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Exploring the conditions and implications of deploying direct air capture at scale

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► **To cite this version:**

Lucas Desport, Angelo Gurgel, Jennifer Morris, Howard Herzog, Henry Chen, et al.. Exploring the conditions and implications of deploying direct air capture at scale. IAMC 16th Annual Meeting, Nov 2023, Venice, Italy. hal-04298491

HAL Id: hal-04298491

<https://hal.science/hal-04298491>

Submitted on 21 Nov 2023

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EPPA Model

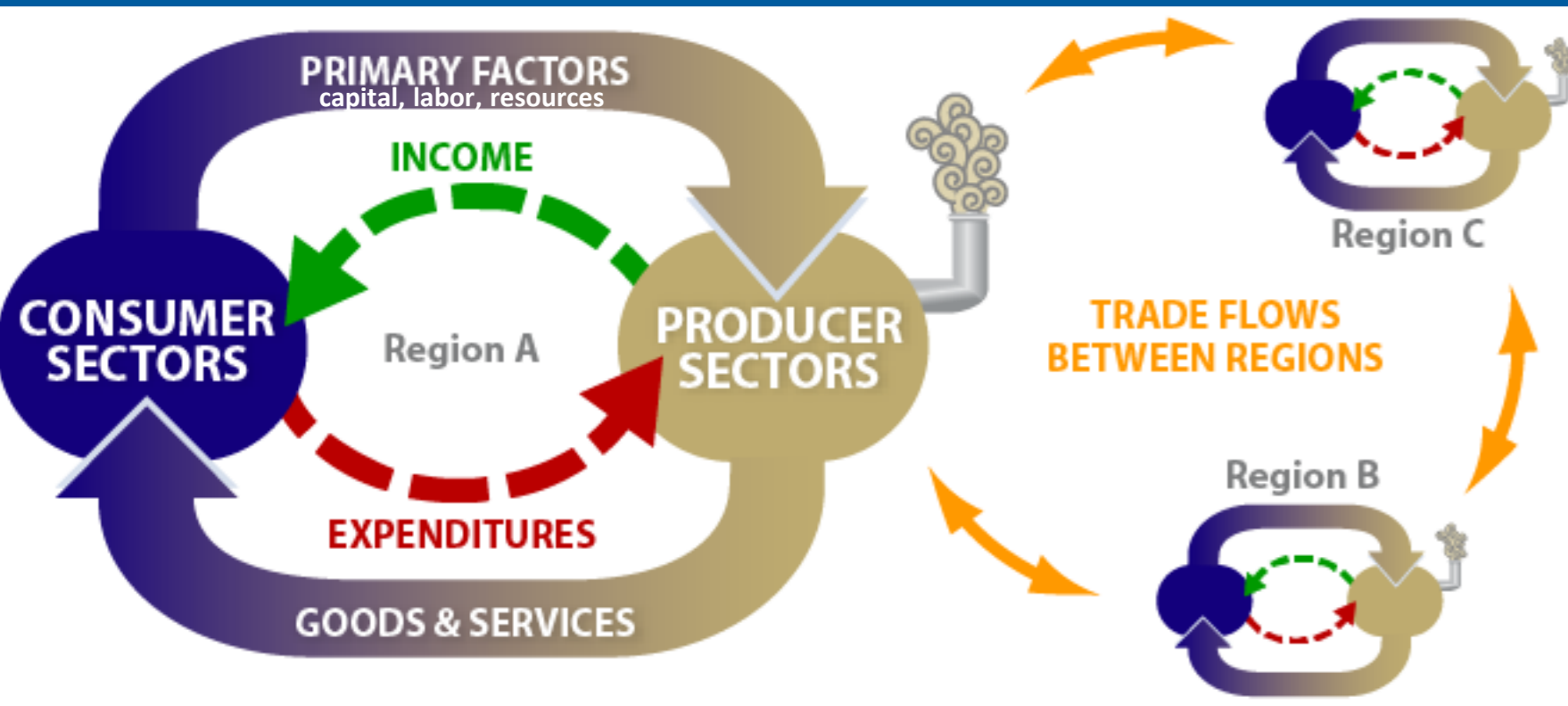
A global multi-region, multi-sector general equilibrium model coupled with an Earth system model.

Major goals: Energy, economy, emissions projections

Model features: Theory-based; Prices are endogenous; International Trade; Inter-industry

Linkages: Distortions (taxes, subsidies, etc.); GDP and Welfare effects

Trade-off: Aggregated representation of regions, sectors, technologies

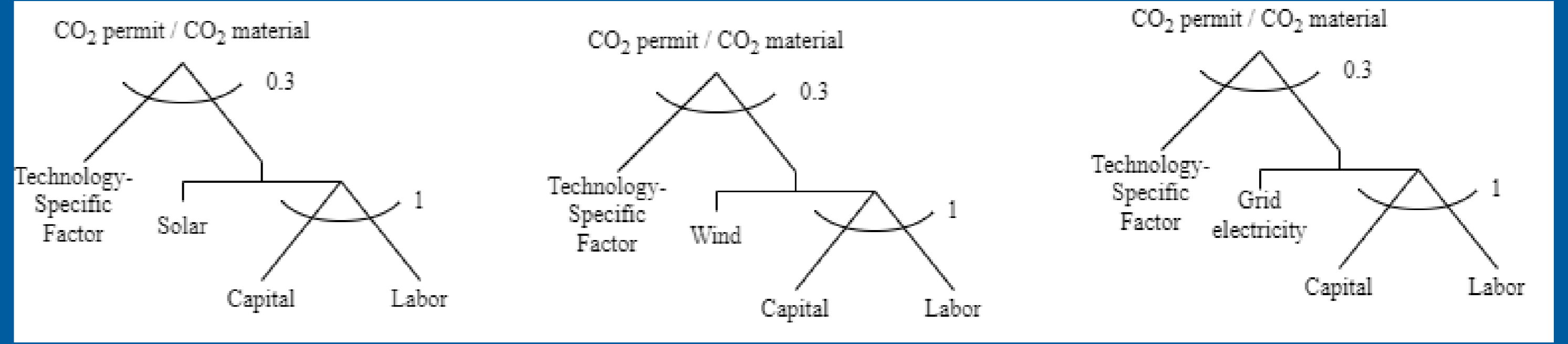


Covers all sectors of economy, with additional detail in energy sectors

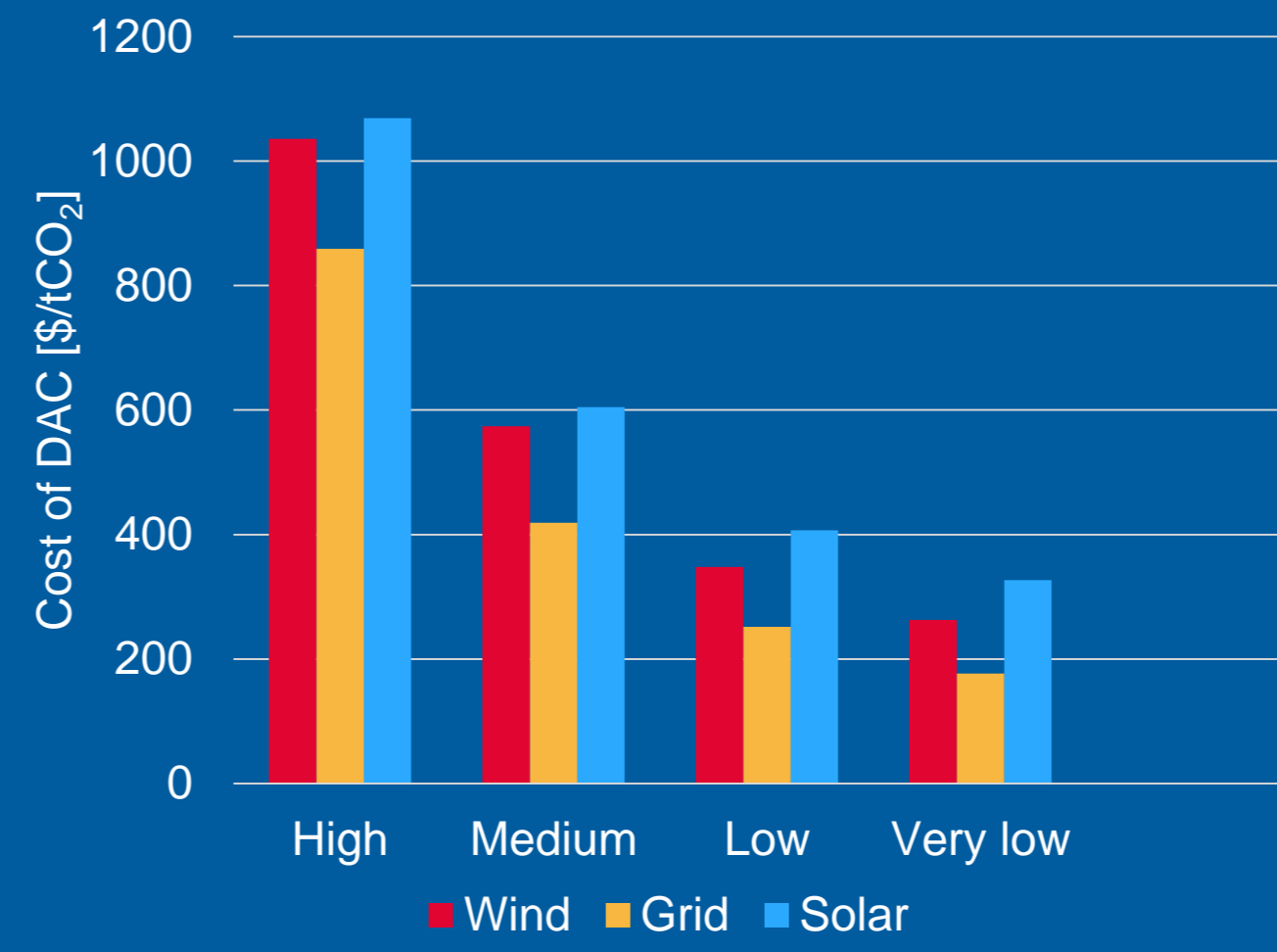
- Non-Energy Sectors**
 - Crops
 - Livestock
 - Forestry
 - Food
- Energy-intensive Industry**
 - Manufacturing
 - Service
 - Commercial Transport
 - Household Transport
- Energy Sectors**
 - Crude Oil
 - Refined Oil
 - Liquid Fuel from Biomass
 - Oil Shale
 - Coal
 - Natural Gas (conv., shale, tight)
 - Electricity
 - Synthetic Gas (from Coal)
- Other**
 - Iron & Steel
 - Cement
 - Chemicals
 - Non-Ferrous Metals + low-carbon options including CCS
 - ICE (gasoline & diesel)
 - Plug-in Electric
 - Battery Electric
 - Hydrogen
 - Synthetic fuels
 - Current Generation
 - Advanced Biofuel
 - Conv. Fossil (coal, gas, oil)
 - Adv. Fossil (NGCC, Adv. Coal)
 - Coal with CCS
 - Coal + Bio Co-firing w/ CCS
 - Gas with CCS
 - Gas with Advanced CCS
 - Nuclear
 - Advanced Nuclear
 - Hydro
 - Solar
 - Wind
 - Renewables with Backup
 - Biomass
 - Biomass with CCS

- Key Inputs**
- Policy Assumptions**
 - Population Growth
 - Capital/Labor Productivity Growth
 - Energy Efficiency Improvements
 - Technology Costs**
 - Rate of Technology Penetration
 - Elasticities of Substitution (related to labor, capital, energy, fuels, etc.)
 - Fossil Fuel Resource Availability
 - Urban Pollutant Initial Inventories & Trends
 - Land Productivity
- Key Outputs**
- GDP
 - Consumption
 - Emissions (GHGs, Air Pollutants)**
 - Primary/Final Energy Use
 - Electricity Generation
 - Technology Mix**
 - Commodity and Factor Prices**
 - Sectoral Output
 - Land Use
- *At global and regional levels*

Modeling of direct air capture (DAC)



Cost of DAC depending on techno-economic assumptions (NASEM, 2019) and energy supply (Herzog, 2022)



DAC is modeled in nested constant elasticity of substitution (CES). For DAC units powered with dedicated wind or solar, we oversize the capacity of these and implement a battery:

$$\text{Capacity of intermittent power} = \frac{\text{Energy consumption} \times \text{DAC capacity}}{8760 \times \text{availability factor}}$$

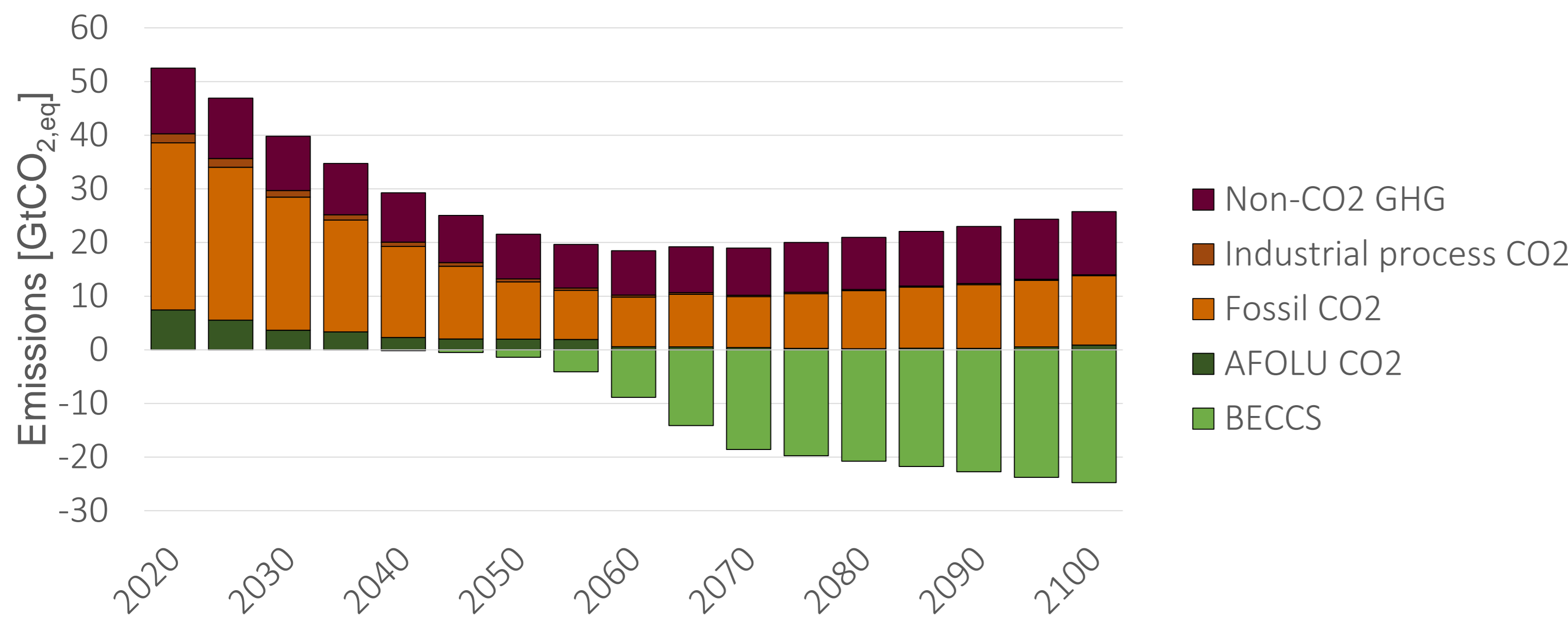
$$\text{Capacity of battery} = \text{Capacity of intermittent power} \times 24 \times (1 - \text{availability factor})$$

The **Technology-Specific Factor (TSF)** limits technology expansion as this factor is limited initially but grows as a function of past investments in the technology, capturing learning, monopoly rents, and adjustment costs.

Results for a scenario targeting net-zero emissions by 2070

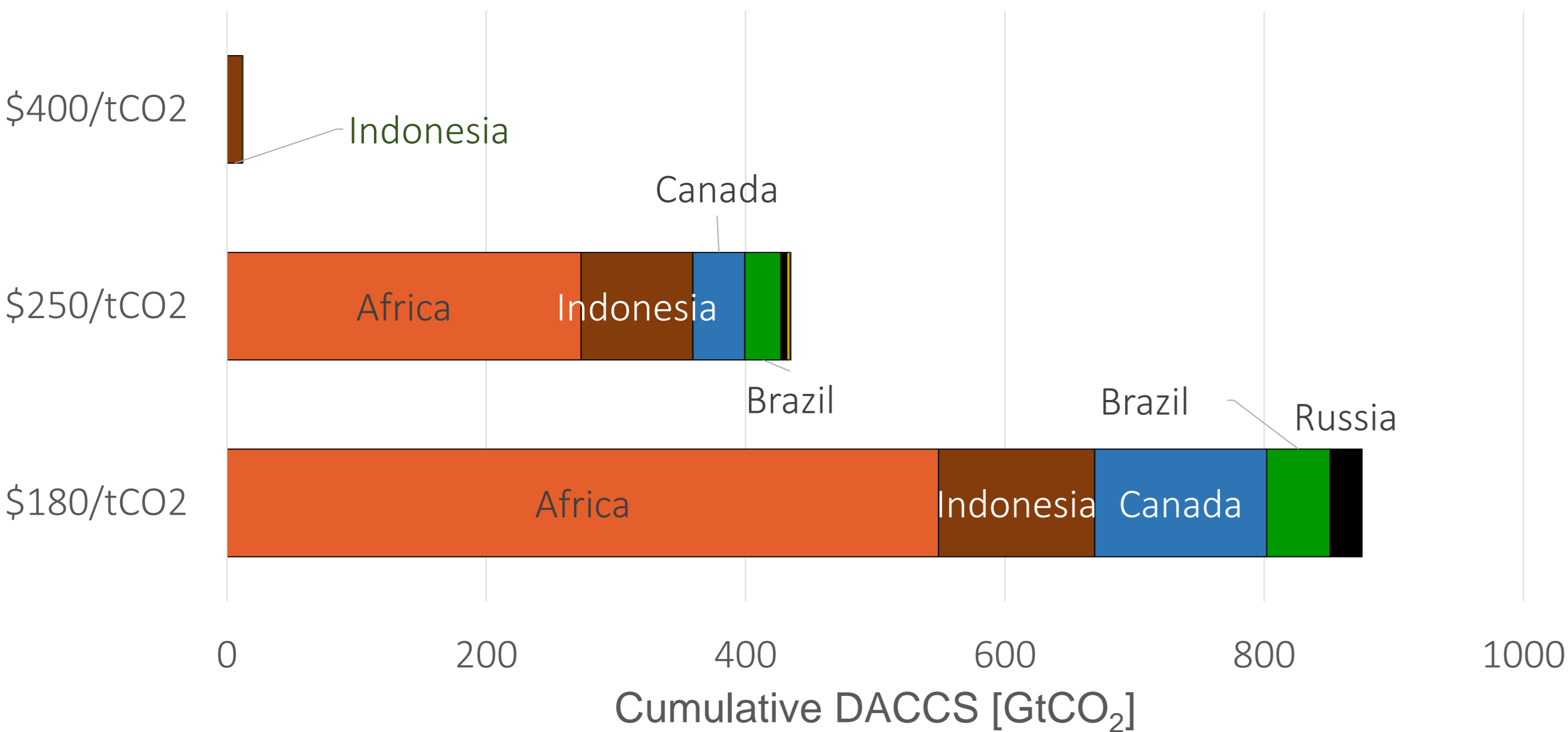
Without DAC, BECCS is deployed massively to reach net-zero by 2070.

Global emissions profile without DAC (or High cost DAC)



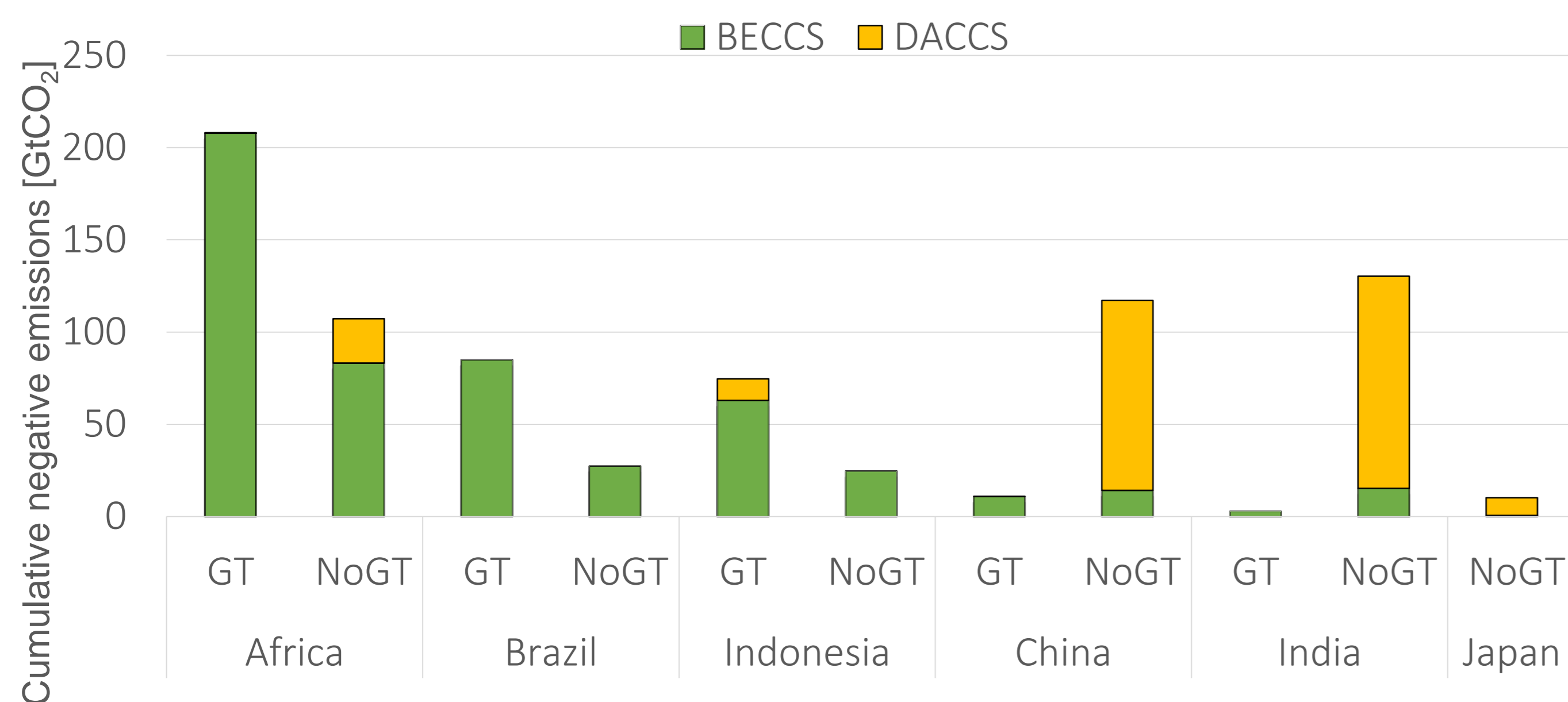
Africa proves to be a massive supplier of negative emissions to offset residual emissions of the rest of the world, as the continent possesses large renewable capacities at low costs.

Cumulative regional negative emissions through DACCS



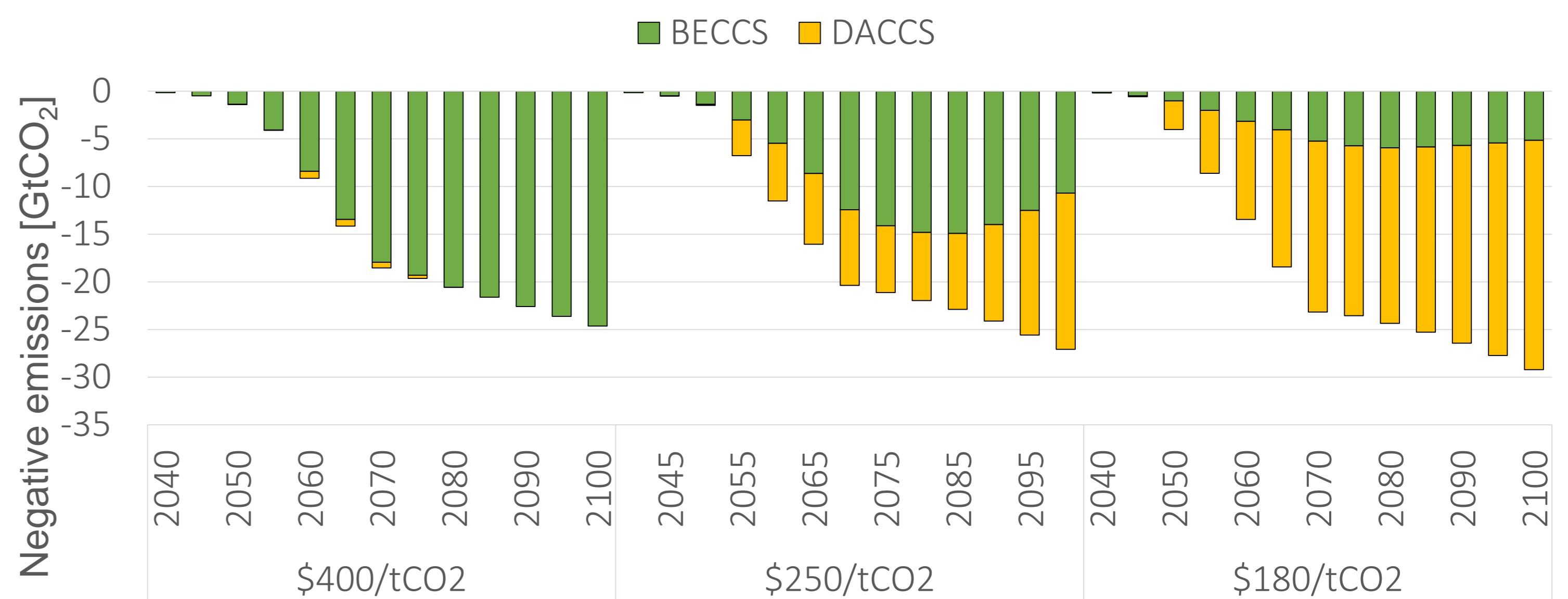
In the absence of an Emission Trading System (ETS), China and India heavily rely on DACCS as they are unable to deploy BECCS due to limited available land.

Cumulative generation of negative emissions in selected countries with GHG trading (GT) and without GHG trading (NoGT) for a Medium Cost DAC (~\$400-600/tCO2)



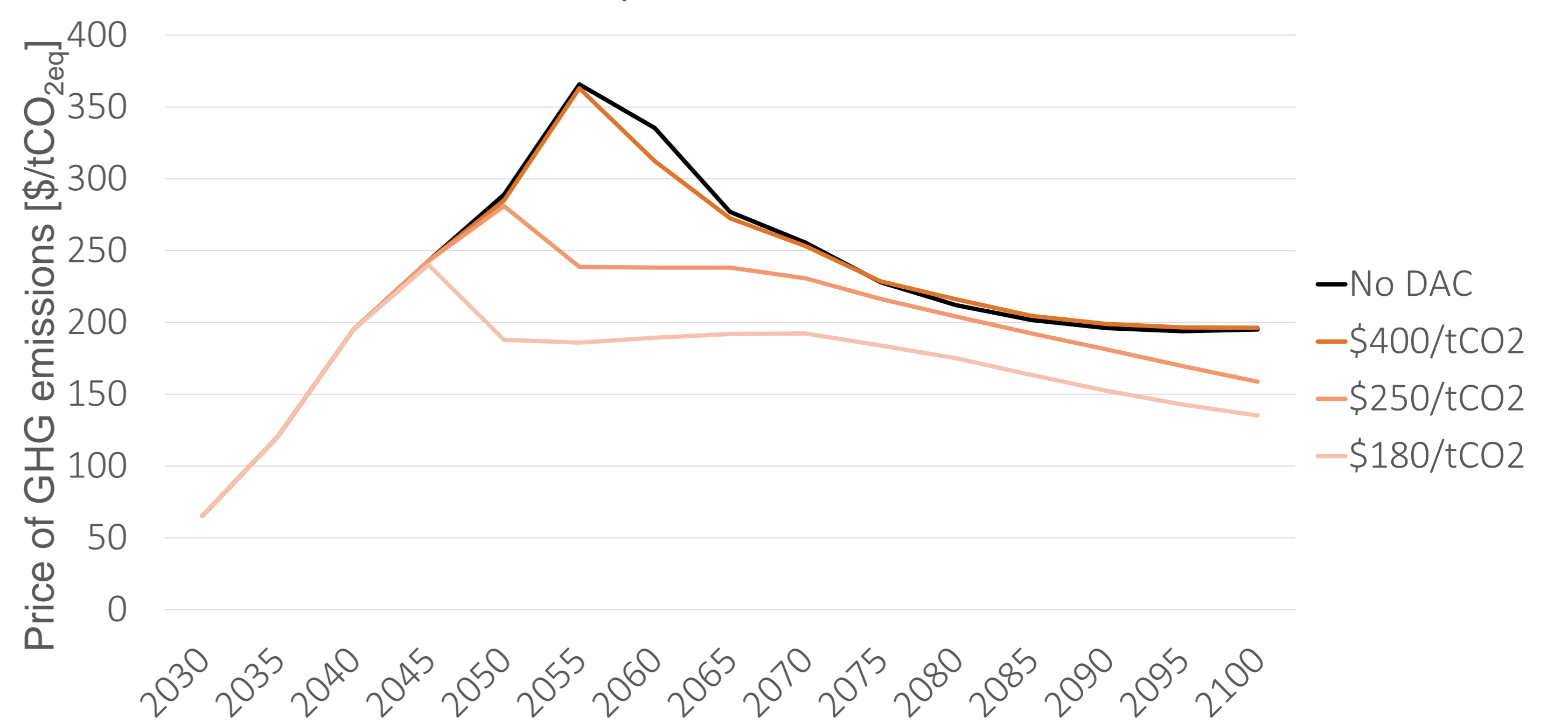
DACCS competes with BECCS for costs below \$380/tCO2. DACCU is never rolled out.

Breakdown of global negative emissions according to DAC cost



Cheap DAC lowers the cost of the transition and gives a positive signal to stakeholders.

Global price of GHG emissions



In the absence of an Emission Trading System (ETS), DACCS drastically reduces the cost of the transition for countries like China, India, Japan or South Korea.

Effect of GHG trading (GT) and no GHG trading (NoGT) on the price of GHG emissions for selected countries with Medium cost of DAC

