



HAL
open science

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

Lucas Desport, Angelo Gurgel, Jennifer Morris, Howard Herzog, Henry Chen, Sandrine Selse, Sergey Paltsev

► **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-04298491v1>

Submitted on 21 Nov 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Lucas Desport^{1,2*}, Angelo Gurgel³, Jennifer Morris³, Howard Herzog³,
Yen-Heng³ Henry Chen³, Sandrine Selosse¹, Sergey Paltsev³

¹ Mines Paris - PSL, CMA - Centre for Applied Mathematics, Rue Claude Daunesse, 06904, Sophia Antipolis, France

² TotalEnergies, OneTech, 2 place Jean Millier, 92078 Paris la Défense, France

³ Massachusetts Institute of Technology, Joint Program on the Science and Policy of Global Change, Cambridge, MA 02139, USA

EPPA Model

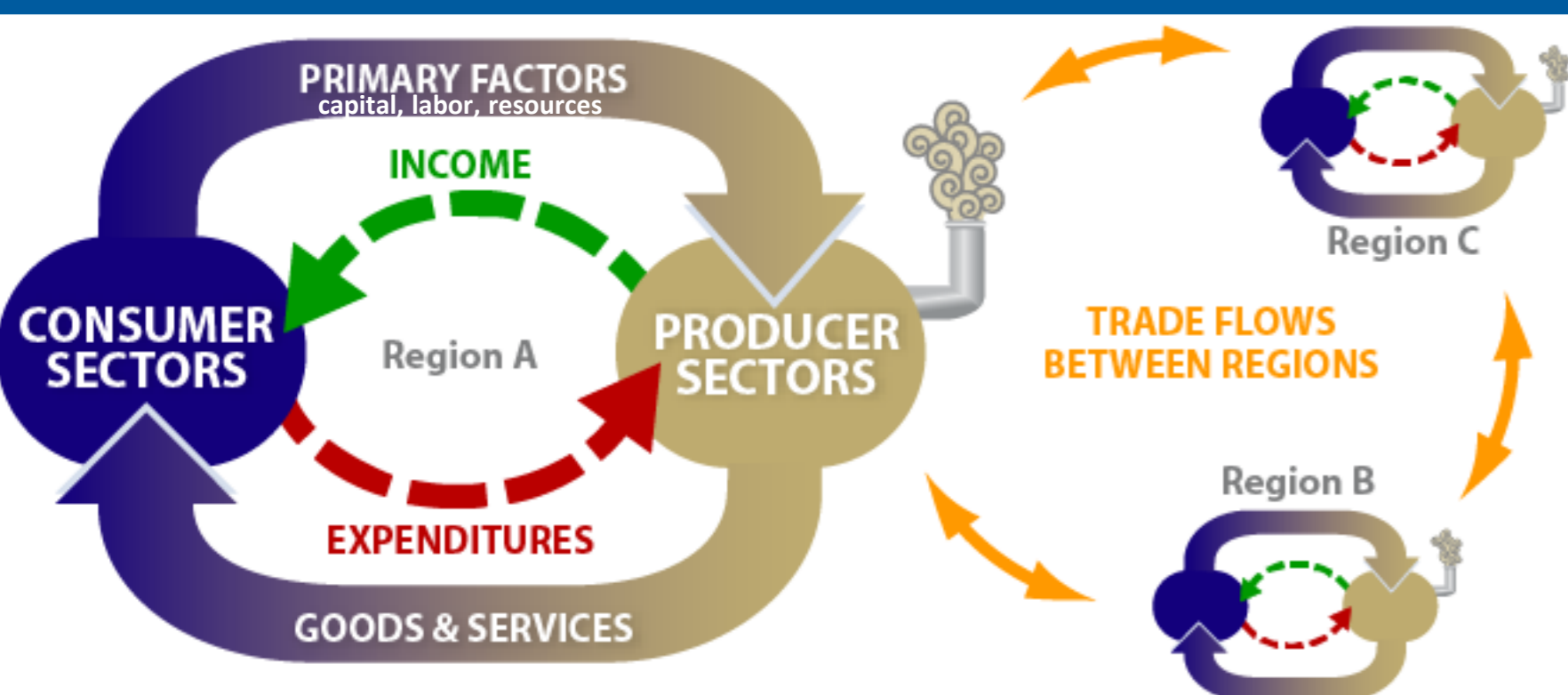
A global multi-region, multi-sector general equilibrium model coupled with an Earth system model.

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

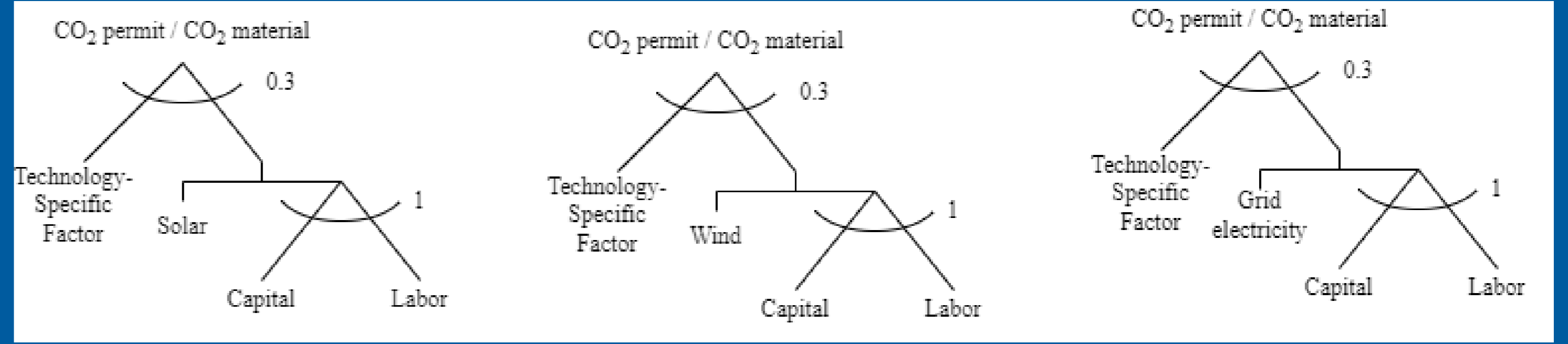


Covers all sectors of economy, with additional detail in energy sectors

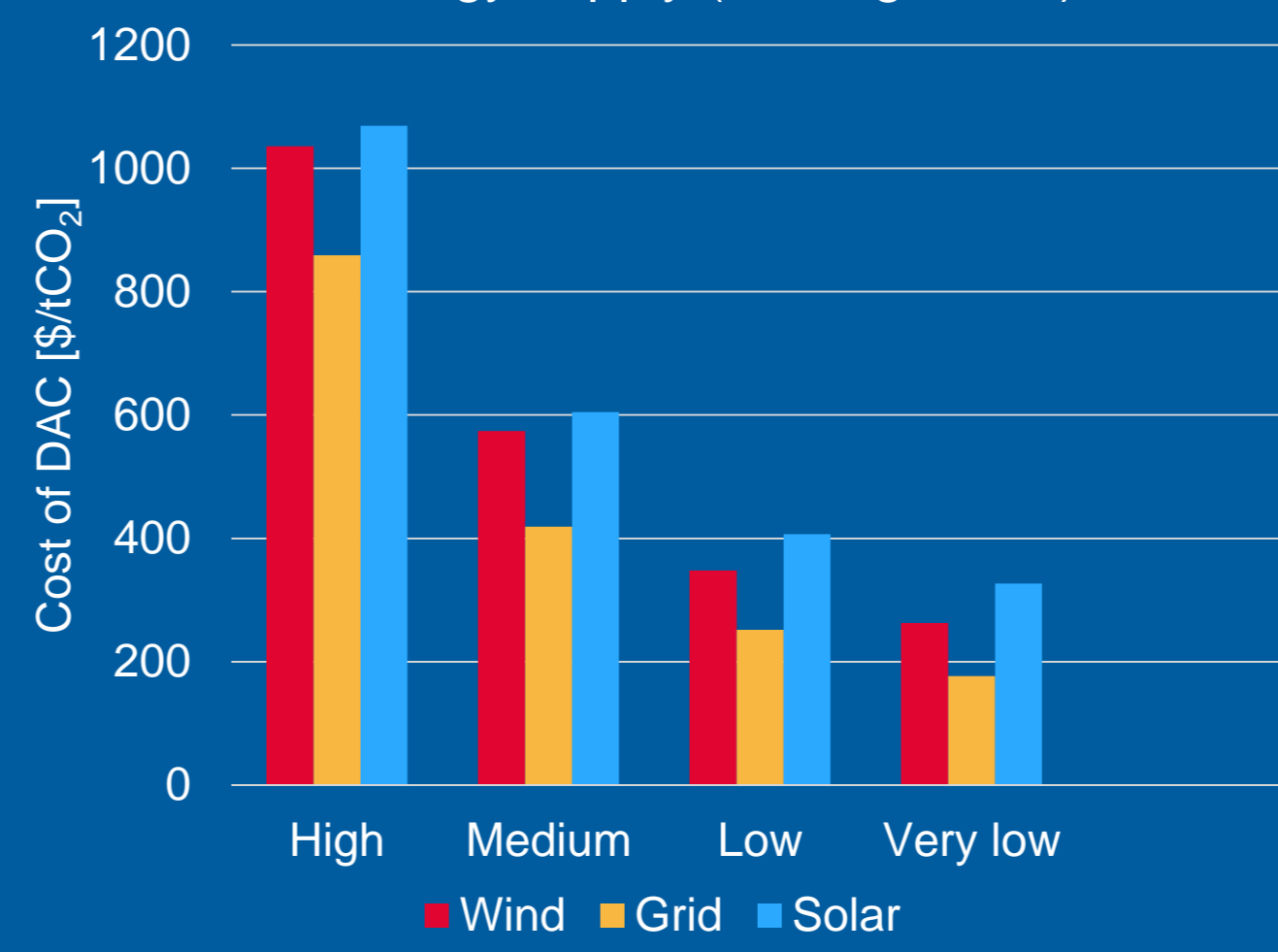
- Non-Energy Sectors**
 - Crops
 - Livestock
 - Forestry
 - Food
- Energy-intensive Industry**
 - Iron & Steel
 - Cement
 - Chemicals
 - Non-Ferrous Metals + low-carbon options including CCS
- Energy Sectors**
 - ICE (gasoline & diesel)
 - Plug-in Electric
 - Battery Electric
 - Hydrogen
 - Synthetic fuels
 - Current Generation
 - Advanced Biofuel
 - Refined Oil
 - Liquid Fuel from Biomass
 - Coal
 - Oil Shale
 - Natural Gas (conv., shale, tight)
 - Electricity
 - Synthetic Gas (from Coal)

- 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:

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

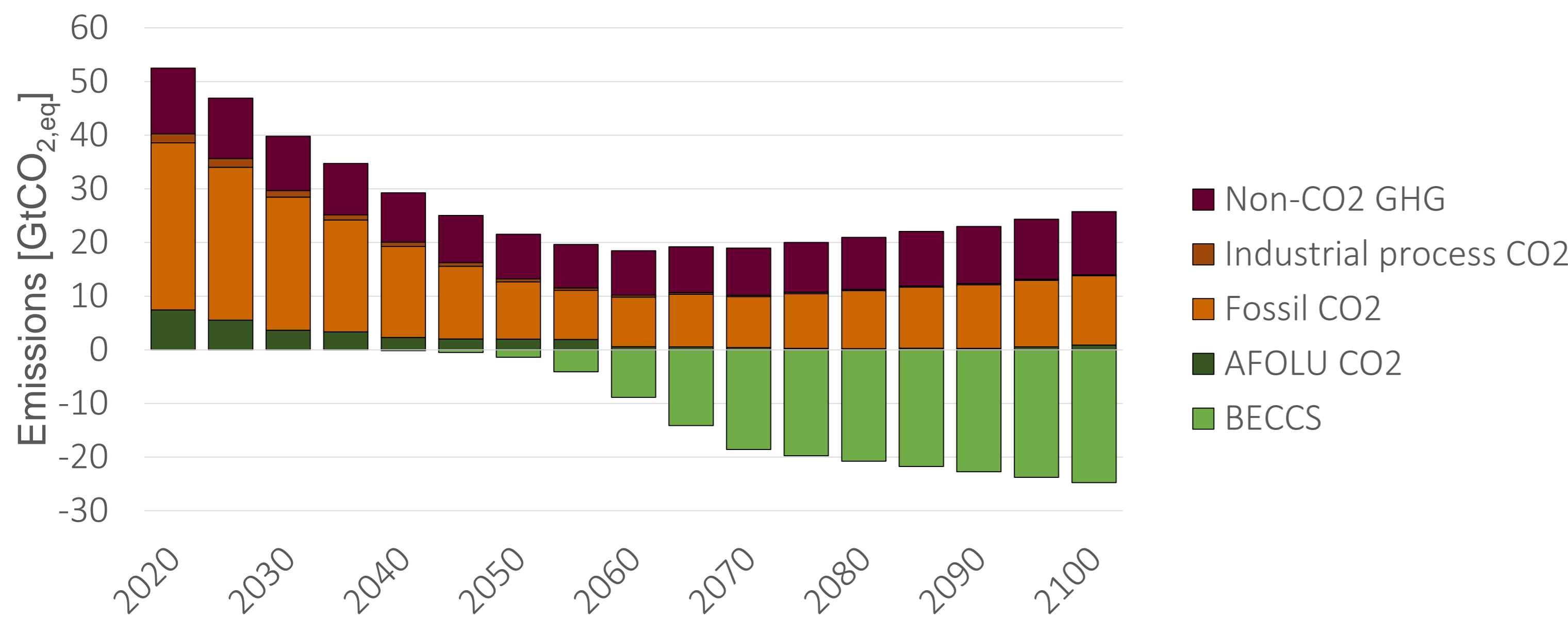
$$\text{Capacity of battery} = \text{Capacity of intermittent power} \times 24 \times (1 - \text{availability factor})$$

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

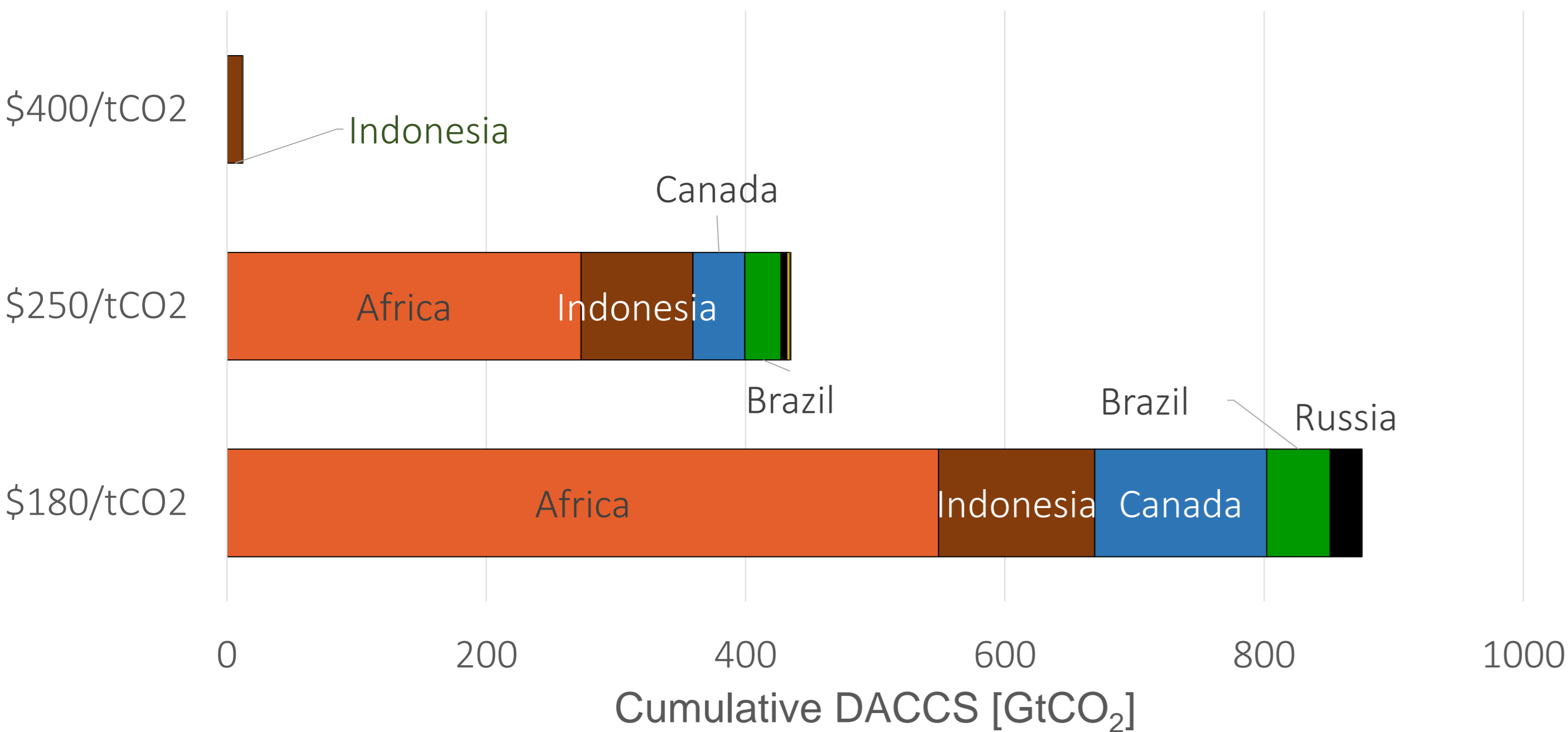
Without DAC, BECCS is deployed massively to reach net-zero by 2070.

Global emissions profile without DAC (or High cost DAC)



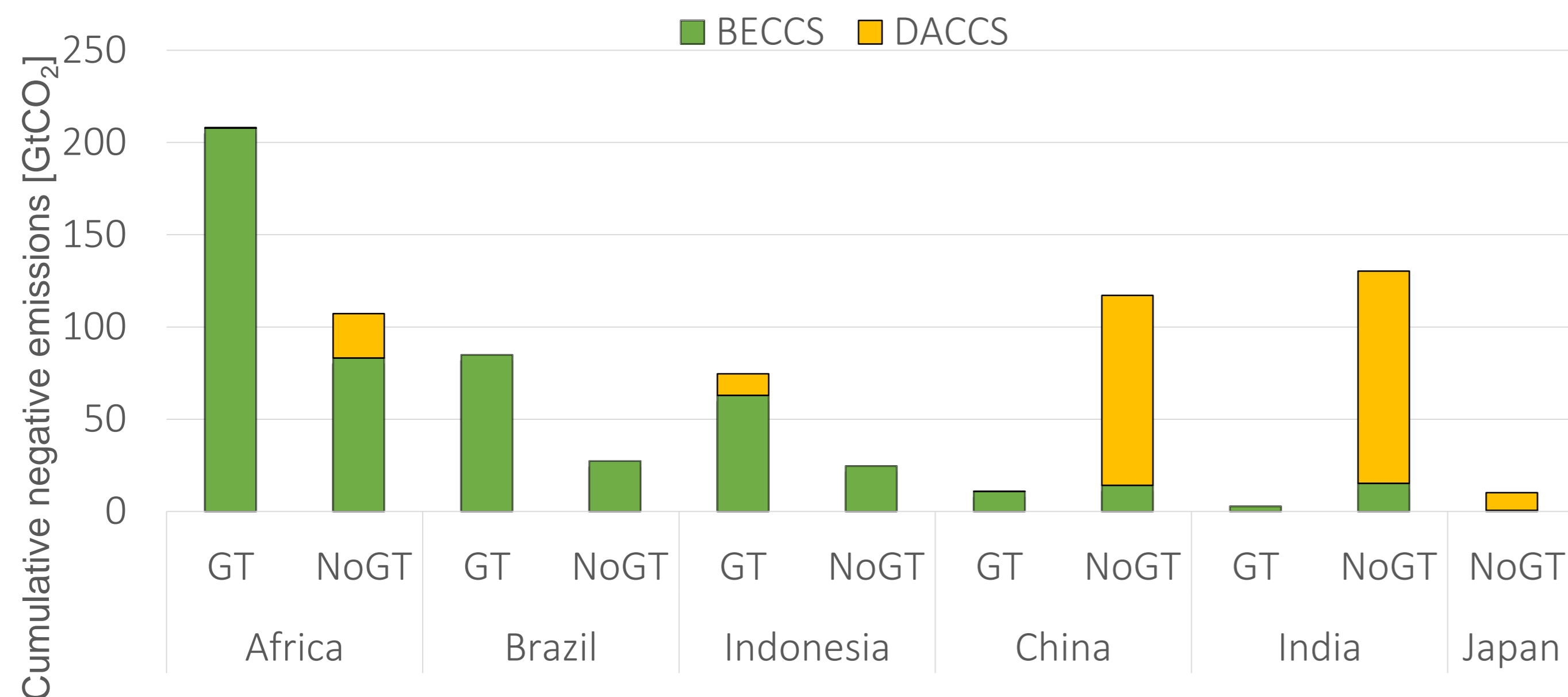
Africa proves to be a massive supplier of negative emissions to offset residual emissions of the rest of the world, as the continent possesses large renewable capacities at low costs.

Cumulative regional negative emissions through DACCS



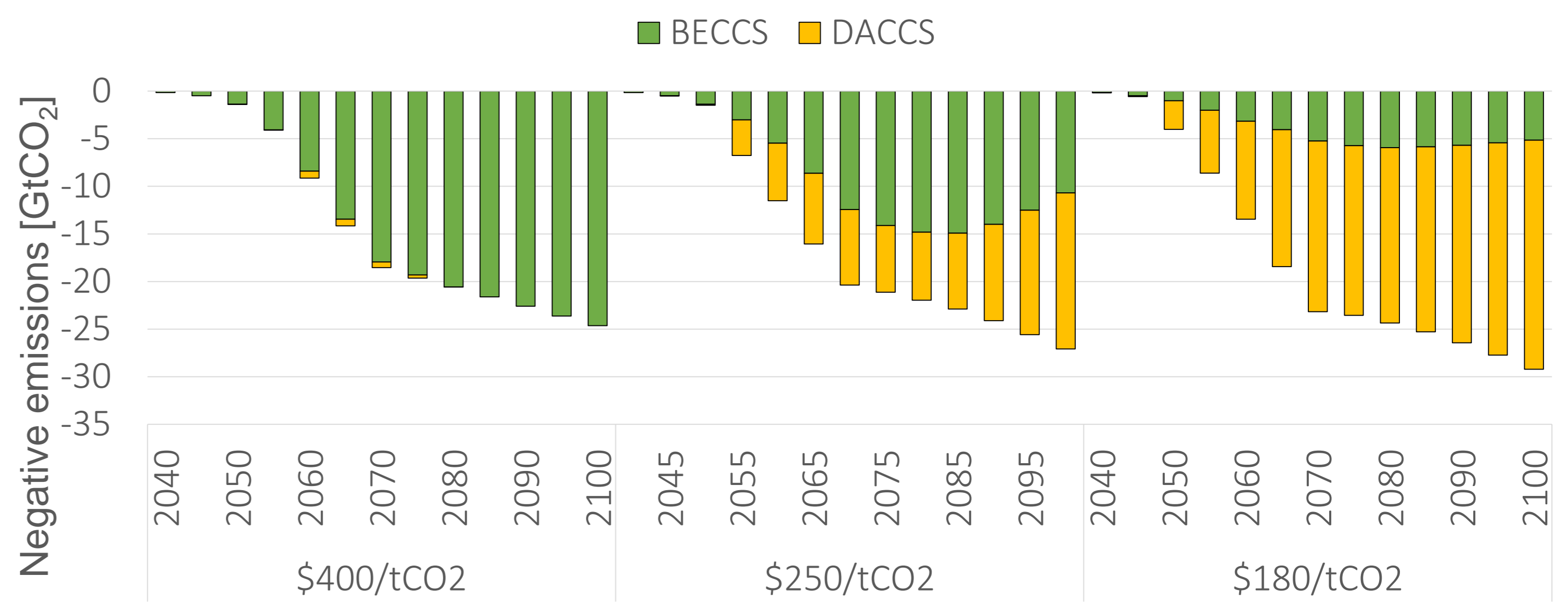
In the absence of an Emission Trading System (ETS), China and India heavily rely on DACCS as they are unable to deploy BECCS due to limited available land.

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)



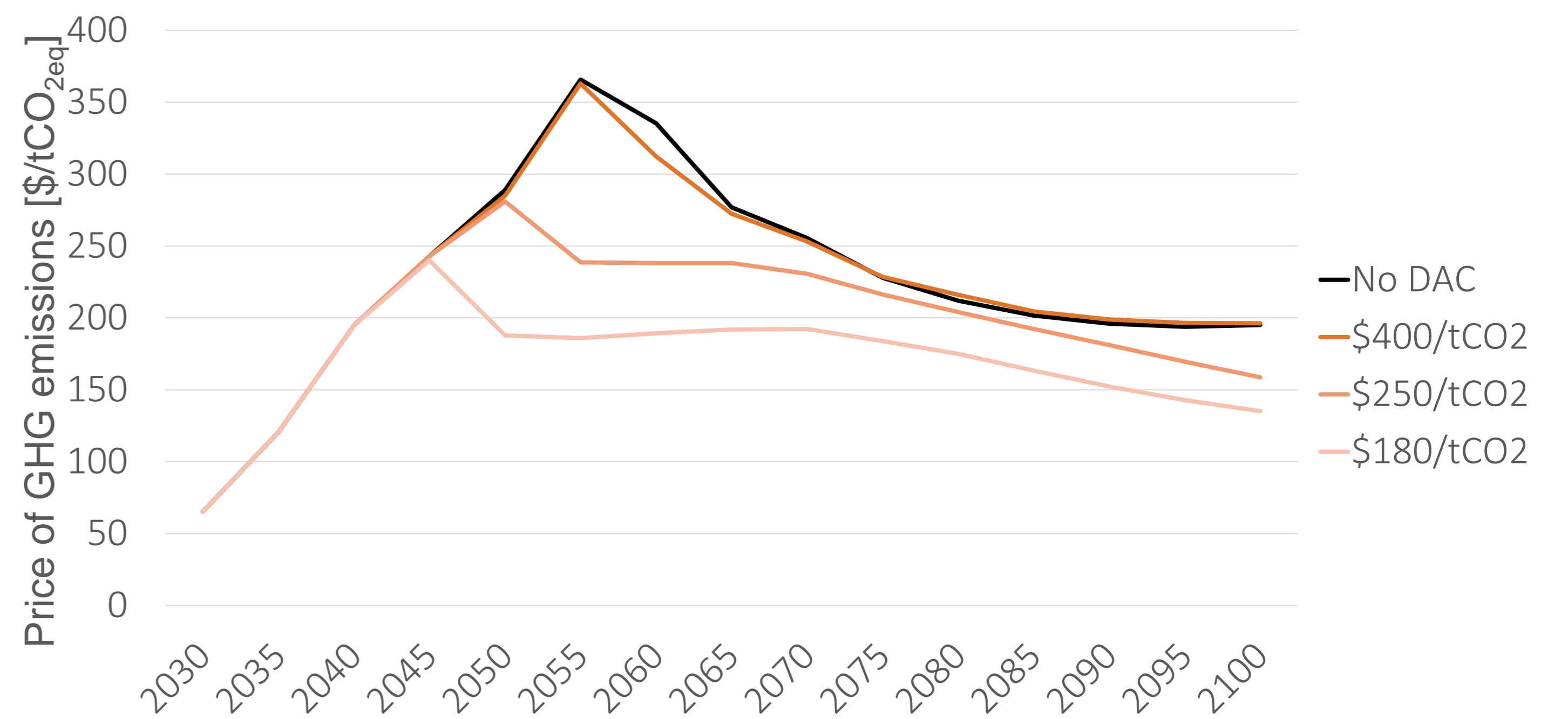
DACCS competes with BECCS for costs below \$380/tCO2. DACCU is never rolled out.

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

