POTENTIAL OF REPURPOSED COOLING TOWERS FOR DIRECT AIR CAPTURE IN GERMANY

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Content

To successfully mitigate climate change, a transition of all sectors to renewable energy sources is required. In addition, to reduce the atmospheric CO2 concentration, offset emissions from hard-to-abate sectors, and provide CO2 as a feedstock for a circular carbon economy, negative emission technologies (NETs) will play a crucial role. Among NETs, the direct separation of CO2 out of ambient air (Direct Air Capture, DAC) is considered as a particularly scalable option. However, DAC faces major challenges in terms of high energy demands and high investment cost as large air mass flows must be processed given the low CO2 concentration in ambient air (~400 ppm). Cooling towers of thermal power plants (e.g., coal-fired power plants) process air mass flows comparable to those anticipated for large-scale DAC units (i.e., 1 Mt_{CO2}/a capture capacity). Consequently, as countries phase out coal-fired power plants, an opportunity arises to repurpose existing cooling towers as absorption-based DAC units. In this context, within the research project *ConTACtFuels*, funded by the German Ministry of Transport, the potential of repurposing components of thermal power plants for DAC and subsequent fuel synthesis was assessed. Within this scope, techno-economically feasible combinations of DAC and fuel synthesis were evaluated, considering the reuse of existing power plant infrastructure to lower investment cost. In this paper, selected results on potential annual capture capacities and specific capture costs are presented for different power plant sites in Germany. In addition, an outlook on a potential rollout strategy is provided.

Methodology

Promising DAC variants are sorption-based processes due to their specific energy demand: a solid (adsorption) or liquid (absorption) sorbent is exposed to air and selectively binds CO2 through physical or chemical mechanisms. A preliminary study has shown that German thermal power plants above 150 MW_{el} mainly employ natural draft wet cooling towers (NDWCT) [1]. NDWCT are typically equipped with distribution nozzles and packing structures to enhance the gas-liquid contact area, components which are likewise installed in the capture unit (air contactor) of absorption-based DAC. Therefore, the present study focuses on the repurpose of NDWCT of coal-fired power plants (lignite and hard coal) as air contactors in an absorption-based DAC unit. As a case study, the absorption process developed by Carbon Engineering is evaluated, which uses a potassium hydroxide solution as absorbent and a calcium hydroxide cycle for sorbent regeneration (i.e., CO2 release) [2]. A simplified model of the absorption behavior for different absorber heights as well as liquid and gas mass flows is formulated to analyze the effect of the repurposed cooling tower geometry on the capture process [1]. Using gas and liquid mass flows as degrees of freedom, the Levelized Cost of Direct Air Capture (*LCODAC*) are minimized for a target annual capture capacity for different energy-cost scenarios in 2030 and power plant sites [3].

Results and Discussion

For each power plant site, an optimum annual capture capacity is identified as a trade-off between economies of scale (i.e., decreasing the specific capital expenditure) and specific energy demand (i.e., operational expenditure) associated with air mass flow rates through the cooling tower. The position of this optimum strongly depends on the energy-cost scenario: with increasing energy procurement costs, the optimum shifts toward smaller annual capture capacities. In the case of a conservative energy-cost scenario, the *LCODAC* of the repurposed NDWCT-based DAC facility can exceed that of a newly built DAC unit of the same annual capture capacity.

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Figure 1 illustrates the annual CO2 capture capacity and the associated optimal *LCODAC* for different power plant sites in Germany, assuming a lifetime of 25 years and an optimistic energy-cost scenario. The highest theoretical potential can be found at lignite-fired power plant sites, as these exhibit the highest nominal power output at a single site associated with the number and size of the corresponding NDWCT. Moreover, to ensure a net-emission-negative CO2 capture process, low-emission energy supply by photovoltaic (PV) and wind power is required, which further favors the lignite-fired power plant sites. Overall, repurposing NDWCT as air contactors of absorption-based DAC units exhibits a potential to capture 2.3 Mt_{CO2}/a in Germany. However, the estimated techno-economic potential is associated with considerable uncertainty regarding:

- the optimal absorbent and its mass transfer characteristics,
- the on-site performance relative to the simplified modeling approach,
- additional reuseable components, and
- maintenance cost due to the new operating conditions.

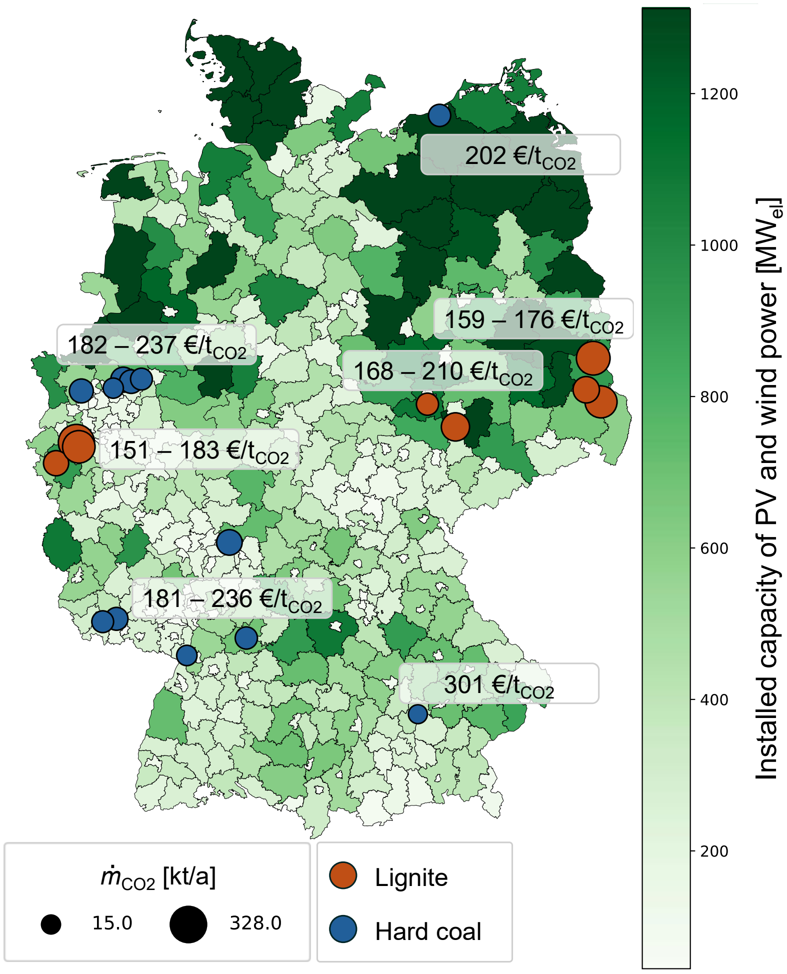

Figure 1 Results of the annual capture capacity and LCODAC for existing coal-fired power plant sites in Germany assuming an optimistic energy-cost scenario and a lifetime of 25 years

References

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