Carbon removal trading can promote economic growth in the Global South but could undermine food and energy security

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Abstract

A fundamental mismatch between countries' carbon dioxide removal (CDR) responsibilities and their domestic capacities to fulfil them poses a major challenge to achieving the Paris Agreement's long-term temperature goal. Interregional CDR trade offers a solution, yet there has been no quantitative assessment of how such trade could reshape the economies of exporting regions and impact their economy–food–energy systems. Here we address this gap by integrating country-level CDR trading into a global integrated assessment model, enabling Global South countries to export carbon removal credits to the Global North in exchange for financial transfers. We find that by 2060, the Global South could export approximately 5 $GtCO_2$ per year in international CDR credits, generating US$3.1 trillion annually in financial transfers and creating 17 million jobs in the CDR sector. However, by 2060, imports of biomass, natural gas, beef, and corn in the Global South could rise by 36%, 18%, 3%, and 2%, respectively.

Introduction

Addressing climate change requires carbon dioxide removal (CDR) on the order of 100–1000 $GtCO_2$ this century to accelerate net emission reductions, counterbalance hard-to-abate residual emissions at the point of net zero, and enable sustained net-negative emissions necessary to return global warming to below 1.5°C following a temporary overshoot [1–3]. Despite this critical role, current CDR deployment remains significantly slower due to high costs, technological constraints, trade-offs with energy-water-land system, and limited domestic resource availability [4–13]. This deployment gap [8] raises an urgent question: could interregional CDR trade serve as a viable international development strategy to accelerate large-scale deployment? Many Global North countries face multi-gigatonne equitable CDR contribution due to higher historical emissions or advanced economic growth[14–17] but lack the capacity (land, biomass, and geological storage resources) to meet them domestically [14]. In contrast, several Global South countries possess abundant biomass potential, favorable geological and biophysical resources, and lower deployment costs [18,19] but have relatively lower equitable CDR expectations [14–17]. For example, CO_2 offshore storage is only economically viable at prices above 115 euros per ton in the European Union but becomes viable at 45 euros per ton in China [20]. Similarly, the cost of enhanced rock weathering in Germany is $287 per ton of CO_2 removed, compared to $175 in Kenya [21]. For bioenergy with carbon capture and storage (BECCS), the cost ranges from $85 per ton in South China to $405 per ton in the United Kingdom [22].

Similar to cost-efficiency and reliability co-benefits associated with energy trade [23,24], redirecting CDR investment to regions with large-scale potential at relatively cheaper costs could accelerate its large-scale deployment [22], and promote economic growth especially in Global South countries seeking to translate natural wealth into industrial growth, employment, and sustainable development [18]. However, CDR trade may also introduce risks in the food-energy-water-land system that remain underexplored in the existing literature. Without proper safeguards, countries importing carbon removal credits (CRC) may over-rely on cheaper international removals, undermining domestic emission reduction efforts and compromising global climate targets [25]. Exporting countries, in turn, may overextend land, energy, and water resources in pursuit of revenue, jeopardizing food and energy security and potentially undermining broader sustainability targets. Earmarking of relatively cheaper CDR potential for exports of CRCs, might also frustrate and increase the cost of a country's domestic low-carbon pathway towards which these traded CRCs cannot be counted.

Quantitative analysis of these removal-specific trade-offs remains limited especially in Global South contexts despite the growing interest in CDR trade markets [26–29]. This study addresses this gap by quantitatively assessing the economic and sustainability implications of interregional CDR trade, with particular focus on the Global South. We develop and implement a CDR trade workflow within a modified version of the Global Change Analysis Model (GCAM-TJU), covering over 200 countries. In our model, we establish a structured international CDR market that includes safeguards to prevent mitigation deterrence by establishing dual submarkets that separate emissions reductions from removals [30,31] (Methods). Also, participation in CDR trade is governed by eligibility rules that ensure climate responsibility is not shifted to trade without domestic action. Global North countries are allowed to purchase CDR credits only if their equitable CDR contributions exceed their domestic cost-effective removal capacities. Conversely, Global South countries are allowed to sell CDR credits only if their domestic cost-effective removal capacities exceed their equitable removal contributions. These rules ensure that trading reflects real capacity gaps while safeguarding domestic mitigation commitments in both importing and exporting regions. We also exclude land-use and forestry-based (LULUCF) removals from the trade market to prioritize exports of durable, high-quality CRCs. We then evaluate how CDR trade affects job creation and labor-wages, gross economic output, and value-added to economy in exporting countries, alongside its implications for energy and food security (Methods). Finally, we include a sensitivity analysis to analyze the extent of these trade-offs if CDR exports were solely limited to Bioenergy with carbon capture and storage (BECCS) as opposed to a diversified CDR portfolio approach (Supplementary Discussion 1, Extended Data Figure 4).

Our conceptual framework (**Figure 1**) illustrates a hypothetical global CDR trade structure. It also compares our modeled CDR deployment within a region's borders with regional CDR deployment under scenarios assessed in the IPCC Sixth Assessment Report – highlighting the importance of international CDR trading. Our CDR trade analysis yields several new insights that complement results from previous studies [22,32]. Here we find that the Global South could export up to 5Gt CO_2 of CRCs (**Figure 2a-c**) and create nearly 17 million jobs within the CDR sector by 2060 (**Figure 2e**). Net economic gains in 2060 could reach US$3.1 trillion in gross domestic product (GDP), US$1.7 trillion in value-added, and US$1.4 trillion in labor wages (**Figure 2d** and **Figure 2f**). However, the expectation of multi-gigatonne scale CDR within the Global South on behalf of the Global North may also compromise food, water and energy security of the export regions (**Figure 2g-i**). By 2100, annual gross imports of biomass and natural-gas rise about 30% and 27%, while that of beef and legumes grow by 1.3% and 1.2%, respectively (**Figure 2l**). Our key message is that if the world prioritizes decarbonization and limits reliance on CDR to critical functions such as offsetting hard-to-abate residual emissions and addressing temporary overshoots [33], then global CDR requirements could remain within safe planetary boundaries [6,34]. This would make the trade-offs associated with CDR trade more manageable, while still enabling economic growth in developing regions (see Discussion and the section on "Strategies to manage sustainability trade-offs associated with CDR trade").

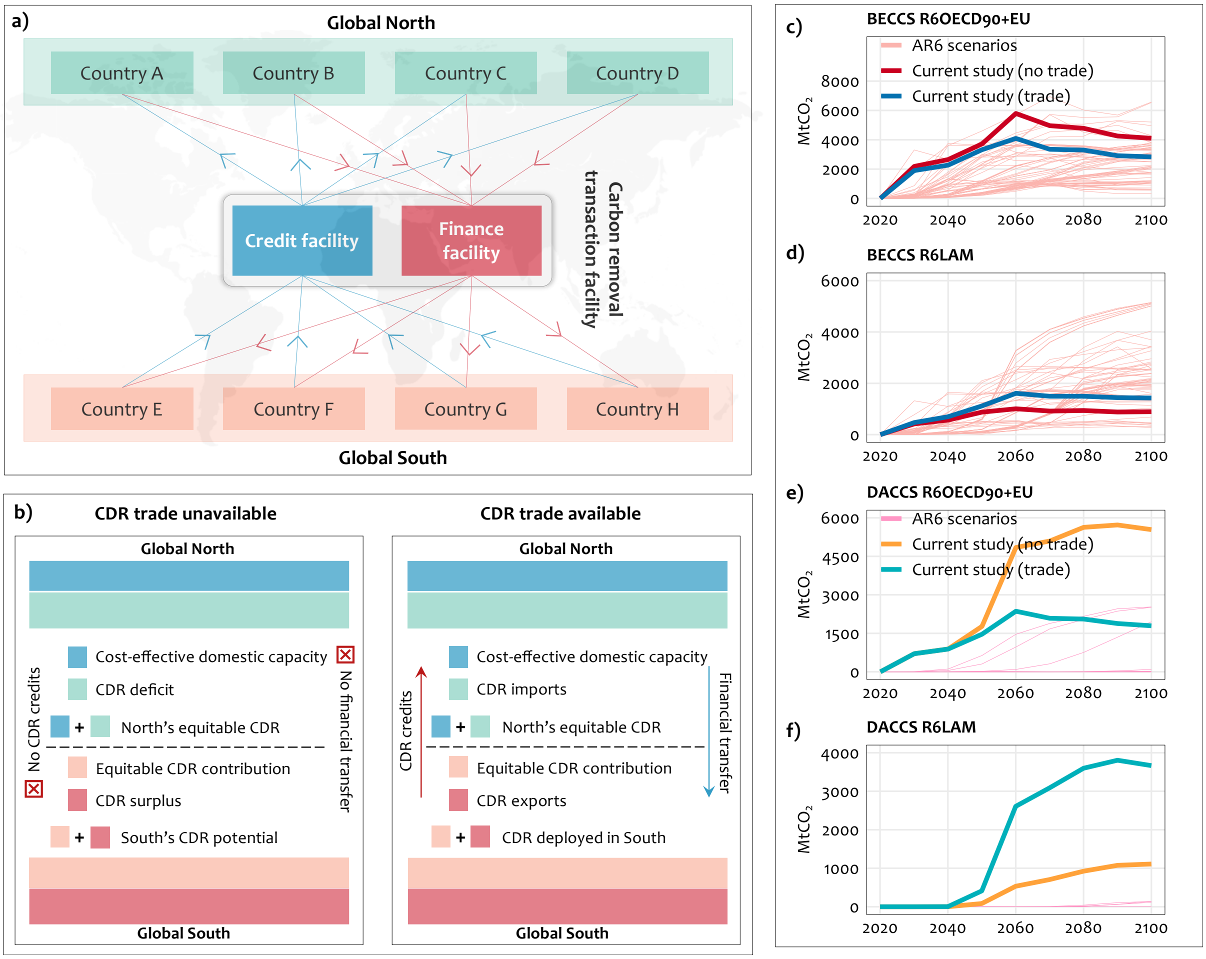


Figure 1 Conceptual framework of the international CDR trade system modeled in this study. *(a), Hypothetical structure of a global CDR trade market in which Global South countries serve as exporters and Global North countries as importers. Instead of bilateral exchanges, all CDR and financial transfers are mediated through a centralized institution, comparable to a carbon central bank, which oversees the issuance of removal certificates [35]. (b), Eligibility criteria for trade participation. Global North countries may import CDR credits only when their equitable obligation exceeds their cost-effective domestic capacity (endogenous model output), while Global South countries may export credits only when their cost-effective domestic capacity exceeds their equitable obligation. To preserve the study's emphasis on Global South benefits, a Global South country is not allowed to act as an importer, even in a period when its equitable obligation surpass cost-effective domestic capacity. In such cases, they are required to meet all CDR commitments domestically, through higher-cost (non-cost-effective). Likewise, in response to corrective justice in carbon removal benefits [36], a Global North country such as the US is not permitted to participate as an exporter, even when they possess surplus capacity (to prevent them potentially reducing the benefits to Global South). To illustrate the importance of CDR trade, panels (c-f) compares modeled outcomes from this study (total CDR deployed within borders) with CDR deployment levels across scenarios assessed in the IPCC Sixth Assessment Report (AR6). Using BECCS and DACCS as examples, the comparison focuses on one major importing region in the Global North (R6OECD90+EU) and one major exporting region in the Global South (R6Latin America). The AR6 scenarios included are those vetted and with warming estimates and limit warming to 1.5°C (72 scenarios for BECCS and 9 scenarios for DACCS in each of the R6OECD90+EU and R6LAM regions).*

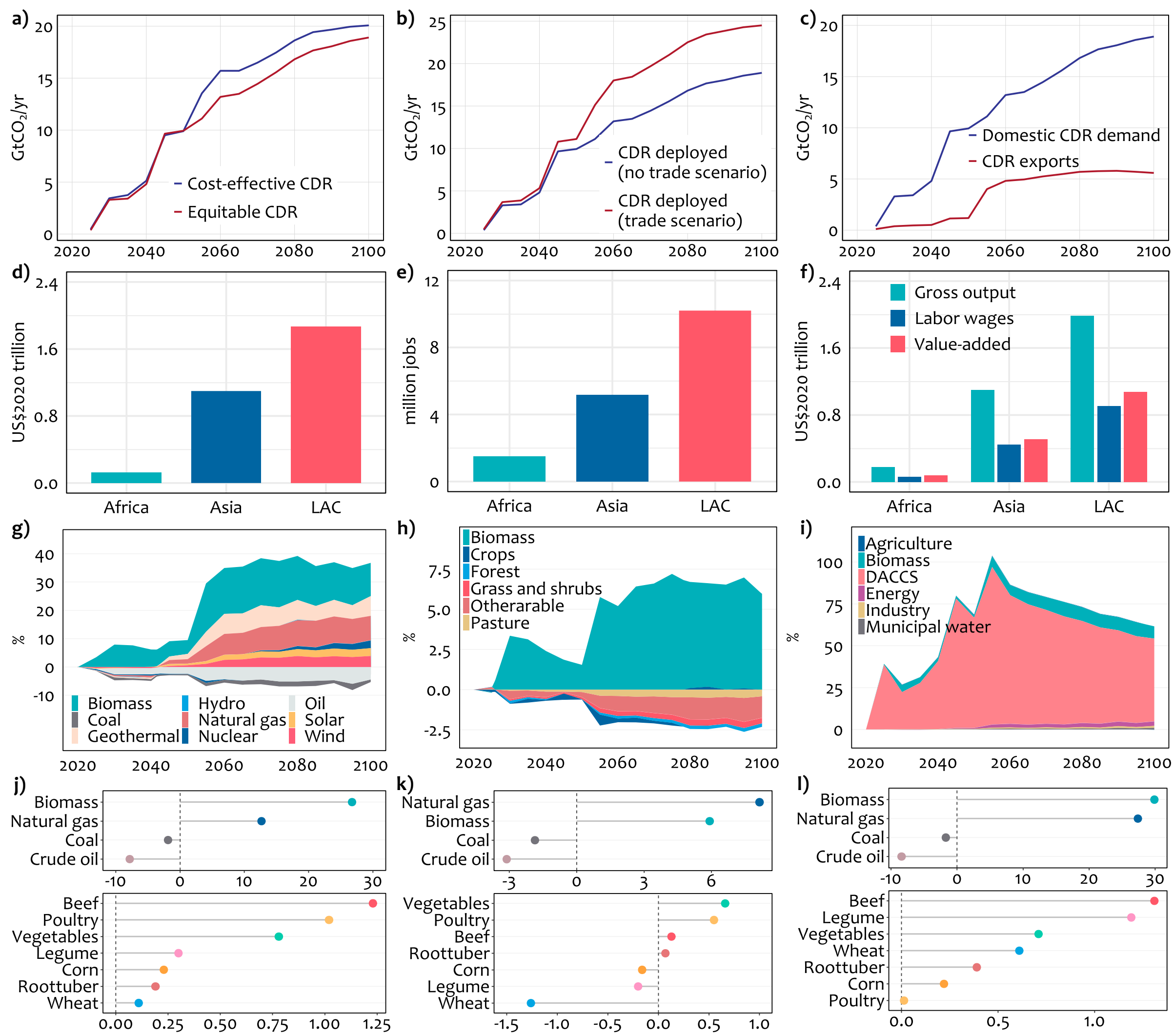


Figure 2 Carbon removal demand and supply by Global South, and associated synergies and trade-offs.

(a), Cost effective and equitable CDR deployment by Global South. Cost effective deployment refers to model CDR output under a global net zero GHG by 2060 while equitable CDR refers to the redistribution of cost-effective CDR based on burden-sharing principles (here, ability-to-pay). (b), CDR deployed within the borders of the Global South.Under no trade, Global South only deploys its equitable CDR obligation, but under trade, there is an additional CDR deployment owned by the Global North. (c), Domestic CDR demand which is also equal to equitable CDR deployment by Global South while international CDR exports refers to carbon removal credits transferred from the Global South to be purchased by the Global North. (d), Annual financial transfers received by Global South associated with CDR sales in 2060. LAC: Latin America and Carribean. (e), Additional job gains created within the CDR sector in Global South by 2060. (f), Macro-economic net gains from CDR exports by 2060. It should be noted that for these particular results, Central Asia has not been reported – hence the relatively larger gap between Asia and LAC. (g), Annual percent change in primary energy consumption in the Global South under CDR trade scenario relative to a no CDR trade scenario. (h), Annual percent change in land allocation (same area of land being allocated differently) in the Global South under CDR trade scenario relative to a no CDR trade scenario. (i), Annual percent change in water consumption in

*the Global South under CDR trade scenario relative to a no CDR trade scenario. (j), Difference in domestic food and energy **consumption** by CDR-exporting regions in the Global South under CDR trade scenario relative to a no CDR trade scenario by 2100 (%). (k), Difference in domestic food and energy **production** by CDR-exporting regions in the Global South under CDR trade scenario relative to a no CDR trade scenario by 2100 (%).(l), Difference in food and energy gross **imports** by CDR-exporting regions in the Global South under CDR trade scenario relative to a no CDR trade scenario by 2100 (%).*

Results

We model six scenarios in this study, based on three distinct burden-sharing principles used to equitably redistribute cost-effective (model-endogenous) CDR deployment across countries (**Table 1**, Methods). Three burden-sharing principles are applied: historical responsibility (RESPO), capability or ability-to-pay (CAPAB), and equal per capita allocation (EQUAL). For each principle, we model both a no-trade case, where countries fulfill their equitable CDR contributions entirely with domestic capacity regardless of cost, and a CDR trade-enabled case, where Global North countries facing higher costs of meeting their full equitable CDR contributions domestically can purchase their deficits (the portion of equitable CDR contributions exceeding cost-effective domestic capacity) as CRC from Global South countries with surplus CDR capacity (the portion of equitable CDR contributions below cost-effective domestic capacity) where removal is relatively cheaper. This structure allows us to examine how different burden-sharing principles interact with the existence or absence of international CDR trade.

Among these, the ability-to-pay principle (CAPAB) assigns the highest CDR contributions to Global North countries, resulting in the largest volume of CDR exports from the Global South. As a result, trade-related synergies and trade-offs assessed in this study reach their most significant levels under the CAPAB regime, compared to the responsibility-based (RESPO) and equal per capita (EQUAL) approaches. For RESPO, we use 1990 as the baseline year for calculating historical cumulative emissions, as it marks the publication of the first Intergovernmental Panel on Climate Change (IPCC) Assessment Report. Using this 1990 baseline, RESPO leads to 156 $GtCO_2$ of cumulative CDR credit trade between 2025 and 2100, compared to 270 $GtCO_2$ under CAPAB and 70 $GtCO_2$ under EQUAL. While RESPO would result in a higher exchange volume if the baseline were set to 1830 (442 $GtCO_2$) (**Extended**

Data Figure 1 and Extended Data Figure 2), our focus on the 1990 baseline makes CAPAB the regime with the highest levels of CDR trade and associated impacts.

Given our aim to assess the economic and sustainability implications of large-scale CDR trade (rather than compare different regimes), we present and discuss results primarily for the CAPAB scenario. RESPO and EQUAL outcomes are reported in the Supplementary Information (**Supplementary Figure 1 to Supplementary Figure 25, Supplementary Table 1**).

Table 1 Modeled CDR trade scenarios and assumptions

Scenario	Burden-sharing principle for re-distribution of cost-effective CDR	CDR pathway	Gross FFI CO_2 emission reduction pathway [a]	CDR trade enabled?	Criteria for purchasing/selling credits from technological CDR	Financial transfer enabled?
RESPO-A	Responsibility	Cost-effective CDR from global net zero GHG emission target by 2060 while net negative GHG by 2100 reaches 7 $GtCO_2e$/yr. Total novel CDR reach 15 $GtCO_2$/yr by 2050 and 30 $GtCO_2$/yr by 2100	Countries' cost-effective gross FFI CO_2 emissions consistent with our global net GHG emission reduction pathway	No.	Not applicable. If a regions equitable CDR exceeds its cost-effective CDR, they must enhance domestic capacity to achieve all equitable CDR at expensive cost	Not applicable
CAPAB-A	Capability					
EQUAL-A	Equal per capita					
RESPO-B	Responsibility	Cost-effective [b] CDR from global net zero GHG emission target by 2060 while net negative GHG by 2100 reaches 7 $GtCO_2e$/yr. Total novel CDR reach 15 $GtCO_2$/yr by 2050 and 30 $GtCO_2$/yr by 2100	Countries' cost-effective gross FFI CO_2 emissions [c] consistent with our global net GHG emission reduction pathway	Yes.	Here, a Global North country is only required to purchase international CDR if its fair CDR obligation exceeds its cost-effective CDR allocation. Such a country only needs to do cost-effective CDR within borders, and purchase deficit (i.e., equitable CDR minus cost-effective CDR) from Global South A Global South country is only eligible to sell CDR credits only if its cost-	Yes
CAPAB-B	Capability					
EQUAL-B	Equal per capita					

					effective CDR allocation exceeds its fair CDR obligation	

[a] Each country's or region's fossil fuel and industry (FFI) CO_2 emissions are kept fixed under each scenario. This is to prevent countries from delaying emission reductions by over-relying on cheaper carbon removal credits (CRC). The maximum amount of CRC that a country can import is strictly the amount that exceeds its cost-effective capacity in relation to its equitable obligation.

[b] In this context, cost-effective CDR refers to the endogenously determined CDR capacity allocated to each region within the model, reflecting the region's capacity to deploy CDR technologies using its available resources at the lowest possible cost.

[c] This constraint applies solely to FFI-CO_2-emitting technologies and it is different from the typical emission constraint usually used in IAM studies which applies to net GHG/net CO_2 emissions (meaning both GHG-emitting and CDR technologies).

Exports of carbon removal credits and economic impact

International CDR trade facilitates the exchange of large volumes of CRCs between the Global North and Global South. From 2025 to 2100, approximately 270 $GtCO_2$ of CRCs are projected to be traded globally under our central scenario (CAPAB). Latin America and the Caribbeans, led by Brazil, emerges as the largest exporter, contributing 58.3% of total exports due to its extensive biomass resources[37] and geological storage capacity[11,38]. Asia follows with 39.4%, primarily driven by China, while Africa contributes 2.3% (**Figure 3a**). It is worth noting that, despite the Middle East's large geological sequestration potential and high deployment capacity, the region plays a negligible role as a CRC exporter. This is primarily because, under the ability-to-pay regime, the Middle East carries relatively higher domestic CDR obligations, leaving little to no surplus capacity available for export to the Global North (**Extended Data Figure 1 and Figure 3c**). On the import side, Europe, largely represented by the EU-27, is the dominant buyer, accounting for over 75% of total imports, followed by Japan at 11% and Korea at 6%. Russia, with relatively abundant land, biomass, and storage capacity, does not import CRCs at any point during the century. The United States imports CRCs until 2055, after which it also becomes self-sufficient in meeting its equitable CDR obligations using domestic resources.

Figure 3b shows the breakdown of CRC exports and imports by technology type. As a scalable backstop technology that can stabilize carbon and food prices [11,39], DACCS accounts for the largest share of cumulative global CRC supply between 2025 and 2100, contributing 63%. BECCS follows with 33%, while enhanced rock weathering (ERW) contributes 4%. This dominance of DACCS in the model is a reflection of its increasing cost competitiveness over time relative to land-based options, as also indicated in Fuhrman et al. [40], combined with its limited land competition. The realization of these high DACCS deployment rates in the Global South, despite the near absence of current deployment in the region, could be enabled through global investment flows, technology transfer, learning-by-doing, economies of scale, and access to cheaper low-carbon electricity. Recent assessments suggest that DACCS costs could decline from current levels of \$500-3100 per tCO_2 to approximately \$100-600 per tCO_2 by mid-century [41], making large-scale deployment in the Global South increasingly feasible under supportive policy frameworks.

Figure 3c displays the annual surplus CDR capacity of Global South countries, representing the portion of cost-effective domestic potential that exceeds their equitable CDR obligations. Over the century, this surplus is projected to total 396 GtCO_2, which is 126 GtCO_2 more than the Global North's total cumulative CRC imports. Conversely, **Figure 3d** illustrates the annual CDR capacity deficit in the Global North, defined as the gap between equitable obligations and domestic cost-effective capacity. The United States, Canada, and Australia_NZ show a combined deficit of less than 15 GtCO_2 over the entire century, indicating lower reliance on Global South to meet their CDR obligations. In perspective, South Korea alone has a cumulative CDR deficit of 15.7 GtCO_2. South Korea's limited land and storage potential means that over 80% of its equitable CDR contribution will be met through investment in the Global South, compared to 72% for the EU-27, despite the latter importing a larger volume of CRCs.

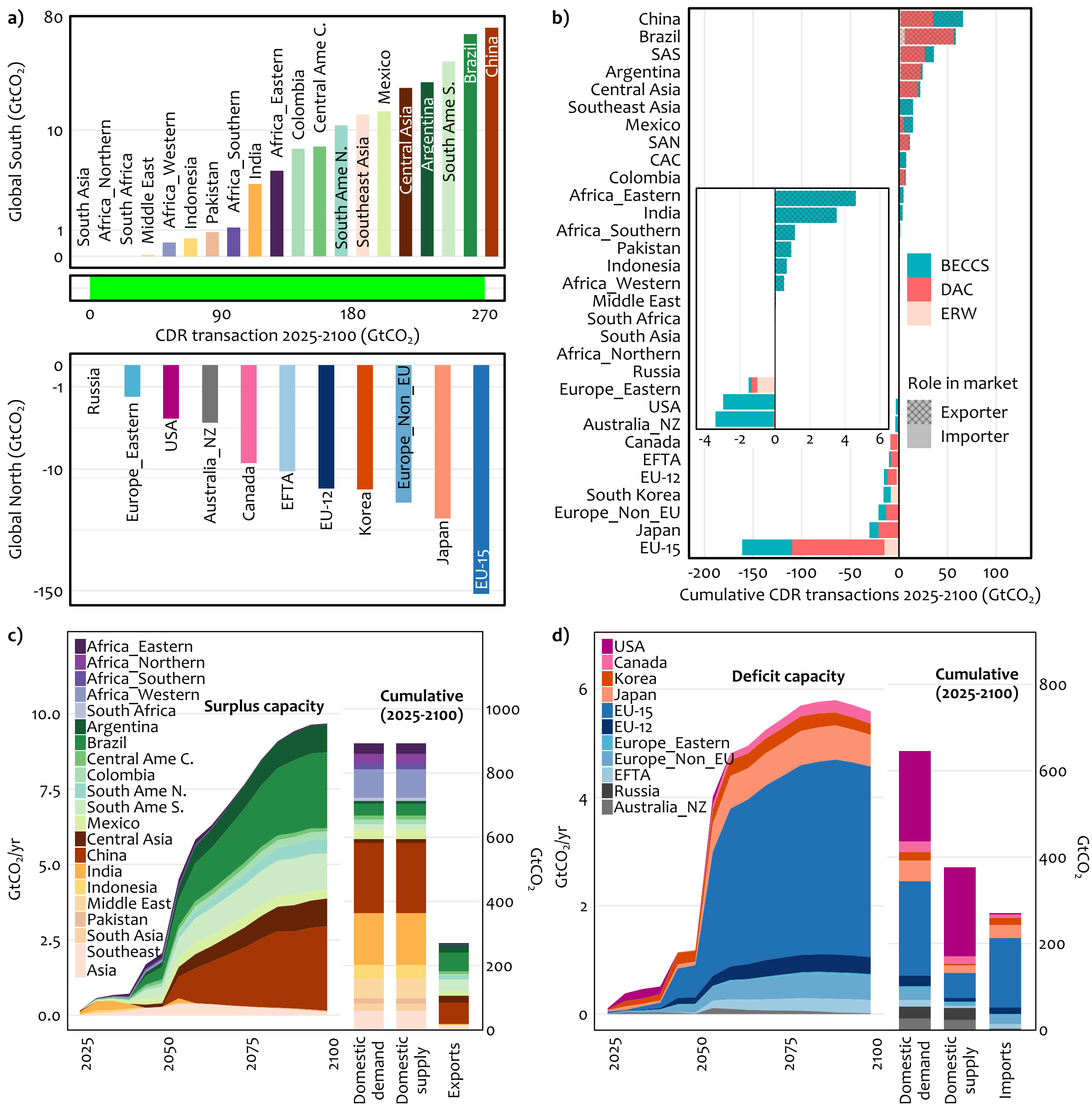


Figure 3 Regional trends and technology composition in global CDR trade markets.

(a) Spatial distribution of cumulative carbon removal credit (CRC) exports by Global South regions and corresponding imports by Global North regions. (b) Composition of CRC exports and imports by technology type, including DACCS, BECCS, ocean enhanced rock weathering (ERW). (c) Annual surplus CDR capacity in Global South regions, defined as the positive difference between cost-effective domestic capacity and equitable CDR obligations. Surplus capacity is used to allocate CRC sales, ensuring proportional access and limiting dominance by individual regions. (d) Annual CDR capacity deficits in Global North countries, capturing the extent to which equitable obligations exceed domestic cost-effective capacity. Central Ame C. or CAC: Central America and Caribbean; South Ame N. or SAN: South America_Northern; South Ame S. or SAS: South America_Southern; EFTA: European Free Trade Association. It is worth noting that after meeting the demands of the Global North, the Global South would still have untapped capacity which could offer an additional economic development pathway for Global South beyond CRC markets through green methanol production and exports. Independent of the DAC facilities funded through CRC trade, additional DAC plants could be established within the Global South to capture CO_2 specifically for synthetic fuel production [42]. By combining

this captured CO_2 with renewable hydrogen, Global South regions could produce green methanol for export to Global North countries such as Japan and South Korea. In these countries, limited land availability excludes nearly 90% of their territory from renewable electricity generation, which constrains domestic hydrogen production [43].

The demand for CRCs by the Global North offers a promising international strategy to boost economic growth in the Global South through financial transfers. Financial transfers are estimated by multiplying traded CRC volumes by exogenously applied CO_2 prices, which are based on the median (50th percentile) CO_2 price trajectory from 1.5°C-consistent scenarios assessed in the IPCC AR6 database (Methods, Supplementary Figure 27). Financial transfers linked to CRC trade are projected to reach 3.1 trillion US dollars annually by 2060 (undiscounted) (**Figure 4a**), representing approximately 3% and 3.5% of the combined GDP of exporting Global South and importing Global North countries at that time, respectively. Europe is expected to account for the largest share of these payments at 2.4 trillion US dollars per year, followed by South Korea and Japan with a combined 576 billion US dollars. As the leading exporter by mid-century, Brazil could receive 640 billion US dollars in annual financial transfers from CRC sales. As a result, Brazil's net economic gains are projected to rise by 380 billion US dollars in value-added output (+6.5%) and 630 billion US dollars in gross output (+6.8%) by 2060 (**Figure 4b**)

CRC trade also presents a new pathway to reduce unemployment in the Global South. By 2060, direct annual jobs from CDR investments are projected to reach 17 million across the region (**Figure 4c**). Although financial flows and trade of CRCs are balanced between exporters and importers, regional differences in labor intensity [44] create an uneven distribution of job impacts. By 2060, job creation in the Global South is expected to be 1.34 times greater than job losses in the Global North, due to higher job multipliers in labor-intensive economies [44]. In addition, broader economic stimulation from CDR trade contributes to rising labor wages in the Global South, with a projected 1.8% increase by 2060 (**Figure 4d**). With GDP, countries that tend to gain or lose the most are not necessarily the largest exporters or importers. For example, Argentina sees the second-highest GDP increase in 2060 at 17.3%, yet ranks fourth in CRC exports that year. Similarly, South Korea experiences the largest GDP decline in 2060 at 4.9%, despite being the fourth largest CRC importer (**Figure 4d**).

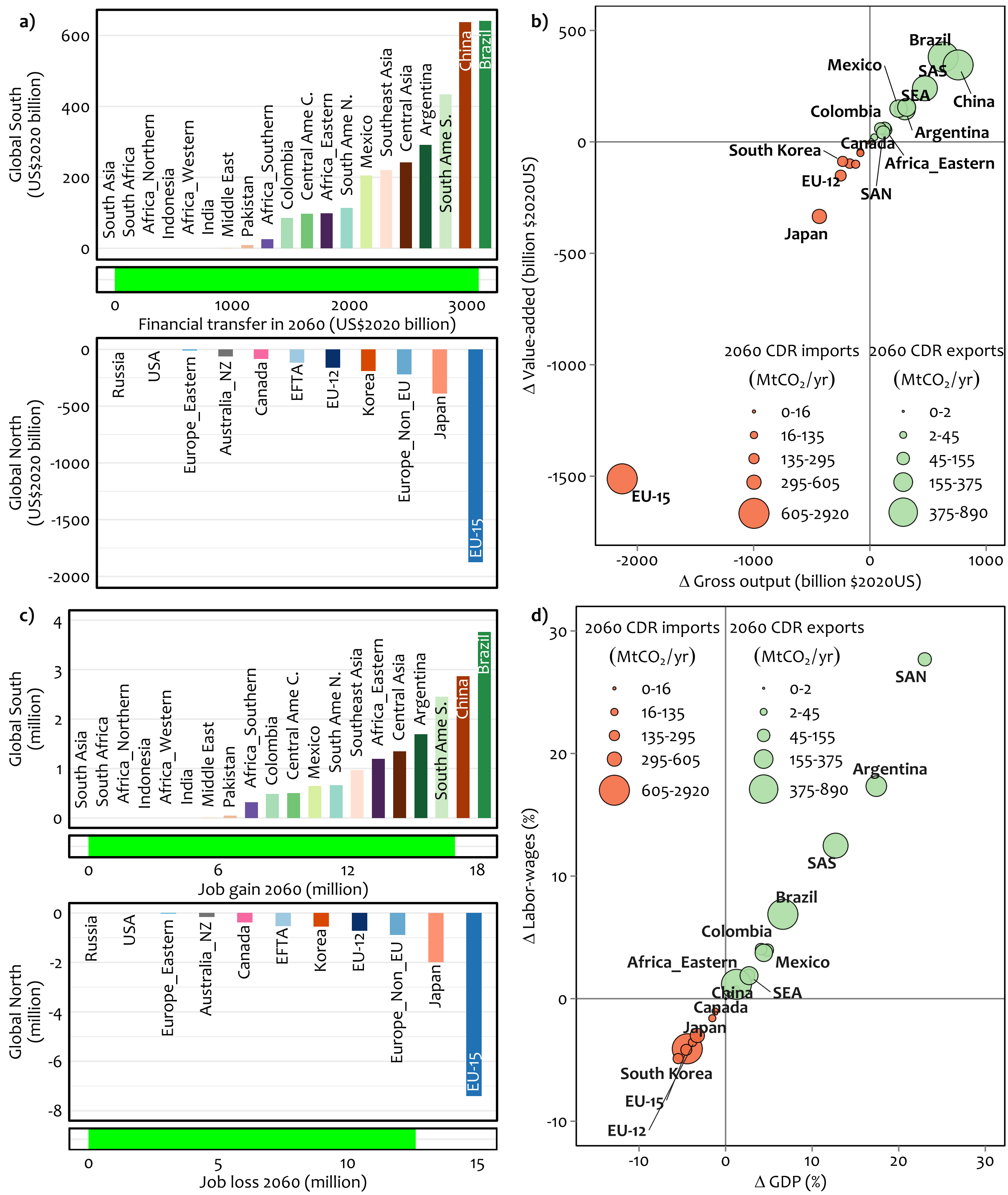


Figure 4 Economic and job impacts of international CDR trade between the Global North and South.

(a) Annual financial transfers associated with the purchase of carbon removal credits (CRCs) by Global North countries and the corresponding revenues received by exporting Global South countries. (b) Absolute difference in gross output and value-added in key importing and exporting regions due to CDR trade relative to no CDR trade by 2060. Within the boundaries of GCAM [45], Gross output is the total economic value of the total produce per each GCAM region, while value-added counts the "new" value added by labor, capital, energy, and land in

a given region. In our the context of our analysis, gross output indicates how much total economic activity is being generated because of CDR trade and value-added shows how much net benefit/loss is being created domestically.

(c) Job creation associated with increased CDR deployment in the Global South and related job loss in the Global North by 2060. Temporary job could arise from DACCS infrastructure construction and installation, while longer-term jobs could be generated in biomass supply chains and mineral processing for enhanced weathering. Since the job multipliers for the various technologies are not specific to construction, manufacturing, or operating and maintenance, our estimates are tied to each ton of international CDR deployed in the Global South within a specific period. We considered the influence of regional differences in labor intensities in our calculations based on regional job multipliers from Ram et al.[44] Job gains in the Global South are estimated as the volume of CRCs exported by each country multiplied by the employment multipliers for the corresponding CDR technologies deployed domestically and the product is multiplied by labor intensity of the specific country. Conversely, job losses in the Global North are estimated as forgone employment opportunities: if CDR obligations were fulfilled domestically, additional jobs would be created. When these obligations are instead met through imports of CRCs, those domestic employment gains are not realized and are considered as job losses. We quantify this as the volume of CRCs imported by each Global North country multiplied by their corresponding employment multipliers for the relevant CDR technologies, and the product is multiplied by labor intensity of the specific country.

(d) Percent change in GDP and labor wages under CDR trade relative to no CDR trade by 2060. Central Ame C.: Central America and Caribbean; South Ame N. or SAN: South America_Northern; South Ame S. or SAS: South America_Southern; EFTA: European Free Trade Association; SEA: Southeast Asia

Risks to food, energy, and water security

As international CDR deployment and economic activity expand in the Global South, driven by financial transfers from the Global North, total resource demand across the energy, land, and water sectors is projected to rise. In the primary energy sector, biomass and natural gas consumption are expected to increase by 16.2% and 7.4%, respectively, by 2060—mainly to support BECCS and natural gas-powered DACCS facilities located in the Global South but owned by entities in the Global North (**Extended Data Figure 3a**). On the end-use side, electricity demand rises by 3.4% by 2060, driven by the operation of electricity-based DACCS and increased lifestyle-related energy use, especially in the buildings sector. Indirect electrification via hydrogen also grows by 7.8%, particularly to support the decarbonization of hard-to-abate sectors [46]. Natural gas consumption grows by 16%, both to support these difficult-to-electrify sectors and to power natural gas-based DACCS systems (**Extended Data Figure 3b**).

Rising biomass demand for BECCS leads to an expansion of biomass cropland by 5.2% by 2060 (**Extended Data Figure 3c**). This expansion displaces other land uses, reducing land for food crops by 0.2%, grasslands and shrubs by 0.3%, and forests by 0.2%. Meanwhile, increased energy demand and economic activity drive up water consumption, particularly for DACCS operations (76.8%), bioelectricity CCS plant cooling (34.7%), biomass irrigation (6%), and hydrogen production and delivery (4.7%) by 2060 (Extended Data Figure **Figure 3d**).

While energy demand rises and land use changes accelerate (**Extended Data Figure 3**), the energy and food security of CRC-exporting regions may become increasingly vulnerable (**Figure 5**). By 2100, biomass consumption in the Global South is projected to increase by 26.7%, requiring a 6% rise in domestic production. However, this growth will not be sufficient to meet demand, resulting in a 30% increase in biomass imports and a 7.4% decline in exports. A similar pattern is observed in the natural gas demand and supply (**Figure 5a**).

It is important to note that the resulting impact on food security is less severe because the expansion of biomass cropland occurs primarily at the expense of other land types such as grasslands, forests, pastures, other arable lands, and shrubs, rather than food croplands (**Extended Data Figure 3c**). Nonetheless, domestic consumption of beef, wheat, and legumes grow by 1.2%, 0.1%, and 0.3%, respectively. But reductions in food cropland and pasture land—due to the expansion of biomass cropland—limit domestic production. As a result, imports of beef, wheat, and legumes are projected to increase by 1.3%, 0.6%, and 1.2%, respectively (**Figure 5b**).

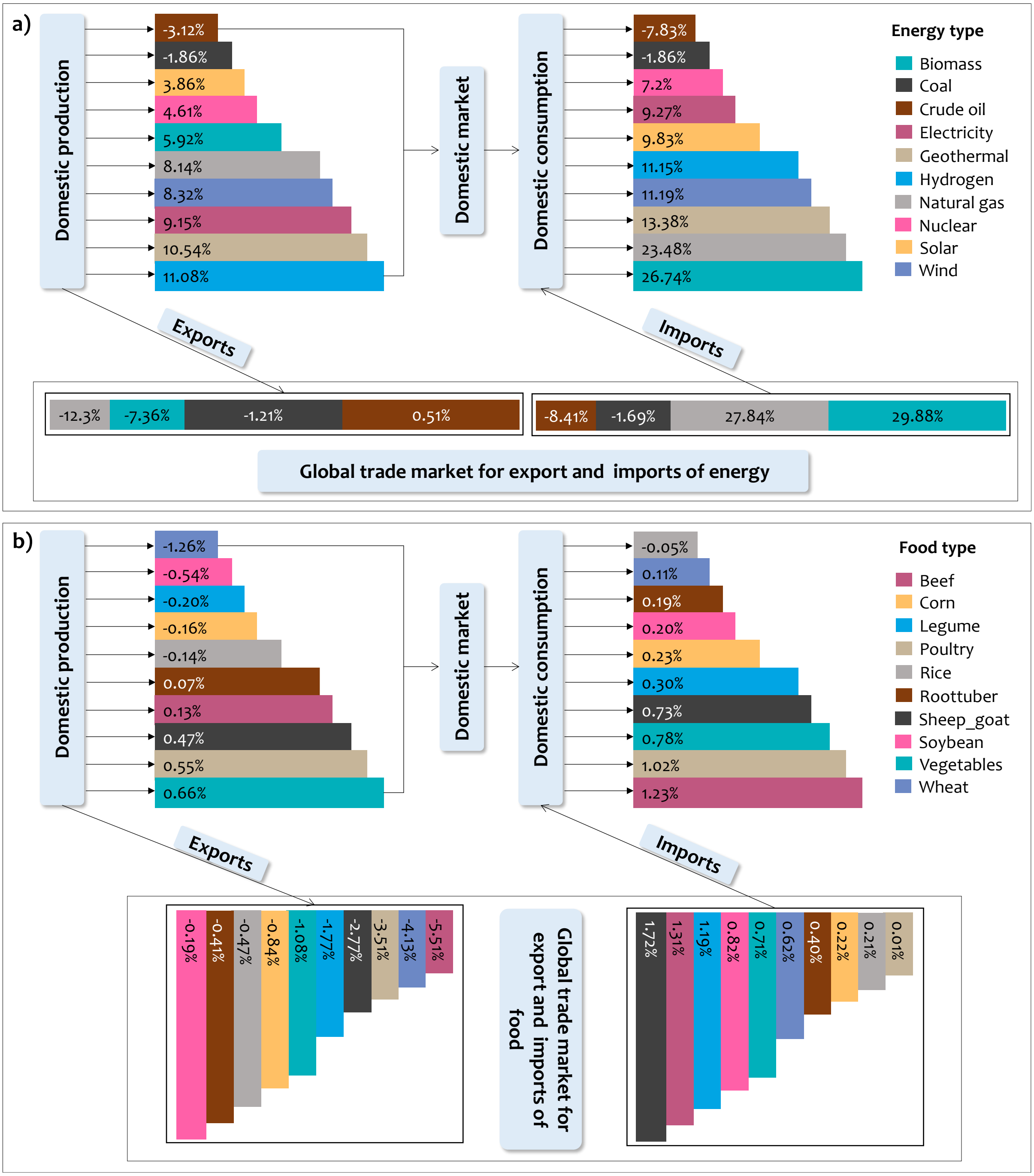


Fig. 5 Impact of CDR trade on food and energy supply in the Global South.

Results show the annual percent change in food and energy supply and demand in 2100 under a CDR trade scenario, relative to a no-trade baseline. The results here is solely based on Global South countries and regions projected to have CDR export capacity by 2100, including Latin America and the Caribbean, China, Central Asia, Southeast Asia, Pakistan, and Africa_Eastern. Panel (a) presents changes in domestic energy demand, production, exports, and imports, while panel (b) shows the same for food commodities. It is important to note that in some cases, imports may increase even when domestic consumption declines. For instance, rice imports grow despite a reduction in consumption, because consumption does not fall to zero, and insufficient domestic supply necessitates continued imports. In the energy sector, domestic solar production refers to distributed solar *resources, and nuclear production reflects enriched uranium. Due to model limitations, interregional trade of hydrogen and electricity is not represented; therefore, import and export bars are not shown for these commodities, as well as for geothermal, nuclear, solar, and wind energy, where export and import is not applicable. Height/length of bars are for ranking and not drawn to scale – hence, the figure is simply a mixture of conceptual qualitative schematic with actual quantified impacts*

Strategies to manage sustainability trade-offs associated with CDR trade

The environmental and sustainability risks associated with CDR exports from the Global South may be difficult to avoid entirely, but they can be managed if a careful balance is achieved between economic growth and the sustainable use and conservation of resources. Several strategies could support this goal (see Discussion), but a key priority is to ensure that future global CDR requirements remain within scientifically defined sustainable limits. Recent studies estimate sustainable CDR deployment at 6.6–8.9 $GtCO_2$ per year by 2050 [6,47], while Deprez et al.[34] suggest that annual BECCS deployment should not exceed 2.8 $GtCO_2$ per year to remain within a medium-risk threshold, accounting for biodiversity, water availability, and food production. In contrast, the CDR trade flows modeled in our analysis exceed these sustainability boundaries. In the 1.5°C pathway where CDR trade occurs, total global CDR deployment reaches 16.5 $GtCO_2$ per year by 2050, including 11.8 $GtCO_2$ per year from BECCS alone.

If the world proceeds with large-scale CDR trade, it is essential to respect these planetary boundaries, especially in relation to BECCS and overall CDR levels. This would require intensified decarbonization efforts, particularly in sectors that are relatively easier to decarbonize, and reserving CDR primarily for critical functions such as offsetting hard-to-abate residual emissions and addressing temporary overshoot [33]. While this approach would likely reduce the economic benefits the Global South could gain from CDR exports and increase the cost of meeting global climate targets, it would also reduce pressure on exporting regions and help manage trade-offs related to energy and food security.

Discussion

This study explores the transformative potential of interregional CDR trade in advancing global climate goals while addressing critical socio-economic challenges. Here we find that CDR trade could help address the global mismatch between equitable CDR contributions and domestic capacities to fulfil them [14], creating vast economic opportunities. Specifically, without contributions from the Global South, up to 5 $GtCO_2$ per year of required CDR could remain unmet by mid-century if the Global North pursues cost-effective removals within its own borders. Through CRC sales, the Global South is projected to generate US$3.1 trillion annually in financial transfers and create 17 million CDR-related jobs by 2060. An additional key insight from our study is that enabling CDR exports accelerates the phase-out of coal and oil in the Global South, although this is partially offset by increased natural gas consumption. However, a key concern emerging from our results is the food and energy security risks facing Global South countries as they scale up CDR exports. While reducing global reliance on CDR and prioritizing rapid decarbonization to reserve CDR for hard-to-abate residual emissions and temporary overshoot [9] could lessen these risks, further policy measures are needed to minimize resource pressures.

First, diversifying the CDR technology portfolio is essential. Our sensitivity analysis (Supplementary Discussion 1, Extended Data Figure 4) reveals that relying solely on BECCS to meet export demands exacerbates trade-offs related to land, water, and food systems compared to using a mix of technologies. This confirms previous findings that have identified significant sustainability risks associated with large-scale BECCS deployment [11,25,34,48,49]. Diversifying CDR approaches enables exporting regions to reduce their reliance on biomass, thereby lowering risks to food security and biodiversity. Secondly, the affordability and accessibility of renewable energy sources such as solar and wind will be critical in reducing the resource intensity of DACCS deployment [50]. Expanding the use of clean energy would allow these regions to meet growing CDR demand without undermining domestic energy security through continued dependence on fossil-fuel-based electricity or natural gas-powered DACCS. Third, despite the financial incentives, regions should not be allowed to export unlimited amounts of CDR if doing so undermines local food and energy security. Export volumes should be capped based on domestic sustainability thresholds, similar to how the US government regulates electricity exports, which are permitted only after meeting domestic needs [51]. Applying this principle to CDR would institutionalize sustainability safeguards while still enabling Global South countries to benefit economically from trade.

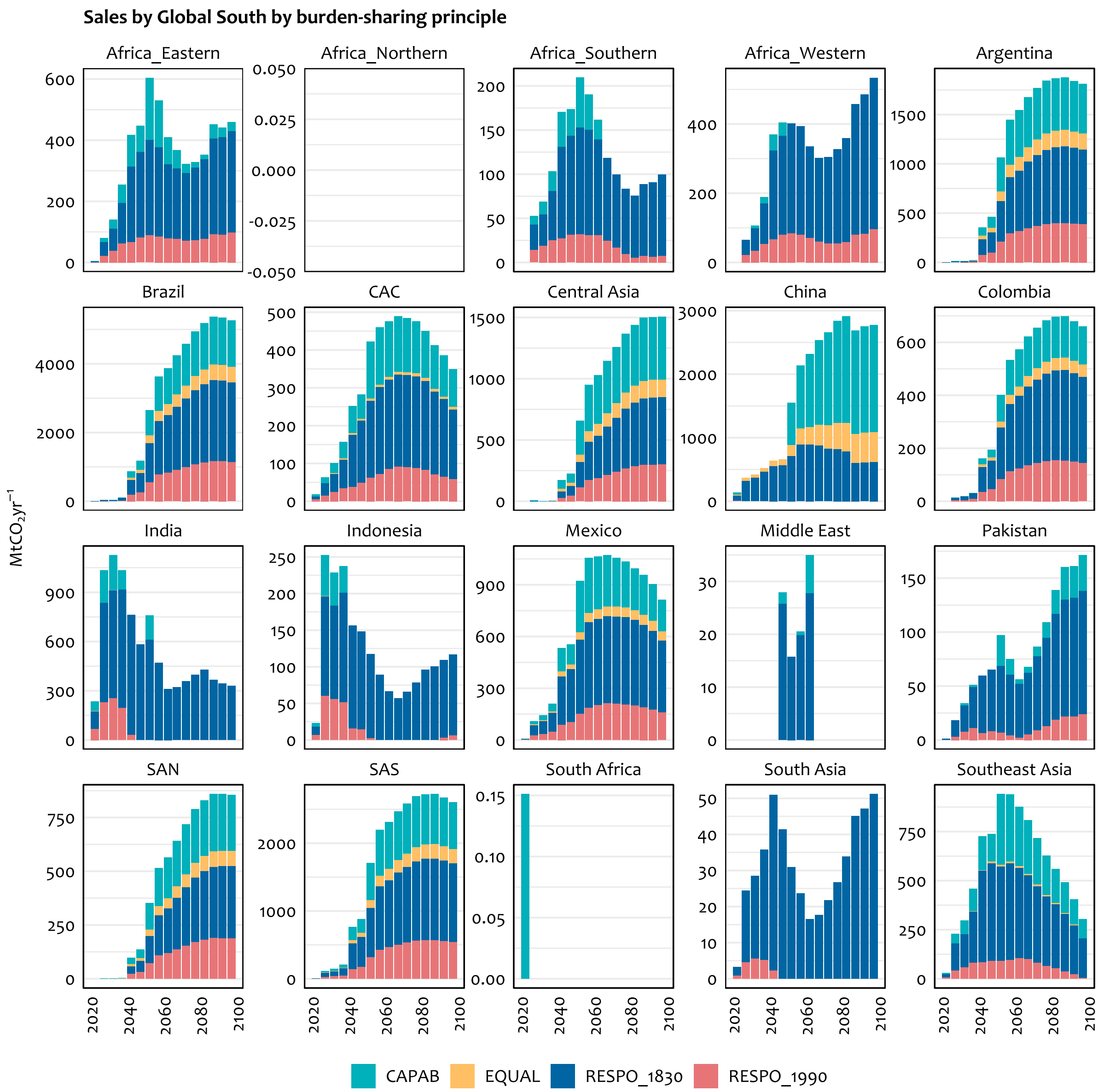
Beyond these resource-based trade-offs, several important governance and market design challenges require attention. The structure of bargaining power between buyers and sellers will strongly influence CDR pricing [32]. The Global North faces large CDR obligations but limited domestic capacity, which may give it leverage. At the same time, Global South exporters hold significant bargaining power due to their abundant biomass and storage resources [32]. An internationally coordinated pricing system involving both buyers and sellers may be needed to ensure transparency and fairness. Eligibility for participation in CDR markets also raises important questions. While this study focuses on Global South exporters under a corrective justice framing [36], surplus CDR capacity may emerge in countries such as Russia, the United States, and Australia. Initially, it may be appropriate to limit CDR sales to the Global South, but as countries like Australia, US or Russia develop surplus CDR capacity, their inclusion in the market should be managed carefully to ensure that the socio-economic benefits for the Global South are not undermined [36]. A phased approach to including new sellers, with appropriate safeguards, could help prevent market oversaturation and ensure fair compensation [52].

This study also adopts a market design that prevents mitigation deterrence [30,31,53]. CDR trade occurs in a separate market from global emission reduction markets, which ensures that neither importing nor exporting countries can substitute removals for domestic decarbonization. Each country follows a strict emissions reduction pathway derived from a cost-effective global 1.5°C scenario, with domestic mitigation targets fixed and not substitutable with traded removals. CDR trading is limited to bridging the capacity gap between equitable obligations and cost-effective domestic CDR capacity. As discussions continue on integrating CDR into compliance markets [26,54,55], the risk of mitigation deterrence may grow if not carefully addressed [53,56]. In such cases, reducing the total market cap to reflect expected CDR contributions would help maintain environmental integrity and ensure that emission reduction targets remain credible [53].

Several modeling uncertainties remain. Employment estimates rely on available labor multipliers, but actual job creation and losses across regions and technologies may vary. Improved empirical data on CDR workforce requirements would strengthen future assessments. Financial transfers in this study are valued using uniform global carbon prices, while real-world prices will likely vary depending on negotiations, resource costs, and market power. Future work should explore pricing structures that reflect these dynamics. This study also excludes LULUCF-based removals to focus on durable CDR approaches. Although this approach prioritizes permanence, future work could examine the role of high-quality, verifiable LULUCF credits, particularly as some countries aim to monetize forest-based offsets [57].

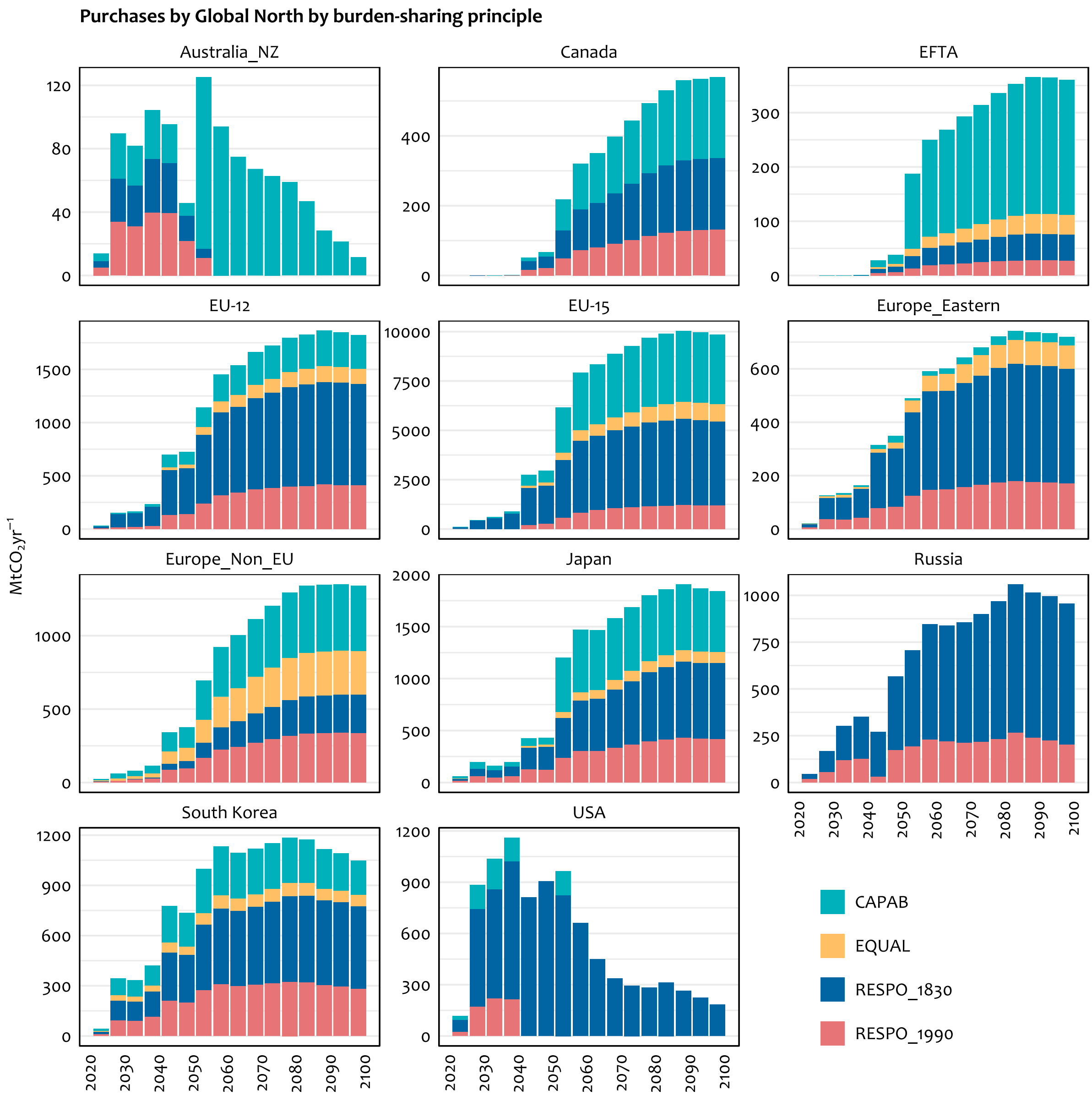
The results presented here offer an initial global quantification of both the opportunities and risks associated with large-scale CDR trade. As international carbon removal markets evolve, design elements such as market separation, eligibility rules, sustainability safeguards, and price governance will be critical to ensuring that CDR trade supports global climate ambition while safeguarding broader sustainability objectives.

Extended Data



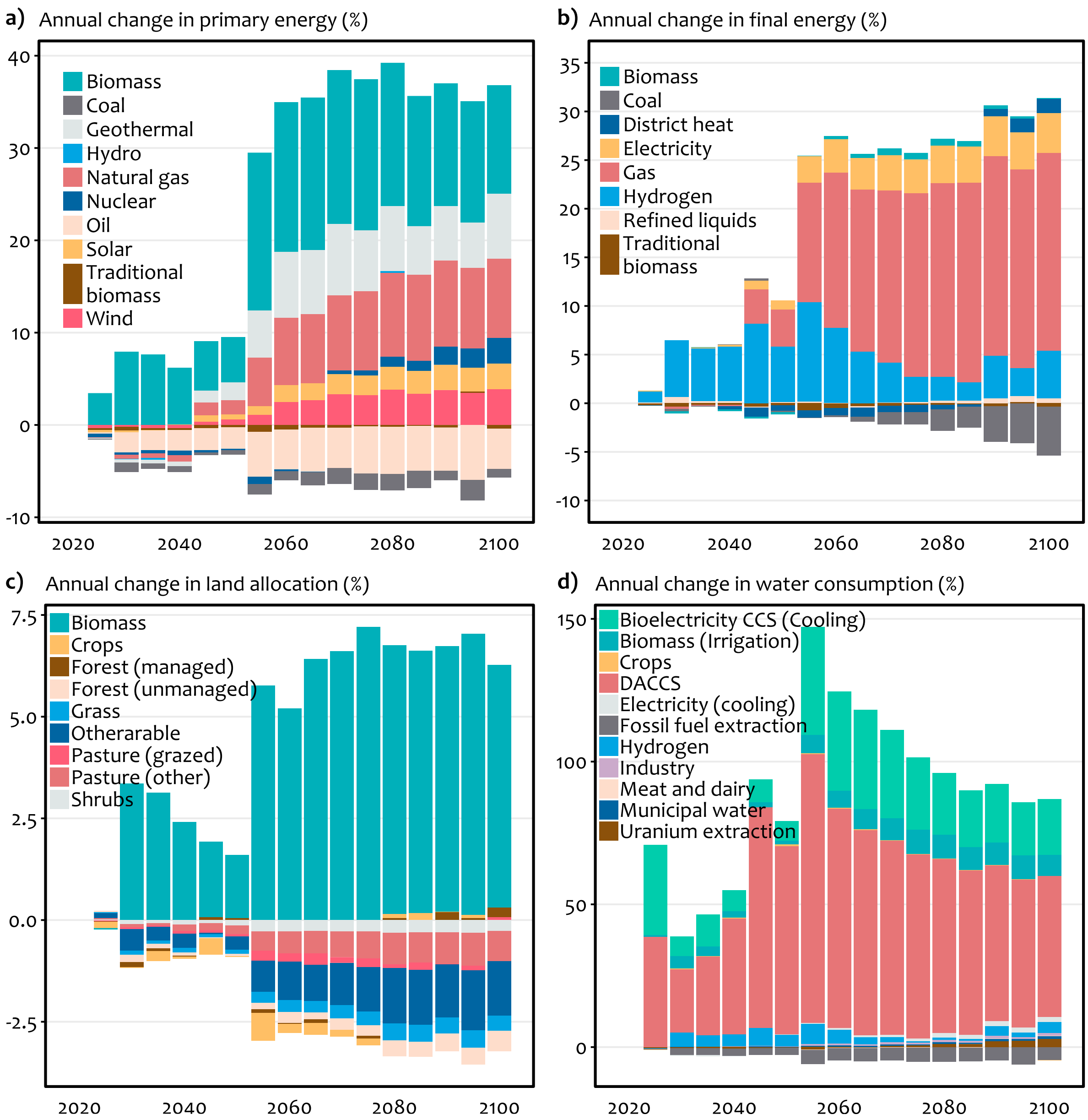
Extended Data Figure 1 Carbon removal credit sales by Global South according to type of burden-sharing principle.

CAC: Central America and Caribbean; SAS: South America_Southern; SAN: South America_Northern. RESPO_1830 refers to historical cumulative emissions starting from 1830, while RESPO_1990 starts from 1990



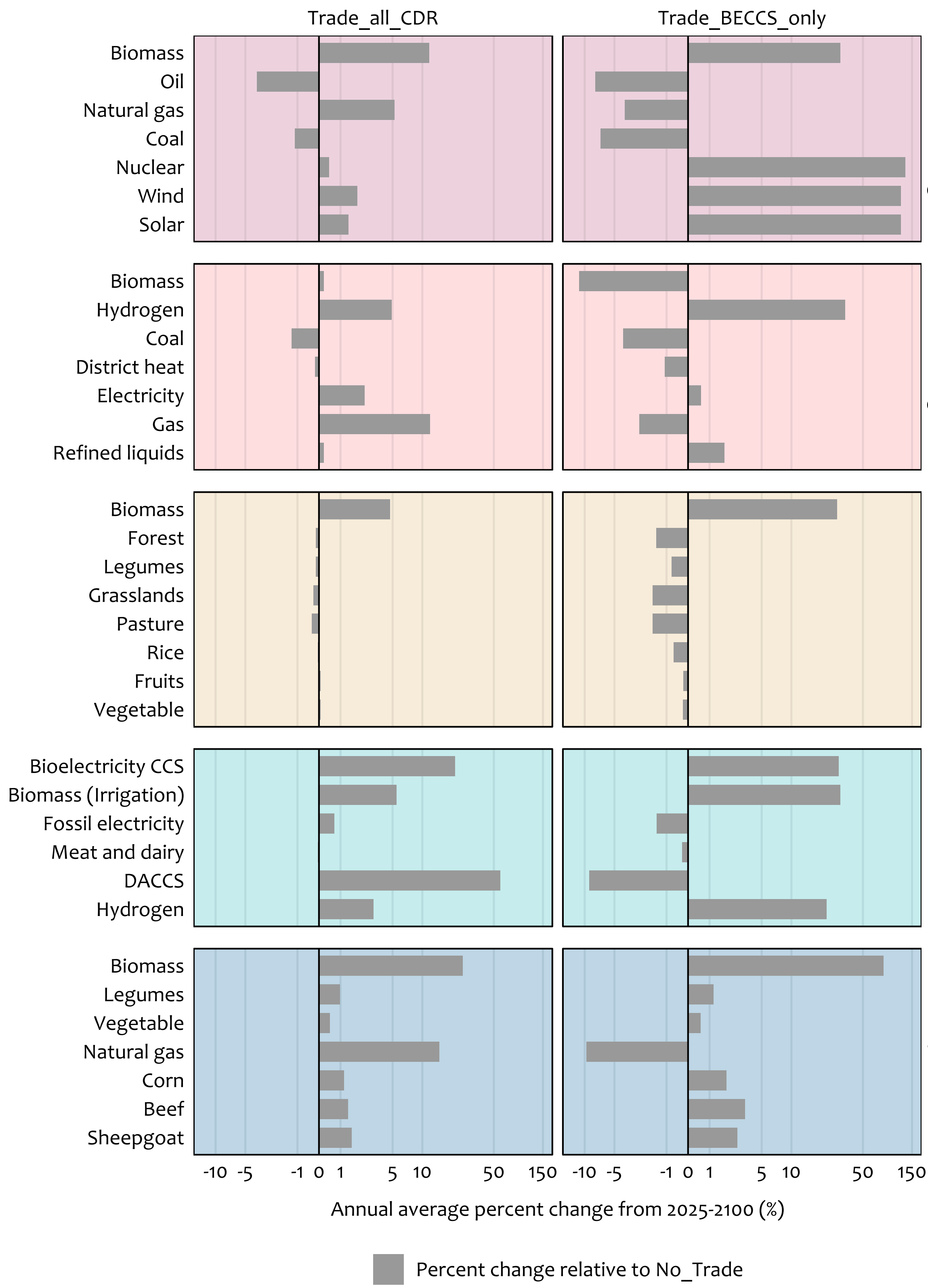
Extended Data Figure 2 Carbon removal credit purchases by Global North according to type of burden-sharing principle.

EFTA: European Free Trade Association. RESPO_1830 refers to historical cumulative emissions starting from 1830, while RESPO_1990 starts from 1990



Extended Data Figure 3 Impacts of international CDR trade on energy, land, and water consumption in the Global South.

(a) Annual percent change in primary energy consumption under the CDR trade scenario relative to the no trade scenario (b) Projected annual percent change in end-use sector energy consumption by fuel type. (c) Annual percent change in land use allocation. (d) Annual percent change in water consumption by different sectors. Refined liquids refers to liquids produce by oil refining or biomass liquids or gas to liquids or coal to liquids.



Extended Data Figure 4. Sensitivity analysis on technological option for CRC supply.

The figure shows how results differ when CRC demand by Global North is met by BECCS+ERW+DACCS (Trade_all_CDR) or solely via BECCS (Trade_BECCS_only) in the Global South and both are relative to a no CDR trade scenario. Percent changes are based on annual averages from 2025-2100 (See Supplementary Discussion 1 for detailed discussion of sensitivity analysis)

Methods

Updates to GCAM

To achieve the objectives of this study, we utilized our modified version of GCAM 7.0, known as GCAM-TJU. We developed into GCAM-TJU, CDR trading capabilities which follows exactly the steps highlighted in subsequent subsections. GCAM-TJU is particularly well-suited for our research due to its enhanced capability to isolate CDR technologies and explicitly model carbon removal policies. This contrasts with the traditional constraint or ceiling-based approach in the core GCAM model, where meeting an emissions constraint is considered successful as long as it is not exceeded—sometimes leading to outcomes that fall short of precisely achieving the intended target. Our version ensures that the model delivers the exact amount of carbon removal specified, making it more reliable for modeling fixed CDR obligations. Additionally, GCAM-TJU offers a way to design scenarios that eliminate the potential CDR trade and mitigation deterrence loophole. Specifically, in GCAM-TJU, CDR technologies and CO_2-emitting technologies are assigned separate emission tracking tags, which allows for CDR technologies to be excluded from the emission constraint. As such, emission reduction and emission removals are pursued in separate markets in our model, preventing any country from using CDR trade as an excuse to delay emission reduction. Additionally, in the core version of GCAM, negative emissions from BECCS technologies automatically count toward satisfying the emission constraint [58], which can lead to mitigation deterrence when high CDR pathways are pursued [25]. GCAM-TJU cancels out this effect – enabling high CDR pathways to be pursued by CDR-exporting regions without compromising their emission reduction efforts.

Determining cost-effective and equitable technological CDR allocation

To effectively implement CDR trading, it is crucial to establish the maximum volume of CDR that each region and country can feasibly achieve in a cost-effective manner, considering their local resource availability, and compare this to the CDR they are equitably obligated to perform based on fairness principles. In this context, cost-effective CDR refers to the endogenously determined CDR capacity allocated to each region within the model, reflecting the region's capacity to deploy CDR technologies using its available resources at the lowest possible cost. We model a 1.5°C-consistent pathway by targeting global net-zero GHG emissions by 2060, reaching net negative 7 $GtCO_2e$/yr in 2100. Under this framework, each region's endogenous CDR capacity is determined, resulting in a total global technological CDR deployment of 15 $GtCO_2$/year by 2050 and 30 $GtCO_2$/year by 2100. To ensure a fair distribution of the global CDR burden, this cost-effective deployment is reallocated across regions based on established equity principles. Three widely recognized burden-sharing principles (historical responsibility; ability to pay; and equal per capita) are adopted for this reallocation, consistent with existing equitable CDR allocation studies [14,15,17].

CDR trading rules

To ensure the integrity and sustainability of the CDR trading system, this study implements several key restrictions and safeguards. First, CDR credit sales and purchases are strictly limited to credits derived from durable CDR technologies due to the inherent risk of reversal associated with removals from LULUCF [59]. This exclusion maintains the permanence and credibility of traded CDR credits. Additionally, for the purpose of modeling and ensuring equitable participation, the world is divided into two major blocs: the Global North and the Global South (See Supplementary Figure 26). This division reflects existing disparities in economic capacity and resource availability, allowing for more targeted analysis of how CDR trade impacts different regions. For corrective justice in the distribution of CDR-related economic benefits [36]—such as job creation and GDP growth—we restrict CDR credit sales to Global South countries that have surplus CDR-enabling resources after fulfilling their own domestic CDR obligations. Conversely, CDR credit purchases are limited exclusively to Global North countries that lack sufficient domestic resources to meet their equitable CDR obligations. This structure ensures that financial transfers and economic benefits flow to resource-rich but economically constrained regions, supporting sustainable development while maintaining fairness in climate mitigation efforts.

We apply a set of eligibility rules for participation in the CDR trade market (Table 1): For Global North countries or regions, international CDR credits can only be purchased if their equitable CDR obligation in a given period exceeds their cost-effective CDR capacity in the same period. This condition ensures that only regions with legitimate resource constraints engage in CDR trade. If a Global North region has sufficient cost-effective CDR capacity to meet or exceed its equitable obligation, it is deemed capable of fulfilling its climate responsibility domestically and is excluded from the CDR market during that period. For Global South countries or regions, participation as a CDR credit seller is contingent upon their cost-effective CDR capacity exceeding their equitable CDR obligation. This surplus capacity indicates that the region has the means to engage in international CDR deployment without compromising its ability to meet domestic obligations. Conversely, if a Global South region's cost-effective CDR is less than or equal to its equitable obligation, it is ineligible to sell CDR credits, as it must prioritize fulfilling its own climate commitments before assisting other regions.

Once Global North regions with CDR deficits and Global South regions with CDR surpluses are identified, the deficit CDR amounts are systematically distributed among the surplus regions. This allocation is done proportionally, where regions with larger surplus capacities receive a greater share of the CDR demand relative to other surplus regions. Specifically, the amount of international CDR allocated to each selling region is proportional to the size of its surplus compared to the total surplus available among all eligible sellers. This proportional distribution ensures that no single region is overburdened and that the global CDR demand is met efficiently and fairly. This process effectively completes the CDR credit trading cycle for each period. Regions that are not involved in the trade market during a given period fulfill their entire equitable CDR obligations domestically. However, for regions participating in the market: Buyer regions (Global North) implement only their cost-effective CDR domestically, which is also their equitable CDR obligation minus the deficit that has been offset through purchased credits. This allows them to avoid pursuing high-cost domestic CDR options while still meeting their overall obligations. Seller regions (Global South) carry out their own equitable CDR obligations and additionally fulfill the deficit CDR purchased by buyers. This means sellers undertake a combined CDR effort equal to their own equitable share plus the allocated share of the buyers' deficit.

Monetizing CDR credits traded, job potential, and macro-economic analysis

The CDR quantities traded through the deficit-surplus mechanism are formalized as CDR credits, with each credit representing the removal of one ton of CO_2. These credits are then monetized using the marginal abatement cost of carbon, consistent with limiting global warming to 1.5°C, based on the 50th percentile estimates from the IPCC AR6 report (Supplementary Figure 27) [47]. This monetization strategy aligns with the approach employed by Fanning and Hickel [52], where countries exceeding their fair-share carbon budgets compensate those that remain within their limits through financial transfers. Although the price of CDR credits could have been derived from the buyers' or sellers' perspectives, we opted to use the IPCC marginal abatement cost of carbon due to the current absence of a globally standardized market price for purchasing and selling CDR credits. The nascent state of the CDR market and the lack of a universally agreed-upon valuation make the marginal abatement cost a robust and scientifically grounded proxy for valuing traded CDR credits.

In assessing the job impacts of CDR trade, it is important to recognize that the technological CDR sector is still in its early stages of development. Unlike more established sectors such as renewable energy, where extensive research has quantified job creation potentials, the literature on CDR-related jobs remains limited. Nevertheless, emerging studies have begun to estimate the job intensities associated with various CDR technologies[60–63]. This study adopts those available job intensity estimates to quantify the job potential linked to CDR trade, while acknowledging the inherent uncertainty due to the lack of comprehensive field data on CDR-specific job creation. Supplementary Table 2 provides a detailed summary of the job intensities applied for each CDR technology used in this study. These intensities offer a basis for estimating the potential number of jobs generated in Global South regions as they scale up CDR deployment to meet both domestic and international CDR demand. Since the job multipliers for the various technologies are not specific to construction, manufacturing, or operating and maintenance, our estimates are tied to each ton of international CDR deployed in the Global South within a specific period. GCAM 7's macro-economic model[45] is used in our modified version of the model to estimate labor wages, value-added, and gross output.

Avoiding CDR trade and mitigation deterrence loophole

If transnational CDR trading policies are poorly designed or inaccurately modeled, they can give rise to mitigation deterrence. If Global North countries are allowed to meet their equitable CDR obligations affordably by purchasing CDR credits from abroad, they may be disincentivized to reduce their own emissions. These countries could continue to generate wealth through cheap fossil fuels, opting to spend a small portion of that wealth on foreign CDR credits instead of investing in domestic emissions reductions or in the deployment of costly domestic CDR infrastructure. This reliance on purchasing removal credits becomes especially appealing when domestic CDR deployment is more expensive due to limited local resources, stricter regulations, or higher operational costs. Such a dynamic risks allowing wealthier countries to delay meaningful decarbonization while transferring the responsibility for carbon removal to regions in the Global South with abundant and cheaper CDR-enabling resources.

To prevent this loophole, a well-structured CDR trading system must be designed so that it does not deter domestic emission reductions. Countries should continue pursuing their emission reduction commitments independently, with CDR trading serving solely as a cost-effective mechanism to meet their equitable CDR obligations. In other words, CDR trade should complement, not replace, domestic climate action. To ensure this integrity, we designed our model to separate CDR trading from countries' emission reduction pathways. Specifically, we structured the model to operate under two distinct markets: 1. A market dedicated to meeting CDR targets—focused on fulfilling equitable carbon removal obligations through domestic or international CDR deployment. 2. A separate market for managing gross fossil fuel and industry (FFI CO_2) emissions—targeting direct emissions reductions in the energy and industrial sectors. This separation ensures that CDR trading does not interfere with countries' efforts to reduce their own gross emissions in critical sectors. Countries must continue decarbonizing their domestic energy systems and industries while leveraging CDR trade solely to bridge the gap between their cost-effective and equitable CDR commitments.

Limitations with study design and assumptions

One of the main limitations is our use of a uniform global CDR price to value financial transfers for all countries. In reality, there could be significant regional variations in the price of CDR, driven by factors such as local resource availability, technological readiness, and economic conditions. A critical question arises: should CDR be traded based on the price of the seller or the buyer? Which side should hold more bargaining power in such a trade? This is usually determined by buyer's willingness to pay but Jagu Schippers et al.[32] find that it is not that straighforward. Both groups, ie., (1) regions with minimal historical responsibility towards climate change but abundant resources for CDR implementation (exemplified by Global South in this study); and (2) regions with limited domestic resources amidst large CDR targets (represented by Global North here) have considerable bargaining power. Additionally, while we have relied on general labor requirements estimates for CDR project found in the literature [60–63], the actual job intensity associated with different CDR technologies is likely to vary by region. More data on labor requirements for different types of CDR proejcts in different regions would allow for a more accurate assessment of the job potential associated with CDR trade.

Also, in our current framework, we excluded LULUCF credits to focus solely on durable removal credits. This decision resulted in some Global South countries playing a relatively smaller role in the CDR trade market. However, some countries are indeed planning to sell offsets from forest projects to high-emitting countries [57]. If the monitoring and verification of such projects could be strengthened to ensure the sale of high-quality durable offsets, it would be worthwhile to explore the additional economic gains and trade-offs associated with LULUCF credits in the market.

Moreover, our study was designed under corrective justice in carbon removal benefits [36], limiting CDR sales to Global South countries. However, in the long term, well-endowed countries like the Russia, the US and Australia could also accumulate surplus CDR capacity and could play a key role as sellers in the market. Future research could explore a more inclusive market structure, where countries are entitled to sell CDR credits as long as they have additional capacity beyond their historical obligations.

Code and Data Availability

GCAM is an open-source community model available at https://github.com/JGCRI/gcam-core/releases. Input files for GCAM-TJU used in this work will be made available in a public GitHub repository upon publication.

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Competing Interests

The authors declare no competing interests.

Contributions

J.D.A, C.J., H.L., H.M., Y.O., conceived the study. J.D.A and H.M., conceived the scenario designs. J.D.A. developed the CDR trade framework in the model. H.M., P.K. and J.F. contributed to modeling tools. J.D.A modelled all scenarios. J.D.A., S.A., H.A., R.W.A, and X.Z. performed data analysis while J.D.A and S.A. created the figures. M.Y., Z.G., Z.X., H.L., C.J., supervised the research. J.D.A wrote the original and final manuscripts with input and feedback from J.R., C.J., H.L., Z.G., R.W.A., J.F., Y.O., D.M., D.T.H., H.M.

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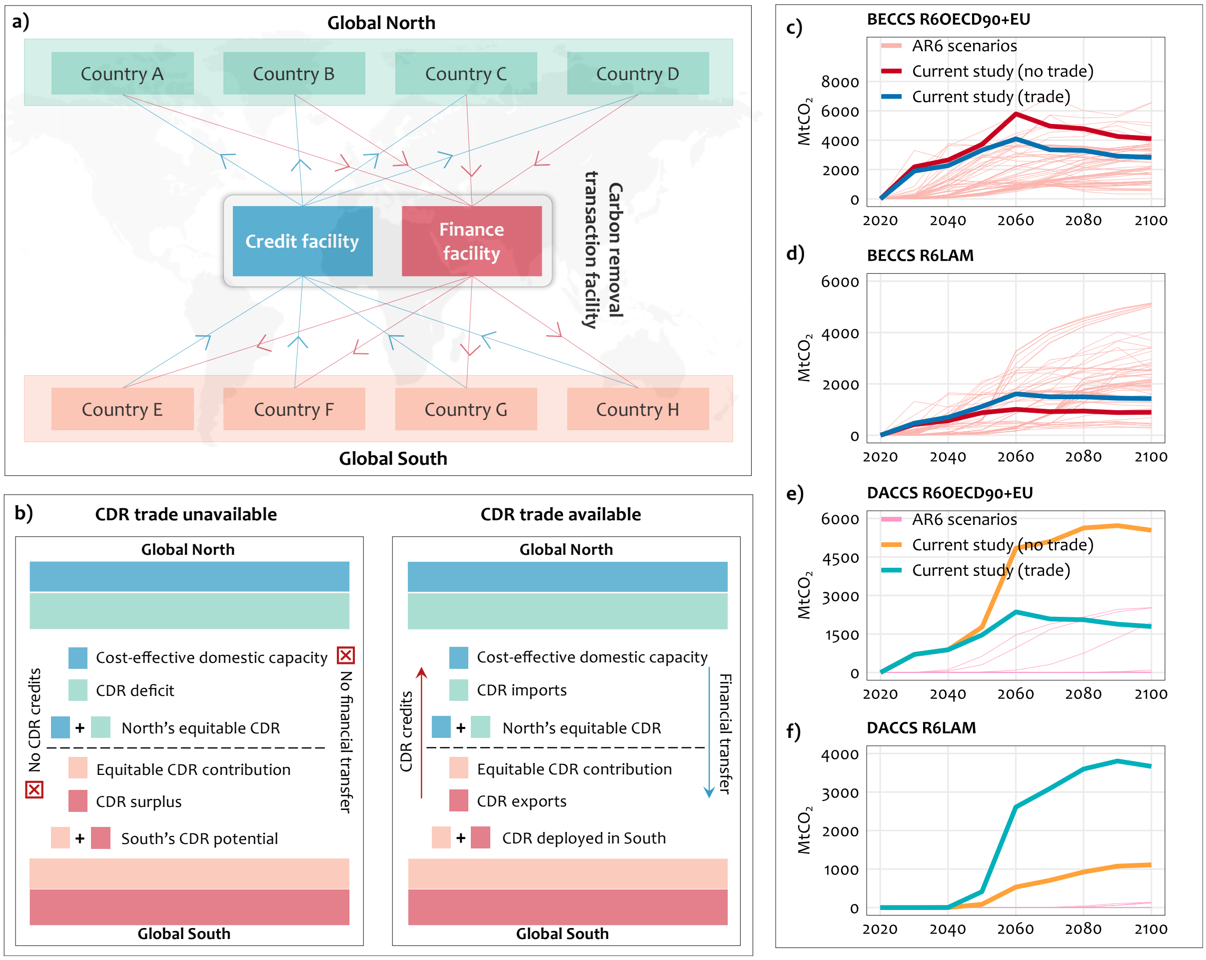
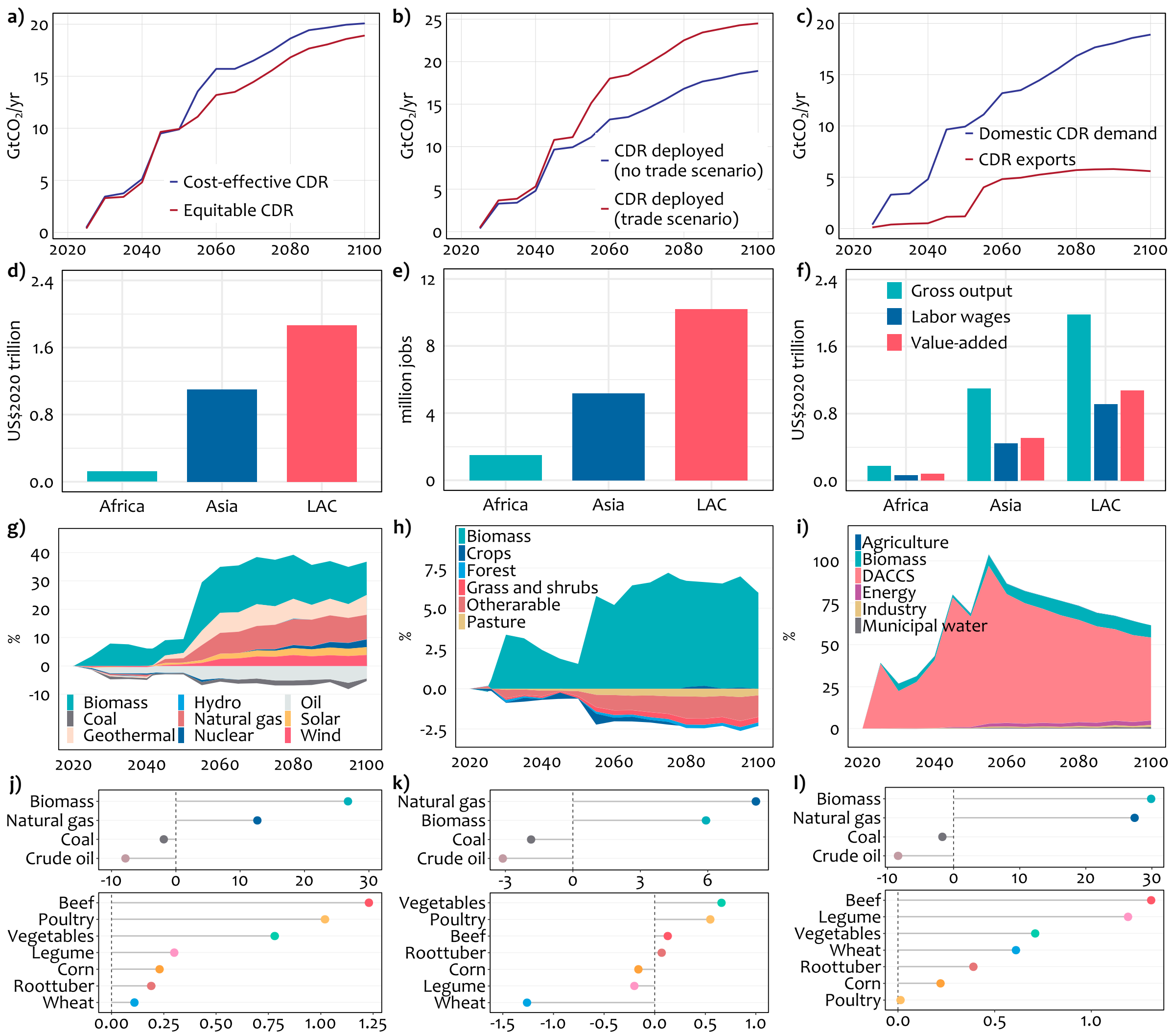
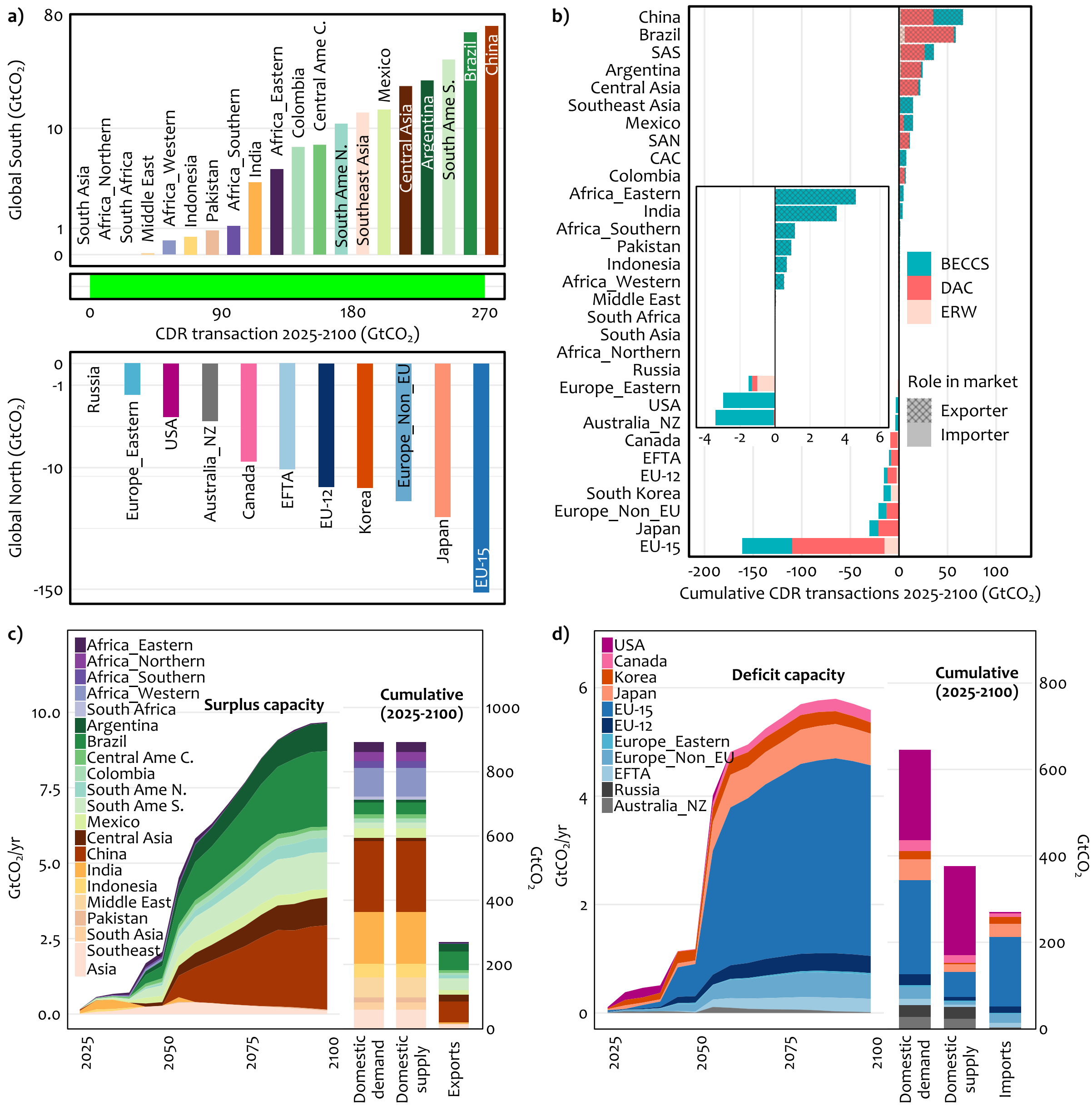
FIGURES

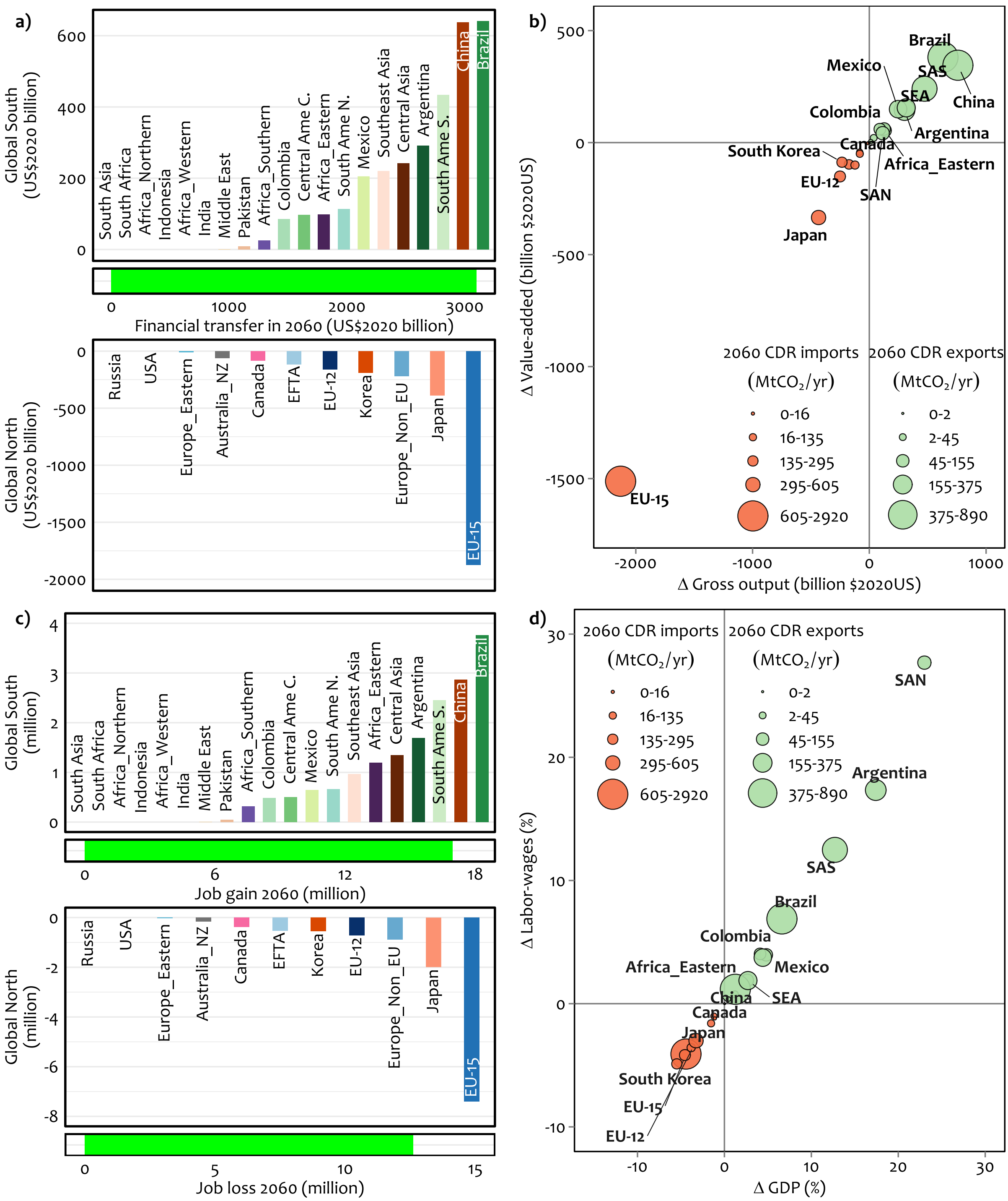


a)
Global North
Country A
Country B
Country C
Country D
Credit facility
Finance facility
Carbon removal transaction facility
Country E
Country F
Country G
Country H
Global South
b)
CDR trade unavailable
Global North
Cost-effective domestic capacity
CDR deficit
North's equitable CDR
No CDR credits
No financial transfer
Equitable CDR contribution
CDR surplus
South's CDR potential
Global South
CDR trade available
Global North
Cost-effective domestic capacity
CDR imports
North's equitable CDR
CDR credits
Financial transfer
Equitable CDR contribution
CDR exports
CDR deployed in South
Global South
c)
BECCS R6OECD90+EU
AR6 scenarios
Current study (no trade)
Current study (trade)
MtCO$_2$
8000
6000
4000
2000
0
2020
2040
2060
2080
2100
d)
BECCS R6LAM
MtCO$_2$
6000
4000
2000
0
2020
2040
2060
2080
2100
e)
DACCS R6OECD90+EU
AR6 scenarios
Current study (no trade)
Current study (trade)
MtCO$_2$
6000
4500
3000
1500
0
2020
2040
2060
2080
2100
f)
DACCS R6LAM
MtCO$_2$
4000
3000
2000
1000
0
2020
2040
2060
2080
2100

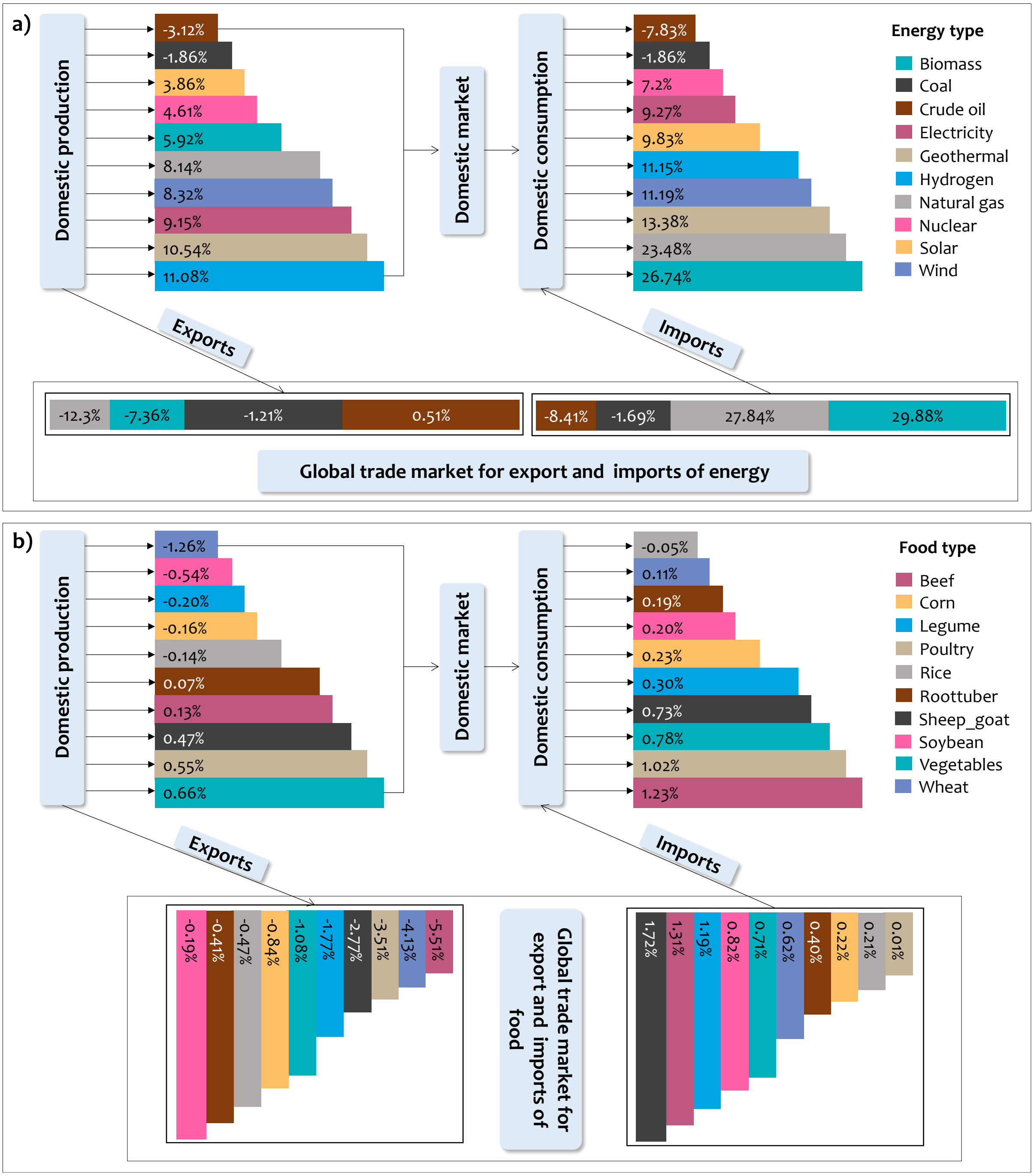


a)
GtCO2/yr
Cost-effective CDR
Equitable CDR
b)
CDR deployed (no trade scenario)
CDR deployed (trade scenario)
c)
Domestic CDR demand
CDR exports
d)
US$2020 trillion
Africa
Asia
LAC
e)
million jobs
f)
Gross output
Labor wages
Value-added
g)
%
Biomass
Coal
Geothermal
Hydro
Natural gas
Nuclear
Oil
Solar
Wind
h)
Biomass
Crops
Forest
Grass and shrubs
Otherarable
Pasture
i)
Agriculture
Biomass
DACCS
Energy
Industry
Municipal water
j)
Crude oil
Beef
Poultry
Vegetables
Legume
Corn
Roottuber
Wheat
k)
l)

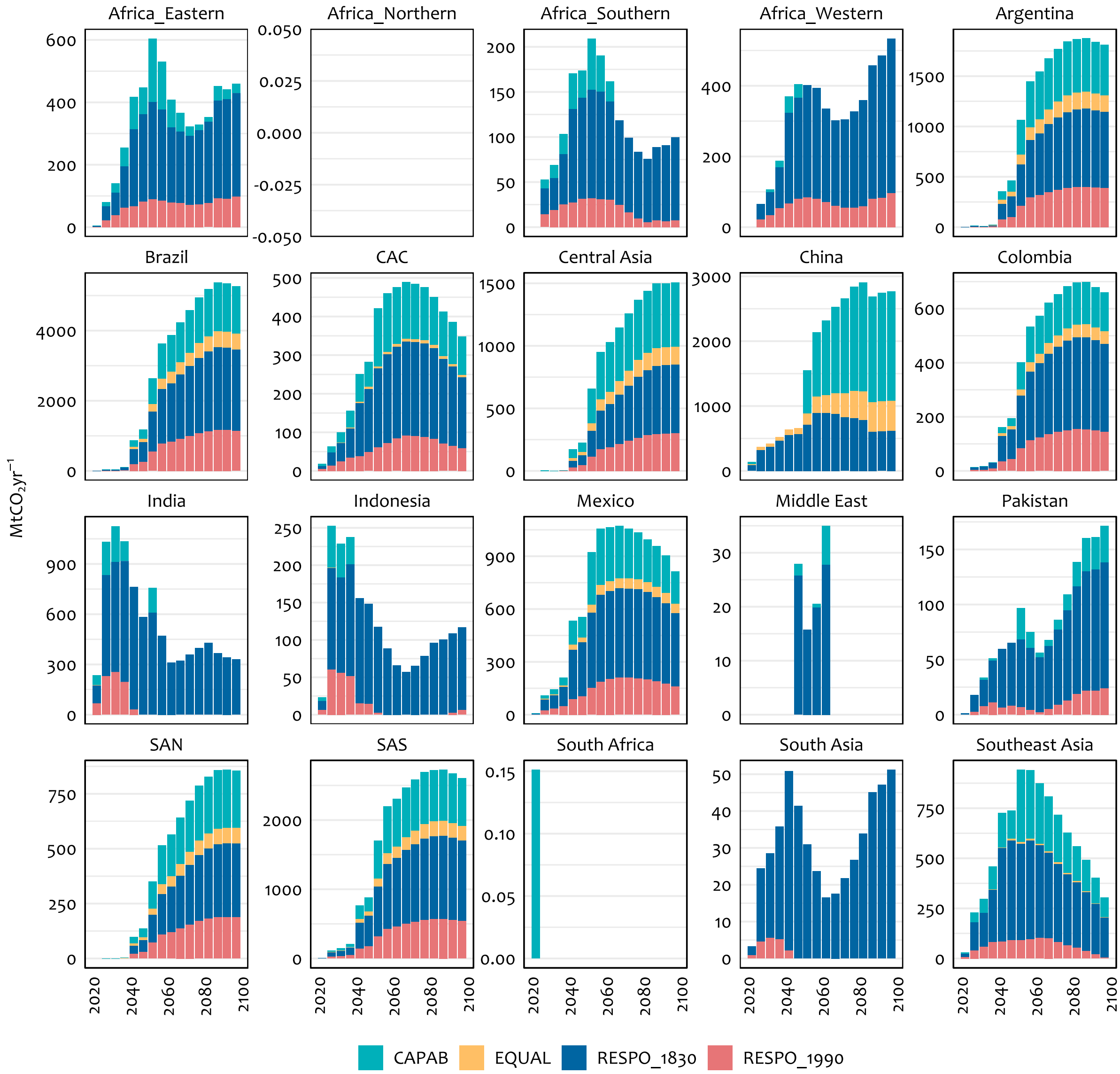

a)
Global South (GtCO$_2$)
South Asia
Africa_Northern
South Africa
Middle East
Africa_Western
Indonesia
Pakistan
Africa_Southern
India
Africa_Eastern
Colombia
Central Ame C.
South Ame N.
Southeast Asia
Mexico
Central Asia
Argentina
South Ame S.
Brazil
China
CDR transaction 2025-2100 (GtCO$_2$)
Global North (GtCO$_2$)
Russia
Europe_Eastern
USA
Australia_NZ
Canada
EFTA
EU-12
Korea
Europe_Non_EU
Japan
EU-15
b)
China
Brazil
SAS
Argentina
Central Asia
Southeast Asia
Mexico
SAN
CAC
Colombia
Africa_Eastern
India
Africa_Southern
Pakistan
Indonesia
Africa_Western
Middle East
South Africa
South Asia
Africa_Northern
Russia
Europe_Eastern
USA
Australia_NZ
Canada
EFTA
EU-12
South Korea
Europe_Non_EU
Japan
EU-15
BECCS
DAC
ERW
Role in market
Exporter
Importer
Cumulative CDR transactions 2025-2100 (GtCO$_2$)
c)
Surplus capacity
Cumulative (2025-2100)
Africa_Eastern
Africa_Northern
Africa_Southern
Africa_Western
South Africa
Argentina
Brazil
Central Ame C.
Colombia
South Ame N.
South Ame S.
Mexico
Central Asia
China
India
Indonesia
Middle East
Pakistan
South Asia
Southeast Asia
GtCO$_2$/yr
GtCO$_2$
Domestic demand
Domestic supply
Exports
d)
Deficit capacity
Cumulative (2025-2100)
USA
Canada
Korea
Japan
EU-15
EU-12
Europe_Eastern
Europe_Non_EU
EFTA
Russia
Australia_NZ
GtCO$_2$/yr
GtCO$_2$
Domestic demand
Domestic supply
Imports

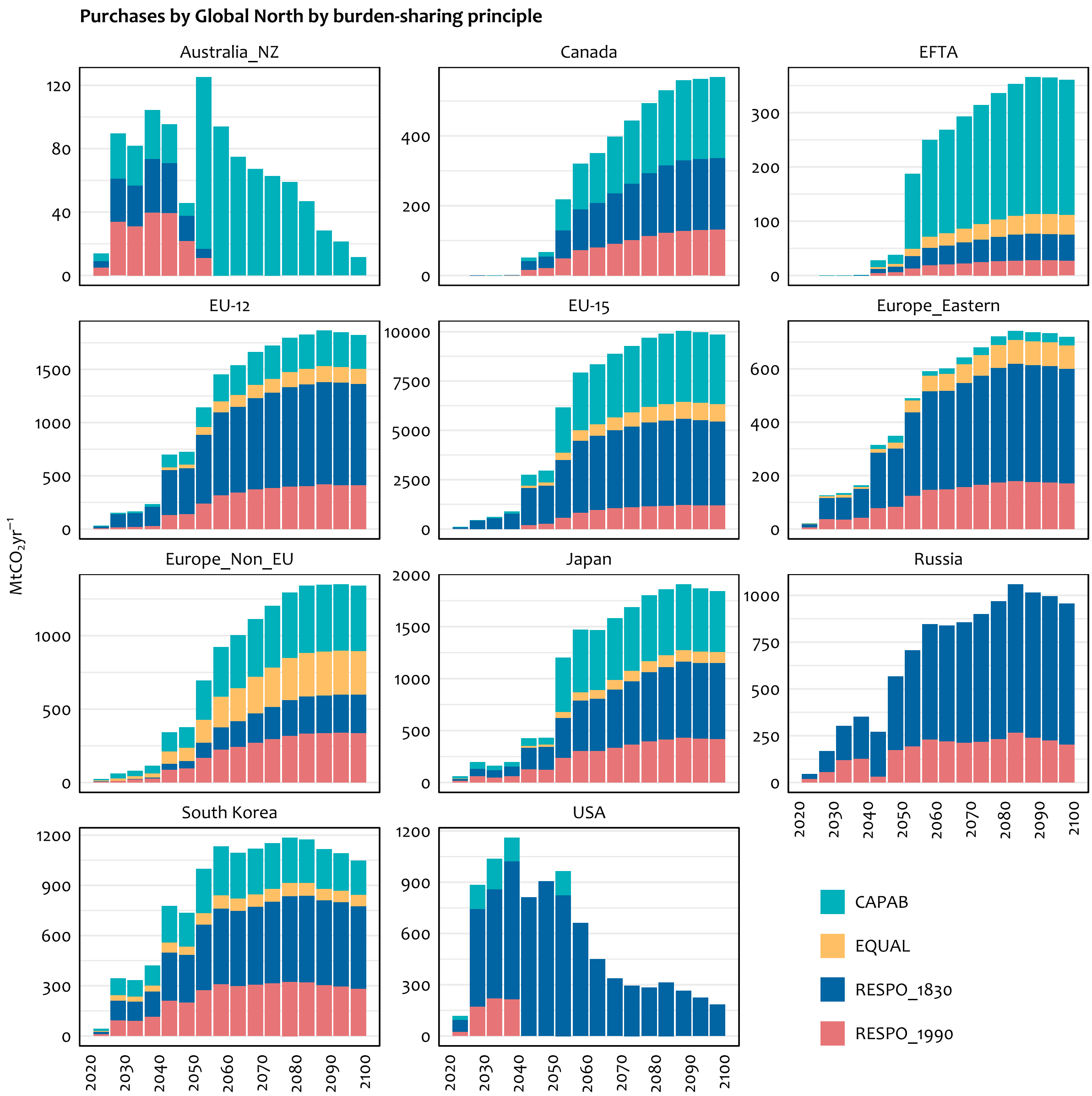


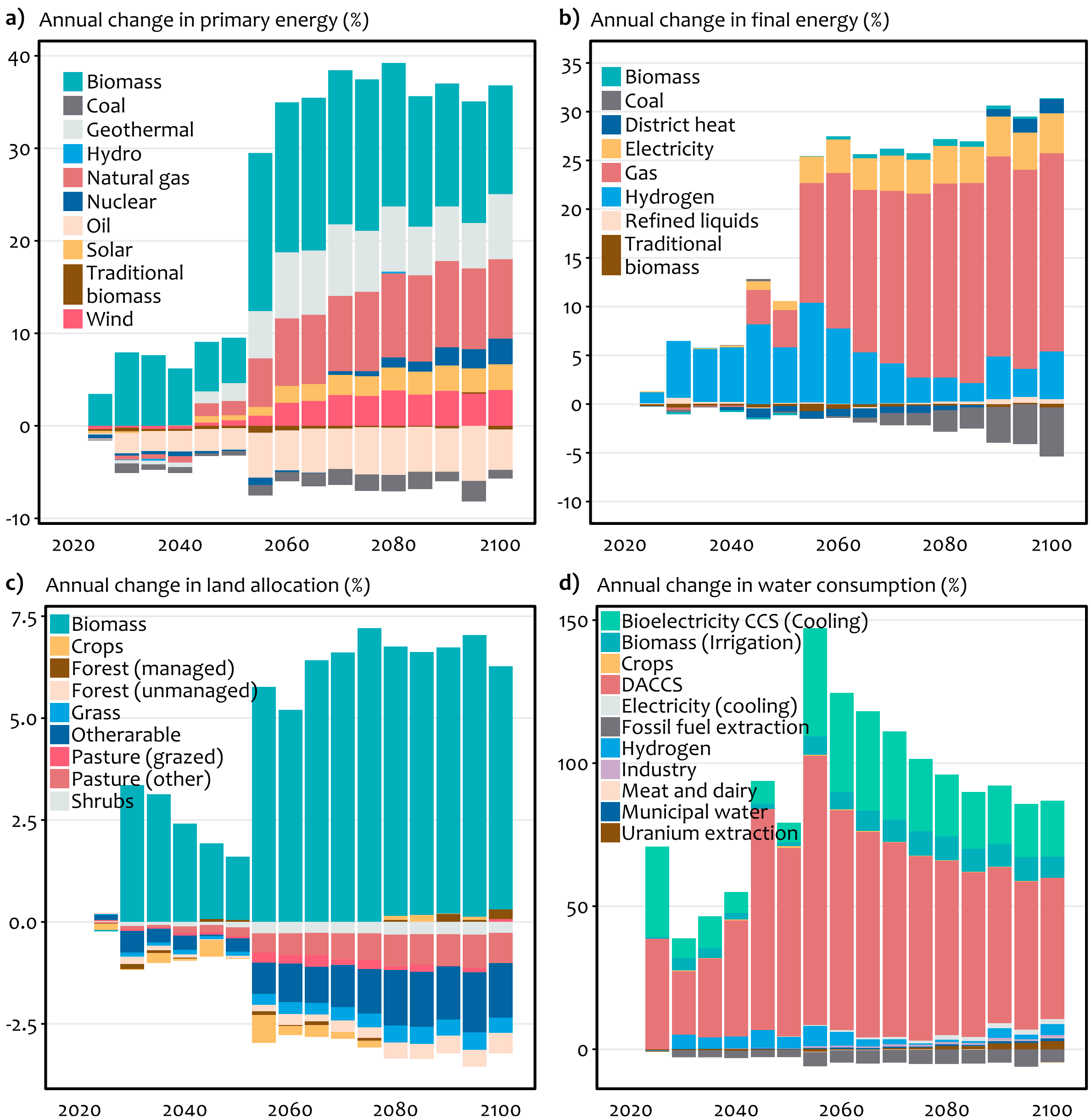
a)
Global South (US$2020 billion)
South Asia
South Africa
Africa_Northern
Indonesia
Africa_Western
India
Middle East
Pakistan
Africa_Southern
Colombia
Central Ame C.
Africa_Eastern
South Ame N.
Mexico
Southeast Asia
Central Asia
Argentina
South Ame S.
China
Brazil
Financial transfer in 2060 (US$2020 billion)
Global North (US$2020 billion)
Russia
USA
Europe_Eastern
Australia_NZ
Canada
EFTA
EU-12
Korea
Europe_Non_EU
Japan
EU-15
b)
Δ Value-added (billion $2020US)
Δ Gross output (billion $2020US)
2060 CDR imports (MtCO$_2$/yr)
0-16
16-135
135-295
295-605
605-2920
2060 CDR exports (MtCO$_2$/yr)
0-2
2-45
45-155
155-375
375-890
Brazil
Mexico
SAS
SEA
China
Colombia
Argentina
South Korea
Canada
Africa_Eastern
EU-12
SAN
Japan
EU-15
c)
Global South (million)
Job gain 2060 (million)
Global North (million)
Job loss 2060 (million)
d)
Δ Labor-wages (%)
Δ GDP (%)

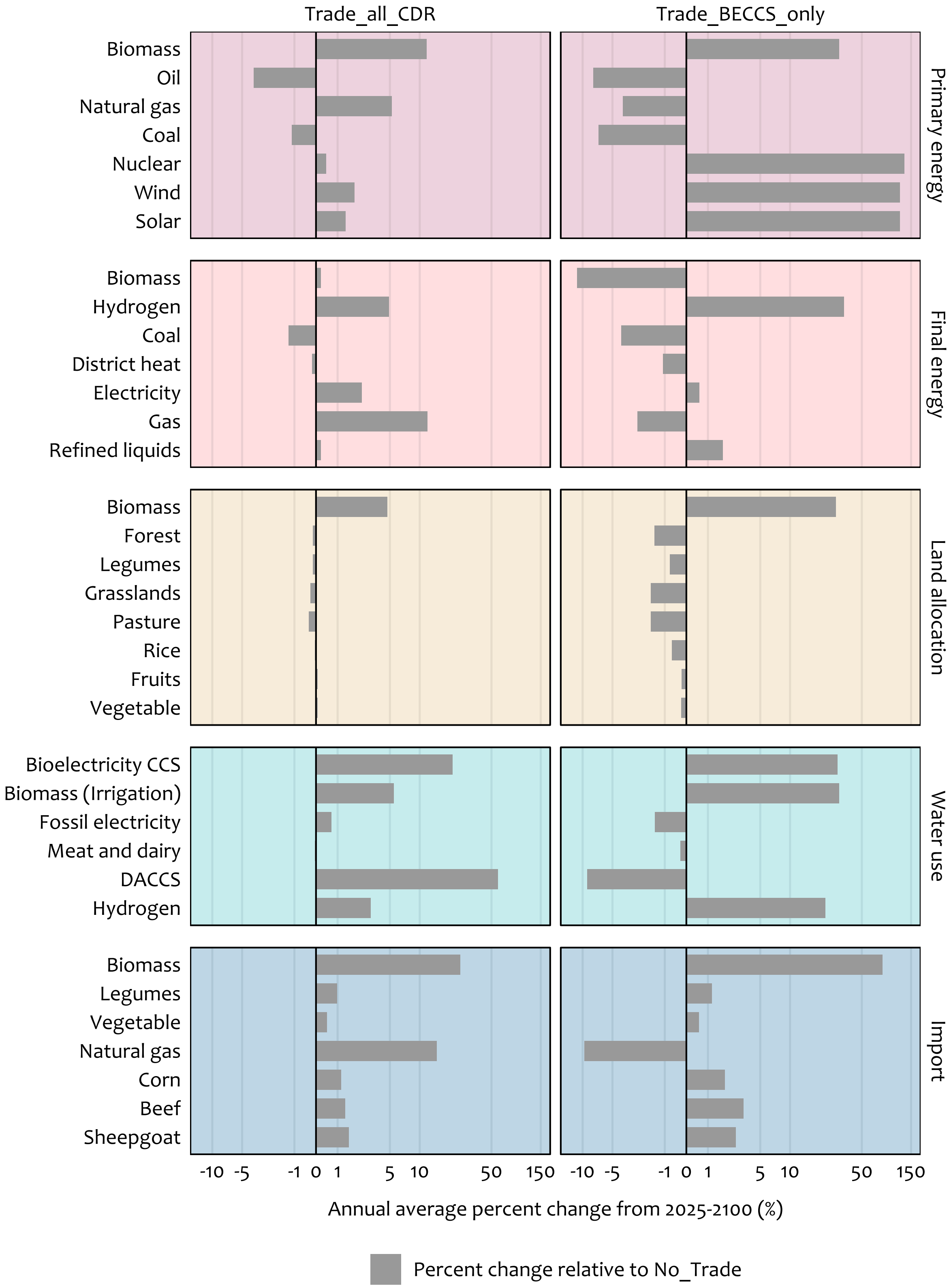

a)
Domestic production
-3.12%
-1.86%
3.86%
4.61%
5.92%
8.14%
8.32%
9.15%
10.54%
11.08%
Domestic market
Domestic consumption
-7.83%
-1.86%
7.2%
9.27%
9.83%
11.15%
11.19%
13.38%
23.48%
26.74%
Energy type
Biomass
Coal
Crude oil
Electricity
Geothermal
Hydrogen
Natural gas
Nuclear
Solar
Wind
Exports
Imports
-12.3%
-7.36%
-1.21%
0.51%
-8.41%
-1.69%
27.84%
29.88%
Global trade market for export and imports of energy
b)
Domestic production
-1.26%
-0.54%
-0.20%
-0.16%
-0.14%
0.07%
0.13%
0.47%
0.55%
0.66%
Domestic market
Domestic consumption
-0.05%
0.11%
0.19%
0.20%
0.23%
0.30%
0.73%
0.78%
1.02%
1.23%
Food type
Beef
Corn
Legume
Poultry
Rice
Roottuber
Sheep_goat
Soybean
Vegetables
Wheat
Exports
Imports
-0.19%
-0.41%
-0.47%
-0.84%
-1.08%
-1.77%
-2.77%
-3.51%
-4.13%
-5.51%
Global trade market for export and imports of food
1.72%
1.31%
1.19%
0.82%
0.71%
0.62%
0.40%
0.22%
0.21%
0.01%

Sales by Global South by burden-sharing principle




Purchases by Global North by burden-sharing principle
Australia_NZ
Canada
EFTA
EU-12
EU-15
Europe_Eastern
Europe_Non_EU
Japan
Russia
South Korea
USA
MtCO₂yr⁻¹
2020
2030
2040
2050
2060
2070
2080
2090
2100
CAPAB
EQUAL
RESPO_1830
RESPO_1990


a) Annual change in primary energy (%)
Biomass
Coal
Geothermal
Hydro
Natural gas
Nuclear
Oil
Solar
Traditional biomass
Wind
b) Annual change in final energy (%)
Biomass
Coal
District heat
Electricity
Gas
Hydrogen
Refined liquids
Traditional biomass
c) Annual change in land allocation (%)
Biomass
Crops
Forest (managed)
Forest (unmanaged)
Grass
Otherarable
Pasture (grazed)
Pasture (other)
Shrubs
d) Annual change in water consumption (%)
Bioelectricity CCS (Cooling)
Biomass (Irrigation)
Crops
DACCS
Electricity (cooling)
Fossil fuel extraction
Hydrogen
Industry
Meat and dairy
Municipal water
Uranium extraction
2020
2040
2060
2080
2100



Trade_all_CDR
Trade_BECCS_only
Biomass
Oil
Natural gas
Coal
Nuclear
Wind
Solar
Primary energy
Biomass
Hydrogen
Coal
District heat
Electricity
Gas
Refined liquids
Final energy
Biomass
Forest
Legumes
Grasslands
Pasture
Rice
Fruits
Vegetable
Land allocation
Bioelectricity CCS
Biomass (Irrigation)
Fossil electricity
Meat and dairy
DACCS
Hydrogen
Water use
Biomass
Legumes
Vegetable
Natural gas
Corn
Beef
Sheepgoat
Import
-10 -5 -1 0 1 5 10 50 150
-10 -5 -1 0 1 5 10 50 150
Annual average percent change from 2025-2100 (%)
Percent change relative to No_Trade