Optimal Deployment of Bioenergy with CCS (BECCS) in the UK

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Abstract

Bio-energy with carbon capture and storage (BECCS) is a key negative emissions technology that has the potential to substantially reduce atmospheric CO\textsubscript{2} concentration and limit global warming to below 2°C. Among the available negative emission technologies, BECCS is reported to produce 50TWh/yr of power generation with \(-47\) Mt CO\textsubscript{2}e in 2050 by the Committee on Climate Change in the UK. BECCS is challenged by its emissions from the biomass supply chain, including cultivation, harvesting, transportation and processing. An important factor when considering the deployment of BECCS on a large scale, is to ensure BECCS has a negative carbon balance of the biomass supply chain. Furthermore, land competition with agriculture land is another concern. Meanwhile, recovering energy from waste wood and municipal solid waste (MSW) is promising to generate electricity and reduce CO\textsubscript{2} emissions, while saving land usage and biomass fuel importation.

This study optimises the design of BECCS deployment in the UK with a mixed integer linear programming (MILP) model. The fuels considered for this work include: MSW derived “power fuel”, waste wood (grade A and B), indigenous miscanthus, indigenous poplar, and imported pine pellets from the US. Geographic locations of possible biomass land are enclosed while avoiding using agriculture land. Emissions and costs along the supply chain are included.

Three UK scenarios for BECCS are presented across three decades between 2025–2055:

1. indigenous virgin biomass only;
2. indigenous virgin biomass + imports;
3. indigenous virgin biomass + waste wood + MSW + imports.

The key decision variables include raw material supply, pellet production and electricity generation rates, flows of materials between cells and imported pellets and fuel burn rates. The model provides insight into the spatial-temporal effects of decision making on BECCS power plant supply chain.

BECCS deployment pathways have been studied, deploying BECCS quickly or slowly results in different average emission costs. The BECCS supply chain optimisation results indicate that MSW and waste wood are consumed as the basic material supplies, which can provide low-cost alternative to imported biomass. By using MSW and waste wood, the total system cost would be reduced up to 20%. Miscanthus is preferred over poplar as the virgin biomass supply and the farms are mostly located in the southwest of the UK, which has higher production yield and land availability. The selection of BECCS plant locations tends to be near cities where waste wood and MSW are more readily available. Based on the sensitivity analysis, power plant efficiency has more influence on the electricity prices than embodied emissions, MSW availability, farmland availability and power plant CAPEX learning rate.