Exploring the role and value of negative emissions technologies (NETs) to the UK energy system

H. A. Daggash\textsuperscript{1,2,3}, C. F. Heuberger\textsuperscript{2,3}, N. Mac Dowell\textsuperscript{2,3}

\textsuperscript{1}Grantham Institute for Climate Change and the Environment, Imperial College London, UK
\textsuperscript{2}Centre for Environmental Policy, Imperial College London, UK
\textsuperscript{3}Centre for Process Systems Engineering, Imperial College London, UK

Abstract

Negative emissions technologies (NETs) could, purportedly, offset emissions from sectors with more difficult or expensive mitigation solutions such as transport and residual emissions from thermal power plants. The UK power sector must be completely decarbonised by 2050 to meet its economy-wide decarbonisation targets set out in the Climate Change Act 2008\textsuperscript{1}. It is also estimated that ~50 Mt\textsubscript{CO2}/yr of negative emissions are needed by 2050 to be compliant with the Paris Agreement target\textsuperscript{2}. This study investigates the potential role of direct air capture and storage (DAC\textsubscript{S}) and bioenergy with CCS (BECCS) for decarbonisation of two sectors for the UK: transport via fuel substitution, and power via integration of NETs.

CO\textsubscript{2}-derived fuels, often made using curtailed intermittent renewable energy sources (iRES), have been proposed as substitutes for gasoline/diesel in vehicles to avoid further emissions. The first part of this study quantifies a) the likely future availability of curtailed renewable electricity, b) the amount of fossil CO\textsubscript{2} emissions which can be avoided by using this electricity to convert CO\textsubscript{2} to methanol for use as a transport fuel - Power-to-Fuel, or to directly remove CO\textsubscript{2} from the atmosphere via DAC, Power-to-DAC. Both processes are illustrated in Fig. 1 below. Our analysis shows that curtailed electricity availability is unlikely to increase beyond current levels (1277 GWh/y) until iRES account for more than 50% of total installed capacity. This is unlikely to be the case in the UK before 2035. It was found that, in all cases, using curtailed iRES for DAC is a less costly and more effective option to mitigate climate change than using it to produce methanol to substitute gasoline.

![Figure 1: Simplified representation of the Power-to-Fuel and Power-to-DAC processes investigated](image-url)
In the second part of this study, BECCS and DACS are integrated into the Electricity Systems Optimisation (ESO) model\textsuperscript{3-5} to determine their potential role in power sector decarbonisation. We observe that complete decarbonisation of the electricity system – defined here as a carbon intensity of less than 10 kg\textsubscript{CO2}/MWh – is very costly in this absence of NETs, and requires an investment of \(\sim\)£310 billion in the period to 2050, with extensive expansion of iRES, energy storage and interconnection capacity. Moreover, whilst thermal power plants (CCGTs) are not entirely displaced from the power system, their capacity factors are less than 20\% after 2025. CCGT operators will therefore face stranded asset issues due to the underutilisation of their power plants.

Once BECCS or DACS is made available to the system, the investment needed to achieve complete decarbonisation is reduced to £160 billion and £193 billion, respectively. This is because negative emissions allowed for increased operation of cheaper thermal power plants, which replace costly iRES and energy storage that would otherwise be needed. NETs therefore have the potential to ease the cost burden of decarbonisation.

The System Value (SV)\textsuperscript{3} metric was used to evaluate the value added to the electricity system by the integration of BECCS and DACS. The SV quantifies the reduction in total system cost for a given deployment of a technology. Fig. 2 shows the SV curves for BECCS and DACS technology within the UK electricity system. On initial deployment, the system value of BECCS - £124,000/kW - is three times greater than that of DACS. As its economic level of deployment is approached, \(i.e.\) the limit beyond which there is no added deployment as added capacity is made available, \(SV\textsubscript{BECCS}\) falls to approximately £43,000/kW. We find that BECCS provides greater value to the energy system by allowing for increased operation of cheaper, unabated fossil plants.

![Figure 2: System value curves for BECCS and DACS technology in the UK electricity system](image-url)
References


