Using old coal mines for geothermal energy: underground flow and heat transfer simulations as a pre-feasibility study in Liège (Belgium)

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Groundwater pumped in abandoned coal mines can potentially be used as a renewable energy vector involving heat and cold production. Coupled with a fifth-generation heating/cooling network (5GDHC), this can provide the needed heat and cold for a low-temperature district heating/cooling system. In the Walloon Region of Belgium, three cases are currently being investigated with the financial support of the Walloon Government (through SPW Energy within the Recovery Plan) to assess the potential of a mining geothermal pilot project ('Feasibility studies in the Liège, Charleroi, and Mons basins to launch a mining geothermal pilot project'). The case located in the city of Liège is detailed here.

A study site was chosen by cross-referencing and comparing data from the surface and existing old mines. Specifically, heat and cold users/producers to be connected were identified and their current (and future) demand profiles were examined. From the hydrogeological point of view, flooded abandoned mines form highly heterogeneous aquifer compartments that are artificially and locally highly permeable around former underground works (i.e., tunnels, galleries, mined extraction zones, wells, shafts). A thermal energy storage (ATES) system is planned using an open loop with a groundwater pumping and re-injection doublet. Ideally, hot water should be pumped in the deepest parts of the open network and cold water re-injected in the shallower parts (i.e. in shallower galleries). Inversion of the system could be planned at least seasonally for example for cooling the buildings during the summer. However, optimising such a system remains a huge challenge as many uncertainties may influence the system's efficiency. The true geometry of the interconnected network made of old open galleries and shafts can be highly complex and partially unknown. Indeed, high-velocity groundwater flow and heat transport are expected in this network inducing potentially a full or partial bypass of the fractured and porous rock massif.

A model of the mine reservoir was first elaborated by digitizing and conceptualising the true geometry of most of the interconnected galleries, shafts, and extracted coal panels of the flooded former mine in the fractured Westphalian formations. The mine reservoir must be described as realistically as possible to ensure the reliability and robustness of the results of the modelling of its behaviour under defined exploitation scenarios. Then, using Feflow ©, the groundwater flow coupled to heat transfer is simulated considering, step by step, an increasing complexity in the model. From a network considering just 1D and 2D elements representing old galleries and broken exploitation panels to a full 3D model including also all the heterogeneous zones of the rock massif. The simulation of short-, mid-, and long-term temperature evolution in pumping and injection zones is performed considering the temperature-dependent density and viscosity of groundwater. Those results will be crucial to assess the efficiency of the future system. At this stage, we observe a high dependence of the results on a few key system parameters including, among others, as, for example, actual hydraulic conductivity values. Accordingly, for a robust feasibility study, the priority should be to determine the hydraulic conductivity values around the future pumping and re-injection wells.

The first numerical simulations of this geothermal system show the importance of relying on modelling approaches using detailed mine data to provide predictions and sensitivity analysis allowing financial risk estimation.

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