Master Thesis

Environmental and Economic Assessment of Advanced Adiabatic Compressed Air Energy Storage

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Abstract

Advanced Adiabatic Compressed Air Energy Storage (AA-CAES) is a promising utility-scale electricity storage option, innovative by storing not only compressed air, but also the heat from the compressor which can be recuperated during the expansion phase. The thermal energy storage (TES) system is built with a packed bed of rocks and phase change material to combine the use of sensible and latent TES. The world's first underground AA-CAES pilot plant was built in the Swiss Alps near the city of Biasca by ALACAES and project partners. As part of the Swiss Competence Center for Energy Research and the National Research Programme Energy Turnaround, an environmental and cost assessment of AA-CAES in Swiss-specific boundary conditions is required to evaluate the potential of scaling the plant up to utility scale. In this work, both a life cycle assessment and a life cycle cost analysis of such a system are performed. For the cradle-to-gate and decommissioning analysis, a parametrized life cycle inventory was compiled based on literature and input from project partners. For the operational phase, an in-house scheduling model based on economic optimization for energy arbitrage was coupled with hourly projections for electricity spot market prices and hourly average supply mixes from Swissmod. The results show that the environmental impact of the AA-CAES infrastructure is 2-4 times smaller than for pumped hydro storage. The results also show that the combined sensible/latent TES is 3-5 times smaller than oil-based TES. The results for the operational phase suggest that the system is likely to charge overnight when prices are low, which is related to a larger share of fossil-based technologies in the supply mix due to cheap imports. This result is however not technology-specific, and could be complemented with further analysis based on a marginal approach. The cost analysis shows that the capital investments are smaller per unit of power rating for AA-CAES than for any other bulk electricity storage technology. The levelized cost of electricity of AA-CAES is also low due to the long lifetime and low operation and maintenance costs of the system. All in all, the outcomes of this work suggest that AA-CAES is a cost-effective solution with small carbon footprint, thereby underlining its potential for bulk electricity storage.