.19*	2.01	0.29	70.5	**10.85**
Veresegyház									
Min	15	0.043	0.01	80	0.2				
Max	20	0.116	0.07	85	0.3				
"p90"	*15.5*	*0.051*	*0.016*	*80*	*0.21*	0.88	0.02	4.5	**1.11**
"p50"	*17.5*	*0.08*	*0.04*	*83*	*0.25*	1.39	0.051	11.2	**2.78**
"p10"	*19.5*	*0.109*	*0.064*	*85*	*0.29*	1.93	0.099	21.8	**5.47**
Szentes									
Min	45	0,135	0.05	103	0.1				
Max	57	0,255	0,07	132	0.2				
"p90"	*45.9*	*0.137*	*0.054*	*104*	*0.11*	6.89	0.405	142	**19.26**
"p50"	*51*	*0.195*	*0.06*	*117*	*0.15*	9.9	0.59	213	**31.29**
"p10"	*56.2*	*0.251*	*0.067*	*130*	*0.19*	13.08	0.8	299	**48**
Miskolc									
Min	50	0,069	0.01	90	0.2				
Max	60	0,099	0.07	105	0.3				
"p90"	*51.0*	*0.073*	*0.016*	*91*	*0.21*	4.28	0.074	20.9	**5.12**
"p50"	*55.1*	*0.084*	*0.040*	*98*	*0.25*	4.63	0.18	52.3	**12.9**
"p10"	*59.0*	*0.095*	*0.064*	*104.*	*0.29*	4.96	0.29	84.4	**21.48**

Table 1: Input and calculated parameters of the four Hungarian direct use case studies (for discussion see the text)

Category	UNFC-2009 Definition	Reasoning for classification
E.1.1.	Extraction and sale is economic on the basis of current market conditions and realistic assumptions of future market conditions	• existing heat market • all production licenses available and guaranteed within reasonable timeframe • very positive and quantified effects on the reduction of gas consumption and decreased CO_2 emission, as well as reduced heating costs
F.1.1.	Extraction is currently taking place.	• the gradually expanding project has been operating since 1954 • technically feasible use (district heating, communal hot water supply) with good thermal efficiency
G.1.	Quantities associated with a known deposit that can be estimated with a high level of confidence *(High confidence / low estimate)**	A volumetric Monte Carlo assessment has indicated a 90% probability of **2,88 PJ** of recoverable geothermal energy *(Table 1).*
G.2.	Quantities associated with a known deposit that can be estimated with a moderate level of confidence *(Moderate confidence / best estimate, incremental to G1)**	A volumetric Monte Carlo assessment has indicated a 50% probability of 5,69 PJ of recoverable geothermal energy *(Table 1).* Therefore G2 is: 5,69-2,88=**2,81 PJ**
G.3.	Quantities associated with a known deposit that can be estimated with a low level of confidence *(Low confidence / high estimate, incremental to G2) **	A volumetric Monte Carlo assessment has indicated a 10% probability of 10,85 PJ of recoverable geothermal energy *(Table 1).* Therefore G3 is: 10,85-2,81=**8,04 PJ**

Table 2: UNFC classification of the Hódmezővásárhely district heating project (*additional definition for recoverable quantitites that are extracted as fluids)

The wells produce water with outflow temperature of 75-89 C from a depth interval of 1800 to 2000 m. The wells tap aquifers with high hydraulic conductivity (1,15-5,8 x 10^{-5} m/s) and effective porosity (0,13-0,16), therefore they may yield thermal water up to 30 l/s, however during the use the maximum production rate is around 20 l/s. So far no detectable temperature decrease occurred in the aquifer at a 300 m distance from the reinjection wells due to the high heat capacity of the rock matrix (Szanyi and Kovács 2010).

The intensive use of the wells completed in the Upper Pannonian sandy aquifers in the 1970’s and 1980’s decreased the hydraulic heads continuously, which was the reason for initiating reinjection. 2 reinjection wells were drilled in 1998 and 2007. However, only about 50% of the total produced amount for heating purposes is reinjected (Ádok 2012) due to technical challenges associated with the clogging of the pore-throats. Well maintenance using compression cleaning is needed every 2 years since the injected water is filtered using a microfiber filter system. The average reinjection temperature is 35 C which underpins a good thermal efficiency.

Since the expansion of the geothermal system (1993), the gas consumption of the heating centers dramatically dropped (from 4,6 million m^3 to 0,5 million m^3). In 2011 the share of geothermal in the total heating was about 86%. The increasing use of geothermal has a very positive effect on air quality, an annual saving of 4,5 million m^3 of gas is calculated, which is equivalent of 4680 t CO_2 emission.

The UNFC classification of the Hódmezővásárhely district heating project is shown on Table 2.

4.2 Veresegyház

Veresegyház is a 18000 inhabitant town NE of Budapest (Fig. 2), a very prosperous settlement in the agglomeration of the capital. Its continuous expansion is mostly due to the growing investments (thus job opportunities), as well as the low heating prices, which all result from the continuously developing geothermal heating system. The first well feeding the local spa was drilled in 1987 to a depth of 1462 m, which yielded thermal water from a Triassic basement reservoir at an outflow temperature of 65 C. In 1993 the city council decided to use the thermal water also for the heating of several public buildings, which was the start of a continuously developing town-heating cascade project, when the thermal water pipeline, as well as the heated buildings has been expanded in several phases, partly co-financed by the ERDF-sourced Energy and Environment Operative Program. At the moment the system consist of 3 production and 1 reinjection well providing heating for primary schools, Culture House, a nursery, Town Hall, Church, Elderly People’s Home, shopping centres, Health Center, private houses, and also some industrial users (Szita 2015).

Category	UNFC-2009 Definition	Reasoning for classification
E.1.1.	Extraction and sale is economic on the basis of current market conditions and realistic assumptions of future market conditions	• existing and continuously expanding heat market • all production licenses available and guaranteed within reasonable timeframe • very positive and quantified effects on the reduction of gas consumption and decreased CO_2 emission, as well as reduced heating costs
F.1.1.	Extraction is currently taking place.	• the gradually expanding project has been operating since 1993. • technically feasible cascade use with good thermal efficiency
G.1.	Quantities associated with a known deposit that can be estimated with a high level of confidence *(High confidence / low estimate)**	A volumetric Monte Carlo assessment has indicated a 90% probability of **1,11 PJ** of recoverable geothermal energy *(Table 1).*
G.2.	Quantities associated with a known deposit that can be estimated with a moderate level of confidence *(Moderate confidence / best estimate, incremental to G1)**	A volumetric Monte Carlo assessment has indicated a 50% probability of 2,78PJ of recoverable geothermal energy *(Table 1).* Therefore G2 is 2,78-1,11=**1,67 PJ**
G.3.	Quantities associated with a known deposit that can be estimated with a low level of confidence *(Low confidence / high estimate, incremental to G2) **	A volumetric Monte Carlo assessment has indicated a 10% probability of 5,47 PJ of recoverable geothermal energy *(Table 1).* Therefore G3 is 5,47-1,67=**3,8 PJ**

Table 3: UNFC classification of the Veresegyház thermal cascade water town heating project (*additional definition for recoverable quantitites that are extracted as fluids)

A reinjection well was drilled in 2007 (with 35 °C reinjection temperature) which significantly increased the capacity of the system with joining of new consumers and also made the production sustainable and thermally efficient. The total length of the thermal water pipeline system is 14,5 km, but further expansion is foreseen especially related to the heat demand of horticulture and industrial parks.

The UNFC classification of the Veresegyház project is shown on Table 3.

4.3. Szentes

In the Szentes area altogether 32 thermal water wells are found, thus this is the most intensively produced hydrothermal reservoir (Upper Miocene sandstone aquifer at a depth range between 1500 and 2500 m) in Hungary (Fig. 2). The wells have an outflow temperature higher than 60 °C, out of the 32 wells 12 wells produce water 90-99 °C. The wells have a significant yield (1500-1800 l/min).

In addition to the existing geothermal district heating in the town (heating of 1304 flats and public buildings equivalent with 1500 flats) and medicinal-balneological purposes, the largest proportion of utilisation of the thermal water in the Szentes area is for the heating of greenhouses operated by a large agriculture company (Árpád-Agrár Ltd.), and several other smaller companies and family farms.

Despite the massive utilisation and abstraction of thermal water (it was 6,5 million m^3/year at its peak, than it decreased to 5,7 millon m^3/year) there is no reinjection at all in this area, although more than 90% of the abstracted water is for energetic use. The used thermal water is discharged to the Kurca river and 2 artificial lakes of 40 and 100 ha territory respectively. These lakes became part of the natural landscape and provide shelter for more than 170 different bird species and also provide recreational purposes. The decrease of hydraulic heads reached its maximum in the early 1990s, with 25–40 m drawdown. Later, the heads increased 4–8m due to decreasing thermal water production up to 2000 (Szanyi and Kovács 2010).

The *Árpád-Agrár Ltd* in the Szentes area is one of Hungary's largest agriculture companies with long lasting traditions in production of vegetables and horticulture, but its wide portfolio also includes monoculture of corps, chemical control, forage, etc. The company has 20 thermal water wells (out of which 14 have been operational during the past few years), drilled between 1964 and 1992. Greenhouses of 30 ha and plastic tents of 30 ha are heated by the thermal water. In addition about 35 000 m^2 of poultry yards and some stables (mostly for pigs) are also heated by thermal water, and geothermal energy is used for crop drying, too. The office buildings and yards, garages of the large company are also heated by thermal water.

The UNFC classification of the Árpád-Agrár project project is shown on Table 4.

4.4. Miskolc

Miskolc is Hungary's 2nd largest town in NE-Hungary (Fig. 2), a classical industrial town with an existing district heating system feeding the large blocks of housing estates.

Hungary's largest geothermal district heating project with 2 production and 3 reinjection wells targeting karstified-fractured Triassic basement carbonates at a depth of 1500-2300 m with a total installed capacity of 55 MWth was completed in 2013. The yield of the production wells is between 6600-9000 l/min, the outflow temperature is 95 and 105 °C respectively.

The system with full reinjection supplies district heating and domestic water for the large panel blocks of the 'Avas' housing estate in Miskolc with an annual net heat production of ~ 662 000 GJ. The main heat center is found in Kistokaj, about a 1 km north of the production wells. During the 2nd phase of project development (2013) another heat supply center was established within the city, which made possible to heat the historical city center and the university buildings (+ provide domestic hot water supply).

The operator company (Miskolc Geotermia Ltd) is 90% owned by Pannergy (project developer) and 10% by the Municipality of Miskolc. The total investment cost was about 25 million euro, which was partly co-financed by the ERDF sourced Energy and Environment Operative Programme.

The UNFC classification of the Miskolc district heating project is shown on Table 5.

Category	UNFC-2009 Definition	Reasoning for classification
E.1.1..	Extraction and sale is economic on the basis of current market conditions and realistic assumptions of future market conditions	• existing heat demand (agriculture) • all production licenses available, and guaranteed within reasonable timeframe *(although no reinjection, but it is not required by the current regulation)* • positive effects on the reduction of gas consumption and decreased CO_2 emission, as well as reduced heating costs
F.1.1.	Extraction is currently taking place.	• the project has been operating for more than 25 years
G.1.	Quantities associated with a known deposit that can be estimated with a high level of confidence *(High confidence / low estimate)**	A volumetric Monte Carlo assessment has indicated a 90% probability of **19,26 PJ** of recoverable geothermal energy *(Table 1).*
G.2.	Quantities associated with a known deposit that can be estimated with a moderate level of confidence *(Moderate confidence / best estimate, incremental to G1)**	A volumetric Monte Carlo assessment has indicated a 50% probability of **31,29 PJ** of recoverable geothermal energy *(Table 1).* Therefore G2 is: 31,29-19,26=**12,03 PJ**
G.3.	Quantities associated with a known deposit that can be estimated with a low level of confidence *(Low confidence / high estimate, incremental to G2) **	A volumetric Monte Carlo assessment has indicated a 10% probability of 48 PJ of recoverable geothermal energy *(Table 1).* Therefore G3 is: 48-12,03=**35,97 PJ**

Table 4: UNFC classification of the Árpád-Agrár agriculture direct use project (*additional definition for recoverable quantitites that are extracted as fluids)

Category	UNFC-2009 Definition	Reasoning for classification
E.1.1.	Extraction and sale is economic on the basis of current market conditions and realistic assumptions of future market conditions.	• existing large heat market with further demands • all production licenses available and long-term guaranteed, PPA • very positive and quantified effects on the reduction of gas consumption and decreased CO_2 emission
F.1.1.	Extraction is currently taking place.	• the project has been operating since 2013
G.1.	Quantities associated with a known deposit that can be estimated with a high level of confidence *(High confidence / low estimate)**	A volumetric Monte Carlo assessment has indicated a 90% probability of **5,12 PJ** of recoverable geothermal energy *(Table 1).*
G.2.	Quantities associated with a known deposit that can be estimated with a moderate level of confidence *(Moderate confidence / best estimate, incremental to G1)**	A volumetric Monte Carlo assessment has indicated a 50% probability of 12,9 PJ of recoverable geothermal energy *(Table 1).* Therefore G2 is: 12,9-5,12=**7,78 PJ**
G.3.	Quantities associated with a known deposit that can be estimated with a low level of confidence *(Low confidence / high estimate, incremental to G2) **	A volumetric Monte Carlo assessment has indicated a 10% probability of 21,48 PJ of recoverable geothermal energy *(Table 1).* Therefore G3 is: 21,48-7,78=**13,7 PJ**

Table 5: UNFC classification of the Miskolc geothermal district heating project (*additional definition for recoverable quantitites that are extracted as fluids)

5. DISCUSSION

All four presented projects are in operation where active production of thermal water is taking place for district heating (Hódmezővásárhely, Miskolc), cascade thermal water town heating (Veresegyház) and heating of greenhouses and plastic tents (Szentes), therefore they all classify for F1.1.

The different reservoir properties (basin fill porous sandstone aquifers in Hódmezővásárhely and Szentes and basement carbonate reservoirs in Veresegyház and Miskolc) control the estimated amount of recoverable thermal energy (differences in porosity, depth / temperature, recovery factor, etc.), however their classification into different G-classes are based on the same method (Monte-Carlo based probability distribution).

Regarding the E classes, three projects (Hódmezővásárhely, Veresegyház, Miskolc have been subsidized during their development. However as this happened *before* the effective date of evaluation (2015), this does not result their classification into E.1.2. Concerning market conditions, the district- and town-heating projects (Miskolc, Hódmezővásárhely, Veresegyház) clearly build on the existing heat demands. As greenhouses can be installed in a more flexible way, this is not a decisive factor for the Szentes agriculture project.

The main environmental aspect of Hungarian direct use projects is reinjection, its absence/existence and rate. Out of the four case studies, the Miskolc project operates with full reinjection, Hódmezővásárhely and Veresegyház with partial reinjection, whereas it is missing in Szentes. Although this is a major difference among the projects, it does not influence their E-classification. Reinjection witnessed many legislative changes and heated debates within the geothermal and water management sector over the last 10 years in Hungary: from being compulsory (with exemptions till a certain deadline) to non-compulsory. Due to the modification of the Water Act in 2013, the reinjection of thermal waters used for energetic purposes is not obligatory, but being assessed and authorized on individual basis (depending on the local reservoir conditions). As at the effective date of evaluation all projects possess the necessary water licences for their current ways of operation (with- or without reinjection), and no changes are expected within a reasonable timeframe (<1-2years), they all classify as E.1.1. The projects' positive impacts on the reduction of gas consumption (therefore heating costs) and decreased CO_2 emission further underpin their E.1.1.classification.

6. CONCLUSION

It was demonstrated that the UNFC-2009 system is suitable for the classification of geothermal projects. However at the moment the system cannot accommodate significant differences among operational projects, mostly due to the complexity of the E-class comprising all environmental, legal-regulatory, market access, social and political features. Project classification in the UNFC-2009 scheme requires detailed data not only about the geological conditions, but all the other technical and non-technical data, kept by project developers/operators.

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