Geophysical Research Abstracts
Vol. 18, EGU2016-12697, 2016
EGU General Assembly 2016

Site specific comparison of H2, CH4 and compressed air energy storage in porous formations

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The supply of energy from renewable sources like wind or solar power is subject to fluctuations determined by the climatic and weather conditions, and shortage periods can be expected on the order of days to weeks. Energy storage is thus required if renewable energy dominates the total energy production and has to compensate the shortages. Porous formations in the subsurface could provide large storage capacities for various energy carriers, such as hydrogen (H2), synthetic methane (CH4) or compressed air (CAES). All three energy storage options have similar requirements regarding the storage site characteristics and consequently compete for suitable subsurface structures. The aim of this work is to compare the individual storage methods for an individual storage site regarding the storage capacity as well as the achievable delivery rates. This objective is pursued using numerical simulation of the individual storage operations.
In a first step, a synthetic anticline with a radius of 4 km, a drop of 900 m and a formation thickness of 20 m is used to compare the individual storage methods. The storage operations are carried out using -depending on the energy carrier- 5 to 13 wells placed in the top of the structure. A homogeneous parameter distribution is assumed with permeability, porosity and residual water saturation being 500 mD, 0.35 and 0.2, respectively. N2 is used as a cushion gas in the H2 storage simulations. In case of compressed air energy storage, a high discharge rate of 400 kg/s equating to 28.8 mio. m^3/d at surface conditions is required to produce 320 MW of power. Using 13 wells the storage is capable of supplying the specified gas flow rate for a period of 31 hours. Two cases using 5 and 9 wells were simulated for both the H2 and the CH4 storage operation. The target withdrawal rates of 1 mio. sm^3/d are maintained for the whole extraction period of one week in all simulations. However, the power output differs with the 5 well scenario producing around 317 MW and 1208 MW and the 9 well scenario producing 539 MW and 2175 MW, for H2 and CH4, respectively. The difference in power output is due to the individual energy density of the carriers as well as working gas mixing with the cushion gas.
To investigate the effects of a realistic geometry and parameter distribution on the storage performance, a realistic field site from the North German Basin is used. Results show that the performance of all storage options is affected as the delivery rate is reduced due to reservoir heterogeneity.
Acknowledgments: This work is part of the ANGUS+ project (www.angusplus.de) and funded by the German Federal Ministry of Education and Research (BMBF) as part of the energy storage initiative ”Energiespeicher”.