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Mapping Geothermal: A planning instrument for power and heat generation in Germany

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Germany defined an ambitious social and economic plan in order to cut 80 % of CO2 emissions by 2050. In this context, geothermal energy can play a key-role, since the high capacity factor and the possible heat and power configuration. Several power plants and district heating systems are currently running in Germany on geothermal sources.

In this work, an extended techno-economic analysis of several geothermal binary solutions in Germany is proposed. Six organic Rankine cycles (ORC) power plant models are developed and analysed in order to provide a planning instrument for geothermal energy exploitation. This planning tool aims at power and heat generation and considers different energy system characteristics and distinct geothermal reservoir properties. The investigated examples are here listed:

1. Traunreut supercritical
2. Traunreut (subcritical)
3. Kirchstockach in double-stage configuration
4. Kirchstockach in single-stage configuration
5. Insheim with high performance components
6. Insheim with low performance components.

The investigated solutions cover the whole range of geothermal reservoir properties and power plant technical features available in Germany. Each example is firstly developed according to on-design analysis, where the evaporating pressure is varied in order to maximize the turbine power output. Later, each simulating model has been extended according to the implementation of off-design correlations for each component of the ORC power unit. Real ambient temperature data are therefore implemented and each model is hourly simulated. For each power plant model, three different configurations are evaluated: power-only and heat and power, with respectively 5 and 10 MW as maximum heat demand. Techno-economic analyses according to annual input data are therefore developed for the CHP configurations.

The double-stage Kirchstockach power plant shows the highest on-design turbine power output (4910 kWel), followed by Insheim high performance with 4427 kWel. The thermal efficiency results in 12.51 % in Insheim high performance, while only 8.21 % in Traunreut supercritical. In fact, the very high auxiliary power requirement affects the overall power unit efficiency. An economic analysis on the component level is applied to calculate the levelized cost of electricity (LCOE) of each ORC power plant. In power-only configuration, Insheim with high performance shows the lowest LCOE (10.79 €ct/kWh) while the highest value is reached by the supercritical case study in Traunreut (19.40 €ct/kWh). This solution requires the highest-cost and longest-term total investment. In general, the obtained results show how a very high geothermal well-head temperature could improve the techno-economic results. Current calculations show how an increasing maximum heat demand negatively affects the LCOE and the BEP but increases the Net Present Value at the end of the investment.

The results enable operators and planers to identify the most suitable power plant configuration in dependence of reservoir conditions and specific heating demand. In this work, Aspen V8.8 has been chosen as simulating environment.

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