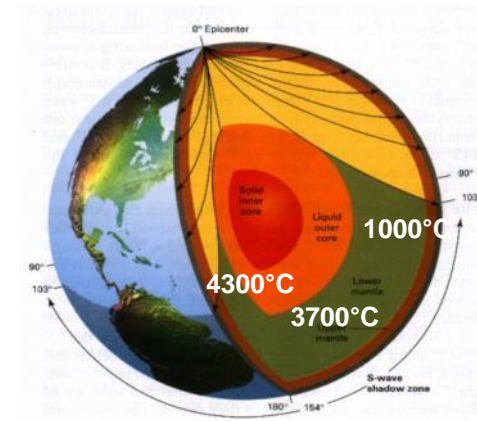
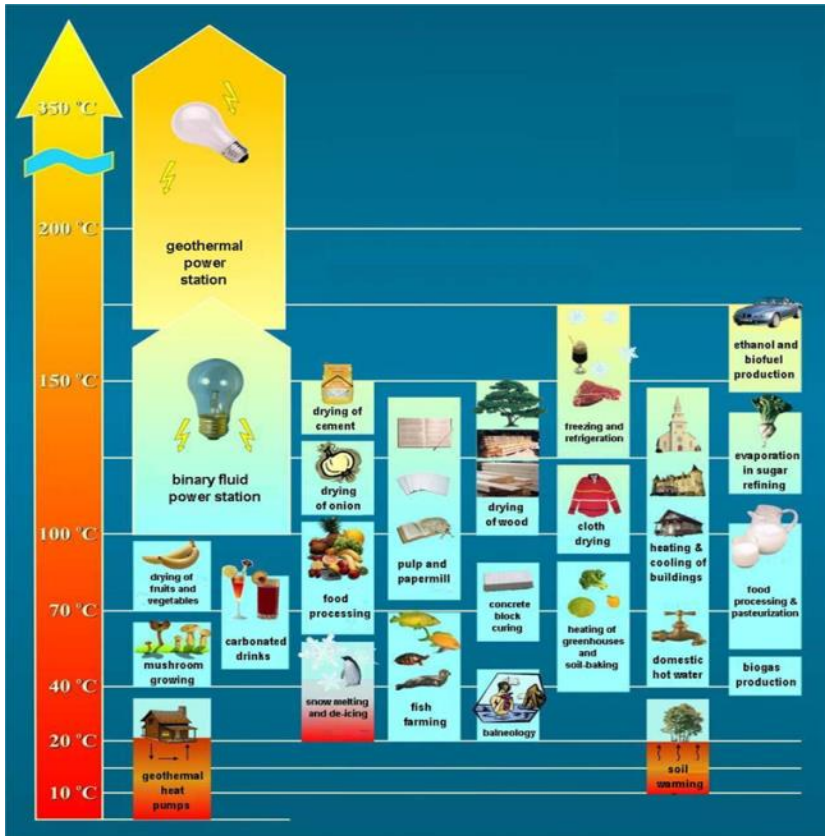


How can geothermal resource assessment and mapping influence decision-making for district heating: Experience from Hungary and the Danube Region

Annamária Nádor
Mining and Geological Survey of Hungary

**IRENA - Energy Solutions for Cities of the Future: Facilitating the Integration of Low-Temperature Renewable Energy Sources into District Energy Systems.
Capacity building workshop, December 5-6, 2019, Belgrade, Serbia**

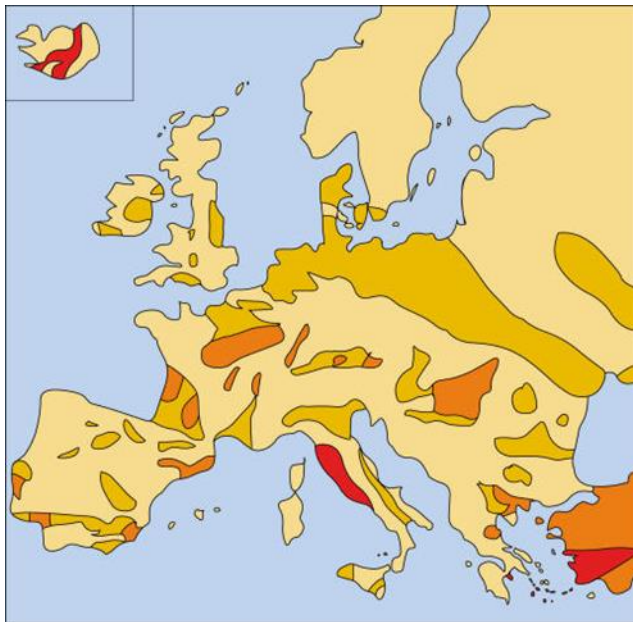
Why geothermal?



- ✓ Widely available
- ✓ 24/7 delivery
- ✓ Large untapped potential
- ✓ Predictable output
- ✓ Numerous applications
- ✓ Domestic and green resource
- ✓ Can be combined with other energy sources to increase efficiency
- ✓ Suitable for cooling
- ✓ Low environmental footprint, invisible

Geothermal energy – how to classify?

- Very low: $<30^{\circ}\text{C}$ – requires heat pumps
 - Low: $30\text{-}125^{\circ}\text{C}$ – direct heat
 - Medium : $125\text{-}150^{\circ}\text{C}$ – electricity generation
with binary cycles, CHP
 - High: $>150^{\circ}\text{C}$ – „efficient” electricity production. Heat source: mainly magma in magma chambers located at shallow depths (restricted in Europe)
- Heat source: mainly Earth's heat flux



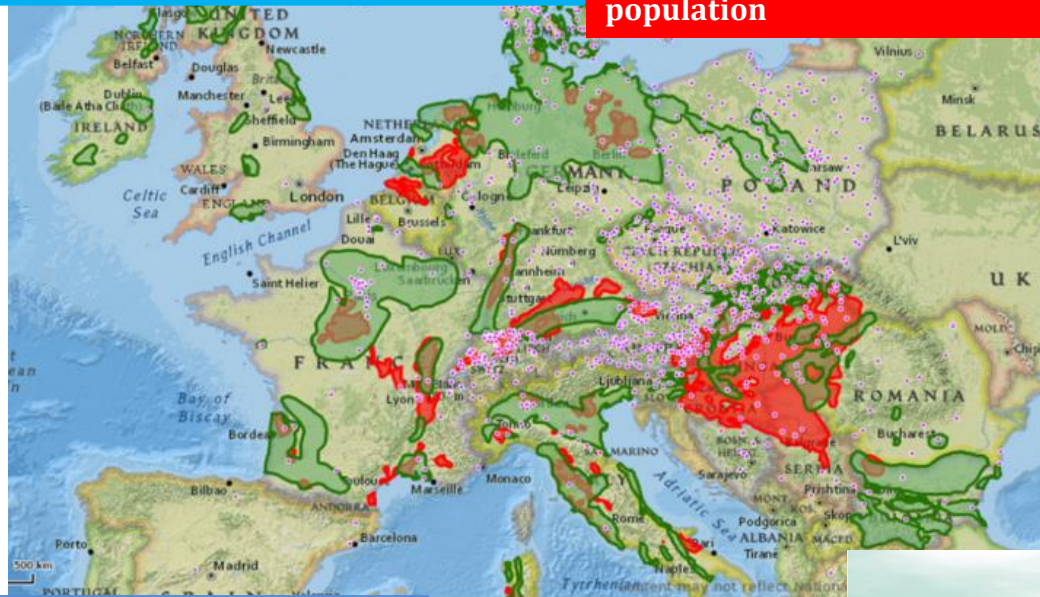
Direct uses



Geothermal energy for the decarbonisation of the heating sector

Matching resources and heat demand in Europe – GeoDH project (2011)

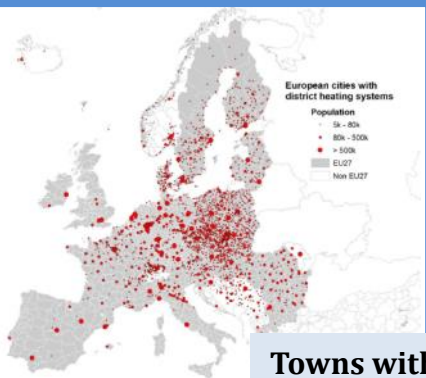
Geo-DH would be available for 26% of the EU-27 population



47% of EU energy consumption is heating & cooling (HC)

12% of the total communal heat demand is district heating

RES / geothermal must be a pillar in the clean energy transition



Towns with DH infrastructure
3882 – Europe
3070 – EU-27

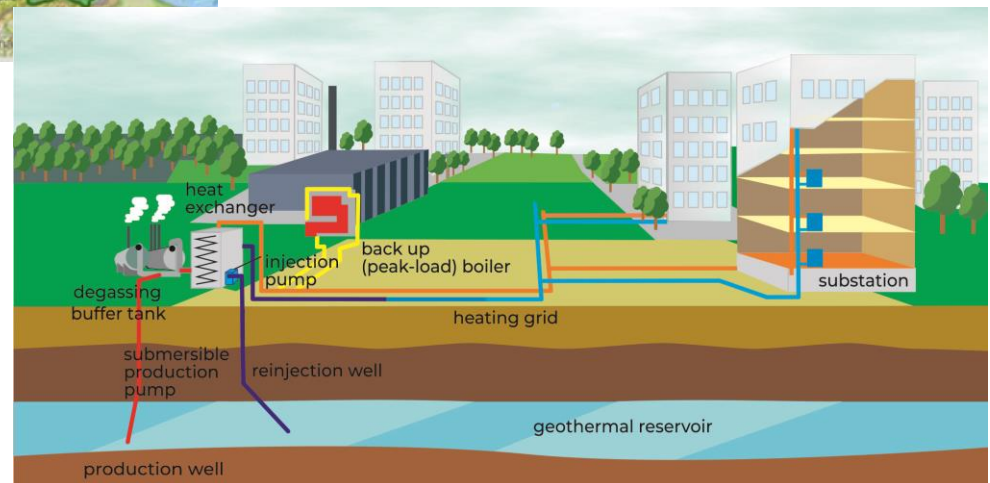
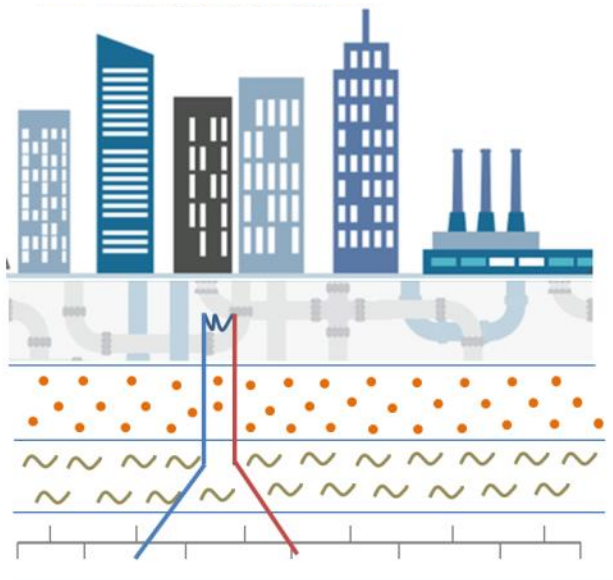
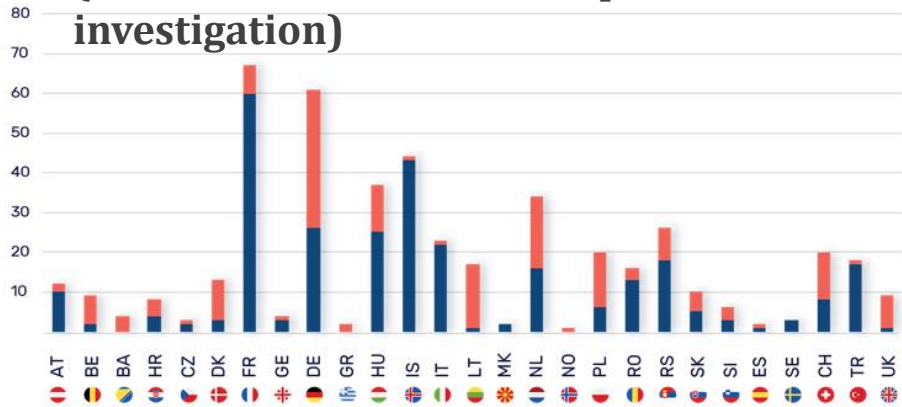


Figure 47. District heating systems in Europe by city size and for cities leading with DH systems. Source: Rademacher University DHC Database.

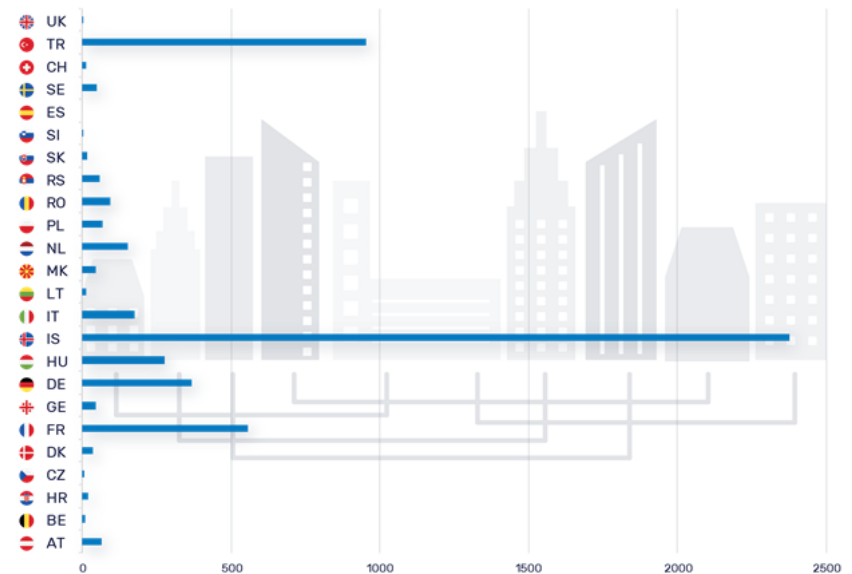
Geothermal district heating: an increasing momentum

EGEC Market Report 2017

**280 GeoDH systems in operation in Europe
(another 164 under development or
investigation)**

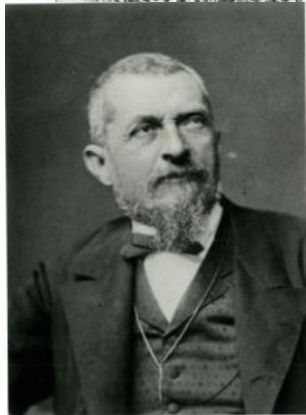


Total installed capacity 4,8 GWth (2017)

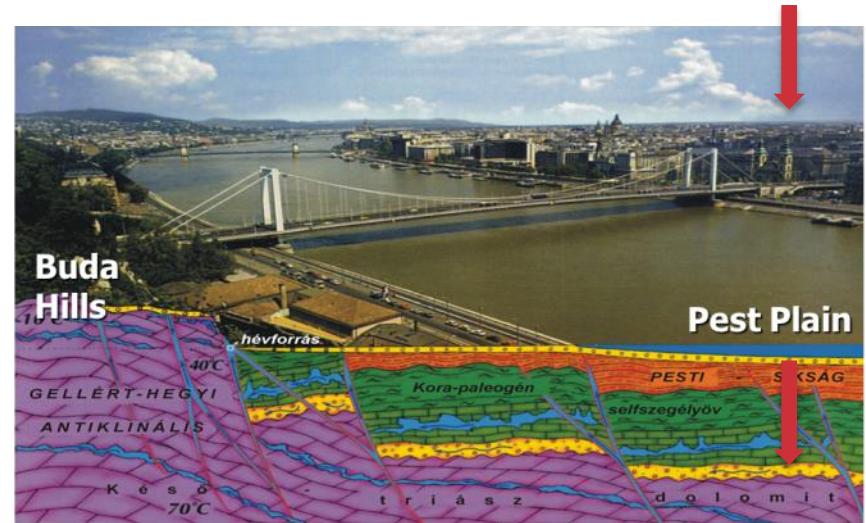


Traditions of geothermal energy use in Hungary

1878: Városliget well: 970 m (deepest well in Europe): 78 °C



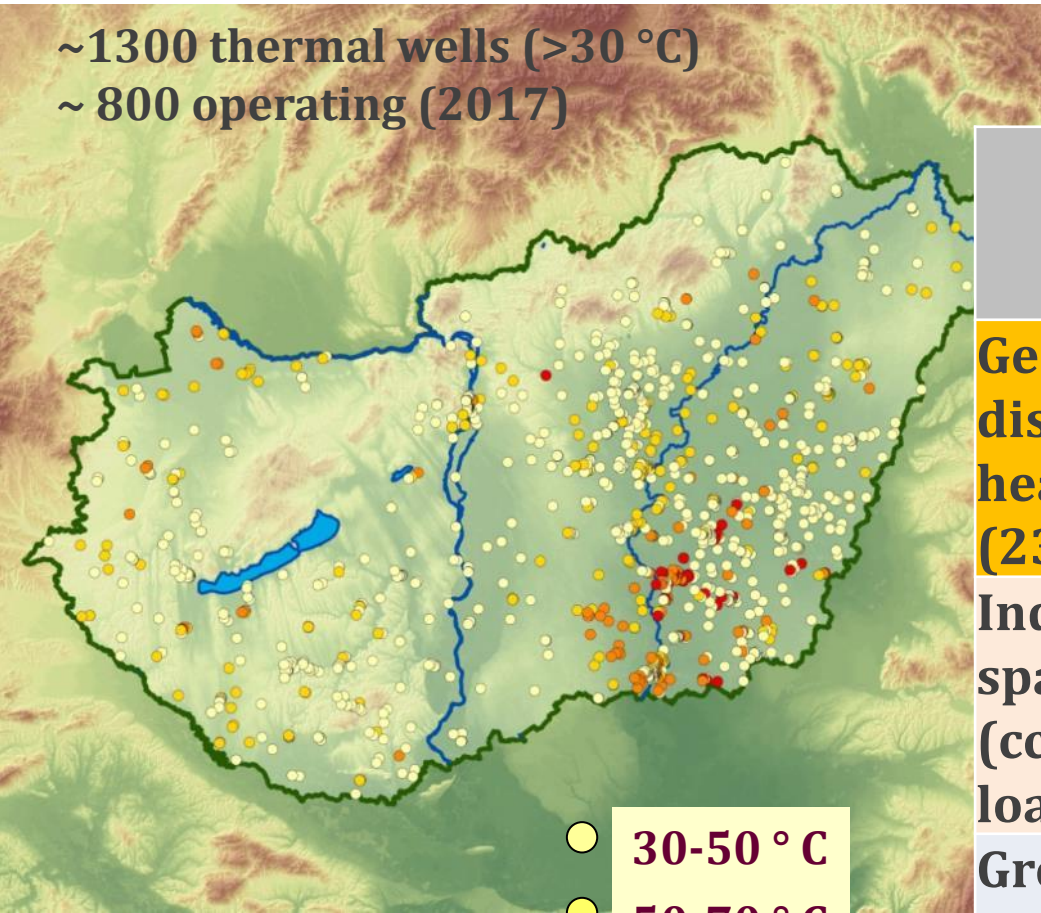
**Vilmos Zsigmondy
(1821-1888)**



Széchenyi Spa, Budapest

Current utilization schemes in Hungary

~1300 thermal wells (>30 °C)
 ~ 800 operating (2017)



- 30-50 °C
- 50-70 °C
- 70-90 °C
- 90 °C <

	installed capacity (MWt)	annual production (GWh/y)
Geothermal district heating (23 towns)*	223,36	635,66
Individual space heating (cca 40 locations)	77,2	83,1
Greenhouse heating	358	803
Balneology (cca 250 wells)	249,5	745,5
	908,06	2267,26

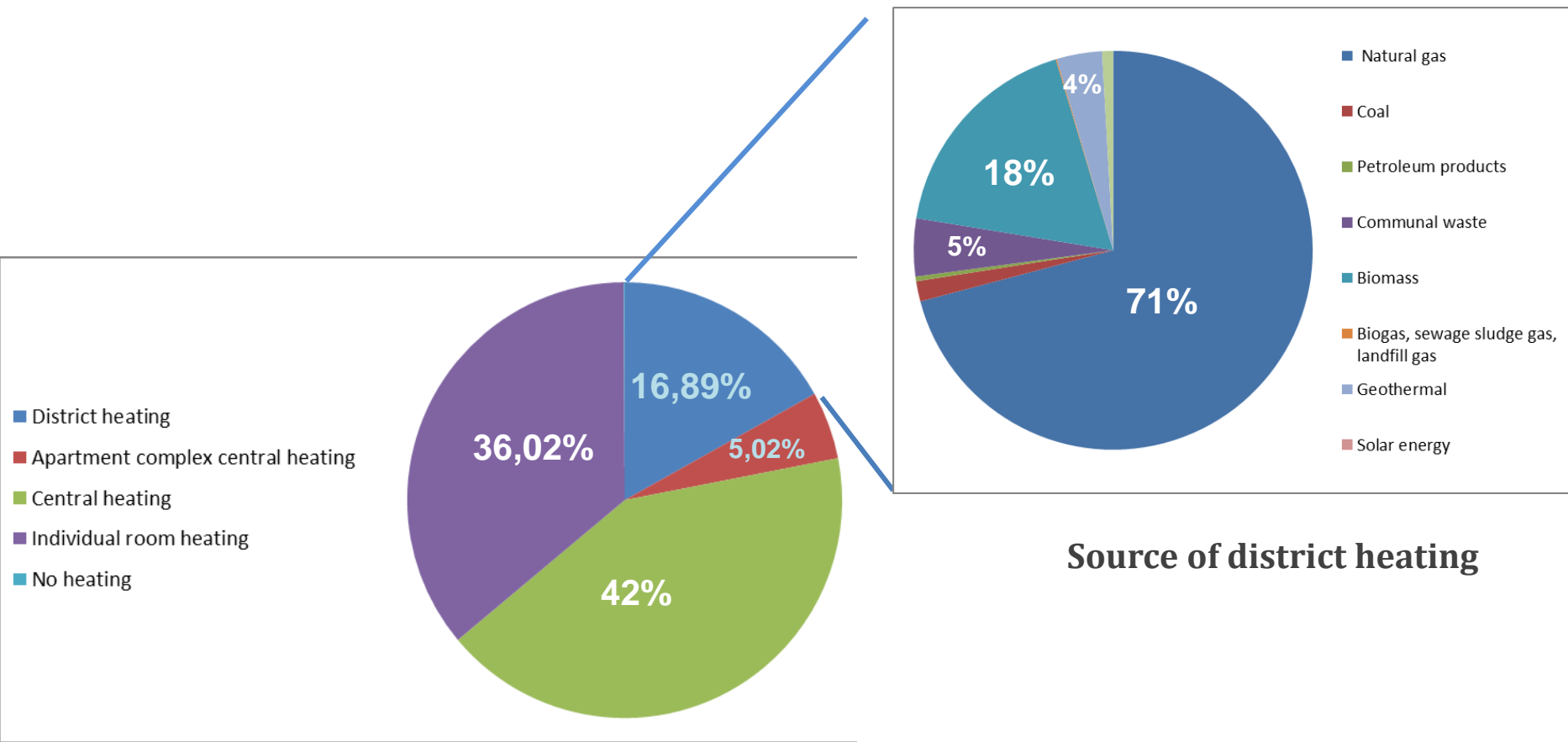
* DH: 8, thermal water town heating: 15

District heating in Hungary

Settlements with district heating infrastructure	95
District heating suppliers	110
District heating networks	220
Number of flats with district heating	648 500



District heating in Hungary



Distribution of Hungary's housing stock according to the type of heating

Good examples for geoDH: Miskolc (Pannergy Ltd)

- ❖ Miskolc, Hungary's 2nd largest town (industrial), population: 170 000 (heat market)
- ❖ Offtake partner: city-owned company, offtake contract: 15 y
- ❖ CAPEX: 25 million euro (appr. 9 million euro non-refundable grant (2010-2013))
- ❖ Capacity: 55 MW
- ❖ Annual production: 800-950 TJ







- Triassic carbonate reservoir
- 2 production and 3 reinjection wells
- Production depth: 1500-2300 m
- $Q = 6600-9000$ l/min
- T outflow = 95, 105 °C
- Installed capacity: 55 MWt

Good examples for geoDH: Szeged (Szetáv Ltd)HU

- ❖ Szeged: Hungary's 3rd largest town, population: 162 500 (heat market)
- ❖ Fossil fuel (gas) based distric DH system: 50% of the city's population (27 000 apartments and 500 public buildings)
- ❖ 23 DH circuits, 235,8 MW / 843 TJ/y
- ❖ Ongoing development: replacement of 9 circuits with geothermal: 1 production – 2 reinjection wells each
- ❖ 140 M euro investment (50% EU funding)
- ❖ Porous reservoir: 1700-2000 m, T outflow= 90 °C, Q= 1200 l/min



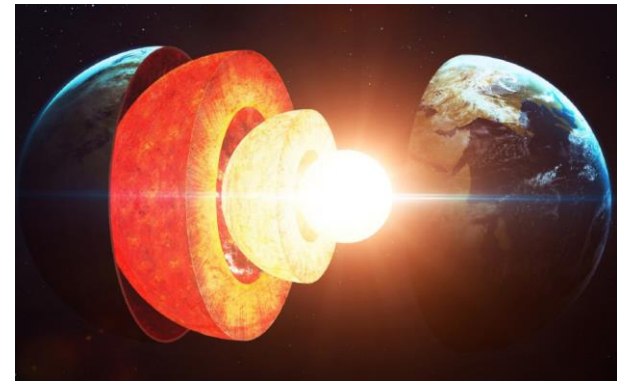
Development plans in Hungary

	2020		2030	
				
Share of RES	20%	14.65%	32%	20%

Modernization of the DH system is in focus!
(Efficiency and RES)

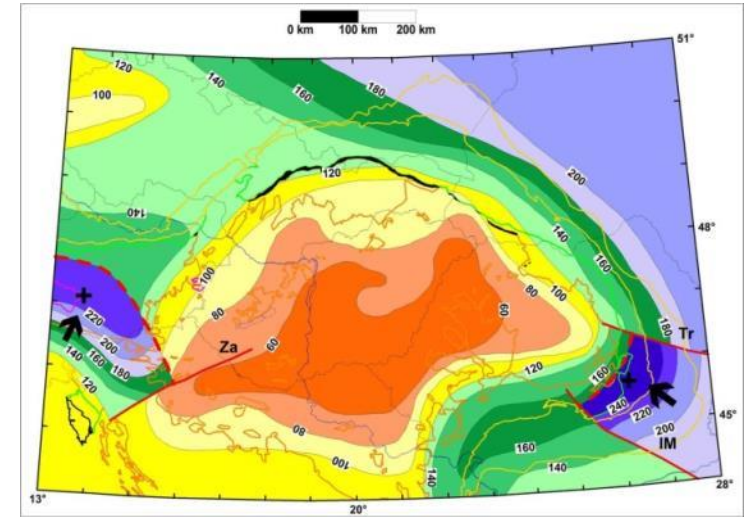
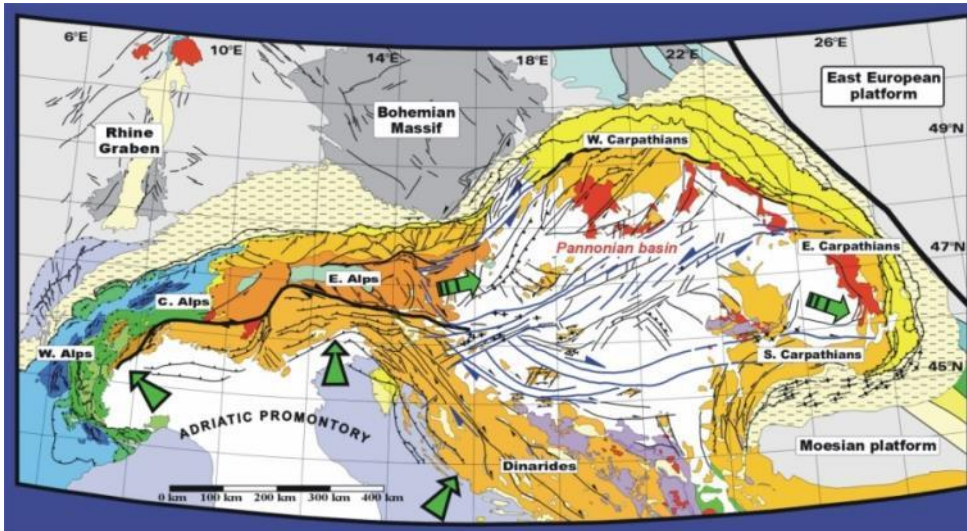
Source: NECAP of Hungary

	2018	2020
Geothermal		17% of total RES
Heat	~8,2 PJ	14,95 PJ
Power	3 MW	57 MW



Preparation: feasibility studies: selected DH systems, assessment of geothermal potential in the given regio - 3 categories
Cots assessments (CAPEX from 1-2 M euro/MW, OPEX 0,5 M euro/year)

Geothermal energy in Central Europe



Outstanding potential due to favourable geological conditions (formation of the Pannonian basin):

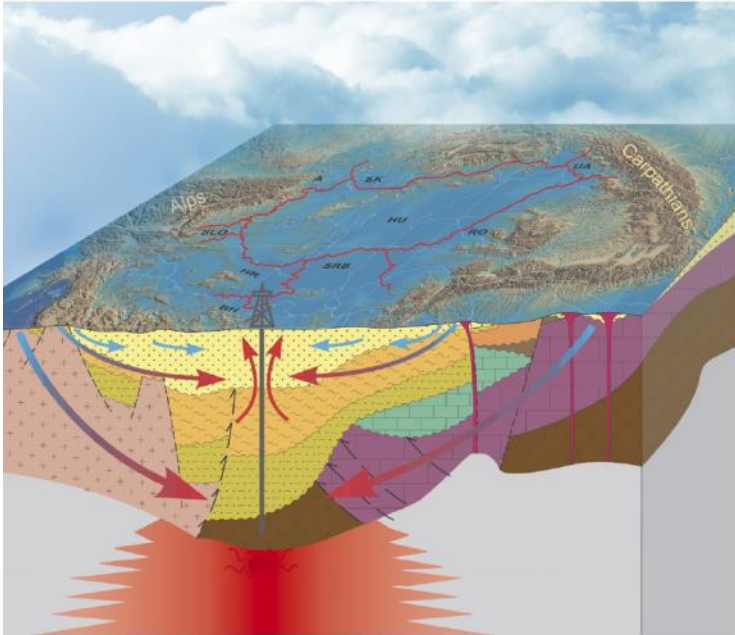
Thinned lithosphere → high heat flux 100 mW/m² (continental average: 60 mW/m²)

High geothermal gradient: 45 °C/km (continental average: 33 °C/km)

Thick porous basin fill sediments – thermal insulation + geothermal aquifers

Rich low-enthalpy resources (up to 125 °C) – largely untapped

DARLINGe project

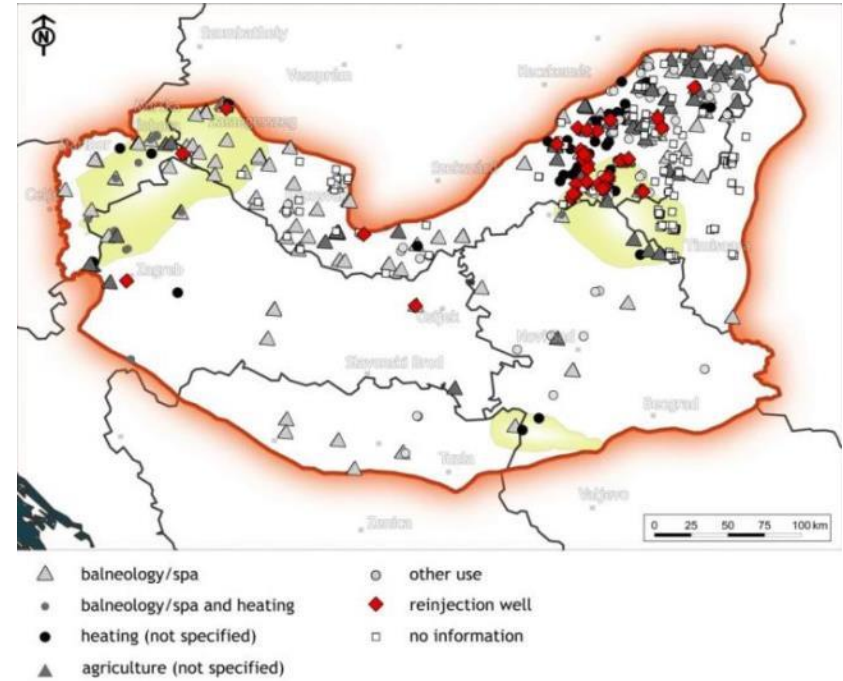
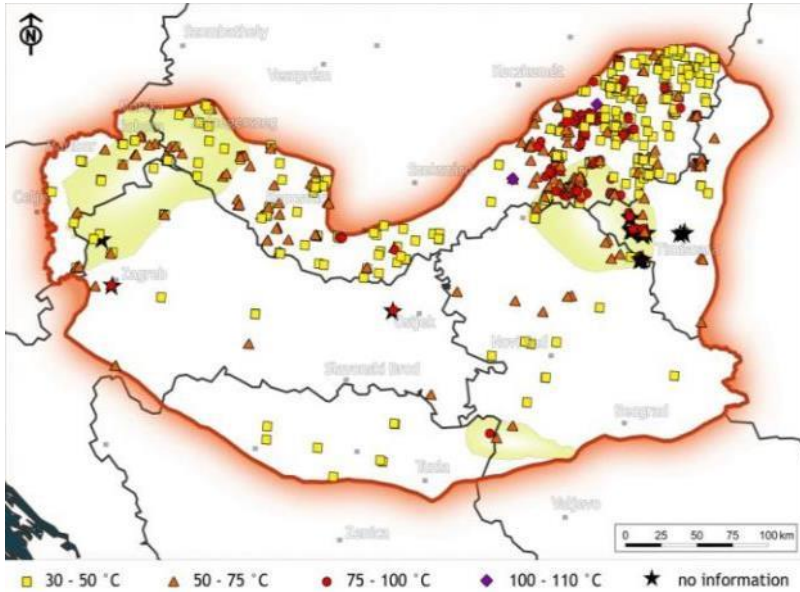


Geothermal reservoirs are controlled by regional geological structures – cut-cross by country borders – **needs for joint evaluation and harmonized management**

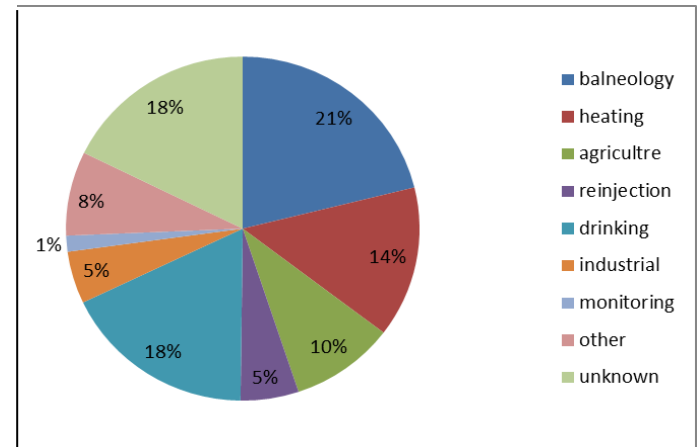
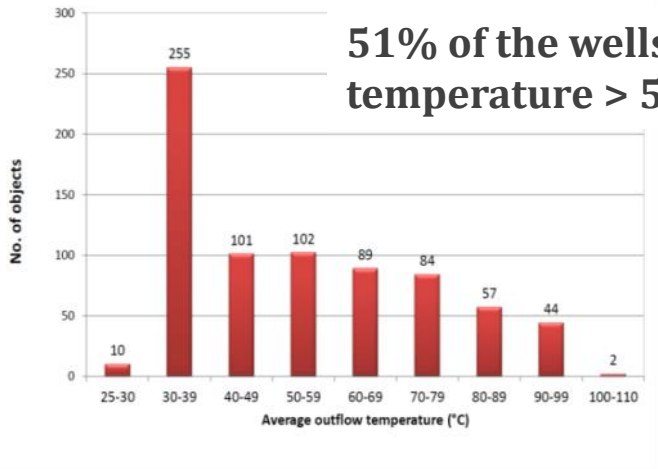


State-of-art: Current utilization

760 geothermal wells and 7 springs
($T_{out} > 30\text{ }^{\circ}\text{C}$)



51% of the wells have outflow temperature $> 50\text{ }^{\circ}\text{C}$



How to identify joint transboundary geothermal reservoirs and make potential assessment at regional scales?

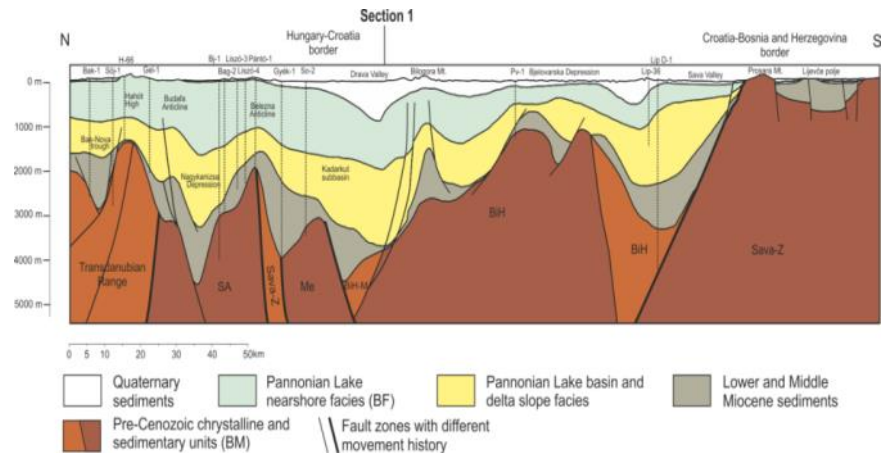
Geothermal reservoir: Subsurface 3D space where the rocks contain hot fluidum which can be exploited economically.

To identify „potential reservoirs” – i.e. geological / hydrogeological units containing thermal water suitable for heating in the Danube Region (1:500 000)

Make a potential assessment

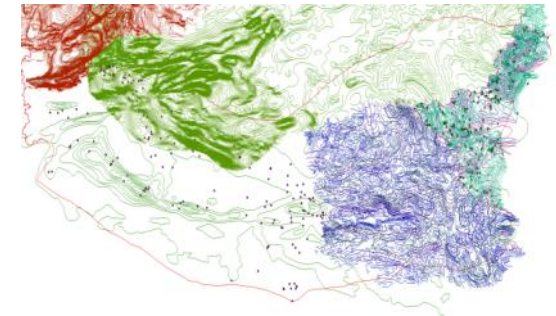
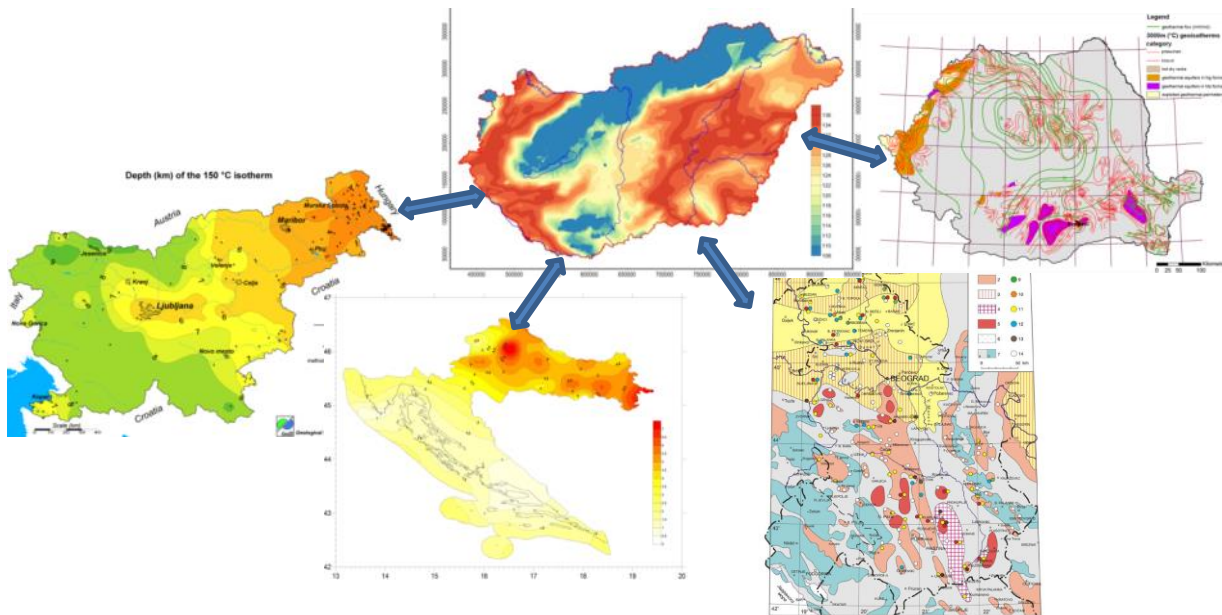
2 main reservoir types:

- **fractured, karstified basement – „BM”**
- **porous basin fill – „BF”**



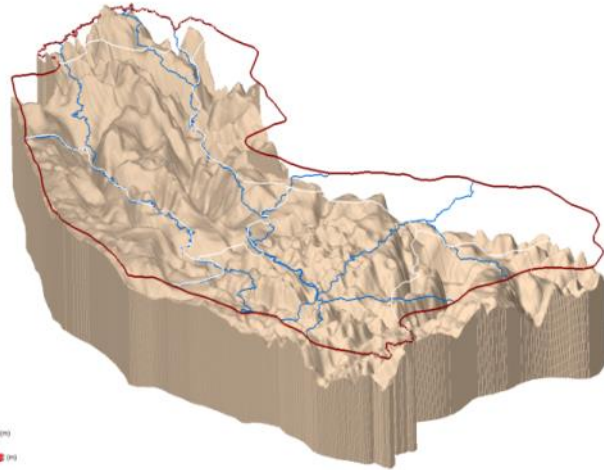
(1) Data collection and harmonization

HU, SI, HR, BiH, SRB, RO

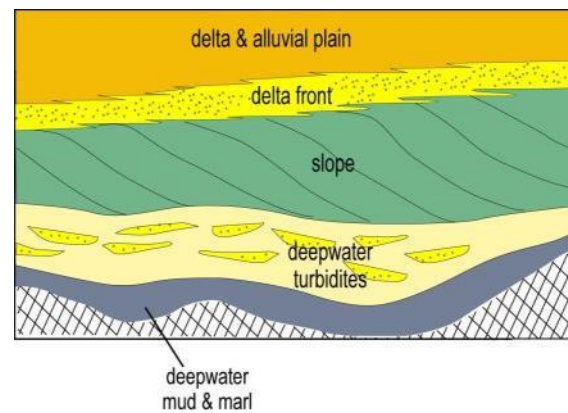
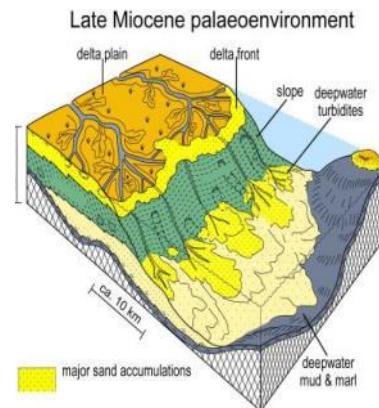


(2) Editing harmonized geological surfaces

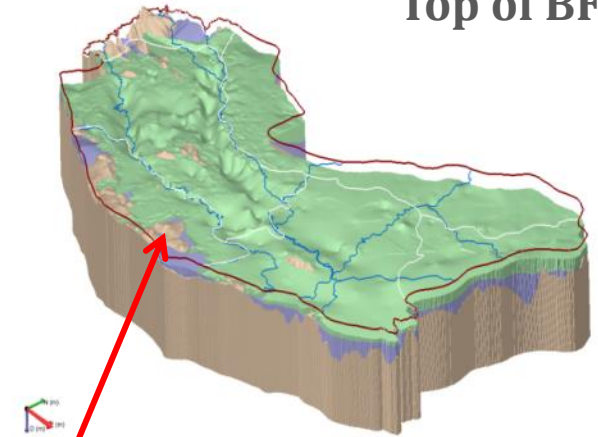
Basin fill sediments („BF reservoirs”)



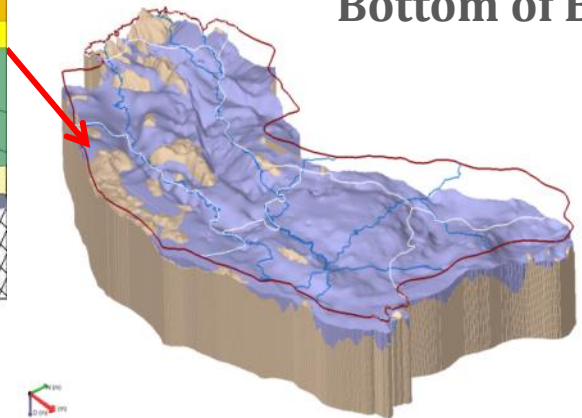
Top of the pre- Cenozoic basement („BM reservoirs”)



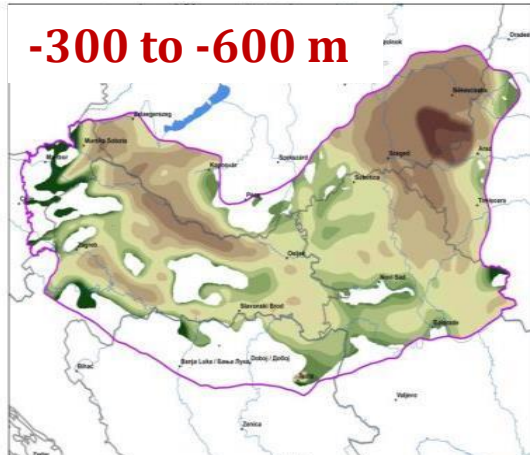
Top of BF



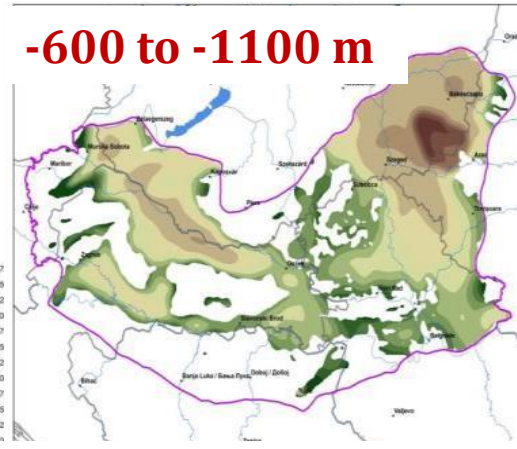
Bottom of BF



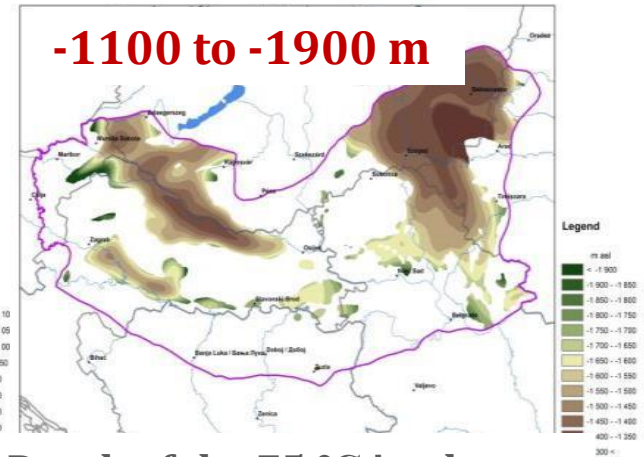
(3) Simplified geothermal model - Harmonized subsurface temperature maps



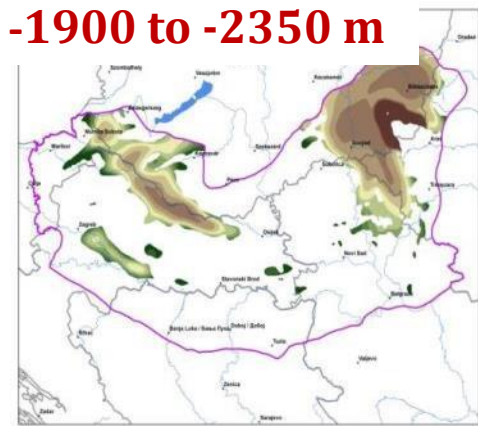
Depth of the 30 °C isotherm



Depth of the 50 °C isotherm



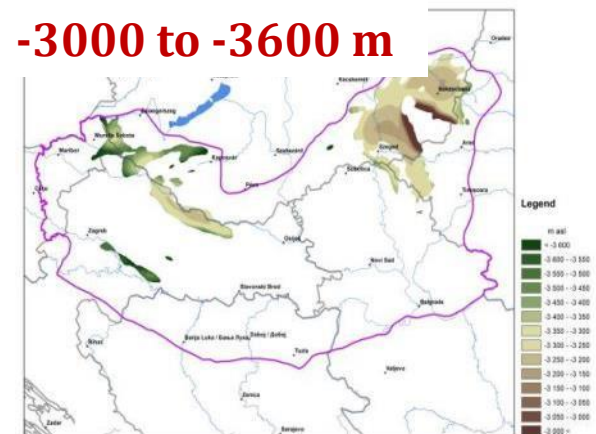
Depth of the 75 °C isotherm



Depth of the 100 °C isotherm



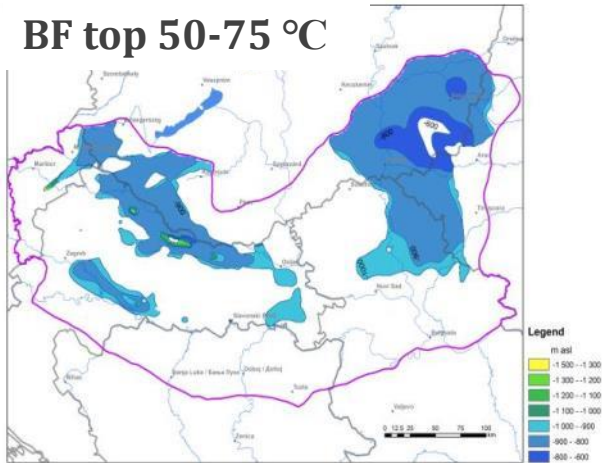
Depth of the 125 °C isotherm



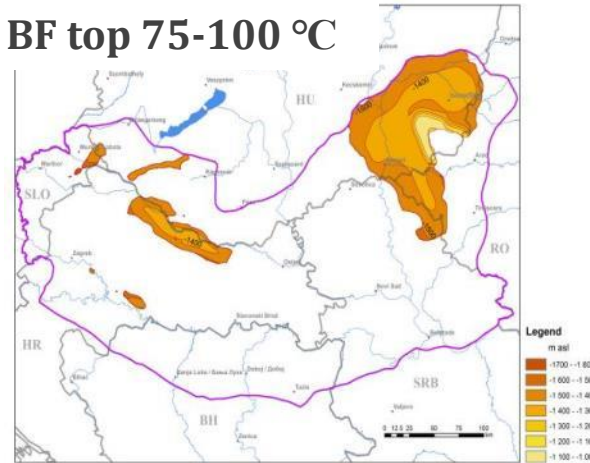
Depth of the 150 °C isotherm

(4) Delineating potential reservoirs: geological bounding surfaces + isotherms

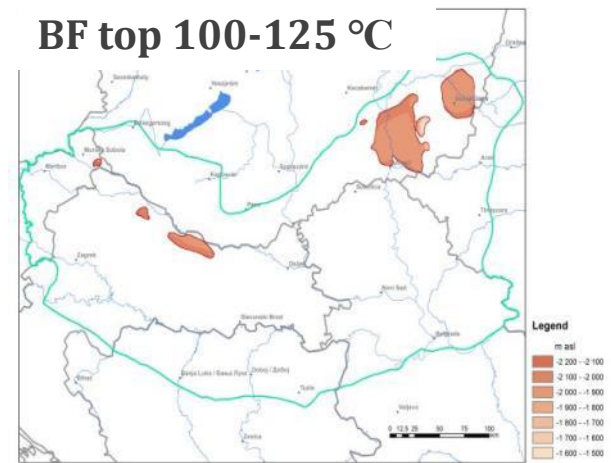
BF top 50-75 °C



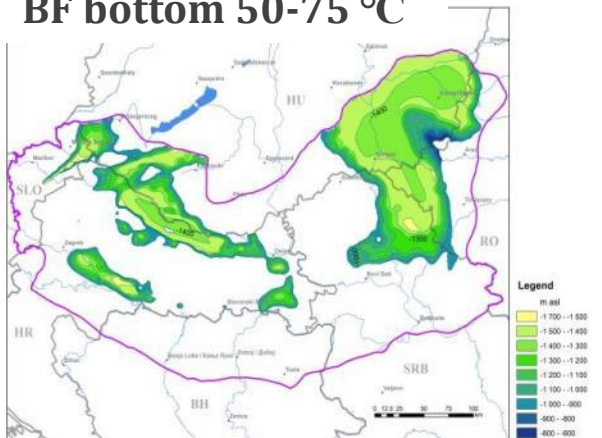
BF top 75-100 °C



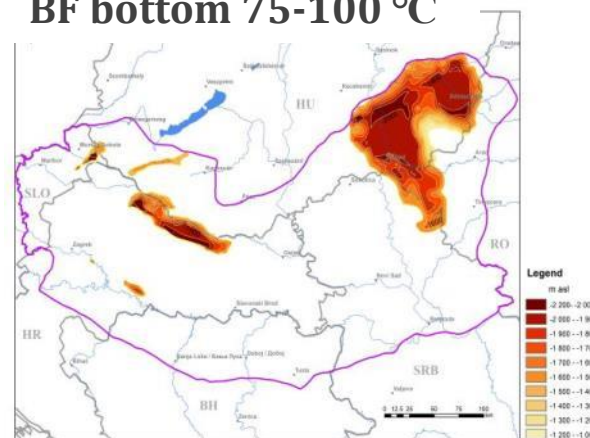
BF top 100-125 °C



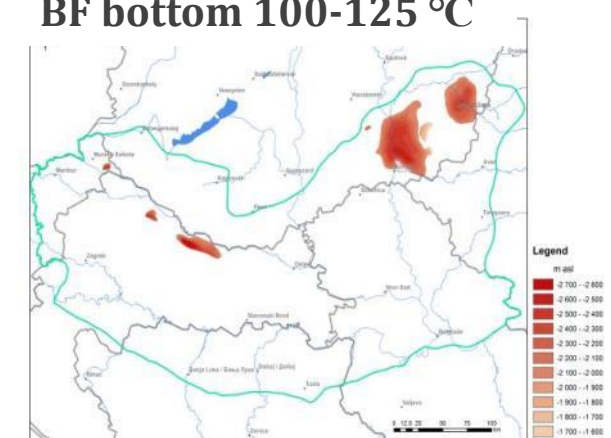
BF bottom 50-75 °C



BF bottom 75-100 °C



BF bottom 100-125 °C



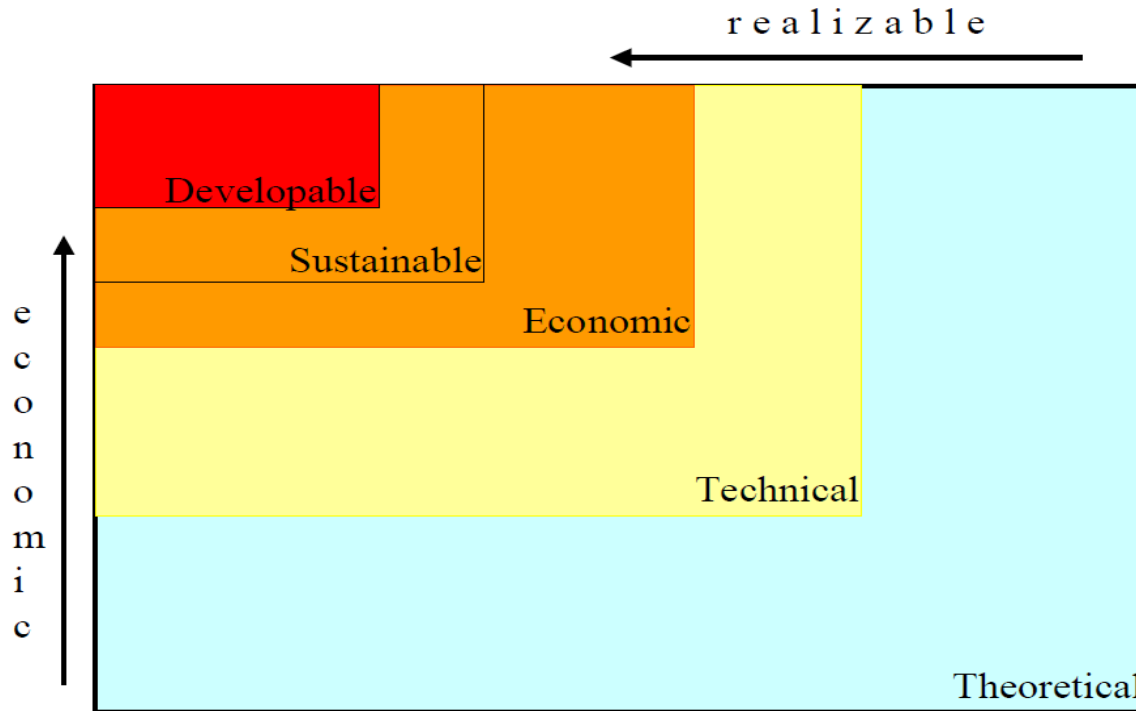
(5) How to assess the geothermal potential of the identified reservoirs?

According to the International Geothermal Association (IGA):
geothermal potential = **the exploitable amount of geothermal energy during a year** → also depends on technical and economical parameters.

Several (and no uniform) approaches worldwide

- I. Prediction from production data: extrapolated from the annual production rates
- II. Static resource estimation: based on Heat in Place calculation (volumetric method) [Muffler és Cataldi (1978), Mufler (1979)]
 $H_0 = c \times V \times \Delta T$ – **huge numbers, not exploitable**
- III. Dynamic resource estimation: water and heat recharges also considered (poro/permeability, conductive/convective heat flow)

Categories of Geothermal Potential



Rybach, 2010

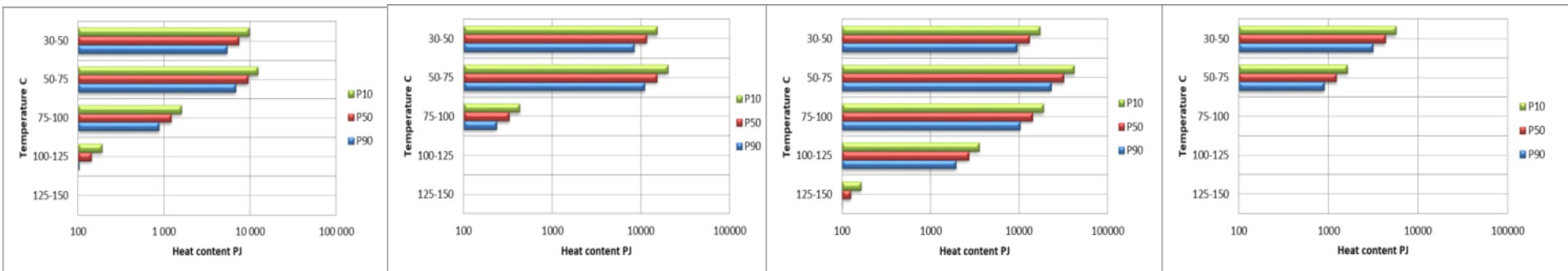
Theoretical = physically usable energy supply (heat in place)

Technical = % of theoretical potential that can be used with current technology

Economic = time & location dependent % of technical potential that can be economically used

Sustainable = % of economic potential that can be used by applying sustainable production levels (regulations, environmental restrictions).

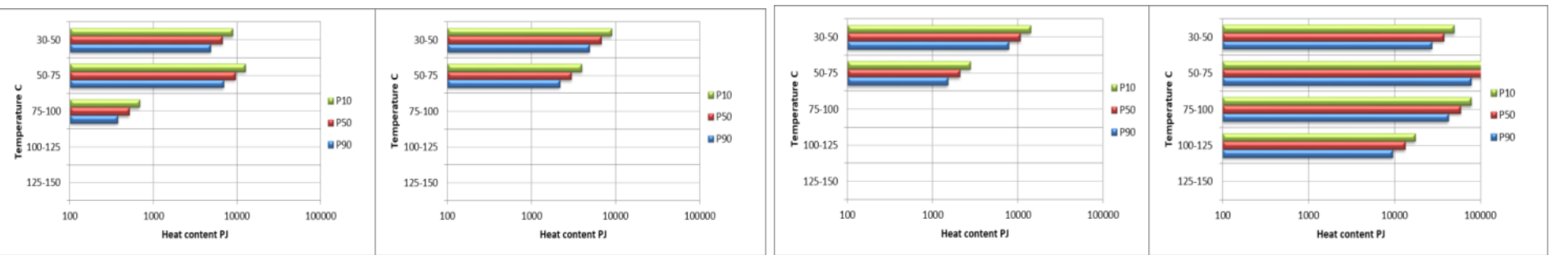
(6) Probabilistic estimation of the recoverable heat



1. Mura-Zala basin (SI-HU-HR) 2. Somogy region (HU)

3. Dráva basin (HR-HU)

4. Zagreb region (HR)

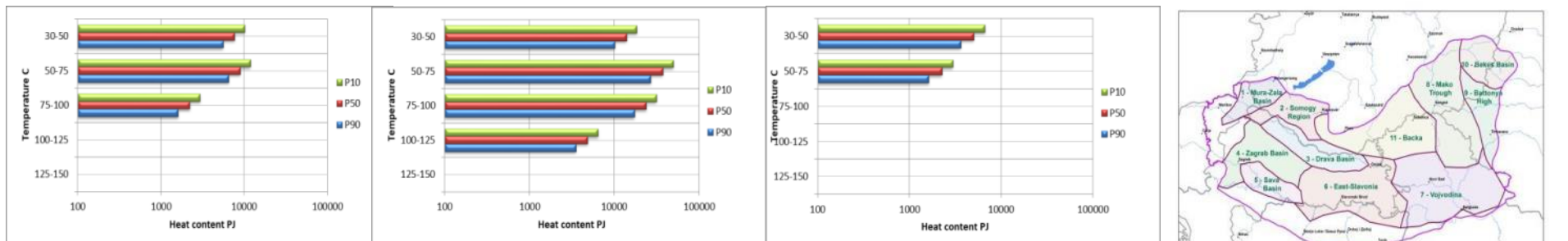


5. Sava basin (HR)

6. East Slavonia (HR-BiH)

7. Vojvodina (SRB)

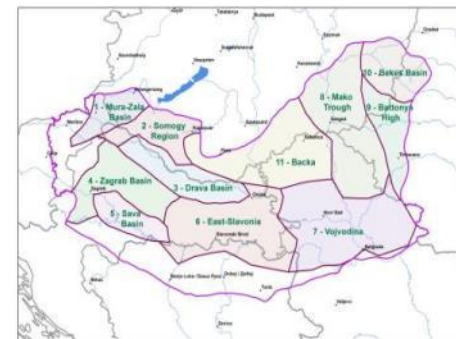
8. Makó Trough (HU-SRB-RO)



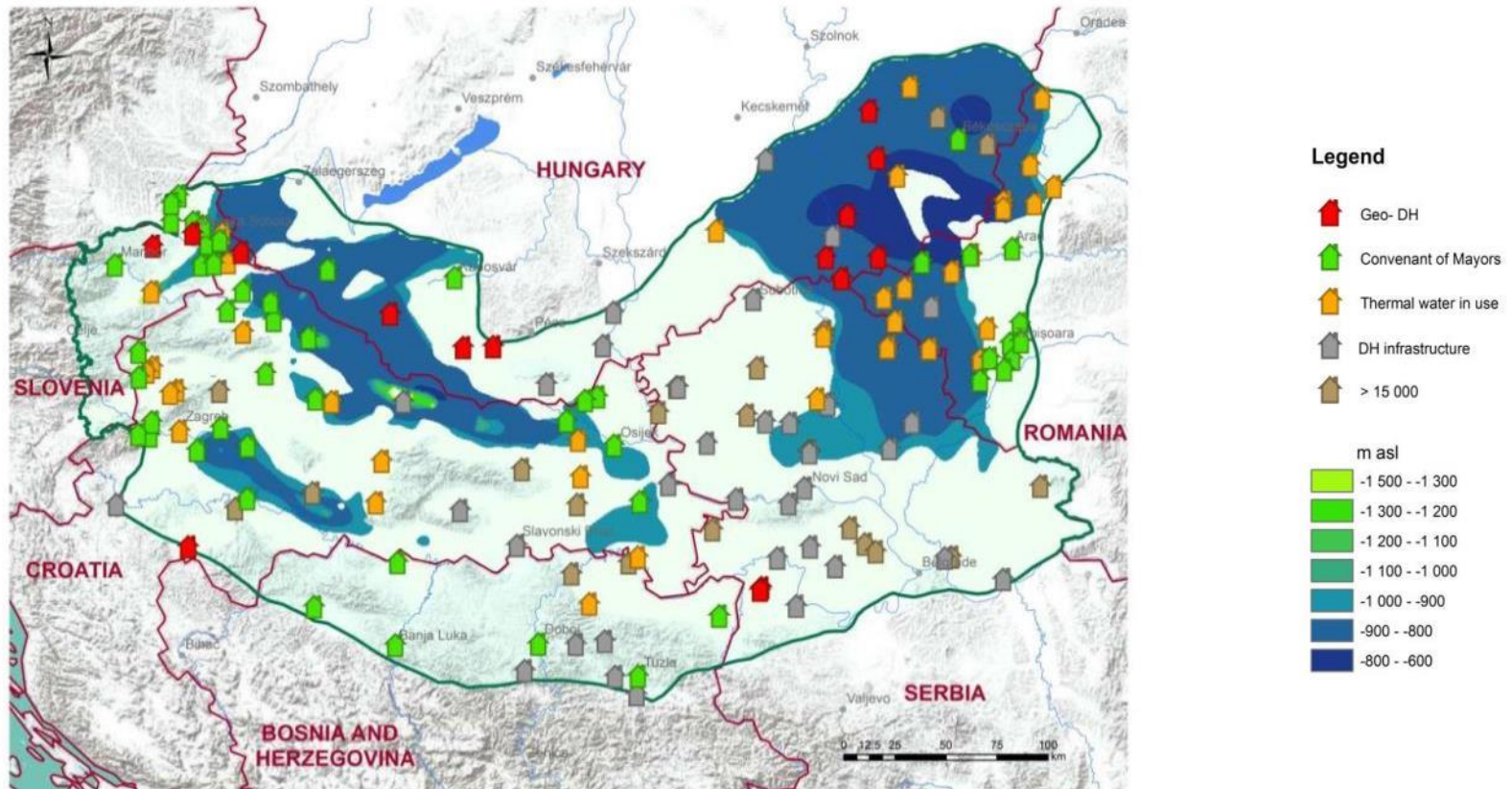
9. Battonya High (HU-RO)

10. Békés Basin (HU-RO)

11. Bácska (HU-SRB)



(7) Matching resources with the heat demand: Development of geoDH is a real option!



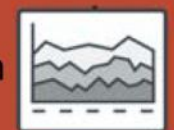



Based on sophisticated geological and geothermal models delineated transboundary geothermal reservoirs – resource estimations – matched them with heat demands → **Science-based recommendations for tangible developments**

How to communicate scientific results to non-technical audiences?

Experts in their fields produce large amounts of complex data.



environmentally sensitive areas
topography **lithologic cores** *wellbore control* *transmission*
flow tests *depth* **policies** *wildfire hazard* 
tribal resources *calcite* *temperature* *Atomic absorption spectrometry* *cold water breakthrough*
tribal resources *land ownership* **degree of isolation**
geothermometry **fluid inclusions** **FMI logs**
state lease queue *titration* 
non-condensable gas content *active seismic reflection* 
permeability *reaulation*  *pH analysis* *water for cooling*
conductivity *drilling experience* *bottom hole diameter*
field mapping *conceptual model* **gravity survey**

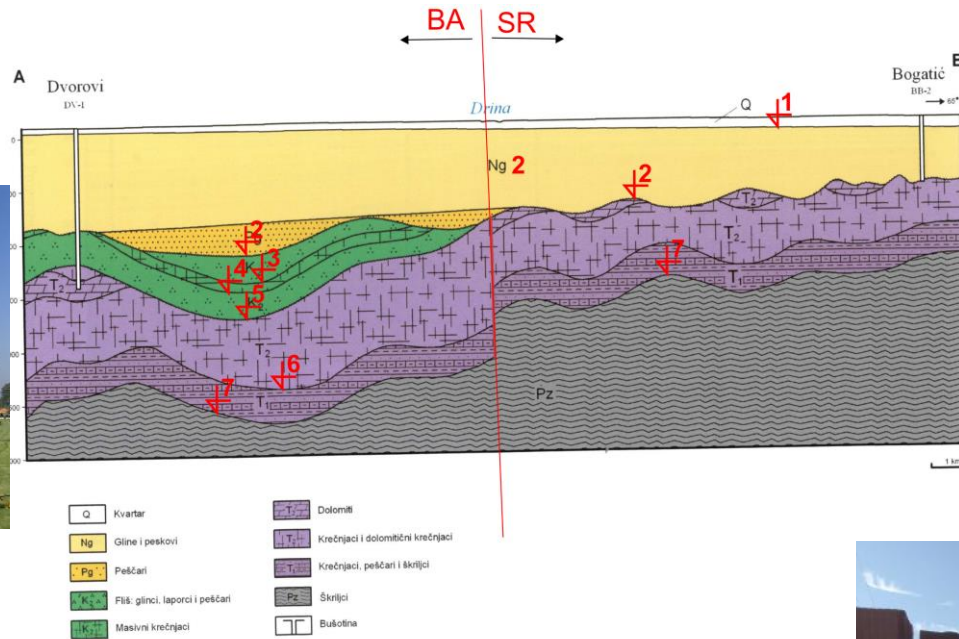
Volumes of scientific data can be incomprehensible and overwhelming for decision makers



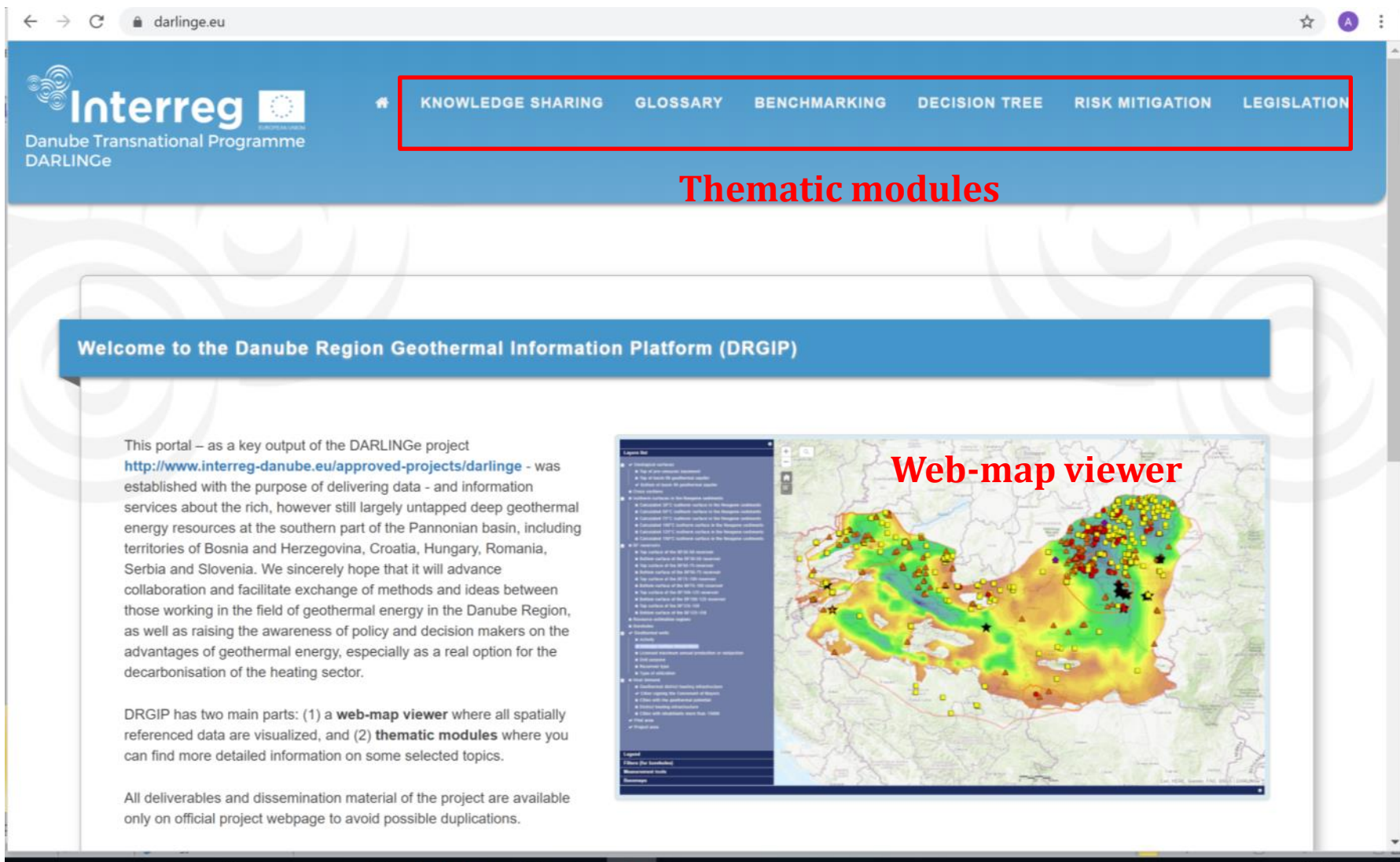
National events and trainings for stakeholders with cross-border field trips – appr. 350 participants



Bogatic (SRB) – Slobomir (BH)



Danube Region Geothermal Information Platform (DRGIP) <https://www.darlinge.eu/>

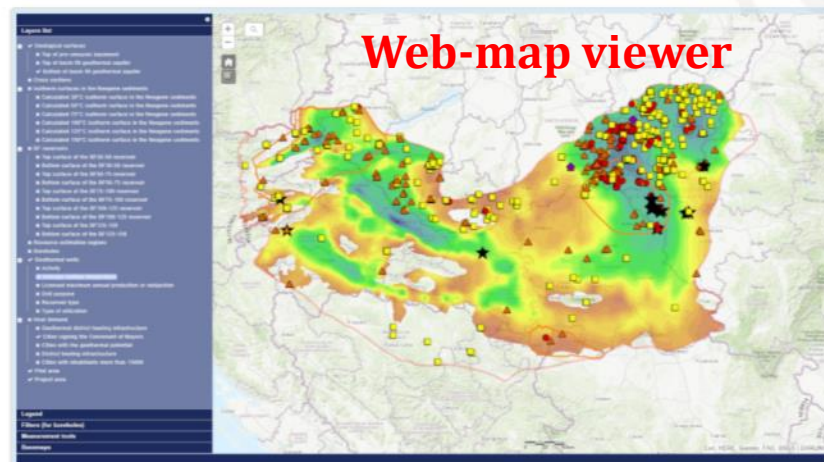


Welcome to the Danube Region Geothermal Information Platform (DRGIP)

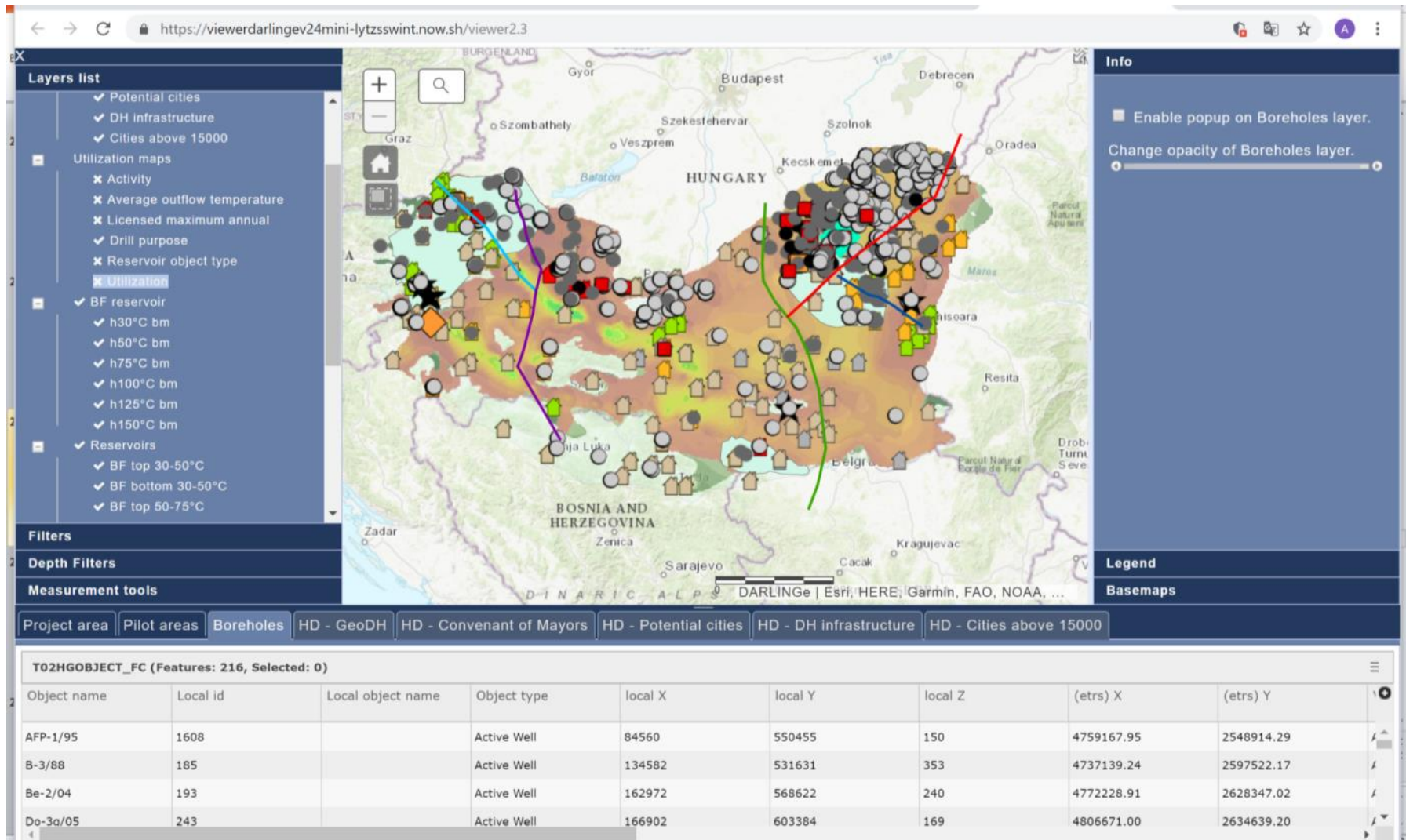
This portal – as a key output of the DARLINGe project <http://www.interreg-danube.eu/approved-projects/darlinge> - was established with the purpose of delivering data - and information services about the rich, however still largely untapped deep geothermal energy resources at the southern part of the Pannonian basin, including territories of Bosnia and Herzegovina, Croatia, Hungary, Romania, Serbia and Slovenia. We sincerely hope that it will advance collaboration and facilitate exchange of methods and ideas between those working in the field of geothermal energy in the Danube Region, as well as raising the awareness of policy and decision makers on the advantages of geothermal energy, especially as a real option for the decarbonisation of the heating sector.

DRGIP has two main parts: (1) a **web-map viewer** where all spatially referenced data are visualized, and (2) **thematic modules** where you can find more detailed information on some selected topics.

All deliverables and dissemination material of the project are available only on official project webpage to avoid possible duplications.



Danube Region Geothermal Information Platform (DRGIP) <https://www.darlinge.eu/>



The screenshot displays the DRGIP web application interface. The main map shows the Danube region, including parts of Hungary, Bosnia and Herzegovina, and the Dinaric Alps. The map is overlaid with various data layers, including potential cities, DH infrastructure, and geothermal reservoirs. The interface includes a layers list on the left, filters, and measurement tools. The bottom panel shows a data table for selected features.

Layers list

- ✓ Potential cities
- ✓ DH infrastructure
- ✓ Cities above 15000
- Utilization maps
 - ✗ Activity
 - ✗ Average outflow temperature
 - ✗ Licensed maximum annual
 - ✓ Drill purpose
 - ✗ Reservoir object type
 - ✗ Utilization
- ✓ BF reservoir
 - ✓ h30°C bm
 - ✓ h50°C bm
 - ✓ h75°C bm
 - ✓ h100°C bm
 - ✓ h125°C bm
 - ✓ h150°C bm
- ✓ Reservoirs
 - ✓ BF top 30-50°C
 - ✓ BF bottom 30-50°C
 - ✓ BF top 50-75°C

Filters

Depth Filters

Measurement tools

Info

- Enable popup on Boreholes layer.
- Change opacity of Boreholes layer.

Legend

Basemaps

Project area | **Pilot areas** | **Boreholes** | **HD - GeoDH** | **HD - Covenant of Mayors** | **HD - Potential cities** | **HD - DH infrastructure** | **HD - Cities above 15000**

T02HGOBJECT_FC (Features: 216, Selected: 0)

Object name	Local id	Local object name	Object type	local X	local Y	local Z	(etrs) X	(etrs) Y
AFP-1/95	1608		Active Well	84560	550455	150	4759167.95	2548914.29
B-3/88	185		Active Well	134582	531631	353	4737139.24	2597522.17
Be-2/04	193		Active Well	162972	568622	240	4772228.91	2628347.02
Do-3a/05	243		Active Well	166902	603384	169	4806671.00	2634639.20

Danube Region Geothermal Information Platform (DRGIP) <https://www.darlinge.eu/>

Interreg Danube Transnational Programme DARLINGe

PUBLICATIONS LEGISLATION DECISION TREE DICTIONARY BENCHMARKING RISK MITIGATION VIEWER

Select a question:

5.1: Are there differences in licensing for various types of ge...
Question: 5.1: Are there differences in licensing for various types of geothermal resources? (e.g. according to different depths, utilization types, technologies, e.g. - for energetic use, only for balneology, heat exploitation with or without groundwater extraction, with or without re-injection, etc.)?

More detailed answers by countries in the list below:

- Bosnia and Herzegovina - Federation of Bosnia and Herzegovina
- Bosnia and Herzegovina - Republika Srpska
- Croatia
- Hungary
- Romania
- Serbia
- Slovenia



Interreg Danube Transnational Programme DARLINGe

PUBLICATIONS **LEGISLATION** DECISION TREE DICTIONARY BENCHMARKING RISK MITIGATION VIEWER

Bosnia and Herzegovina - Federation of Bosnia and Herzegovina




Fig. 1: Licensing steps for geothermal water in Bosnia and Herzegovina - Federation of Bosnia and Herzegovina.

Bosnia and Herzegovina - Republic of Srpska



Fig. 2: Licensing steps for geothermal water in Bosnia and Herzegovina - Republic of Srpska.

Croatia




Fig. 3: Licensing steps for geothermal water in Croatia.

Hungary




Fig. 4: Licensing steps for geothermal water in Hungary.

Romania

Serbia

Slovenia

Altogether 25 questions on various aspects of legislation/licensing

Final recommendations: Danube Region Geothermal Strategy and Action Plans

Large number of data (drillings etc.)

Long-term experience on exploitation – decreased risks

Extensive reservoirs, especially 50-75 C at depth 1000-2000 m with rich resources, often matching heat demand (e.g. cities with DH infrastructure)

Ambitious NREAP targets – to decrease energy-import dependency

Growing interest of municipalities willing to invest into RES projects

Concentrated thermal water abstraction – regions with overexploitation

Insufficient reinjection (porous media)

Not energy-efficient systems (lack of cascaded uses, high temp. discharge of spent water)

Unfair competition with (subsidized) conventional sources (e.g. gas), regulated prices

Obsolete heating systems

Lack of comprehensive national/regional/local geothermal regulatory framework

Lack of awareness on advantages of RES / geothermal heating

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Developments need:

- ✓ **Responsive policy environment**
- ✓ **Raising awareness on advantages of geothermal (at all levels)**
- ✓ **Knowledge sharing and transfer of best practices**
- ✓ **Encourage domestic and foreign investments in geothermal projects**



**Thank you for your
attention!**

For further information:

**[http://www.interreg-
danube.eu/approved-
projects/darlinge/](http://www.interreg-danube.eu/approved-projects/darlinge/)**

nador.annamaria@mbfsz.gov.hu