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EPPA Model

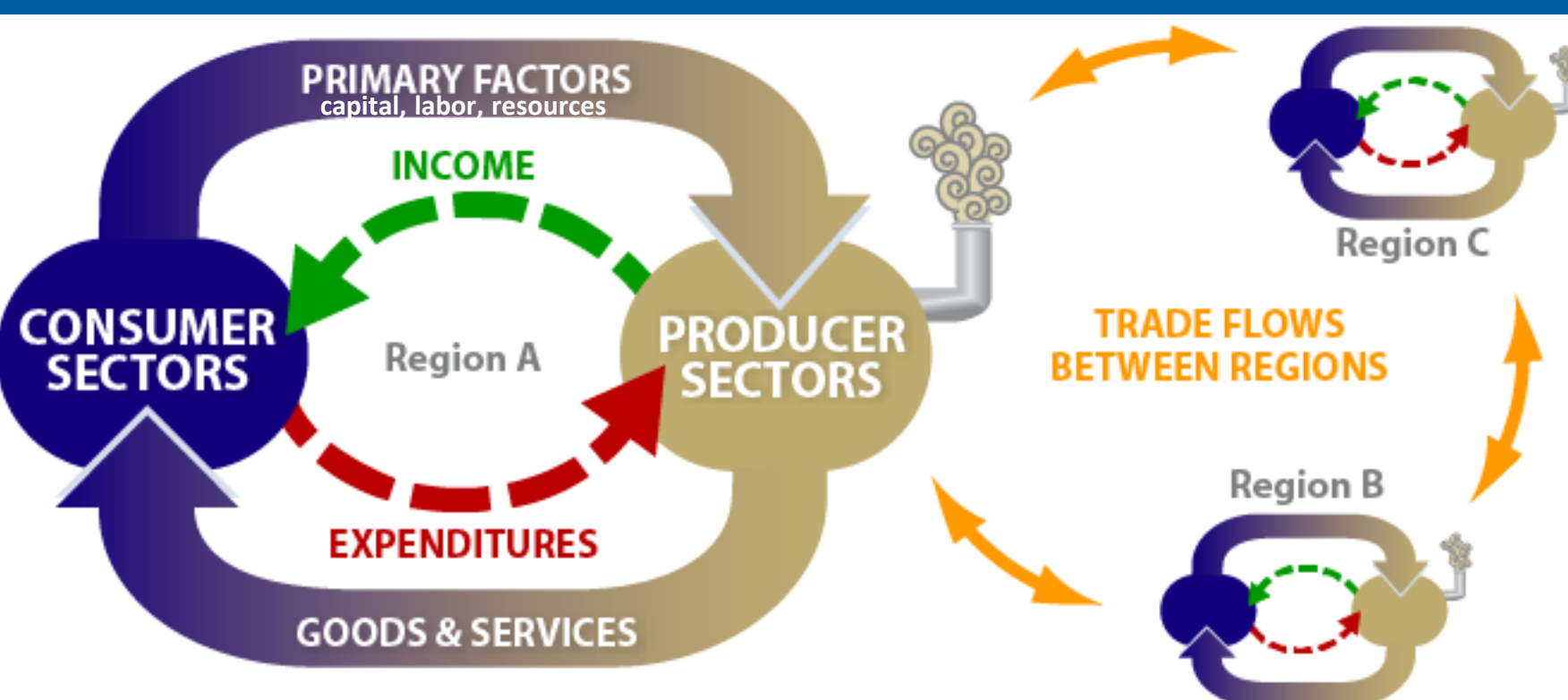
A global multi-region, multi-sector general equilibrium model coupled with an Earth system model.

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

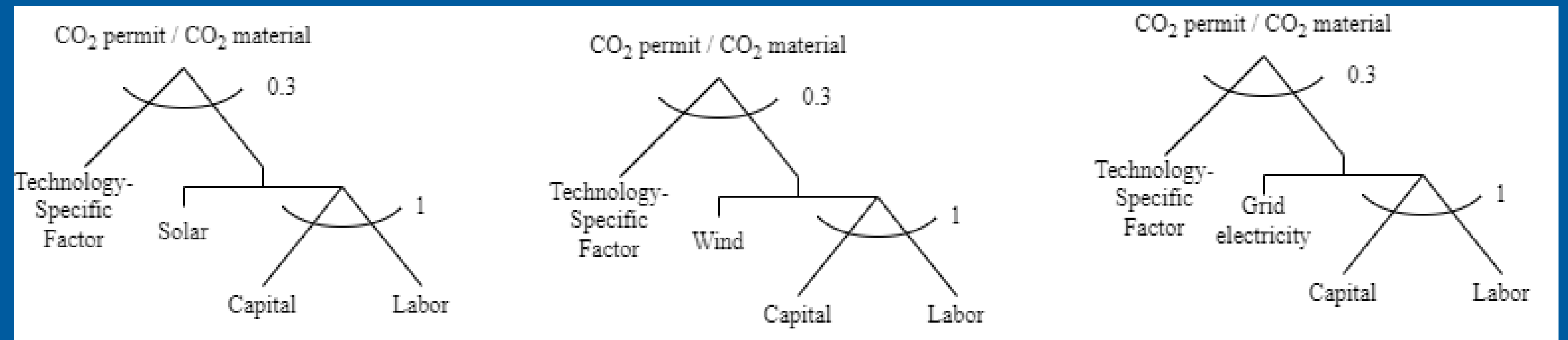


Key Inputs	Key Outputs
Policy Assumptions	GDP
Population Growth	Consumption
Capital/Labor Productivity Growth	Emissions (GHGs, Air Pollutants)
Energy Efficiency Improvements	Primary/Final Energy Use
Technology Costs	Electricity Generation
Rate of Technology Penetration	Technology Mix
Elasticities of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

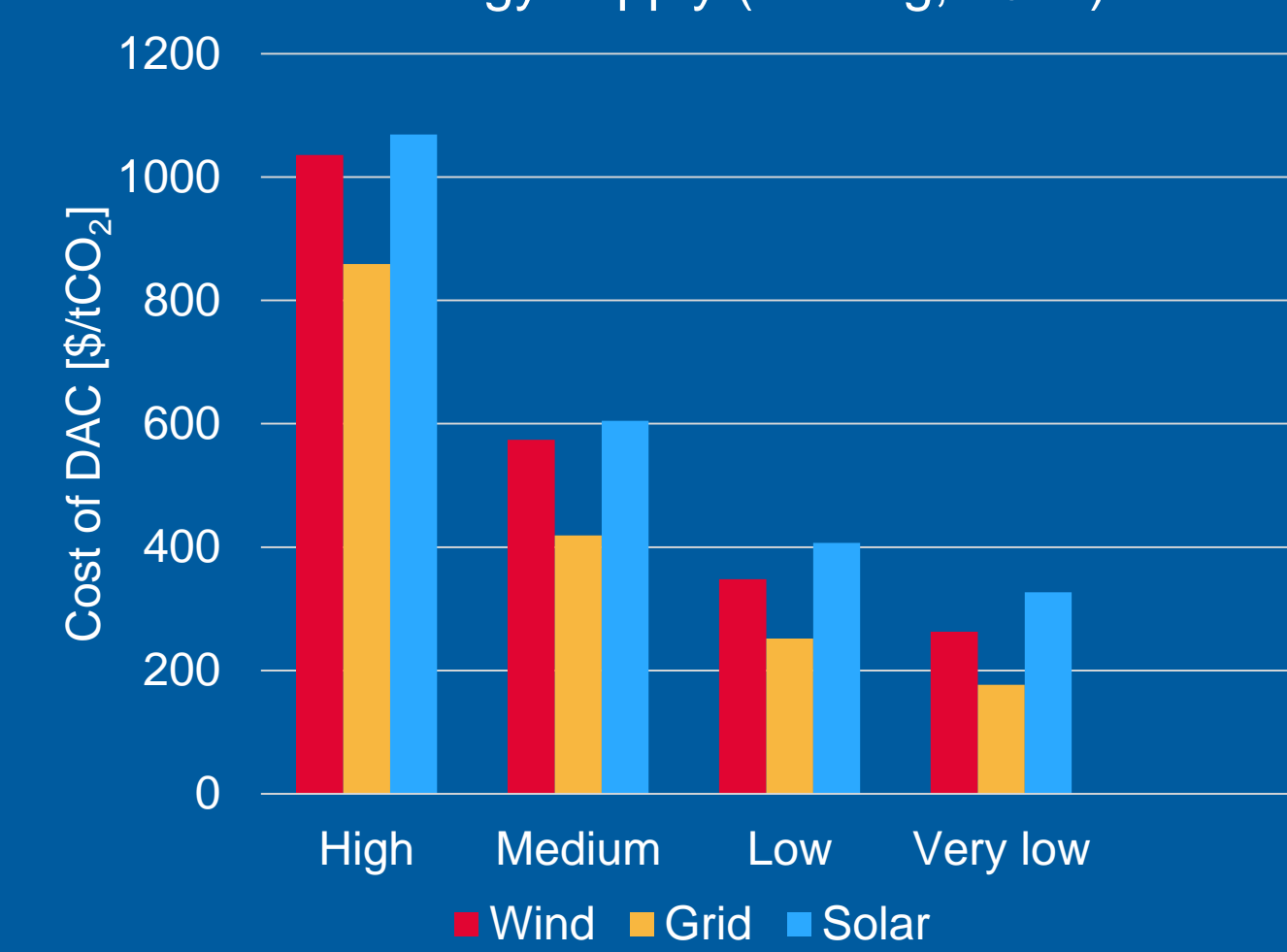
Covers all sectors of economy, with additional detail in energy sectors

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

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:

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

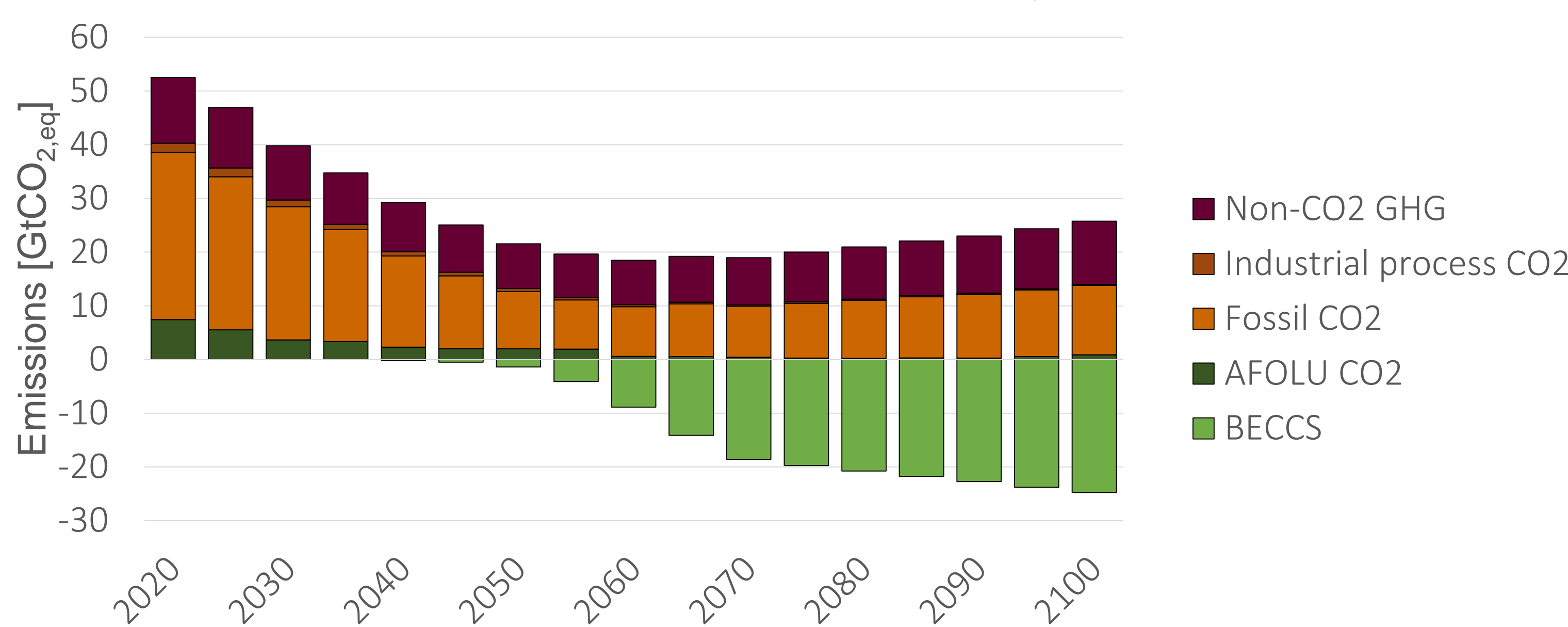
$$\text{Capacity of battery} = \text{Capacity of intermittent power} \times 24 \times (1 - \text{availability factor})$$

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

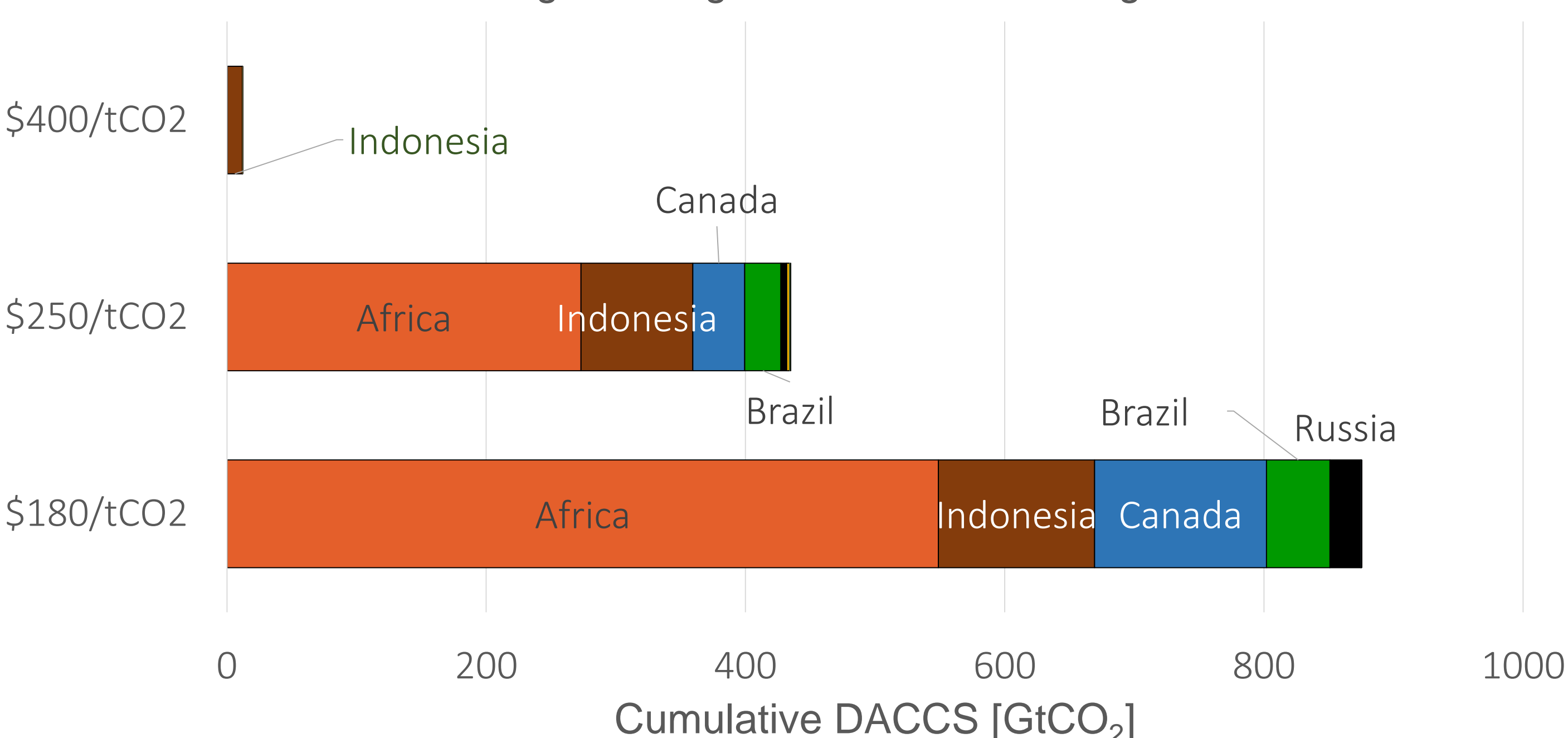
Without DAC, BECCS is deployed massively to reach net-zero by 2070.

Global emissions profile without DAC (or High cost DAC)



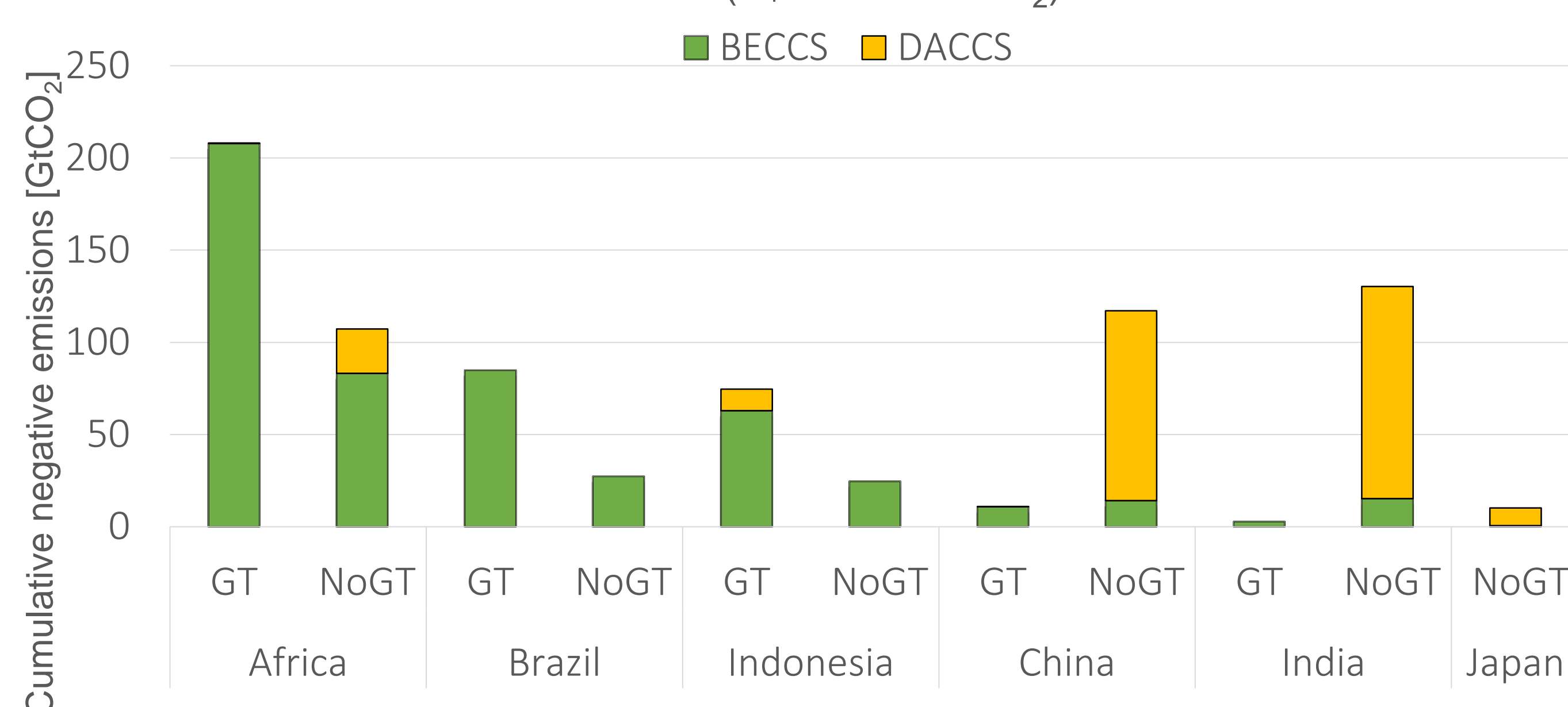
Africa proves to be a massive supplier of negative emissions to offset residual emissions of the rest of the world, as the continent possesses large renewable capacities at low costs.

Cumulative regional negative emissions through DACCS



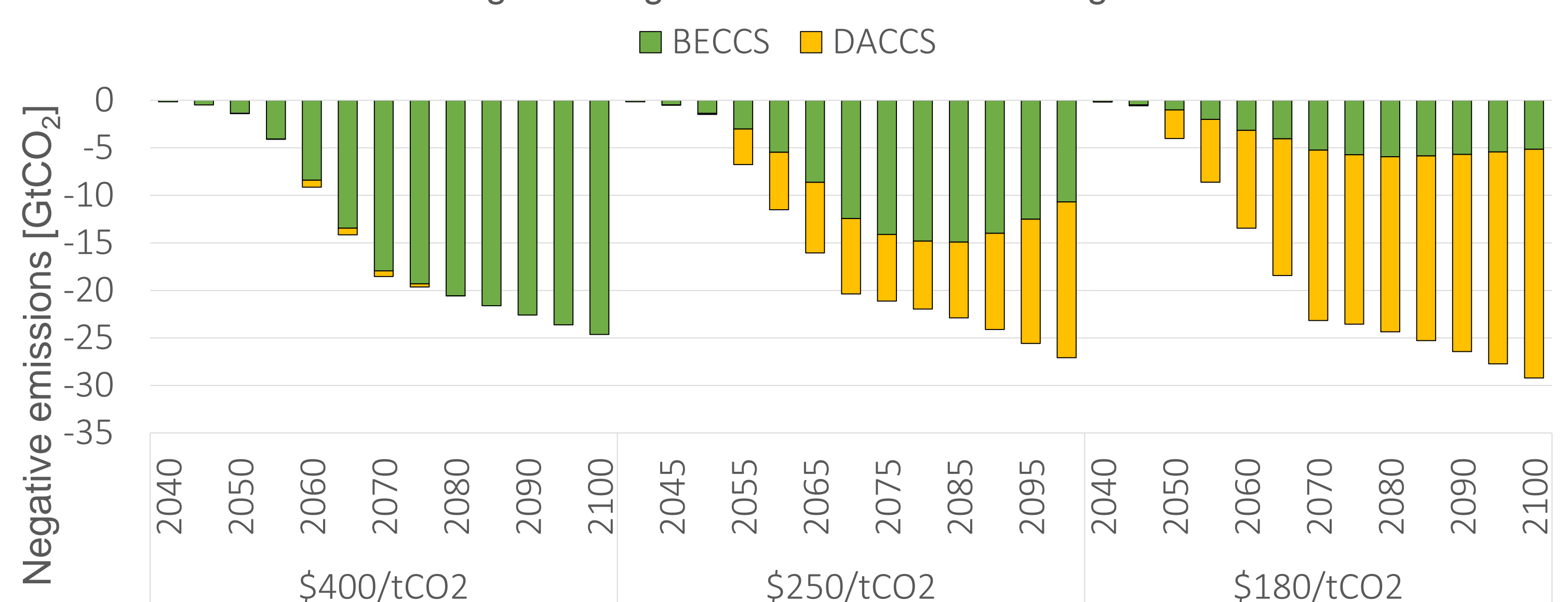
In the absence of an Emission Trading System (ETS), China and India heavily rely on DACCS as they are unable to deploy BECCS due to limited available land.

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)



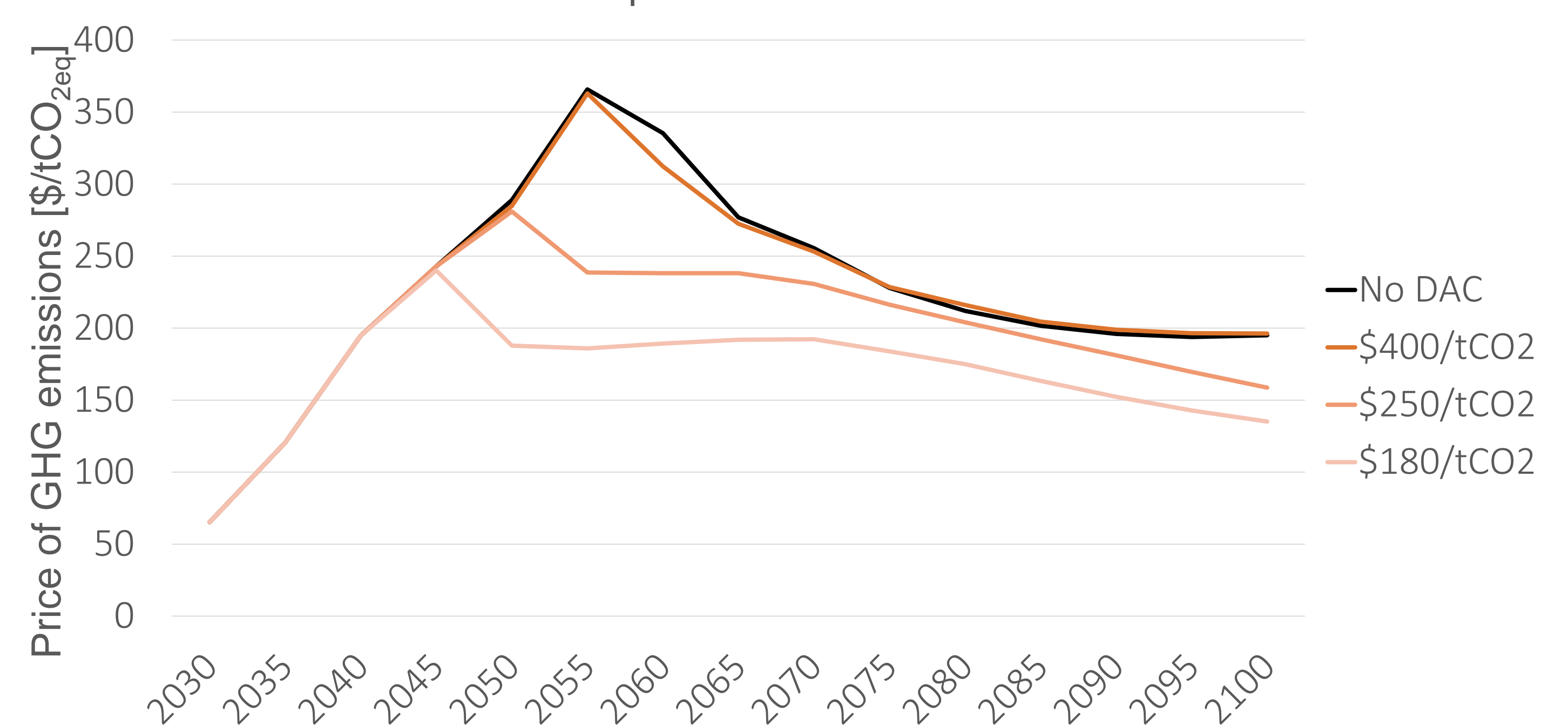
DACCS competes with BECCS for costs below \$380/tCO2. DACCU is never rolled out.

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

