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Greenhouse gas emissions of aquifer thermal energy storage (ATES)

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Aquifer Thermal Energy Storage (ATES) is an open-loop geothermal system enabling seasonal storage of thermal energy in groundwater. It is a promising technology for environmentally friendly energy generation that can overcome the seasonal mismatch between demand and supply of heating and cooling and helps to reduce greenhouse gas (GHG) emissions. Yet, there are only few studies quantifying GHG emissions caused by ATES systems over their entire life cycle. This study presents a novel life cycle assessment (LCA) regression model focusing on the GHG emissions that is a fast alternative to conventional time-consuming LCA. Due to its parametric structure, the regression LCA model can be used to perform Monte Carlo simulations of a wide range of different ATES configurations. Accordingly, it allows the environmental evaluation of the technology as a whole.

The application of the model reveals that the median value of investigated ATES configurations is 83.2 gCO_{2eq}/kWh_{th} with most of the emissions resulting from electricity consumption during the operational phase. Compared to conventional heating systems based on heating oil and natural gas, this value reveals potential GHG savings of up to 74 %. In terms of cooling, ATES can save up to about 59 % of GHG emissions compared to conventional, electricity-based technologies. Specific GHG emissions from a modified LCA regression model considering a projected electricity mix for the year 2050 add up to 10.5 gCO_{2eq}/kWh_{th} forecasting even higher emission savings of up to 97 %. A sensitivity analysis reveals that in particular the operational time for cooling and the coefficient of performance (COP) of the heat pump should be carefully considered when planning or optimizing new systems under current conditions. In contrast, when considering the projected 2050 electricity mix, the most important system parameter is the number of wells. This reflects the decreasing importance of the electrical power necessary for ATES operation due to the much lower specific GHG emissions of the projected 2050 electricity mix.