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

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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: 30-125 °C – direct heat
- Medium: 125-150 °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
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
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)
Current utilization schemes in Hungary

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

<table>
<thead>
<tr>
<th></th>
<th>installed capacity (MWt)</th>
<th>annual production (GWh/y)</th>
</tr>
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<tbody>
<tr>
<td>Geothermal district heating (23 towns)*</td>
<td>223.36</td>
<td>635.66</td>
</tr>
<tr>
<td>Individual space heating (cca 40 locations)</td>
<td>77.2</td>
<td>83.1</td>
</tr>
<tr>
<td>Greenhouse heating</td>
<td>358</td>
<td>803</td>
</tr>
<tr>
<td>Balneology (cca 250 wells)</td>
<td>249.5</td>
<td>745.5</td>
</tr>
<tr>
<td></td>
<td><strong>908.06</strong></td>
<td><strong>2267.26</strong></td>
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* DH: 8, thermal water town heating: 15
# District heating in Hungary

<table>
<thead>
<tr>
<th>Settlements with district heating infrastructure</th>
<th>95</th>
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<tbody>
<tr>
<td>District heating suppliers</td>
<td>110</td>
</tr>
<tr>
<td>District heating networks</td>
<td>220</td>
</tr>
<tr>
<td>Number of flats with district heating</td>
<td>648 500</td>
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![Map of Hungary showing districts with district heating infrastructure](image)
District heating in Hungary

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

Source: Association of Hungarian District Heating Suppliers / www.tavho.org
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 district 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

<table>
<thead>
<tr>
<th>Share of RES</th>
<th>2020</th>
<th>2030</th>
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<tr>
<td>20%</td>
<td>14.65%</td>
<td>32%</td>
</tr>
<tr>
<td>20%</td>
<td>20%</td>
<td></td>
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</table>

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

Source: NECAP of Hungary

<table>
<thead>
<tr>
<th>2018</th>
<th>2020</th>
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<tbody>
<tr>
<td>Geothermal</td>
<td>17% of total RES</td>
</tr>
<tr>
<td>Heat</td>
<td>~8,2 PJ</td>
</tr>
<tr>
<td>Power</td>
<td>3 MW</td>
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Preparation: feasibility studies: selected DH systems, assessment of geothermal potential in the given region - 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 $\rightarrow$ 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 untapped
Geothermal reservoirs are controlled by regional geological structures – cut across by country borders – **needs for joint evaluation and harmonized management**
State-of-art: Current utilization

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

51% of the wells have outflow temperature $> 50 \, ^\circ\text{C}$
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
-300 to -600 m

Depth of the 50 °C isotherm
-600 to -1100 m

Depth of the 75 °C isotherm
-1100 to -1900 m

Depth of the 100 °C isotherm
-1900 to -2350 m

Depth of the 125 °C isotherm
-2350 to -3000 m

Depth of the 150 °C isotherm
-3000 to -3600 m
(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)
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. Non-condensable gas content, topography, lithologic cores, wellbore control, transmission, wildfire hazard, cold water breakthrough, degree of isolation, fluid inclusions, FMI logs, state lease queue, permeability regulation, conductivity field mapping, pH analysis, drilling experience, conceptual model, gravity survey, acoustic reflectivity, land ownership, atomic absorption spectrometry, temperature, calcite, flow tests, depth, tribal resources, geothermometry, titration, water for cooling, bottom hole diameter, site road access, active seismic reflection, wellbore control, transmission.

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/](https://www.darlinge.eu/)

**Thematic modules**

**Web-map viewer**

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/]
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Altogether 25 questions on various aspects of legislation/licensing
Final recommendations: Danube Region Geothermal Strategy and Action Plans

**Green (Pros):**
- 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

**Red (Cons):**
- 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
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/
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