Zeszyty Naukowe

Instytutu Gospodarki Surowcami Mineralnymi i Energią Polskiej Akademii Nauk

rok 2016, nr 92, s. 337–358

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Some factors determining the geothermal energy uses' development in the Central and Eastern European countries in coming years

Abstract: The paper presents the results of research on socio-economic aspects of the current state and prospects of wider geothermal resource development in the group of countries in Central and Eastern Europe (including Poland).The research was done by the team from the Mineral and Energy Economy Research Institute, PAS, Division of Renewable Energy Sources (in cooperation with partners from six countries)within the framework of the Project "Geothermal communities – demonstrating the cascaded use of geothermal energy for district heating with small scale RES integration and retrofitting measures", GEOCOM). The project was part of the 7th Framework Programme and conducted in 2010–2015. The studies, with application of some foresight approach, allowed researchers to obtain the orientation of the types and groups of factors likely to influence the development of geothermal energy uses in theupcoming 10–20 years, as well as the actions that should betaken to create favorable development conditions for this energy sector.

Keywords: geothermal energy, Central-Eastern Europe, development factors, foresight approach

Niektóre czynniki warunkujące rozwój wykorzystania energii geotermalnej w krajach Europy Środkowo-Wschodniej w nadchodzących latach

Streszczenie: Artykuł przedstawia wybrane wyniki badań dotyczących aspektów socjologiczno-ekonomicznych obecnego stanu i perspektyw szerszego rozwoju wykorzystania zasobów geotermalnych w krajach Europy Środkowo-Wschodniej (także m.in. w Polsce). Badania wykonał zespół z Pracowni Odnawialnych Źródeł Energii IGSMiE PAN (przy współudziale partnerów z sześciu krajów) w ramach projektu unijnego pt. „Społeczności geotermalne – demonstracja kaskadowego wykorzystania energii geotermalnej w ciepłownictwie w integracji na małą skalę z innymi OZE wraz z modernizacją i opomiarowaniem" (GEOCOM). Projekt należał do 7 Programu ramowego UE, był realizowany w latach 2010–2015. Badania, w których posłużono się elementami podejścia

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typu *foresight*, pozwoliły na uzyskanie orientacji co do rodzaju i grup czynników, które prawdopodobnie będą miały wpływ na rozwój wykorzystania geotermii w perspektywie nadchodzących 10–20 lat, a także działań i środków, jakie powinny być podjęte dla kreowania sprzyjających warunków dla tego sektora energii.

Słowa kluczowe: energia geotermalna, Europa Środkowo-Wschodnia, czynniki rozwoju, podejście foresightowe

Generals

Many European countries possess prospective geothermal energy resources suitable for many applications. In that group are several Central and Eastern European (CEE) states: Macedonia, Hungary, Italy, Poland, Romania, Serbia, and Slovakia. They were the focus of the EU co-funded Project "Geothermal communities – demonstrating the cascaded use of geothermal energy for district heating with small scale RES integration and retrofitting measures", GEOCOM.

However, to increase geothermal uses in CEE countries, several actions should be introduced in order to place it on equal market ground with other energy carriers, including renewable energy. Relevant actions will be implemented on the basis of prior identification of essential factors and conditions that control the geothermal energy development (Kępińska and Kasztelewicz 2015). Research done for the group of CEE countries conducted as part of the GEOCOM project gave insight into basic factors (legal, economic and environmental) that determine the current situation and can be regarded as constraints, market drivers and best practices of geothermal deployment (details are in the report on "Overview of market drivers, fiscal measures and subsidies"; www.geothermalcommunities.eu). That research also attempted to identify the factors (i.e. set of events and trends) that would most likely impact geothermal energy use deployment in the next 10–20 years, as well as their interactions and roles. The foresight-like approach was applied – an exercise which was done for the first time with the CEE states. The results are described in this paper.

1. Geothermal energy potential and the current state of its applications in some Central and Eastern European countries

Europe has perspective geothermal energy resources suitable for practical use, including a wide spectrum of direct applications and, in some areas, for power generation. This is also a case of a group of the CEE countries covered by the GEOCOM project. It is worth noting that some of best geothermal fields in Europe are located in these countries, e.g: the Larderello region (Italy), the Panonian Basin (Hungary, Serbia, Slovakia, Romania and several other countries), the Polish Lowlands – part of the European Lowlands (Poland), and the Palaeogene systems of the Inner Carpathians (Poland, Slovakia).

Europe is one of the world leaders in geothermal direct uses and occupies second place ahead of Asia. According to data presented at the World Geothermal Congress 2015 (Lund and Boyd 2015), the total installed capacity for direct uses in Europe (37 countries) was ca. 25 037 $MW_{th,}$ while heat production amounted to ca 220 420 TJ in 2013, i.e. 36% and 38% of the world total (table 1). The total contribution of the seven CEE countries to those uses was ca. 2966 MW_{th} of installed capacity and ca. 28 472 TJ of heat produced in 2013, i.e. 13% and 14% respectively. The main areas that dominate direct uses both in Europe and in the GEOCOM countries are space heating, heating greenhouses and foil tunnels, and bathing and swimming (balneotherapy). These also indicate the direction of likely future demand and prospects in this field. In many cases the utilities operate in integrated systems.

TABLE 1. The Central and Eastern European countries covered by the GEOCOM project: geothermal energy uses on a general European background, 2013

TABELA 1. Kraje Europy Środkowo-Wschodniej objęte projektem GEOCOM: wykorzystanie energii geotermalnej na tle Europy, 2013

Country	Direct uses		Electricity generation	
	Installed capacity [MWth]	Heat production [TJ/a]	Installed capacity [MWe]	Production [GWh/a]
Macedonia	46.68	601.11	–	–
Hungary	654.6	10 268.06	–	–
Italy	1 355.0	11 065	916	5 660
Poland	488.84	2 742.60	–	–
Romania	245.13	1 905.32	0.1	0.4
Serbia	115.64	1 802.48	–	–
Slovakia	132.2	2469.60	–	–
GEOCOM countries total (% of total Europe)	3 306.27 (13.20%)	30 854.17 (14%)	916.1 (42.95%)	5 660.4 (38.19%)
Europe total	25 037.12	220 419.17	1640.8	11 147.8
World total	70 037.12	587 786.43	12 635	73 549

Data sources: Lund and Boyd 2015, and country update papers submitted for the World Geothermal Congress 2015.

2. Current and predicted share of geothermal in the renewable energy mix – the Central and Eastern European countries involved in the GEOCOM project

According to the statistics, in 2013 the average share of all renewable energy sources (RES) in the gross final energy consumption in the 27 European Union countries amounted to 15% on average, the dominant being biomass, wind and hydropower (e.g. http://europa.eu/rapid/press-release_IP-15-5180_en.htm; http://ec.europa.eu/eurostat/web/energy/data/shares). Among GEOCOM countries this share was ca. 16% on average; in particular cases it ranged from 9.8% (Hungary, Slovakia) to 23.94% (Romania). However, geothermal only contributed a small share in the RES mix in Europe as a whole and the GEOCOM states (Macedonia, Poland, Romania, Serbia, Slovakia), with more significant figures obtained from Italy and Hungary. From these figures it can be seen that the geothermal resources in that group of CEE countries have been exploited on a scale much lower than (even conservatively) possibilities offered by the resources' potential.

The European countries are in the process of increasing the use of RES following the provisions of the Directive 2009/28/EC of the European Parliament and of the Council. These provisions (indicating 20% as an average share of RES in final gross energy consumption in the EU–member states by 2020) were transposed into the National Renewable Energy Action Plans and national energy strategies. In general, hydro, biomass, and wind are treated as priorities while smaller contributions are envisaged for other RES, including geothermal. Despite its officially forecasted share that will not exceed a few percent in most countries, locally and regionally geothermal can reach a significant contribution in absolute terms and in a variety of fields.

For particular GEOCOM countries, the share of RES in final gross energy consumption is projected to be in the range 14–27% in 2020. This takes into account the share of geothermal in the final gross RES consumption in 2020, projected to be 0.04–19.16%, with the lowest percentage forecasted in Macedonia, and the highest in Hungary.

It should be noted that geothermal experts and communities have repeatedly called for a higher share of geothermal in the national energy strategies and National Renewable Energy Action Plans (NREAPs) for 2020 than was eventually included into official documents. All the more reason that, despite low official prognoses, this type of energy shall be successfully implemented on a much wider scale in many countries than now. This also refers to CEE states (Bujakowski and Kasztelewicz 2012; Kasztelewicz and Kępińska 2013).

3. Factors that impact current geothermal energy development in the Central and Eastern European countries

The factors which create the circumstances for current geothermal energy development in the European countries belong to several basic groups, i.e. environmental, technological, economic, social, legal, and – last but not least – political. Among them are those facilitating the development of this sector, however, the majority of them act as constraints hampering its progress. This is especially visible in several CEE states included in the GEOCOM project as evident from the detailed study "Overview of market drivers, fiscal measures and subsidies" (www.geothermacommunities.eu).

If one were to illustrate the current circumstances of geothermal deployment, one could say that its minor role in official EU and state strategic documents results in generally weak financial conditions for its development, with a shortage of dedicated measures. Some existing incentives and support tools are, in the majority of cases, available in frames of wider systems/programs addressing the RES sector as well as the enhancement of economic activities, and job creation (small and medium entrepreneurs, SMEs). However, in many cases, this is not tailored to the geothermal specifics. This fact is justified by the current situation in a prevailing number of the GEOCOM countries.

4. Factors impacting geothermal energy development in the group of Central and Eastern European countries in the coming years – research using the foresight approach

4.1. Research methods

In the case of the seven CEE countries (subjects of GEOCOM project), in order to investigate the factors which might impact geothermal energy uses development, costs, and promotion in the next 10–20 years, some elements of the foresight methods survey were applied. The main objective of such an approach was to identify the potential factors (i.e. set of events and trends), their interactions and roles for given future development (treated as a system). It was expected that several factors (and their groups) that would determine the evolution of the system in the assumed timeframe would be defined, including the key factors of essential importance for future development.

Before presenting the results of the study done for the group of CEE states, a general introduction to the foresight technique is given, as well as an introduction to the structural cross-impact analysis, one of the methods applied during the study and interpretation of results. This introduction is based mainly on Czaplicka-Kolarz (ed.) et al. (2007a, 2007b), Kuciński (2006), Pyka and Czaplicka-Kolarz (eds.) et al. (2001), Wójcicki and Ładyżyński (eds.) et al. (2008), as well as other sources cited in the text. An interesting and still growing literature on foresight, concerning both its theoretical basis and particular application examples, is available in papers and e-publications. The European Foresight S&T Knowledge Sharing Platform and European Foresight Website, for instance, belong to the latter.

4.2. Foresight methodology – generals

Foresight is a methodology used for future prediction analyses and prognoses. Foresight allows the participants ("actors", "experts") to actively shape the future, being a non-deterministic, participatory and multidisciplinary approach. It can be envisaged as a triangle combining "Thinking the future", "Debating the future" and "Shaping the future" (For-Lern JRC EC 2014; fig. 1).

Foresight is a process of collaboration, discussion and consultation among a group of partners leading to the joint refining of future visions and establishing common strategies that guide the opportunities of the long-term development through science, technology and innovation (UNIDO 2005).The representatives of many groups (public authorities, science, industry, mass media, non-government organizations, R&D institutions) become involved in open future-oriented discussion. It is also a tool in building a culture that focuses on thinking of future generations and creates a language in the public debate space (Czaplicka-Kolarz ed. et al. 2007a). These groups being familiarized with science, economy and related regulations ensure the correct substantive definition of problems and provide for their possible solutions.

This technique and its results provide information about new development trends to policy-making bodies, assistance in establishing development strategies and scenarios, road

Fig. 1. The concept of foresight methodology (For-Lern JRC EC 2014)

Rys. 1. Koncepcja metodologii *foresight* (For-Lern JRC EC 2014)

-maps, as well as help coordinate activities of various social partners. They may help to create and implement state science, technology and innovation policies.

The goal for foresight projects is researching „possible", „probable" and „preferred versions of the medium and long-term future". Foresight attempts to predict what the world might look like at some point in the future („shaping the future") in the analyzed area. It is concerned with the longer term, typically ranging between ten and twenty years, therefore it does not seek to predict. Instead, it is a process that seeks to create shared visions of the future, visions that stakeholders are willing to endorse by the actions they choose to take today. Foresight does not replace forecasting, futures studies, or strategic planning. Each activity has its role, which in many instances can be mutually supportive.

4.3. Basic analytic tools applied in foresight – generals

There are several primary methods that are used in foresight exercises. Selecting amongst the methods depends on the type of project and resources available, especially time and money. Some methods are best used together, combined in a variety of ways (Wójcicki and Ładyżyński eds. et al. 2008):

- Exploratory methods (determining events and extrapolating trends into the future),
- Quantitative methods,
- Methods identifying key aspects of activities important for strategic planning,
- Methods based on experts' knowledge,
- Environmental scanning (diagnosis of the state).

A systematic analysis of some documentary sources providing information about the regional, national and international environments is applied to forecast directions of future development. These sources may be: databases, websites, literature, patents, and expert panel discussions. Expert panels and „brainstorming" play a significant role in foresight exercises. Foresight projects are applied to various project levels – international, national, regional, local, technological.

In the case of foresight exercises for the CEE countries, the expert-based techniques (panels, brainstorming) and environmental scanning were employed. Structural cross-impact analysis was used to interpret obtained knowledge in the subject.

4.4. Structural cross-impact analysis – one of the foresight research methods (MicMac)

Cross-impact analysis is an expert-based method that forces attention to chains of causality to create a matrix of conditional probabilities. This matrix can be subject to mathematical analysis (via specialized software programs) to assign probabilities of occurrence to each of the possible scenarios resulting from the combinations of events.

The use of the cross-impact method is one of the various numbers of tools that can be used to organize and interpret subjective knowledge by means of rigorous collective and structured reflection about the interrelations between different elements within a particular system (UNIDO 2005). The MicMac method for structural analysis was used in the GEOCOM project. This software was developed and delivered by the Laboratory for Investigation in Prospective Strategy and Organization (LIPSOR). The method and dedicated MicMac software described below are partly based on information in MicMac Version 6.1.2 – 2003/2004 (MicMac 2014). The MicMac forecasting method was created by Michel Godet (Godet 2001).

Structural analysis is above all a tool for structuring ideas. It makes it possible to describe a system with the help of a matrix connecting all of its components. By studying these relationships, this method makes it possible to reveal the variables essential to the evolution of the system. It is possible to use it alone (as a help for reflection and/or decision making) or as part of a more complex forecasting activity (scenarios).

The structural analysis is conducted in three main phases:

Phase 1. Considering the variables affecting the development of the analyzed system within a specific time frame:

It is focused on considering all the variables that characterize the studied system (external as well as internal). It is recommended at this phase to be as comprehensive as possible and not exclude, *a priori,* any possible path of research. Detailed explanation of the variables is essential; it allows a better perception of the relationships between these variables further in the analysis. One finally obtains a homogeneous list of internal and external variables of the system (based on experience, it should not exceed 70 to 80 variables).

Phase 2. Finding of the relationships between the variables and their description – creating the Matrix of Influence:

In a systemic vision, a variable doesn't exist other than as part of the relational web with the other variables. Also, structural analysis allows for the connection of variables in a two-entry table/matrix (direct relations). This Matrix serves as an input to define key variables.

This entry of the Matrix is generally qualitative: 0 if there is no relation between variables I and J, and 1 in the contrary case. It is, however, possible to adjust the intensities of the relations (0 = null, 1 = weak, 2 = average, 3 = strong, P = potential). This phase of entry helps to put for N variables N × N questions, of which some would have escaped without such a systematic and comprehensive reflection. This procedure of questioning allows one not only to avoid errors, but also to order and classify the ideas by creating a common language within the group. It also gives the opportunity to redefine the variables and thus refine the system's analysis.

Every matrix of influence (and mean matrix) already filled up by an exercise player is analyzed by the MicMac software program(also applied for research described in this paper). It results in distinguishing several groups of the following factors:

- **Key factors:** combine high impact with a high degree of dependence thus indicating which actions should be given priority in the development of foresight strategic plans,
- **Targets and Results:** evolution of these factors will depend on how other variables of the system will develop,
- **Determinants, motors and brakes (Determinant variables):** have a very strong impact on the system, so they can act as drivers and inhibitors, but are very difficult to control. Knowledge of them is essential in the process of observing long-term trends in the study of the future,
- **Regulating factors, Auxiliary factors:** located near the center of the matrix and can help to achieve strategic objectives, but their effect on the whole system is not decisive,
- **Autonomous factors**: have the least impact on the changes taking place in the system as a whole.

Phase 3. Identification of the key variables for the evolution of the analyzed system in assumed time frame:

Key variables (factors) are the most crucial elements since they can act on the system. They have a high level of influence over behavior and development of the system and a high level of dependency.

Phase 3 consists of identification of the key variables (factors) by the experts; first, by *direct classification* (easy to realize), then by *indirect classification and potential indirect classification.*

The comparison of the results (direct, indirect and potential classification) gives the possibility to confirm the importance of certain variables, but also to reveal some variables which, because of their indirect actions, play a dominating role (and which the direct classification did not reveal). Therefore, the comparison of the hierarchy of variables in various classifications is rich in information.

The analysis of the interrelations among different elements within a particular system is essential for roadmapping and scenario planning, the methods of the final stage of the foresight process.

Among the advantages of the method one shall note that the first goal of structural cross-impact analysis is to stimulate thinking within the group and to initiate reflection on "counter-intuitive" aspects of the system's behavior. It is clear that there isn't just one and "official" reading of the MicMac results and it's appropriate for the group to move forward on the reflection with new interpretations (it's generally the objective of the following phase of the method, the scenarios). In addition, the method presents the advantage of allowing a qualitative study of extremely different systems.

The limits of this method concern the subjective character of the list of variables established in the first phase, just like that of the relations between the variables, consequently, the interest in communicating with the system's players. Moreover, the matrix of influences contains relationships of very different intensity that have to be considered during the work. Lastly, it is necessary to test the sensitivity of the results for a variation of the input data because these results should never be taken literally but only used to invite thought.

Structural analysis is a tool adapted for global thinking over a given sector. If 80% of the results obtained are obvious and confirm the first intuition, they specifically give the opportunity to put forward the 20% of "counter-intuitive" results.

5. Application of foresight techniques to energy sector – examples

Japan has been engaging in foresight since the 1970s. During the 1990s, foresight became much more widespread in many countries including in Europe. The complexity of the interrelation of the science, technology and society as well as depleting fund sources make it more difficult to take financial decisions. These factors contribute to the increasing popularity of foresight in governments, R&D and commerce institutions (Wójcicki and Ładyżyński eds et al. 2008).

The foresight projects concern many areas in the economy and in social life. Among the research directions in which foresight exercises were initiated were energetics on the global, state and regional level (often being correlated to the environmental protection and the use of natural resources). Some foresight exercises dealt with such issues as the applications of RES and other alternative energy sources, energy savings and efficiency and clean energy providing systems. The example projects are those being realized in the Czech Republic, United Kingdom, and Poland (Czaplicka-Kolarz ed. et al. 2007; Pyka and Czaplicka-Kolarz eds et al. 2011).

In the field of energy, a European regional foresight project was done in 2000-2004: the EueEnDel "Europe's Energy System by 2030" in the frame of 5th RTD Framework Program (Velte et al. 2004). The research proved that EU's long-term strategy in achieving its energy independence should include considerable RES applications with increased actions for energy savings and efficiency mainly by applying new production technology and energy-efficient buildings with intelligent energy supply systems (Czaplicka-Kolarz ed. et al. 2007).

The above may be recognized as important evidence that present development actions and foresight for geothermal are also justified. Energy foresight for Poland was done for 2005–2030 (Czaplicka-Kolarz ed. et al. 2007). This technique was also applied to elaborate scenarios of the development of "zero emission" energy economics until 2050 including RES and geothermal (Pyka and Czaplicka-Kolarz eds et al. 2011).

The GEOCOM project just attempted to apply some elements of the foresight method for the geothermal energy sector in CEE countries.

6. Basic groups of factors that may impact geothermal energy development in the Central and Eastern European countries in the coming years – through the consideration of the structural cross-impact analysis

6.1. Objectives, organization of research

In research embraced by the GEOCOM project the elements of the foresight approach and the structural cross-impact analysis method (supported by the MicMac software) were applied. The main objective was to identify, or at least to gain some data, on what factors might impact geothermal energy use development in seven CEE countries: Macedonia, Hungary, Italy, Poland, Romania, Serbia, and Slovakia in a 10–20 years' perspective.

The research applying a foresight-like approach and its outcomes can be regarded as being made on a regional scale, of mixed strategic-technological types, done by a panel of fourteen experts (appointed by the GEOCOM partners). The experts represented various groups of the community (the government and local authorities, science, industry and civil society) that was meaningful for the proper research course, following the basic foresight assumptions and obtaining halfway impartial results. Their knowledge (of quantitative and qualitative character) and the environmental scanning being carried out by experts and other GEOCOM partners were the up-to-date base for the foresight exercises. Then, selection, defining and verification of initial variables of some main groups were done.

The experts invented and suggested the variables (factors) which might affect the geothermal energy use development in the 10–20 years' prospective. There were several types of variables considered: political, technological, environmental, economic, social, and energy efficiency.

After discussions and verification, a final list of 32 factors (classified into 6 types) was composed.

Next, the Matrix of Influences was prepared, the pairs of variables were ranked by the experts, and then analyzed by the MicMac software. As a result several groups of factors were distinguished. As a third phase of cross-impact analysis, the key variables of for the evolution of the studied system were identified.

6.2. Factors selected for structural analysis and Mean Matrix of Influences (MicMac method)

Table 2 contains the final list of factors that potentially could affect the geothermal energy uses in the CEE countries in the future. It presents 32 factors (and their descriptions) which may have an impact on the analysed system (among these factors based on experts' ratings and data processing, there were extracted key factors – determiners, objectives, results and autonomous factors). Particular factors were ascribed to six main groups (types of factors), i.e.:

- ➡ Environmental,
- ➡ Technological,

- Economic,
- Social,
- Political,
- Legal.

These factors were placed in an excel file as a Matrix of Influences and filled by the experts by ranking the interactions between particular pairs of factors as follows:

0 = no influence, 1 = weak influence, 2 = moderate influence, 3 = strong influence.

The final list of factors served to prepare the Matrix of Influences to filled by the experts. The factors/variables were included for the MicMac software and formed subjects of further data processing. Based on the obtained data, the Mean Matrix of Influences was defined (fig. 2). It was calculated as an arithmetic mean of the data provided by particular Matrixes of Influence filled by individual experts.

TABLE 2. Final list of factors selected to further cross-impact analysis (MicMac method)

TABELA 2. Ostateczna lista czynników wybranych do dalszych etapów krzyżowej analizy wpływów (metoda MicMac)

No.	Factor name	Symbolic description	Description	Type of factor
1.	Availability of geothermal energy resources	AvaGeoRes	The prevalence (accessibility) energy carrier in the given area is crucial for the applicability of the technology. Technology can be widely applied only when the widely available energy source is used	Environmental
2.	Renewability of geothermal energy resources	RenGeoRes	Renewability of resources on a regional scale enables the safe dissemination of technology over sufficient time span	Environmental
3.	Possibility of combined cooperation of geothermal energy source with other primary energy carriers in one hybrid source	PosGeoHyb	Possibility of combined cooperation of geothermal with other primary energy sources often gives much better results that systems applying only one primary energy carrier. This contributes to optimization of energy resources' uses and production at lower costs (-> cheaper energy prices)	Technological
4.	Trans-boundary impact of geothermal energy exploitation	CorsBouEx	Unsustainable exploitation of geothermal reservoirs /covering several states/ may cause local disputes or conflicts	Environmental
5.	Costs of geothermal wells' drilling	CostDrill	Cost of drilling may affect economic efficiency of geothermal energy 'mining', its use and the level of exploration and recognition of available resources	Economic
6.	Level of public knowledge on possibilities and effects of rational energy use	LevKowRUE	Level of public knowledge on possibilities and effects of rational energy use	Social

TABLE 2. cont.

TABELA 2. cd.

No.	Factor name	Symbolic description	Description	Type of factor
7.	Consistency of dominating design parameters with available temperature of geothermal resources	ConsDesT	Consistency of heating systems design standards with available temperature of geothermal resources is of great importance for efficiency of their use. Consistency of design parameters and geothermal resources is referred mainly to temperature: if geothermal resources (water) are at a temperature at least equal as demanded for heat energy carrier then geothermal can be used directly, i.e. without e.g. heat pumps or gas boilers as auxiliary / peaking sources (which significantly increases already high capital expenditures)	Technological
8.	Availability of professional manpower specializing in the use of geothermal energy and rational use of energy (RUE)	StaffGeo	Human resources professional in technology used – number and level of knowledge of available professionals. This factor may reflect in costs and reliability of accessing to and exploitation of energy sources as well as RUE applying	Social
9.	Demand for final manufactured form of energy (heat or electricity)	DemFormEn	Demand for final manufactured form of energy – heat or electricity	Technological
10.	Mineralization of geothermal water (energy carrier)	MineralGeo	Mineralization of available reservoir fluids may affect the features and attractiveness of geothermal energy resources in two ways: 1. in the case of energy use it may be a serious technical problem; 2. in case of use for recreation and balneotherapy it may be an undeniable asset	Environmental
11.	Impact of exploited geothermal water / energy resources on local / regional development, eg. creating new jobs, enhancing tourism sector	InfluDevel	Start-up of geothermal investments, especially focused on spas and recreation, may help to increase the tourist and recreation offer of a given area/locality. This may result in creation of new jobs and region development	Social
12.	Disposal of spent geothermal fluids	DispUsedWat	Disposal of spent geothermal fluids is a big problem especially for large outflows and significant mineralization	Technical and Environmental
13.	Financial support for the operational phase	FinSupOper	Financial support for operational phase when energy is sold from geothermal systems (e.g. FiTs, green certificates)	Economic
14.	Financial support for the investment phase	FinSupInvest	Financial support for investment phase	Economic

TABLE 2. cont.

TABELA 2. cd.

No.	Factor name	Symbolic description	Description	Type of factor
15.	Improving the environment	ImprvEnvir	This factor describes the impact of geothermal energy exploitation on the environment. It shall cover all aspects – positive (eg reduction of emissions) and negative (eg pollution of surface water courses by cooled water discharge, emission of gases dissolved in water)	Environmental
16.	Energy security of countries and regions	EnSecurity	Security of energy supplies for countries and regions. Stability and reliability of energy supply. Independence from imported energy carriers	Political and Legal
17.	Failure frequency and environmental impact during potential failures	FailFreqImEn	Failure frequency and environmental impact during potential failures	Technical
18.	Social acceptability	SocialAccept	Social acceptability of the acquisition and use of energy carrier	Social
19.	Level of recognition of the resources	LevRecogRes	Degree of recognition of an energy resource	Technical
20.	Global development trends of energy recovery technologies	GlobTrenDev	Global development trends in energy sources' use may contribute to local intensification of use of some energy carriers and their technologies	Political and legal
21.	Impact on degradation of local distribution systems in case of their liquidation	ImpEnSysDeg	Introduction and dominance of some technologies may cause irreversible changes in the energy distribution system. This can lead to a lot of technical problems in case of desire to return to its original state. E.g.: promotion of local electricity generation systems causes disappearance of national electricity transmission system	Political and Legal
22.	Clarity and transparency of legal provisions related to geothermal energy use	ClearLegal	Clarity and transparency of legal provisions related to the use of geothermal energy	Political and Legal
23.	Political acceptance of geo-thermal resource and political will for its deployment	PolAcc	As a factor influencing the energy trends in the country	Political
24.	Pricing of supplied energy	EcSus	Price defines the sustainability (economical) of geothermal system, further development and investments	Legal and Financial
25.	Cascaded (multi-use) geothermal uses and their support from the state	CasUse	Support for multi-purpose use of a single geothermal source, use for different purposes (e.g. heat – spa and recreation, heat – agriculture)	Political and Legal Economic
26.	Possibility of combined cooperation of geothermal with other RES' source	PosGeoRen	The combination of low-temperature geothermal energy with other renewable energy sources for heat (or electricity)	Technical

TABLE 2. cont.

TABELA 2. cd.

No.	Factor name	Symbolic description	Description	Type of factor
27.	Unambiguous state energy concept (using different types of energy carriers and their support)	UnStaSup	Clear long-term access to use of energy resources from the state and clear public support for their use	Political and Economic
28.	Knowledge and awareness among highest-level politicians and decision makers	KnAwaPol	Knowledge and awareness among highest-level politicians and decision makers creates positive climate for legal, fiscal, regulations and give green light for proper investment decisions and market situation	Political and Economic
29.	Knowledge among potential investors, and designers of energy installations	KnInDes	Knowledge among potential investors, and designers of energy installations creates an indispensable base for considering geothermal energy as subject of investments and concrete technical design works	Technical
30.	Including geothermal energy in national/regional NREAPs and Energy Strategies	NREAES	Including geothermal energy in national/ regional NREAPs and Energy Strategies is a sine qua non condition for its development giving a background for decisions on investments	Political and Economic
31.	Geothermal drilling risk insurance fund / other insurance funds	GeoRisFu	Geothermal drilling risk insurance fund / other insurance funds increases the will to invest in geothermal projects by limiting the economic and technical risks	Economic
32.	Best practices technical and economic examples	BePrExa	Best practices technical and economic examples belong to best promoters of geothermal energy uses development	Economic

7. Results of structural cross-impact analysis

7.1. Identification of basic groups of factors that may impact future geothermal energy development

Based on data processed by the MicMac software, several maps/graphs presenting the results of structural cross-impact analysis were developed, e.g.:

- Direct influences – dependences map,
- Direct influences map,
- Displacement map,
- Direct–Indirect influence/dependence map.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG
1		1. AvaGeoRes	2. RenGeoRes	3. PosGeoHyb	4. CorsBouEx	5. CostDrill	6. LevKowRUE	7. ConsDesT	8. StaffGeo	9. DemFormEn	10. MineralGeo	11. InfluDevel	12. DispUsedWat	13. FinSupOper	14. FinSupInvest	15. ImprvEnvir	16. EnSeciurity	17. FailFreqImEn	18. SocialAccept	19. LevRecogRes	20. GlobTrenDev	21. ImpEnSysDeg	22. ClearLegal	23. PolAcc	24. EcSus	25. CasUse	26. PosGeoRen	27. UnStaSup	28. KnAwaPol	29. KnInDes	30. NREAES	31. GeoRisFu	32. BePrExa
2	1. AvaGeoRes		2	2	2	2	1	2	2	2	1	3	2	2	2	3	3	0	2	2	2	1	1	2	2	2	2	2	1	2	2	2	2
3	2. RenGeoRes	2		1	2	1	1	1	1	1	1	2	2	2	2	3	2	1	1	1	2	1	1	1	2	1	2	2	1	1	2	1	2
4	3. PosGeoHyb	1	1		0	1	2	2	1	2	1	2	1	2	2	2	2	1	2	1	2	2	1	1	2	2	2	2	1	2	2	1	2
5	4. CorsBouEx	1	1	0		1	2	1	1	1	0	2	1	1	1	1	2	1	2	2	1	1	1	2	1	1	1	1	1	1	1	1	1
6	5. CostDrill	1	0	2	1		1	1	2	1	1	1	2	1	3	1	1	1	2	2	1	1	1	2	2	1	1	1	1	2	2	2	2
7	6. LevKowRUE	1	1	1	1	0		0	1	1	0	1	1	1	1	2	1	0	3	1	1	1	1	2	1	1	1	1	2	1	1	1	1
8	7. ConsDesT	1	1	3	1	1	1		1	2	1	2	1	1	1	2	1	1	1	1	1	1	1	1	2	2	3	1	1	2	2	1	2
9	8. StaffGeo	1	1	2	1	2	2	1		1	0	1	1	1	1	2	1	2	2	2	2	1	1	1	1	2	2	1	1	2	1	1	2
10	9. DemFormEn	1	1	2	1	2	1	2	1		0	2	1	2	2	2	2	1	2	2	2	1	1	1	2	2	2	1	1	2	1	1	1
11	10. MineralGeo	1	1	2	1	1	1	1	0	1		2	3	1	1	2	1	2	1	1	1	1	1	1	1	2	1	0	1	1	1	1	1
12	11. InfluDevel	1	1	2	1	1	2	1	2	2	1		1	2	2	2	1	1	3	2	1	1	1	2	1	1	1	2	2	2	1	1	2
13	12. DispUsedWat	2	2	1	2	1	1	1	1	1	1	2		1	2	3	1	1	2	1	2	1	2	2	1	2	1	1	1	2	1	1	2
14	13. FinSupOper	1	1	2	1	1	1	1	1	1	1	2	1		2	2	1	1	2	1	1	1	1	1	2	1	2	1	1	2	1	1	2
15	14. FinSupInvest	1	1	2	1	2	1	1	1	2	1	2	2	2		2	2	1	2	2	1	1	1	1	2	2	2	2	1	1	1	2	2
16	15. ImprvEnvir	1	1	1	1	0	2	1	1	1	1	2	2	1	1		1	0	3	1	2	1	2	2	1	1	1	2	2	1	2	0	2
17	16. EnSeciurity	1	1	1	1	0	2	1	1	2	0	2	1	2	2	1		1	2	1	2	1	2	2	2	1	2	1	2	2	2	1	2
18	17. FailFreqImEn	1	1	1	1	1	1	1	1	1	1	2	1	2	2	2	1		2	1	1	1	1	2	1	1	1	1	1	2	1	1	2
19	18. SocialAccept	0	1	2	1	0	2	1	1	2	0	2	1	1	1	2	1	1		1	1	1	1	2	1	1	1	1	2	2	1	0	1
20	19. LevRecogRes	1	1	1	1	1	2	1	2	1	1	2	1	1	2	1	2	1	2		1	0	1	2	1	1	1	1	2	2	1	1	1
21	20. GlobTrenDev	1	1	2	1	1	2	1	2	2	1	2	1	1	2	2	2	1	2	1		1	1	2	2	2	2	1	2	2	2	1	1
22	21. ImpEnSysDeg	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	2
23	22. ClearLegal	1	1	1	1	1	2	1	1	1	1	2	1	2	1	2	1	1	2	1	1	0		2	2	1	1	2	2	2	2	2	2
24	23. PolAcc	1	0	1	2	1	1	1	1	1	0	2	1	2	2	2	2	0	2	2	1	0	2		2	1	1	2	2	2	2	2	2
25	24. EcSus	1	1	2	1	2	1	1	1	2	1	2	1	2	2	1	1	0	2	1	2	1	1	2		2	2	2	2	2	2	1	2
26	25. CasUse	1	1	2	1	1	1	2	2	2	1	2	1	2	2	2	1	1	2	1	2	1	1	1	2		2	1	1	2	1	1	2
27	26. PosGeoRen	1	1	2	1	1	2	2	2	1	0	1	1	2	2	2	1	1	2	1	2	1	1	1	2	2		1	2	2	2	0	3
28	27. UnStaSup	1	1	2	1	1	2	2	1	2	1	2	1	2	2	2	2	1	2	2	2	1	2	2	2	1	1		2	2	2	1	2
29	28. KnAwaPol	1	1	2	2	1	1	1	2	2	1	1	2	2	2	2	2	1	2	2	2	1	2	3	2	1	2	2		2	2	2	2
30	29. KnInDes	1	1	2	1	1	1	1	2	2	1	2	1	1	1	2	1	1	1	2	2	1	2	1	1	2	2	2	2		1	1	2
31	30. NREAES	1	1	2	2	1	1	1	2	2	1	2	1	2	2	2	2	1	2	2	2	1	2	2	2	1	1	2	2	2		2	2
32	31. GeoRisFu	1	1	1	1	2	1	0	1	1	1	2	1	1	3	1	1	1	1	2	1	0	1	1	2	1	1	1	1	2	1		1
33	32. BePrExa	1	1	2	2	1	2	1	2	1	1	2	2	2	2	2	1	2	2	2	2	1	2	2	2	2	2	2	2	2	2	1	

Fig. 2. The Mean Matrix of Influences (based on Matrixes of Influence fulfilled by individual experts). MicMac software calculations (the screen shot)

Rys. 2. Średnia macierz wpływów (uzyskana na podstawie indywidualnych macierzy wpływów wypełnionych przez ekspertów). Obliczenia oprogramowania MicMac (zrzut ekranu)

In particular, figure 3 shows the map of direct influences – dependences: taking into account the positions of each from the 32 particular factors considered, they were assigned into several groups:

- key factors,
- determinants,
- motors and brakes,
- other groups of factors which may potentially determine the development of geothermal energy uses in of the CEE countriesin the coming years.

Their description and some interpretation is presented below.

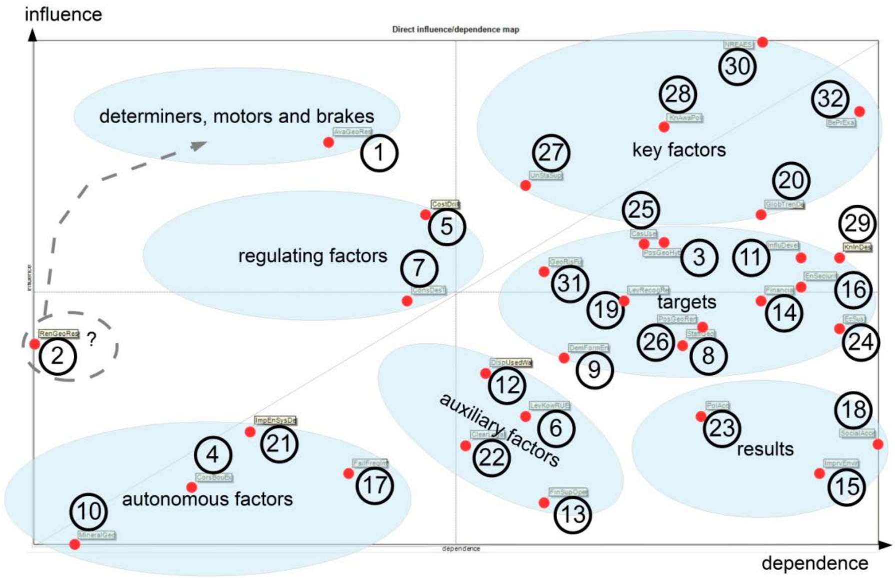

Fig. 3. Map of direct influences – dependences: allocation of analyzed factors to main groups (MicMac software calculations). Position of individual factor in each main group is marked by rectangle and dot, number refers to its detailed name and description given in table 2

Rys. 3. Mapa wpływów – zależności bezpośrednich: przydział analizowanych czynników do grup głównych (obliczenia oprogramowania MicMac). Położenie indywidualnego czynnika w każdej grupie głównej oznaczono prostokątem i kropką, numer odnosi się do jego szczegółowej nazwy i opisu w tabeli 2

Key factors

They will have the most significant impact if and how geothermal energy uses in the CEE countries will develop and the factors which should be given priority in the development of foresight strategic plans. Key factors are of political, legal and economic types (wherein some factors were assigned to two types):

- Political
  - Including geothermal energy in national/regional NREAPs and Energy Strategies
  - Knowledge and awareness among the highest-level politicians and decision makers
- Political & legal
  - Global trends in development of energy recovery technology
- Political& economic
  - Unambiguous state energy concept (using different types of energy carriers and their support)
  - A clear long-term access to permit for use of energy resources from the state and a clear system of public support for their use
- Economic
- Best practices technical and economic examples
- Knowledge and awareness among highest-level politicians and decision makers

Targets

Evolution of these factors will depend on how other variables of the system will develop. They also indicate what items, activities, and provisions should be considered and realized to contribute to the development of geothermal energy. This group is particularly reachable and includes 17 factors (53% of all factors concerned) of wide spectrum of types, i.e. political, legal, social, economic and technology types (some variables were assigned to two types):

- Political
  - Energy security of countries and regions
- Political& legal
  - Cascade options (multi-use) geothermal and its support from the state
  - Energy security of countries and regions
  - Pricing of the supplied energy
- Economic
  - Geothermal drilling risk insurance fund/other insurance funds
  - Cascade options (multi-use) geothermal and its support from the state
  - Impact of exploited geothermal water/energy resources on local/regional development, e.g. creating new jobs, enhancing tourism sector
  - Financial support for the investment phase
  - Pricing of the supplied energy
- Technology
  - Possibility of combined cooperation of geothermal energy source with other primary energy carriers in one hybrid source
  - Level of recognition of the resources
  - Cascade options (multi-use) geothermal and its support from the state
  - Knowledge among potential investors, and designers of energy installations
  - Demand for final manufactured form of energy (heat or electricity)
  - Possibility of combined cooperation of geothermal energy source with other RES' source
- Social
  - Impact of exploited geothermal water/energy resources on local/regional development, e.g. creating new jobs, enhancing tourism sector
  - Availability of professional manpower specializing in the use of geothermal energy and RUE.

Results

As in case of the Targets group, evolution of these factors will depend on how other variables of the system will develop. This group contains political, social and environmental factors:

- Political
  - Political acceptance of the geothermal resource and political will for its deployment
- Social
  - Social acceptability
- Environmental
  - Improving the environment

Determinants, motors and brakes

These have a very strong impact on the system, so they can act as drivers and inhibitors, but are very difficult to control. Knowledge of them is essential in the process of observing long-term trends in the study of the future. This group is represented by two *environmental* factors:

- Availability of geothermal energy resources
- Renewability of geothermal energy resources.

This result points out the sound role of "renewability" of geothermal energy, and – as one may suspect – several other features related to this adjective (e.g. local, clean, independent, assuring safety of supply, etc.) which are essential to develop both geothermal as well as other renewable sources of energy.

Regulating and Auxiliary factors

This can help to achieve strategic objectives, but their effect on the whole system is not decisive. These groups contain several political, legal, economic, technology, environmental and social factors:

- Political& legal:
  - Clarity and transparency of legal provisions related to the use of geothermal energy
- Economic
  - Costs of geothermal wells' drilling
  - Financial support for the operational phase (while Financial support for the investment phase was ascribed to Targets)
- Technology
  - Consistency of dominating design parameters with available temperature of geothermal resources
  - Disposal of spent geothermal fluids
- Environmental
  - Disposal of spent geothermal fluids
- Social
  - Level of public knowledge on possibilities and effects of rational energy use.

Autonomous factors

These have the least impact on the changes taking place in the system as a whole. Three factors were designated to this group:

- Political& legal:
  - Impact on degradation of local distribution systems in case of their liquidation
- Technology
  - Failure frequency and environmental impact during potential failures
- Environmental
  - Mineralization of geothermal water (energy carrier).

7.2. Main findings from structural cross-impact analysis

The research described above attempted to apply the approach of the foresight method and elements of structural cross-impact analysis in order to gain an insight into main factors that will impact and control the geothermal energy uses development in an RUE context in the GEOCOM countries in the future. Even if the research was a kind of preliminary and limited exercise, it did indicate for the complexity and importance of several various factors for the development in question. Moreover – it gave some thoughts as to the actions and direction which shall be considered if we are willing to enhance geothermal energy development and make it competitive with other energy sources.

Especially interesting was to indicate Key factors, Determinants and Targets. It seems that analysis and results pointed out the Key factors and Targets (even intuitively) are and will be important in the future, and many also playa role already.

The Key factors are essentially of the political and legal variety (!), not technological or environmental as one might initially expect. The expectations are focused on the need to change the situation with regard to these factors, as well as better awareness among top politicians and decision makers in many countries in order to create the proper political and legal environment for geothermal energy deployment in many CEE countries (because without this element there will be no real development).

In the case of Determinants, motors and brakes, two factors of environmental variety were identified: "availability" and "renewability of geothermal energy resources". However, one might expect that more factors of a different variety would show up in this group (political, legal, economic, technology), especially taking into account the initial objective and expectations as to cross-impact analysis in GEOCOM works. For example – one could expect that some factors (political, legal, and economic) now regarded as shortages or barriers (i.e. "brakes") for geothermal development would be included into this group. Instead, they were placed in Targets, which may be interpreted that in the future they shall be treated as subjects of concrete actions which need to be taken to remove them, thus paving the way to achieve for geothermal energy development in the CEE countries.

As already mentioned, the group of Targets identified is particularly rich, covering 17 factors (53% of all concerned) of different types: political, legal, social, economic, and technological (some variables were assigned to two types). This relatively large and diversified group confirms and indicates that several important items, activities, and provisions should be considered and realized in order to achieve the assumed objective, i.e. the development of geothermal energy in the CEE/GEOCOM countries. Indicating some factors included into the Targets, i.e. "the application of cascaded geothermal systems" was classified as one of the targets which should be pursued. To the same group of factors, another important variable assigned is "the possibility of combined cooperation of geothermal energy with other primary energy carriers in one hybrid source". It describes the possibility of integration with other sources of geothermal energy.

Among the Targets and Auxiliary factors identified were the factors of social types that confirmed their role for geothermal (as presented in separate GEOCOM report on "Public perception and understanding of geothermal energy"; www.geothermal communities.eu).

In the case of Autonomous factors, the cross-impact method indicated "the lack of negative impact on degradation of local distribution systems in case of their liquidation" on the development of geothermal district heating. Also "the failure frequency and environmental impact during potential failures" was included into this group. It may be interpreted that these factors were defined in this group also because such cases had been not frequent so far, rather incidental, are not known in general and, most likely, are expected not to have larger impact (especially considering that innovative and improved technologies minimizing potential negative impacts are expected in the future).

Closing remarks

The application of the foresight-like approach and elements of the structural cross-impact analysis method enabled the researchers to identify essential factors (and their types) that may impact the future development of geothermal energy in the CEE countries.

The resulting set of key factors may suggest a strong influence of political and legal factors of future geothermal energy development. Also significant is the group of targets(technological, economic, social), which indicates that focus will be necessary in this area to achieve the assumed objective (i.e. development of the mentioned sector).

The results are also useful to suggest some actions and solutions which could contribute to facilitate and improve current and future conditions for geothermal deployment ("shaping the future").

The research and analyses applying the foresight exercise and cross-impact analysis indicated and confirmed the conviction that a number of factors that had been identified as the present constraints and best practices, would control and impact future development of geothermal energy as well. It is therefore necessary to take appropriate actions, reduce barriers and implement measures that will facilitate the true development of this prospective sector now and in the future.

The research done as part of the GEOCOM Project attempted to apply (for the first time, most likely) the foresight elements, and obtained results encouraging enough to consider more comprehensive foresight research on geothermal issues in the future. Both the CEE and other European states are experiencing a great many challenges resulting from the current and predicted energy and political situation and such research would be very valuable. Some attempts in relation to RES and geothermal energy exist; they could be used as seed money for a possible concept.

Acknowledgements:

The paper presents some results of research conducted in the frame of the 7 FP EU co-funded Project "Geothermal communities – demonstrating the cascaded use of geothermal energy for district heating with small scale RES integration and retrofitting measures" (Contract TREN/FP7EN/239515/"GEOCOM"). The work is based on inputs provided by the GEOCOM project partners and experts from Hungary, Italy, Poland, Macedonia, Romania, Serbia, and Slovakia. All of them are acknowledged for their contributions.

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