Levelized Cost of Renewable Powered Direct Air Capture in Germany by 2045

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Germany's legal commitment to achieve greenhouse gas neutrality by 2045 highlights the need for negative emissions to offset remaining emissions. In addition to natural emissions sinks, Direct Air Capture (DAC) of CO_2 is a promising technology for large scale carbon dioxide removal (CDR) from the atmosphere. Multiple studies emphasize the anticipated importance of DAC in Germany, with recent research projecting a significant CDR demand of 57 Mt CO_2 annually through DAC [1]. However, no comprehensive evaluation of potential DAC siting within Germany exists to date. This work answers the research questions where DAC plants should be sited in Germany and what levelized costs of DAC (LCOD) are to be expected in the year 2045.

We create an hourly resolved optimization model with the ETHOS.FINE framework [2] to analyze the two currently most promising DAC approaches, the solid sorbent adsorption approach [3] and the electrified liquid solvent absorption approach [4],[5]. We use land-use and weather data with high spatial resolution [6] to model off-grid energy systems consisting of onshore wind turbines, open-field photovoltaics, battery storages, heat pumps and DAC plants. Considering the influence of weather conditions on the energy demand of DAC plants, we minimize annual systems costs to find optimal capacities and operation for DAC plants and their energy supply for each German municipality.

Our results show that energy demand of DAC can vary more than 100% over the course of a year for solid sorbent DAC within certain German municipalities while the energy demand varies only by about 10% between the different municipalities. Comparing the levelized costs of DAC in the year 2045 for both approaches, our optimization model shows that the average LCOD for Germany are 285 €/tCO_2 (223-848 €/t_{CO2}) for the solid sorbent approach and 265 €/tCO_2 (197-1035 €/t_{CO2}) for the liquid solvent approach. Lowest LCOD for both approaches are achieved in northern Germany which is beneficial due to proximity to potentially suitable geological storage sites for permanent CO_2 storage in the Baltic or Northern Sea. Main site-specific cost drivers are the costs for renewable energy supply, but also the site-specific energy demand of DAC has a significant influence on LCOD. Energy supply systems which combine onshore wind turbines and open-field photovoltaics lead to lower costs than systems which solely rely on wind energy or photovoltaics and battery storage. In conclusion, our analysis shows that Direct Air Capture could become cost-effective if CO_2 prices in Germany rise significantly.

References

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