Factsheet Temperature

The temperature distribution in the subsurface, i.e. the amount of heat stored underground, is the crucial baseline data for any geothermal reservoir assessment.

The Earth's internal heat comes from a combination of residual heat from planetary accretion, heat produced through radioactive decay, and latent heat from core crystallization. As a general rule, the Earth's crust temperature is rising with depth due to the heat flow from the much hotter mantle causing a temperature change with increasing depth, the geothermal gradient. Beneath the shallow subsurface, where the uppermost about 25 m are influenced by the seasonally varying ambient temperature, and the subjacent hundreds of meters which may reflect past climate conditions, the Earth's interior heat sources dominate, making the warmth increasing steadily at an appraised average of about 25-30 °C per km of depth in most of the world.
This deeper part of the subsurface, away from any (paleo-)atmospheric influence, hosts the carbonate reservoirs considered in HotLime. The geothermal conditions in this technically accessible part of the Earth's crust, in general, are propelled by three processes:

- heat conduction,
- forced convection (advection),
- free convection.

Due to regional and local scale effects the geothermal gradient may vary considerably.

At regional scale and beneath the impact of surface temperatures, the geothermal regime is predominately influenced by heat conduction, determining the distribution of subsurface temperatures by

- the distribution of thermal rock parameters (thermal conductivity),
- the distribution of internal radiogenic heat sources (rock parameter radiogenic heat production rate), and
- the heat-flux from deeper parts of the Earth's crust.

Superposed to this large-scale conductive regime, local variations result from convective transport processes driven by the movement of groundwater. This convective transport is governed by external processes such as gravitation (forced convection or advection) or internal processes (free convection), the latter resulting from the thermal uplift of heated groundwater due density reduction, entailing vertical convection cells.

Basically, subsurface temperature assessments should consider all these thermal processes either in an explicit (numerical 3D process modelling) or implicit (geo-statistical inter-/extrapolation of measured subsurface temperatures) way. For a summary of assessment methodologies, data preparation and evaluation see GeoMol Team (2015).

Due to the diverse baseline data for HotLime's Cases Study Areas, the paucity and the uneven distribution of temperature data available, the elaboration of temperature models for HotLime's Cases Study Areas has been beyond the project's objective and scope. Thus, the temperature data used for geothermal base assessment in HotLime, their derivation and evaluation, are pronouncedly diverse: Areas in a more advanced state of geothermal exploration and/or subject to hydrocarbon E&P commonly feature an appropriate number of subsurface temperature measurements to implement reliable temperature modelling. Accordingly, temperature models or maps could be utilized for HotLime's Case Study Areas #1 Molasse Basin (BayStMWIVT 2010, Agemar et al. 2013, GeoMol Team 2015, Agemar & Tribbensee 2018), #4 Flanks of London-Brabant Massif (Békési et al. 2020) and #5 Po Basin (ISPRA 2015). In all other Case Study Areas assessment of subsurface temperatures is based on regionalized geothermal gradients, in some cases derived from borehole measurements of merely one well, or solely based on literature data also beyond the spatial scope of the case study.

The diverse area specific procedures for assessing the reservoir temperatures and the baseline data used are described in HotLime's Report 2.0 and Report 3.1.

References

Agemar, T., Brunken, J., Jodocy, M., Schellschmidt, R., Schulz, R. & Stober, I. (2013): Untergrundtemperaturen in Baden-Württemberg. - ZDGG – German Journal of Geosciences, 164: 49–62. https://doi.org/10.1127/1860-1804/2013/0010

Agemar, T. & Tribbensee, K. (2018): GeotIS-Verbundmodell des Top-Malm im Bereich des Vorlandbeckens der Alpen: ZDGG – German Journal of Geology, 169: 335-341. https://doi.org/10.1127/zdgg/2018/0126

BayStMWIVT [Hrsg.] (2010): Bayerischer Geothermieatlas. - 96 S., Karten-CD, München (Bayerisches Staatsministerium für Wirtschaft, Infrastruktur, Verkehr und Technologie).

Békési, E., Struijk, M., Bonté, D., Veldkamp, H., Limberger, J., Fokker, P.A., Vrijlandt, M. & van Wees, J.-D. (2020): An updated geothermal model of the Dutch subsurface based on inversion of temperature data. - Geothermics, 88: 101008. https://doi.org/10.1016/j.geothermics.2020.101880

GeoMol Team (2015): GeoMol – Assessing subsurface potentials of the Alpine Foreland Basins for sustainable planning and use of natural resources – Project Report, 188 pp. (Augsburg, LfU). https://www.geomol.eu/report/GeoMol_Report_web_reduced.pdf [2021-07-30]

ISPRA [Istituto Superiore per la Protezione e la Ricerca Ambientale] (2015): Modello geologico 3D e geopotenziali della Pianura Padana centrale (Progetto GeoMol). Rapporti ISPRA, 234/2015, pp. 104 e Appendice. http://www.isprambiente.gov.it/it/pubblicazioni/rapporti/modello-geologico-3d-e-geopotenziali-della-pianura-padana-centrale-progetto-geomol [2021-07-30]