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

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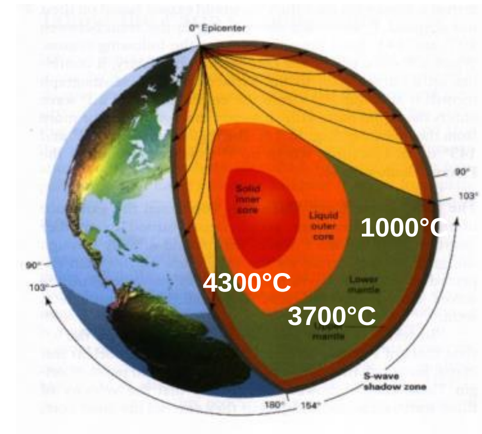
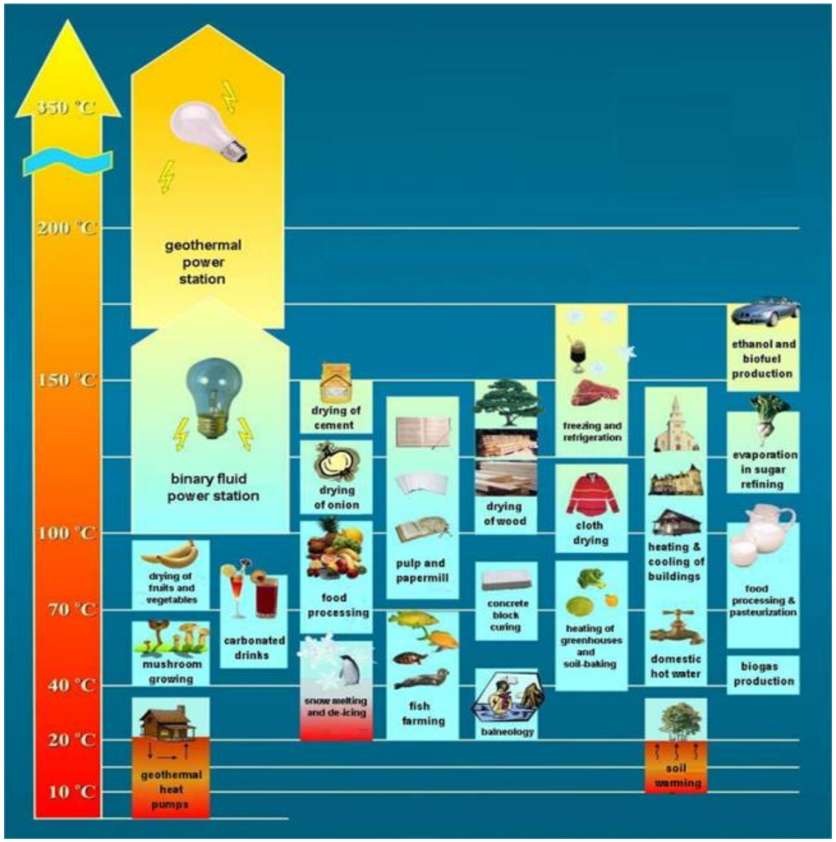
Mining and Geological Survey of Hungary

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?





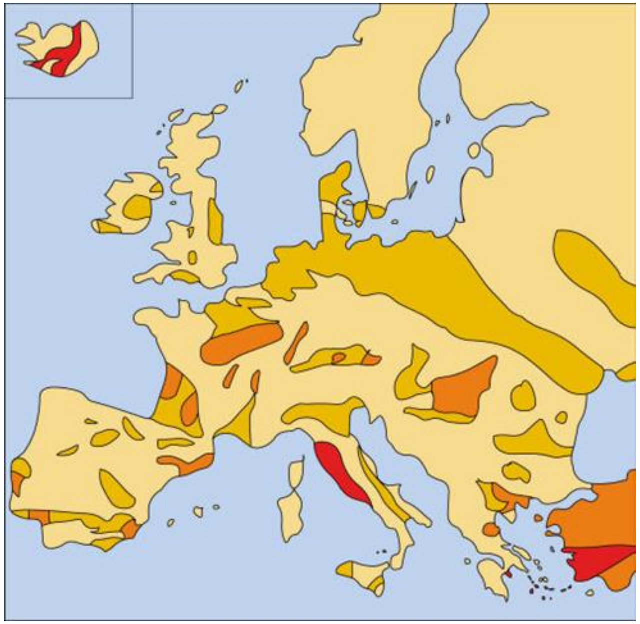
- ✓ Widely avaliable
- ✓ 24/7 delivery
- ✓ Large untapped potential
- ✓ Predictable output
- ✓ Numerous applications
- ✓ Domestic and green resource
- ✓ Can be combined with other energy sources to increase efficiency
- ✓ Suitable for cooling
- ✓ Low environmental footprint, invisible

Geothermal energy – how to classify?

- Very low: <30°C – requires heat pumps
- Low: 30-125 °C – direct heat
- Medium : 125-150 °C – electricity generation with binary cycles, CHP

Heat source: mainly Earth's heat flux

- High: >150°C – „efficient" electricity production. Heat source: mainly magma in magma chambers located at shallow depths (restricted in Europe)

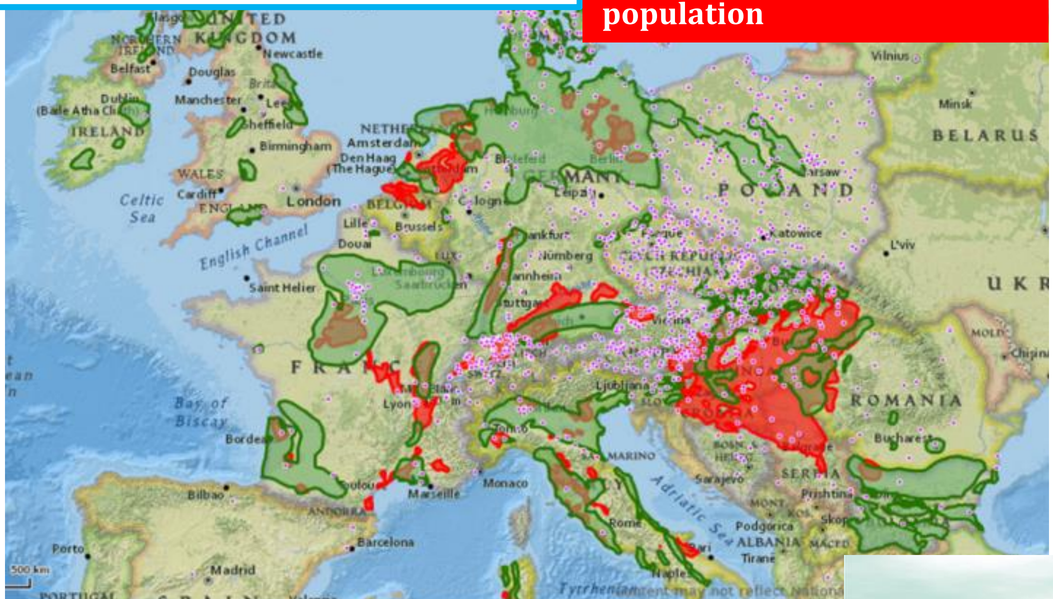


Direct uses

Geothermal energy for the decarbonisation of the heating sector

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

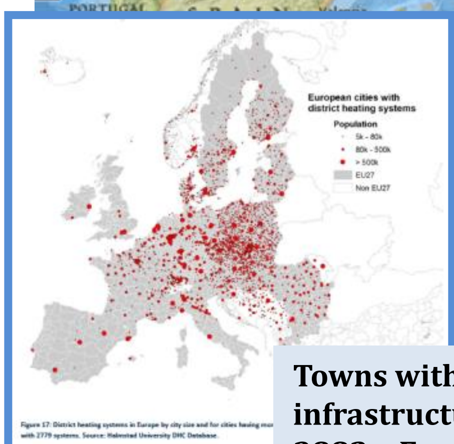
Geo-DH would be available for 26% of the EU-27 population



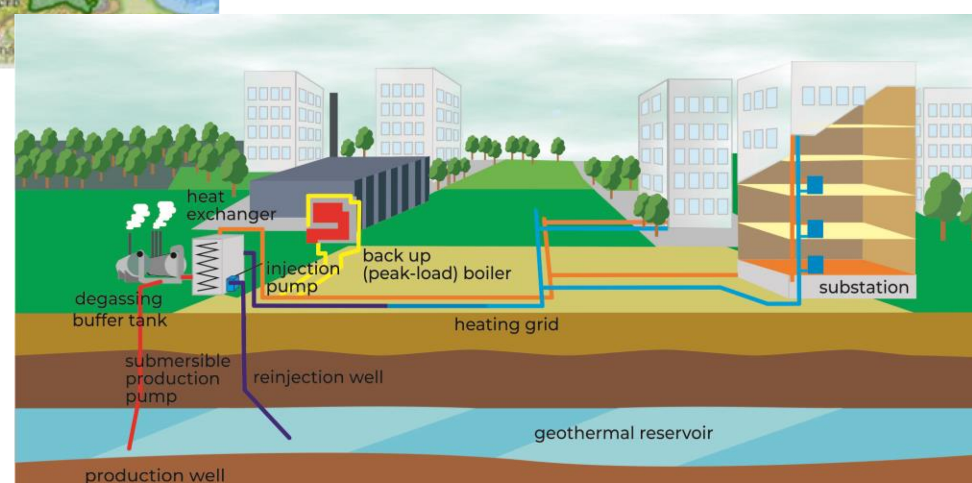
47% of EU energy consumption is heating & cooling (HC)

12% of the total communal heat demand is district heating

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



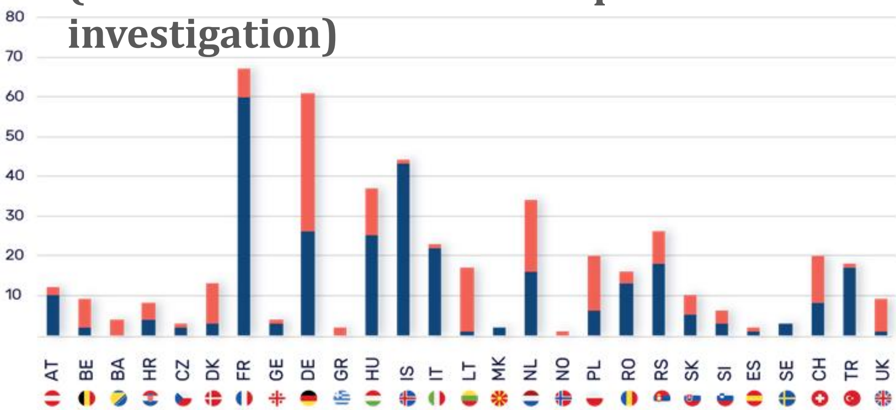
Towns with DH infrastructure
3882 – Europe
3070 – EU-27

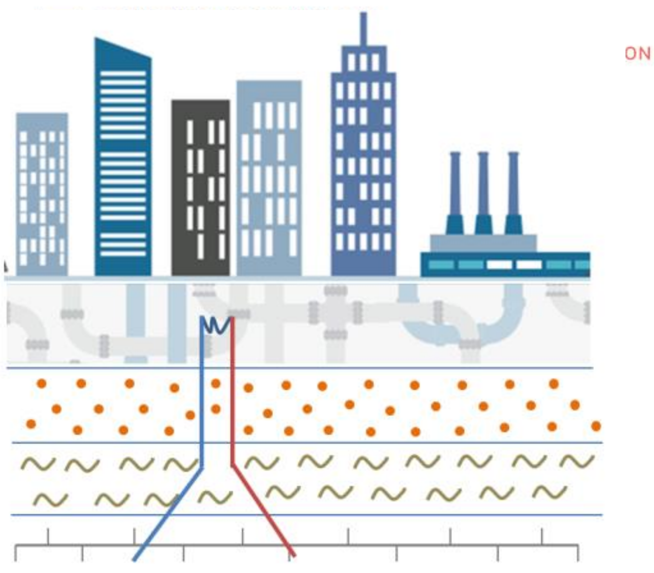


Geothermal district heating: an increasing momentum

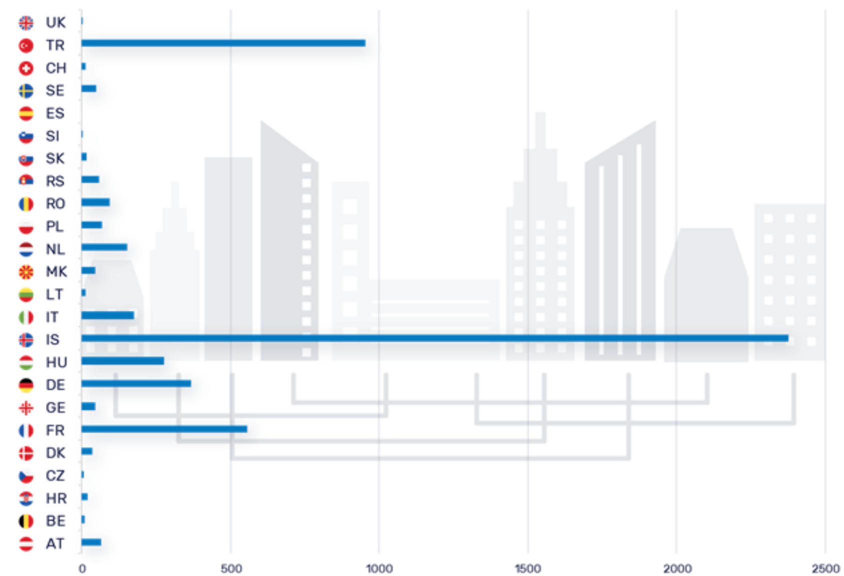
EGEC Market Report 2017

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





Total installed capacity 4,8 GWth (2017)



Danube Region Strategy (EUSDR) (2011)

DANUBE REGION strategy Energy

115 million people, 14 countries

EU member states: AT, BG, HR, CZ, DE, HU, RO, SK, SI

Accession countries: BH, MNG, SRB

Neighbourhodd countries: MD, UA

Highly heterogeneous macro-region (cultural, etnical, econmical)

Goal: to strenghten econmical , social, territorial cohesion, determine common goals, promotre cooperation, prepare joint projects

THE FOUR PILLARS

Connecting the Region			Protecting the Environment			Building Prosperity			Strengthening the Region	
Mobility and multimodality	Sustainable energy	Culture and tourism, People to People	Water quality	Environmental risks	Biodiversity, landscapes, air and soil quality	Knowledge society	Competitive-ness	People and skills	Institutional capacity and cooperation	Security

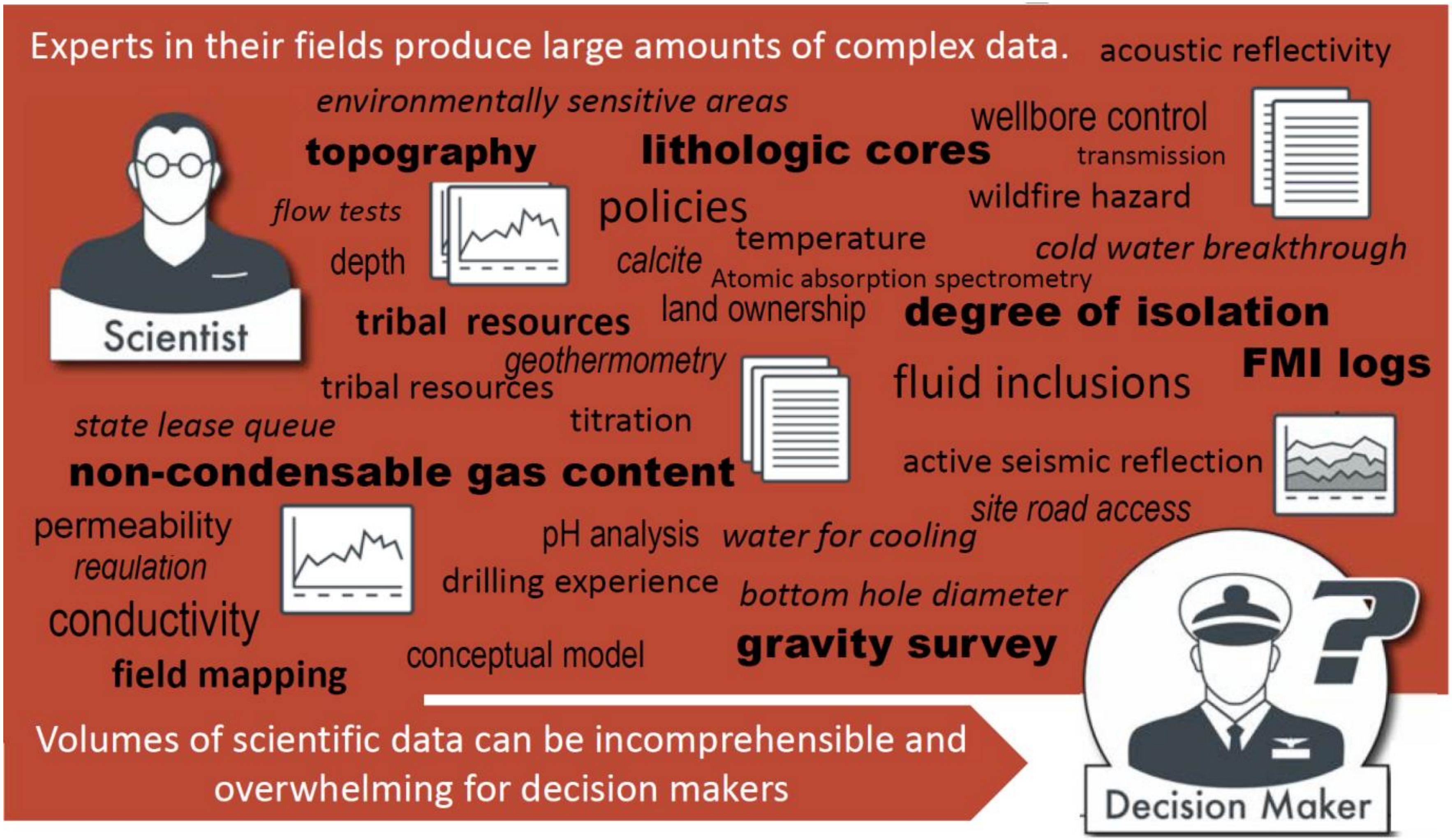
11 priority areas, coordinated by a priority area coordinator

Actions	Projects

Renewed Action Plan of PA2

Target I: To help to achieve the national targets based on the Europe 2030 climate and energy targets	Target II: To remove existing bottlenecks in energy to fulfil the goals of the Energy Union within the Danube Region	Target III: To better interconnect regions by joint activities with relevant initiatives and institutions
To further explore the **sustainable use of biomass, solar energy, geothermal, hydropower and wind power** to increase the energy autonomy and to promote and support multipurpose cross border	To enforce **regional cooperation** with the aim of supporting the implementation of projects **connecting the gas and electricity markets** and particularly focusing on the priority projects of the Central and South	To ensure that actions are coherent with the general approach of the **Energy Community and with Energy Union Governance**, and explore **synergies** between the Energy Community and the Danube
To promote **energy efficieny and use of renewable energy in buildings and heating systems** including district heating and coling	To exchange best practices and to develop activities to decrease **energy poverty**, to increase the protection of vulnerable consumers and to empower	To reinforce the **Carpathian Convention** to share best practices and to develop joint projects
To promote **decarbonisation of the transport sector**, regarding both public and freight transportation by developing the infrastructure for alternative fuels	To explore new and innovative solutions of **subsurface energy storage**	To encourage exchange of information and best practices to **improve cooperation,** create synergies and to initiate joint projects with **other macro-regional**
To improve energy efficient, cost efficient and innovative **low-carbon technologies,** including smart solutions while respecting		To encourage project generation related to the energy field

How to communicate scientific results to non-technical audiences?



Geothermal potential, resources estimation methods

According to the recommendation of 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 worlwide

I. Prediction from production data: extrapolated from the annual production rates

II. Static resource estimtion: bsed on Heat in Place calculation (volumetric method) [Muffler és Cataldi (1978), Mufler (1979)]

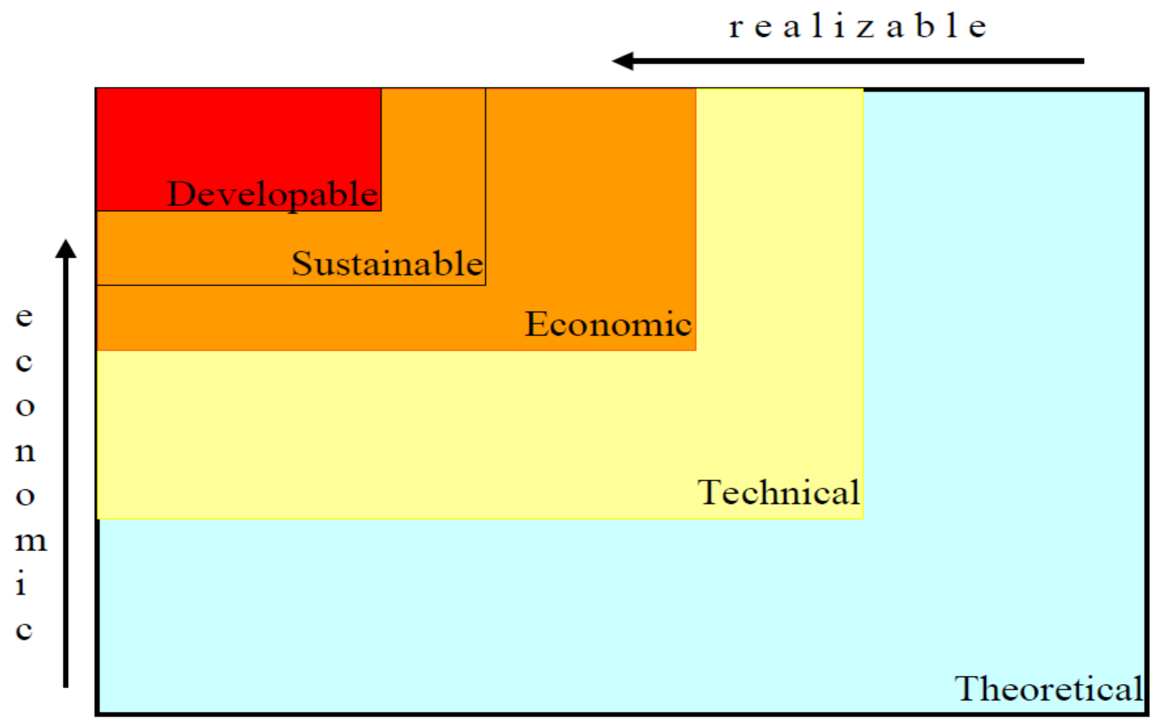
$H0 = c \times V \times \Delta T$ – **huge numbers, not exploitable**

III. Dynamic resource estimation: water and heat recharges also considered (poro/permeability, conductive/convective heat flow)

Recovery factor (R): economically exploitable part of HIP

$H1 = R \times H0$

Classification: Categories of Geothermal Potential



Rybach, 2010

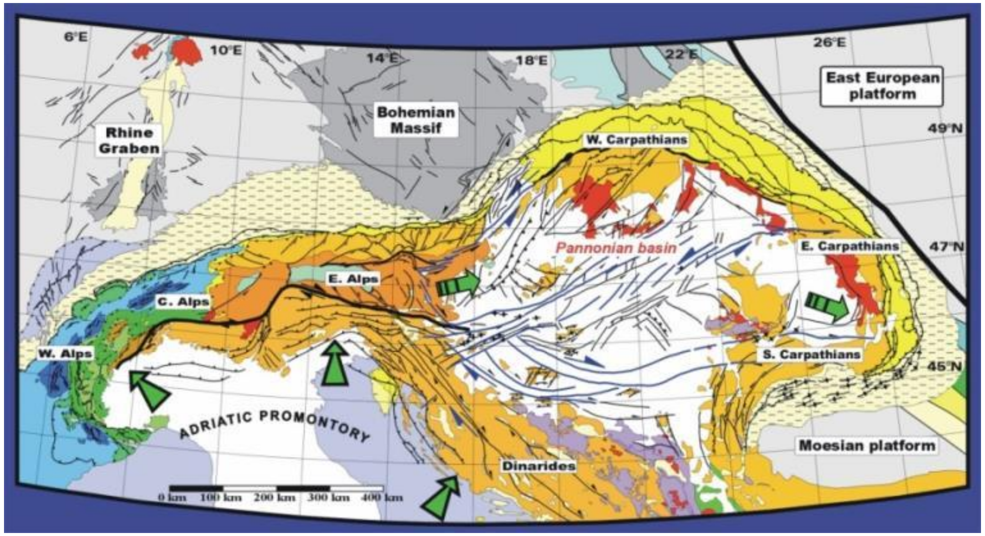
Theoretical = physically usable energy supply (heat in place)

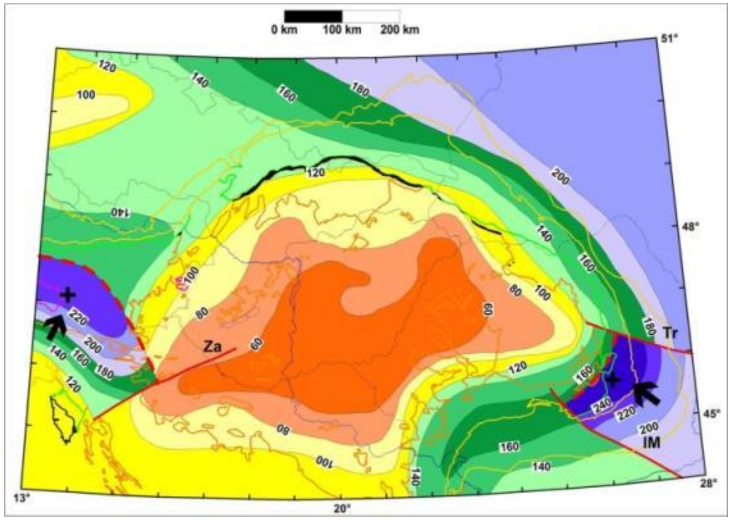
Technical = % of theoretical potential that can be used with current technology

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).

Geothermal energy in Central Europe





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

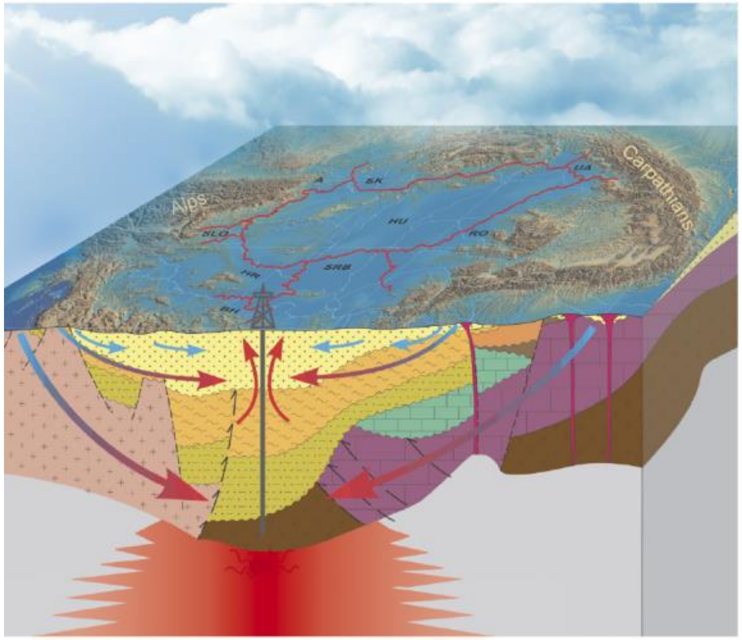
Thinned lihosphere → high heat flux 100 mW/m^2 (continental average: 60 mW/m^2)

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 untepped

DARLINGe project



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

Key challenges: Huge regional disparities

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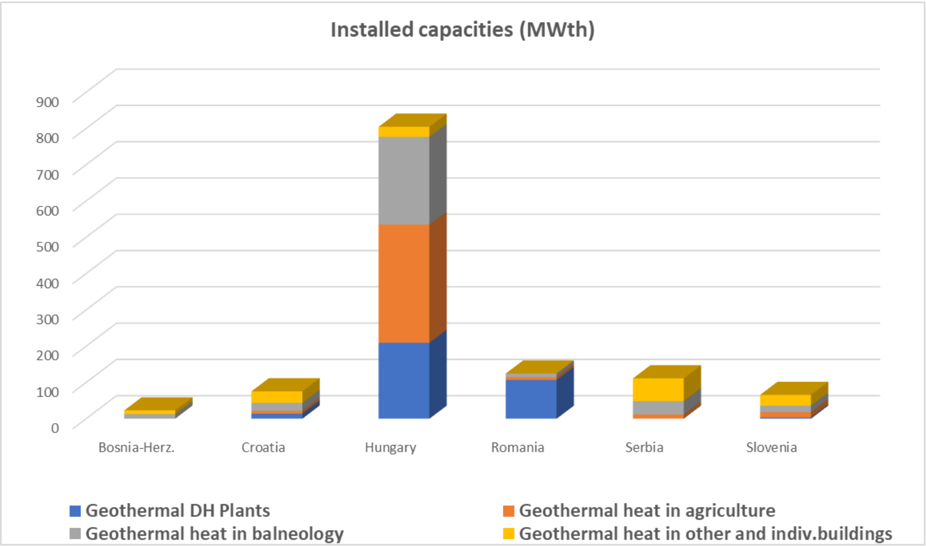
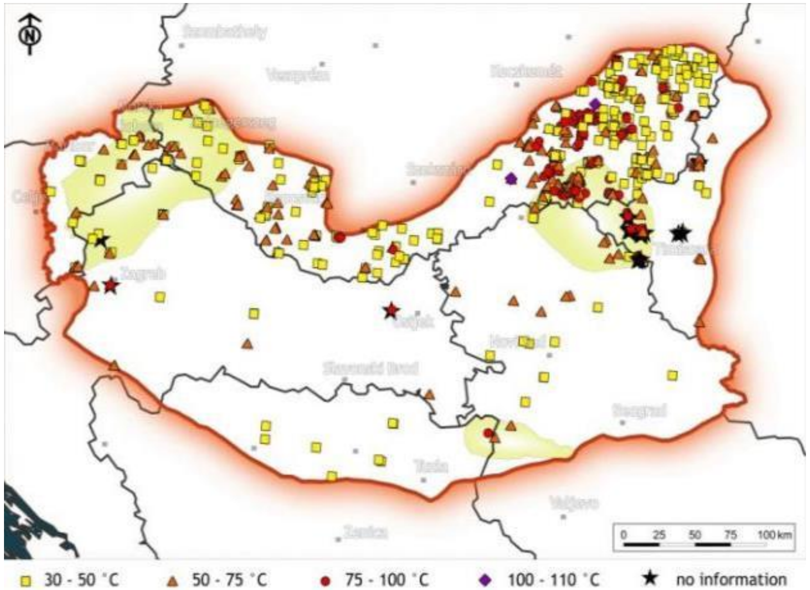
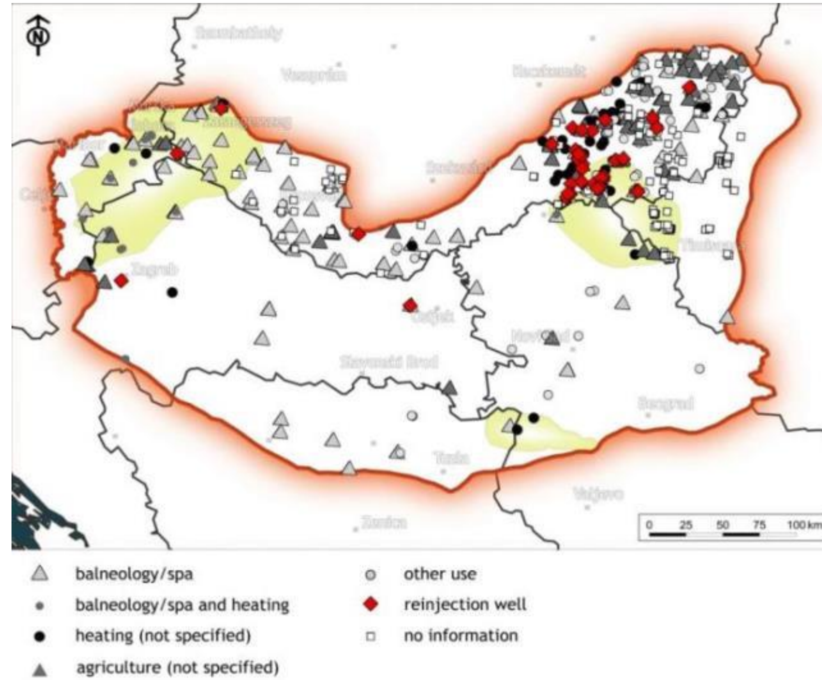


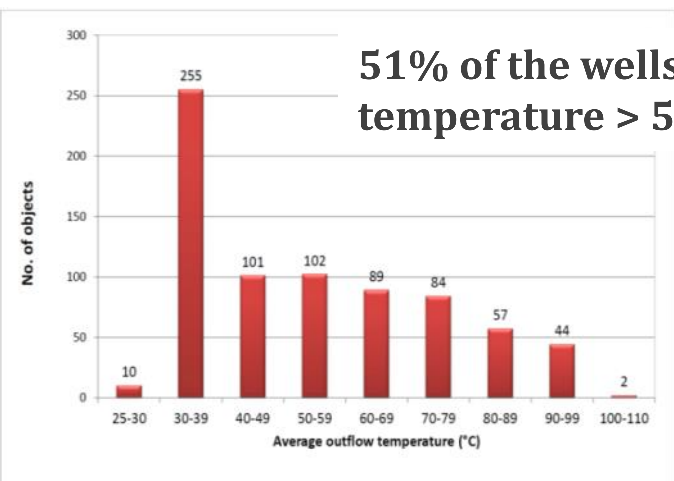
State-of-art: Current utilization

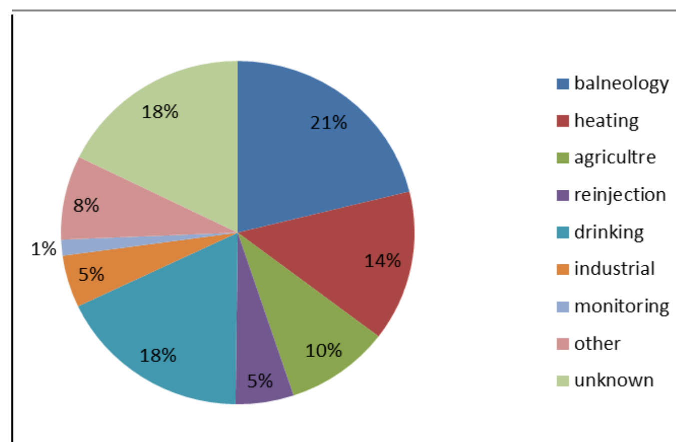
760 geothermal wells and 7 springs (T_{out} > 30 °C)



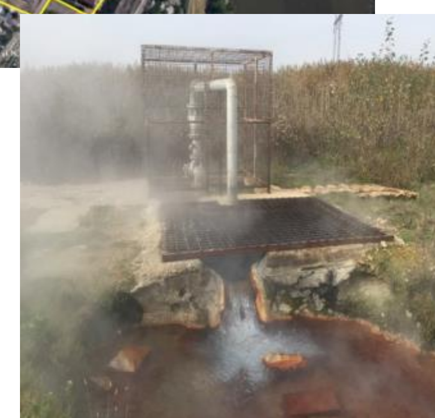


51% of the wells have outflow temperature > 50 °C





Evaluation of case studies – „best practices”



How to identify joint transboundary geothermal reservoirs at regional scales?

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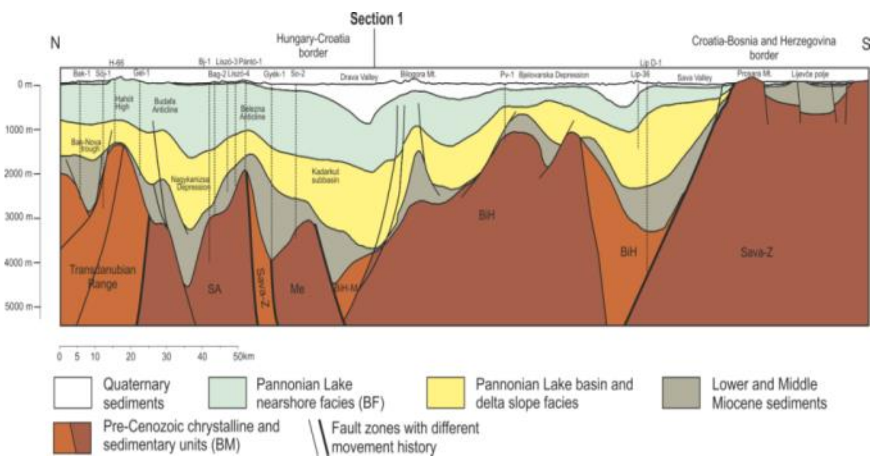
Geothermal reservoir: Subsurface 3D space where the rocks contain hot fluidum which can be exploited economically.

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

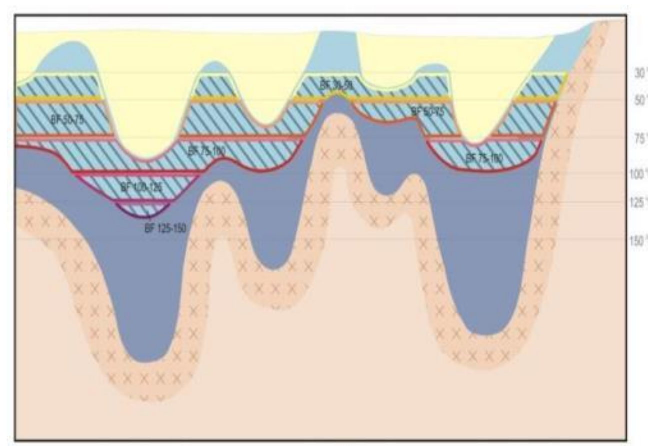
2 main reservoir types:

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

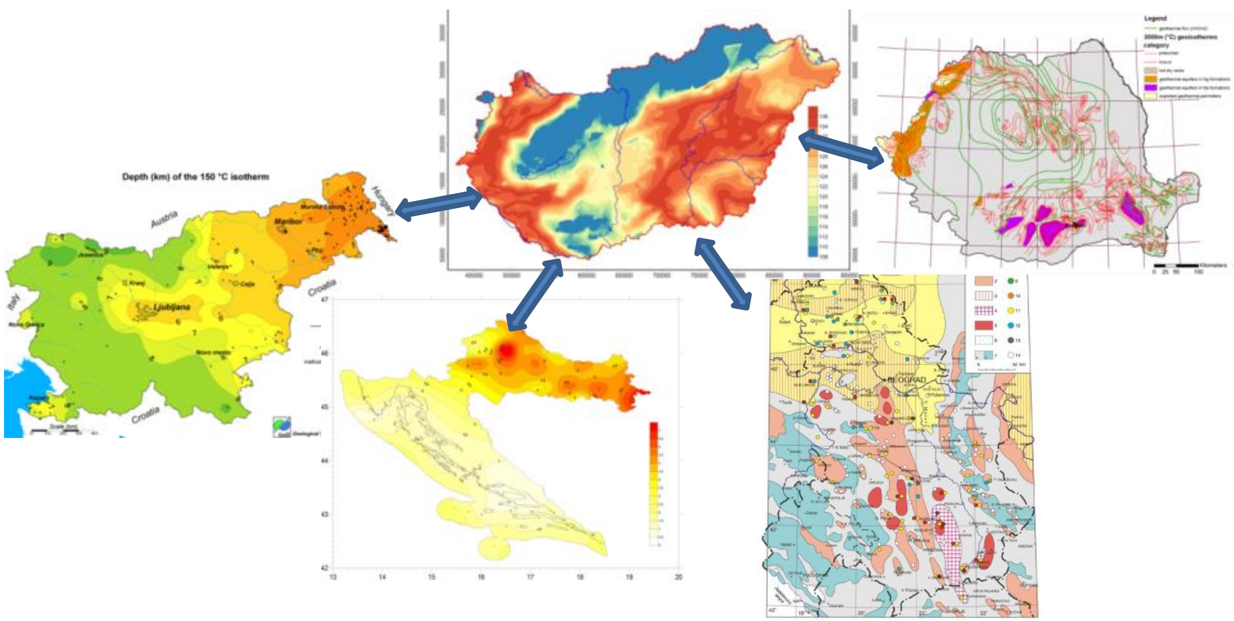


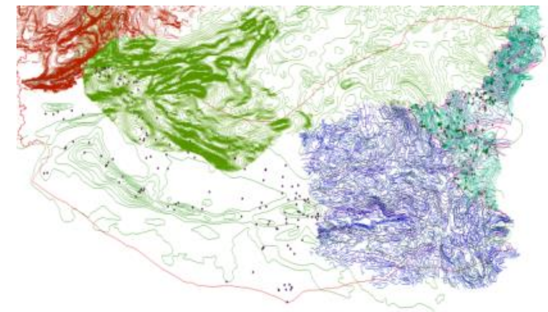
Method: create harmonized maps/grids of:

- ✓ bounding surfaces of geological units
- ✓ isotherms (30 °C, 50°C, 75 °C, 100 °C, 125°C, 150°C
- ✓ match the respective surfaces



(1) Data collection and harmonization
HU, SI, HR, BiH, SRB, RO





(2) Editing harmonized geological surfaces

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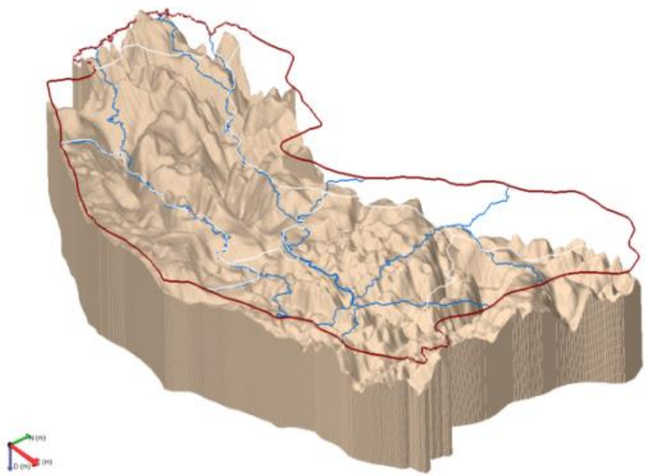
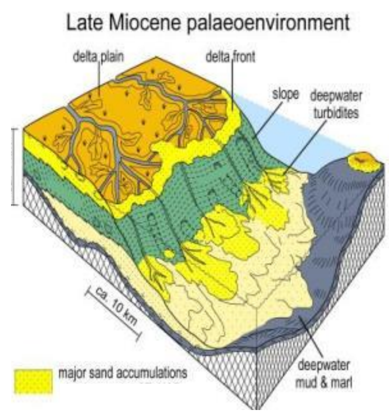
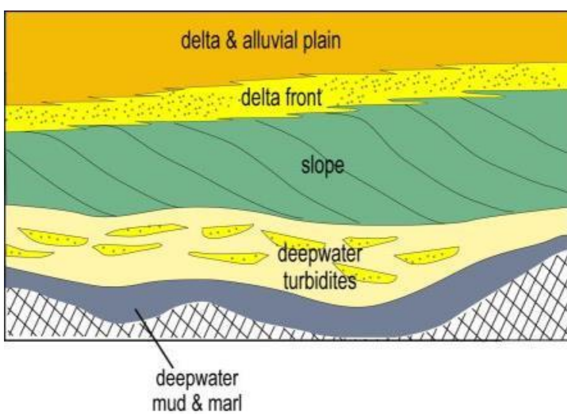
Top of the pre-Cenozoic basement („BM reservoirs”)

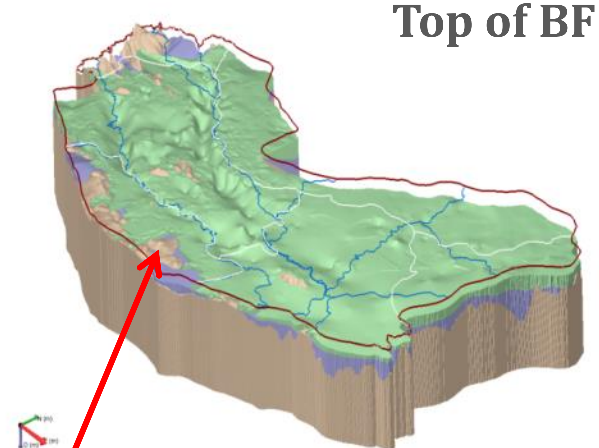


Basin fill sediments („BF reservoirs”)

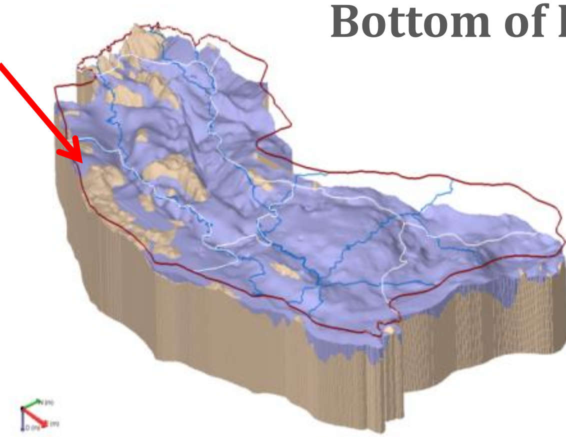




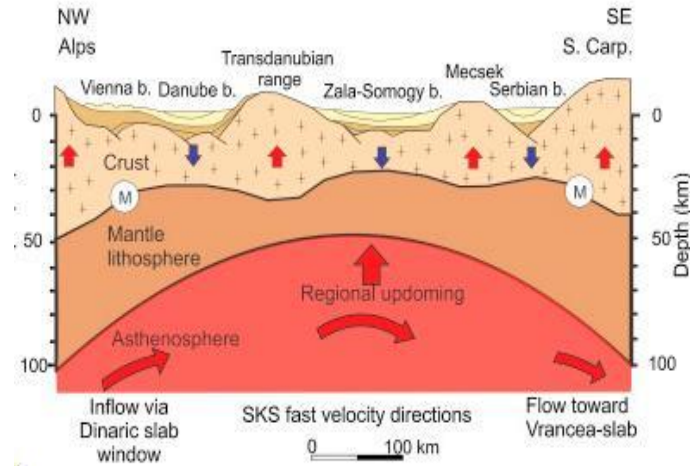
Top of BF



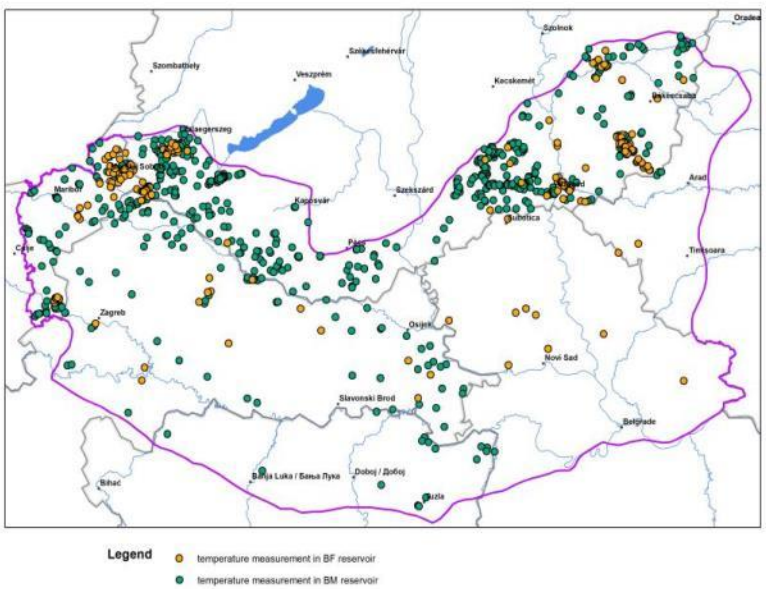
Bottom of BF



(3) A simplified conductive model for the determination of subsurface tempeature distribution



Large heterogentity in data availability and reliability



- **Higher heat-flow is caused by the stretching of the lithosphere coeval with basin formation**
- **The depth of the basin is proportional to the degree of thinning of the crust (thermal subsidence) → the spatial variation of heat-flow density reflects the changes of the basin depth**
- **Isotherm surfaces in basin fill sediments: multiplying the basin depth by the average geothermal gradient**

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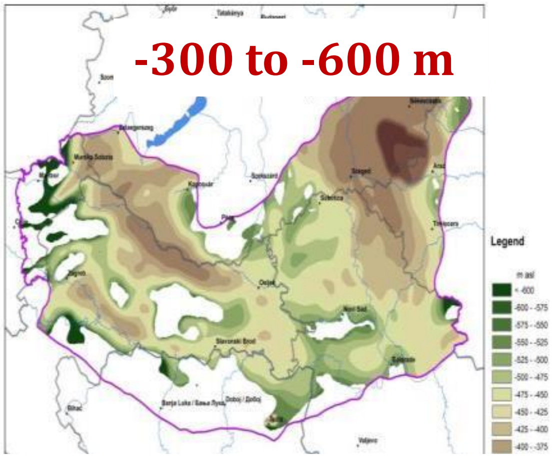
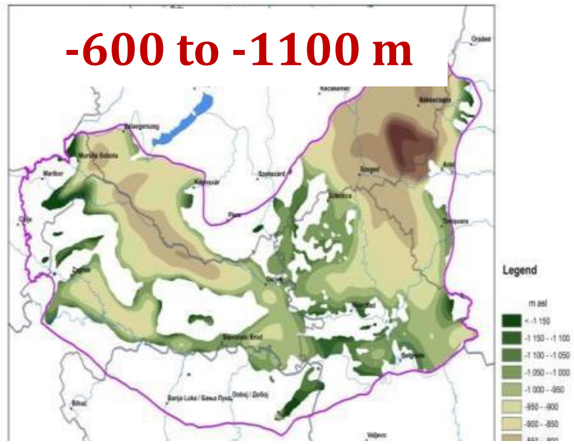
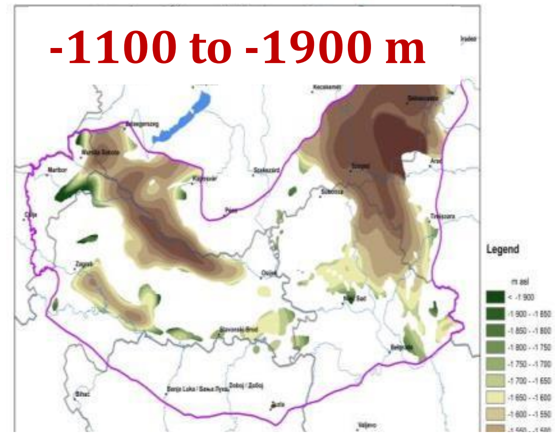
(4) Harmonized isotherm surfaces in the Neogene sediments



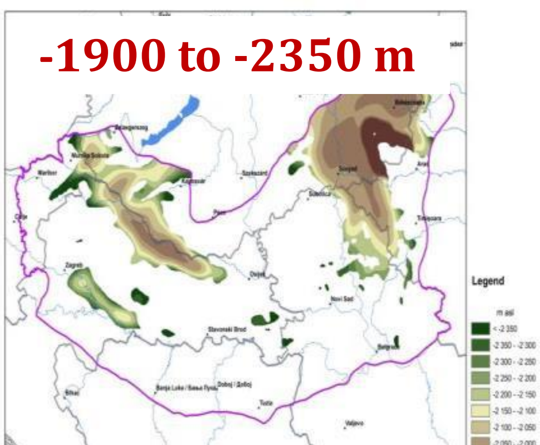
Depth of the 30 °C isotherm



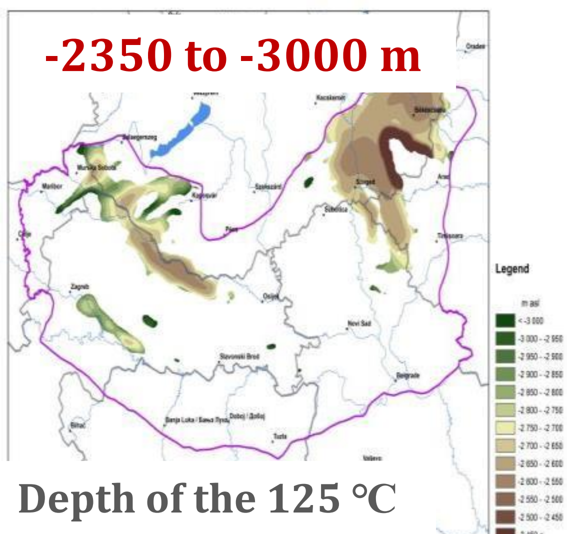
Depth of the 50 °C isotherm



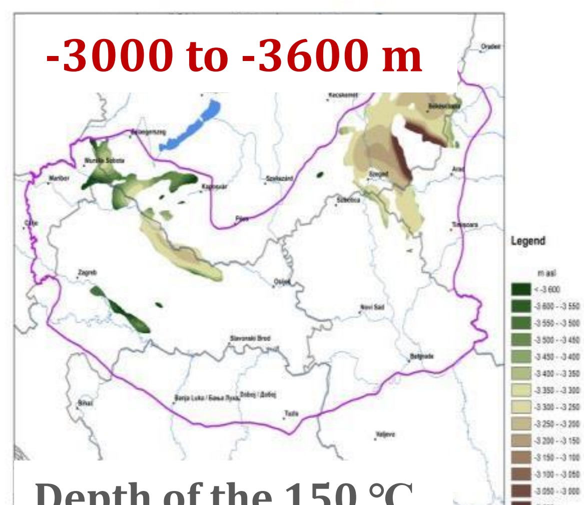
Depth of the 75 °C isotherm



Depth of the 100 °C isotherm



Depth of the 125 °C isotherm



Depth of the 150 °C isotherm

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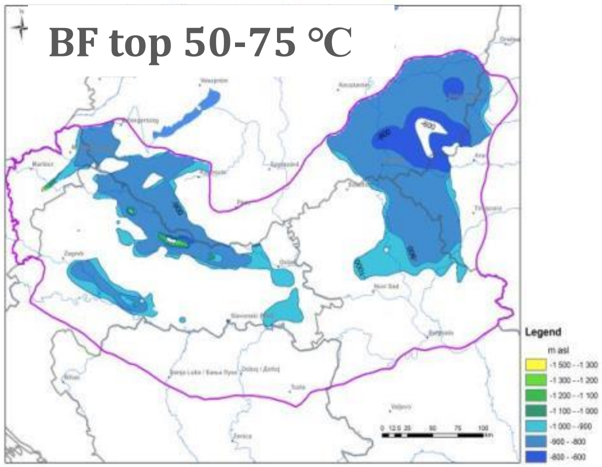
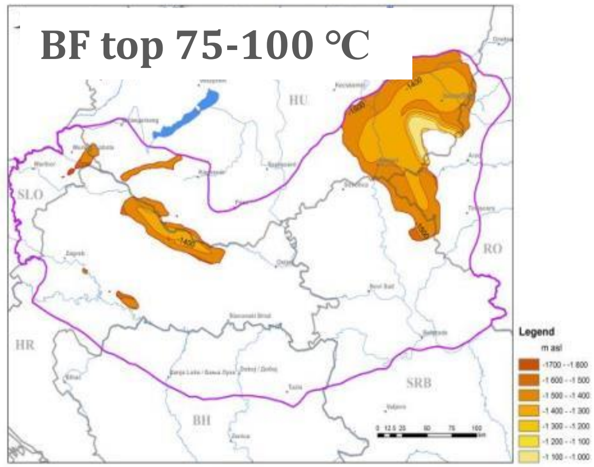
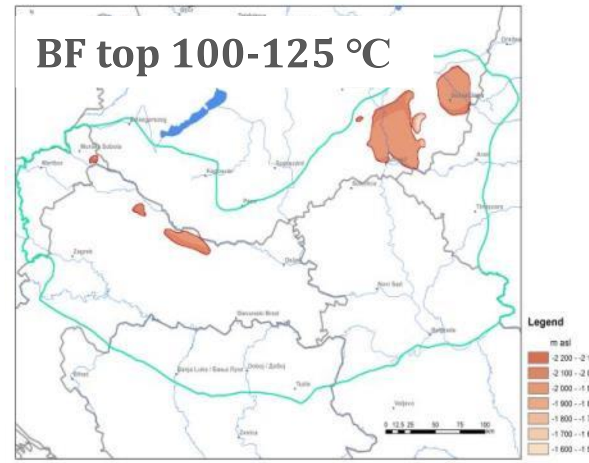
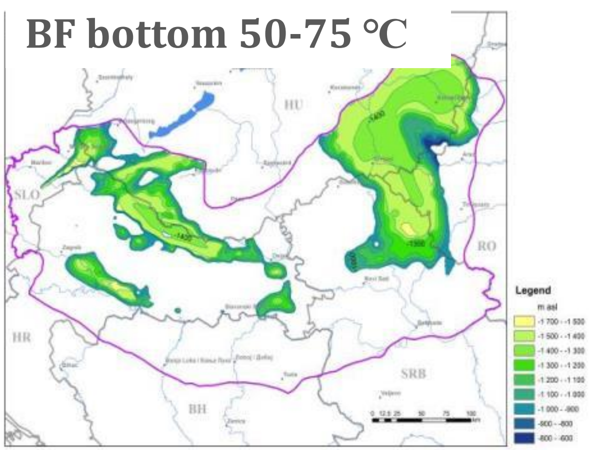
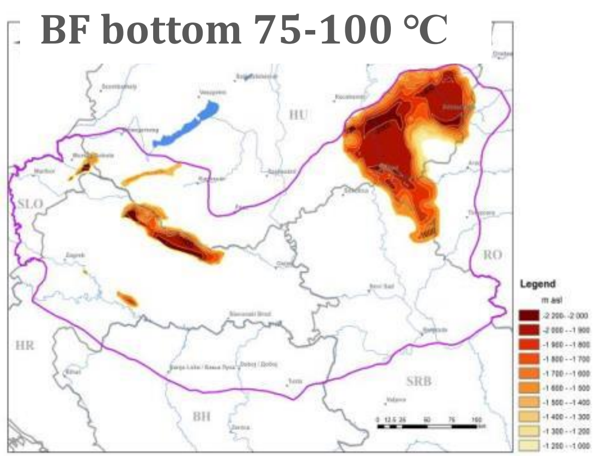
(5) Delineating potential reservoirs: geological bounding surfaces + isotherms

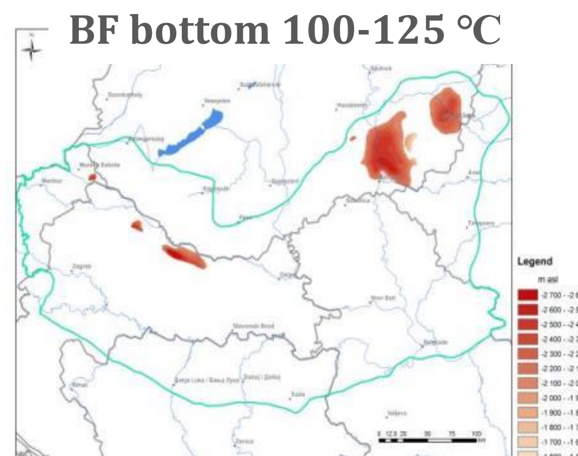






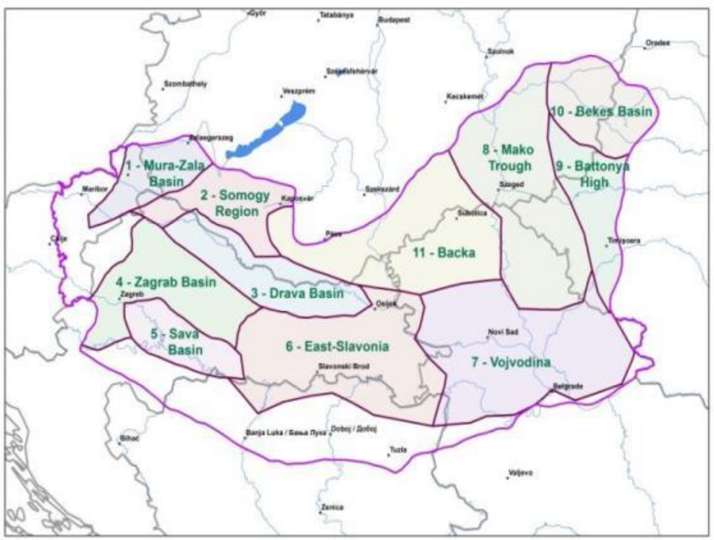






(6) Probabilictic estimation of the heat in place in the effective pore space (Monte Carlo simulation)

Input parameters				Calculated parameters		
A	B	C	D	F	G	H
Reservoir area (km^2)	Reservoir thickness (km)	Average total porosity (Φt)	Reservoir temperature (˚C)	Total volume (km^3)	Effective porosity (Φeff)	Effective porosity heat content (PJ)
				A*B	C* (1-SH)	4.187*F*G * (D-30)



Effective porosity: „moveable water”

SH= the average clay content of the reservoir (20-60%)

	30-50 °C	50-75 °C	75-100 °C	100-125 °C	125-150 °C
estimated average total porosity value (V/V)	0.178	0.131	0.091	0.061	0.039

Probabilictic estimation of the recoverable heat (Monte Carlo simulation)

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Region ID	30-50 °C			50-75 °C			75-100 °C			100-125 °C			125-150 °C		
	P90	P50	P10	P90	P50	P10	P90	P50	P10	P90	P50	P10	P90	P50	P10
	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ
1. region Mura-Zala Basin	5365	7399	9750	6782	9395	12329	874	1201	1579	103	143	189			
2. region Somogy region	8308	11522	15169	10937	15154	20055	235	325	427						
3. region Drava Basin	9500	13014	17228	22945	32041	42005	10265	14164	18798	1933	2691	3531	90	125	164
4. region Zagrab Basin	3119	4317	5667	892	1227	1628									
5. region Sava Basin	4820	6665	8837	6888	9510	12545	372	513	680						
6. region East-Slavonia	4870	6745	8900	2159	2979	3933									
7. region Vojvodina	7776	10683	14052	1497	2075	2751									
8. region Mako Trough	27219	37607	49658	78234	108496	143502	42474	59153	78067	9575	13278	17482			
9. region Battonya High	5562	7628	10077	6499	8924	11835	1597	2213	2930						
10. region Bekes Basin	10057	13925	18391	26802	37267	49258	17255	23648	31213	3509	4832	6410			
11. region Backa	3637	5032	6633	1629	2267	2976									

(7) Regional distribution

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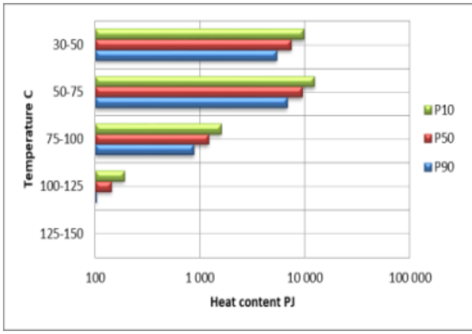
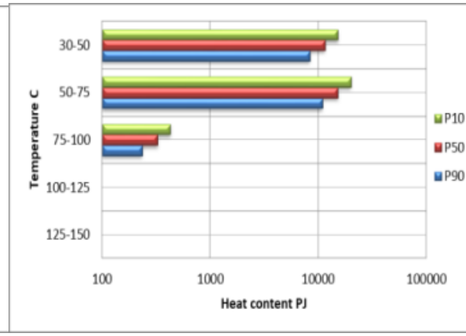
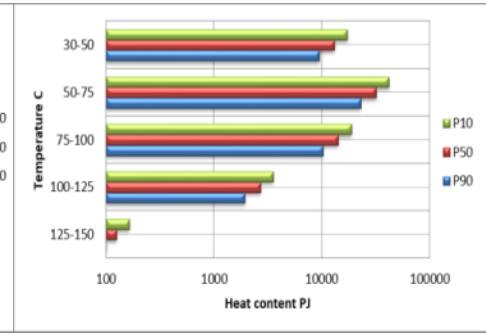


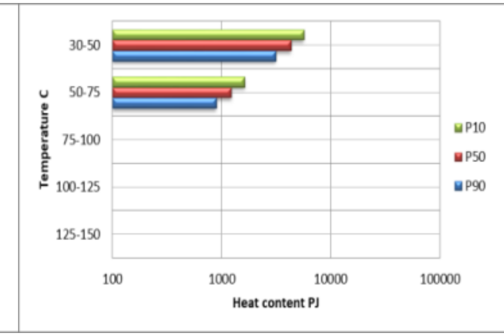
1. Mura-Zala basin (SI-HU-HR)



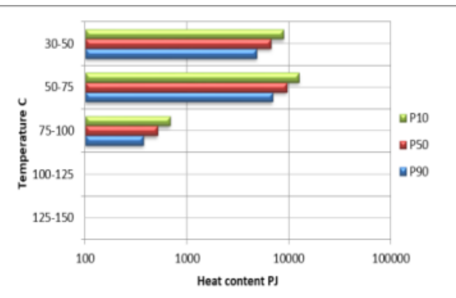
2. Somogy region (HU)



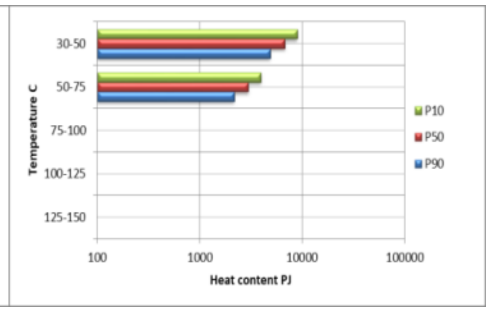
3. Dráva basin (HR-HU)



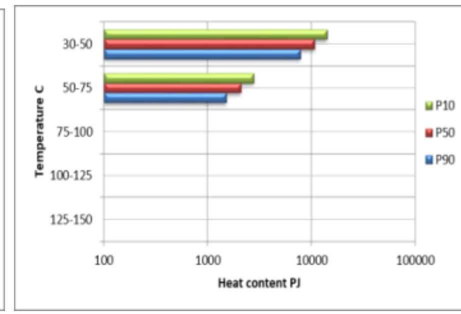
4. Zagreb region (HR)



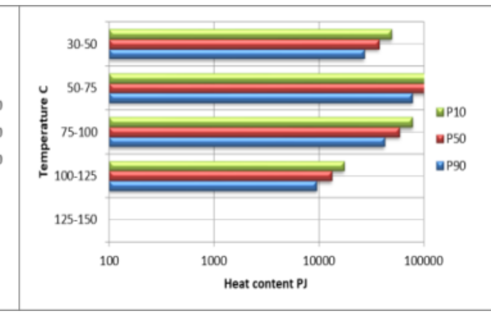
5. Sava basin (HR)



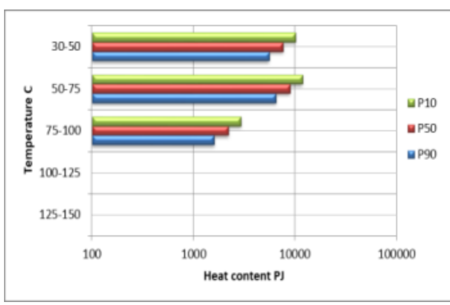
6. East Slavonia (HR-BiH)



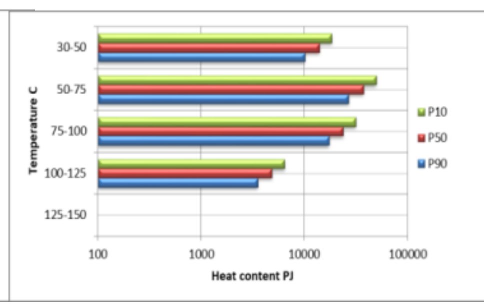
7. Vojvodina (SRB)



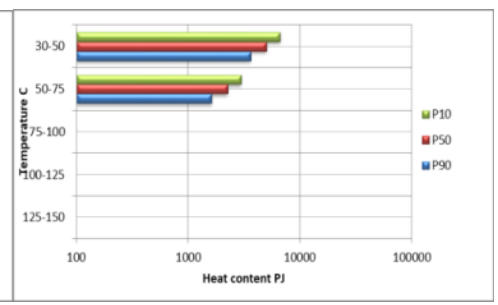
8. Makó Trough (HU-SRB-RO)



9. Battonya High (HU-RO)

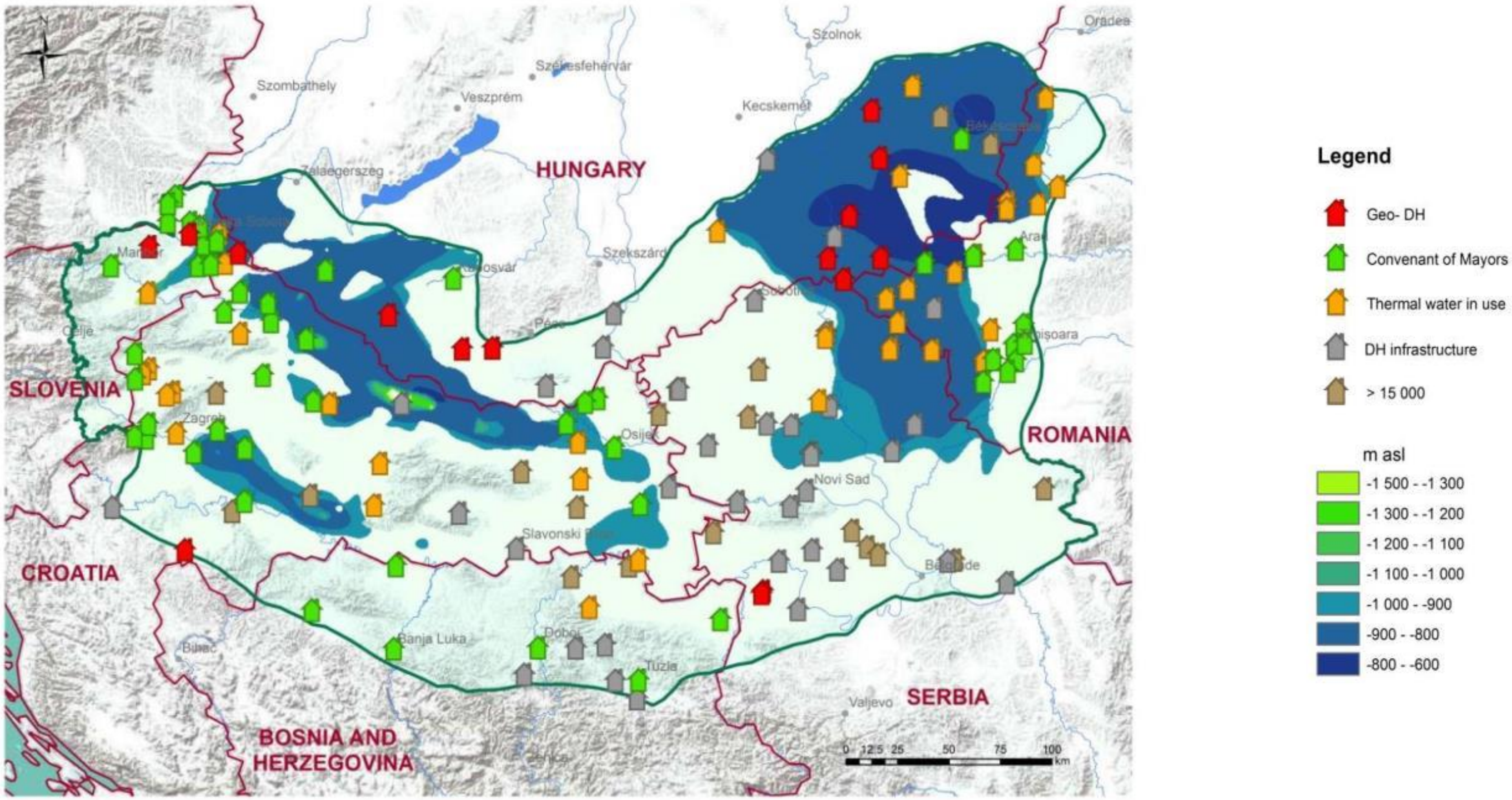


10. Békés Basin (HU-RO)



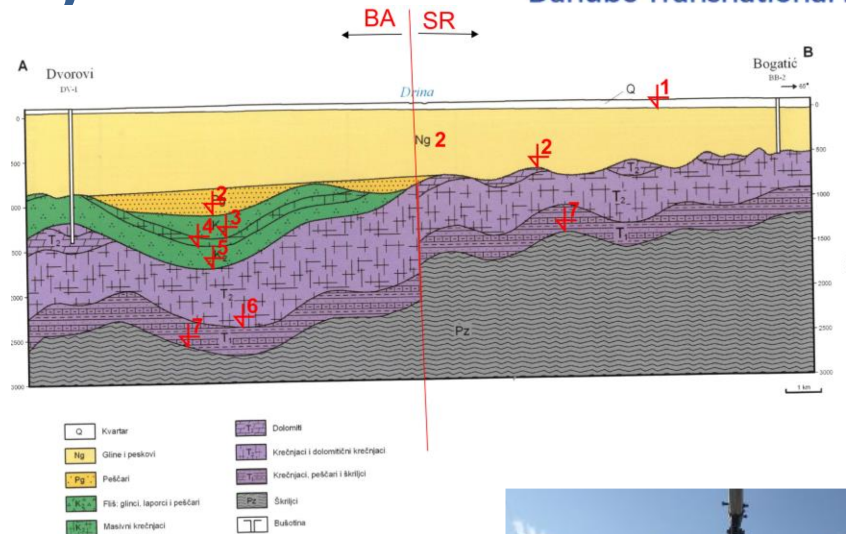
11. Bácska (HU-SRB)

(8) 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

Success stories: Bogatic (SRB)



Success stories: Slobomir (BH)

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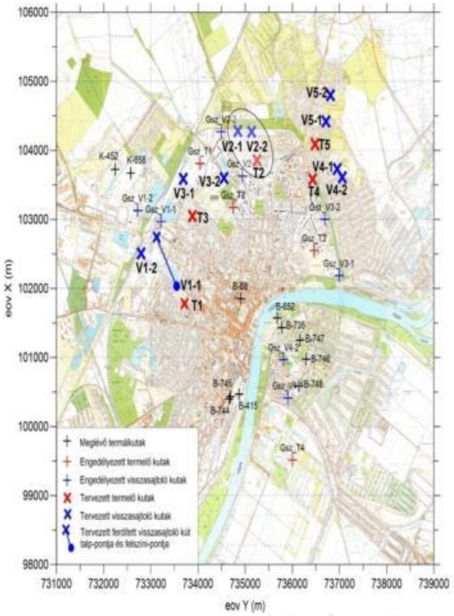
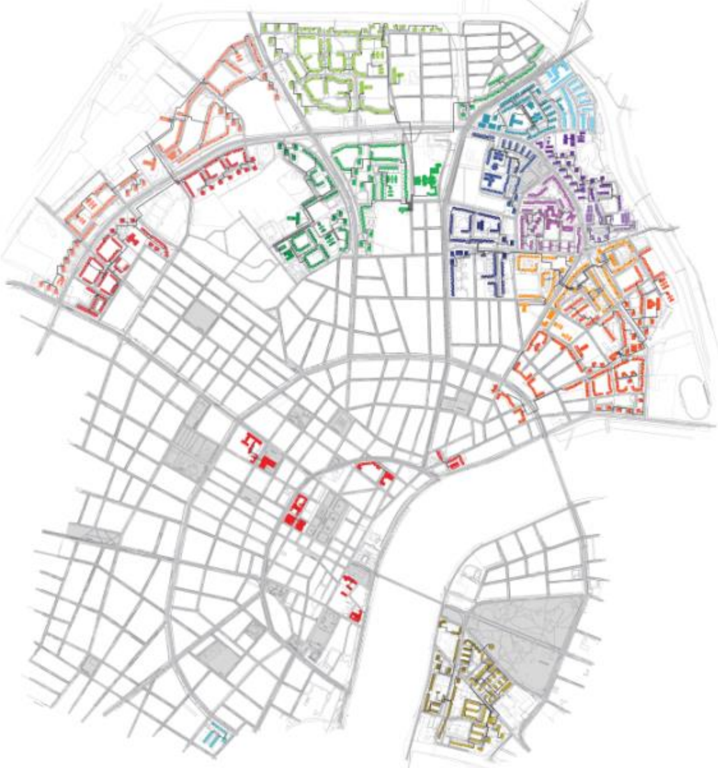
Success stories: Szeged (HU)





Success stories: Moravske Toplice (SLO)

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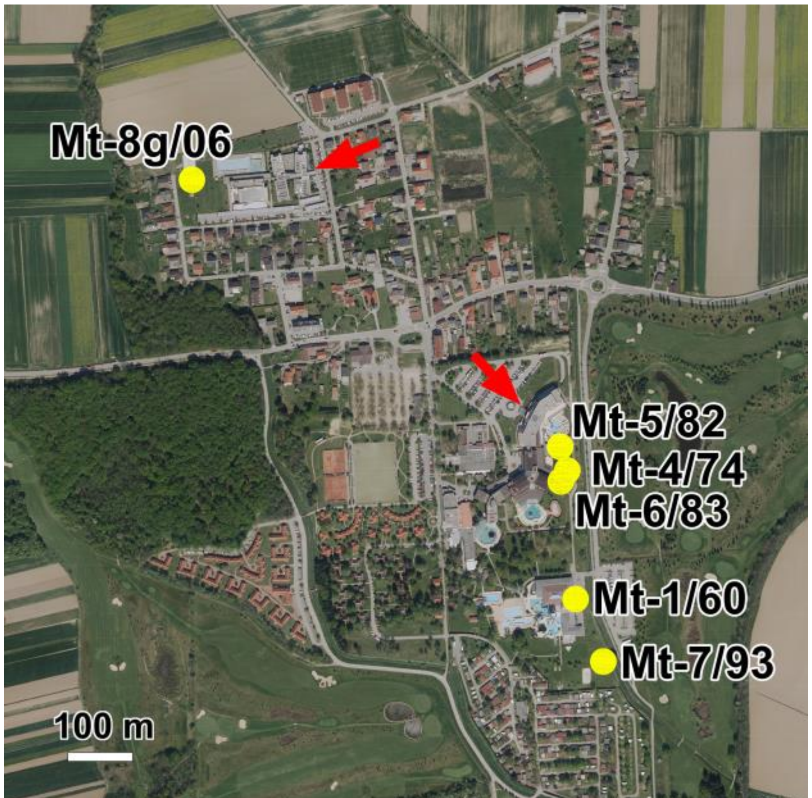

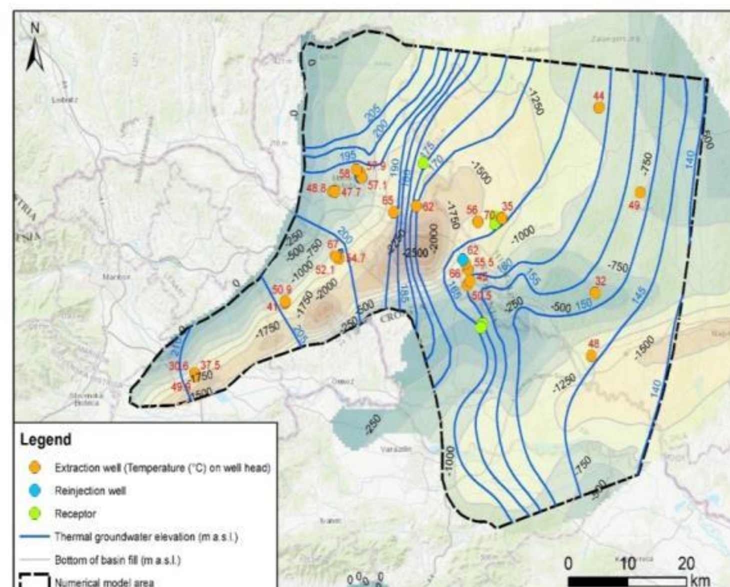

Success stories: Domaljevac (BH)

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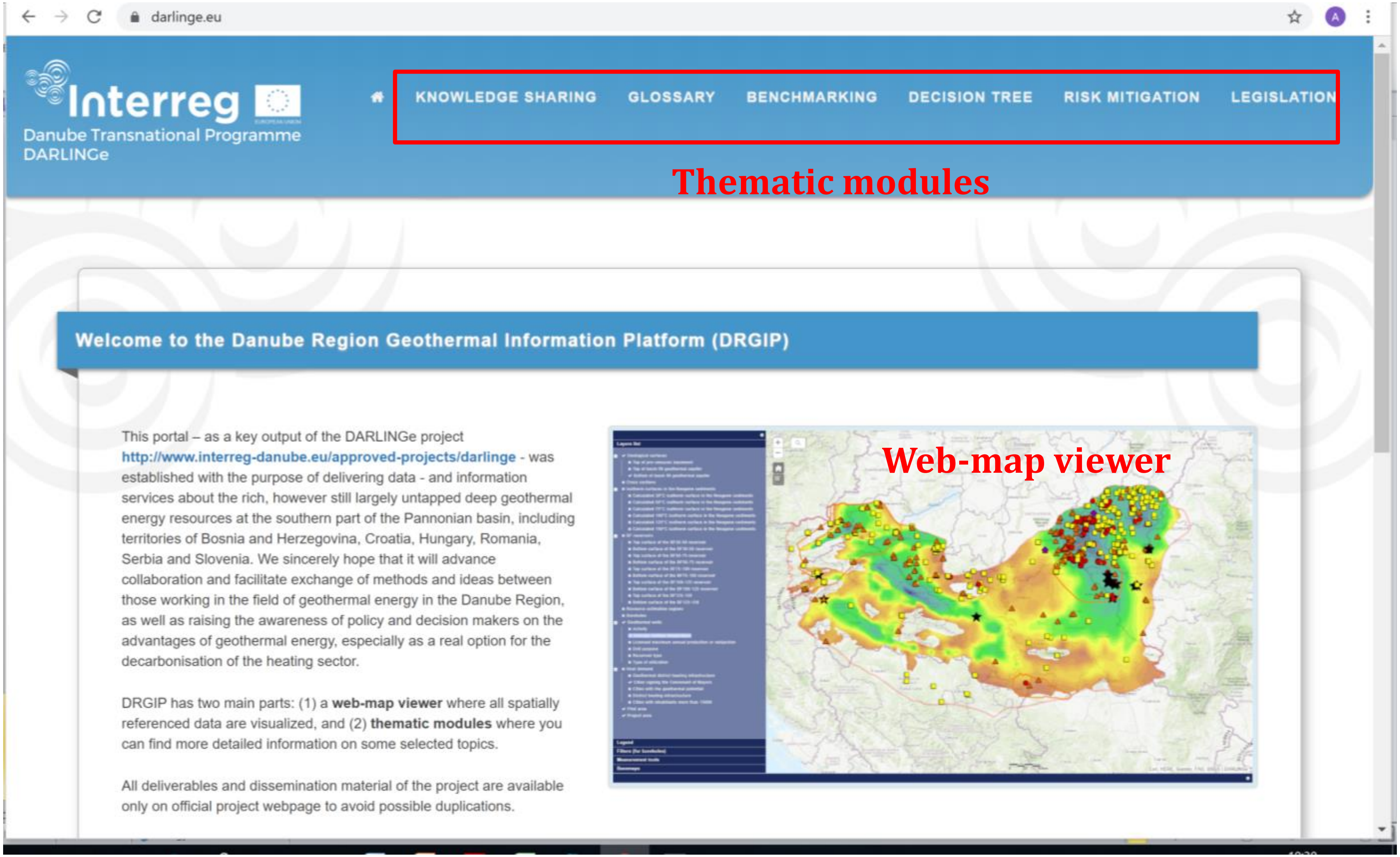
Transnational Stakeholder Forum

6 national events and 6 training for stakeholders with cross-border field trips – appr. 350 participants

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



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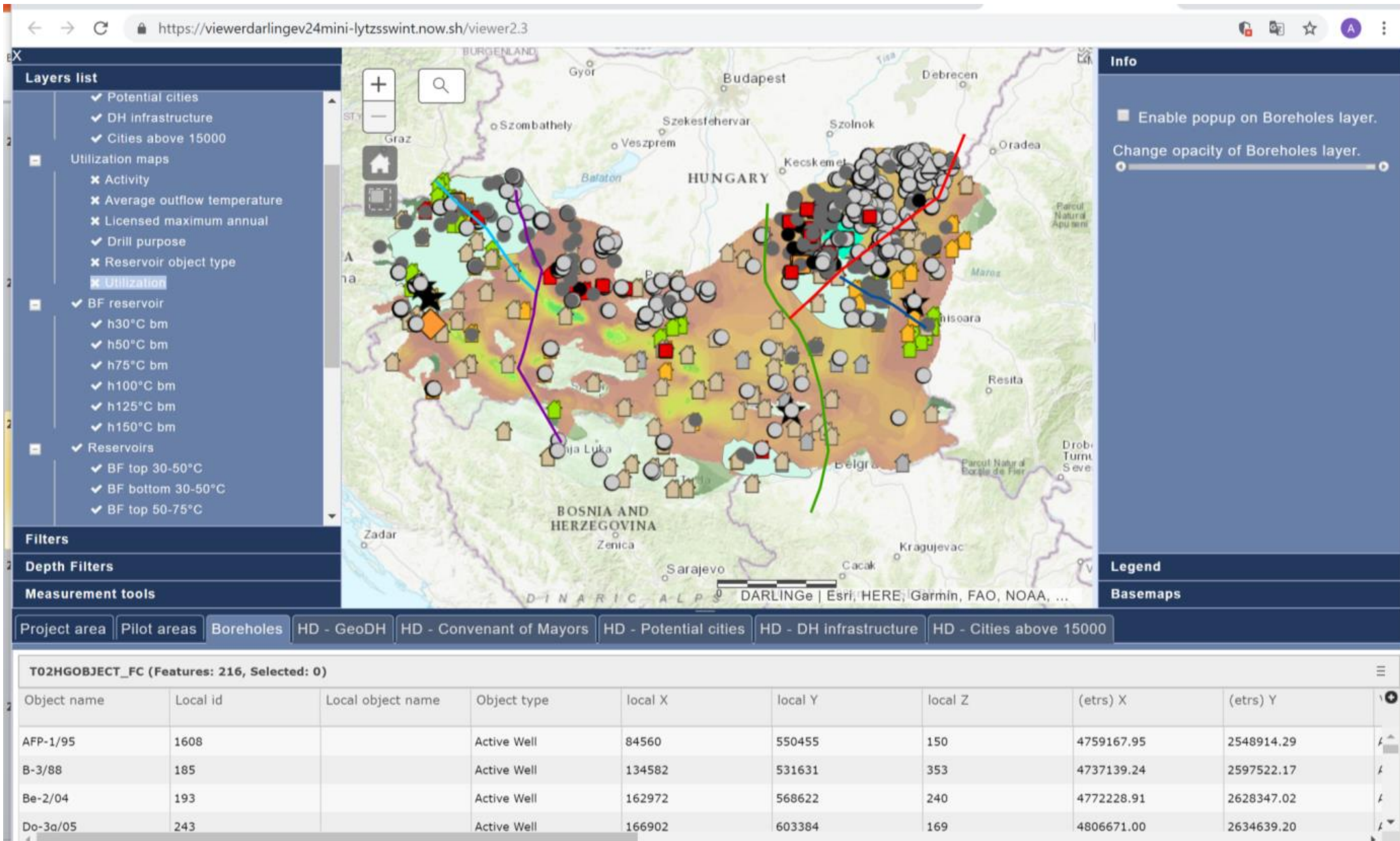

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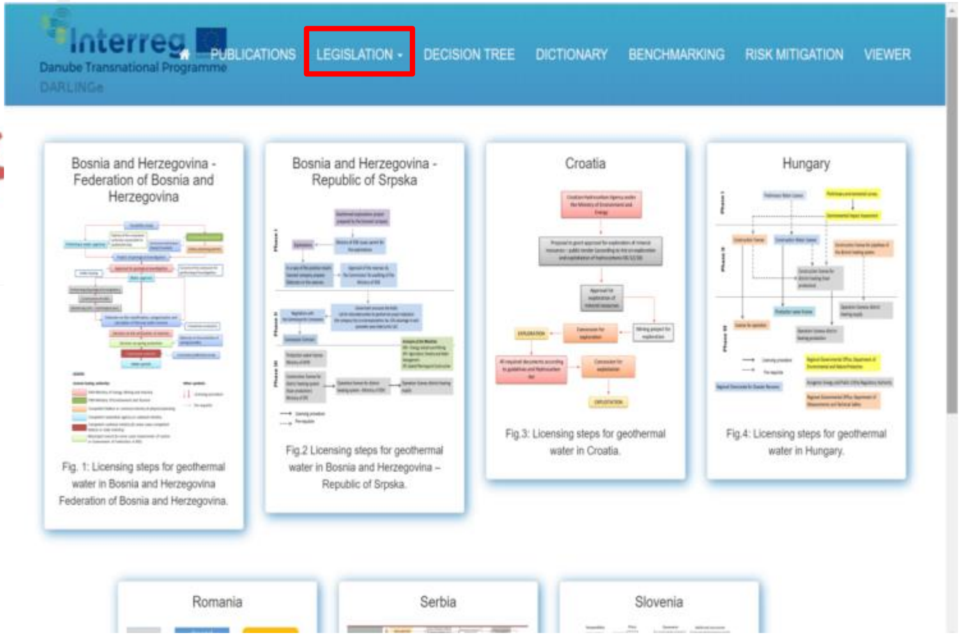
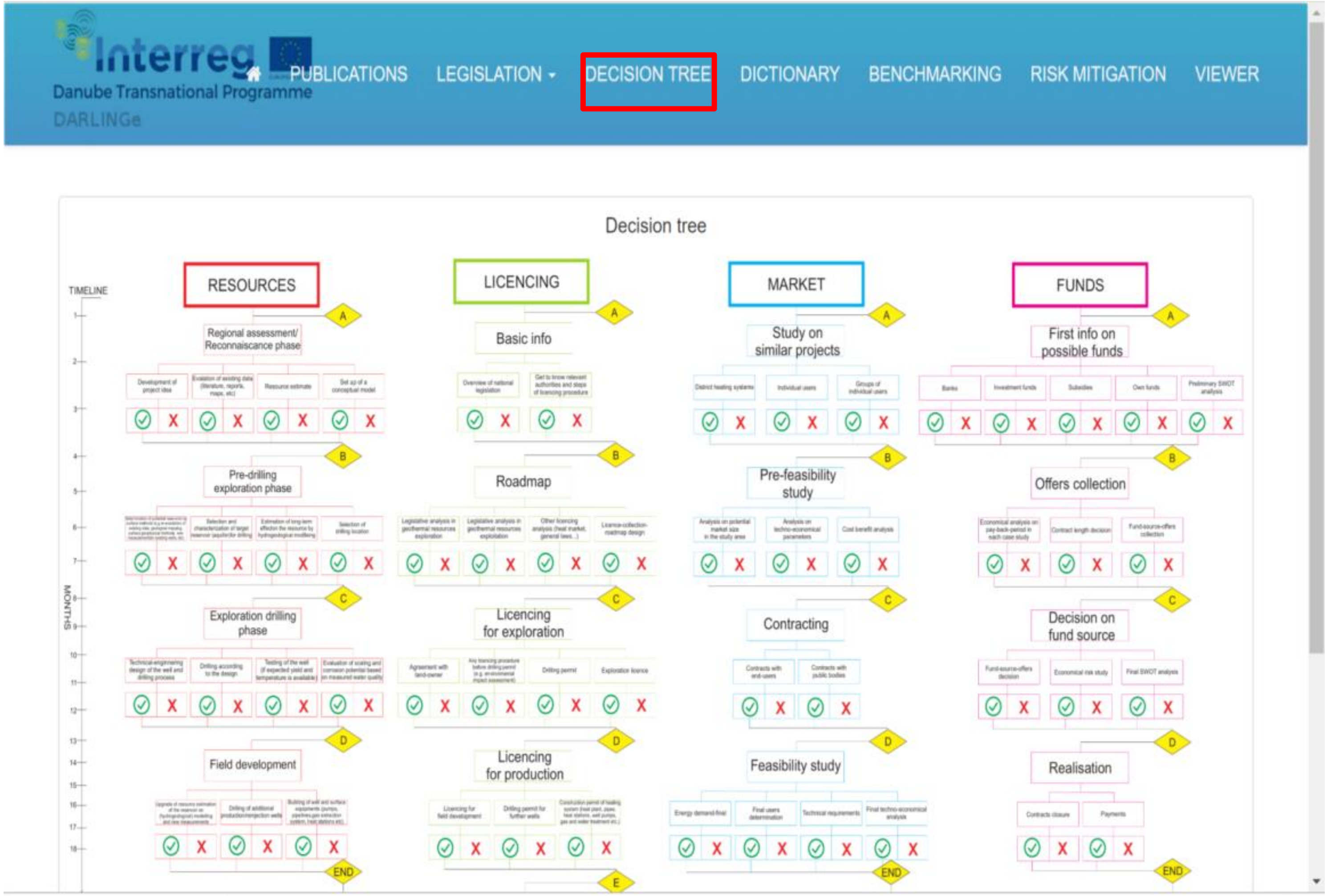


Altogether 25 questions on various aspects of legislation/ licensing

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



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

$$I_{TEF} = \frac{\sum_{i=1}^{n} \eta_i \cdot Q_i}{\sum_{i=1}^{n} Q_i} [\%]$$

Where:

$$\eta_i = \frac{T_{whd} - T_{out}}{T_{whd} - T_o}$$

In case of reinjection :

$$\eta_{r\,i} = \frac{Q_i (T_{whd} - T_{out})}{Q_i (T_{whd} - T_{out}) + Q_{ww\,i} (T_{out} - T_o)}$$

Very good: $I_{TEF} > 70$

Good: $60 < I_{TEF} \leq 70$

Medium: $40 < I_{TEF} \leq 60$

Weak: $30 < I_{TEF} \leq 40$

Bad: $I_{TEF} \leq 30$

Final recommendations: Danube Region Geothermal Strategy and Action Plans

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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 overexplotation

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

Final recommendations: Danube Region Geothermal Strategy and Action Plans

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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/

nador.annamaria@mbfsz.gov.hu