# Climate repair and mitigation value of BECCS pathways

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# Outline

I. BECCS as a CDR technology

- Carbon and cost balance of BECCS pathways
- Impact of different supply chain configurations
- Barrier to scale

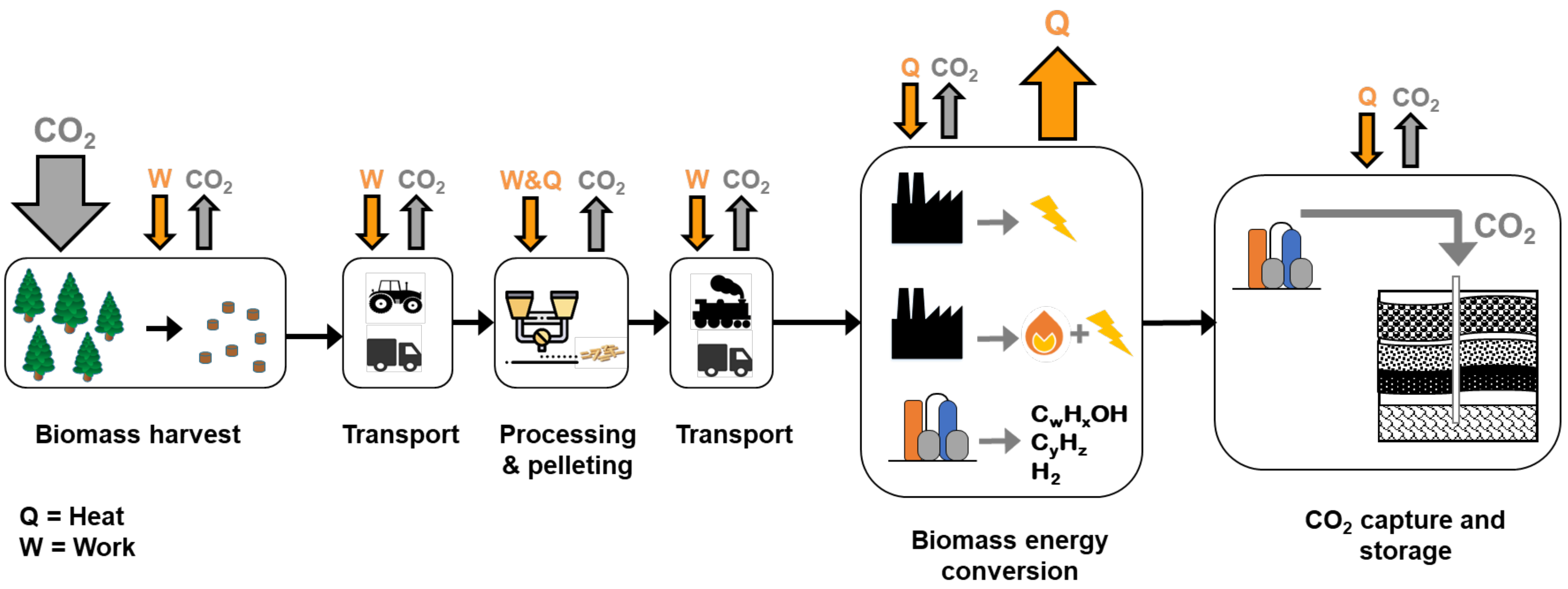
II. Case study: low carbon steel production with BECCS

III. Key ecosystems impacts of BECCS deployment

IV. Take home messages

# BECCS pathways: $CO_2$ avoidance and removal

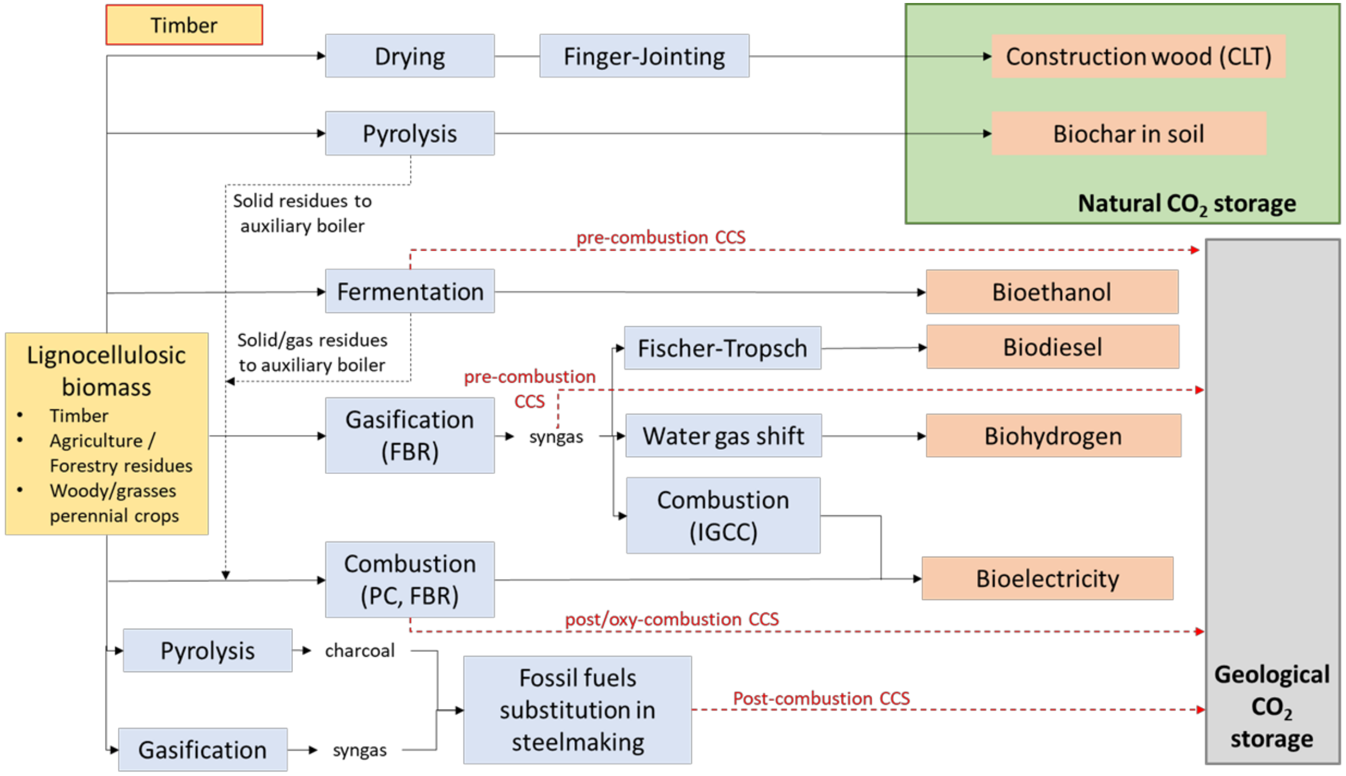
# Bioenergy with carbon capture and storage (BECCS)




Net transfer of $CO_2$ from the atmosphere into the biomass over the lifetime of its growth. The biomass is harvested sustainably, processed and/or pelleted before being transported to a biomass conversion process. The $CO_2$ arising from the conversion step is captured and permanently stored.

The amount of $CO_2$ sequestered geologically ***must exceed*** the amount emitted over the supply chain in order to achieve a net removal of $CO_2$ from the atmosphere.

# BECCS and other biomass based $CO_2$ removal pathways



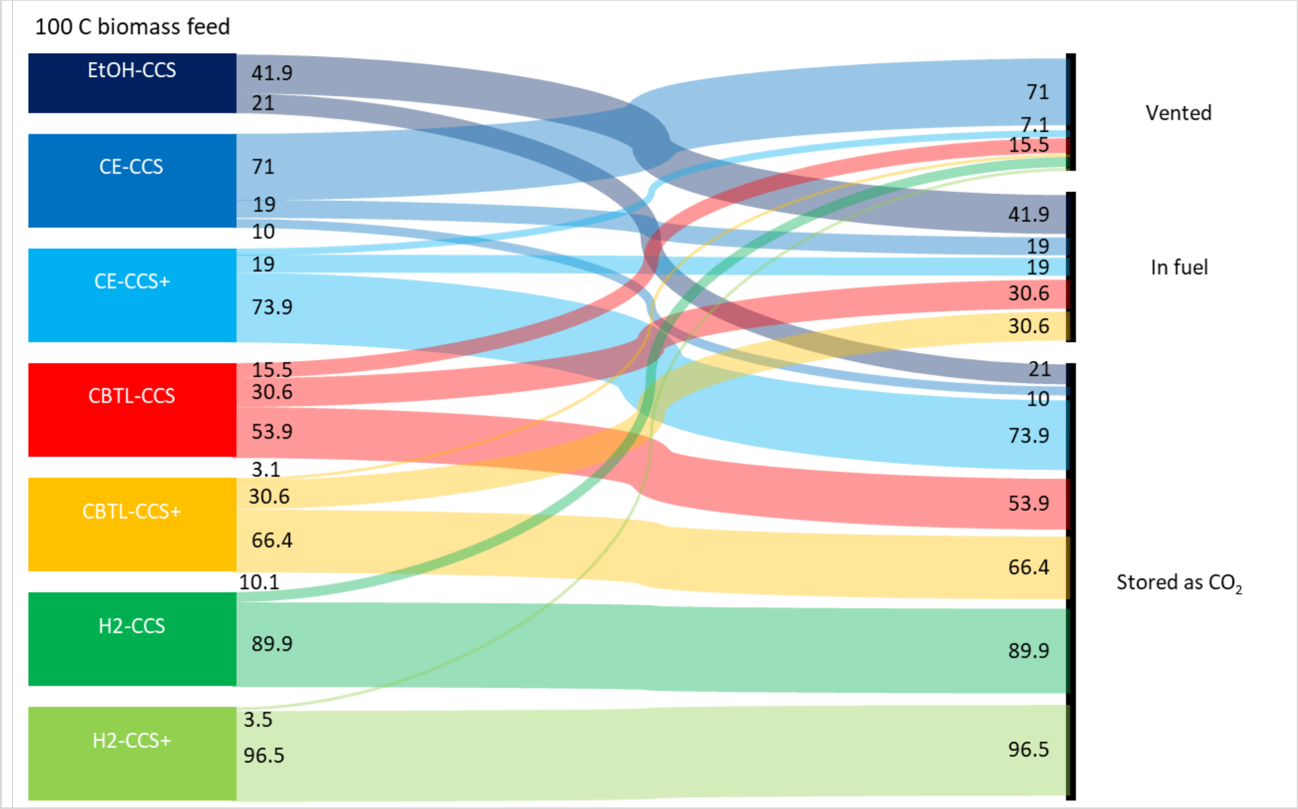

Each biomass feedstock type will be more suitable for a given conversion pathway

Each pathway generates a different product. Those generating a carbon based fuel will emit $CO_2$ back into the atmosphere.

The net $CO_2$ removal potential of each pathway will depend on the lifecycle carbon intensity (i.e. carbon footprint) of the biomass, energy efficiency and the $CO_2$ capture rate.

BECCS sustainability is also influenced by other factors such as the land and water requirements, biomass yield, and the energy/carbon/water balance of the biomass supply chain (harvesting, processing, and transport).

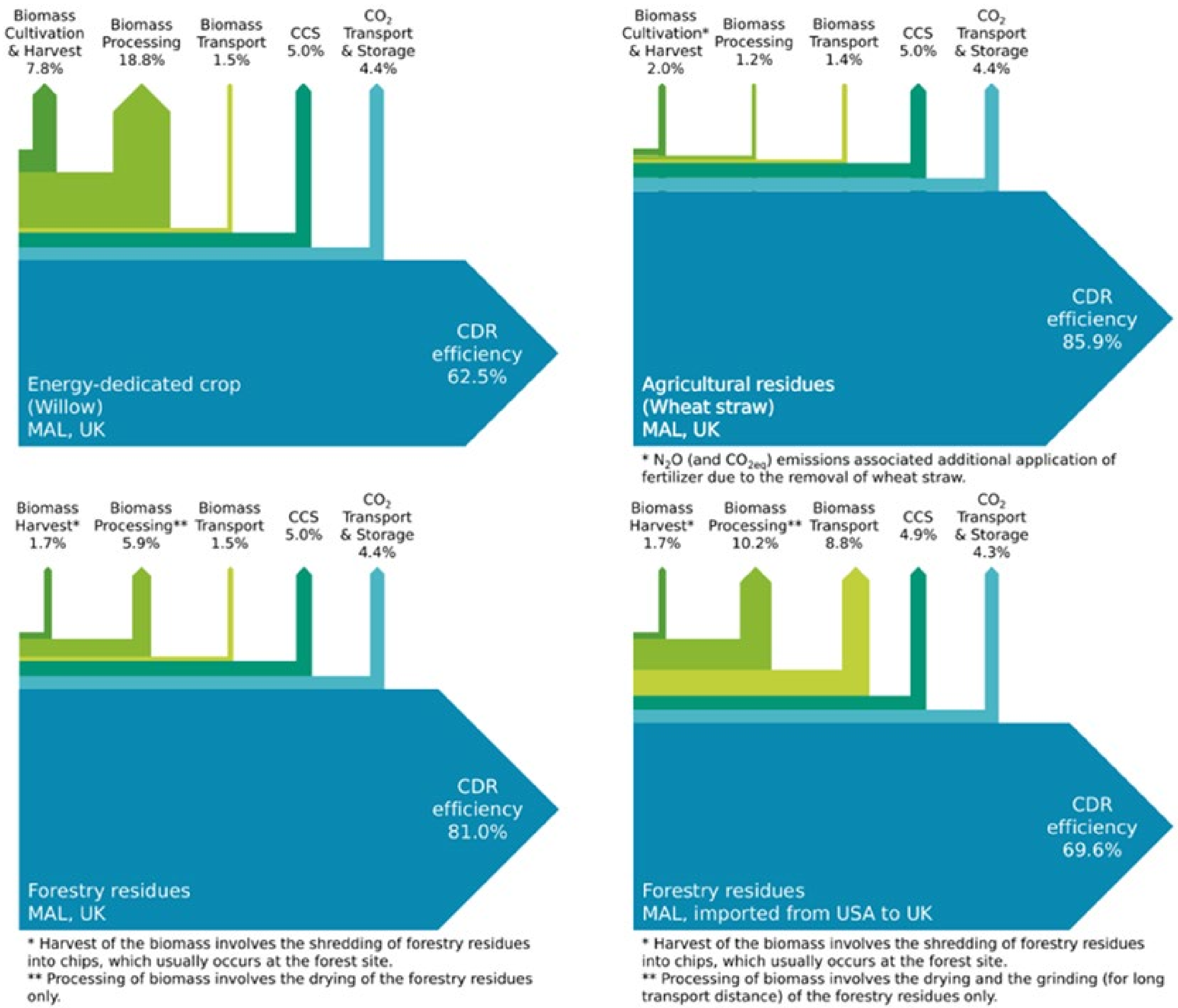
# BECCS to fuels: process carbon balance




Ethanol configurations with base case CCS design have the smallest $CO_2$ capture rates as most of the biomass carbon will end up in the by-products, either distiller's dried grain solids (from corn) or combustion feedstock (from lignocellulosic biomass).

For FT configurations, base case CCS designs already capture most of the available $CO_2$ from the process and the maximal design will only contribute a small addition (combustion of char) to the total capture.

# CDR efficiency of BECCS supply chains



# Comparison of BECCS & Biochar pathways

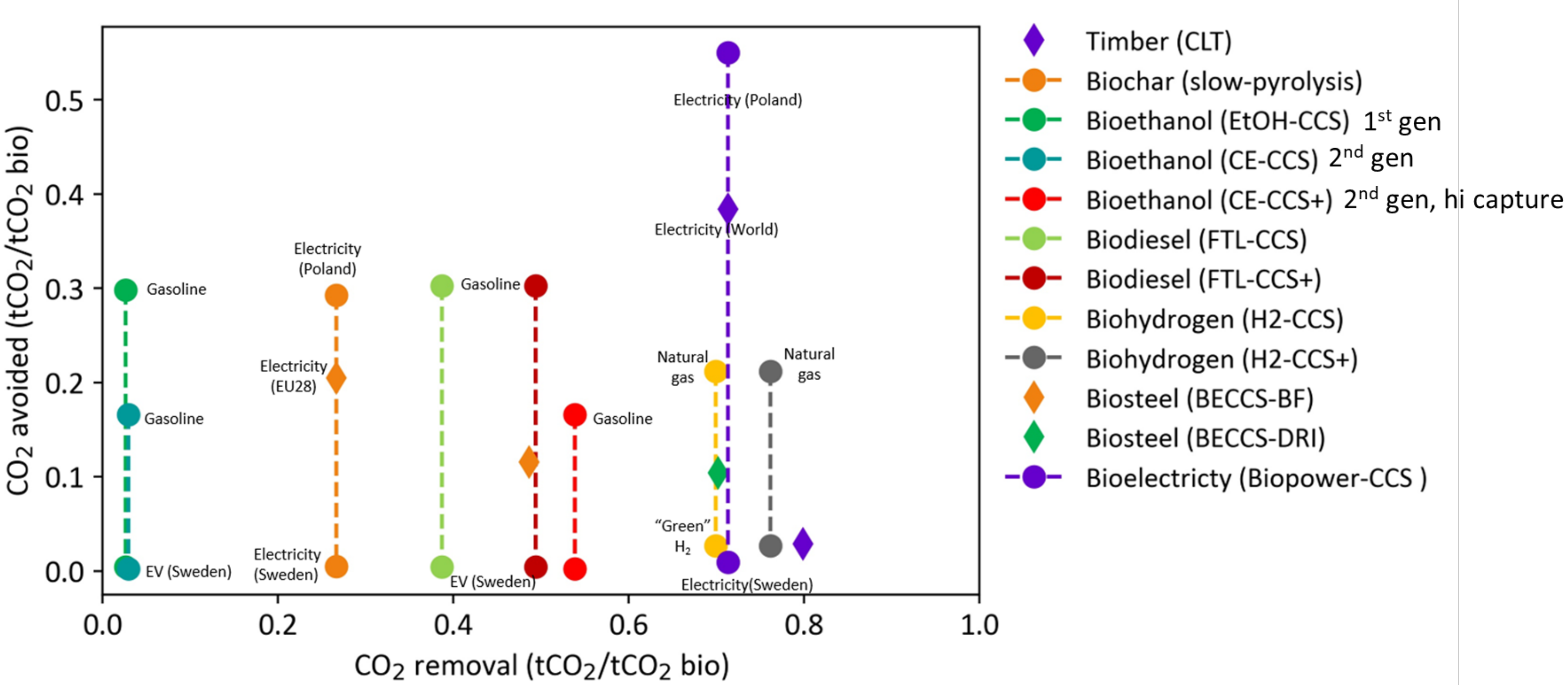



Figure from: Patrizio, P., Fajardy, M., Bui, M. & Mac Dowell, N. (2021). CO2 mitigation or removal, the optimal uses of biomass in energy systems decarbonization. iScience, 102765.

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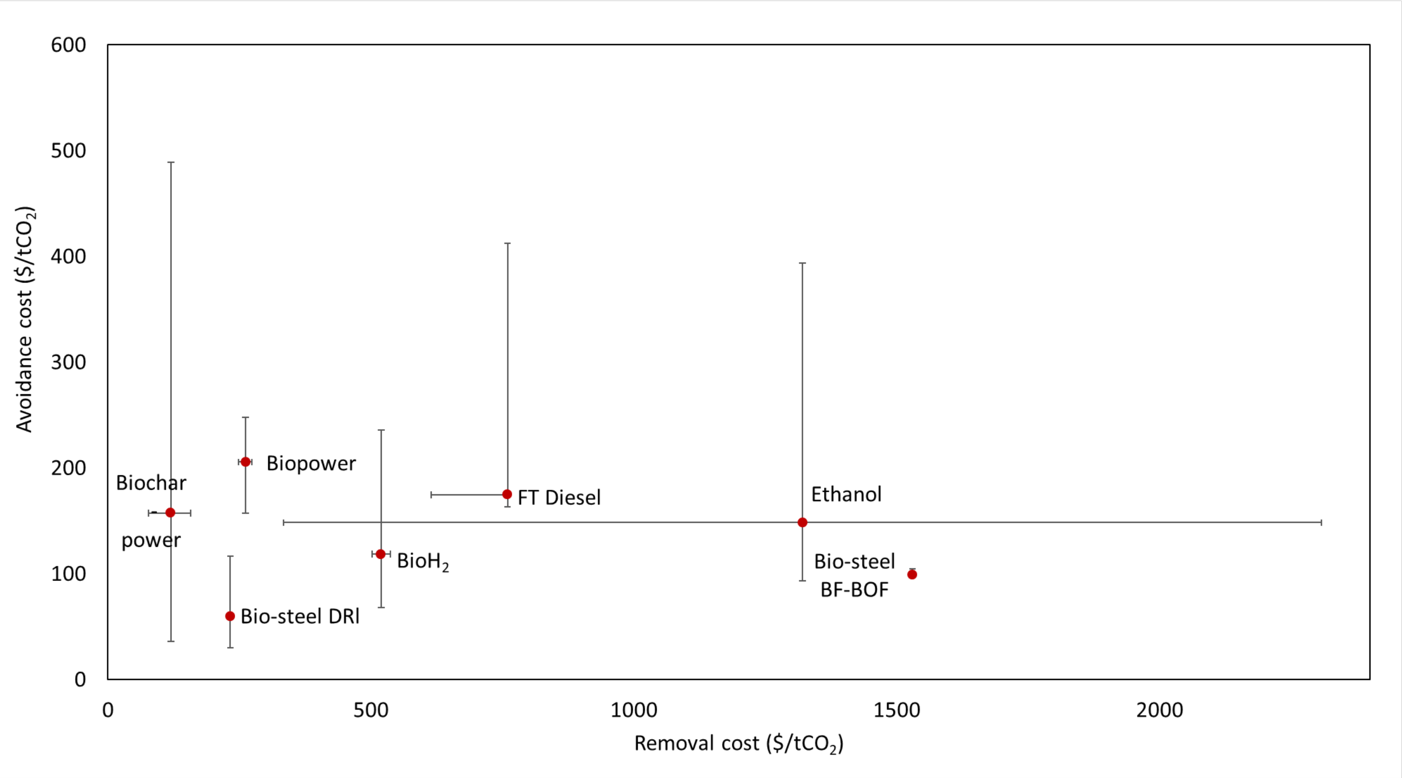



Figure shows $CO_2$ removal & $CO_2$ avoidance costs for selected biomass-based products (average shown as red dots).

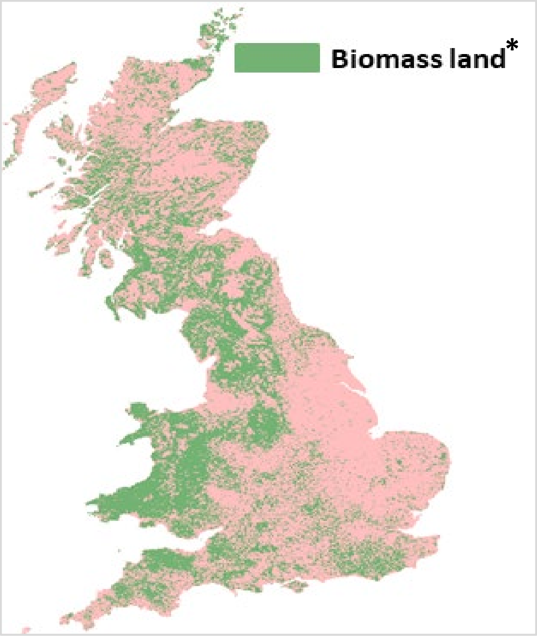
For the analysis, a cost of $30/t$CO_2$ was assigned for transport and geological storage (i.e. BECCS-power, iron & steel and biofuels with CCS).

The variability in avoidance costs can be attributed to the different counterfactual scenarios used in this study.

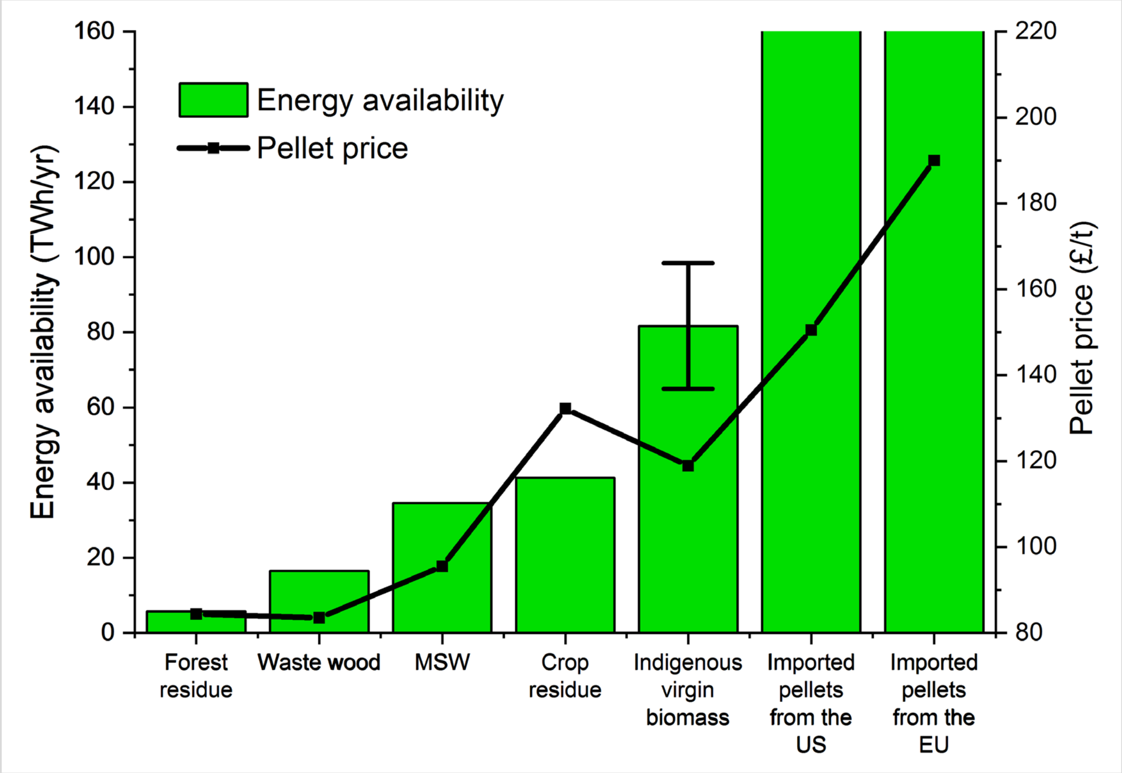
Removal cost variation is associated with the range of $CO_2$ capture rates considered for each pathway. For the biochar slow-pyrolysis process, $CO_2$ removal varies with feedstock type.

Figure from: Patrizio, P., Fajardy, M., Bui, M. & Mac Dowell, N. (2021). CO2 mitigation or removal, the optimal uses of biomass in energy systems decarbonization. iScience, 102765.

# Barriers to scale: Land and biomass availability




* Excludes national parks, bodies of water residential areas, cities, agricultural land, pasture for grazing




The cost of biomass feedstock will vary across the different types. Once biomass is harvested/collected, different steps will influence the cost of the biomass fuel, e.g., degree of drying, processing, transport distance.

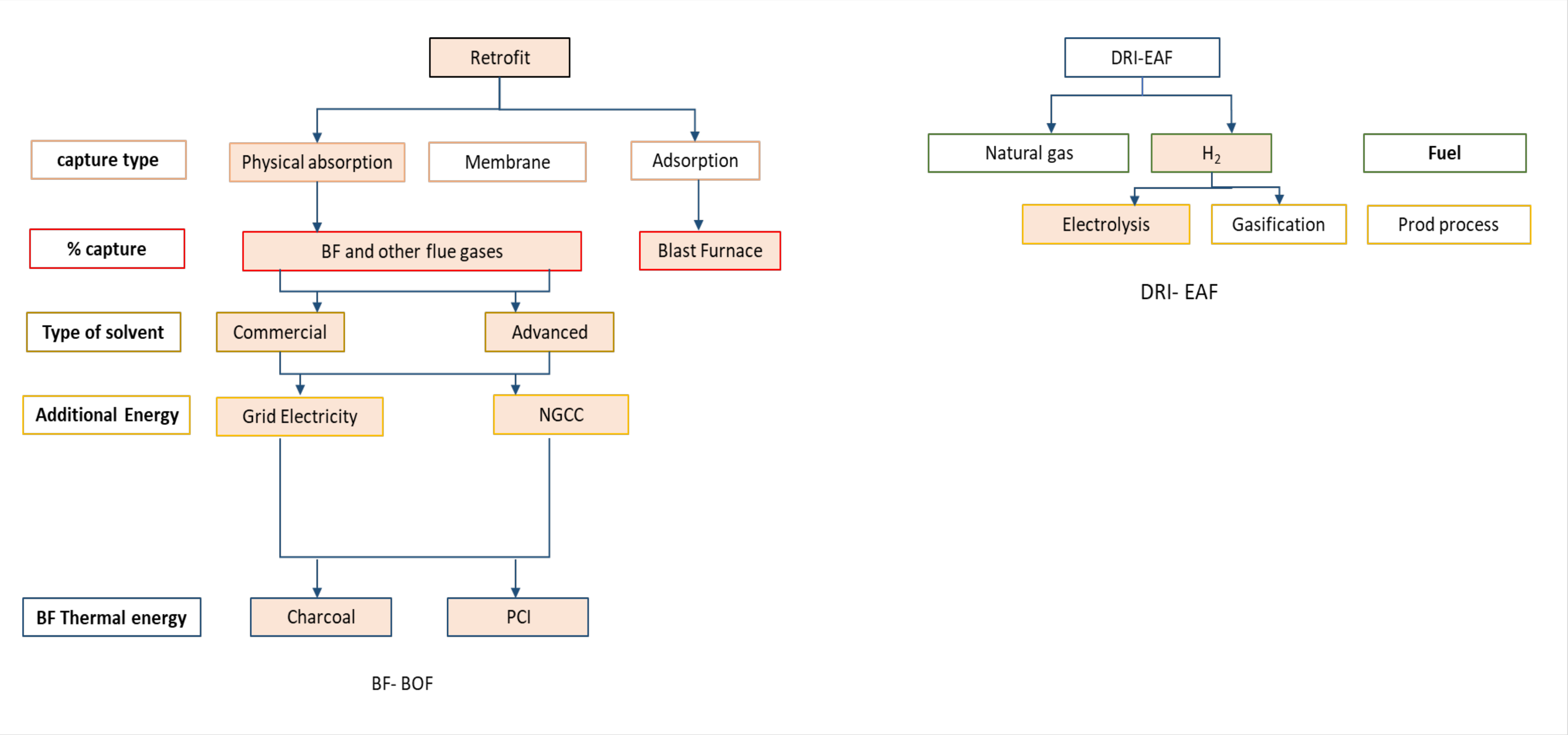
The total UK indigenous biomass could provide up to 56 Mt $CO_2$ removal per year. Possible opportunity to utilise secondary sources of biomass (e.g., MSW, forest or agricultural residues) to supplement primary sources (i.e. dedicated bioenergy crops) WHICH tend to be lower cost and more sustainable, however, availability will be limited.

Note: The use of waste biomass such as MSW in power plants is not permitted under current UK regulations. Waste biomass may be used in other biomass conversion pathways.

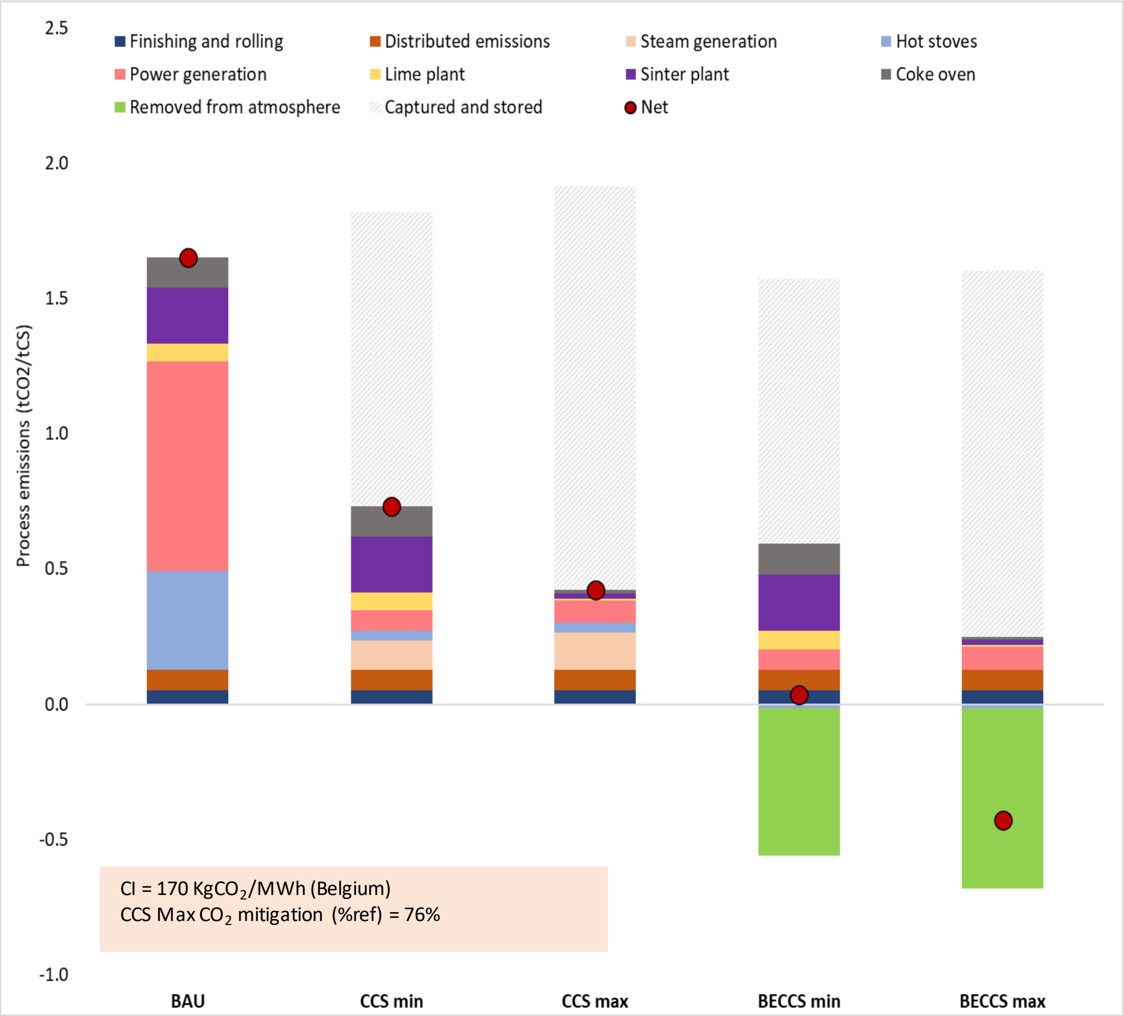
Zhang, D., Bui, M., Fajardy, M., Patrizio, P., Kraxner, F. & Mac Dowell, N. (2020). Unlocking the potential of BECCS with indigenous sources of biomass at a national scale. Sustainable Energy & Fuels, 4 (1), 226-253.

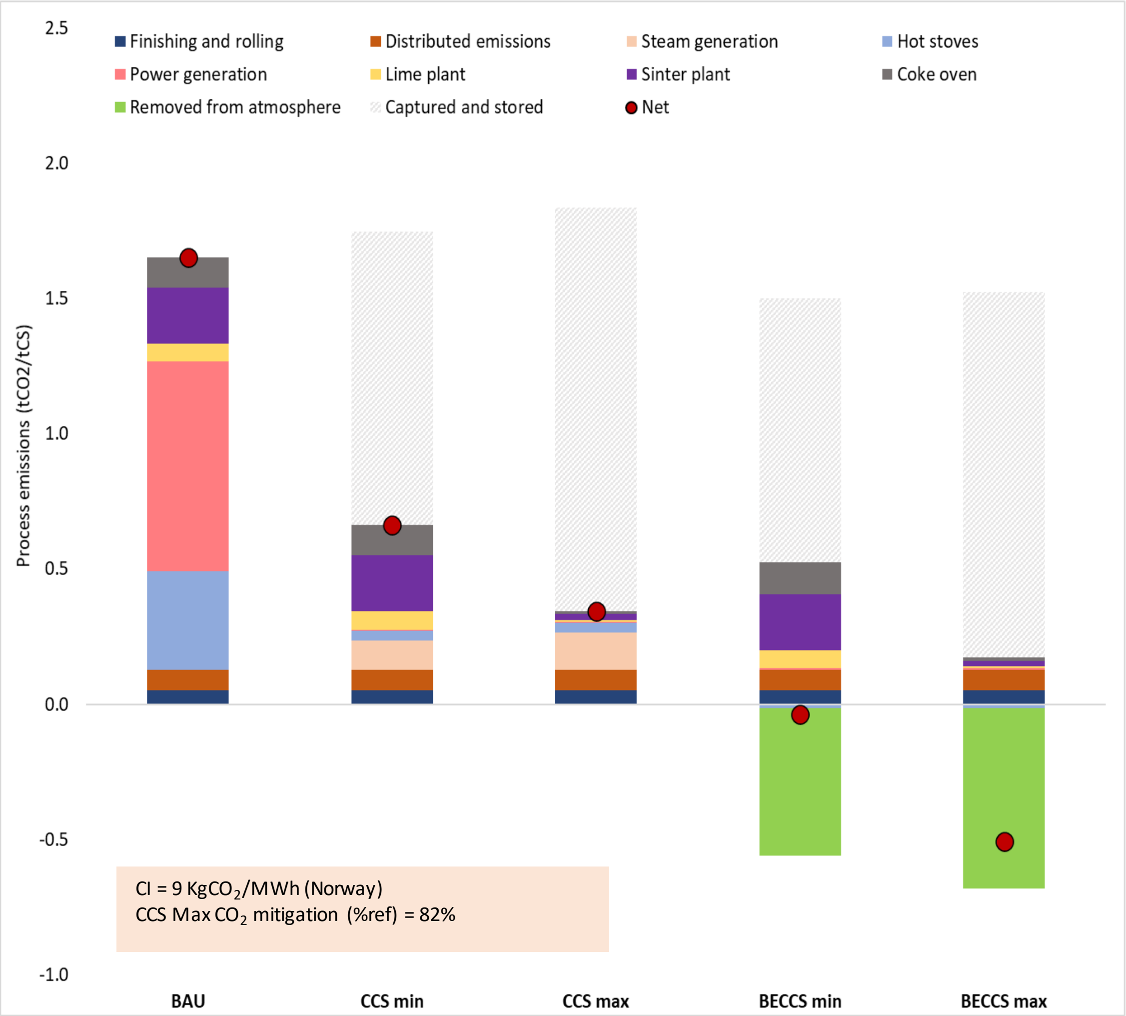
# BECCS in industry: Iron and steel sector

# Low-carbon steel: the role of BECCS

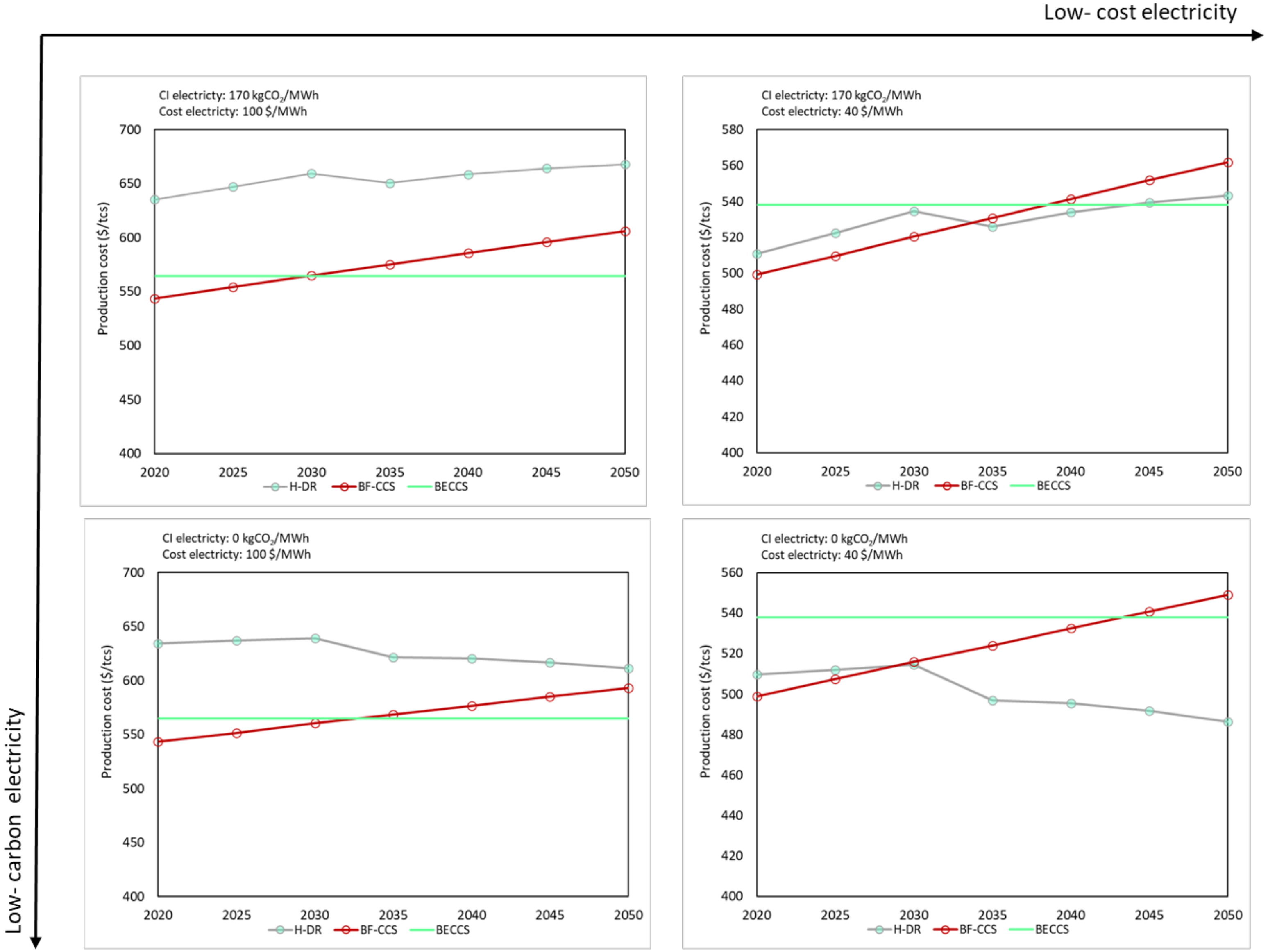


# Emission breakdown: Sensitivity to CI of electricity



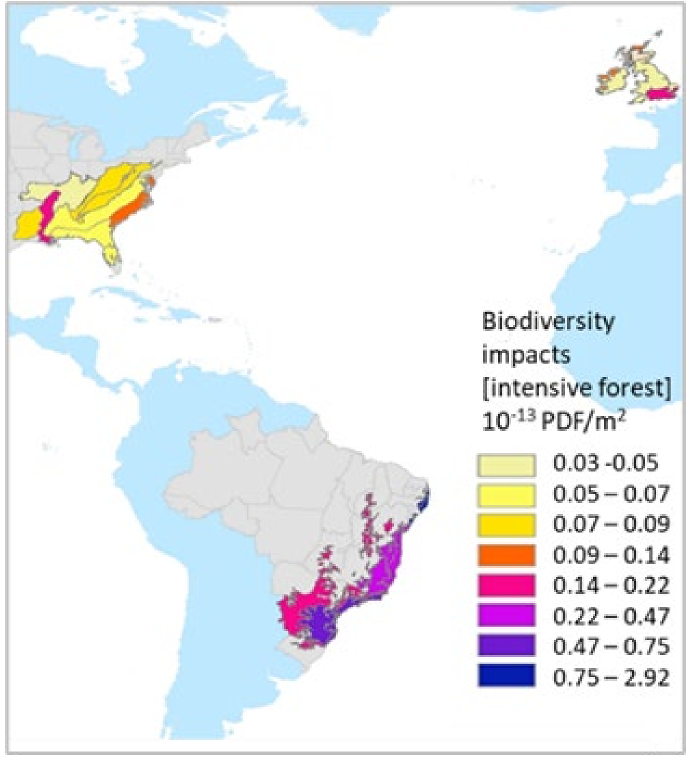



# BECCS competitiveness : impact of low carbon and low cost electricity

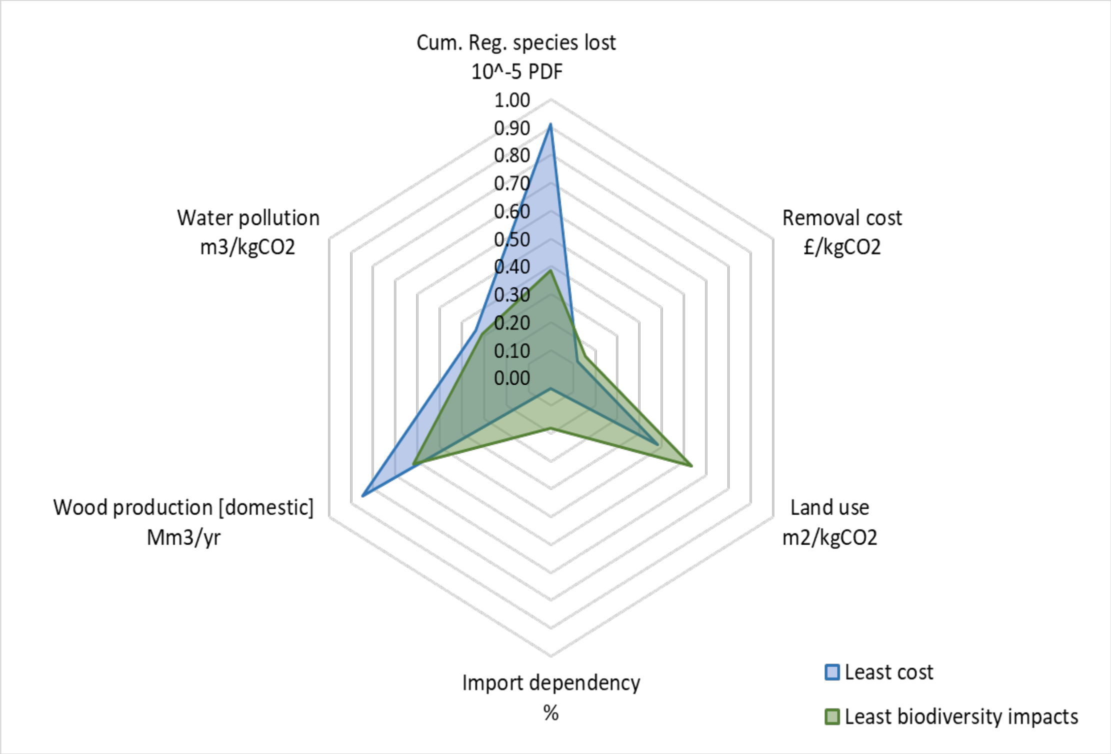


# Trade-offs with ecosystems services

# Ecosystems and energy security trade-offs of BECCS deployment




Biodiversity impacts of forest plantations within different ecoregions in the UK, Brazil and US. Adapted from Chaudhary et al. 2015




Ecosystems and energy security trade-offs associated with the UK 2050 removal targets (BECCS: 50 $MtCO_2$ $y^{-1}$) under a cost minimization scenario (blue) vs a strategy that prioritize biodiversity conservation (green)

# Take home messages

- Each BECCS pathways entails a specific resource footprint (land, water, nutrients). Given the scale at which BECCS would need to deployed for Net Zero, it is important to deploy this technology cost and resource efficiently.

- Whilst the climate repair value of BECCS is contingent to its supply chain configuration, the mitigation potential (i.e. $CO_2$ avoidance) of BECCS-derived energy products depends on the counterfactual . As such, it will (hopefully) decrease over time

- Quantifying the impact of a range of biomass procurement strategies across a multiple sustainability indicators will be key for balancing the ecosystems trade-offs (e.g. biodiversity, land and fresh water use) of BECCS deployment