DANUBE REGION strategy
Energy

Powering Europe

Danube Region Geothermal Report

NEW SZÉCHENYI PLAN

PREPARED BY
MFGI
Magyar Földtani és Geofizikai Intézet

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The countries of the EUSDR summarized in this report[1]

Austria

Bosnia and Herzegovina

Bulgaria

Croatia

Czech Republic

Germany (Baden-Württemberg and Bavaria)

Hungary

Romania

Serbia

Slovakia

Slovenia

[1] European Union Strategy for the Danube Region COM(2010) 715. Available at: http://www.danube-region.eu. As the deep geothermal potential of Montenegro, Moldova and the regions of Ukraine being part of the EUSDR are not prominent compared to the listed countries, country review is not provided for them in this document.

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2 Executive summary

The macro-regional approach of the EU has created a new planning level between the Union and the Member States. After three years of implementation, the Energy Priority Area (PA2) of the Danube Region Strategy has proved to be a successful platform for forming the common position of the Danube countries in several fields of energy. The macro-regional thinking cannot replace the efforts of the Member States but it can provide a comprehensive framework for the harmonized planning of national energy strategies.

The Energy Priority Area is engaged in gradually mapping out the current energy landscape of the Danube macro-region. After completing initiatives that had significant policy impact on the final list of the Projects of Common Interest (PCIs), namely the Danube Region Gas Market Model and the Gas Storage Analysis, the emphasis was put on renewables and electricity. The Priority Area applied the same approach that was successfully used for the gas market by initiating a joint thinking of the countries with the help of regional studies to summarize and present the current status and suggest further steps to promote the development of these renewable energy sources. Taking into account the limited resources available, the Energy Priority Area decided to prioritize and focus on those renewable sources of energy, which still offer significant untapped potential for the Region, i.e. biomass and geothermal energy.

The objective of the Danube Region Geothermal Concept, developed together with the former lead partner of the TRANSENERGY project, the Geological and Geophysical Institute of Hungary (MFGI), is to enhance the sustainable utilization of deep geothermal energy in the Danube Region with the ultimate aim to attract investors to the participating countries. In order to achieve this, the main targets are to provide a harmonized pool of national geothermal datasets, an overview of the current utilization and the potential, an evaluation of selected transboundary pilot areas and a comparison of regulatory and financial frameworks. Knowledge transfer on the implementation of related EU policies to non-EU states with high geothermal potential and with a focus on the INSPIRE regulation is also on the agenda.

The concept was discussed by 19 institutions representing 10 Danube Region countries in a workshop at the end of 2013. At the meeting each country presented its country profile (based on a pre-set template) and the participants jointly discussed the preliminary project idea. Most participants committed themselves to continue with the project as part of the project consortium.

Based on the workshop presentations and the questionnaires received from the workshop participants, MFGI has prepared this regional geothermal report as a first step of executing the Danube Region Geothermal Concept. The in-depth survey of 11 EUSDR countries highlights that due to the favorable geological conditions, the deep geothermal potential is significant in the region and a great diversity of use exists in the different countries from combined heat and power production (even though only at small pilot scales at a few sites), Hot Dry Rock (HDR) technologies targeting granitic rocks, to a large variety of direct heat applications including innovative solutions utilizing low temperature resources by the help of heat pumps. However in the majority of the countries the most common way of use of thermal groundwaters is still balneology, while direct-heat applications are subordinate, although reservoir conditions would be suitable in many places.

Although all countries have profound knowledge about their geothermal resources, the available information is still not sufficient enough. Both geothermal developers and policy / decision makers require detailed and up-to-date, scientifically based information on the available geothermal resources. The joint assessment of geothermal resources is important, as many of the large hydrogeothermal reservoirs in the Danube Region are in transboundary settings, where the abstraction of thermal groundwater may have negative impacts (depletion or overexploitation, even environmental issues) without harmonized cross-border management.

Overexploitation of some geothermal aquifers is a potential problem in several EUSDR countries. Furthermore, as the number of users is increasing, potential interference among the different sites and disputes between nearby users may also arise. Therefore, users and national authorities should as soon as possible establish unified and objective monitoring systems of geothermal resources, by controlling groundwater level, temperature, yield, and chemical composition of thermal water.

In most of the countries the lack / low share of reinjection is a straightforward consequence of the low share of energetic use. Reinjection wells represent a large investment cost, which – without suitable financial support – are not feasible for most of the users. However, due to the positive effects on aquifer hydraulic conditions and mitigation of environmental pollution, reinjection into the same aquifer should be required for all users utilising non-treated thermal water for the purpose of geothermal energy utilization.

Experts from several countries reported a set of technical problems, which are associated with the low thermal and utilization efficiency of the existing wells, however their improvement would lead to a reduction in the total amount of abstracted thermal water. With the more widespread use of heat-pumps, a great proportion of the heat content could be still utilized, which is otherwise wasted. Neither application of cascade systems is widespread, although it would have a direct impact on decreasing the need for additional thermal water, thus increasing utilization efficiency.

Reviewing the (renewable) energy policies, it can be concluded that all EUSDR countries acknowledge the importance of renewables. As the lifetime of a geothermal project is quite long (15-30 years), stable and reliable political and economic conditions are essential. Analysing the most important non-technical barriers, practically almost all EUSDR countries reported a fragmented regulatory system, where the management of geothermal resources and licensing of geothermal projects are shared among different ministries and authorities, most common between the "environment/rural development" sector dealing with abstraction of thermal groundwater, and the "energy /industry /economics" sector looking at geothermal energy utilization without water production. This makes licensing procedures complicated and time-consuming.

Another major obstacle is the lack of sufficient financial incentives (direct subsidies, funds, low interest loans, tax incentives, feed-in-tariff, off-take and support schemes for green-heat). A major missing instrument is the risk insurance system that would help to mitigate the high up-front costs of a geothermal project, where the risks are the highest at the stage of drilling the first wells.

The public awareness of geothermal energy should be increased everywhere. The possible negative impacts of geothermal energy production are often highlighted and misinterpreted, without emphasizing its definite advantages, thus political decision makers and potential investors are worried about the possible risks involved in implementing geothermal projects and social resistance often results in practical obstacles, such as significant slowdowns of the projects. To make sure that geothermal energy will play an important role in Europe's future energy supply, it is essential to engage with strategic groups including decision makers, possible investors into geothermal projects, the general public, and local communities in order to provide them reliable information, thus to relieve possible concerns which might hamper the increased use of geothermal technologies. This material will hopefully contribute to such efforts.

3 Introduction

3.1 Background and objectives of the Danube Region Geothermal Report

The Danube Region represents one fifth of the European Union's total area and covers 9 EU (Austria, Bulgaria, Croatia, Czech Republic, Germany, Hungary, Romania, Slovakia, Slovenia) and 5 non-EU countries (Bosnia and Herzegovina, Moldova, Montenegro, Serbia, Ukraine). The countries show significant regional disparities in economic and social development. In order to foster growth and strengthen cooperation at a macro-regional level, the European Union established the Danube Region Strategy, endorsed by the European Council in June 2011 [2]. The Strategy was jointly developed by the European Commission, the Danube Region countries and stakeholders in order to jointly address common challenges. The Strategy tackles various topics relevant for the region in a structured way through 4 pillars and 11 priority areas, one of which is the "Sustainable Energy Priority Area" (PA2), jointly coordinated by Hungary and the Czech Republic.

The coordination of regional energy policies - one of the 3 main actions of PA2 - also encompasses renewable energies. First the Danube Region Biomass Action Plan was established which provides a comprehensive analysis of the biomass potential, legal framework and regulatory environment of biomass utilization in the Danube Region. However it was realized that other renewable energy resources, especially geothermal energy also play an important role in the Danube Region.

Due to the favorable geological conditions, the deep geothermal potential is high in many areas of the Danube Region, especially in Baden-Württemberg, Bavaria, the eastern parts of Austria, Slovakia, Hungary, NE-Slovenia, Croatia, Serbia, Bosnia and Herzegovina, the western parts of Romania, parts of Bulgaria, etc. (Figure.1). Nevertheless, in the majority of the countries the most common way of thermal groundwater utilization is balneology, with direct-heat applications being subordinate (district-heating in Hungary, Romania, Serbia, to less extent in Austria, Croatia and Slovakia; in agriculture in Hungary, Serbia, Slovakia, Slovenia and Croatia), whereas power production hardly exists (Austria, Germany, Romania) (Table 1), although reservoir conditions would be suitable in many places.

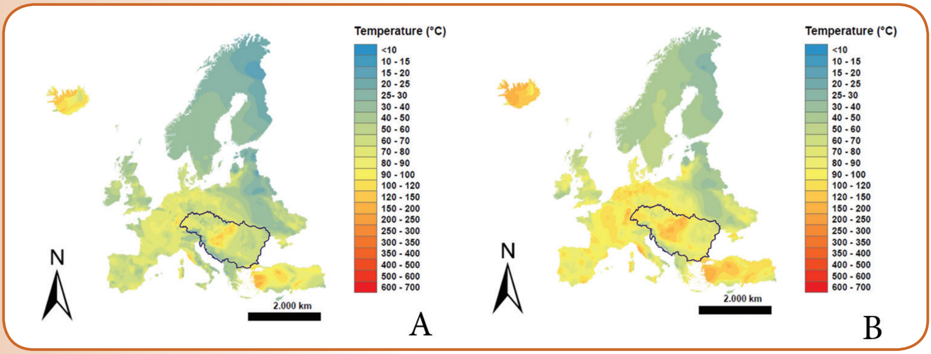

Figure 1: Temperature at a depth of 2 km (A) and 3 km (B) in the Danube Region [1]

	Geothermal power plants		Geothermal district heating plants		Geothermal heat in agriculture and industry		Geothermal heat in balneology and other	
	Installed capacity (MW_e)	Production (GWh_e/y)	Installed capacity (MW_t)	Production (GWh_t/y)	Installed capacity (MW_t)	Production (GWh_t/y)	Installed capacity (MW_t)	Production (GWh_t/y)
Austria	1,85	2,2	117,6	158,9	2	4,6	2,4	20,6
Bosnia and Herzegovina	0	0	0	0	1,6	11,25	19,94	59,36
Bulgaria	0	0	1,83	8,03	1,65	7,67	82,3	586,08
Croatia	0	0	36,66	NA	NA	NA	77,24	NA
Czech Republic	0	0	6,56	25	0	0	2,12	NA
Germany *	4,11	18,83	157,25	331,17	0	0	48	380
Hungary	0	0	132,97	339,65	250,14	825,066	312,37	1648,743
Romania	0,05	0,4	106,63	148,34	8	50	10	12
Serbia	0	0	53,646	231,254	16,955	82,881	55,595	258,41
Slovakia	0	0	27,5	NA	29,5	NA	73,6	NA
Slovenia	0	0	3,72	6,27	13,96	31,61	45,48	126,42

Table 1: The use of geothermal energy in the EUSDR countries (*Numbers of geothermal power and district heating plants of Germany refer to Baden-Württemberg and Bavaria, while numbers of balneology and other to the entire territory of the country)

The successful expansion of the geothermal market requires two basic conditions:

- available geothermal resources (supply side) and their in-depth geoscientific knowledge;
- an investment-friendly political and economic environment (supportive national strategic frameworks, transparent regulatory system, easy licensing procedures, available financial incentives, social acceptance, etc.).

Based on a thorough analysis of the EUSDR countries' deep geothermal resources and markets complemented by detailed data collection and consultations with experts from their respective governmental organizations (mainly national geological surveys, universities, scientific associations responsible for geothermal at a national level) this material provides the first macro-regional overview about the potentials and possible utilizations of deep geothermal energy in the Danube Region, also tackling some of the technical and non-technical barriers. This state-of-the art summary intends to raise the awareness on the sustainable use of the untapped geothermal resources and will provide useful information for decision makers, for investors interested in geothermal development in the region, as well as to the concerned public.

3.2 Geothermal energy in a nutshell

3.2.1 History of geothermal

The presence of volcanoes, hot springs, and other thermal phenomena must have led even our ancestors to assume that parts of the interior of the Earth were hot. Naturally discharging thermal waters have been widely used even in the ancient roman times and medieval ages mostly for balneological purposes, but the very first applications of using the heat content of thermal waters also date back to a very long time, shown by numerous historical remnants all across Europe and worldwide.

The use of hot steam/water systems for the generation of electric power is also more than a century old, the first geothermal power station with a 10kW generator has been accomplished in 1904 in the Tuscan Larderello, Italy. (Figure 2).

Figure 2: The world's first geothermal power station with a 10kW generator in Larderello dry steam field, Tuscany, Italy (Source: IGA)

3.2.2 Geothermal energy: definition and basic concepts

Geothermal energy, by definition (2009/28/EC - RES Directive) is the energy stored in the form of heat below the surface of the solid Earth. The heat content of the Earth is enormous: 99% of our planet's temperature is above 1000 °C. The estimated total heat amount of the Earth is $12{,}6 \cdot 10^{24}$ MJ.

This immense heat has several origins:

- "residual" heat of the Earth interior (mantle and core);
- continuously producing heat from the decay of radioactive isotopes: U^{238}, U^{235}, Th^{232}, K^{40};
- solar radiation (limited to 5-25 m below the ground).

Although the solid crust represents only 2% of the total volume of the Earth, it is rich in radioactive isotopes, therefore it provides most of the renewing heat production. The hot and viscous mantle represents the largest part (82%) of the total volume of the Earth, but due to the much smaller amount of radioactive isotopes, its role in average heat production is much less. The hottest core in the interior of the Earth accounts for 16% of the total volume, but contains no radioactive isotopes (Figure 3).

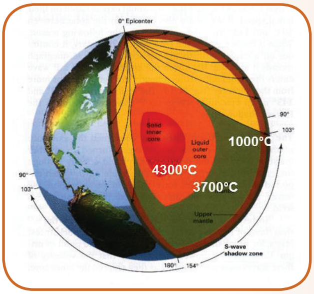

Figure 3: The interior structure of the Earth is layered in spherical shells, like an onion. It has an outer silicate solid crust, a highly viscous mantle, a liquid outer core, and a solid inner core (Source: IGA)

Modern thermal models of the Earth demonstrated that there is no equilibrium between the radiogenic heat generated in the Earth's interior and the heat that is dissipated into space via terrestrial heat-flow and that our planet is slowly cooling down. However the cooling process is very slow. The heat content of the Earth would take over 10^9 years to exhaust via global terrestrial heat flow, so it is practically inexhaustible on human-scales.

The fact that the temperature increases towards the depth was discovered in the 16-17th centuries when the first mines were excavated to a few hundred metres below ground level, and people had the simple physical sensation of rising temperatures. The geothermal gradient expresses the increase in temperature with depth in the Earth's crust. In continental areas the average geothermal gradient is 33 °C/km, while in tectonically active, or volcanic regions it can be as much as 500°C/km.

3.2.3 Geodynamics and geothermal

The planet Earth consists of a crust, which reaches a thickness of about 20-65 km in continental areas and about 5-6 km in oceanic areas, a *mantle*, which is roughly 2900 km thick, and a core, about 3470 km in radius (Figure 3). The outermost rigid shell of the Earth, known as the *lithosphere*, is made up of the crust and the upper layer of the mantle, which thickness is less than 80 km in oceanic zones and is up to 200 km in continental areas. Below the lithosphere, the 200-300 km thick hot and plastic *asthenosphere* is found. Because of the difference in temperature between the various parts of the asthenosphere, extremely slow (a few centimetres per year) convective movements are present, which are maintained by the heat produced by the decay of the radioactive isotopes and the heat coming from the deepest parts of the Earth.

In oceanic areas, where the lithosphere is thinner, it is pushed upwards and broken by the very hot, partly molten material of the ascending asthenosphere (Figure 4). This mechanism creates *spreading ridges* that extend for more than 60 000 km beneath the oceans, emerging in some places (Azores, Iceland) and even creeping between continents, as in the Red Sea.

The continuous formation of the new oceanic crust along the spreading ridges has caused to drift apart its two branches in opposite directions at a rate of a few centimetres per year. Since the Earth's surface cannot expand, the newly forming oceanic lithosphere along the spreading ridges must be accompanied by a comparable shrinkage in other parts of the globe. This is happening in the *subduction zones*, which are indicated by huge ocean trenches, such as those extending along the western margin of the Pacific Ocean and the western coast of South America, where the oceanic lithosphere folds downwards and plunges under the adjacent cold continental lithosphere with higher density, and re-descends to the very hot deep zones, where it is „digested" by the mantle and the cycle begins all over again (Figure 4).

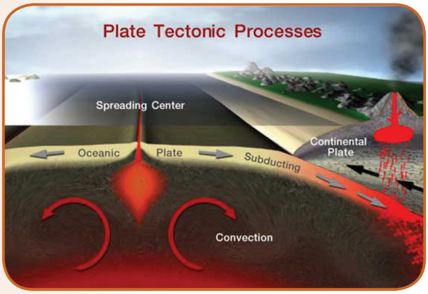

Figure 4: Schematic sketch of plate tectonic processes (Source: IGA)

Part of the digested lithospheric material returns to a molten state and may rise to the surface again through fractures in the crust forming *magmatic arcs* (volcanoes) parallel to the trenches (Figure 4).

Spreading ridges and subduction zones form a vast network that divides our planet into six immense and several other smaller lithospheric plates, which – due to the above described mechanisms: spreading and subduction – are moving against each other very slowly, shifting their positions continuously. The margins of the plates correspond to weak, densely fractured zones of the crust, characterised by an intense seismicity, by a large number of volcanoes and, because of the ascent of very hot materials towards the surface, by a high terrestrial heat flow. Therefore the most important geothermal areas are located around these plate margins (Figure 5).

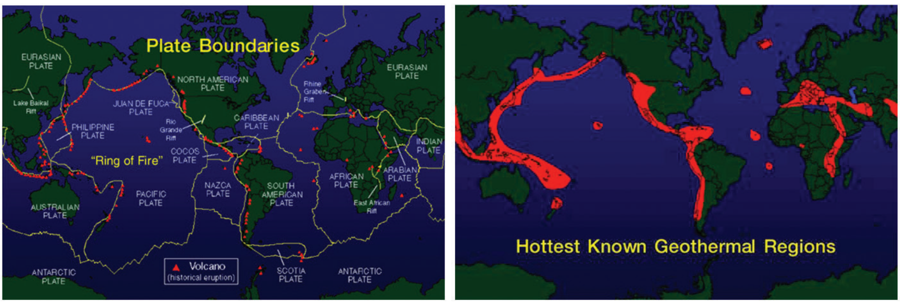

Figure 5: Plate boundaries and related hottest geothermal regions (Source: IGA)

3.2.4 How to classify geothermal resources?

The thermal energy of the Earth is immense, but only a fraction could be utilized by mankind. There are several ways how to classify geothermal energy. One most obvious way is according to the temperature of the geothermal reservoir. A geothermal reservoir can be defined as „a part of the geothermal field that is so hot and permeable that fluid or heat can be economically exploited. Rock that is hot, but impermeable is not part of the reservoir." [3]. We can differentiate between high- and low temperature reservoirs.

High-temperature (HT): >100°C

- geothermal steam reservoirs (dry, wet steam);
- heat source: mainly magma in magma chambers located at shallow depths (reaching the surface as lava during volcanic eruptions).

Low-temperature (LT): < 100°C

- hydrogeothermal reservoirs;
- heat source: mainly heat flux of the Earth;
- low-temperature systems and related hydrogeothermal reservoirs occupy much larger areas.

It is also possible to classify geothermal energy according to the type of the resource. So far the most common way of utilization of geothermal energy has been limited to areas in which geological conditions provide a carrier/medium (water in the liquid phase, or steam) to "transfer" the heat from deep hot zones to near-surface. In these *hydrogeothermal systems* the large scale regional groundwater flows are governed by convection. Heating from the Earth interior causes thermal expansion of the subsurface fluids causing lower density, and therefore their rising along permeable pathways, e.g. faults. Usually cold water from precipitation with higher density and higher hydraulic potential recharges the systems (Figure 6).

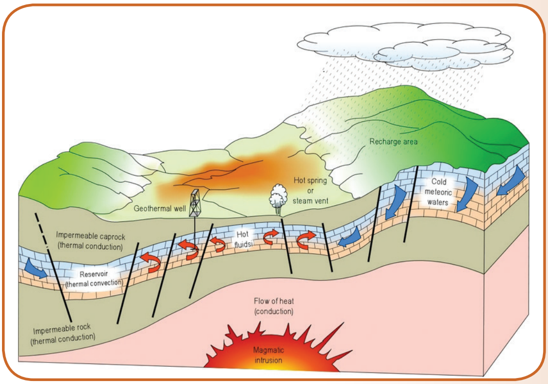

Fig. 6: Schematic sketch of a hydrogeothermal system: thermal groundwater forms large-scale convectional flows in the deep subsurface, rainwater recharges the system (Source: IGA)

A new emerging technology is represented by the *Enhanced Geothermal Systems (EGS)*, where the extraction of heat energy happens by circulating water via production and reinjection wells through artificially created fractures (by hydraulic fracturing) in massive hot rock volumes in the deep subsurface (Figure 7).

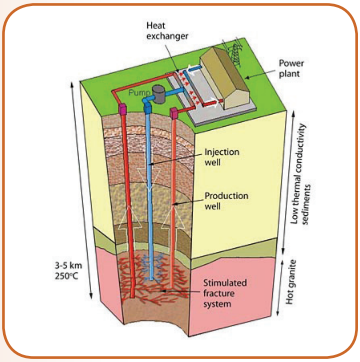

Figure 7: Schematic sketch of an EGS system: water is circulated via an artificially created fracture system in the deep-lying hot rock volume (Source: IGA)

3.2.5 Utilization of geothermal energy

The temperature of the geothermal resources also determines their possible utilizations, which is best represented by the so called Lindal diagram (Figure 8).

Efficient electricity generation can happen only from high-temperature resources (>150°C) by conventional steam turbines. However lower temperature resources (100-150 °C) may also be suitable for power generation in the so called binary plants. In these plants the geothermal fluid heats a secondary working fluid that has low boiling point and high vapour pressure at low temperatures (organic fluid in a Rankine cycle – ORC, or water-ammonia mixture in a Kalina cycle) through heat exchangers in which this fluid is heated and vaporised. The produced vapour drives a flow turbine, then it is cooled and condensed, and the cycle begins again. Binary plants have relatively low efficiency in power generation (around 10%), however they are often combined to utilize the waste heat (combined heat- and power plants – CHP) making them more economic.

Direct heat use is one of the oldest and most common form of utilization of geothermal energy. In addition to bathing, space and district heating, agricultural applications, aquaculture and some industrial uses are the best known ways. Utilization of low-temperature resources (<30°C) is also feasible, however requires heat pumps.

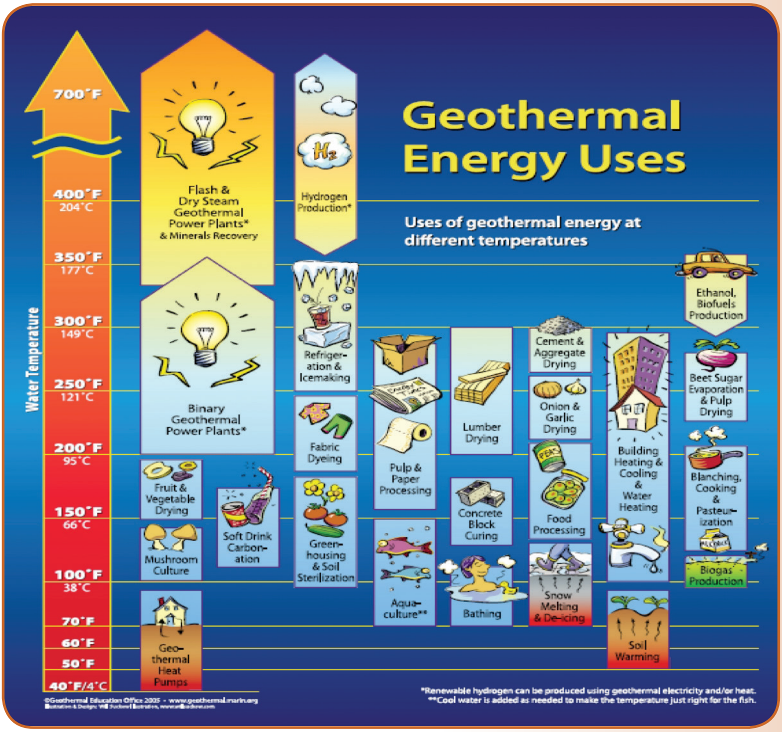

Figure 8: Temperature ranges determining the possible utilizations are best represented on the Lindal diagram (Source: IGA)

Geothermal resources can be utilized in the most efficient way in cascade systems, where the plants are connected in series, each utilising the waste water from the preceding one (e.g. electricity generation – industrial uses – district heating – agriculture applications) (Figure 9).

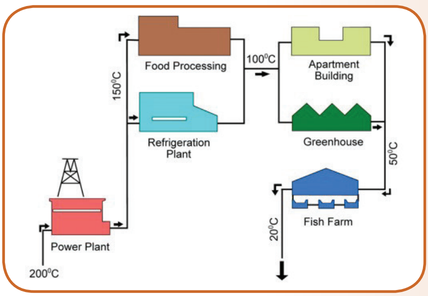

Figure 9: Cascade utilization of geothermal energy (Source: IGA)

3.2.6 Geothermal energy and the environment - sustainable use of resources

Although geothermal energy provides a stable and reliable heat supply 24 hours a day, 365 days a year in contrast with some other renewable energy sources (RES) and generates few or none greenhouse gas emission, it has some potential environmental impacts. Exploitation of high-pressure reservoirs may cause well blow-outs. Geothermal power plants operate at high noise-level and some poisonous gases being part of the steam may pollute the air. Nevertheless the most important environmental impact is related to disposal of used thermal waters on the surface, where these might endanger the surface ecosystems by their high temperature and/or dissolved content. The question of *re-injection* goes beyond environmental issues and also raises concerns associated with reservoir management.

The sustainable production of geothermal energy refers to a balanced fluid/heat production, i.e. not producing more than the natural recharge re-supplies. For each geothermal system and for each mode of production a certain level of maximum energy production exists, below which it will be possible to maintain a constant energy production from the system for a very long time (100 - 300 years) [4, 5]. However these production rates are limited and often not economical for use and re-injection might be necessary to increase these rates and to compensate the limited natural recharge, as well as the dropping reservoir pressure and yield. In these cases the heat-depleted geothermal water is re-injected back to the same reservoir, where it warms up in the depth, and thus makes the repeated exploitation of the enthalpy of the rock matrix possible (Figure 10).

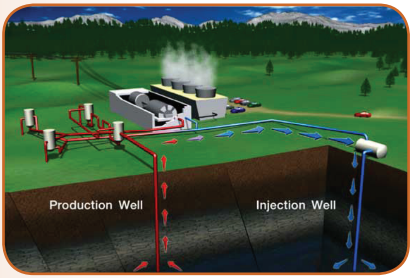

Figure 10: Production and re-injection well form a doublet, which makes the repeated utilization of the heat content of the rocks in the deep subsurface possible (Source: IGA)

In addition to maintaining suitable reservoir conditions, the other major aspect of re-injection is the protection of surface aquifers and ecosystems. The used thermal waters of high temperature and dissolved material content released into rivers or lakes are increasing the heat load and pollution of surface waters and the geological environment.

Although injection of heat-depleted brines into reservoirs has been used for a long-time in the hydrocarbon industry (enhanced oil recovery), it still cannot be considered as a mature technology in the geothermal sector. Re-injection is relatively simple into fissured carbonate reservoirs, where major subsurface conduits provide permeable pathways. Nevertheless in sandstone reservoirs the necessary injection pressure can substantially increase within a relatively short time. The most common reasons are the plugging of screens (perforation) in the well and pore throats of the reservoir formation. The permeability may decrease due to clay swelling, pore-space blocking by fine particles, or precipitation of dissolved solids due to the mixing of injected and formation water.

4 European geothermal energy policy framework

This chapter provides a brief summary on the most important elements of the European policy framework regarding renewable energies, especially geothermal energy. Clear targets are set only for 2020, while climate and energy goals are less explicit for 2030 and even vaguer beyond. After a short overview of these, a brief sum-up follows on the most important documents and policy papers prepared by different international organizations, providing in-depth analyses on the main research priorities, technology roadmaps and future development trends of geothermal energy in Europe until 2030-2050. Finally an introduction to the Water Framework Directive is presented, which has strong links to the management of thermal aquifers, thus to hydrogeothermal resources.

4.1 Towards 2020

4.1.1 Green Paper: A European Strategy for Sustainable, Competitive and Secure Energy

In March 2006 the European Commission released a new European energy strategy [COM 2006/105], which set out the new energy landscape of Europe, outlined questions to debate and suggested possible actions at European level. The strategy defined three main objectives, namely sustainability, competitiveness and security of supply. To meet these objectives it put forward concrete proposals and measures. The new policy aimed to encourage the development of competitive and effective renewable energy sources.

4.1.2 The EU climate and energy package – the EU 2020 targets

In March 2007 the EU leaders set concrete targets aiming to reduce greenhouse gas emissions, to increase the EU's energy security and sustainability and to strengthen its competitiveness to help the EU becoming a highly-efficient and low carbon economy. Together with other papers [COM (2006) 848: Renewable Energy Road Map - Renewable energies in the 21st century: building a more sustainable future; COM (2010) 639: Energy 2020 - A strategy for competitive, sustainable and secure energy] these documents set out the long-term strategy of the Commission for renewable energy in the European Union.

The three main objectives are:

- A 20% reduction in EU greenhouse gas emissions from 1990 levels;
- Raising the share of EU energy consumption produced from renewable resources to 20%;
- A 20% improvement in EU energy efficiency.

4.1.3 Directive on the promotion of the use of energy from renewable sources

Directive 2009/28/EC is part of a package of energy and climate change legislations which provides a legislative framework for EU targets regarding greenhouse gas emission savings. It encourages energy efficiency, energy consumption from renewable sources and the improvement of energy supply. Each Member State has a target calculated according to the share of energy from renewable sources in its gross final consumption for 2020. This target is in line with the overall '20-20-20' goal for the EU.

The Member States were to prepare national action plans which set the share of energy from renewable sources for 2020. These action plans must take into account the effects of other energy efficiency measures on final energy consumption (the higher the reduction in energy consumption, the less energy from renewable sources will be required to meet the targets).

The progress of reaching the goals set in the NREAP's has to be reported every second year from 2011 onwards to see how far the EU has got in reaching the policy targets. In accordance with the reporting requirements of the Member States, the European Commission publishes a Renewable Energy Progress Report every second year.

Each Member State must be able to guarantee the origin of electricity, heating and cooling produced from renewable energy sources.

4.2 Towards 2030

4.2.1 Green Paper „A 2030 framework for climate and energy policies"

The Green Paper "A 2030 framework for climate and energy policies" [COM 2013/169] adopted by the European Commission in March 2013 has launched a public consultation on the contents of the 2030 climate and energy policy framework.

The EU has a clear framework up to 2020 and is making a good progress towards meeting its climate and energy targets. To provide clarity on a policy framework for 2030, the consultation asked for insights and viewpoints on the basis of a set of questions – e.g. relating to the main lessons from the 2020 framework; type, nature and level of climate and energy targets for 2030; coherence between different policy instruments; competitiveness and security of energy supply; and distribution of efforts between Member States.

Although geothermal energy is not mentioned specifically in the Green Paper (while references are made to renewables), the European Geothermal Energy Council (EGEC) addressed several questions. Their response – among others – stated that to dismantle the main barriers to the development of a European grid, it is crucial to simplify national/regional regulations and administrative procedures related to geothermal power and to adopt a licensing procedure that also clarifies the geothermal resource ownership.

The still existing unfair competition on the market was also highlighted by the EGEC response: at present all EU electricity and gas markets, except in Nordic countries, remain national in economic sense and they do not provide customers with a real alternative to the nationally established suppliers, therefore there is no effective internal renewable electricity market for renewables to compete in. By addressing this issue, the major advantage of geothermal energy, i.e. its availability all day and night throughout the year, was highlighted.

4.3 Towards 2050

4.3.1 A Roadmap for moving to a competitive low carbon economy in 2050

Within the framework of initiating a resource-efficient Europe [COM (2011) 21, COM (2011) 571] the European Council has given a long term commitment to the decarbonisation path with a target for the EU and other industrialized countries of 80 to 95% cuts in emissions by 2050 [COM(2011) 112]. In order to guarantee that Europe achieves its long-term emissions reduction ambitions, policies promoting renewable energy must be extended. This will not only ensure meeting emissions reduction targets, but also stimulate further development of innovative solutions, create new job opportunities, maintain Europe's first mover advantage in renewable energy technologies, and unlock private investments, especially needed in times of limited public budgets.

However, as stated by EGEC, to reach these ambitious goals, some barriers have to be dismantled as well, e.g. the externalities of energy production should be adequately internalised, subsidies to fossil fuels and nuclear should be removed, new binding RES targets should be established for 2030 with a sectorial approach (electricity, heating & cooling, transport) and the competition on the electricity market must be improved.

4.3.2. Energy Roadmap 2050

In this Roadmap [COM (2011) 885/2] the Commission explores the challenges posed by delivering the EU decarbonisation objective (to cut the domestic energy-related CO2 emissions of the EU by 85% by 2050) while at the same time ensuring security of energy supply and competitiveness via the analyses of different scenarios. One of the scenarios is 'High Renewable Energy Sources' leading to a very high share of RES in gross final energy consumption (75% in 2050) and a share of RES in electricity consumption reaching 97%.

However, as pointed out by EGEC, this document underestimates the tangible development of geothermal electricity technologies, notably Enhanced Geothermal Systems (EGS), which will allow the full deployment of geothermal power anywhere in Europe. It also disregards the fact that geothermal has the best load factor of all energy technologies (>80%). The large benefits provided by geothermal electricity in terms of costs and grid management have not been highlighted either in the document. Geothermal does not have external costs such as storage, grid and supply infrastructure, or waste management. It also provides flexible and renewable baseload that can operate around the clock and ensures system stability.

Although the Roadmap mentions renewable heating and cooling, the accompanying impact assessment does not contain a comprehensive analysis of the heating and cooling sector, where geothermal energy will become a key player. With 43%, heating and cooling gives by far the largest share of the final energy consumption in Europe. This sector is not only huge in size but also already provides low- or no-carbon solutions including geothermal, which is vital to decarbonisation (there are already 216 geothermal DH systems in operation in Europe and 157 in the EU-27).

4.4 Position papers, research agendas, technology roadmaps on the future of geothermal

There is a great range of different documents [6, 7, 8, 9, 10, 11] that provide in-depth analyses on the main research priorities, technology roadmaps and future development trends of geothermal energy in Europe till 2030-2050, prepared by the European Geothermal Energy Council (EGEC), the European Renewable Energy Council (EREC), the Renewable Heating-Cooling Platform, the International Energy Agency (IEA) and the International Panel on Climate Change (IPCC). The overview of these documents goes beyond the scope of the present material, but some of the most important statements are summarized below:

- The concept of Enhanced Geothermal Systems (including the classical Hot-Dry-Rock idea) will tremendously increase potential.
- Innovative power plants permitting the production of electricity using low thermal water temperatures of the order of 100 °C, with larger plants using clusters of wells, and for micro-generation will also gain importance.
- Developing hybrid systems for heating & cooling but also for electricity (benefitting from the geothermal base load ability) with biomass, solar, etc. are also promising for the future.

- Improvements of drilling technologies (adaption of hydrocarbon drilling advances), novel drilling concepts especially in high-temperature and high-pressure environments and new well completion ideas will enable to deploy deep high-enthalpy reservoirs.
- Improving plant efficiency, decreasing installation and operation costs, development of user-friendly software tools for the design and management of heating and cooling systems are foreseen.

4.5 Other relevant policies

4.5.1 EU Water Framework Directive

The 'Directive establishing a framework for Community action in the field of water policy' (Directive 2000/60/EC - EU Water Framework Directive or WFD) is a firm and definite step away from "water treatment principle" towards an "integrated water management", where the principles "precautionary", "sustainable development" and "polluter-pays" are emphasized. The WFD establishes important milestones to 2015 when its environmental goals have to be reached, i.e. there is sufficient quantity of water (surface and groundwater) in good quality, not only for human consumption, but also to supply the water dependent ecosystems.

In the case of groundwater the term "groundwater body" is introduced and defined as a "distinct volume of water within an aquifer". As thermal groundwater aquifers / groundwater bodies constitute hydrogeothermal reservoirs, therefore it is obvious that during exploitation of hydrogeothermal reservoirs (for energetic purposes), the main principles of the Water Framework Directive (i.e. keeping the aquifers in good quality and quantity status, see below) have to be taken into account.

According to the WFD, groundwater is in good quantitative status if the available groundwater resource is not diminishing by the long-term annual average rate of abstraction. Alterations to flow direction resulting from level changes may occur temporarily, or continuously in a spatially limited area, however such reversals should not cause saltwater, or other intrusions, and should not indicate a human induced change in the subsurface flow direction.

Thermal groundwater abstraction could provoke the alteration of natural water level regime in such a way that natural springs' discharge is diminished. Overexploitation of thermal groundwater could cause "mining" of water resources (no natural replacement from recharge) and therefore a decrease of available groundwater resource, or could cause the intrusions of less suitable water from neighbouring aquifers.

The good chemical status of groundwater is reached when the concentration of pollutants does not exceed the quality standards, diminish the ecological quality of surface water or cause any significant damage to terrestrial ecosystems. These provisions are less relevant for deep-seated thermal groundwaters. Nevertheless the quality status of groundwaters becomes an important aspect when considering reinjection of thermal waste water, which has to be taken into account during the utilization of geothermal energy.

The first EU regulation on groundwater (Council Directive 80/68/EEC of 17 December 1979 on the protection of groundwater against pollution caused by certain dangerous substances) had its actions limited on the control over emission of substances from industry and urban sources. WFD and the actual daughter directive 2006/118/EC of the European Parliament and of the Council on the protection of groundwater against pollution and deterioration (adopted 12 December 2006 – Groundwater Directive - GWD) is definitely establishing the "emission" principle. This means that any pressure (emission, input) to the water body should not cause any significant actual or future impact on the groundwater body. Any direct discharges of pollutants into groundwater are prohibited, while reinjection of water used for geothermal purposes into the same aquifer may be authorized under specific conditions provided that such discharges do not compromise the good quality status of groundwater.

Comparing the two most relevant EU Directives (Renewable Energy Directive - RED and WFD) in relation to hydrogeothermal resources, the different objectives, measures and time-frames of the policies are striking (Table 2): the WFD is focusing on the protection of resources (i.e. achieving and maintaining the good status of waters by 2015), while the RED puts the maximum utilization of resources in focus, in line with the target numbers of the National Renewable Energy Action Plans (NREAP).

	Water policy (2000/60/EC - WDF)	**Energy Policy (2009/28/EC - RED)**
target	groundwater within aquifer, groundwater body	heat energy stored below the subsurface
objective	achieving and maintaining good (quality and quantity) status (constant level, no intrusions, etc.)	increase the proportion of RES/geothermal
framework	national River Basin Management Plans (groundwater body delineation and status assessment, monitoring)	National Renewable Energy Strategy and NREAP (programs of actions and incentives)
competence of governmental bodies	ministries of "environment"	ministries of "energy and economics"
time frame	2009 – 2015 – 2021 –	2010 – 2020 – 2030

Table 2: Comparison of European water management and energy policies

5 The current state of deep geothermal energy in Europe - a framework

In 2012 the total installed capacity was around 1.71 GW_e producing 11.38 TWh of electric energy every year. There were 62 geothermal power plants is Europe, with 48 of these located in EU Member States, mainly in Italy (Figure 11) [12].

It can be seen that EUSDR countries are practically not represented.

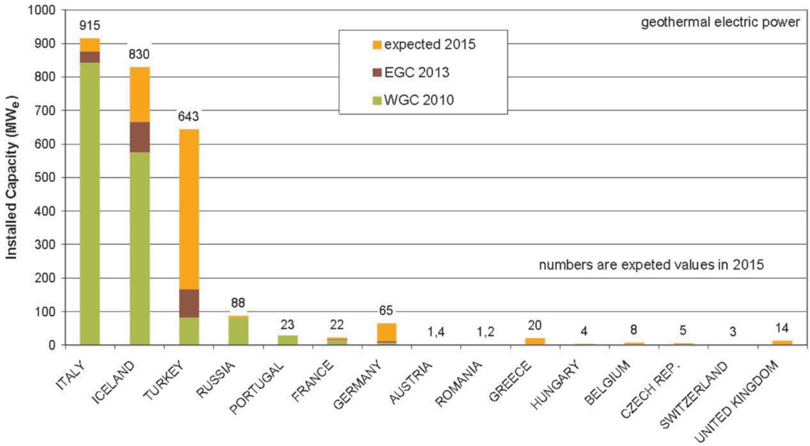

Figure11: Installed geothermal power in Europe. WGC 2010 refers to numbers reported at the World Geothermal Congress 2010 in Bali, whereas EGC 2013 to numbers reported at the European Geothermal Congress 2013 in Pisa, Italy [13]

In 2012 there were 216 geothermal district heating (Geo-DH) systems in operation in Europe with a total installed capacity of 4700 MW_{th}. 157 Geo-DH systems were installed within the EU-27 displaying a total installed capacity of 1622 MW_{th} (Figure 12) [12].

The heating and cooling sector represents nearly half of the energy demand, so the decarbonisation of this sector is of primary interest, in which geothermal energy can play an important role. The hot Geo-DH markets within the EU are Italy, Germany, France and Hungary, but Geo-DH systems can be installed in all European countries. Systems can be small (0.5-2 MW_{th}) developed and managed by local authorities, or large ones (over 50 MW_{th}) with higher capital costs operated by utility companies. With developing new technologies Geo-DH systems can utilize shallow geothermal (low temperature) resources assisted by heat pumps.

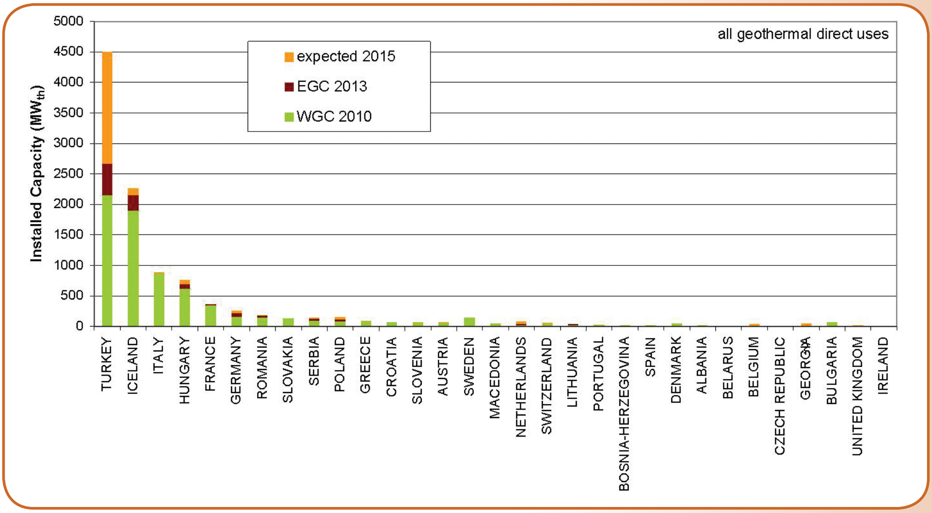

Figure 12: Installed capacity in geothermal direct use in Europe. WGC 2010 refers to numbers reported at the World Geothermal Congress 2010 in Bali, whereas EGC 2013 to numbers reported at the European Geothermal Congress 2013 in Pisa, Italy [13]

6 Assessment of the EUSDR countries

6.1 Methodology of data collection

As a first step countries/regions with prosperous deep geothermal conditions in the Danube Region have been identified using publicly available information (publications, online search, etc.). These are: Austria, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Germany, Hungary, Romania, Serbia, Slovakia and Slovenia. As the deep geothermal potentials of Montenegro, Moldova and the regions of Ukraine being part of the EUSDR are not prominent compared to the above listed countries, country review is not provided for them in this document.

After the selection of countries with promising deep geothermal potential, governmental institutions (national geological surveys, ministries, agencies) and research organizations (e.g. universities, geothermal associations) dealing with the exploration of geothermal energy and being authorized to handle national geoscientific datasets were contacted with the assistance of the EUSDR PA2 Steering Committee. A detailed questionnaire requesting information on the resources, utilization and most important technical and non-technical barriers of geothermal development in each country was sent to these institutions.

Parallel to this, a preliminary summary was made for all selected countries based on the country update reports (CUR), compiled by the national geothermal experts of each country for the International Geothermal Congress, organized by the International Geothermal Association (IGA) every 5 years. 2013 was a special year, as the European Geothermal Energy Council (EGEC) launched the European Geothermal Congress, therefore similar country update reports were compiled for the majority of the EUSDR countries, providing the most concise and up-to-date country information [14-24].

On 28 November, 2013 a one-day workshop was organized in Budapest, at the Geological and Geophysical Institute of Hungary, where altogether 38 participants attended from 10 EUSDR countries. The aim of this workshop was to discuss the current questions related to the exploration and exploitation of geothermal energy in the Danube Region, and also to establish a project consortium which may submit a project proposal at a later stage about the sustainable utilization of deep geothermal energy. Based on the preliminary literature survey, the outcomes of the workshop and the infilled questionnaires, the following chapter provides a concise summary on the state-of-the art of the geothermal energy resources and utilization in the EUSDR countries. Furthermore a short information is provided on the renewable energy policy targets, the regulatory framework and available financial incentives.

As the long-term goal is to set up a Geothermal Information System for the Danube Region that provides access to relevant data for exploration and exploitation of geothermal energy, it was essential to make an overview on the availability of data in each country, which has not been compiled before. Therefore the questionnaire also asked for the main types of information that are necessary to start-up a geothermal project, and whether data are existing and/or publicly available (Table 3). The short country profiles also contain brief information on the national data policies.

Although countries are introduced in a uniform structure, some disparities may arise from the uneven data availability and sporadic information.

	Existing	Public
Temperature data in the subsurface (e.g. oil and gas borehole BHT/DST).		
Temperature maps at depth (Available depth?) 500, 1000, 2000 m		
Surface heat flow measurements and map		
Thermal spring analyses (physical and chemical, e.g., temperatures, pH, chemical elements, geothermometers)		
Geothermal reservoir temperature in high enthalpy geothermal fields		
Any other reservoir information (e.g. pressure, production level depth, flow range, fluid characteristic, enthalpy)		
Published temperature model interpretation (e.g. regional heat flow, local effects due to meteoric effects)		
Basin layout and sediment-basement interface depth		
Outlines of granitic formations		
Geothermal and oil&gas wells masterlogs (including litho-stratigraphy, wells technical aspects, geophysics logs)		
Geophysical survey (e.g. seismic cross-sections, MT survey, geoelectrical survey)		
Fault mapping, Tertiary and Quaternary fault systems		
Recorded seismicity		
Porosity – Permeability measurements, porosity/depth relationship		
Monitoring network data		
Information regarding geographical restricted areas for geothermal (consider mining, oil exploration and/or exploitation, CCS, nuclear storage, spa's, interference with drinking water, population density, natural parks, high seismicity areas, etc.)		
Does a national geothermal energy statistics exist?		

Table 3: Content of the questionnaire dealing with the existence/availability of geothermal data

6.2 Austria

Geothermal resources and potential

The geothermal conditions are diverse in the country controlled by the complex geology of the Alpine orogeny and the neighbouring Pannonian Basin. The main potential areas for deep geothermal developments are the Upper Austrian and Salzburg Molasse basin, the Styrian Basin (especially its south-eastern part), the Vienna basin and the eastern margin of the Molasse Basin in Lower Austria (Figure 13).

The major reservoirs for hydrothermal use in the western Molasse Basin are the Upper Jurrasic carbonates (Malm Karst), which are partly karstified and at some parts actively recharged by meteoric water, therefore characterized by low mineralisation. This reservoir is the most developed one for hydrogeothermal use in Austria.

The Styrian Basin is characterized by an enhanced terrestrial heatflow density up to >100 mW/m^2 due to the thermal influence of the Pannonian Basin. Relevant hydrogeothermal reservoirs are located both in Tertiary basin fillings (mostly sands and sandstones of Miocene age) and Palaeozoic basement rocks (Devonian carbonates). In contrast to the Molasse Basin and the Vienna Basin, the reservoirs in the Styrian Basin are locally confined and show strongly varying hydraulic attributes. Nevertheless, the first hydrogeothermal project for energetic use in Austria has been developed in the Styrian Basin (Waltersdorf).

Although the Vienna Basin offers very favourable conditions for hydrogeothermal use, it has not been developed yet. The major reservoirs are associated to carbonates of Upper Austroalpine Units (Hauptdolomit and Wetterstein Dolomit), which form the basement of the Vienna Basin, as well as Miocene conglomerates and sandstones.

The eastern margin of the Molasse Basin in Lower Austria also shows favourable conditions for hydrogeothermal use, although this region is affected by a low density of settlements (i.e. lacking heat market). The most relevant reservoirs are located in fractured Upper Jurassic limestones and Middle Jurassic sandstones, reaching a thickness of several hundreds of meters.

The estimated total hydrogeothermal resources are in the range of 500 MW_{th} to 1 000 MW_{th} in the above described regions of interest. As most of the reservoirs are located in a temperature range between 80°C and 130°, the estimated resources for geothermal electric power generation are in the range of 50 MW_e to 100 MW_e.

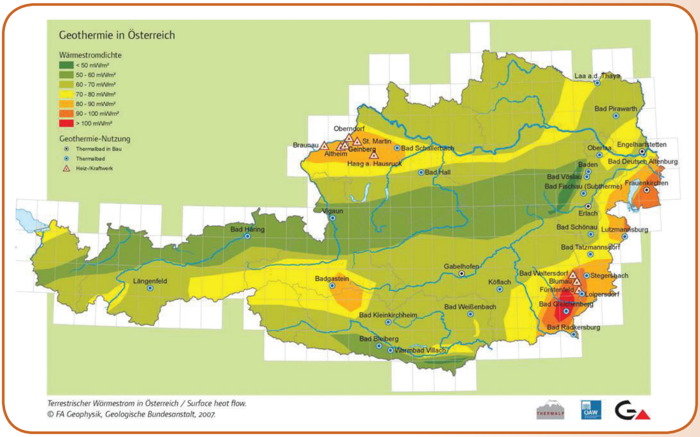

Figure 13: Terrestrial heat-flow map showing the main geothermal areas of Austria

Utilization

Using natural thermal water for balneological purposes has a long tradition is Austria. The oldest uses can be traced back to Roman times (e.g. Baden bei Wien). The highest growing rates of spas in Austria were observed during the 1990s until the 2000s. Currently the market for spa tourism is mostly saturated in Austria. During the past 5–10 years new spas were opened in the skiing resorts in the Austrian Alps (e.g. Längenfeld / Ötztal).

The energetic use of thermal water commenced in the late 1970-s at Waltersdorf (Styrian Basin). Since then several projects have been developed in the Upper Austrian Molasse Basin and the Styrian Basin. At the moment there are 3 operating geothermal power plants, all small Organic Rankine Cycle (ORC)-binary plants (Altheim, Simbach-Braunau and Blumau) with a total installed capacity of 1.85 MW_e producing altogether 2.2 GWh_e/y.

There are 8 operating geothermal district-heating systems (Altheim, Geinberg, Simbach a.Inn, Obernberg, St. Martin im Innkreis, Haag am Hausruck, Bad Blumau, Bad Waltersdorf) with a total installed capacity of 117.6 MW_{th} and a geothermal heat production of 158.9 GWh_{th}/y.

Recent geothermal activities in Austria have focused on 2 projects. In the Vienna Basin a drilling was deepened in 2012 to establish the geothermal district heating of Aspern (eastern district of Vienna) at an aimed installed capacity of ~45MW_{th}. It targeted the fractured dolomites in the basin floor of the Vienna Basin. The borehole was designed to be appr. 5000 m deep, thus providing temperatures as high as 140 °C. Unfortunately due to the extremely complex geology of the basin floor (different Alpine nappes in overthrusted positions), some unexpected geological units in unfavourable geological setting were exposed by the drilling which was thus stopped at a depth of 4224 m. Nevertheless, the total hydrogeothermal resources at the eastern districts of Vienna have been recently estimated in the range of 200–300 MW_{th} in 4 different carbonate reservoirs at the basement of the Vienna Basin, which could play an important role in the future energy supply of Vienna.

In the Upper Austrian Molasse Basin a geothermal district heating project was implemented at Ried im Innkreis in 2011-2013 targeting the Malm (Jurassic) carbonate aquifers at a depth of cca 2300 m. The successful drilling provided high temperature and yield thermal water (105 °C with a flow rate of 64 l/s). The Ried project is still under development, as hydraulic interferences has been observed at an nearby balenological well during long-term pumping tests.

In the Styrian basin a project for the heat supply of greenhouses was launched in Fuerstenfeld, targeting Palaeozoic fractured dolomite aquifers. The production borehole is planned to be 3600 m deep with expected temperature > 130 °C. The first drillings were planned to start by the end of 2013.

Geothermal within the NREAP

The overall target is to increase geothermal from 0.803 (2010) to 1.682 PJ by 2020. Despite the 3 operating power plants and the relatively good potentials, the Austrian NREAP does not specify a target for geothermal electricity by 2020. The proposed measures (a steady growth (+2 ktoe/y) for developing geothermal heating are not in line with the current uses and planned new projects.

Regulatory framework

The use of natural thermal water for energetic purposes is governed by the federal Water Act (WRG 1959) and Mining Act (MinROG, 1999). A specific act dealing with the use of heat is lacking in Austria. Therefore there are no claims specified for geothermal use in Austria. According to the WRG 1959, the heat stored in natural thermal water is possessed by the land-owner above. Within an active hydrocarbon exploitation claim, the license holder is allowed to block any geothermal activities according to the MinROG 1999.

Financial supporting schemes

Direct investment support is available both for power production and direct uses. A feed-in-tariff system exists for geothermal electricity, however much lower than for other RES.

Data policy

More than 1000 temperature datasets exist, mostly gained from hydrocarbon wells owned by the relevant oil companies. In the frame of several projects (e.g. Transenergy, Transthermal) the Geological Survey of Austria has compiled temperature and heatflow maps for the Vienna Basin, the Styrian Basin, the eastern margin of the Molasse Basin as well as for parts of Carinthia (intra-mountainous basins). Temperature maps for the Upper Austrian Molasse Basin are currently being compiled in the frame of the GeoMol project. However, temperature maps at a scale lower to or equal than 1:500,000 covering the entire territory of the country are still missing. In 2007 the Geological Survey of Austria published a conceptual heatflow density map for Austria in 1:1.5 million scale. Many other geology related information are available at the Geological Survey of Austria, as well as in published maps and literature. Data reletad to certain reservoirs and their production (e.g. porosity-permeability data, well-logs) are not public.

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6.3 Bosnia and Herzegovina

Geothermal resources and potential

Within the Alpine orogeny Bosnia and Herzegovina belongs to the Dinaric tectonic unit and has a very complex geology. About 50% of the country's territory has various geothermal potential arranged into 9 hydrogeothermal zones located north of the Bihać – Konjic – Foča line, where the main reservoirs are Middle and Upper Triassic carbonates at a depth of 1500 m and below (Figure 14). Heat flow and subsurface temperatures increase from central to the northern parts of country. The largest positive geothermal anomalies are in the Pannonian Basin.

There are 87 active deposits of thermal and thermomineral waters with 175 springs and 130 artesian and pumping boreholes with total yield of 2921.1 l/s. The depth of all 127 active wells range from <100 m to 1345.5 m, they represent low enthalpy hydrogeothermal resources (outflow temperature <20°C to 96 °C). The thermal waters have large range of mineralization from 0.15 g/l to as much as 300 g/l with a variety of dissolved gas content.

Priorities of investigation according to temperatures and success to obtain geothermal resources are the following: 70 – 100°C: Middle Bosnian Basin; 50 – 70°C: Banja Luka Basin, Spreča fault zone; 30 – 50°C: Ophiolites, Bihać Basin and Una-Sana Paleozoic massif and ca. 30°C – Mid and South-East Bosnian Paleozoic massif.

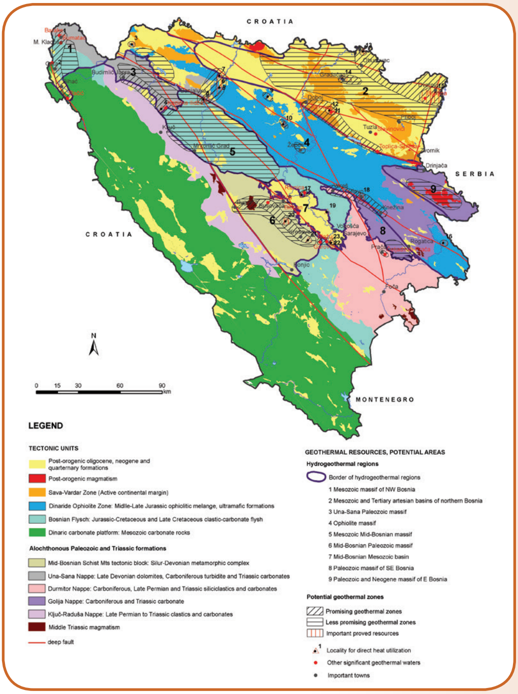

Figure 14: The main tectonic units of Bosnia and Herzegovina with their lithological composition and geothermal resources with potential areas [15]

Utilization

There are 19 spas of thermal and thermomineral waters and recreation centres with swimming pools, which are heated by geothermal waters directly or indirectly through heat exchangers. Water temperatures in thermal spas range from 17.4 to 75°C. The total geothermal energy used for bathing and swimming is estimated at 27.67 GWh_t/y. Individual space heating with heat exchangers is performed in 5 localities (Ilidža Terme, Ilidža Termalna rivijera, Slatex-Slatina, Slatina and Dvorovi). Total geothermal energy used for individual space heating is 31.69 GWh_{th}/y. The heating of greenhouses with geothermal water began in the 1970-s at Domaljevac (Northern Bosnia) for production of flowers and vegetables for domestic market and export to Croatia. The total geothermal energy used in the greenhouses is about 10.94 GWh_{th}/y. Fish farming exists in a swimming-pool in one locality (Sedra Breza) during cold period, which serves as recreation bathing and swimming basin in the warm season. Total geothermal energy used for fish farming is 0.31 GWh_{th}/y.

No geothermal power production exists, however there are some proven medium enthalpy Triassic carbonate reservoirs hit by the borehole Bij-1 Bijeljina with a temperature ca. 120°C at a depth of 2410 m below the surface.

Geothermal within the NREAP

Not being a member state of the EU, Bosnia-Herzegovina does not have a NREAP at the moment. There is an Energy Strategy of the Republic of Srpska up to 2030 and a Strategic Plan and Program of the Energy Sector Development of the Federation of B&H which set up targets for renewables.

Regulatory framework

Investigation and exploitation of hydrogeothermal resources is under the jurisdiction of the two entities of state Bosnia and Herzegovina: 1) Federation of Bosnia and Herzegovina (Federal Ministry of Energy, Mining and Industry) and 2) Republic of Srpska (Ministry of Industry, Energy and Mining) and one district – District Brčko of B&H. These two ministries give approvals for investigations and exploitations on the respective areas of Bosnia and Herzegovina according to the basic requirements of the Law on Concession, Law on Geological Explorations and the Law on Mining.

Financial supporting schemes

There are no financial supporting schemes available for the geothermal sector.

Data policy

A GIS database developed by the Federal Institute for Geology-Sarajevo of mineral, thermal and thermomineral waters of Federation of Bosnia and Herzegovina contains all available data about the loaction, quantity, quality and use of these waters with continuous update. The Geological Survey of Republika Srpska has a similar database for the area of the entity Republika Srpska. This information is available through these institutes and via the entity Ministries of Energy, Mining and Industry. Some data (especially new seismic researches) are owned by Jadran Naftagas Banja Luka, which has oil and gas exploration concession on in the territory of the Republika Srpska.

Most of the data listed in the questionnaire were reported to exist and being available through publications and through the above listed organizations, as well as through INA-MOL Zagreb and NIS GASPROM NJEFT Novi Sad.

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6.4 Bulgaria

Geothermal resources and potential

Bulgaria is divided into three major hydrogeological units: the Moesian plate, the Sredna Gora zone (including Balkan zone) and the Rila-Rhodopes massif. In the Moesian plate the main geothermal reservoirs are situated in carbonate rocks of Jurassic, Lower Cretaceous, Middle Triassic and Upper Devonian age. They consist of up to 1000 m thick artesian aquifers built up of limestone and dolomite, very fractured with high permeability. The Sredna Gora zone is a rich and heterogeneous hydrothermal region where unstratified (fault-fractured), stratified and mixed hydrothermal systems are present. Hydrothermal circulation takes place in the fractured massif of granite and metamorphic rocks and in the Upper Cretaceous volcano - sedimentary deposits. The western Rila-Rhodopes massif is mainly built up of Precambrian metamorphic and granite rocks, densely fractured with seismically active faults. Hydrothermal systems with thermal waters of low salinity, meteoric origin and of highest measured temperature up to 100 °C are found in this area. The most perspective regions for geothermal application are located in the central and eastern part of Moesian plate and in the Rila-Rhodopes massif.

The majority of the thermal waters have temperature of 20-50°C and a flow rate up to 20 l/s. Higher temperatures of about 150°C are expected at the deeper seated sedimentary water bearing units of Devonian and Triassic age in the Moesian plate, North Bulgaria mostly with high total dissolved content.

Utilization

Majority of the use is for balneology in the Black Sea and mountain regions, the leading sites are Sandanski, Velingrad, Hisarya, Pavel Banya and Varna. It is followed by water supply (where no alternative is available, mostly along the northeastern Black Sea coast). Bottling of mineral water is also important, about 18 bottling enterprises are currently in operation and 5 of them are located in the capital of Sofia and its vicinity. The development of this application is mainly driven by the low Total Dissolved Solids (TDS), below 1g/l, typical for more than 90% of the discovered thermal waters in southern Bulgaria, although they discharge different geological formations (volcanic, intrusive and metamorphic rocks).

The direct heat application is subordinate: space heating in buildings and greenhouses and some other uses (public laundries, industrial processes, irrigation). Geothermal energy in the country is used for individual space heating in 7 sites as 3 of them are located on the Black Sea resorts north of Varna city. No geothermal district heating systems are presently available. Greenhouses are located in 7 sites, 6 of them are in southwest Bulgaria and only one in the northeastern part near Varna city.

The total installed thermal capacity in 2012 was estimated to about 85.8 MW_{th} (and the produced energy to 2166.4 TJ/y). Only about 25.3% of the discovered thermal water quantity is presently used in Bulgaria.

Geothermal within the NREAP

The share of renewable energy in the gross final energy consumption was 13.8 % in 2010, however the share of geothermal within all renewables is only 2.7%. For deep geothermal heating and cooling an increase from 0.042 PJ (2010) to 0.377 PJ (2020) is expected, however this is not in line with the current productions.

Regulatory framework

The amendments of the Water Act at the end of 2010 are expected to promote the direct applications of thermal water in the near future. Under the new provisions the state-owned geothermal deposits could be granted to municipalities to meet local needs for a period of 25 years. At the moment 102 geothermal fields from all over the country are specified as exclusive state property and 138 as public municipal property.

Between 2007-2012 a 3-4 times decrease in the fees for water use aimed at increasing the apetite of local businesses to invest in thermal water applications.

Financial supporting schemes

Recent administrative and legislative changes are aiming to promote RES-based electricity (e.g. feed-in tariff system), but Bulgaria does not propose any target for geothermal power production, since thermal waters in the country are of temperature below 100 °C%. There are tax reductions paid for direct use of thermal water.

Data policy

There was no information available.

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6.5 Croatia

Geothermal resources and potential

Croatia can be divided into two significantly different geothermal regions: the Dinaric and the Pannonian. The Dinaric region is characterized by low heat flow and temperature gradient, while the northern Pannonian part has favourable geothermal conditions: the average heat flow is 76 mW/m^2, the geothermal gradient is 49 °C/km (Figure 15).

In the northern part of Croatia (part of the Pannonian Basin - Mura, Drava, Sava and Slavonija-Srijem depressions) there are multiple sandstone aquifers identified in Miocene and Pliocene formations. Also, Triassic dolomite and Paleozoic metamorphic aquifers are present at greater depth. In accordance with the depth, the waters also have higher temperatures (50 – 200 °C). A great number of wells drilled for hydrocarbon exploration were unsuccessful for the production of oil and gas, however discovered significant geothermal reservoirs. Data obtained from the hydrodynamic measurements and production tests of those dry hydrocarbon wells – performed by the Croatian oil company INA – served a basis for reservoir engineering calculations. This resulted in the definition of ten geothermal fields, classified in two categories, medium temperature reservoirs with water between 100 and 200°C, and low temperature ones, producing water with temperatures between 65 and 100°C. (For economic reasons only those wells are classified as geothermal, that are producing water with temperatures above 65°C).

In the Dinaric parts of Croatia there are characteristic tectonic structures consisting of a single fold and a marginal fault where geothermal waters come to the surface. In these settings uplifted mountains are the recharge areas, while the lowlands are dicharge areas and the springs appear at fault locations, usually at fractured anticline crests, yielding (thermal) water from 20 to 65 °C.

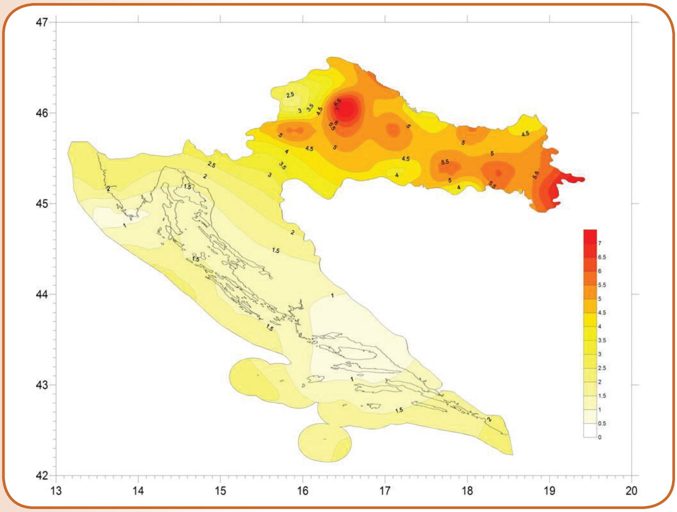

Figure 15: Map of geothermal gradient in Croatia [17]

Utilization

In spite of the considerable geothermal potential, the rate of direct heat utilization is low. Low temperature thermal water is widely used for bathing, swimming and medical purposes in traditional spas. In 2011 17 spas were operating, of which 14 were situated at locations of natural geothermal springs and 3 were supplied from deep boreholes. There are 7 localities with proven reserves and water temperatures between 68 and 96 °C, of which 3 are currently being utilized for direct heat, but with low efficiency, others are not utilized at all. Most of the direct heat use is related to space heating of spas, hospitals and hotels with swimming pools where heat exchangers and heat pumps are used. Majority of the use is in the surroundings of Zagreb (Mladost Sport Centre, University Hospital). Another location is at Bizovac near to the town Osijek in northeast Croatia, where the pools of a recreation centre are heated by thermal water. The total installed capacity for individual space heating was 31.77 MW_{th}, and 77.24 MW_{th} for bathing and swimming.

Since all geothermal reservoirs that are currently still not in use are located in agricultural areas, utilization of geothermal energy for greenhouse heating and the subsequent industrial processing of fruit and vegetable production would significantly increase the efficiency of the agricultural sector.

Waters with temperatures higher than 100 °C, even up to 200 °C (at deep oil and gas fields) could be used for electricity generation and then also cascading to lower the temperature for other direct heat applications. There are 9 known locations with potentials for power production, but no geothermal electricity generation exists up to now. The first geothermal power plant in Croatia is expected to be commissioned during 2016 (Marija-1 in Velika Ciglena, T = 170 °C) with installed capacity of 4.71 MW_e.

Geothermal within the NREAP

NREAP of the Republic of Croatia predicts a 39.0 % RES share in electricity production and 19.6 % in heating and cooling by 2020. Of the total RES, geothermal is expected to have a 2.6% share in heating (excluding GSHP) and 0.9% in power generation.

Regulatory framework

There is a dual regulation, depending on the purpose of utilization. If the purpose is to use water (bottling, swimming, balneology) then the Water Act is applicable. In case the purpose is to use the energy content (heating, electricity generation) the Mining Act is relevant.

Water above and below ground and mineral resources are the property of the Republic of Croatia, so concessions and water permits are needed for their utilization. Research and utilization of geothermal energy have followed the pathway of petroleum industry and the same regulations are amenable. By the end of 2013 - beginning of 2014 a new special renewable energy act is expected, which should unify the formery diverse RES regulations and facilitate the procedures of acquiring permits for RES projects.

Financial supporting schemes

Direct investment supports and low rate interest loans are available both for electric power and direct heat projects. The feed-in-tariff for geothermal electricity amounts to 0.16 €/kWh, regardless of the installed capacity. The project of district heating, CH_4 gas separation for electricity generation and recreational and balneological touristic complex in Draškovec locality has been declared a project of national interest and will be supported.

Data policy

National geothermal spatial data sets are partial, dispersed and in general are not available to the public.

Data about geothermal aquifers acquired during hydrocarbon exploration were gathered by the national oil company INA and are the property of the Republic of Croatia, administered by the Ministry of Economy. The data are currently being transferred to the Croatian Geological Survey (borehole data, 2D and 3D seismics, masterlogs from 1200 boreholes), but the regulation concerning data utilization and availability is still not defined.

A large quantity of data was gathered in the frame of the GEOEN project of geothermal energy utilization by the Energy Institute Hrvoje Požar. Many data regarding the potential for utilization were published. Data have also been gathered and organized into spatial data sets as a part of the project Geothermal Map of Croatia at the Croatian Geological Survey. The maps are available but the data themselves are not accessible for the public.

The layout of sedimentary basin was discussed and published in many peer-reviwed papers, as well as sediment-basement interface depth.

Physical and chemical parameters of the majority of geothermal waters in Croatia were published in the geological monography "Geothermal and mineral waters of Republic of Croatia" by Croatian Geological Survey and in several other publications.

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6.6 Czech Republic

Geothermal resources and potential

The territory of the Czech Republic is formed by granite bed rock of the Bohemian Massif. Considering the slow cooling down of the enormous granite massive, the theoretical potential is as much as 500,000 PJ, however only a part of it can be tapped. The average heat flux is 60 mW/m^2. The maximal heat flux rises up to 90-100 mW/m^2 in a vicinity of Karlovy Vary, Litoměřice or Ostrava (Figure 16).

More than 60 sites potentially favourable for geothermal energy exploitation might be identified within the Czech territory (in total, an estimated 250 MW$_e$ for geothermal electricity and 2,000 MW$_{th}$ for heating). The northern part of the Czech Republic seems to be rather favourable for deep geothermal exploration due to tectonic setting as well as the sedimentary layer being 900 m thick.

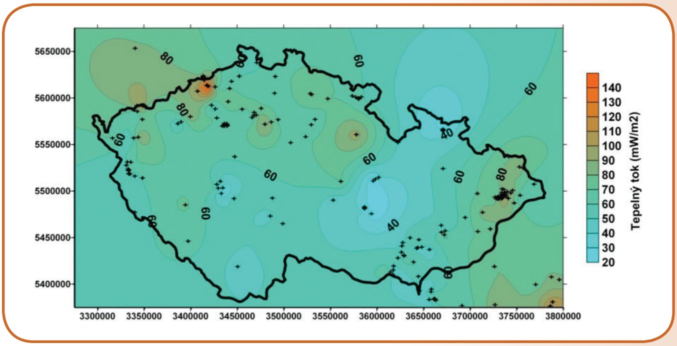

Figure 16: Distribution of the heat flux in the Czech Republic [18]

Utilization

Balneology has a long history in the Czech Republic. Thermal water is used in spas, wellness centers and swimming pools (e.g. Usti nad Labem, Velke Losiny, Pasohlavky and Chrastava). The most successful project using thermal groundwater for balneological purposes is located at Pasohlavky / Musov in the southeastern part of the Czech Republic, geologically in the Northern Vienna Basin targeting a Jurassic reservoir.

Although there are several sites favorable for development of geothermal district heating systems, only the area around the municipality of Děčín has such installation with cogenerating gas units. Here low temperature (30 °C) water is used by heat pumps. The total installed capacity is 6.56 MW$_{th}$ and the heat production is 25 GWh$_{th}$/y. Geothermal heat is also used for the heating of two zoological gardens: in Ústí nad Labem, where water of 32 °C is tapped by heat pumps from shallow depth and in Prague, where heat pumps are used, too.

A combined heat and power production plant using Hot Dry Rock (HDR) technology is under development in Litomerice.

Geothermal within the NREAP

Nowadays geothermal energy generates < 0,1% of the overall energy production of the Czech Republic. The NREAP forecasts the installation of the first geothermal power plant in the country in the next 10 years and aims to utilize 0.694 PJ geothermal energy by 2020.

Regulatory framework

Geothermal resources are owned by the state. However in the Czech Republic, there is currently no unified legal/technical regulation dealing with geothermal energy sources for their use in transparent and comprehensive manner.

Financial supporting schemes

Feed-in-tariff exists, and proposes a specific tariff for geothermal: 17.7 €ct/kWh. Support for district heating and cooling from RES in general is also available through:

- investment support from Structural Funds;
- liberation from „property taxes“ if using geothermal energy sources (including heat pumps);
- indirect support via support of combined electricity and heat generation from renewable energy sources;
- direct support for heat from RES via annual green bonuses (13.3 €ct/kWh).

Data policy

Most of the the relevant geothermal information is available in the forms of various maps via the websites of the relevant organizations (Czech Geological Survey, Geophysical Institute of the Academy of Science of the Czech Republic, GEOMEDIA Ltd.) and in publications, however the data themselves are not publicly accessible. Data reletad to certain reservoirs and their production (e.g. porosity-permeability data, well-logs, geophysical measurements) are not public either.

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6.7 Germany (Bavaria and Baden-Württemberg)

As only the states of Bavaria and Baden-Württemberg are part of the EUSDR from Germany, the present summary focuses on the geothermal potential and utilization of these two provinces only (which practically encompasses the German part of the Molasse basin and part of the Upper Rhine Graben, the two most prominent geothermal areas of Germany) (Figure 17).

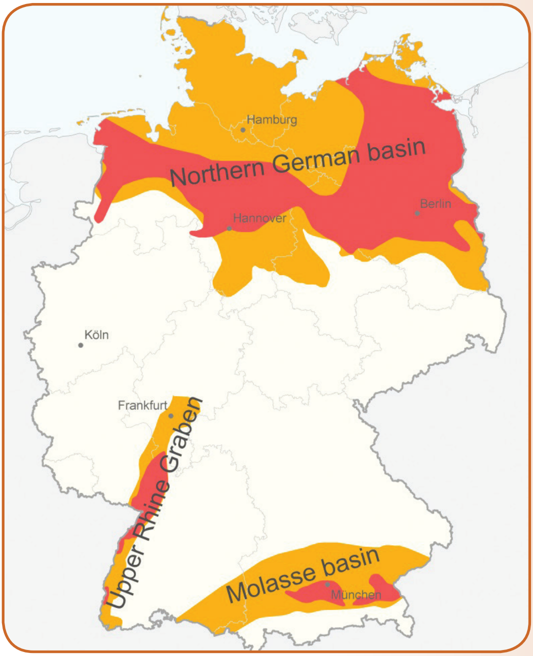

Figure 17: The main geothermal areas of Germany [19]

Geothermal resources and potential

The Molasse Basin in Southern Germany is an asymmetrical foreland basin associated with the uplifting of the Alps. It extends over more than 300 km from Switzerland in the southwest to Austria in the east. The basin is made up mainly by Tertiary, Upper Jurassic (Malm) and Triassic sedimentary rocks, in which eight aquifers are of interest for direct use of geothermal energy. The Malm (karstic limestone aquifer of the Upper Jurassic) is one of the most important hydrogeothermal reservoirs due to its excellent reservoir properties (high permeability combined with elevated temperature). It is found throughout the almost entire Molasse Basin, in the Bavarian part in several hundred meters thickness. Due to the southward inclination of the water-bearing horizon, fluid temperatures increase towards the Alps, reaching temperatures usable for power generation in the area of Munich.

The Upper Rhine Graben belongs to a large rift system which crosses the European plate. The structure was formed in the Tertiary by up-doming of the crust-mantle boundary due to magmatic intrusions in 80-100 km depth. The induced thermo-mechanical stress resulted in extensional tectonics. Six aquifers (Tertiary, Jurassic, Triassic and Permian) are of interest for direct use of geothermal energy in this region. High geothermal gradients make this area suitable for the development of electricity projects, too.

Utilization

At the end of 2012, five geothermal power plants were in operation, out of which 3 are found on the study area (Bruscal along the Rhine Graben, Unterhaching and Simbach-Braunau in Bavaria). The plant in Unterhaching operates a 3.3 MW_e Kalina unit. With 8.4 GWh_e electric power produced in 2012, it contributed significantly to geothermal power generation in Germany. The 0.55 MW_e Kalina unit in Bruchsal was being in operation mainly for tests in 2012, feeding 0.5 GWh_e power into the grid. The 0.2 MW_e ORC unit in the Austrian-German district heating project Simbach-Braunau did not produce power in 2012. The installed geothermal capacity of the heating plant is 7 MW_{th}, however it is about to be dismantled due to economic considerations. Furthermore another three power plants with around 5 MW_e each were about to start operation in Bavaria in 2013.

Geothermal heat is produced in 170 larger installations in Germany using thermal waters. The total installed geothermal capacity for district heating in Bavaria (13 plants) and Baden- Württemberg (2 plants) is 157.25 MW_{th}, with a heat production of 331.17 GWh_{th}/y.

Geothermal within the NREAP

By 2020, the share of RES in the heat and cooling sector shall amount to 15.5%, electricity to 38.6%. Within this the expected growth for geothermal is highly ambitious, from 1,521 PJ (2010) to 34,676 PJ by 2020.

Regulatory framework

For deep geothermal energy plants, mining regulations must be observed first and foremost. Geothermal heat is considered to be a natural resource. The right to exploit geothermal energy using deep geothermal energy plants has to be granted by state authorities. In addition, the provisions of laws relating to water, construction, planning and nature conservation must also be observed.

The successful market introduction of renewable energy sources for electricity generation is strongly dependent on the feed-in tariffs provided for by the German Renewable Energy Sources Act (EEG). The Renewable Energy Heat Act (EEWaermeG) obliges building developers to source a minimum percentage of the energy requirement for heating and hot water from renewable energy sources.

Financial supporting schemes

The development of geothermal projects is supported by the German Government by project funding and subsidies for drilling costs. A loan program in collaboration with the KfW Banking Group helps to cover exploration risks. The feed-in tariff for geothermal electricity guaranteed in the Renewable Energy Sources Act (EEG) has been increased to 25 €ct /kWh, with additional 5 €ct /kWh for EGS systems. Furthermore, a market incentive program (MAP) offers financial support for geothermal developments.

Data policy

The Geothermal Information System for Germany (GeoTIS) operated by the Hannover LIAG (Leibniz Institute for Applied Geophysics) (www.geotis.de) is one of the most advanced web-applications in Europe providing a wide range of information about the potential and utilization of geothermal energy. Another web-based map server offers information on hydrocarbon systems, strongly linked to geothermal reservoirs (Hydrocarbon Information System operated by LBEG (State Agency for Mining, Energy and Geology of Lower Saxony) – NIBIS map server (www.lbeg.de). Despite these impressive visualizations which provide a uniquely rich source of information, background databases are not available for the public. Environmental data are managed by the State Geological Surveys or State Agencies for the Environment (e.g. Bavaria).

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6.8 Hungary

Geothermal resources and potential

The geothermal potential of the Pannonian Basin is outstanding in Europe, as it lies on a characteristic positive geothermal anomaly, with heat flow density ranging from 50 to 130 mW/m^2 with a mean value of 90-100 mW/m^2 and geothermal gradient of about 45 °C/km. This increased heat flux is related to the Early-Middle Miocene formation of the Pannonian Basin, when the lithosphere stretched and thinned and the hot astenosphere got closer to the surface. During the continuing subsidence a large depression formed, occupied by a huge lake (Lake Pannon), which was gradually filled up by sediments transported by rivers, originating in the surrounding uplifting Alpine and Carpathian mountain belts. These several thousand meter thick multi-layered porous sediments (Upper Miocene-Pliocene "Pannonian sequene") have low heat conductivity and are composed of successively clayey and sandy deposits. Within this basin-fill sequence the main thermal-water bearing sandy aquifers are those 100-300 m thick sand-prone units which are found in a depth interval of ca. 700-1800 m in the interior parts of the basin, where the temperature ranges from 60 to 90 °C. These are widely used for direct heat purposes as well as for balneology.

The karstified zones of the Palaeozoic-Mesozoic carbonates, as well as fractured zones in the crystalline rocks in the basement are also good thermal water reservoirs. They are characterized by high secondary porosity. At this depth (on average 2000 m or below) temperature can exceed 100-120 °C and may provide favourable conditions for development of medium enthalpy geothermal systems (e.g. CHP plants). Some high-enthalpy reservoirs also exist in Hungary. Furthermore the southeastern part of the Pannonian Basin is one of the most promising regions in Europe for EGS systems with sufficiently high in-situ rock temperatures (≥ 200 °C), favourable seismo-tectonic settings (extensional regime, low level of natural seismicity) and suitable lithologies (widespread granitoid rocks in the pre-Tertiary basement).

Utilization

Geothermal power production does not exist in Hungary yet. Traditionally, the geothermal energy production of the country focuses mainly on the direct heat, with most of the thermal water used in spas. In 2011 595 active thermal water wells (Figure 18) produced 68.5 million m^3 of thermal water in Hungary representing 695.48 MW_{th} installed capacity and an annual use of 10.255TJ/y. The majority of the abstracted water was used for balneology (265 MW_{th} / 5285 TJ/y). In direct heat utilization the main sector was agriculture (241.84 MW_{th}/2800 TJ/y). Of this about 75% was used for heating of greenhouses and plastic tents and the rest for animal husbandries. As of 2011, geothermal energy contributed to the heating of 19 settlements. At an additional 16 locations individual buildings were heated by thermal water. These altogether represent an estimated installed capacity of 132.97 MW_{th} and use of 1350 TJ/y. The industrial use was relatively low (8.3 MW_{th} / 170 TJ/y). In the "other" category (including public water supply – mainly for drinking water, sanitary water and some undefined utilization schemes) altogether an installed capacity of 47.37 MW_{th} and an estimated use of 650 TJ/y was reported.

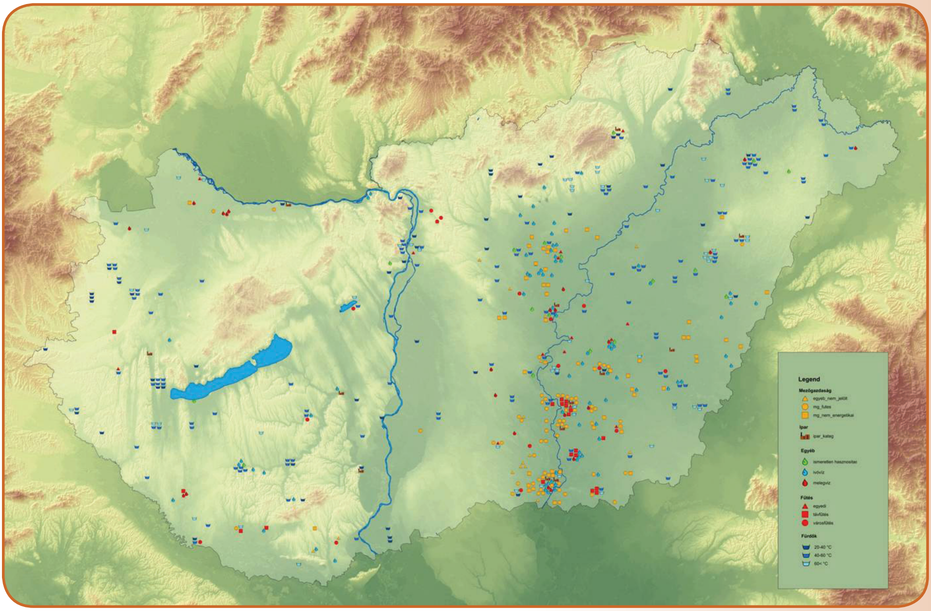

Figure18: Thermal water utilization in Hungary [20]

Geothermal within the NREAP

The National Energy Strategy of Hungary for 2011-2030 warns that energy-import dependency of Hungary is serious security of supply issue, therefore the Strategy looks at how the country could utilize its own resources more efficiently. In this context the increased share of renewables is an important pillar. In the NREAP Hungary targeted a 14.65% RES by 2020 referring to a share of geothermal in total RES from 9% to 17%. Geothermal direct use is expected to reach 14.95 PJ (357 ktoe), geothermal electricity capacity 57 MW_e by 2020 (however the NREAP is currently under supervision and the 57 MW_e aim is expected to be modified to 14.3 MW_e). According to the present and forecasted positions, Hungary will remain among the leaders in deep geothermal among the EU countries.

Regulatory framework

The legal framework for geothermal energy use is rather complex in Hungary, regulations and licensing procedures are shared by the mining, energy, environmental protection and water management sectors. Despite continuous efforts at legal harmonization, legal contradictions and time consuming licensing processes still delay investment.

The two decisive legal parameters for geothermal utilization in Hungary (including licensing) depend on: (1) whether groundwater is abstracted and (2) whether the depth exceeds -2,500 m. The exploration and exploitation of geothermal energy, if not connected to the abstraction of thermal groundwater, falls under the scope of the Mining Act. However, survey and abstraction of thermal groundwater yielding geothermal energy is regulated by the environmental and water management legislations and a water license is required. Utilization of thermal groundwater above -2,500 m ("open area") is based on a water license and is considered as a license for prospection and exploitation of geothermal energy as well. According to the amendment of the Mining Act in 2010, the exploration of geothermal energy from a depth below -2,500 m ("closed area") can take place only in the frame of a concession system (with, or without groundwater abstraction), which is licensed by the Ministry of National Development.

The Hungarian legislation related to water management focuses on the long-term protection of (thermal) groundwater quality and quantity, in line with the Water Framework Directive, and does not promote the enhanced use of thermal waters for energetic purposes. At the moment the formerly compulsory re-injection for energetic use is optional and assessed case by case.

Financial supporting schemes

Direct investment supports are available both for geothermal power generation and direct use projects, mainly from the Structural Funds. A feed-in-tariff system exists, however there is no geothermal electricity production at the moment.

Data policy

According to the Mining Law 1993. XLVIII, all geological and geophysical data acquired before 1992 are state owned and these are freely accessible (except for areas under production / exploration). The authorised manager for state geological data is the Hungarian Office for Mining and Geology (MBFH). All data are stored in the National Geological and Geophysical Archive handled by MBFH: mostly hard copy of reports (e.g. well-documentations), uniform digital databases do not exist, however big efforts have been made recently towards establishing databases in modern IT environments.

Digital geological databases (more than 11 000 boreholes deeper than 500 m, different surface and subsurface geological maps) and various geophysical databases (seismics, well-logs, geoelectrics, magnetotelluric, gravity, etc.) are available at the Geological and Geophysical Institute of Hungary. Raw data are not publicly available, but value-added interpretations are prepared through an on request basis.

A geothermal database containing temperature data of 4 477 deep boreholes (mostly hydrocarbon wells) was compiled by the Department of Geophysics of the Eötvös Loránd University, Budapest. Data are not public.

The ownership, data handling, access rights of different hydrogeological databases are shared among water management authorities and institutions (National Environmental Institute (NeKI), Regional Inspectorates for Environment, Nature and Water („green authorities"), National Water Management Chief Authority (OVF), etc.

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6.9 Romania

Geothermal resources and potential

A lot of thermal springs have been known, even from pre-historic times (Oradea, Felix Spa, Herculane Spa, Geoagiu, Calan, Caciulata, Mangalia). Exploration of geothermal resources was related to hydrocarbon drillings which exposed low enthalpy resources (40-120 °C).

The best well known geothermal resources in Romania are the geothermal aquifers in the Pannonian Plain, where the mean groundwater temperatures at -2000 m are around 127°C, arriving to 150°C at 3000 m depth along the western border of Romania (Figure 19). In this area the main geothermal resources are found in Upper Pannonian porous and permeable multi-layered sandstones and siltstones on an appr. 2500 km^2 large area, where the aquifer is situated at the depth of 800 to 2400 m yielding thermal water of 50-85°C from 37 active wells. The Ciumeghiu geothermal reservoir 50 km south of Oradea is found in Lower Pannonian gritstone, at an average depth of 2200 m providing water with wellhead temperature of 105°C and high mineralization. Other reservoirs are related to basement carbonates, such as the Oradea geothermal reservoir which is located in Triassic limestones and dolomites at depths of 2200 to 3000 m, on an area of about 75 km^2 producing thermal water with a total flow rate of 140 l/s and well head temperatures of 70-105°C. It is hydrodynamically connected to the Felix Spa Cretaceous aquifer. The Bors geothermal reservoir north of Oradea is a small closed reservoir in fissured Triassic carbonates with high TDS. The reservoir temperature is higher than 130°C at the average depth of 2500 m. The Beius geothermal reservoir is situated about 60 km southeast of Oradea and is located in fissured Triassic carbonates too, at 1870 – 2370 m depth. The geothermal water here has a low mineralization and 85°C wellhead temperature.

Another area with geothermal waters is in the central and southern parts of the country (Figure 19), in the Getic Unit and the Moesian Platform (the Romanian Plain), between the Dambovita Valley and Olt Valley. The Cozia-Calimanesti geothermal reservoir (Olt Valley) produces artesian geothermal water from fissured siltstones of Senonian age from a depth of 2700-3250 m, with well head temperature of 70-95°C. The Otopeni geothermal reservoir north of Bucharest is a huge aquifer located in fissured limestone and dolomites, situated at a depth of 2000-3200 m, with wellhead temperatures of 58-84°C, and a rather high TDS.

In addition to these three zones with well known hydrogeothermal resources, there are also areas with "hot dry rocks" at great depths characterized by geothermal anomalies (temperatures of 150°C at 3000 m depth and heat flux values of 100 mW/m^2). These are in Gutâi-Tibles Mountains, and in Ciuc Depression, both in the Eastern Carpathians.

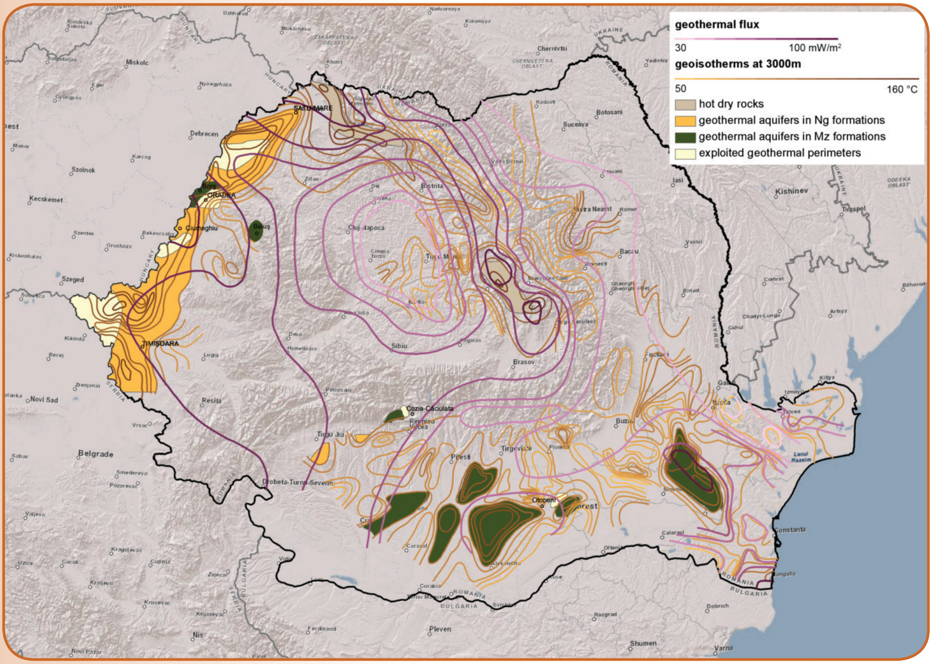

Figure 19: Geothermal map of Romania [21]

Utilization

The total capacity of the existing wells is about 480 MW_{th} (for a reference temperature of 25°C). Of this total, only about 180 MW_{th} is currently used, from about 80 wells (of which 35 wells are used only for balneology and bathing) that are producing hot water in the temperature range of 40-115°C. In 2012 the annual energy utilization from these wells was about 360 GWh_{th}. The main direct uses of the geothermal energy are space and district heating (106 MW_{th}/148GWh_{th}/y), greenhouse heating (8 MW_{th}/50GWh_{th}/y), bathing using about 40 wells in 16 spas, with a capacity of over 850,000 people/year, industrial process heat, fish farming and animal husbandry. The annual utilization of geothermal energy in Oradea represents almost 35% of the total geothermal heat produced in Romania.

Geothermal based power production also exists (Oradea) with 0.05 MW_e installed capacity producing 0.4 GWh_e/y.

Geothermal within the NREAP

Romania has an ambitious NREAP which aims to have a 24% share of RES in the final energy consumption by 2020, and to increase electric power produced from renewable sources to 38% of the total. Separate share of geothermal energy is not defined, however it is expected to be a much as 3.349 PJ by 2020 (with no power production foreseen).

Regulatory framework

Mineral resources (including geothermal energy) are public property owned by the Romanian State. The exploitation of geothermal water resources (with temperatures above 20°C, for any purpose) is regulated by the Mining Law. Exploration and exploitation happens on the basis of concession contracts regulated by the Concession Act and issued by the National Agency for Mineral Resources. Concession contracts are tax–royalty type, royalties are paid only for the amount of extracted water, even if it is reinjected.

Water Act and Environmental Protection Act have some relevant contents related to the geothermal activities (especially drilling), the latter has provisions associated with discharging the used geothermal waters into surface waters.

The Act for the Promotion of Energy Production from Renewable Energy Sources regulates all aspects regarding the "green certificates" issued for electricity produced from renewable energy sources, geothermal included. Unfortunately, the National Agency for Energy Regulation has not awarded yet any green certificates for geothermal power, claiming that there are too few producers.

The Thermal Energy Act sets the general rules for district heating systems and is intended to stimulate the use of renewable energy sources, among which geothermal is specifically mentioned. According to this law, all district heating systems have to be public property, but the operation can be licensed to a specialized private company or to a public-private joint venture.

Financial supporting schemes

In addition to private and public funds also available for exploration, tax exemptions and green certificates are the main incentives.

Data policy

In Romania geothermal data are not hosted in a single organisation, they are produced and managed by several organisations. Companies (e.g. OMV – Petrom – Institute of Technological Research and Design Câmpinahave, FORADEX S.A., TRANSGEX S.A.) have to deliver borehole data to the National Agency for Mineral Resources (NAMR). Further use of these data has to be approved by NAMR. The Geological Institute of Romania handles most of the geology related information and operates borehole and map databases (in paper and digital format). Some value added data can be produced by interpreting, processing and extracting the requested information by a GIS spatial analysis of multiple layers (e.g. basin boundaries, granitic outlines etc.). Most of the information listed in the questionnaire are available in Romania, but not publicly accessible.

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6.10 Serbia

Geothermal resources and potential

The territory of Serbia has favourable geothermal characteristics with more than 80 hydrogeothermal systems arranged into four geothermal provinces. Terrestrial heat flow density under most of Serbia is higher than the average for continental Europe. The highest values are in the Pannonian Basin, (>100 mW/m^2), in the Serbian-Macedonian Massif and in the border zone of the Dinarides and the Serbian-Macedonian Massif. The most promising geothermal areas are the Pannonian and Neogene magmatic provinces located at the southern edge of the Pannonian Basin with 81 geothermal wells with a total average flow of about 650 l/s, and water temperature ranging from 21 to 82 °C. In this region there are 4 hydrogeothermal systems arranged in a vertical succession: Upper and Lower Pannonian, underlain by Miocene limestones, sandstones, basal conglomerates, and the deepest ones are the magmatic, metamorphic and sedimentary rocks of the Triassic and Palaeozoic, of which the Triassic basement reservoirs are the most important.

Other geothermal areas include the Dinarides, where the most important reservoirs are Triassic limestones and granitoid intrusions which yield thermal water of 70-80 °C. The Serbian-Macedonian massif as the third major province has fractured marbles and granitoids as main reservoir types. In the Carpatho-Balkanides region reservoirs are also found in karstified Triassic, Jurassic or Cretaceous limestones yielding thermal water of 38-43 °C.

In Serbia there are altogether 159 natural springs of thermal water, with temperature above 15 °C, most of them are found in the Dinarides and in the Carpatho-Balkanides. The thermal springs with the highest temperature are Vranjska spa (96 °C), Josanicka Spa (78 °C), Sijarinska Spa (72 °C), Kursumlijska Spa (68 °C) and Novopazarska Spa (54 °C). The total flow of all natural springs is about 4000 l/s.

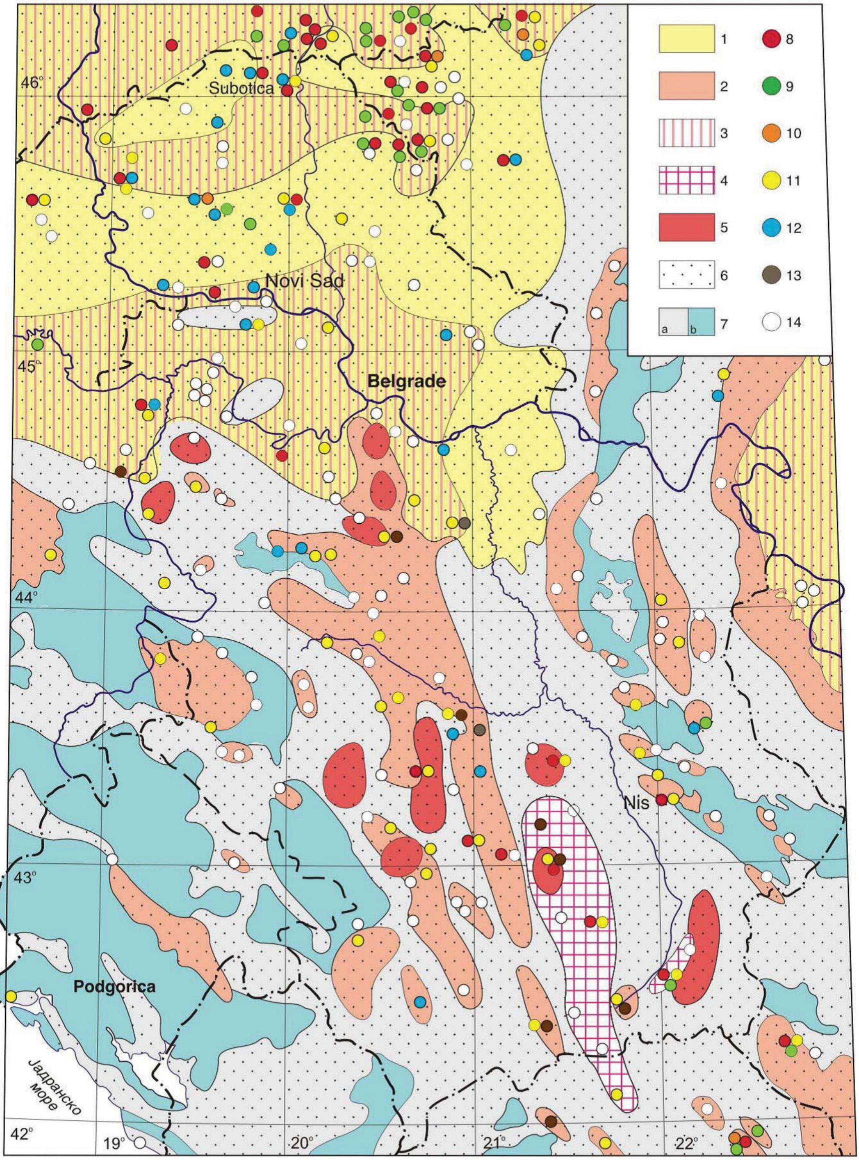
Geothermal energy in Serbia has a significant potential to contribute to the national energy balance, especially in power generation. The prospective geothermal reserves amount up to 400 x 106 tonnes of thermal-equivalent oil. For intensive use of thermal waters in agro- and aquacultures and in district heating systems, the most promising areas are west of Belgrade, westward to the Drina, i.e. Posavina, Srem, and Macva. Reservoirs are Triassic limestones and dolomites >500 m thick, which lie under Neogene sediments. The priority region is Macva, with reservoir depths at 400-600 m, and water temperature of 80°C, where a project for space-heating and for greenhouse heating over 25 ha is in a pending situation.

In addition to the favorable conditions for direct use from hydrogeothermal reservoirs, Serbia also has significant potential for electricity generation from hot dry rocks, as there are ten identified Neogene granitoid intrusions.

Utilization

The total heat capacity of all hydrogeothermal boreholes in Serbia is about 188 MW_{th}. The total heat capacity of all natural springs and wells is about 352 MW_{th}. Most of the thermal water is used for balneological purposes in spas at 59 locations (55.6 MW_{th} installed capacity and 258.4 GWh_{th}/y production). The direct heat use in agriculture (16.95 MW_{th}/82.88 GWh_{th}/y) and for space heating with heat exchangers and heat pumps (53.64 MW_{th}/231.25 GWh_{th}/y) are considerable, however there are significant untapped resources (Figure 20).

Pre-feasibility studies by international companies were performed for 33 promising locations, out of which 12 were selected for detailed exploration for utilization of geothermal energy.



RESOURCES: 1-Hydrogeothermal aquifer in Cenosoic rocks; 2-Hydrogeothermal aquifer in Mesosoic rocks; 3-Hydrogeothermal aquifer in Mesosoic rocks bellow Cenosoic rocks; 4-Hydrogeothermal aquifer in Paleosoic rocks; 5-Petrogeothermal resources in Tertiary granitoide rocks; 6-Hydro-petrogeothermal resources up to 200 m for exploitation of geothermal energy with heat pumps; 7-Areas without significance hydrogeothermal resources: a) terrains with rocks of Paleosoic and Proterosoic age, b) karstic terrains; UTILIZATION OF RESOURCES: 8-Heating; 9-Food production; 10-Industry 11-Balneotherapy; 12-Recreation and sport;

Figure 20: Map of geothermal resources of Serbia and Montenegro [22]

Geothermal within the NREAP

In 2013 renewable energy accounted for 1.835 Mtoe or 16 % of the domestic production of primary energy, however geothermal energy accounted for less than 1%. Serbia is a non-EU country, but it foresees a 27 % share of renewable energy in gross final energy consumption by 2020, nevertheless there are no projections for geothermal.

Regulatory framework

To achieve the targeted RES share, adequate laws and acts have been made together with guides for potential investors that define legislative steps for a power plant construction for electric energy production utilizing the hydrogeothermal resources along with the feed-in- tariff system.

Nevertheless the regulatory system is mismatched and the area of exploration and exploitation of geothermal energy is under the auspices of 3 ministries: Ministry of Natural Resources, Mining and Spatial Planning, Ministry of Energy, Development and Environmental Protection and Ministry of Agriculture, Forestry and Water Management.

Financial supporting schemes

Direct investment supports and low interest loans are available for the direct uses, while feed-in-tariff exists for RES-based power production.

Data policy

The largest number of data have been produced during research carried out by the Faculty of Mining and Geology, University of Belgrade, by the Geological Institute of Serbia, and by „NIS" (Petroleum Industry of Serbia), which was privatized in 2008 (NIS Gazprom Neft).

At state level, there is no centralized and unified database. Most of the information listed in the questionnaire are available in Serbia at the above listed organizations, but not publicly accessible.

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6.11 Slovakia

Geothermal resources and potential

The majority of Slovakia is occupied by the West Carpathian mountain system, characterized by a complex nappe structure, only a part of Eastern Slovakia is assigned into the East Carpathians. The southern part of the country is vast lowlands - extensions of the Pannonian Basin. Within this variable geological setting altogether 27 hydrogeothermal areas or structures have been identified (Figure 21): 1-Danube Basin central depression, 2-Komarno high block, 3-Komarno marginal block, 4-Vienna Basin, 5-Levice marginal block, 6-Banovce Basin and Topolcany embayment, 7-Upper Nitra Basin, 8-Skorusina Basin, 9-Liptov Basin, 10-Levoca Basin (west and south parts), 11-Kosice Basin, 12-Turiec Basin, 13-Komjatice depression, 14-Dubnik depression, 15-Trnava embayment, 16-Piestany embayment, 17-Central Slovakian Neogene volcanics (northwest part), 18-Trencin Basin, 19-Ilava Basin, 20-Zilina Basin, 21-Central Slovakian Neogene volcanics (southeast part), 22-Horne Strhare – Trenc graben, 23-Rimava Basin, 24-Levoca Basin (north part), 25-Humenne ridge, 26-Besa – Cicarovce structure, 27 – Lucenec Basin. They represent a great variety of geological settings and reservoir types.

Geothermal waters were proven by 159 geothermal wells with the depth of 9 m to 3616 m. The temperature on the well-head ranges from 18 to 129 °C, yields reach up to 70 l/s.

The total amount of geothermal potential in prospective areas (proven, predicted and probable) represents 6,653.0 MW_{th}. This amount consists in 708 MW_{th} of geothermal resources and 5,945 MW_{th} of reserves.

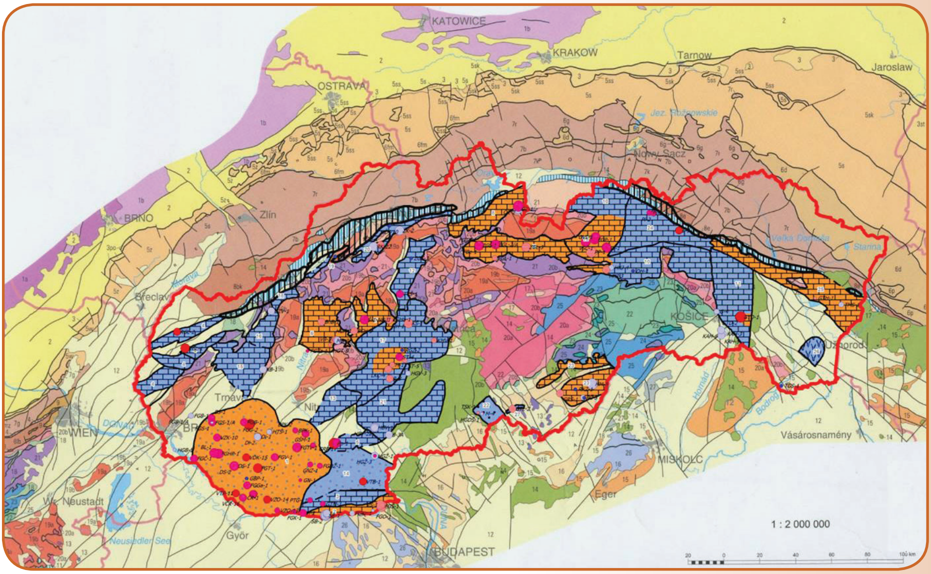

Figure 21: Main geothermal areas of Slovakia [23]

Utilization

The highest number of geothermal installations is located in Nitra County (southwest of central Slovakia), with 19 utilization localities. The highest utilization of thermal power is in Trnava County (western Slovakia) in 13 localities. The smallest number of geothermal installations is located in the eastern part of Slovakia – in Kosice County, where geothermal energy is used only in 5 localities. On the other hand, the Kosice depression is one of the most prospective areas of Slovakia with possibilities to use high temperature waters for electricity production in the future.

Altogether, 11 localities use geothermal water in the agricultural sector (17.6 MW_{th} installed capacity, 461.1 TJ/y annual energy use). Geothermal energy is used for space heating in 21 localities among them for heating of blocks of flats and a hospital in Galanta, for hotels in Besenova, Podhajska, Sturovo and Velky Meder, for dressing rooms and air heating in brown coal mine in Novaky, and for service buildings heating in many localities (27.5 MW_{th}/613.1 TJ/y). There are 59 localities using geothermal water for balneology (73.6 MW_{th}/1708.5 TJ/y). In some of them, the combined utilization for greenhouses, district heating and bathing has been developed, for instance in Topolniky and Podhajska.

Geothermal within the NREAP

The Slovakian national overall target for the share of energy from renewable sources in gross final consumption of energy is 14% in 2020. Within the total RES, geothermal energy is expected to have a share of 17.5%. The renewable energy sources for electricity production are 31.0% for 2010; however, no electricity is expected to be produced from geothermal energy sources.

Regulatory framework

The owner of the geothermal resources is the state. The regulatory framework is rather fragmented; the competence of government authorities in connection to geothermal water prospection and development is under the auspices of several ministries:

- Ministry of Environment – Geological Act: Prospection and research in geological, hydrogeological, geothermal problems and other research related to geology;
- Ministry of Environment – Water Act: Water (surface, groundwater) utilization, disposal, quantity, quality, protection problems and objects;
- Ministry of Environment – Environmental Impact Assessment;
- Inspectorate of Spas and Springs under the Ministry of Health – Balneology Act: Geothermal or mineral water with classification as healing water;
- Ministry of Economy – energy regulations, heat and electricity productions, price regulations, energetic utilization of geothermal water.

Financial supporting schemes

In Slovakia the state role in support of the geothermal energy sources is through government funded projects of the geological exploration and prospection (deep hydrogeological or geothermal wells) which mitigates risks due to geological uncertainty to a certain level. There are few examples of direct investment by the private sources or financial institutions and loans, but no systematic scheme is present concerning direct investment schemes. Projects can be financed from the Structural Funds.

In Slovakia, electricity is subject to a consumption tax, except for if it is produced by renewable energy. Geothermal energy in theory would benefit from the tax exemption, but at the moment there is no geothermal-based electricity production. The amount of tax is calculated on the basis of the amount of electricity tariffs. In Slovakia the feed-in tariff (in general) is 80.91 €/MWh.

Data policy

Most of the information listed in the questionnaire are available in Slovakia and many of them have been published in the "Geothermal Atlas of Slovakia". Additional data are available through published works and final reports from research. Geology related data including web-map services are available through the State Geological Institute of Dionýz Štúr, which also handles „Geofond" the geoscientific data archive of Slovakia. Hydrogeological and environmental related data are handled by the Slovak Hydrometeorological Institute and by the Ministry of Environment of the Slovak Republic.

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6.12 Slovenia

Geothermal resources and potential

The best geothermal conditions are found in NE-Slovenia, being part of the Pannonian Basin (Mura-Zala Basin) (Figure 22). The area has an elevated surface heat flow density (> 100 mW/m^2) with expected temperatures above 80 °C at 2 km depth east of Maribor and Ptuj. In this area all production wells exploit thermal water from Neogene sandy aquifers yielding thermal water of 40-65 °C, with the exception of Maribor and Benedikt, where geothermal aquifers are formed in the fractured metamorphic rocks of the pre-Tertiary basement. The best production wells have flow rates at maximum utilization of few tens of l/s.

There are three potential reservoirs in NE-Slovenia for power generation, however these are very limited in space: Miocene clastic aquifers northeast of Murska Sobota and in Lendava in depths to 3 km and at temperature high above 80 °C; carbonate rocks of the pre-Neogene basement in the Radgona-Vas tectonic graben in depths of 3 to 6 km and at temperature above 150 °C; and low permeable metamorphic or magmatic rocks in the Pohorje granodiorite massif, representing a potential for HDR/EGS.

In the eastern part of Slovenia and south of the Ljutomer-Balaton fault the main geothermal aquifers are located beneath the sediments of the Pannonian Basin, such as at Rogaška Slatina, where thermal water is captured with a 1.7 km deep well in the Triassic dolomitized clastic rocks. Further to the south in Podčetrtek thermal water is found in Triassic dolomite.

There are some other exploitation wells in the central part of the country too that capture lukewarm water mostly from the Mesozoic or Palaeozoic carbonate and clastic rocks in the fault zones, running along the Tertiary basins.

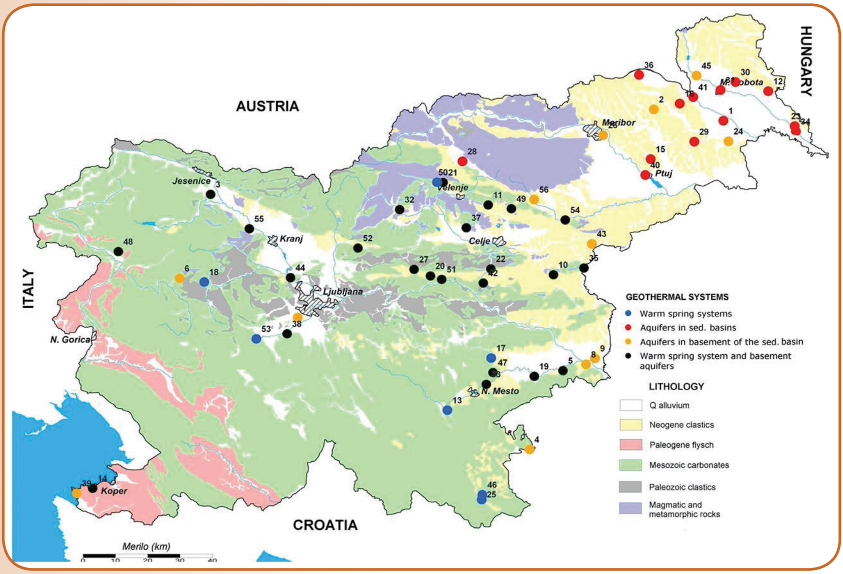

Figure 22: Geothermal systems of Slovenia [24]

Utilization

The direct use of geothermal energy in Slovenia is based on the exploitation of low temperature resources. At the end of 2012, 24 thermal (natural and captured) springs and 58 operational geothermal wells all over the country produced thermal water warmer than 20 °C from a variety of hydrogeothermal reservoirs. Out of these, 35 wells (60 %) are used for multipurpose utilization, i.e. at least for two categories of direct use. In addition at least 15 potential production boreholes exist which are currently out of use, however, some of them are occasionally in production.

At present 32 users exploit geothermal energy directly from thermal water with various categories of use, mostly in thermal spas and health resorts, or recreation centres. Individual space heating is carried out at 18 locations with 35 production wells with installed capacity of 27.3 MW_{th} and 311 TJ/y energy used, mostly in the balneology centers, thermal spas and resorts, where heat exchangers or heat pumps are used for better performance. Cascade use is widely used, where individual space and sanitary water heating is usually followed by heating of spa infrastructure (swimming pools) and balneology. Geothermal energy is used for district heating at Murska Sobota, Lendava and Benedikt with a total installed capacity of 3.7 MW_{th} and 22.6 TJ/y energy used. Greenhouse heating operates also at 3 locations (13.6 MW_{th}/113.8 TJ/y). Balneological use is significant (16.6 MW_{th} installed capacity, 120.8 TJ/y energy used). Snow melting and air conditioning also exist.

Geothermal electricity production is foreseen only by 2030.

Geothermal within the NREAP

In the National Renewable Energy Action Plan of Slovenia a 3-3.5 times increase of geothermal heat production from 2010 to 2020 (from 1.11 to 3.42 PJ) is aimed which is based on the promising geothermal potential of the Pannonian Basin. However, geothermal electricity is not foreseen in the period 2010-2020, but the proposition of the Slovenian national energetic plan already foresees geothermal power plants of 25 MW_e by 2030.

Regulatory framework

Renewable energy resources, including geothermal energy, are discussed in various regulations and national development strategy documents. Geothermal energy is under the auspices of the Mining Act. The legal basis for exploration and utilization of geothermal energy is under the jurisdiction of the Ministry of the Environment and Spatial Planning and the Ministry of Economy. Exploitation of geothermal energy resource without groundwater extraction is regulated by the Mining Act, but when it happens with thermal water abstraction, than by the Water Act. Exploration rights for thermal water are issued by the Environmental Agency of Slovenia (ARSO). If the temperature of thermal water is more than 20 °C, a water concession is required, granted by the government.

Financial supporting schemes

Some governmental pubic funds have been available for geothermal projects. Financial support for direct heat projects are available through different "energy-related" operative programs financed by the Structural and Cohesion Funds. A feed-in-tariff system exists, however Slovenia foresees geothermal electricity production only by 2030.

Data policy

Most of the information listed in the questionnaire are available in Slovenia, the geology-related ones at the Geological Survey of Slovenia, where they are stored and accessible via advanced GIS applications. Much of the hydrogeological and environmental data are managed and handled by the Slovenian Environmental Agency (ASRO).

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7 Regional analysis – Conclusions

The country overviews prove that the deep geothermal potential is significant in almost all EUSDR countries and many of the resources are still untapped. There is a great diversity of use in the different countries from combined heat and power production (even though only at small pilot scales at the moment), HDR technologies of granitic rocks, to a large variety of direct heat applications including innovative solutions utilizing low temperature resources by the help of heat pumps. However in the majority of the countries the most common way of use of thermal groundwaters is balneology, direct-heat applications are subordinate, although reservoir conditions would be suitable at many places.

All EUSDR countries foresee an increase in the share of geothermal energy by 2020 and beyond (Table 4). However to reach these goals it is obvious that favourable geological conditions are not enough, a wide range of technical and non-technical issues should be addressed in order to speed up the expansion of the geothermal sector, which are briefly discussed below.

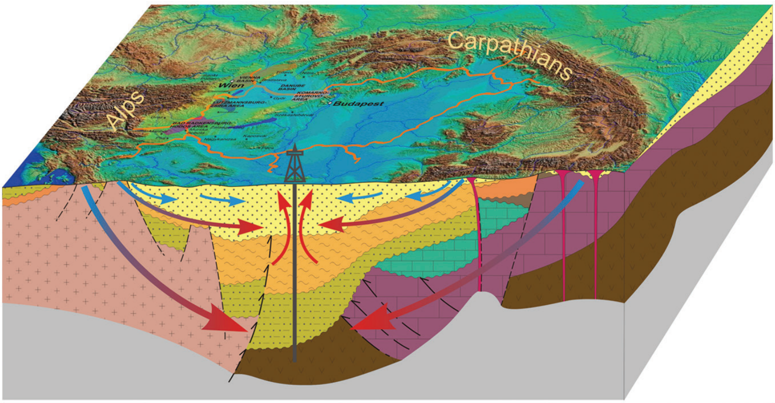
	Geothermal energy in NREAP (PJ)	
Country	**2010**	**2020**
Austria	**0,803**	**1,682**
Bulgaria	**0,042**	**0,377**
Czech Republic	**0,000**	**0,694**
Germany	**1,521**	**34,676**
Hungary	**4,229**	**14,95**
Romania	**1,047**	**3,349**
Slovenia	**0,754**	**0,837**
Slovakia	**0,126**	**3,876**

Table 4: NREAP target numbers of the EU countries of EUSDR. Most of the countries plan with a 2-3 fold increase by 2020

Although all countries have profound knowledge on their geothermal resources, the available information is still not sufficient enough. Both geothermal developers and policy / decision makers require ***detailed and up-to-date, scientifically based information on the available geothermal resources.*** However the type and details of information are quite different. While a project developer needs site-specific, mostly technical information at a local (reservoir) scale (special surveys, e.g. 3D seismic, specific well-tests, etc. are usually done by the project company); policy makers, licensing authorities require a more general and regional overview on the geothermal resources, limits on their sustainable use (e.g where and how much thermal water abstraction can be licensed without threatening the depletion of the reservoirs, expected environmental impacts, etc.).

In the EU (and also in the EUSDR countries), geothermal data and information are currently organized by national geothermal information systems tailored to the specific needs of the individual countries, and their content and formats are depending on the expertise and objectives of those organizing the data. Even though relevant data are very similar in each country (e.g. subsurface temperature maps), it is difficult for a potential operator, local/regional government, or citizen to get a comprehensive overview at a regional / macro-regional scale. Moreover, information is fragmented, often available in the local language only and has to be retrieved from a multitude of websites and documents.

Another important issue, especially in the Pannonian Basin and its adjacent areas, is that the large-scale geothermal reservoirs are strongly linked to geological-hydrogeological settings irrespective of state-borders and are often shared by neighboring countries (Figure 23). Thermal water abstraction from the same ***transboundary*** hot water aquifer without harmonized cross-border management may have negative impacts (depletion or overexploitation, even environmental issues) in a neighboring country leading to economic and political tensions. In order to align national strategies and establish a multi-national management system, a joint assessment of geothermal potential on regional level done by the neighboring countries is essential.



Main geothermal reservoirs	Paleo-Mesozoic fractured, karstified basement rocks	Miocene porous and carbonate reservoirs	Mio-Pliocene porous basin fill: multi-layered sandstones, shales
depth (top)	>2-3000 m	Basement highs	600-1500 m
temperature	>100-150 °C	50-150 °C	50-100 °C
prospect	power, CHP	CHP, direct heat	direct heat, balneology

Figure 23: Schematic geological model of the Pannonian basin and adjacent neighboring areas showing the most important potential geothermal reservoirs and their utilization potentials

In addition to the above outlined large-scale actions (joint data sources and common evaluations) that are necessary for the sustainable management of the geothermal resources of the Danube Region, there are many tasks that address directly the current utilization.

Overexploitation of the geothermal aquifers in areas with intensive thermal water abstraction is a potential problem in several EUSDR countries. The increasing demand for thermal water from the same aquifers (especially coupled with insufficient reinjection – see below) causes negative quantitative trends in the reservoirs (e.g. drops in yield). Furthermore, as the number of users is increasing, potential *interference* among the different sites and disputes between nearby users may also arise, as already noticed at several locations. Therefore, users and national authorities should as soon as possible establish unified and objective ***monitoring systems*** of geothermal resources, by controlling groundwater level, temperature, yield, and chemical composition of thermal water. Such combined interpretation of the active (carried out by water users) and passive (carried out by governmental organizations in non-exploited observation wells) monitoring data would allow to follow systematically the changes in aquifers, and make regional evaluations of the available thermal water resources possible that is necessary for leasing new water permits.

In most of the countries the lack of / ***low share of reinjection*** is a straightforward consequence of the ***low share of energetic use*** (thermal water used for baleneological purposes cannot be reinjected due to human induced pollution). In addition to maintaining proper reservoir conditions (pressure, yield), reinjection also helps to mitigate the thermal / chemical pollution of surface waters which might result from the emitted and untreated thermal water. As already mentioned in Chapter 2, re-injection, especially into porous reservoirs has its technical challenges (plugging of perforation in the well and pore throats of the reservoir formation leading to a decreased permeability). Reinjection wells represent a large investment cost, which – without suitable financial support – are not feasible for most of the users. However, due to the positive effects on aquifer hydraulic conditions and mitigation of environmental pollution, reinjection into the same aquifer should be required for all users utilising non-treated thermal water for the purpose of use of geothermal energy. Limited time of derogation and appropriate financial support should be given to current users for the implementation of (new) reinjection wells, while new users should establish the necessary doublet system before starting production. Location and design of reinjection wells should be based on numerical simulation of aquifer capacities, appropriate technical design of reinjection wells and cost-benefit analyses, which require significant R&D support.

Several countries reported a set of technical problems, which are associated with the ***low thermal and utilization efficiency*** of the existing wells. Only a few users cool thermal water near to the mean annual air temperature (12 °C). Higher thermal efficiency (i.e. using a higher temperature difference between the inlet and outlet water) would lead to a reduction in the total amount of abstracted thermal water, as well as lower thermal pollution of surface streams into which waste water is emitted. With the more widespread use of heat-pumps, a great proportion of the heat content could be still utilized, which is otherwise wasted. It was also reported that in many cases geothermal resources are not exploited at the full capacity of the reservoirs and wells. A major cause is often the lack of adequate production facilities (e.g. geothermal waters often corrode the transport pipes due to the H_2S and CO_2, plugging of pipes due to scaling, etc.). Application of ***cascade systems*** (utilization in series, where each sequential utilization type uses the heat or the waste thermal water from the preceding utilization type) is not widespread either, although it would have a direct impact on decreasing the need for additional thermal water, thus increasing utilization efficiency.

Overviewing the (renewable) energy policies, it can be concluded that although all EUSDR countries acknowledge the importance of renewables, national characteristics (e.g. being rich in fossil fuels, such as coal, having significant capacities in other type of renewables, such as hydropower, or nuclear power as a major contributor to power generation) often does not make geothermal energy an attractive alternative.

As the lifetime of a geothermal project is long (15-30 years), stable and reliable political and economical conditions are essential to ensure the safety and profitability of investments. Analysing the most important ***non-technical barriers*** practically almost all EUSDR countries reported a ***fragmented regulatory system,*** where the management of geothermal resources and licensing of geothermal projects are shared among different ministries and authorities, most common between the "environment/rural development" sector dealing with abstraction of thermal groundwater, and the "energy /industry /economics" sector looking at geothermal energy utilization without water production. This makes licensing procedures complicated and time-consuming.

Another major obstacle is the ***lack of sufficient financial incentives*** (direct subsidies, funds, low interest loans, tax incentives, feed-in-tariff, off-take and support schemes for green-heat). A major missing instrument is a risk insurance system that would help to mitigate the high up-front costs of a geothermal project, where the risks are the highest at the stage of drilling the first wells.

The lack of qualified personnel in policy making, research, sustainable management of the resources, as well as the protection of the environment also holds back geothermal development.

At last, but not least we have to mention the low rate of ***public awareness.*** Although geothermal energy has the major advantage of offering a wide range of possible applications in the field of both electricity and heating and cooling, and is an ecologically and economically worthwhile local energy solution for a very wide public (local communities, citizens and consumers, and industry), its advantages are little known. Media reports often focus more on its disadvantages (e.g. induced seismic risk of EGS projects, negative impacts of fracking/stimulation on groundwaters, contamination of surface waters, swelling ground, etc.). As a result, political decision makers and potential investors have concerns about possible risks involved in implementing geothermal projects, and social resistance often results in practical obstacles, such as significant slowdowns of the projects.

This document intended to raise the awareness on the untapped deep geothermal energy potential of the Danube Region and by that, attract investors to the region. As Europe (and the whole world) looks for alternatives to fossil fuels – which are growing ever scarcer, with issues of security of supply and carbon-dioxide emissions that can cause climate change – geothermal energy promises a clean, renewable alternative source of energy. This is underlined by numerous international and EU policies and strategies including roadmaps with concrete actions how to achieve the targets. Based on the detailed analysis of these documents, as well as the in-depth enquiry of the national (renewable) energy strategies, it is clear that the increase of renewable/geothermal energy in the DSR countries is one of the biggest challenges in their energy policies during the coming years. The enhanced use of geothermal energy does not only support the fulfilment of EU obligations (achievement of NREAP target numbers), but the expected growth contributes to the security of energy supply, the decentralized rural development, creation of new working places and a safer and cleaner environment.

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Notes

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