Simulation of closed-loop geothermal systems (516)

Magnus Wangen (1), Vlasios Leontidis (2), Edgar Hernadez Acevedo (3), Virginie Harcouët-Menou (3) Pietro Ungar (4)

(1) Institute for Energy Technology (IFE), Norway, E-mail: Magnus.Wangen@ife.no; (2) IFP Energies Nouvelles (IFPEN), France; (3) Flemish Institute for Technological Research (VITO), Belgium; (4) University of Florence (UNIFI), Italy.

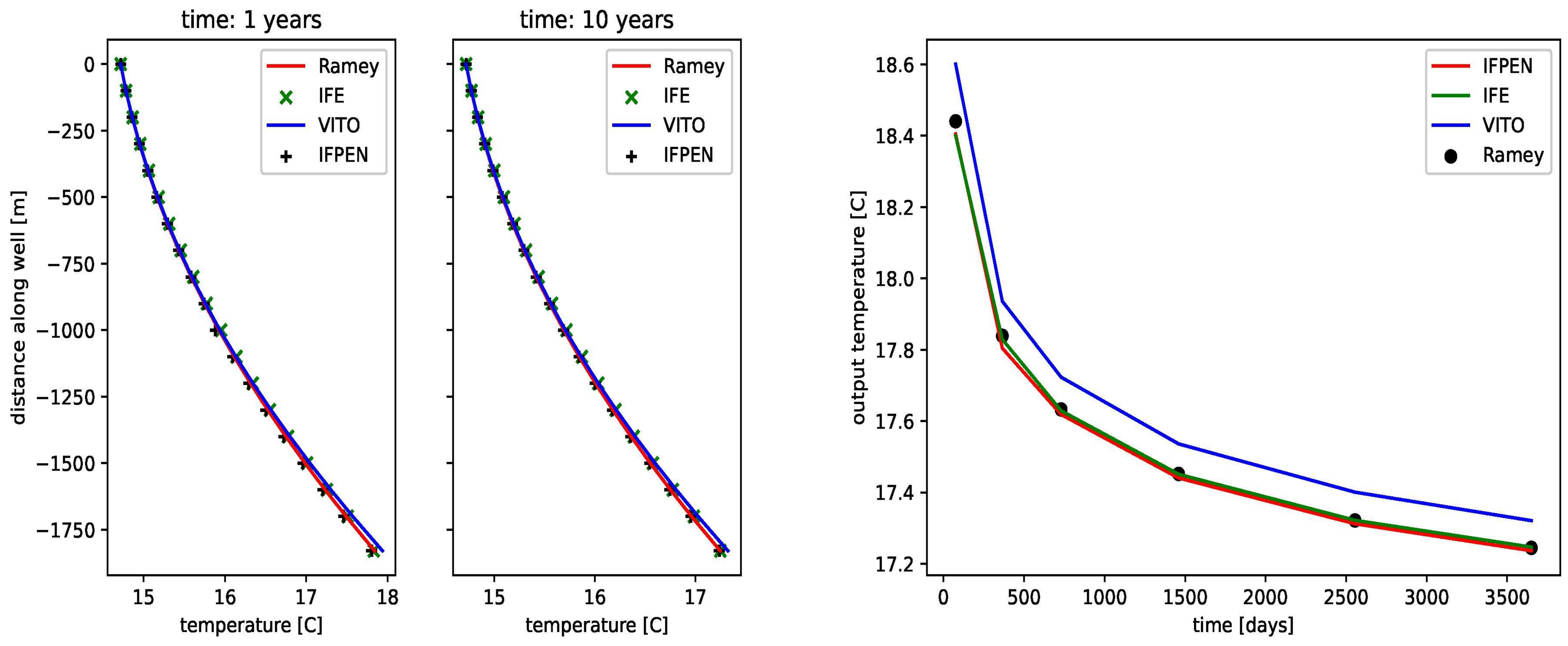
Introduction

We present simulation results from the EU-Horizon project HOCLOOP: A circular by design environmentally friendly geothermal energy solution based on a HOrizontal Closed LOOP. The aim of the HOCLOOP project is to qualify and develop technologies for closed-loop geothermal heat extraction from deep wells.

Coaxial Borehole Heat Exchanger

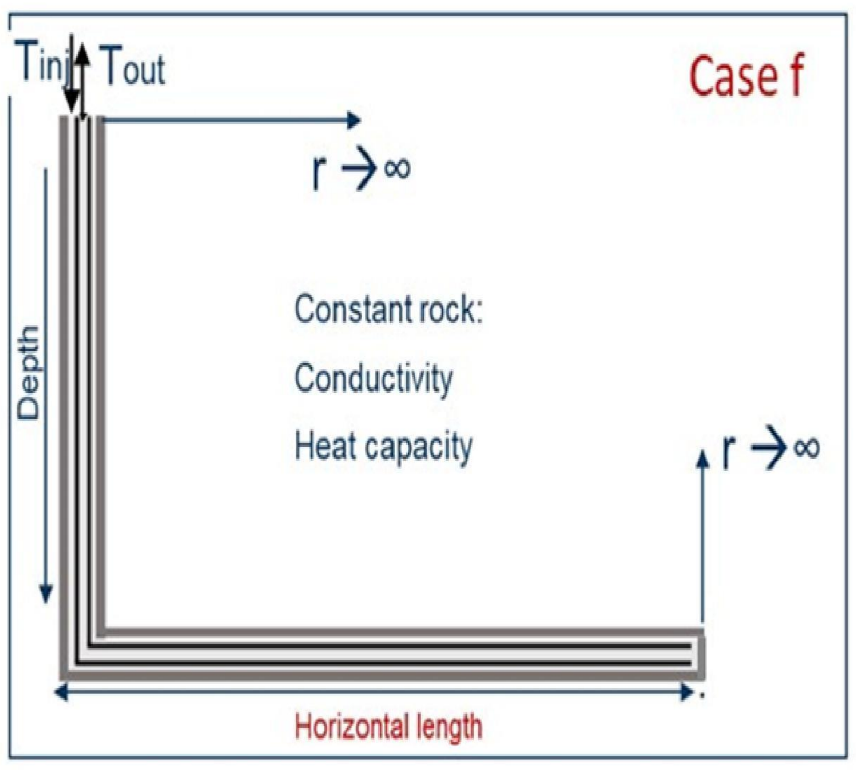
The HOCLOOP project is based on a coaxial heat exchanger, where the "cold" fluid is heated from the surrounding rock on its way down the annulus. When the heated fluid reaches the bottom of the well, it returns to the surface through an inner tube insulated from the annulus.

Benchmarking



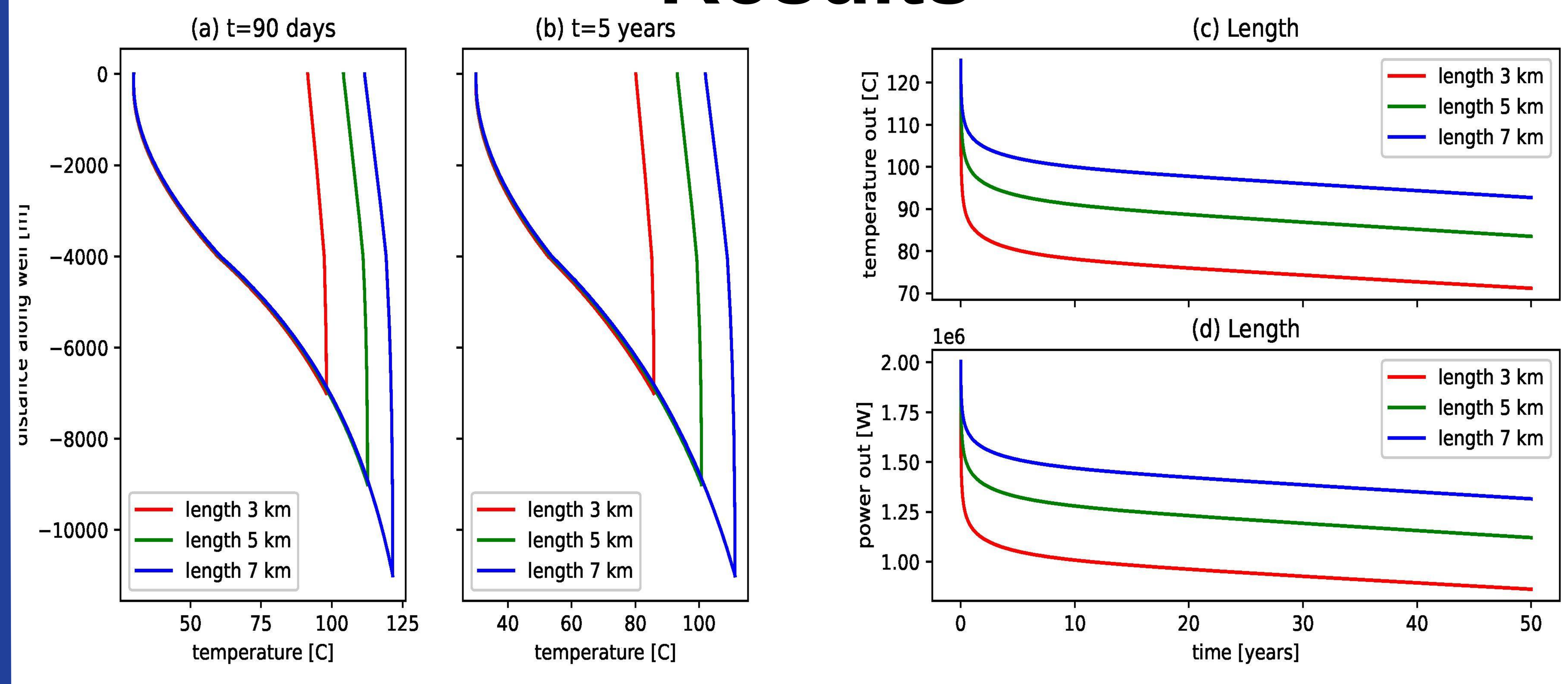
In-house tools (from IFE and IFPEN) and the commercial software COMSOL were benchmarked against each other and the analytical solutions of Ramey (1962), Al Saedi et al. (2018) and Sharma et al. (2020) for a series of benchmark cases (Leontidis et al, 2023).

Reference case

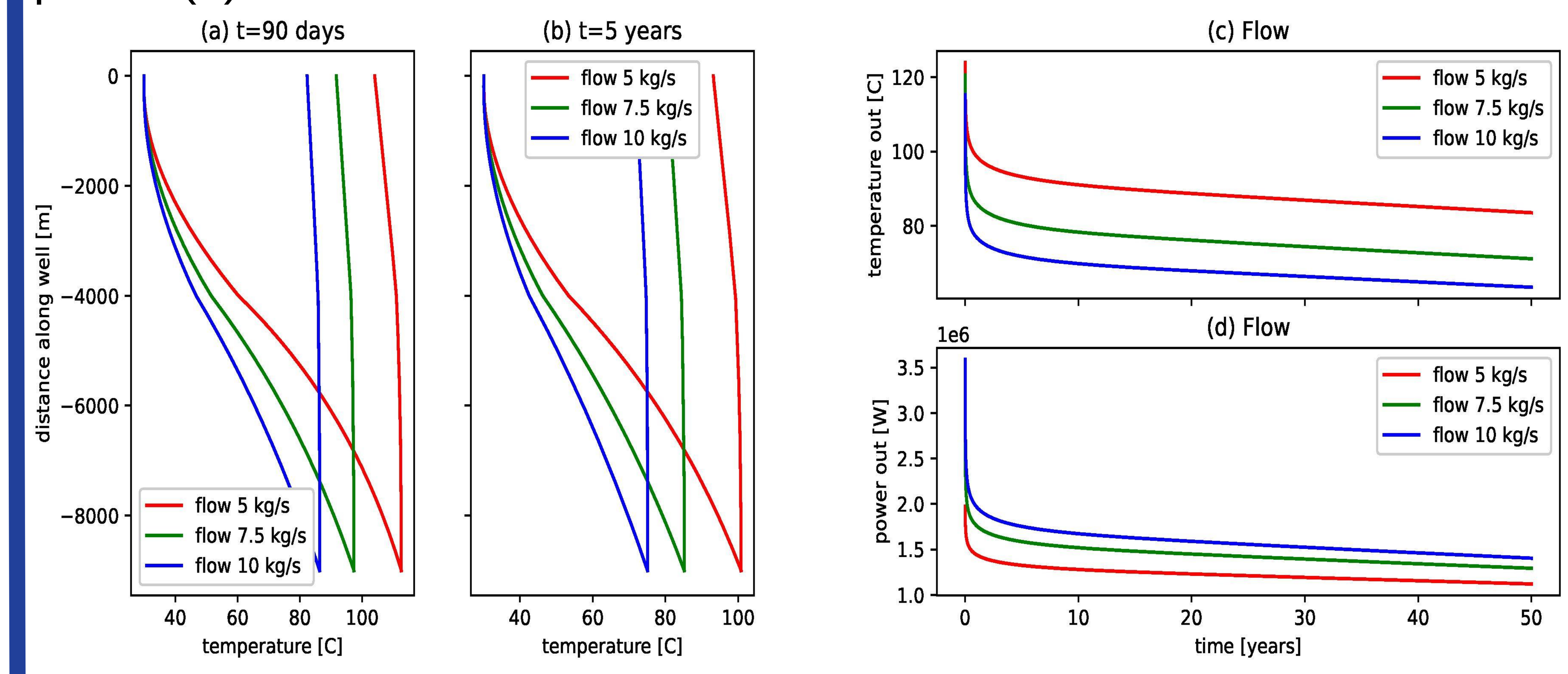


Several versions of a closed horizontal geothermal well were simulated, where it goes down to 4 km and then into a horizontal segment of 5 km (reference configuration). The inner and outer diameters of the annulus are 122 mm and 140 mm, respectively. The corresponding diameters of the tubing are 85 mm and 101 mm, respectively, with a heat conductivity of 0.01 W/m/K. The geothermal gradient is 30 °C/km, and the rock heat conductivity is 2 W/m/K for the vertical part and 3 W/m/K for the horizontal part. The injection temperature is 30 °C and the flow rate in the reference configuration is 7.5 kg/s. The implications of different flow rates, well depths and horizontal lengths were tested.

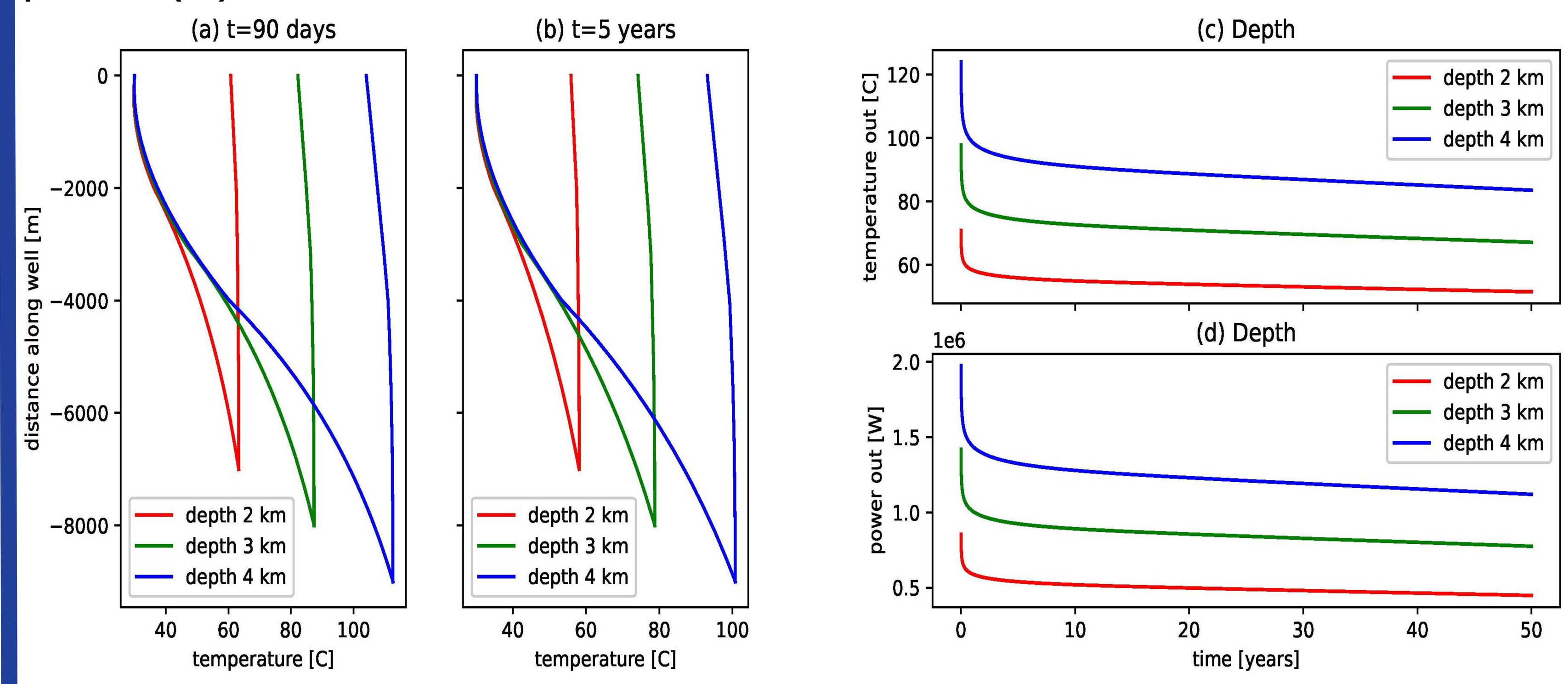
Results



The well temperature after 90 days (a) and 5 years (b) for three horizontal lengths and a flow rate of 7,5 kg/s. The output temperature (c) and the power (d) as a function of time.



The well temperature after 90 days (a) and 5 years (b) for three flow rates and a horizontal well length of 5km. The output temperature (c) and the power (d) as a function of time.



The well temperature after 90 days (a) and 5 years (b) for three depths. The output temperature (c) and the power (d) as a function of time.

Conclusions

- The software has been applied to the design of geothermal systems that can deliver 1 MW of hot water for large buildings or district heating.
- The simulations show that when the geothermal gradient is 30 °C/km, at least a 3 km deep well with a 5 km horizontal segment is needed to produce the power when the heat conductivity is 2 W/m/K surrounding the vertical well and 3 W/m/K surrounding the horizontal segment.
- The simulations show a gentle decline in power production over time after a short thermal transient.
- If the injection temperature is 30 °C, the output temperature stays above 70 °C after 50 years, except for the shallowest test well.

Acknowledgements: This research was funded by the European Union's Horizon Research and Innovation Program under grant agreement No 101083558 (The HOCLOOP Project).