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Excess renewable energy flexibilisation by integration of geological storage

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The European Strategic Energy Technology (SET) Plan provides various approaches to address challenges of the future energy sector by, e.g., the implementation of low-carbon energy systems based on Carbon Capture and Storage (CCS), improving the electricity grid as well as solar and wind initiatives. However, in line with increasing renewable energy supply, exhibiting high daily to monthly fluctuations, the implementation of concepts to store and utilise excess energy during periods of peak-demand as well as the development of enhanced and reliable energy storage technologies has become indispensable. An innovative approach that complies with essential SET Plan demands is the patented "Power-to-Gas-to-Power" (PGP) approach, an extension of the state-of-the-art "Power-to-Gas" (P2G) technology characterized by a closed carbon cycle (Kühn, 2015). Hereby, excess electricity from wind power is transformed into H2 and then into CH4 using CO_2. CH4 is stored in a geological reservoir and electrified on demand in a Combined-Cycle Gas Turbine (CCGT) power plant. Carbon dioxide is captured at the CCGT and stored in a secondary reservoir, closing the carbon cycle.

Compared to conventional P2G approaches, the extended PGP concept has the advantage of CO_2 emission mitigation by capturing and temporarily storing CO_2 in a subsurface reservoir. As successfully demonstrated at the German Ketzin pilot site, CO_2 storage is technically feasible and can also comply public acceptance. Besides, the PGP technology can be applied immediately, as it is complementary to available infrastructure and supports base load energy supply, while countries decrease their dependence on energy imports.

Based on a regional show-case study for the two German cities of Potsdam and Brandenburg/Havel (Kühn et al., 2014), providing first predictions on the overall PGP efficiency, we performed an enhanced analysis here. Innovations in our present study mainly comprise the tight integration of the surface-based PGP process chain with subsurface geological storage by means of thermodynamic process modelling.

In summary, our results demonstrate that capturing CO_2 from the CCGT flue gas and temporarily storing it in a local subsurface reservoir allows for the implementation of a closed carbon cycle. Our assessment for the two cities of Potsdam and Brandenburg/Havel shows that about 30% of the electricity demand can be provided as base load by renewable electricity. Taking into account the entire process chain, we have quantified a total PGP process efficiency of 32%, exhibiting costs of about 20 Eurocent/kWh. Although the level of efficiency is lower than that of pump and compressed air storage technologies, resulting costs are on the same order of magnitude. Hence, PGP is economically feasible compared to other state-of-the-art excess energy storage technologies.

Literature

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