The role of negative emissions technologies in decarbonising the UK energy system

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Broader context

The *Climate Change Act 2008* mandates a decarbonisation of the UK electricity system by 2050. NETs are technologies that can, directly or indirectly, remove CO_2 from the atmosphere. Two are considered in this work: bioenergy with carbon capture and storage (BECCS), which involves permanently sequestering the carbon absorbed by biomass during its growth; and direct air capture and storage (DACS) which removes CO_2 from the air using sorbents. We apply a power systems planning model[1] to explore the potential role and value of BECCS and DACS deployment in decarbonising the UK electricity system.

What could a decarbonised UK electricity system look like?

To achieve decarbonisation without NETs, the UK would need significant expansion of intermittent renewable energy sources (iRES), energy storage and nuclear technologies in the electricity system. NETs can compensate for emissions from CO_2 emitting power plants, thereby allowing for their continued utilisation.

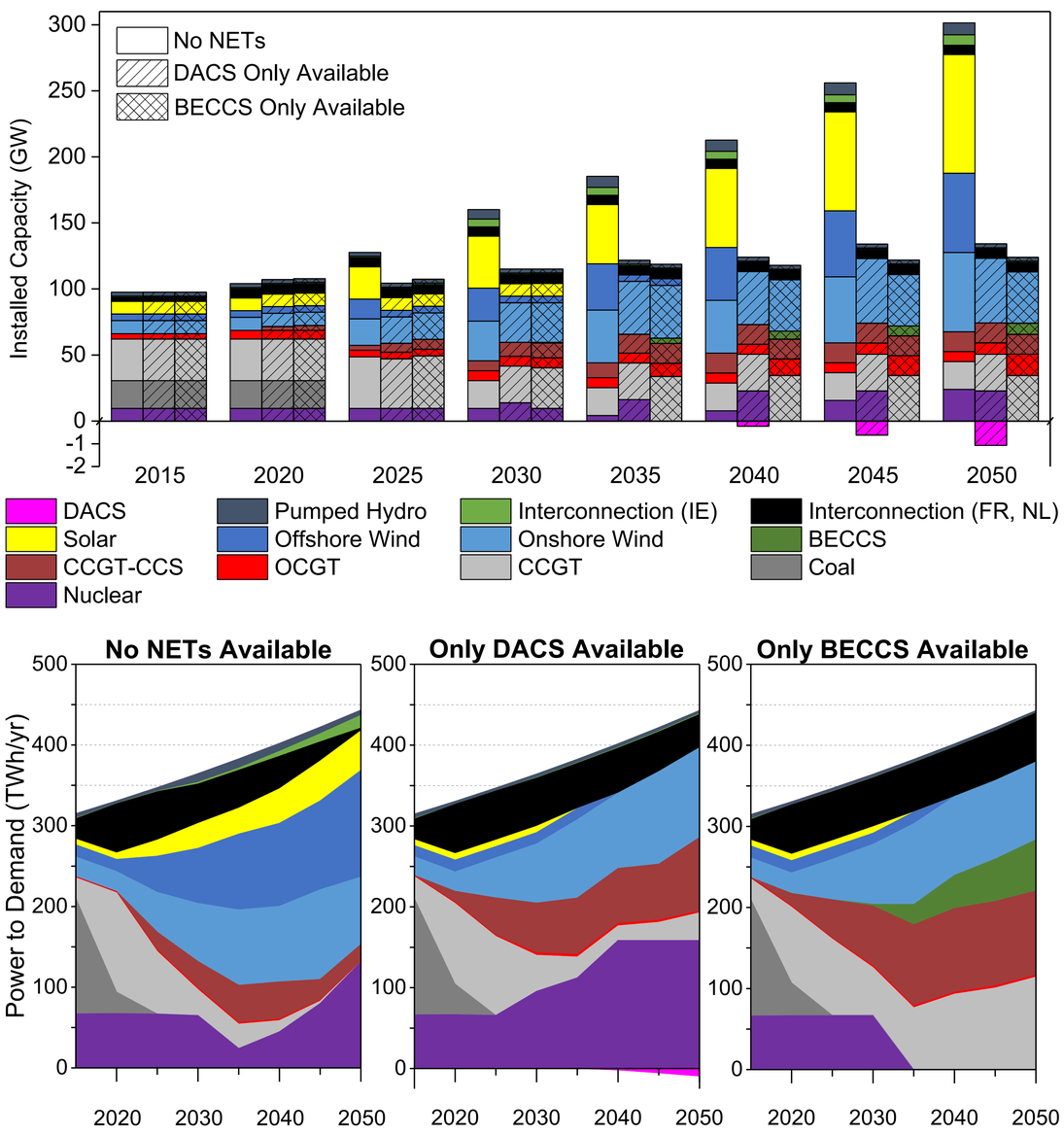

Figure 1: The optimal capacity and electricity generation mix for the UK from 2015 to 2050, given the availability of NETs

Economic implications of NETs deployment

Decarbonisation without NETs is estimated to cost £310 billion by 2050 due to the rapid expansion of capital-intensive iRES and nuclear technologies[2]. NETs ease the cost of decarbonisation by 37-48%, with BECCS providing the greatest reduction in total system cost.

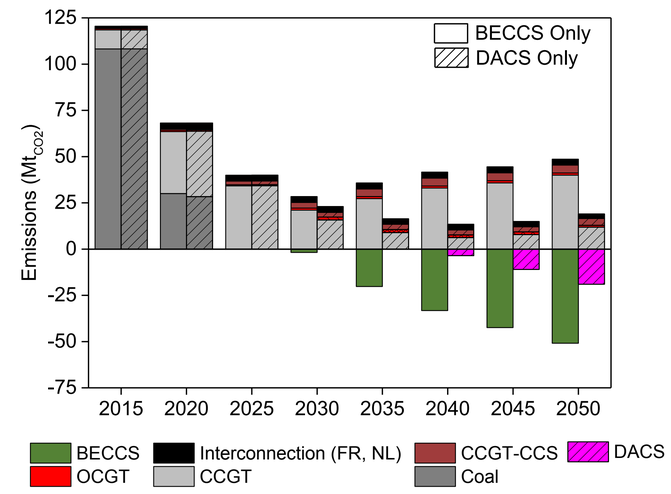

Figure 2: CO_2 emissions from power generation from 2015 to 2050

Marginal electricity prices are seen to quadruple by 2050 if BECCS is not deployed. This is due to the need for Ires expansion, or high OPEX of DACS plants to offset CO_2 emissions from thermal power plants.

BECCS deployment reduces the MEP in 2050 by 50%, relative to the *No NETs* and *DACS Only* scenarios.

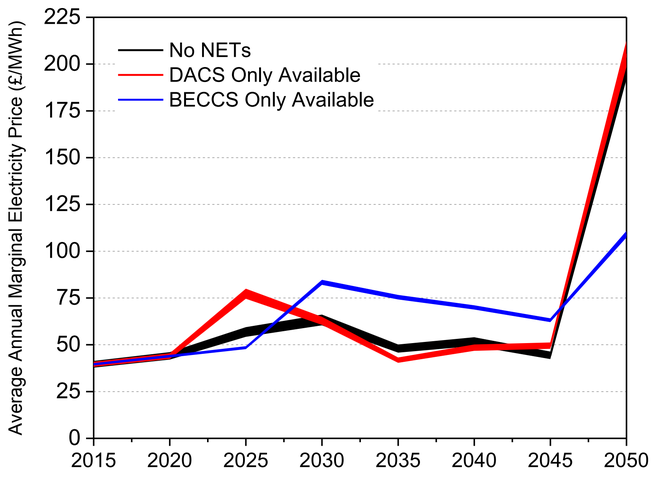

Figure 3: Average annual marginal electricity prices from 2015 to 2050

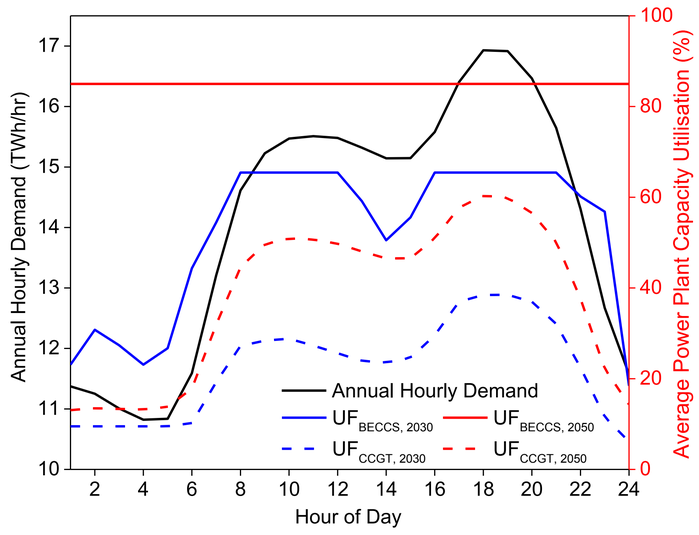

Figure 4: Hourly utilisation factor of BECCS and CCGT plants

What service(s) is BECCS providing to the system?

In 2030, BECCS is observed to exhibit load-following behaviour. As the emissions target becomes more stringent towards 2050, BECCS is operating at its maximum output.

BECCS is therefore providing offset for CCGT emissions initially but transitions to maximum CO_2 removal.

Value Transfer: a route to NETs commercialisation?

NETs allow for the increased utilisation of CO_2 emitting plants, especially CCGTs. CCGT revenues were seen to increase with NETs deployment, therefore NETs accrue value to CCGTs. Allowing some of this value to accrue to NETs could potentially reduce the public burden of delivering negative emissions.

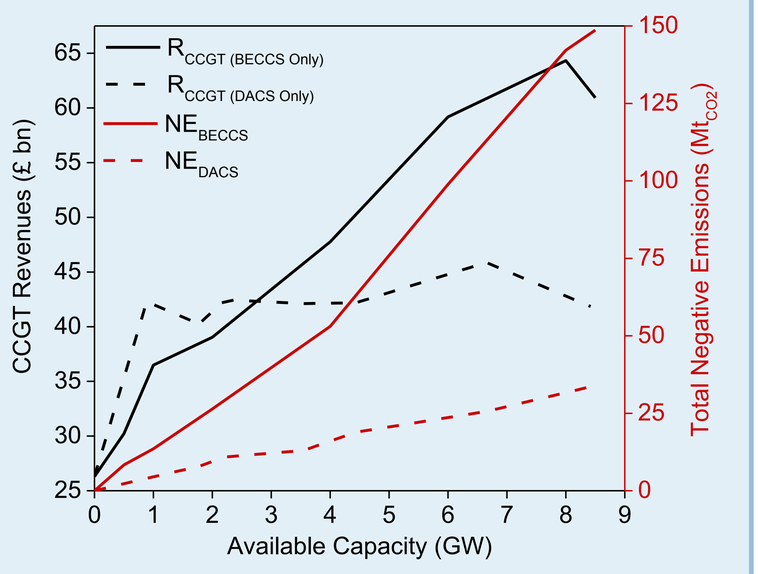

Figure 5: Variation in CCGT revenues & negative emissions deployed with NETs capacity installed

Focus for innovation

Both DACS and BECCS were made available for deployment to meet a 50 Mt_{CO2}/y negative emissions target by 2050. We observe that DACS is uncompetitive with BECCS unless DACS CAPEX falls by a factor of 10 or greater.

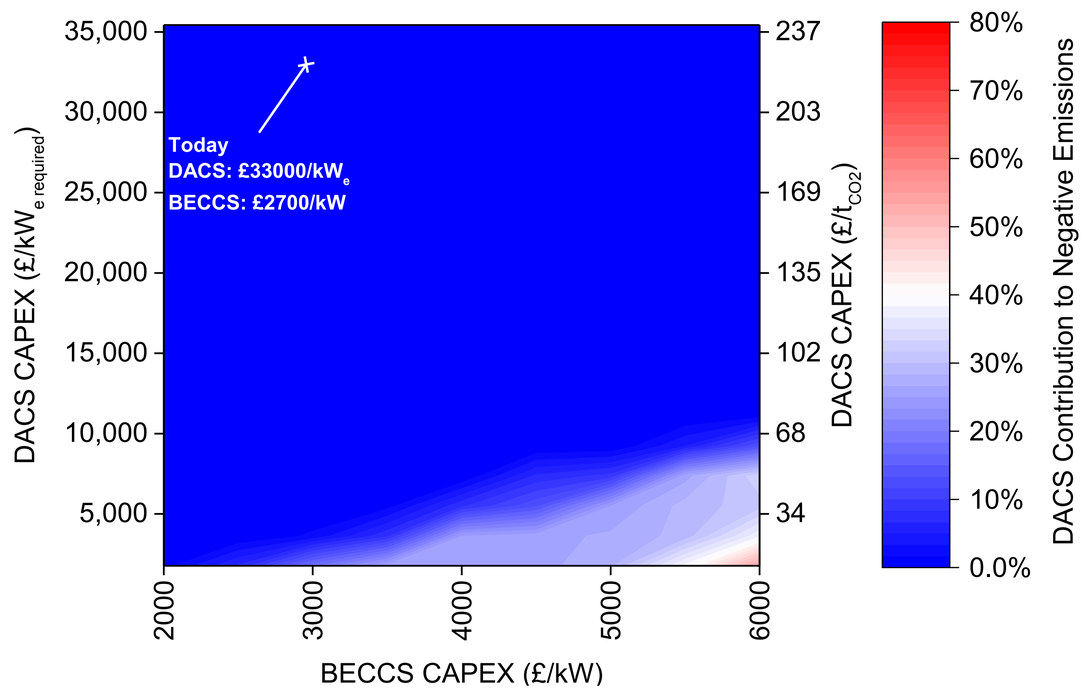

Figure 6: Contribution of DACS to meeting 50 Mt_{CO2}/yr negative emissions target by 2050, at different BECCS and DACS CAPEX

REFERENCES

[1] C. F. Heuberger, *et al.*, *Computers & Chemical Engineering*, 2017, **107**, 247–256.

[2] H. A. Daggash, *et al.*, *submitted*.