

EGU21-9842

EGU General Assembly 2021

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Life cycle assessment of geothermal power generation in the Southern German Molasse Basin – The binary plant Kirchstockach

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Under geologically beneficial conditions, geothermal facilities are often rated as efficient, as well as clean and climate-neutral energy technologies. In fact, for supporting a good environmental performance of a technology, the total environmental impact caused by all associated material and energy consumption needs to be examined. Life cycle assessment (LCA) according to ISO standards 14040 and 14044 considers not only operation, but also the construction and decommissioning phases while addressing different environmental impact categories. Therefore, LCA-based environmental evaluation has been proposed in several previous studies. A review of the state-of-the-art in this field shows that some critical system parameters are often disregarded. Furthermore, many existing studies are solely based on theoretical datasets without validation to specific application cases.

Our work addresses these two shortcomings by performing a comprehensive LCA using operational data of the binary, two-stage ORC, Kirchstockach power plant in the Southern German Molasse Basin. Given its technical specifications, a representative base case scenario provides an excellent reference for benchmarking against other power plants. Environmental impacts of different technical modifications are assessed in terms of global warming potential, non-renewable energy consumption, aquatic acidification and eutrophication. Using scenario analyses, we consider the influence of emerging key factors, such as refrigerant leakage, focusing on various system components. Firstly, we identify reinforcing effects due to interrelationships between these system parameters, e.g. when using environmentally friendly ORC refrigerants. Secondly, uncertainty analyses provide insights into potential measures for ecological system improvements by using different materials and methods in the construction and operation phases. For comparison and benchmarking purposes, conventional power generation resources and comparable studies in the field of binary geothermal systems, enhanced geothermal systems, and flash systems are included. Besides the general positive ranking of the Kirchstockach power plant environmental performance, our multi-objective study ultimately reveals not only key performance factors, but it also underlines the overall relevance of case studies to validate generic and global assumptions.