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°C – requires heat pumps
- Low: 30-125 °C – direct heat
- Medium: 125-150 °C – electricity generation with binary cycles, CHP
- High: >150°C – “efficient” electricity production. Heat source: mainly magma in magma chambers located at shallow depths (restricted in Europe)
Geothermal energy for the decarbonisation of the heating sector

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

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

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

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)

115 million people, 14 countries
EU member states: AT, BG, HR, CZ, DE, HU, RO, SK, SI
Accession countries: BH, MNG, SRB
Neighbourhood countries: MD, UA
Highly heterogeneous macro-region (cultural, ethnical, economical)

Goal: to strengthen economical, social, territorial cohesion, determine common goals, promote cooperation, prepare joint projects

THE FOUR PILLARS

11 priority areas, coordinated by a priority area coordinator
# Renewed Action Plan of PA2

<table>
<thead>
<tr>
<th>Target I: To help to achieve the national targets based on the Europe 2030 climate and energy targets</th>
<th>Target II: To remove existing bottlenecks in energy to fulfil the goals of the Energy Union within the Danube Region</th>
<th>Target III: To better interconnect regions by joint activities with relevant initiatives and institutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>To further explore the <strong>sustainable use of biomass, solar energy, geothermal, hydropower and wind power</strong> to increase the energy autonomy and to promote and support multipurpose cross border activities.</td>
<td>To enforce <strong>regional cooperation</strong> 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 Europe countries.</td>
<td>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 Region.</td>
</tr>
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<td>To promote <strong>energy efficiency and use of renewable energy in buildings and heating systems including district heating and cooling</strong>.</td>
<td>To exchange best practices and to develop activities to decrease <strong>energy poverty</strong>, to increase the protection of vulnerable consumers and to empower them.</td>
<td>To reinforce the <strong>Carpathian Convention</strong> to share best practices and to develop joint projects.</td>
</tr>
<tr>
<td>To promote <strong>decarbonisation of the transport sector</strong>, regarding both public and freight transportation by developing the infrastructure for alternative fuels.</td>
<td>To explore new and innovative solutions of <strong>subsurface energy storage</strong>.</td>
<td>To encourage exchange of information and best practices to improve cooperation, create synergies and to initiate joint projects with other macro-regional initiatives.</td>
</tr>
<tr>
<td>To improve energy efficient, cost efficient and innovative <strong>low-carbon technologies</strong>, including smart solutions while respecting local culture and environment.</td>
<td></td>
<td>To encourage project generation related to the energy field.</td>
</tr>
</tbody>
</table>
How to communicate scientific results to non-technical audiences?

Experts in their fields produce large amounts of complex data. 

- topography
- environmentally sensitive areas
- flow tests
- depth
- tribal resources
- geothermometry
- tribal resources
- titration
- non-condensable gas content
- permeability regulation
- conductivity
- field mapping

Lithologic cores:
- policies
- calcite
- temperature
- land ownership
- Atomic absorption spectrometry
- cold water breakthrough
- degree of isolation
- fluid inclusions
- FMI logs
- active seismic reflection
- site road access
- water for cooling
- bottom hole diameter
- gravity survey

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

\[ H_0 = c \times V \times \Delta T \text{ – huge numbers, not exploitable} \]

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

Recovery factor (R): economically exploitable part of HIP

\[ H_1 = R \times H_0 \]
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 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 untouched
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
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?

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

Basin fill sediments („BF reservoirs“)

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

Top of BF

Bottom of BF
(3) A simplified conductive model for the determination of subsurface temperature distribution

Large heterogeneity 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
(4) Harmonized isotherm surfaces in the Neogene sediments

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
(5) Delineating potential reservoirs: geological bounding surfaces + isotherms
(6) Probabilistic estimation of the heat in place in the effective pore space (Monte Carlo simulation)

<table>
<thead>
<tr>
<th>Input parameters</th>
<th>Calculated parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: Reservoir area (km²)</td>
<td>F: Total volume (km³)</td>
</tr>
<tr>
<td>B: Reservoir thickness (km)</td>
<td>G: Effective porosity (Φeff)</td>
</tr>
<tr>
<td>C: Average total porosity (Φt)</td>
<td>H: Effective porosity heat content (PJ)</td>
</tr>
<tr>
<td>D: Reservoir temperature (°C)</td>
<td>A*B</td>
</tr>
<tr>
<td></td>
<td>C* (1-SH)</td>
</tr>
<tr>
<td></td>
<td>4.187<em>F</em>G* (D-30)</td>
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</table>

Effective porosity: „moveable water”
SH= the average clay content of the reservoir (20-60%)

<table>
<thead>
<tr>
<th>Estimated average total porosity value (V/V)</th>
<th>30-50 °C</th>
<th>50-75 °C</th>
<th>75-100 °C</th>
<th>100-125 °C</th>
<th>125-150 °C</th>
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<tr>
<td></td>
<td>0.178</td>
<td>0.131</td>
<td>0.091</td>
<td>0.061</td>
<td>0.039</td>
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</table>
## Probabilistic estimation of the recoverable heat (Monte Carlo simulation)

<table>
<thead>
<tr>
<th>Region ID</th>
<th>30-50 °C</th>
<th>50-75 °C</th>
<th>75-100 °C</th>
<th>100-125 °C</th>
<th>125-150 °C</th>
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<tr>
<td></td>
<td>P90</td>
<td>P50</td>
<td>P10</td>
<td>P90</td>
<td>P50</td>
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<td>3. region</td>
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<td>Bekes Basin</td>
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<td>11. region</td>
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<td>5032</td>
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<td>Backa</td>
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</tbody>
</table>
(7) Regional distribution

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)
(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)
Success stories: Szeged (HU)
Success stories: Moravske Toplice (SLO)
Success stories: Domaljevac (BH)
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/](https://www.darlinge.eu/)

**Thematic modules**

**Web-map viewer**

This portal – as a key output of the DARLINGe project [http://www.interreg-danube.eu/approved-projects/darlinge](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/
Altogether 25 questions on various aspects of legislation/licensing
Danube Region Geothermal Information Platform (DRGIP) https://www.darlinge.eu/
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\[ I_{TEF} = \frac{\sum_{i=1}^{n} \eta_i Q_i}{\sum_{i=1}^{n} Q_i} \times [\%] \]

Where:
\[ \eta_i = \frac{T_{whd} - T_{out}}{T_{whd} - T_o} \]

In case of reinjection:
\[ \eta_{ri} = \frac{Q_i (T_{whd} - T_{out})}{Q_i (T_{whd} - T_{out}) + Q_{ww} (T_{out} - T_o)} \]

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

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/
nador.annamaria@mbfsz.gov.hu