MAXIMISING THE MITIGATION POTENTIAL OF CURTAILED WIND: A COMPARISON BETWEEN CARBON CAPTURE AND UTILISATION, AND DIRECT AIR CAPTURE PROCESSES FOR THE UK

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Carbon capture and storage (CCS) with fossil fuel or biomass plants (BECCS) is considered a critical technology to meet mitigation targets set by the Paris Agreement[1]. However, several drawbacks including high upfront investment costs, significant energy penalty and long-term permanent storage challenges have limited the uptake of CCS on the required scale. Carbon capture and utilisation (CCU) provides an alternative route to recycle CO_2 into chemical feedstock and/or synthetic transport fuels (e.g. methanol, DME) that can displace fossil-derived fuels. As the carbon is only *transformed*, CCU must be integrated with capture/storage to actually offset subsequent emissions from the vehicles consuming them. The mitigation of decentralised emissions poses significant challenges and necessitates the use of carbon dioxide removal technologies (CDR), one of which is direct capture of CO_2 from the atmosphere (DAC).

The last decade has seen increasing penetration of wind power in the UK electricity system to meet mitigation targets. Because of this, periods of surplus wind generation and low demand or limited/full storage capacity arise. Constraint payments then have to be made to wind farms to curtail generation. This work investigates two possible options to achieve mitigation with this curtailed electricity. In **Process A**, curtailed electricity is used to produce electrolytic hydrogen and operate methanol synthesis plants. It is then integrated with a direct air capture (DAC) plant to recapture and recycle emissions from the vehicles. **Process B** assumes curtailed electricity is used to run a DAC plant directly in order to capture decentralised carbon emissions and provide CO_2 feedstock for CCU processes.

The UK was used as a case study and the methanol synthesis process described by Rihko-Struckmann et al.[2] was used as the reference. A range of energy requirements for DAC are cited in literature; the lower and upper bounds of 6.7 GJ/tCO_2 and 12.6 GJ/tCO_2[3], respectively, were used. This work has taken a base case curtailment level of 2.5% of the UK total electricity demand, which is equivalent to 390 GWh/y[4]. Both processes have been compared on the basis of mitigation potential, defined by the proportion of CO_2 emissions from gasoline vehicles that are avoided, and mitigation costs per tonne of CO_2 captured.

Process A resulted in avoiding 0.12% of gasoline emissions (~0.05 MtCO_2/y). Surplus energy (~64% of the curtailed electricity) was required to run the DAC plant and an associated air separation unit. The mitigation of potential of Process B was 0.10% or 0.18%, depending on energy requirement used. Therefore, the process that maximises mitigation potential depends on the DAC process considered; using the lower-bound energy requirement, surplus electricity for DAC only is preferable. Neither process is economically viable. CCU costs ($905/t$CO_2$) were found to be double the DAC-only costs ($449/t$CO_2$), mainly due to high H_2 costs. It will remain financially-unattractive unless the methanol production becomes profitable. This is unlikely as it requires methanol price to almost double, a carbon price of $313/t to be in effect, or H_2 price to reduce to a third of today's price to $1800/t.

References

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