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Integrated underground gas storage of CO_2 and CH_4 to decarbonize the "power-to-gas-to-gas-to-power" technology

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Massive roll-out of renewable energy production units (wind turbines and solar panels) leads to date to excess energy which cannot be consumed at the time of production. So far, long-term storage is proposed via the so called "power-to-gas" technology. Energy is transferred to methane gas and subsequently combusted for power production – "power-to-gas-to-power" (PGP) - when needed. PGP profits from the existing infrastructure of the gas market and could be deployed immediately. However, major shortcoming is the production of carbon dioxide (CO_2) from renewables and its emission into the atmosphere. We present an innovative idea which is a decarbonised extension of the PGP technology.

The concept is based on a closed carbon cycle: (1) Hydrogen (H_2) is generated from renewable energy by electrolysis and (2) transformed into methane (CH_4) with CO_2 taken from an underground geological storage. (3) CH_4 produced is stored in a second storage underground until needed and (4) combusted in a combined-cycled power plant on site. (5) CO_2 is separated during energy production and re-injected into the storage formation.

We studied a show case for the cities Potsdam and Brandenburg/Havel in the Federal State of Brandenburg in Germany to determine the energy demand of the entire process chain and the costs of electricity (COE) using an integrated techno-economic modelling approach (Nakaten et al. 2014). Taking all of the individual process steps into account, the calculation shows an overall efficiency of 27.7 % (Streibel et al. 2013) with total COE of 20.43 euro-cents/kWh (Kühn et al. 2013). Although the level of efficiency is lower than for pump and compressed air storage, the resulting costs are similar in magnitude, and thus competitive on the energy storage market.

The great advantage of the concept proposed here is that, in contrast to previous PGP approaches, this process is climate-neutral due to CO_2 utilisation. For that purpose, process CO_2 is temporally stored in an underground reservoir. If existing locations in Europe, where natural gas storage in porous formations is performed, were to be extended by CO_2 storage sites, a significant quantity of wind and solar energy produced could be stored as methane. The overall process chain is in this case carbon neutral.

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