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Climate-Related Trade Measures: Assessing Impacts for Bolivia, Colombia, Ecuador, and Peru

Aaron Cosbey[1] and Adrien Vogt-Schilb[2]

Abstract

There is a growing wave of concern for the embodied carbon in traded goods. One manifestation of that concern is large economies such as the USA and the European Union enacting climate-related trade measures, including border carbon adjustment. This paper reviews more than ten climate-related trade measures that are currently enacted or under discussion globally and five initiatives from large companies to source low-carbon inputs. It then assesses Bolivia, Colombia, Ecuador, and Peru's vulnerability to trade restrictions, based on estimated greenhouse gas intensity of their exported goods (using an input-output analysis) relative to other global producers, and an exposure analysis that assesses the likelihood that current importers of these products might implement climate-related trade measures. Finally, it reviews existing scenarios of global oil, natural gas and coal demand, and asks what they mean for fossil fuel exports from these countries. Agricultural goods stand out as vulnerable, as they are the main driver of deforestation and associated emissions. The most serious threat is the vulnerability of fossil fuel exports, primarily crude oil and gas, which dominate the four countries' current exports. The paper exposes recommendations in terms of diversifying the economy away from fossil fuels and preparing exporters to comply with emerging climate-related trade restrictions.

Keywords: Trade Policy; Climate Policy; Input-Output Analysis

JEL codes: F18; Q56; Q54; O13

Executive summary

Merchandise exports are a critically important driver of economic vitality. As such, building and maintaining global competitiveness is an important focus of government policy, and of bilateral and multilateral development assistance.

This report explores the contours of an unconventional element of international trade that is becoming increasingly relevant: competitiveness in the face of trade-related climate responses, both by governments and by the private sector. It focuses on Bolivia, Colombia, Ecuador, and Peru, at the request of its funder, the Country Department Andean Group of the Interamerican Development Bank.

The links to trade and competitiveness become more significant as more and more countries ramp up their climate ambition. Country-level commitments to achieve net zero emissions have gone from essentially zero in 2019 to covering countries accounting for more than 80% of global GHG emissions, and more than 90% of global GDP, with more than 30 countries moving beyond pledges to enshrining

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commitments in law. As the climate crisis and its impacts become more acute, the drivers for governmental and private sector action will only strengthen.

Carbon content in traded goods: The coming wave of measures

Countries that export carbon-intensive goods face an increasing focus on the carbon embodied in traded goods – that is, the sum of carbon emissions that have taken place along the goods' value chain. This focus manifests in two types of policies that impact the competitiveness of traded goods:

- Large economies, such as the European Union (EU) and the United States of America (USA), considering and implementing policies to reduce the carbon embodied in certain imported goods.
- Some importing countries are considering and implementing trade policies to reduce "carbon leakage" – the shift of production and greenhouse gas emissions from jurisdictions with strict climate policies to jurisdictions where those policies are less costly.

A survey of this type of policies in place or under consideration by governments shows that climate-related trade measures span a small but significant suite of sectors and products (Table ES1):

- Metals and alloys such as iron, steel, aluminum, and cobalt
- Energy-intensive highly traded goods such as cement, fertilizers, organic chemicals, and plastics
- Fossil fuels
- Agricultural goods used as feedstock for biofuels
- Forest-based products

Table ES1: Survey of existing and proposed climate-related trade measures

Measure	Implementer	Effect	Status
EU Regulation on Deforestation-Free Products	EU	For covered agricultural goods, import is conditional on due diligence attesting to nil or negligible chance they were produced on deforested or degraded lands.	In law as of 2023.
EU Biofuel Regulations	EU	Biofuel feedstock from countries at high risk of indirect land use change are not counted toward mandatory renewable fuel targets in the Renewable Energy Directive.	In law as of 2018. Ongoing review mechanism to determine whether new crops (e.g., soybeans) have a high risk of indirect land use change.
EU CBAM	EU	Forces importers to purchase allowances for the embodied carbon in covered foreign-produced goods.	In law as of 2023.
Other BCA regimes	Canada, UK, US, Japan, Australia	Would apply carbon prices at the border equivalent to those applied domestically, based on embedded carbon in goods.	Consultations complete in Canada (2022) and in UK (2023). Uncertain in the US, Japan, Australia.
EU Methane Regulation	EU	Requires that oil & gas produced in the EU should significantly reduce upstream methane emissions; the same requirements would apply to imports.	EU Parliament voted in May 2023 to apply the rules to imports as well as domestic producers. Final rules to be negotiated with Council in 2023.
UK Provisions on Forest Risk Commodities	UK	Ban on the import of forest risk commodities (to be determined) unless laws of host country were followed.	In law (Environment Act 2021, Schedule 17), but details to be decided by Secretary of State.
US Clean Fuel Standards	US	Mandates reductions in carbon intensity of gasoline and diesel, applied to imports as well as domestic production.	In law in three states: Washington (2021), Oregon (2022), and California (2009). Unlikley at the national level.
EU-US Global Aluminum and Steel Arrangement	EU, US	Will restrict imports of high-GHG intensity steel and aluminum to the US and EU.	Commitment to finalize details of agreement by end of 2023, but no clarity on what those will look like.
US Green Procurement	US	Promotes the purchase of low-embedded-carbon construction materials in public projects.	Enacted in 2021 Executive Order, funded under the IRA. Plans to expand scope of materials covered.
EU-Mercosur Association Agreement	EU	Would have liberalized roughly €45 billion of goods exports from Mercosur to the EU.	Stalled, in large part because of civil society concerns about the embodied carbon in beef imports from Brazil.
Climate club	G7	Unclear - many variations. Some current proposals involve club application of BCA to goods from non-club members.	Uncertain. G7 Declaration in 2022 vows to create such a club, but it is not clear the Japanese Presidency has a desire to follow through.
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US FOREST Act of 2021	US	Restricts covered commodities from entering the US if they are deemed to be the products of illegal deforestation in the country of origin.	Proposed in 2021, but unlikely to pass - stalled in Senate Finance Committee.

In addition, large private-sector buyers are increasingly focused on reducing carbon in their value chains. This responds to pressure from consumers to reduce the embodied carbon in their purchases. Since 2020 there has been an accelerating flurry of high-value multi-year agreements to purchase low-carbon materials for electric vehicles and batteries, green steel, green ammonia, green hydrogen, and low-carbon aluminum, involving suppliers such as BHP Billiton, Rio Tinto, Vale, Glencore, and Alcoa, and manufacturers and sellers such as Tesla, Ford, Toyota, BMW, Stellantis, Apple, and Kobe Steel. Consumer products giants Unilever and Procter & Gamble have committed to a deforestation-free palm oil supply chain. Several buyers are working in tandem with suppliers to jointly develop low-carbon processes, in a bid to lower costs and ensure long-term secure supply.

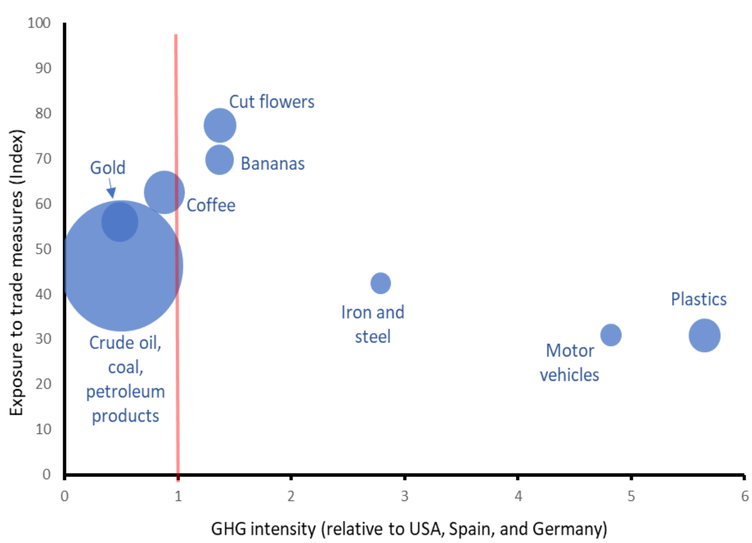
These trade measures and buyer demands are mostly a recent phenomenon. Almost all the examples cited above are less than three years old. Given that they are driven by climate change concern, and that concern is intensifying, we can expect to see an increase in the number and scope of measures accounting for embedded carbon in internationally traded goods. The result will be more types of goods covered, and a greater global market share devoted to low-carbon versions of those goods.

Where are the vulnerabilities?

These trends will affect some goods and countries more than others. The most vulnerable goods are those that are produced in a high-GHG manner relative to international peers and are exported to countries that are likely to implement climate-related trade measures. The most vulnerable countries are those with a significant percentage of exports taken up by vulnerable goods.

Figures ES1 to ES3 show our estimates of how vulnerable Colombia, Ecuador and Peru are to climate-related trade measures, and in what sectors.[3] The vertical axis shows an index that rates the likelihood of existing export destinations adopting climate-based trade measures. The horizontal axis shows the GHG-intensity of production, relative to an average of the values for those goods as produced in USA, Germany, and Spain – a proxy for the benchmarks likely to be used in assessing GHG intensity of imports. Each bubble represents a major exported good, scaled to reflect the value of exports in 2019.

Figure ES1: Exposure to trade measures and GHG intensity of major exports in Colombia



[3] Data for Bolivia was not sufficiently recent or detailed to allow for these calculations.

Figure ES2: Exposure to trade measures and GHG intensity of major exports in Ecuador

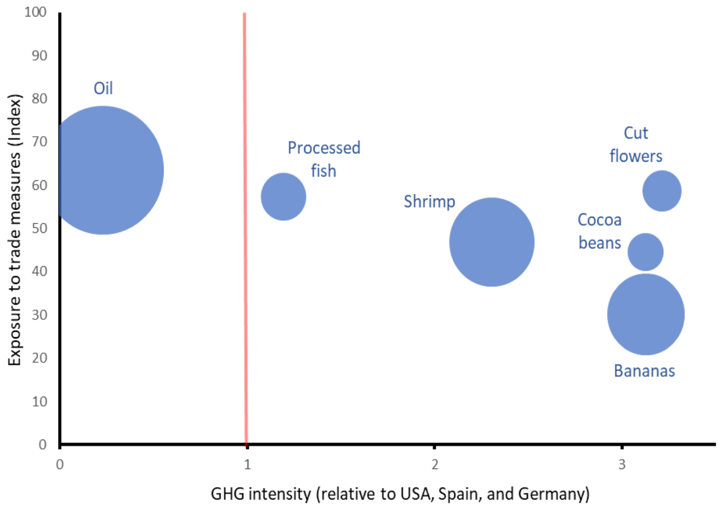
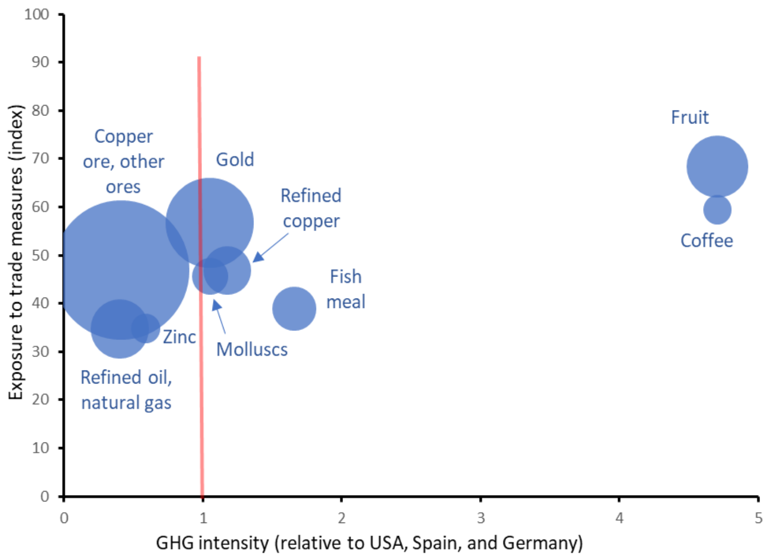


Figure ES3: Exposure to trade measures and GHG intensity of major exports in Peru



A study of the vulnerability shown in these charts, and the measures currently in law and in process, yields some insights on the situation for Bolivia, Colombia, Ecuador and Peru:

- Border carbon adjustment, a policy that has set off alarm bells in capitals worldwide following the EU's adoption of its Carbon Border Adjustment Mechanism, presents relatively few risks to the four countries, focusing as it does on upstream products of heavy industry. Colombia's steel exports are the only major concern for any of the four countries, and those are mostly destined for markets that are not likely to implement climate-related trade measures, as reflected in a relatively low exposure index score of 42 (out of 100).
- Similarly, none of the four countries is likely to be affected by green government procurement of goods like steel, cement and aluminum based on carbon content, given that Colombia's steel is the only export stream covered, but its major markets are not likely to implement such measures in the near term.

- Some of the four countries' substantial agricultural exports may be vulnerable to policies that target land use change, such as the EU's deforestation-free goods law (though that law does not focus directly on GHG intensity at the moment), and to private sector initiatives such as climate-related ecolabels. Peru's agricultural exports, such as fruit and coffee, score relatively high on both GHG intensity and export exposure. Ecuador's cut flower exports also score relatively high on both counts.

This picture of vulnerability is limited in two ways. First, the data for GHG emissions, and the input-output tables to which they were linked to derive GHG intensity, are not adequately disaggregated. As such, for example, Colombia's bananas and coffee are assumed to have the same emissions intensity, being both covered in a broader category of agricultural products in the data we had access to. Better data would yield a more accurate picture of specific product vulnerability. Second, this is a static picture. As noted above, the trends in considering carbon in traded goods are recent and powerful, they may grow in the future to cover more products of interest to exporters from Bolivia, Colombia, Ecuador, and Peru, and may be implemented by more of their export market countries.

Fossil fuel exports show significant vulnerability

A focus on embedded carbon in traded goods is only one type of trade-related climate response. A second type, also relevant for exports, is domestic policies in export markets that indirectly affect demand for goods linked to climate change. Of particular importance to Bolivia, Colombia, Ecuador, and Peru are measures aimed at reducing fossil fuel consumption.

Figure ES4: Share of Fossil Fuels in Merchandise Exports from Bolivia, Colombia, Ecuador, and Peru

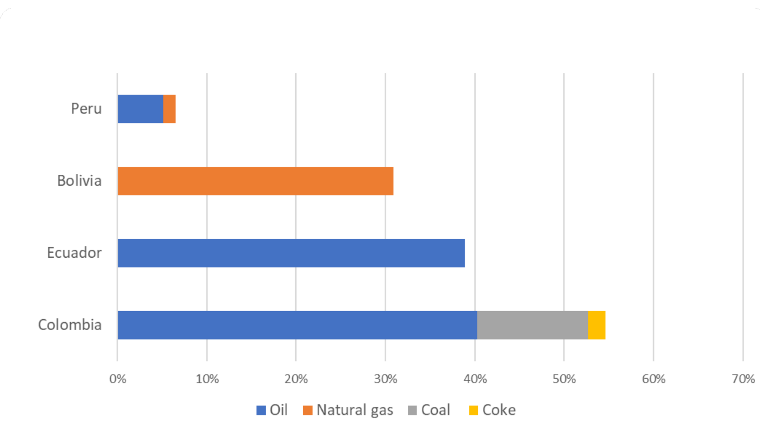


Figure ES4 shows the outsized share of exports taken up by fossil fuels in the four countries. For Colombia, Ecuador, and Bolivia they make up the single largest stream of merchandise exports at the Harmonized System 2-digit code level, while for Peru they are third largest after mined ores and gold. Climate change policies and new technologies will make these exports uneconomic long before the reserves on which they are based are fully exploited.

For oil, many analysts agree that peak demand will come by around 2030. The most significant demand destruction will come from electrification of road transport, which accounts for 43% of total global oil demand. The trends in costs, model choice, range, and public charging infrastructure all indicate that the world is on the upward portion of S-shaped adoption curve of what is, ultimately, a superior product. There are many examples of such a sudden and revolutionary dynamic with past technologies—including cellphones, personal computers and, ironically, internal combustion engine passenger vehicles—and global uptake of electric vehicles (EVs) looks to be on the same track.

If we assumed the International Energy Agency's most ambitious (Net-Zero) scenario for passenger vehicles out to 2030—which seems plausible—and a more conservative (Announced Policies) scenario for the other elements of global oil demand (petrochemicals, shipping, power, heating) the result would be a drop in oil demand from 2021 levels of 13.6 million barrels per day, or 14%, with much steeper drops out to 2050. To put those numbers in perspective, the drop in global demand that devastated oil markets and sent prices for Western Texas Intermediate briefly negative in 2020 amounted to less than 7 million barrels per day – though that was more abrupt than the changes envisioned here.

The future of gas exports is not much brighter. The IEA's (moderately ambitious) Announced Policies Scenario, which sees countries fulfilling current pledges, projects overall global gas demand peaking this decade, falling from 2021 levels by 8% in 2030 and 37% in 2050. Under any scenario, the growth trajectory experienced in recent decades will come to an end, meaning tighter competition for markets. Supply scenarios see the Middle East gaining global market share, on the back of massive new investments in capacity and low costs, but all other regions in most scenarios decrease production levels. Bolivia and Peru are cited as countries where production is expected to decline, even in the most generous (and fundamentally unrealistic) Stated Policies Scenario.

While the vulnerabilities identified from the inclusion of carbon accounting in international trade are a strong concern for some products, especially in the medium term, the vulnerabilities from dependence on fossil fuel exports is immediate and critical, with major government revenue at stake and strong risk of stranding productive assets.

What to do?

There are several ways that governments, and various development agencies, can act to minimize the vulnerabilities described here, and find opportunity in contesting low-carbon markets.

- Diversifying away from fossil fuel exports, to reduce exposure. This is easier said than done. One avenue is to deliberately search for and support opportunities that utilize the considerable expertise currently employed in the fossil fuel sectors. A practical policy guideline is to carefully consider fiscal support to the existing sectors, particularly for expansion of operations, in light of the sector's coming decline. Propping up declining sectors is, as a rule of thumb, not considered to be good industrial policy.
- Compiling data on national sectoral emissions, both to better identify the areas of vulnerability, and to be able to furnish data to foreign agencies that request it under regimes such as the CBAM. In the case of the CBAM, furnishing such data would help exporters avoid punitive default values if they could not provide firm-level data.
- Lobbying regimes such as the CBAM to support exporters' costs of certifying their data, using revenues from border charges. Such support is arguably justified under the principle of common but differentiated responsibilities and respective capabilities of the UNFCCC's Paris Agreement.
- Helping to build exporters' capacity for internal carbon accounting that satisfies the various demands they might face from foreign government-mandated regimes and private sector buyer requirements.

- Supporting the accreditation of nationally or regionally based verifiers for carbon content accounting, so that any required verification is less costly and more accessible for exporters from the region.
- Participating in international efforts to develop standards for carbon accounting, to ensure their specific sectoral realities are taken into account.
- Acting as a conduit of information for exporters on the requirements and likely developments in the various climate-related trade measures that may be on the horizon.
- Ramping up existing support for low-carbon transformation in energy-intensive, highly traded sectors such as iron and steel, plastics, and high-risk sectors such as agriculture, to make them less vulnerable to climate-related trade measures in the global green markets of the future.
- Lowering the GHG-intensity of the electricity used by producers, in anticipation of the time when climate-related trade measures will account for indirect emissions. Foreign climate-related trade measures alone will likely not be a determinative argument to do this, but rather just one of several.

The rest of this document is structured as follows. Section one sets the context by introducing and explaining the rise in different sorts of climate-related trade measures. The section that follows surveys the trends in accounting for carbon in traded goods, both on the part of national governments and on the part of the private sector; both are significant for exporters. Section three then assesses the vulnerabilities of major export streams in light of those trends, estimating the GHG-intensity of major exports and considering other aspects of vulnerability including the specific markets for those exports. Section four considers the impacts of non-trade-related climate measures on exports from Bolivia, Colombia, Ecuador, and Peru, in particular on the global demand for oil and gas which feature prominently in the export profiles of all four members. Section five concludes with policy recommendations for governments and development assistance agencies such as development banks.

1. Introduction

Merchandise exports are a critically important driver of the vitality of the economies of Bolivia, Colombia, Ecuador and Peru. Accordingly, building and maintaining global competitiveness is an important focus of government policy, and of bilateral and multilateral development assistance.

This report explores the contours of an unconventional element of competitiveness that is becoming increasingly relevant: competitiveness in the face of trade-related climate responses, both by governments and by the private sector. It makes the case that embodied carbon will be ever more commonly accounted for in international trade, and that Bolivia, Colombia, Ecuador and Peru need to be aware of their vulnerabilities in that context, and aware of the opportunities.[4]

The starting point is the concept that traded goods “embody” the carbon emissions that have taken place along the value chain as a result of their production.[5] A body of work spanning more than two decades has explored the magnitude and evolution of those global flows of carbon, as well as the policy implications (Ahmad & Wyckoff, 2003; Peters et al., 2012; Wiebe et al., 2012).

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[4] In this paper, “carbon” will be used as a shorthand to describe the six major greenhouse gases (GHGs) covered by the UN Framework Convention for Climate Change.

[5] The focus of this paper is goods, but the embodied emissions in services—such as transport—are also important.

Those policy implications are of two types:

- First, the need for importing countries to account for the carbon they consume in their imported goods. This is an accounting framework that turns on its head the national accounting used as currency for national commitments under the UN Framework Convention for Climate Change and its instruments, including the Paris Agreement. In those instruments, the country where a good is produced is responsible for the GHGs emitted during production, and the country where that good is consumed is not. Consumer pressure to take more responsibility for purchased embodied carbon is driving both government actions and private sector demands to decarbonize supply chains.
- Second, the need for importing countries to staunch one of the sources of those carbon flows – the movement of production and its associated emissions from jurisdictions with strict carbon policies to those where those policies are less costly – a form of "carbon leakage."

Both types of policy implications are becoming more acutely relevant as countries ramp up their climate ambition. Figures 1.1 and 1.2 show the rapid uptake of meaningful climate commitments by national governments just in the last three years, with many moving beyond pledges into national law. To date, Colombia has presented a long-term climate strategy that aims to reach net-zero emissions by 2050 to the UNFCCC (Arguello et al., 2022). Ecuador and Peru have made such pledges, though they are in discussion at this point rather than in law.

As atmospheric concentrations of GHGs grow, the drivers for governmental and private sector action will only strengthen. A clear implication is that there will be an increasing focus on carbon embodied in national trade, whether as a means to protect domestic industries from carbon leakage, or as a means to more meaningfully tackle climate change mitigation in ways that are visible to voters.[6]

Figure 1.1: –Percentage of Global GDP covered by Net Zero

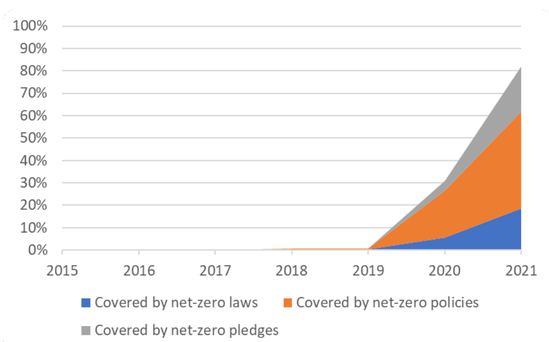
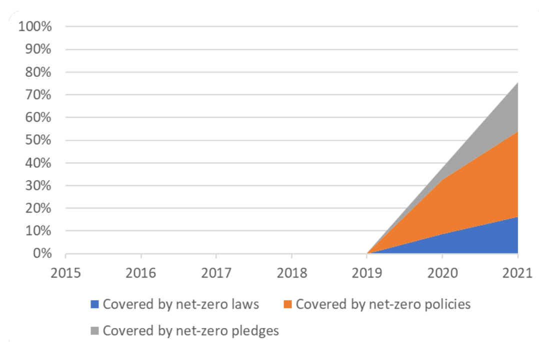


Figure 1.2: Percentage of Global Emissions Covered by Net Zero



Source: (Net Zero Tracker, 2023)
Note: *Net Zero laws, policies and pledges commit countries to achieving net zero GHG emissions by a specified date.*

This study is a first attempt to survey and prioritize the vulnerabilities and opportunities that will arise in Bolivia, Colombia, Ecuador, and Peru from the increasing attention paid to carbon embodied in traded goods, thinking about the implications for the competitiveness of exporting firms.

[6] While risk is the major focus in this report, government and private sector carbon-related trade measures also offer opportunities for low-carbon innovative producers (WTO, 2022).

2. Global trends in climate-related trade measures

We are seeing an increasing trend toward accounting for embedded carbon in traded products. It manifests in government-mandated trade measures, and in private sector net-zero pledges and the requirements that flow from those pledges up the value chain to suppliers.

From the government side, the motivation ultimately flows from increased climate ambition. In the last several years public concerns about, and actions to address, climate change have been on a strengthening trajectory. Figures 1.1 and 1.2 show that just since 2019 the world has seen commitments to achieve net-zero GHG emissions from countries comprising 88% of global emissions and over 92% of global GDP (as of July 2023) (Net Zero Tracker, 2023). Thirty-six countries have enshrined those commitments in law.

That trend look set to accelerate, driven by three underlying factors:

1. Increasing certainty of the science of climate change and necessity to align with 1.5°C scenarios (IPCC, 2021), and growth in public acceptance of that science (Leiserowitz et al., 2021).
2. More frequent and powerful physical impacts of climate change the world over, such as heat waves, floods, storm surges, droughts, and wildfires.[7] These occurrences also augment public acceptance of the science.
3. As a result of both those drivers, growing pressure on governments to take action to mitigate climate change (Leiserowitz et al., 2021).

On the private sector side, there are increasing demands on upstream suppliers as part of supply chain due diligence. As of July 2023, of the top 2,000 publicly traded companies, 944 have net-zero targets (Net Zero Tracker, 2023). They are responding to customers, who assign a premium to low-carbon footprint goods, and to shareholders, who are concerned both for reputation and for future viability of operations in a carbon constrained global market.

These concerns by consumers and producers ultimately translate into climate-related trade measures: trade measures based on carbon content. These are of several different types:

- Government measures to addressing the significant flows of carbon embedded in international trade (Peters et al., 2012). Consumers are sensitive to the embodied carbon that they consume in goods such as forest products, agri-foods, and fuels, and so they press for regulations that deal with both domestic and imported products. For example, several countries have laws that aim to ensure that forest or agricultural products they import are not responsible for climate-damaging deforestation.
- Government measures to protect domestic producers that have been mandated to reduce their operational GHG emissions in ways that increase their costs. Industrial producers are conscious of the costs they incur as a result of carbon pricing, and press for protection against competition from lower-cost high-GHG imports. The EU's CBAM, for example, levies costs on imports that aim to equal those levied on like domestic products.

[7] Compare the last 20 years with the 20 years previous: climate-related disasters (6,681 vs. 3,656); major recorded disaster events (7,348 vs. 4,212); people affected (4.2 billion vs 3.25 billion); and global economic losses (USD 2.97 trillion vs. USD 1.63 trillion) (UN Office for Disaster Risk Reduction, 2020).

- Government measures to support industrial decarbonization by for example creating markets for more costly low-carbon goods. Government procurement aimed at low-carbon products fits in this category.

A selection of existing and proposed measures of this type are catalogued in Table 2.1, where they are arranged in order from most to least likely to impact the Andean region producers. These initiatives are described in greater detail below.

Table 2.1: Selected government-mandated climate-related trade measures

Measure	Implementer	Effect	Status
EU Regulation on Deforestation-Free Products	EU	For covered agricultural goods, import is conditional on due diligence attesting to nil or negligible chance they were produced on deforested or degraded lands.	In law as of 2023.
EU Biofuel Regulations	EU	Biofuel feedstock from countries at high risk of indirect land use change are not counted toward mandatory renewable fuel targets in the Renewable Energy Directive.	In law as of 2018. Ongoing review mechanism to determine whether new crops (e.g., soybeans) have a high risk of indirect land use change.
EU CBAM	EU	Forces importers to purchase allowances for the embodied carbon in covered foreign-produced goods.	In law as of 2023.
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US FOREST Act of 2021	US	Restricts covered commodities from entering the US if they are deemed to be the products of illegal deforestation in the country of origin.	Proposed in 2021, but unlikely to pass - stalled in Senate Finance Committee.

2.1. EU Regulation on Deforestation-Free Products

In March of 2023, the EU regulation on deforestation-free products, a regulation to help avoid the importation of products associated with deforestation and forest degradation, entered into law (European Commission, 2023).

The regulation covers cattle, cocoa, coffee, oil palm, soya, rubber, charcoal, wood, and some palm oil derivatives, requiring that any imports be deforestation-free. That list of products is likely to be expanded to cover more products, go further down the value chain, with the first opportunity to do so being a two-year review of the regulation.

Importers of covered products will have to carry out specified due diligence to ensure that the risk of breaching the regulations is negligible or nil or, where it is not, carry out information gathering and risk mitigation activities to bring that risk down to required levels. The required due diligence may or may not involve third-party verification; the onus is fully on the importer. One result of these requirements is to force full supply chain transparency, down to precise geolocation and date of resource extraction, in the purchasing decisions of traders and processors.

“Deforestation-free,” for the purposes of this legislation, means “that the relevant commodities and products, including those used for or contained in relevant products, were produced on land that has not been subject to deforestation after December 31, 2020, and that the wood has been harvested from the forest without inducing forest degradation after December 31, 2020.”

2.2. EU Biofuel Regulations

The EU’s Renewable Energy Directive (as revised in 2018) sets a target for renewable energy used in transport of 14% by 2030. At the same time, it introduced new sustainability criteria for bioenergy that excluded biofuels from counting toward the target if they derived from countries where the risk of indirect land use change was high. These criteria constituted a quasi-disqualification for imported palm oil as a feedstock for biodiesel, which had been sourced primarily (74% in 2017) from Indonesia and Malaysia (Nadras & Mazlan, 2022). In, 2018 about 65% of EU imports of palm oil were destined for biofuel end use (Transport and Environment, 2019). Biodiesel use in the EU is expected to decline by 24% between 2023 and 2031, mostly thanks to dropping imports of palm oil (European Commission, 2021).

The EU measure was taken to WTO dispute settlement, with the case still pending as of July 2023 (WTO Secretariat, n.d.). The measure includes a review mechanism to regularly update the assessment of risk of indirect land use change. As of July 2023, the EU Parliament is discussing whether to add soybeans to the list of high-risk crops.

2.3 EU CBAM

In May of 2023, the European Union passed into law a Carbon Border Adjustment Mechanism (CBAM), as one element of the Fit for 55 Package of climate measures included in the EU Green Deal (European Commission, 2023). The CBAM will force importers of covered goods (and electricity) to purchase allowances for every tonne of GHGs embodied in the goods they import.

The CBAM was introduced together with reforms to the EU’s emissions trading system that will reduce the number of allowances available, and eliminate free allocation of allowances to EU producers. The aim is to prevent increased carbon prices from resulting in a simple transfer of emissions from the EU to jurisdictions with lower carbon prices – a phenomenon known as leakage. The border charges will ramp up gradually to 100% of ETS allowance value by 2034, in tandem with the ramping down of free allowances granted to EU producers under the ETS. In that sense, the CBAM is designed to mirror the domestic obligations of firms under the EU Emissions Trading System.

Covered sectors are iron and steel, aluminum, cement, hydrogen, fertilizers, and electricity. There was some debate on whether to also include plastics and organic chemicals, as proposed by the EU Parliament in response to the Commission’s narrower proposal. In any case, it is widely expected that the sectoral coverage will eventually expand, perhaps as a result of a mandated 2026 review of the mechanism. The covered goods are high upstream on the value chain: basic and slightly processed products, with only a few downstream goods in iron and steel (screws, for example). No manufactured goods or agricultural goods are covered.

Embodied GHGs will be calculated on the basis of actual data submitted by importers, reporting to standards still under development (a draft standard for the initial 2-year transition period was released for consultation in June 2023), and certified as valid by accredited assurance bodies. If actual data is not available, default assumptions will be applied.

While the legal burden of the CBAM is on importers, it is producers that will the facto bear the burden of compliance. Importers will demand third-party verified data on GHG emissions intensity from firms with which they deal or will assess a price penalty to cover the costs of the default values that the EU would assign to those goods.

Though many of the details of implementation will not be known until after the various pieces of implementing legislation are passed, the broad stroked are now set. It will come into force in October 2023 and consist of a 2-year transition (review) period in which data are collected but no charges assessed, and a nine-year phase in period to 100% border charge, timed to correspond to a nine-year phase out period of free allowances granted to covered installations.

2.4. Other Border Carbon Adjustment Schemes

The EU is the first jurisdiction to apply a border carbon adjustment scheme – of which the CBAM is one variation – to traded goods. But it may not be the last. In January 2022, Canada completed formal consultations on what a border carbon adjustment regime might look like in that country (Canada, 2021), and a UK House of Commons Committee carried out similar consultations that concluded in April 2022 (UK Environmental Audit Committee, 2021), followed by ongoing national consultations that concluded in June 2023 (United Kingdom, 2023).

Both countries were presumably motivated by the fact that they are imposing a carbon price on their energy-intensive trade-exposed industries. In Canada, there is a legislated carbon price that will rise to CAD 170/tonne by 2030. The UK has a cap-and-trade regime for carbon pricing, similar to the EU's ETS. For both countries, imposing a carbon price on those industries is unthinkable without some sort of protection from leakage.

The US has repeatedly announced its intention to put such a regime in place (e.g., USTR, 2021). All of the many carbon pricing bills to come before Congress have contained a border carbon adjustment scheme of some sort. But it is still unclear what such a regime might look like in the US context, since the US does not have domestic carbon pricing for which to adjust at the border, and seems unlikely to get carbon pricing any time soon. One draft piece of legislation – the FAIR Act – proposed quantify the regulatory burden faced by US industrial sectors, and to assess a border charge equal to that burden on all imports, except those from countries deemed by the US to be sufficiently serious about their climate commitments (Coons & Peters, 2021). That particular piece of legislation seems unlikely to pass Congress, but the basic approach is still on the table as a policy option, and a pending bill is expected to similarly propose border carbon charges without a domestic carbon price (Hulac, 2023).

Japan's 2020 Green Growth Strategy called for consideration of border carbon adjustment, though there has been no public consideration since that time (METI, 2020). In Australia, as part of the reform of its keystone climate regulation, the Safeguard Mechanism, the Government has committed to undertaking a review commencing in 2023 of policy options to address carbon leakage, including considering border carbon adjustment, especially for the steel and cement industry (Australia, 2023).

2.5. EU Methane Regulation

The EU Parliament has approved a regulation that mandates that oil and gas producers must carry out regular leak and detection exercises, and report results. Any leaks in excess of 500 parts per million of methane must be immediately repaired or replaced. Venting and routine flaring of methane are prohibited. Member States must compile an inventory of inactive wells, and those wells must have methane measurement equipment installed. The regulation also applies to coal mining, including a prohibition of almost all venting and flaring (European Parliament, 2023).

In May 2023 the Parliament voted to extend those rules to the 80% of EU oil and gas consumption that is imported. Producers from countries with similar domestic regulations would be exempted. It now rests with the EU Council to negotiate with the Parliament whether imports will indeed be covered.

2.6. The UK Provisions on Forest Risk Commodities

The UK's Environment Act 2021 included Schedule 17: *Use of forest risk commodities in commercial activity* (United Kingdom, 2021). The provisions ban the import of any forest risk commodity unless the laws of the host country were followed in relation to that commodity. The scope of commodities covered is to be decided by the Secretary of State, but shall exclude timber and timber products, as well as biofuels.

The requirements are relatively vague in the Environment Act, still to be further fleshed out by the Secretary of State in implementing legislation. They specify that importers must implement a due diligence system in relation to any forest risk commodity imported, but do not describe the detailed requirements of such a due diligence system.

2.7. Clean Fuel Standards

A clean fuel standard governs the life cycle carbon content of transportation fuels such as gasoline, by setting declining caps, applicable to both domestic and imported products. Compliance is typically possible by finding energy efficiencies in production of fuel, by blending conventional fuels with low-carbon fuels such as bio-ethanol or bio-diesel[8], by purchasing credits from cleaner producers, or by purchasing offsets. In the case of imports, those obligations and their costs would fall to the importers and then be passed along to foreign sellers, effectively imposing a cost premium on high-GHG intensity foreign products.

Canada imposed a clean fuel standard in 2022, mandating that the carbon intensity of gasoline and diesel be reduced from 2016 levels by 3.5 grams of carbon dioxide equivalent per megajoule (gCO_2e/MJ) in 2023, rising to reach reductions of 14 gCO_2e/MJ in 2030 (Government of Canada, 2022).

Similar regimes have been implemented at the sub-national level in the US States of California, Oregon and Washington. A national policy was suggested by the reports of the House Select Committee on the Climate Crisis, and the Senate Democrats' Special Committee on the Climate Crisis (House Select Committee on the Climate Crisis, 2020; SCCC, 2020), but it is not clear that the Administration has the appetite for such a policy, since it would be costly for refiners that import crude oil for processing.

2.8. The EU-US Global Aluminum and Steel Arrangement

In October 2021, the EU and US agreed to negotiate a deal by October 2023 that would see them cooperate in pursuit of low-carbon steel and aluminum production, and in addressing over-capacity in

[8] Whether biofuels should count as low carbon is disputed, given their impacts on deforestation (Searchinger et al, 2018)

those sectors (US White House, 2021). The parties outlined a series of six actions that would result from the arrangement, including measures in each jurisdiction to "restrict market access for non-participants that do not meet standards for low-carbon intensity."

The final shape of that agreement has yet to be determined. On the US side, many see the goal as a common external tariff, applied to high-GHG-intensity producers and producers in countries that are guilty of contributing to global over-supply. On the EU side there is less clarity, but it is difficult to see how such a regime would be compatible with the EU's CBAM, so their goal may ultimately be something closer to an agreed product-specific performance standard, based on GHG intensity and enforced at the border.

China is mentioned explicitly as a target, but other steel and aluminum producing countries could get caught in the crossfire. The EU and the US are relatively clean producers of both goods, which might explain the willingness to countenance trade measures based on GHG intensity.

2.9. US low-carbon procurement

The US government is very significant in the green procurement space. It annually spends roughly $75 billion on procurement through the General Services Administration. In December of 2021 an Executive Order mandated five goals around public procurement, including net zero emissions from public procurement by 2050, and a Buy Clean policy that promotes the use of low-carbon construction materials such as concrete, steel, glass, and asphalt (The White House, 2021)

The US Inflation Reduction Act provided funding of $3.5 billion to the GSA to pursue its Buy Clean objectives. In March 2022, the General services Administration issued standards for the first two goods of interest: concrete and asphalt. Vendors of those goods must submit to the administration a third-party-verified environmental product declaration. The new standards require specific production methods (in the case of asphalt) or low GHG-intensity (in the case of concrete) in order to qualify for government tenders (US General Services Administration, 2022a).

These two goods are the leading edge of a trend that is set to intensify. The US Buy Clean Task Force, which is driving the initiative, is also focusing on steel and glass, and further has asked for industry input on low-carbon practices and requirements in aluminum, insulation, roofing materials, gypsum board and structurally engineered wood (US General Services Administration, 2022b).

2.10. Low-Carbon Public Procurement

There is increasing momentum behind a coalition of governments that seek to base their public procurement of materials on, among other things, the embedded emissions they contain. Glasgow's COP 26 saw the launch of a global pledge to procure low-carbon steel and cement, coordinated by the Clean Energy Ministerial's Industrial Deep Decarbonization Initiative (UNIDO, 2021). Those countries signing on (UK, India, UAE, Germany and Canada) pledged to require, by 2025, reporting of embodied emissions in all procured steel, cement and concrete, and to aim for net zero embodied emissions by 2050. The Initiative is working to expand the effort to other basic materials as well, but is starting with steel and cement as they are responsible for a high percentage of global GHG emissions, and are the subject of a substantial amount of government procurement.

The initiative was re-launched at the Clean Energy Ministerial's 2022 meeting in Pittsburg, USA, with more signatory countries (including the US) and more specific asks: signatories pledge that by 2030 all procurement of materials used in all public construction projects should be low-emission – and that "signature projects" should use near-zero emission materials (UNIDO, 2022).

In measuring embedded carbon for low-carbon materials, countries undertaking the pledge will follow the guidance issued by LeadIt – the Leadership Group for Industry Transition, a global public-private collaboration. LeadIt's guidance for green public procurement describes sector-specific environmental product declarations. These are voluntary declarations that give information on the life-cycle environmental impacts from a product's extraction, transportation, and manufacture.

2.11. EU-Mercosur Association Agreement

While it is not a conventional example of a trade-restricting mechanism, the failure to conclude the EU-Mercosur Association Agreement is an example of trade restricted by climate change concerns. Negotiations between the two groups started in 1999, but stalled, only to resume in 2016. In 2019 a much-heralded agreement in principle was reached, and most assumed that ratification and entry into force would soon follow (Economist, 2019).

As of 2022, however, not final text has been issued, and the process seems to have once again stalled (Reuters, 2021). If that is true, it would represent a significant loss of market liberalization for both regions. The EU is Mercosur's largest trading and investment partner, and Mercosur is the only region of Latin America not covered by a trade agreement with the EU. In 2021, Mercosur exported just under €45 billion of goods to the EU, and imported goods valued at €44 billion (EU DG Trade, 2022).

If the deal has stalled, part of the cause is arguably EU civil society concerns that it would lead to increased market access to Brazilian beef, and thereby would contribute to increased Amazonian deforestation and climate change (Reuters, 2021; Sharma, 2020). The EU negotiating demand as of 2023 is that the Mercosur countries must sign a "side letter' to the free trade agreement that commits them to the Paris Agreement targets on avoided deforestation – a demand that for now is being rejected (Harris & Bounds, 2023).

2.12. A Climate Club

In recent years there has been an increasing number of calls for a climate club of ambitious countries to move forward real climate action (Bierbrauer et al., 2021; Falkner, 2016; Leal-Arcas & Filis, 2021; Shawkat et al., 2022; Tagliapietra & Wolff, 2021; Vangenetchen & Lehne, 2022). Most proponents have a different idea of what such a club might do, how it might function. The original proposal came from Nordhaus (2015, 2020), who advocated a common external tariff on goods from non-members, with ambition as a condition for membership. While that proposal is seen by many as unworkable and WTO-illegal, many others have proposed clubs with border carbon adjustment as a common element.

The G7 2022 heads of state meeting produced a commitment to agree on a climate club that seemed focused on decarbonization of energy-intensive trade-exposed sectors (G7 Leaders, 2021). It was born of a German proposal for a climate club that included border carbon adjustment as an element, and Germany's G7 Presidency was key to that commitment being agreed. But the final G7 proposal did not explicitly mention border carbon adjustment – it only referred more generally to "countering carbon leakage at the international level." The German Presidency in December 2022 produced an agreed terms of reference for the climate club, in an effort to move the initiative forward.

The Presidency of the G7 in 2023 has passed to Japan, which was never keen on the carbon clubs proposal, so it remains to be seen what happens to that commitment.

2.13. The US FOREST Act of 2021

While the initiatives in the US are not as advanced as those in the EU or the UK, they seem on a similar trajectory. An example is the FOREST Act of 2021, introduced to Congress in October 2021 (Schatz, 2021) to restrict covered commodities from entering the US if they are deemed to be the products of illegal deforestation. The benchmark date would be the date of entry into force of the legislation.

All covered imports—initially including palm oil, soybeans, cocoa, cattle, rubber, and wood pulp, and certain of their derivative products—would need to be accompanied by a declaration of due diligence. In countries without adequate and effective protection against illegal deforestation caused by the production of commodities likely to enter the United States (as certified by the US Trade Representative), there would be an additional obligation. Importers would have to submit documentation showing precise points of origin for the goods and all inputs, along with testimony on the steps taken to assure that the risk of sourcing from illegally deforested land have been mitigated. As well, for each of those countries, the USTR would eventually create an action plan of legal and regulatory benchmarks which, if achieved, would allow exporters from the country to be removed from the additional reporting obligation.

The FOREST Act seems unlikely to pass in the US – it has been stalled in the Senate Committee on Finance since its introduction. But similar initiatives could eventually lead to law in this area, particularly following the lead set by the EU's Regulation on Deforestation-Free Products.

2.14. Private sector climate-related trade measures

An increasing number of private sector actors are enforcing demands on suppliers, based on their plans to decarbonize scope 1 and 2 emissions (see box), including embodied emissions from up the value chain. As noted above, more than 944 large compagnies have net-zero targets (Net Zero Tracker, 2023).

The result for now is the creation of niche markets for goods with low embedded carbon, with purchasers arranging dedicated supply contracts or offtake agreements that specify low-embedded carbon content. In the longer run, some markets may become dominated by goods that meet the low-carbon standards set out by buyers. The market for cocoa is an instructive analogy; given the small number of global buyers, and their respective commitments, some foresee a global market that will increasingly be hard to contest for producers that do not follow voluntary sustainability standards (Cosbey, 2015).

A full survey of the existing measures of this type would be beyond the scope of this paper. What follows is a sampling of some of the most prominent recent contracts and purchase agreements being conditioned on low embedded carbon.

The different scopes of GHG emissions

Scope 1 emissions, otherwise known as direct emissions, are GHG emissions from sources controlled by, and on the site of, the producer – typically these are process emissions and emissions from fuel combustion.

Scope 2 emissions are a form of indirect emissions – those resulting from the production of purchased electricity, steam or heat.

Scope 3 emissions are all other forms of indirect emissions. The main sources are emissions embedded in purchased input (intermediate) goods, emissions in the transport of goods to market, and emissions from the final use and disposal of goods.

- Tesla in 2022 cut three long-term contracts with nickel mining companies to supply it with low-carbon class 1 nickel for EV batteries, including a deal with BHP Billiton and its Nickel West site in Australia, and with Vale Canada and its Canadian operations in Ontario and Newfoundland & Labrador (TeslaNorth, 2021; Vale, 2022). In similar deals, BHP Billiton will supply low-carbon nickel to Ford and Toyota (Crider, 2022; Reuters, 2021b).
- Also in search of low carbon (and ethical) materials for EV batteries, BMW in 2020 signed a five-year €100 million contract for cobalt from Moroccan miner Managem Group (Holman, 2020), and Mining giant Glencore signed a deal to supply up to 1,500 tonnes of low-carbon sustainably sourced cobalt to Norwegian battery maker FREYR (FREYR, 2021). Leading automaker and battery manufacturer Stellantis has signed a ten-year supply agreement for low-carbon lithium with California-based producer Controlled Thermal Resources Ltd. (Kakade, 2022).
- Apple has committed to achieving a net zero supply chain by 2030, with 75% of that effort coming from emissions reductions along the supply chain (Apple, 2020). Among other things, Apple plans to source low-carbon aluminum for its MacBook Pro line, and it has been partnering with Alcoa and Rio Tinto to help commercialize new low-carbon production processes (Apple, 2018).
- Kobe steel's subsidiary Midrex, which specializes in direct reduced iron technology, has teamed up with H2 Green Steel to build a pioneering production facility for hydrogen-based direct reduced iron, cutting almost all carbon emissions. Kobe steel and H2 Green Steel are currently in negotiations on a supply agreement for low-carbon iron ore products (H2 Green Steel, 2022).
- Consumer products giant Unilever has committed to a deforestation-free palm oil supply chain, with almost 90% of supply coming from certified sources such as the Roundtable on Sustainable Palm Oil (RSPO) in 2021 (Unilever, n.d.). Proctor & Gamble has made similar commitments, with 100% of its sourced palm oil being RSPO-certified in 2021 (Proctor & Gamble, n.d.).

These initiatives, while they are ultimately driven by final consumers, apply to basic commodities that are relatively distant from those consumers in the value chain. This trend, which is only a few years old, differs from the longer-standing trends in voluntary sustainability standards, which are adopted by buyers of agricultural goods in short supply chains such as coffee, cocoa, bananas, and tea (Voora et al., 2022). In part it is driven by buyers that are ultimately manufacturing environmental goods such as electric vehicles and biofuels, for which the full life cycle impacts of components will be a concern for end consumers. The trend is relatively new because the scaled-up markets for such goods are also relatively new. As more such goods enter the market, we can expect to see those trends intensify.

The other driving force, ultimately underlying consumer demands in this space, is simply increased concern about climate change, and increased desire to use personal purchasing choices to affect change. Such concerns will likely intensify as well, as climate change impacts become more visible.

2.15. Conclusions

The survey of initiatives above offers three insights relevant to the subject of this report. First, it shows that low-carbon trade measures and buyer demands span a small but significant suite of products:

- Basic metals such as iron & steel, aluminum, cobalt
- Energy-intensive sectors such as iron & steel, aluminum, cement, fertilizers, organic chemicals, plastics
- Fossil fuels
- Agricultural goods as feedstock for biofuels, or as responsible for deforestation

- Forest-based products
- Building materials such as concrete and steel

Second, it shows that for the moment government-led climate-related trade measures are being implemented mostly by a small number of high-income countries. The measures catalogued in Table 2.1 are being implemented or considered by the EU (6 measures), the US (4), the UK (2), Canada (2), Japan (1), and the G7 (1). This is a select group of countries, but that does not diminish the significance of climate-related trade measures they might take; leaving aside the G7, those countries account for more than half of global merchandise imports (UN Comtrade database, 2019 data).

Third, these types of trade measures and buyer demands are a relatively recent phenomenon.[9] Almost all of the examples cited above are less than three years old. Given that they are driven by climate change concern, and that concern is intensifying, we can expect to see an increase in the frequency and scope of measures accounting for embedded carbon in internationally traded goods. The result will be more types of goods covered, and greater global market share devoted to those goods.

3. The vulnerability of merchandise exports from Bolivia, Colombia, Ecuador, and Peru

There is a growing literature on the trade impacts of climate-related trade measures (Siy et al., 2023). Such measures imply increased risk for exporters of carbon-intensive goods. In Latin America and Caribbean as a whole, production for exports is estimated to account for between 20 and 27 percent of the region's emissions (Dolabella & Mesquita Moreira, 2022), and has increased in absolute terms by almost four times between 1990 and 2014, mostly because of the increased scale of production (Li, 2021).

In order to assess the vulnerabilities of merchandise exports to the growing trends in carbon-restricted trade, we need to know at least the following about the export flows from those four countries:

- **Value of exports:** what are the most significant exported categories of goods, by value?
- **GHG intensity of exports:** How significant is the embedded carbon in those major exports?
- **Market risk:** What are the most important export destinations of major exports? Are those destinations likely to introduce climate-related trade measures?

Others have done similar work, for example in assessing the relative exposure of countries to a loss of competitiveness as a result of CBAM (Maliszewska et al., 2023). The present analysis is original in two respects. First, it tries to assess vulnerability to more than just a single instrument such as the CBAM, but rather to the larger body of climate-related trade measures surveyed above. Second, it incorporates more than just volume of trade and GHG-intensity as elements of vulnerability; it also includes an assessment of the market risk based on the countries to which exports are flowing.

Other elements of vulnerability could also be considered in an expanded analysis. Eicke et al. (2021), for example, in constructing a country-level index of vulnerability to the EU's CBAM, consider national-level statistical capacity as a proxy for the capacity of firms in that country to comply with the onerous

[9] The exception is a spate of product carbon footprinting schemes, primarily centred on food products, that launched in the early 2010s. Mostly spearheaded by retailers, these initiatives quickly lost momentum as it became apparent that consumers were not strongly influenced by them, and that it was technically difficult to accurately determine the carbon embedded in specific products (Coley et al., 2011; Kemp et al., 2010).

measurement and reporting requirements that CBAM imposes. The three variables described above are used here because they are general enough to be relevant for various different types of climate-related trade measures. Each is explored in turn below, followed by a synthesis that brings them together to assess vulnerability.

3.1. Value of major exports of from Bolivia, Colombia, Ecuador and Peru

Tables 3.1 – 3.4 show the major exports of Bolivia, Colombia, Ecuador and Peru. In order to capture granular detail, these were assessed at the 4-digit HS code level, with a *de minimus* cut-off level of USD 10 million (2019 figures).[10] The various 4-digit sectors were then grouped according to 2-digit classifications, the simplified descriptions of which are shown in the tables below. At the 2-digit level, the analysis was again simplified with a cut-off: only those 2-digit sectors whose aggregated 4-digit trade values equaled 1% of merchandise exports or more were considered.[11]

Exports are dominated, with a few notable exceptions, by extractives—mining, oil, and gas—and, to a lesser extent, agricultural goods. Only in Colombia are manufactured goods major sectors, including automobiles, plastics and steel, but oil still dominates at 40% of total exports by value. Oil and gas feature as major export sectors in all four countries, counting for 39% and 31% of total exports in Ecuador and Bolivia respectively, where they are the highest exporting sectors by value, and 6.5% in Peru, where they are third highest. Products of mining feature in all countries but Ecuador, including gold from Bolivia, Peru, and Colombia (at 20%, 15%, and 4% of exports respectively), as well as metal ores such as copper and zinc from Peru and Bolivia (at 37% and 23% of exports respectively), tin from Bolivia, and coal from Colombia. All countries feature some sort of agricultural products in their top four sectors.

Figure 3.1: Exports of Bolivia

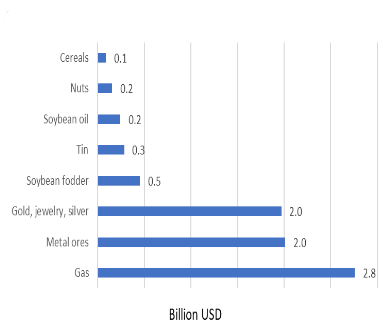
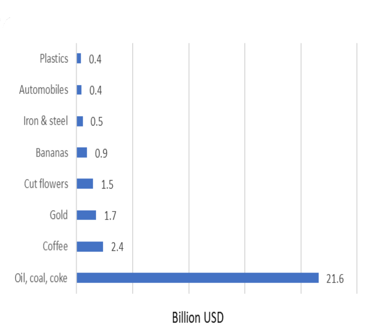


Figure 3.2: Exports of Colombia



[10] The USD 10 million cut-off is not overly restrictive as a filter for major exports, and a lower value would not have changed results significantly. For Colombia, it left 198 4-digit sectors to be considered and excluded 0.9% of total merchandise trade. The most restricted was Bolivia, which has a much less diversified export stream, and for which 37 sectors were covered, and 1.73% of total merchandise trade was excluded.

[11] The 1% cut-off was not overly restrictive as a filter for major exports, resulting in coverage of a range from 89.3% of total merchandise trade (Bolivia) to 74.6% of total merchandise trade (Colombia).

Figure 3.3: Exports of Ecuador

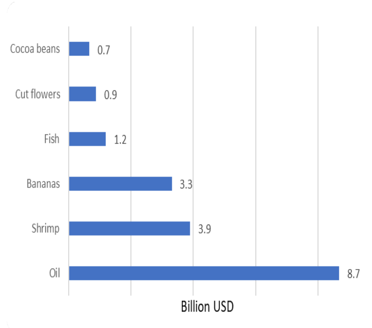
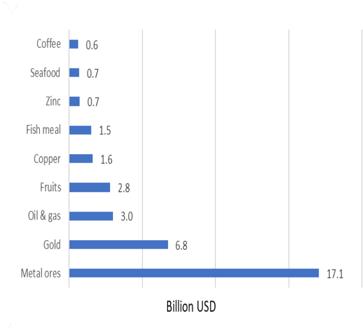


Figure 3.4: Exports of Peru



Source: *UN Comtrade database*

3.2. GHG Intensity of Exports

Few databases feature the GHG-intensity of production at the product level. The EORA Multi-Regional Input-Output database does have GHG intensities, including scope 1, 2 and 3, at the sectoral level, but its disaggregation is limited to only 26 sectors (Lenzen et al., 2013). The OECD database on carbon dioxide emissions embodied in international trade is also a useful resource, but only convers emissions from fuel combustion, leaving out process emissions that are particularly significant in sectors such as steel and cement (OECD, n.d.). The Carbon Disclosure Project's Carbon Catalogue lists carbon footprints of 866 products from 8 industry sectors, but some key sectors are not covered, and it relies on voluntary reporting and thus may be skewed as a representation of all producers (Meinrenken et al., 2022).

To overcome the shortcomings of the existing data, the method adopted in this study, and described below, starts with country-level input-output tables, which are relatively disaggregated (to varying degrees depending on the country), and regular national-level GHG reporting to the United Nations Framework Convention on Climate Change[12]. For each country we mapped the various export goods of interest onto the activities covered under the GHG reporting to find the sector's total emissions. This involved a manual mapping that was necessarily inexact, going from broad categories spelled out under the Intergovernmental Panel on Climate Change guidelines to the more specific activities described in the input-output tables, to the highly specific goods of interest classified in Harmonized System categories (see Annex B).

This calculation gives us direct (or scope 1) emissions for each category of goods. Scope 2 emissions—those generated by purchased electricity, heat, or steam—are estimated directly from the input-output tables, which give the amount of electricity needed to produce each unit of goods, and by the emissions intensity of electricity as specified in the national GHG inventory reporting.[13]

Scope 3 emissions are all other indirect emissions. We focus on only one element of scope 3 emissions – that which is attributable to purchased input goods—by reference to the input-output tables, which give us the value of all input goods to a final product, and by the previously calculated GHG intensities of those input goods. Other scope 3 emissions, such as emissions from transporting goods to market, or from using

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[12] For the method used in the national reports, see (Intergovernmental Panel on Climate Change, 2019). For a repository of developing country national reporting submitted to the UNFCCC, see https://unfccc.int/BURs.

[13] Total scope 2 emissions would also include emissions from purchased heat and steam, but these are typically a minor part of scope 2 emissions and are not estimated here.

goods downstream of exports (e.g., burning gasoline in cars), are not counted in our calculations. These elements are typically of less interest to importers imposing climate-related trade measures.

In the case of each specific country, we note below the particulars of the calculations. At the outset, we have to note that it was not possible to apply this method with an adequate degree of credibility with the available data from Bolivia, for which the most recent public data on goods we could find are contained in a relatively aggregated (35x35) supply-use table from 2014, calibrated on 1990 data (Instituto Nacional de Estadistica, 2014). As a result, no GHG intensity estimations were possible for Bolivia.

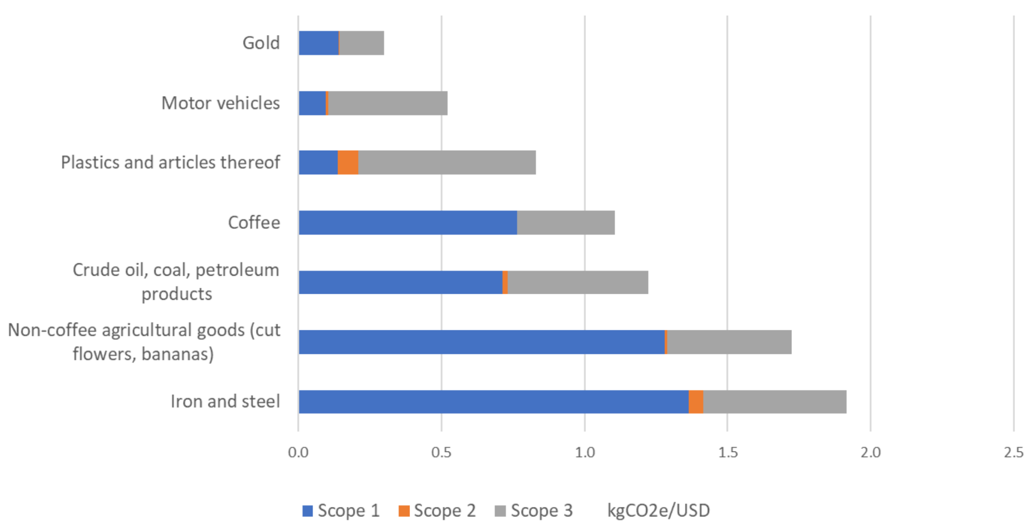
The results should be interpreted as illustrative rather than determinative. A number of caveats apply related to the data used and the conversions from activities to goods, as explained in Annex B. A key limitation is the fact that emissions data—and to a lesser extent input-output classifications—are highly aggregated. So, for example, many specific types of agricultural goods will be lumped together in both sets of accounts, meaning they are assigned the same GHG intensity, though it would be unlikely that the numbers are in fact identical across different crops.

Colombia

The Colombian data start with Colombia's 3rd biennial update report to the UNFCCC, containing its national inventory report (Colombia, 2022), and showing emissions data from 2018. It also uses a 2017 68x68 input output table using the ISIC rev 4 classification of goods (Colombia, 2017).

The results are shown in Figure 3.5. The highest GHG-intensity exports are iron and steel, coffee and non-coffee agricultural goods, and fossil fuel production. Iron and steel scope 1 emissions are almost entirely (90%) the sector's process emissions. Scope 3 emissions for iron and steel are 26% bound up in scrap steel inputs, and 24% in the mining of iron ore. The high scope 1 emissions for coffee and non-coffee cultivation are mostly from nitrous oxide, the result of fertilizer application. Direct and indirect emissions of nitrous oxide account for 62% of scope 1 emissions for the former and 93% for the latter.

Figure 3.5: GHG intensity of Colombia's Major Exports



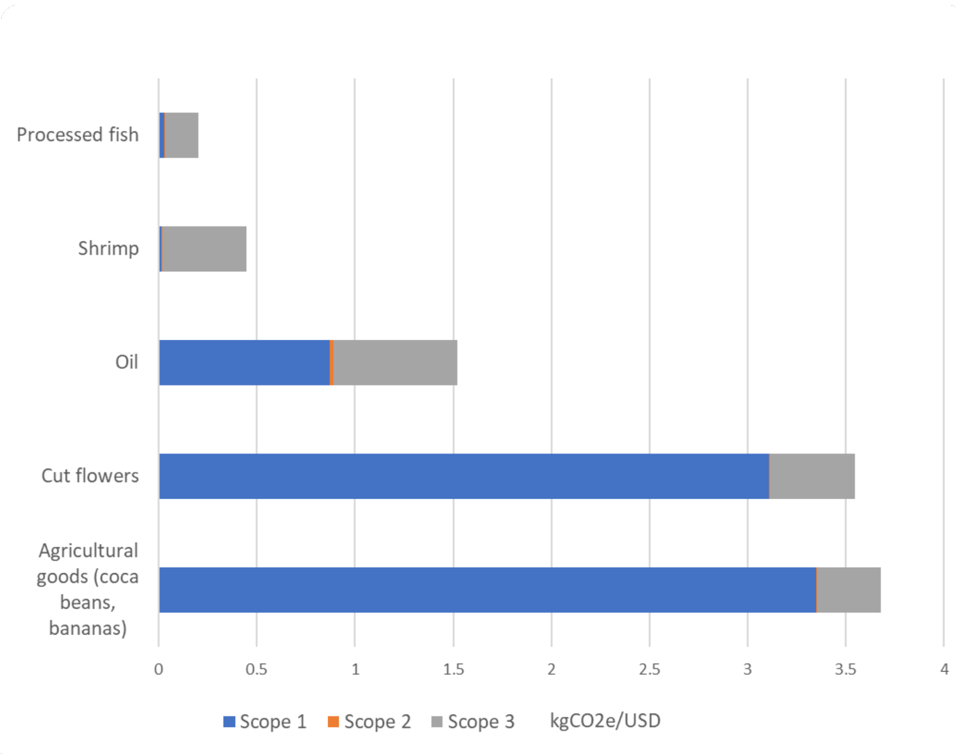
Source: Author's calculations

Scope 3 emissions are significant for plastics. The largest component of those emissions, at 19%, is the upstream plastics industry, which produces basic plastics that are then manufactured into consumer goods. The next highest element, at 18%, are the embodied emissions in input goods from the electricity needed to produce them. Scope 3 emissions in fossil fuel extraction and production are predominantly in pipeline transport (44%) and input materials for refining (28%). Automobile manufacturing shows moderate GHG-intensity because automobiles have significant value added relative to their embodied emissions, being complex manufactured goods.

Ecuador

The Ecuadoran data start with Ecuador's second biennial update report to the UNFCCC (Ministerio del Ambiente, Agua y Transicion Ecologica, 2002) with GHG emissions data from 2018. We use a 2020 supply-use table (69x69) using ISIC nomenclature for activities (Banco Central de Ecuador, 2020).

Figure 3.6: GHG intensity of Ecuador's Major Exports



Source: Author's calculations

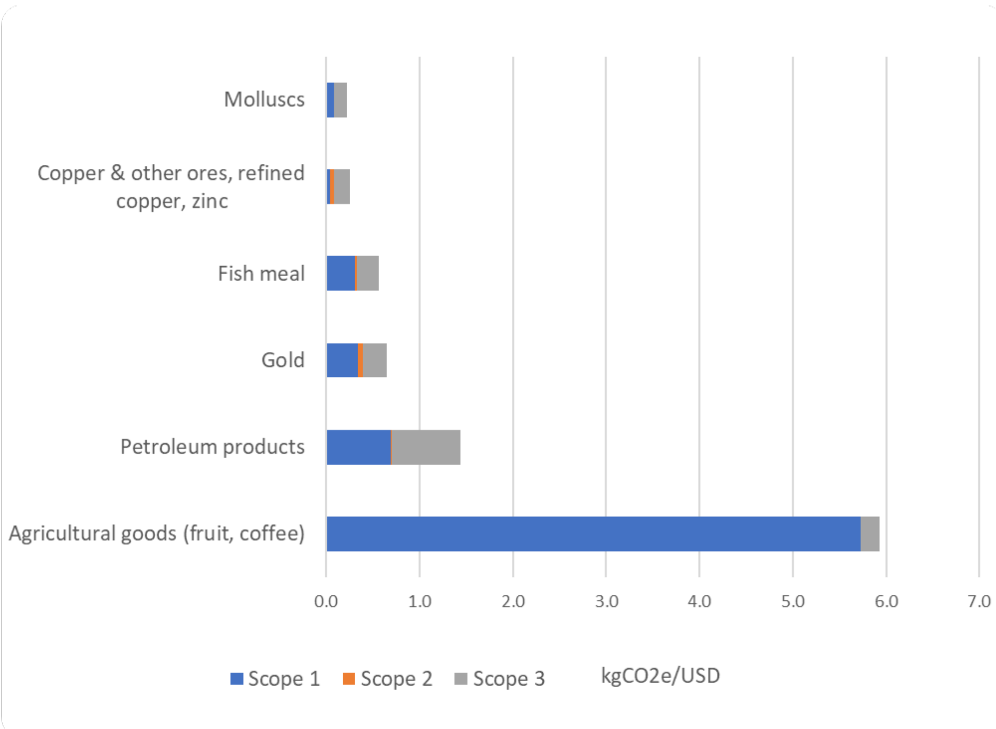
The results are shown in Figure 3.6. Agricultural goods—cocoa beans, bananas—and cut flowers show relatively high direct emissions, roughly 87% of which are due to the emissions resulting from land converted to cultivation. Note that it is impossible to know with certainty whether this attribution is fair, based on the available data. Within agricultural production, the conversion emissions may in fact be centered on modes of cultivation other than these, rather than – as assumed here – spread evenly across all cultivation activities. What can be said with certainty, though, is that conversion of lands in Colombia leads to significant embodied emissions in its agricultural products. Scope 3 emissions are particularly high for shrimp production. Roughly half of those emissions are embodied in feed.

Peru

For Peru, the most recent publicly available input-output table is from 2007 (101x101), which is less than ideal. There is, however, a more recent supply-use table comprising 365 products and 101 sectors

(Instituto Nacional de Estadistica e Informatica, 2021). We adapted this table, using a concordance to collapse the 365 products into 101 sectors and creating in effect an input-output table. GHG emissions data came from Peru's National Inventory Report of 2021 (2016 data) (Ministerio de Ambiente, 2021). The results are shown in Figure 3.7.

Figure 3.7.: GHG intensity of Peru's Major Exports



Source: Author's calculations

Fruit and coffee show a very high GHG intensity, with petroleum products the only other relatively GHG-intense covered export sector. Most of the agricultural emissions are the product of land use change, with 48% from farmland emissions and 39% from grasslands emissions.

To repeat the caveats explained above, the results presented here are based on aggregation of categories in the existing data that cannot distinguish between the GHG intensity of specific types of crop production. As such, some crops will appear more GHG-intense than they are in fact, and others will appear less so. In the Colombian data, which has coffee-specific statistics, coffee production appears much less GHG intense than shown here for Peru, and it is possible that the Peruvian estimates are high, though expansion of coffee production is a main source of deforestation in the Peruvian Amazon (World Bank Group, 2022).

3.3 Market risk: Exposure to trade measures

The third component of the vulnerability of exports from Bolivia, Colombia, Ecuador and Peru is the risk that the countries to which those exports are sent will enact climate-related trade measures. Based on the survey of existing and pending initiatives in section 2, we know that some countries are more likely than others to implement climate-related trade measures: high-income countries that have adopted ambitious climate change policies.[14]

In what follows, the major export streams of the four countries are rated according to a climate-based market exposure index. The index rates the risk that a sector's export destinations and volumes leave it exposed to possible climate-related trade measures.

Three characteristics of export destination countries are used to determine that risk: level of income, climate ambition, and demonstrated propensity to consider climate-related trade measures. Equal weighting is given to each characteristic. For each 2-digit level sector, the final score is a trade-weighted product of scores of the top 5 export destination countries.

For level of income of export destinations, we assign an **income score** based on the World Bank's country classification system (World Bank, 2023): **1** for high income, **2/3** for upper-middle income, **1/3** for lower-middle income and **0** for low income.

For climate ambition of export destinations, we use the country-level ranking assigned by an independent rating exercise assessing climate ambition (Climate Action Tacker, n.d.). The tracker rates several aspects of each country's climate ambition, from which this analysis uses the rating for "policies and action." Countries are given a **Climate Action Tracker score** as follows: **1** - Paris Agreement-compatible; **4/5** – Almost sufficient; **3/5** – Insufficient; **2/5** – Highly insufficient; **1/5** – Critically insufficient.

For the country-level propensity of export destinations to enact climate-related trade measures, we refer to the survey of measures described in section 2. The destination countries are given a **Country Risk score** from 0 – 2 as follows: **1** - Has imposed or proposed one or more of the climate-related trade measures surveyed in section 2 (EU-27, United Kingdom, USA, Canada); **1/2** – Has announced that it will explore the imposition of one or more of the climate-related trade measures surveyed in section 2 (Australia, Japan); **0** – None of the above.

The climate-based market exposure index is then calculated for a given sector *j* as the sum of:

$$100 * (I_i + CR_i + CAT_i)/3 \times value_{ij}/value_j$$

Where:

- *i* is the top 5 export destination countries for sector *j*
- I_i is the income score for country *i*
- CR_i is the Country Risk score for country *i*
- CAT_i is the Climate Action Tracker score for country *i*
- $Value_{ij}$ is the value of exports to country *i* in sector *j*
- $Value_j$ is the total value of exports in sector *j* to the top 5 export destination countries

Thus, the index runs from 0 (no exposure) to 100 (highest exposure).

[14] Our analysis of vulnerability considers only the measures taken by countries, though private sector measures are also significant for some sectors. It would be beyond the scope of this paper to trace exports from Bolivia, Ecuador, Colombia and Peru to the specific buyers, and assess each buyer's likelihood of demanding low-carbon products.

Where the Climate Action Tracker has no data for a particular export destination country, the climate-based market exposure index is just produced using the Income and Country Risk scores.[15]

The results are shown in Table 3.1. Detailed results are appended in Annex C. Some export profiles are more vulnerable to climate-related trade measures than others. The major export destinations for bananas from Colombia, for example, leave it much more exposed than does the export profile of Ecuador in the same sector.

Table 3.1: Climate-Based Market Exposure Index, Major Exports (from 0 –no exposure, to 100—highest exposure)

Bolivia	
Tin	87
Nuts	66
Cereals	59
Metal ores	51
Gold, jewelry, silver	46
Gas	42
Soybean oil	40
Soybean fodder	39
Colombia	
Cut flowers	77
Bananas	70
Gold	56
Coffee	62
Iron and steel	42
Crude oil, coal petroleum products	46
Plastics	31
Motor vehicles	31
Ecuador	

[15] The following export destinations have no Climate Tracker rating: Bolivia, China Hong Kong SAR, Dominican Republic, Ecuador, Guatemala, Haiti, Malaysia, Myanmar, Panama, Paraguay, Saint Lucia. Assigning these countries scores based only on income and country risk scores may affect the exposure scores in those sectors for which they receive significant imports from Bolivia, Colombia, Ecuador and Peru. In only 5 of the 33 sectors considered do such exports constitute 10% or more of the 2-digit level export stream: Peru oil and fish meal; Bolivia soybean oil, Ecuador and Colombia oil. To illustrate sensitivity, take the most significant case: Bolivian exports of soybean oil to Ecuador, at 35% of total exports in that sector. Generously assuming an ambitious climate action score for Ecuador of 4 (equal to the EU's score) would increase the exposure index for that sector by 12.5%. This is the highest possible distortion; in all other cases the maximum potential would be lower, since the average share of sectoral exports in the remaining 4 significant cases is much lower than 35%, at 15%.

Shrimp	57
Cut flowers	59
Oil	64
Shrimp	47
Cocoa	45
Bananas	30
Peru	
Fruit	68
Coffee	60
Gold	55
Refined copper	47
Molluscs	46
Copper ore, other ores	39
Fish meal	39
Zinc	35
Refined oil, natural gas	35

***Source**: Author's calculations*

3.4. Vulnerability of merchandise exports to climate-related trade measures

Vulnerability involves all the variables considered above: exposure—which is a function of export market risk and the size of export streams—and the GHG-intensity of production. The most vulnerable exports are those that are exposed, because of high volumes of trade destined for countries with a propensity to implement climate-related trade measures, and which have the high GHG intensities that would make them less competitive if such measures were enacted.

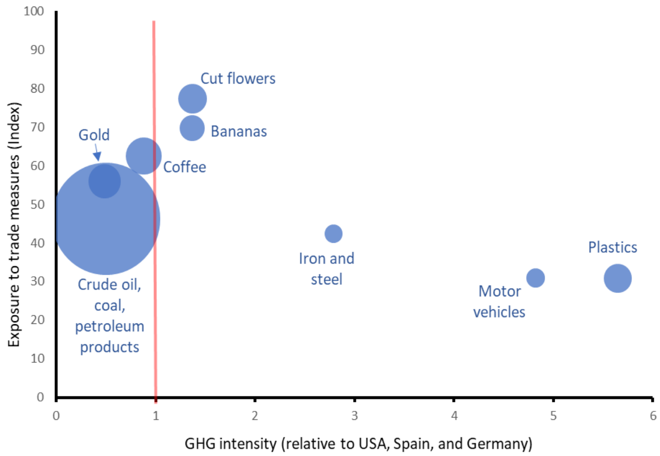
Figures 3.8 – 3.10 show vulnerability as a single graphic representation. Those sectors in the top right quadrants are more vulnerable than those in the bottom left. The vertical axis is the climate-related market exposure index, and the horizontal axis is the ratio of GHG intensity relative to the average of GHG intensities of production in USA, Spain and Germany. That average is used as a global benchmark for countries that might be considering climate-related trade measures.[16]

In Colombia, for example, plastics stand out more than five times more GHG-intense than the average GHG-intensity of production in the US, Germany and Spain. But, as shown by the size of the bubble, total export values are fairly small. Moreover, the export vulnerability is fairly low, since of the top five export destinations only one (US) is ranked as considering implementing climate-related trade measures, and only one (Peru) is ranked as high as "almost sufficient" in terms of climate ambition. The motor vehicles

[16] Finding an appropriate benchmark was challenging. Ideally it would be a country or group of countries with similar patterns of production, and which is likely to adopt climate-related trade measures. Ultimately, the countries that satisfy the second criterion don't tend to satisfy the first; the EU, for example, does not grow bananas or cocoa. The three countries chosen all satisfy the second criterion—they are likely to adopt climate-related trade measures—and they have a good mix of industrial and agricultural production, even if the agriculture in question is quite different from that in Bolivia, Colombia, Ecuador and Peru.

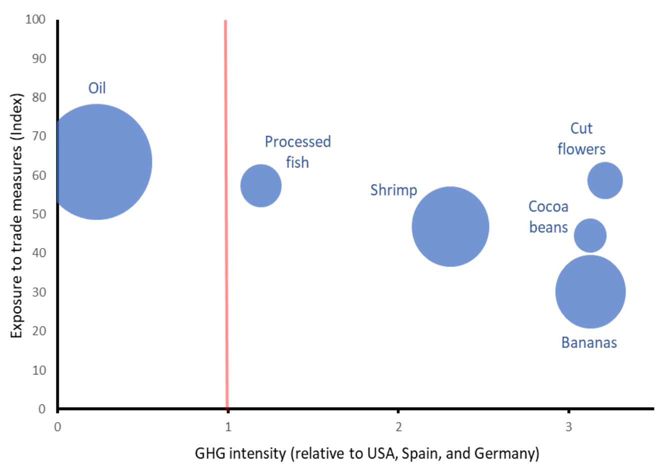
sector is in a similar situation: while emissions are relatively high, the top three export destinations—in order, Ecuador, Mexico, and Argentina—are not ranked likely overall to enact climate-related trade measures.

Figure 3.8: Overall Vulnerability of Exports, Colombia



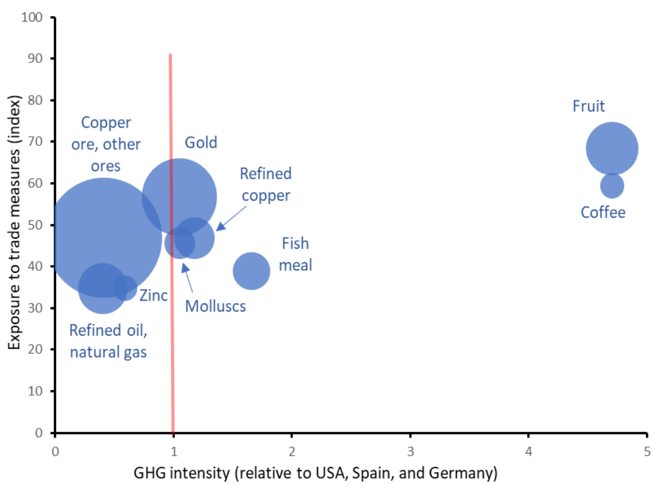
From Ecuador, cut flowers, cocoa beans and shrimp are somewhat vulnerable. All have GHG intensities 2 – 3 times the benchmark values, and export vulnerability is moderately high. Shrimp is a major export sector, and among the top five export destinations are several countries that are prone to using climate-related trade measures: US, Spain and France. But China is the biggest market, accounting for over half of exports, and depressing the trade-weighted vulnerability ranking. Cut flowers are even more vulnerable in terms of export markets, with the top five destinations including US, Netherlands, Italy and Spain, and with a GHG-intensity more than three times the benchmark. The exposure factor for cocoa beans is moderately high, with major exports to USA and Netherlands.

Figure 3.9: Overall Vulnerability of Exports, Ecuador



Peru's agricultural exports, including fruits and coffee, seem particularly vulnerable. They show a GHG emissions intensity at almost five times the benchmark level (though the caveats from above on attribution apply). And they are exported to countries that are likely to impose some sort of climate-related trade measures. The top five export destinations for Peru's coffee are US, Germany, Belgium, Sweden, and Canada. Export patterns for fruit are similar, except with the addition of China as the fifth biggest importer. GHG intensities for all other major sectors are close to the benchmark values, meaning low vulnerability.

Figure 3.10: Overall Vulnerability of Exports, Peru



Notes on Figures 3.8 – 3.10: *The size of the bubbles corresponds to the value of the export flows for that sector. GHG emissions intensity include scope 1, 2, and upstream (input) scope 3 emissions. 2-digit sectors included were determined by summing any 4-digit sub-sectors with value of over USD 10 million, and applying a threshold condition that the sum must constitute more than 1% of total merchandise exports.*

3.5. Conclusions

The major value of the foregoing analysis lies in its illustration of the nature of vulnerability to climate-related trade measures, and the type of analysis necessary to identify the need for urgent policy attention. More in-depth analysis at the country level, working with less aggregated GHG data, is needed to better grasp the relative vulnerabilities of specific export goods, though the analysis here gives some indications as to what types of goods those might be.

Given the agriculturally heavy export profiles described here, a more complete picture of vulnerability also should include a deeper dive into the methodological options for calculating agricultural products' GHG-intensity, focusing on the various ways land use change might be measured. The methods used in this analysis are only one possibility.

A more complete picture should also consider the broader nature of vulnerability to climate-related policy. The export patterns of the four countries show a major dependence on fossil fuel exports, and these may be vulnerable to climate actions that are not strictly trade-related, but which have major trade impacts. This set of issues is examined in the section that follows.

4. The Vulnerability of Fossil Fuel Exports

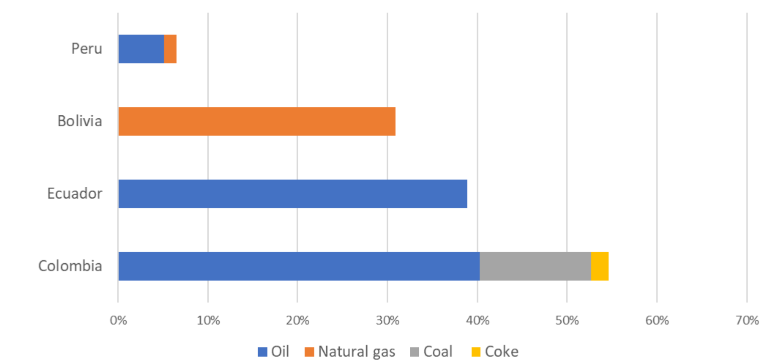
Export revenues from Bolivia, Colombia, Ecuador and Peru are also vulnerable to policies aimed at reducing the use of fossil fuels. In all four countries, fossil fuels make up a considerable portion of total merchandise exports (by value) for which global demand will eventually peak and decline – a casualty of climate change mitigation efforts.

While the mechanics of this risk are different from the risk that trade measures will harm exports, the fundamentals are the same: the nature of the region's exports leaves those countries vulnerable to disruptive loss of markets because of climate actions taken by foreign governments, private sector and consumers.

This section surveys the extent of that vulnerability, and the trends and timelines for climate-related destruction of demand for oil, natural gas and coal. Where possible, it draws on analyses that specifically focus on Bolivia, Colombia, Ecuador and Peru, though there is very little literature that does so.

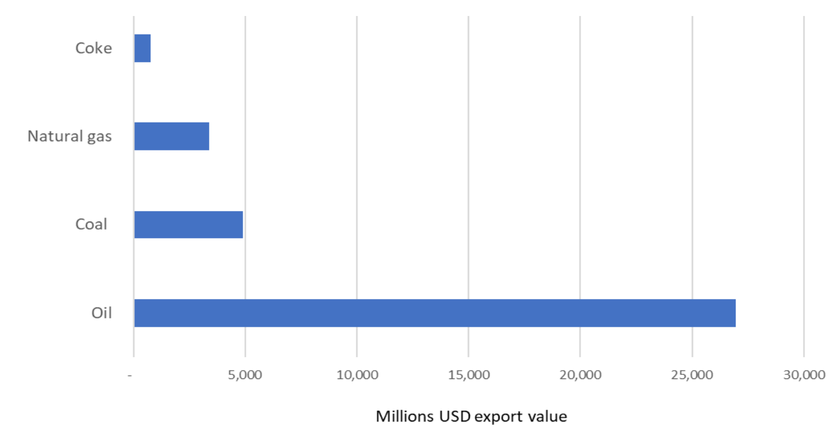
Figure 4.1 shows the extent of the four countries' exports taken up by different types of fossil fuels.[17] For Colombia, Ecuador, and Bolivia they make up the single largest stream of merchandise exports at the Harmonized System 2-digit code level, while for Peru they are third largest after mined ores and gold.

Figure 4.1: Share of Fossil Fuels in Merchandise Exports from Bolivia, Colombia, Ecuador and Peru



Source: UN Comtrade database

Figure 4.2: Fossil Fuel Exports from Bolivia, Colombia, Ecuador and Peru by Component (2019)



Source: UN Comtrade database

[17] Data more recent than 2019 is available, but markets since then have been rocked by volatility that makes recent data more difficult to interpret as any sort of normal baseline.

Crude and refined oil makes up by far the largest portion of total fossil fuel exports from the region, at $26.9 billion in 2019 (Figure 4.2). Coal and coke from Colombia are the next largest component at $5.7 billion. Natural gas, mostly exported from Bolivia, is the least significant component at $4.9 billion.

Well before current reserves of fossil fuels are consumed, the world will have crossed the threshold targets set by the Paris Agreement. (Welsby et al., 2021) calculate that to have a 50% chance of staying within the Paris Agreement 1.5°C target, nearly 60% of current oil and gas reserves and 90% of coal reserves need to be left in the ground unburned. In Latin America and the Caribbean specifically, (Solano-Rodríguez et al., 2021) estimate that as of 2035 between 66 and 81% of proven, probable and possible reserves are unburnable as of 2035 if the Paris Agreement 1.5°C target is to be reached, resulting in trillions of dollars of forgone royalties. Whether the world manages to reach that target or not, climate policies will make demand for fossil fuels peak and decline well before supply does.

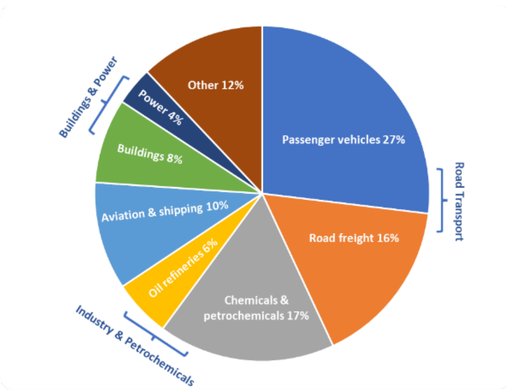
This section surveys trends in policy and technology for oil, natural gas and coal, to assess what kind of timelines are likely for the peak, and at what speed demand will decline thereafter. Given its relative dominance in exports, the most attention is paid to the future of oil.

4.1. Prospects for global demand for oil

All major credible analysts agree that peak demand for oil will come within the next ten years (BP, 2022b; DNV, 2022; IEA, 2022b; McKinsey, 2022; Rystad Energy, 2022). But there is a range of opinions on how significantly and quickly demand will decline post-peak.

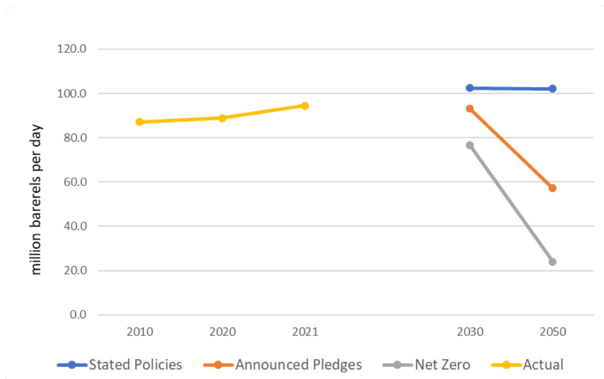
The answer to that question lies in understanding the trends in the various end uses to which oil is put. As shown in Figure 4.3, demand for oil in 2021 was dominated by road transport at 43%. The next largest component was industry and petrochemicals – mainly the production of plastics – at 23%. Almost equal shares went to buildings and power, and aviation and shipping, at 12% and 10% respectively.

Figure 4.3: Components of Global Oil Demand (2021)



Source: Based on IEA (2022), Figure 7.2

Figure 4.4: IEA WEO 2022 Scenarios for Global Oil Demand



Source: IEA (2022)

The most detailed analysis of the future in those sectors comes from the International Energy Agency (IEA) and its annual World Energy Outlook. IEA constructs three scenarios for the future, each with very different implications for future demand for oil (see Figure 4.4).

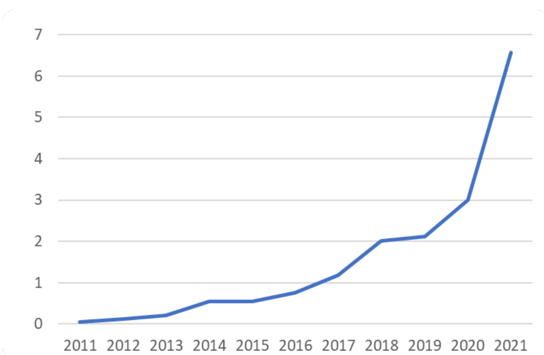
- Stated Policies Scenario (STEPS)—This scenario assumes only current energy-related climate policies and those in progress will be adopted between now and 2050 – i.e., no ratcheting up of climate policies in the next three decades.
- Announced Pledges Scenario (APS)—This scenario assumes the energy-related climate pledges made by governments as of 2021 are fulfilled by 2050, even if policies to achieve these targets are not yet in place.
- Net-Zero (NZE)—This scenario sees the global energy sector reach net-zero GHG emissions by 2050, via a hypothetical set of government policies and behavioral changes.

Where do actual trends sit in relation to these scenarios? The answer is different for each end use.

Road Transport

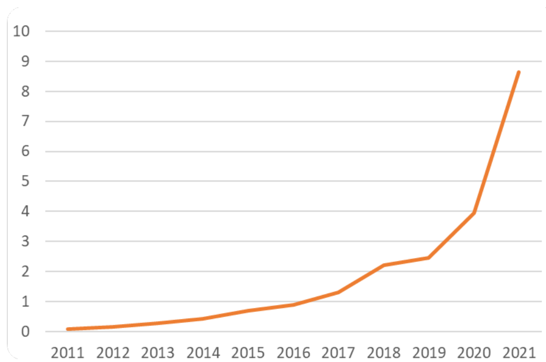
In road transport, Figures 4.5 to 4.8 show accelerating trends in favour of electrification, as shown by electric vehicle (EV) sales, deployment of charging infrastructure, and battery range.

Figure 4.5: Global Light Duty EV Sales (millions)



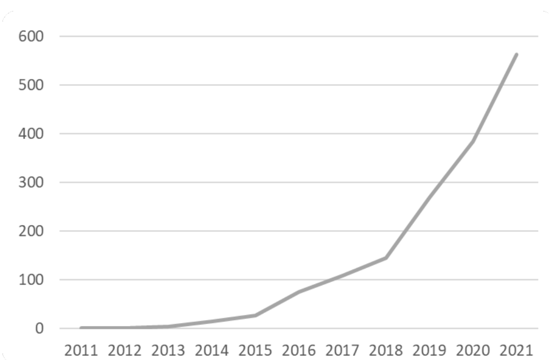
Source: (IEA, 2022a)

Figure 4.6: Global Light Duty EV Sales Share (%)



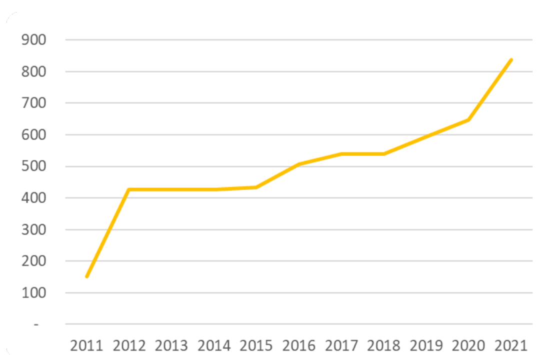
Source: (IEA, 2022a)

Figure 4.7: Global EV Fast Charging Points (000s)



Source: (IEA, 2022a)

Figure 4.8: US EV Fleet Maximum Range (kms)



Source: (US Department of Energy, 2021)

In part, increased investment and sales are being driven by government policy. Half of annual global sales of light duty vehicles are covered by zero-emission vehicle targets for 2035 or earlier, mostly from the EU, China and US, but increasingly from other countries as well, including a number of developing countries (IEA, 2023). These kinds of policies are low-hanging policy fruit for governments looking for ways to address climate change. They do not involve mandating unwanted lifestyle changes or sacrifices – in fact EVs are superior products – and they can be combined with popular industrial subsidies aimed at fostering competitive firms in the green markets of the future, and employment-creating spending on charging infrastructure.

But consumer demand is increasingly also a driver, as trends in price, range, model choice, charging infrastructure, and familiarity all push toward increased uptake (IEA, 2022a).

> "The market is shifting from being driven primarily by policy, to one where organic consumer demand is the most important factor. As regulatory drivers begin to play less of a role, consumer adoption dynamics—the 'S-curve'—take over" (BloombergNEF, 2022).

The S-curve describes the uptake of new technology that eventually takes off not in a linear fashion but exponentially, with sudden and overwhelming effects (Foster, 1986). There are numerous examples of such a dynamic with past technologies—including cellphones, personal computers and, ironically, internal combustion engine passenger vehicles—and arguably global uptake of EVs is now on the same track (Arib & Seba, 2017).

To be in line with the IEA's Net-Zero scenario, 64% of new passenger car sales and 5% of new truck sales would have to be electric by 2030 (IEA, 2021). All the above trends suggest that this trajectory is feasible. Electric vehicles exceeded 13% of global passenger vehicle sales in the first half of 2022, a 50% jump from 2021's 8.7% share (Bloomberg Professional Services, 2022). In China, the world's biggest market for four-wheeled vehicles, 26% of all new passenger vehicle sales were EVs in July 2022, more than double the rate from the previous year (Bloomberg News, 2022).

EVs for medium-duty trucks on urban duty cycles as commercial vehicles are already the cheapest option for many users, and face few infrastructure challenges (BloombergNEF, 2022).

The outlook for uptake in heavy-duty vehicles (HDVs) is not as optimistic in the near-term, a key obstacle being the need for large investments in highway charging infrastructure. However, policy and technological developments for HDVs have been accelerating, with China as an important early adopter (IEA, 2022a).

Industry and petrochemicals

In the industry and petrochemicals sectors, the constraints on demand would come primarily from policies aimed at reducing plastic pollution, with climate policies contributing a more modest share. In many parts of the world, oil is a feedstock to the production of plastics, and that use accounts for 63% of this sector's use of oil.

The IEA scenarios do not see oil demand for plastics changing much between now and 2050 (IEA, 2022b). To the extent demand is constrained, it is a result of increased recycling rates and measures on single-use plastic. In the STEPS, demand rises by 3 mbpd by 2050; in the APS it rises by 0.5 mbpd; and in the NZE Scenario it falls by 1 mbpd. The enduring strength of demand—which runs counter to trends in other sectors, and even to trends in non-feedstock use in the industry and petrochemicals sector—is based on assumptions about economic growth in developing countries and their catching up with OECD rates of plastic consumption (Cetinkaya et al., 2018; Nduagu et al., 2018). Others, by contrast, argue that developing country growth in plastic consumption will not mirror historical patterns in developed countries (McKinsey, 2022).

Measures such as bans on single-use plastics, now in force in a slew of countries, only nibble at the edges of demand, but a global ban would reduce petrochemical-related oil demand by more than a quarter (Barclays Research, 2019). Aggressive recycling policy and legislation could lead to more significant impacts, reducing annual growth in oil demand by up to 1% by 2040 (Bjacek, 2019) or the possibility of peak plastic demand by 2027 (Bond et al., 2020).

There is growing momentum behind regulatory policies to reduce plastic use more broadly and accelerate recycling. For example, a new multilateral environmental agreement on plastics is progressing quickly (Earth Negotiations Bulletin, 2022). The resulting multilateral agreement is expected to facilitate national commitments and actions. Critically, the scope of talks includes considering measures along the entire life cycle of plastics, including production measures.

Aviation and shipping

In aviation and shipping, policies and technologies are not as advanced, but are beginning to take shape. In aviation, 2021 brought a flurry of net-zero pledges from major global carriers and associations (Graver et al., 2022). In the same year, 28 states signed on to the International Aviation Climate Ambition Coalition (UK, 2021), committing to a pathway consistent with the Paris Agreement 1.5°C target, and the U.S. Federal Aviation Authority (2021) committed to net-zero by 2050. Proposed mandates such as ReFuel EU (EC, 2021) and the United Kingdom’s Jet Zero Consultation (UK, 2022) will act as drivers of cost reduction and uptake for sustainable aviation fuel, which will eventually anchor emission reductions in long-haul flights (The Economist, 2022). For short-haul flights, alternatives have advanced enough that Sweden and Denmark have announced that all domestic flights will be fossil fuel-free by 2030, with Norway aiming for 2040 (Frost, 2022).

While the shipping sector is not likely to contribute to a significant displacement of oil demand between now and 2030, a revision to the International Convention for the Prevention of Pollution from Ships came into effect in November 2022, requiring all ships to meet annual ship-specific targets to reduce their carbon intensities—a measure that could cut emissions 11% over 2019 levels by 2026 in a full-compliance scenario (Brooks & Adler, 2021). As well, frustration with the International Maritime Organization’s lack of action is spurring national-level efforts that may have significant impacts, including the European Union's proposal to include shipping in its emissions trading system (European Commission, 2021) and legislative proposals in the United States to mandate low carbon intensity for ships docking at U.S. ports (Clean Shipping Act of 2022).

Buildings and Power

For both buildings and power, where oil is used for heating and electricity generation, oil has alternatives that are, in most cases, cheaper and cleaner (IRENA, 2021; Kelly et al., 2016), and even the IEA’s most conservative STEPS shows demand for both uses falling significantly by 2030. Relative to 2021 global demand for these two sectors of 11.2 mbpd, by 2030 they show a combined decrease in demand of 2.5 mbpd (22%) in the STEPS, 3.1 mbpd (28%) in the APS, or 5.0 mbpd (45%) in the NZE scenario (IEA, 2022b). These are small but significant reductions in global demand that, like the impacts of transport electrification, would manifest in the near term - that is, by 2030.

Conclusions

Near-term demand destruction for oil will be driven primarily by electrification of passenger vehicles, which currently account for 27% of global demand. Trends in climate policies, technological improvements, and consumer behaviour suggest demand reduction in line with the IEA's NZE for that segment of demand. Trends for road transport are more likely to cleave to the more conservative (but still ambitious) APS scenario.

For other drivers of demand, it is less certain whether trends in policy and technology will bring us closer to the APS or NZE. In either scenario, buildings and power, accounting for 12% of global oil demand, will contribute to demand destruction by 2030, dropping by more than 3 mbpd even in the APS.

The other major elements of global oil demand—industry & petrochemicals and aviation & shipping, at 33%—are unlikely to achieve the IEA's NZE conditions by 2030. But, given current trends, in the medium term (post-2030) all of them are likely to contribute significantly to falling demand.

If we assumed the IEA's NZE trajectory for passenger vehicles out to 2030 as argued above, and the more conservative APS trajectory for the other elements of global oil demand whose paths are less certain, the result would be a drop in oil demand from 2021 levels of 13.6 mbpd, or 14%. These same assumptions carried out to 2050 would reduce demand for oil by 45.5 mbpd, or 47%, even without assuming any of the trends in road transport, aviation, shipping, or plastics would lead to more destruction of demand than under currently announced policies. To put those numbers in perspective, the drop in global demand that devastated oil markets and sent prices for Western Texas Intermediate briefly negative in 2020 amounted to less than 7 mbpd (though that was more abrupt than the changes envisioned here). Supply in oil markets is relatively price-inelastic.

Overall, the data suggest that structural changes in road transport, and trends in power generation and heating of buildings, will lead to a peak in global oil demand by the end of this decade. Post-2030, this will be compounded by reduced oil demand for other key uses. Globally, this should mean low and volatile oil prices, particularly if the "green paradox" predictions are correct, and producers liquidate more assets in the present, anticipating that they will have less value in the future (Sinn, 2012). That is bad news for Ecuador and Colombia, where oil production is not low-cost, and where production is expected to decline in the coming energy transition (The Economist, 2023).

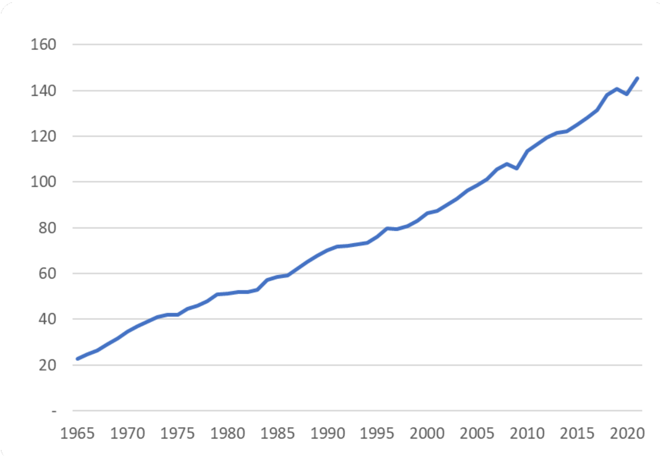
4.2. Global demand for natural gas

Globally, natural gas accounted for roughly 23% of total energy supply in 2021 (BP, 2022a). That share that has grown over the last two decades even as the shares for oil and coal have fallen, as a result of the growth of gas a fuel for electricity generation, whether as new capacity or as part of coal-to-gas switching strategies. Figure 4.9 shows a steady increase in global consumption over time, particularly since the first oil shock in the early 1970s.

Figure 4.10 shows the variety of end uses for gas. Generation of electricity is the highest end use, followed by use in industry, where gas is used as a feedstock (mostly in petrochemicals, but also fertilizers and others) and for process heat. Residential and commercial use is for heating and cooking.

Demand trends for gas are complex to predict, since markets are highly segmented by the necessity of pipeline transport (though the surge in LNG trade over the last decade has softened that segmentation), and since the viability of end uses varies among uses and regions, and often depends on costly distribution infrastructure.

Figure 4.9: Global Gas Consumption (exajoules)

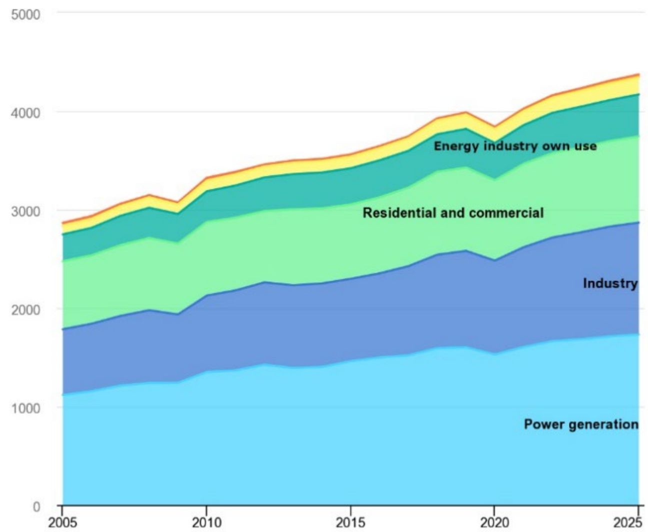


Source: (BP, 2022a).

Tsafos (2020) argues that gas will be hard to displace in regions where it is cheap, such as North America, the former Soviet Union and the Middle East. In the EU gas was costly even before Russia cut off exports in 2022, but now there will be dramatic switching to alternative feedstocks (e.g., hydrogen) and technologies (e.g., residential, commercial and industrial heat pumps), as well as energy efficiency efforts (European Commission, 2022). Asia will likely see its appetite for new energy satisfied by renewables or coal rather than by gas (Hillman, 2022; Tsafos, 2020).

Gas is losing in most places in the cost battle with renewables for new electric power generation capacity. Gas has a more solid hold on industrial applications, and will retain those end uses until technology yields cheaper green hydrogen, more powerful industrial heat pumps, and alternative feedstocks – all medium-term prospects (i.e., perhaps by 2030). Technology trends in heat pumps and induction stoves will likely mean significant reduction of residential gas use toward the end of this decade.

Figure 4.10: Global natural gas demand per sector, 2005-2025



Source: (IEA, 2022c)

The IEA's (unrealistic) Stated Policies Scenario (STEPS) sees overall global gas demand increasing slightly over 2021 levels, by 3.8% in 2030, and falling back slightly to 3.4% higher in 2050. The more climate-ambitious Announced Policies Scenario (APS) sees demand decreasing from 2021 levels by 8% in 2030 and 37% in 2050 (IEA, 2022b). Under any scenario, the demand growth trajectory experienced in recent decades will come to an end, meaning more competition for markets. Supply scenarios see the Middle East gaining global market share, on the back of massive new investments in capacity and low costs, but all other regions in most scenarios decrease production levels. Bolivia and Peru are cited as countries where production is expected to decline, even in the STEPS (IEA, 2022b). While there is no explanation of this outcome, WEO 2022 generally describes the future of gas markets as increasing supply chasing declining demand, with higher-cost producers losing out.

4.3 Global demand for coal

Coal as a share of global energy demand peaked in 2011 at 28%, and has trended down since then, featuring at 25% in 2021 (BP, 2022a). The Russia-Ukraine war has caused coal use to increase thereafter as oil and gas prices spike globally, but most see this as a temporary revival on the way to slow decline for the sector - particularly for thermal coal.

Coal demand falls in all the IEA scenarios, though the picture is widely varied by region, with advanced economies strongly curtailing demand and India strongly increasing. Coal for power faces particular challenges; in advanced economies even the STEPS—which envisions no new climate policies—sees demand falling by 60% by 2030. Overall global demand for coal in the STEPS falls from 2021 levels by 9% in 2030, and 32% in 2050. The APS sees demand falling from 2021 levels by 23% by 2030 and 71% by 2050 (IEA, 2022b). These would be significant reductions, with negative implications for global prices.

Colombia's coal is thermal, used for steam in the generation of electricity, and sold primarily to markets in Europe. It is a major global exporter, but 2021 exports were well below previous highs, the result of low prices and production issues (Coal Hub, 2021). IEA sees a hard future for this sector as the EU transitions away from high-GHG energy sources. Even the STEPS sees reductions in Colombian production of 35% by 2030, and the APS pegs it much higher, at 60% reduction (IEA, 2022b).

4.4. Conclusions

Bolivia, Colombia, Ecuador and Peru countries have a significant share of their merchandise exports devoted to oil and, to a lesser extent, coal and gas. While these three products are varied in terms of their future trends, for all of them there is significant risk of loss of future markets as global demand declines in the face of climate action and new technology.

In the case of oil and coal, those declines look likely to materialize by 2030 with steady downward trend thereafter. Gas has a stronger near-term future, but it too will peak and decline shortly after 2030 under most realistic scenarios.

The implications for exporters will depend on the behaviour of their global competitors, on the relative cost competitiveness of producers, and on the specific products they export in those sectors. But ultimately the global markets in all three products will probably decline, with uncertain effects on price and volatility.

As much as any export stream from these countries, the case of fossil fuels deserves forward planning to anticipate the loss of export markets in the face of global climate policies, and to focus on diversification, cooperation, and other adaptive strategies (Peszko et al., 2020).

5. Conclusions

The carbon content of traded goods is increasingly important as an unconventional element of global competitiveness, as major markets respond to climate change with ambitious and stringent policies that restrict trade on the basis of embodied carbon, and private sector players move to decarbonize their supply chains. The suite of government-mandated climate-related trade measures and private sector measures surveyed here are not a final list, but rather a snapshot of a global trade landscape in the process of dynamic change.

These trends will affect some goods and countries more than others, and this report sought to identify those areas where Bolivia, Colombia, Ecuador and Peru might be vulnerable. The most important vulnerability is the peak and decline in global demand for oil that all credible analysts see arriving by 2030 (BP, 2022b; DNV, 2022; IEA, 2022b; McKinsey, 2022; Rystad Energy, 2022). Oil is by far the highest value export stream for Ecuador and Colombia, with a total annual value of roughly $24 billion in exports in 2019, and their prospects in the energy transition are not good (The Economist, 2023). Bolivia's gas exports are predicted to decline by 2030 even under the most optimistic IEA scenarios (IEA, 2022b). Coal demand may be in even more urgent straits. For these four countries, there is significant risk of lost government revenues, and stranding of productive assets (Solano-Rodríguez et al., 2021; Vogt-Schilb et al., 2021).

Colombia's steel exports are the only major concern for any of the four countries, and those are mostly destined for markets that are not likely to implement climate-related trade measures, as reflected in a relatively low vulnerability index score of 40 (out of 100).

Similarly, none of the four countries is likely to be affected, in the short term, by green government procurement of goods like steel, cement and aluminum based on carbon content, given that Colombia's steel is the only export stream covered, but its major markets are not likely to implement such measures in the near term.

Some of the four countries' substantial agricultural exports may be vulnerable to policies that target land use change, such as the EU's deforestation-free goods law (though that law will not focus directly on GHG-intensity), or to private sector initiatives such as climate-related ecolabels. Peru's agricultural exports, such as fruit and coffee, score relatively high on both GHG intensity and export vulnerability. Ecuador's cut flower exports also score relatively high on both counts.

Finally, this picture of vulnerability is limited in two ways. First, the data for GHG emissions and the input-output tables to which they were linked to derive GHG intensity, are not adequately disaggregated, as noted above. As such, for example, Colombia's bananas and coffee are assumed to have the same GHG intensity, being both covered in a broader category of agricultural products. Better data would yield a more accurate picture of specific product vulnerability. Second, this is a static picture. As noted above, the trends in considering carbon in traded goods are recent and powerful, and beyond the short term they may grow to cover more products of interest to exporters from Bolivia, Colombia, Ecuador and Peru, and may be implemented by more of their export market countries.

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Annex A: Major Exports from Bolivia, Colombia, Ecuador and Peru

Merchandise exports from Bolivia, 2019 (USD current)				
sectoral de minimus cut off: 1% of merchandise exports at 4-digit level				
TOTAL	**All Commodities**		**8,924,397,790**	
27	**Mineral fuels, mineral oils and products of their distillation; bituminous substances; mineral waxes**		**2,758,823,146**	**30.9%**
	2711 Petroleum gases and other gaseous hydrocarbons	*2,758,823,146*		
26	**Ores, slag and ash**		**2,011,764,965**	**22.5%**
	2608 Zinc ores and concentrates	*1,336,580,298*		
	2616 Precious metal ores and concentrates	*504,067,165*		
	2607 Lead ores and concentrates	*171,117,502*		
71	**Natural, cultured pearls; precious, semi-precious stones; precious metals, metals clad with precious metal, and articles thereof; imitation jewellery; coin**		**1,970,342,343**	**22.1%**
	7108 Gold (including gold plated with platinum) unwrought or in semi-manufactured forms, or in powder form	*1,738,981,061*		
	7113 Jewellery articles and parts thereof, of precious metal or of metal clad with precious metal	*136,807,960*		
	7106 Silver (including silver plated with gold or platinum); unwrought or in semi-manufactured forms, or in powder form	*94,553,322*		
23	**Food industries, residues and wastes thereof; prepared animal fodder**		**452,858,693**	**5.1%**
	2304 Oil-cake and other solid residues; whether or not ground or in the form of pellets, resulting from the extraction of soya-bean oil	*452,858,693*		
80	**Tin; articles thereof**		**285,162,859**	**3.2%**
	8001 Tin; unwrought	*285,162,859*		
15	**Animal or vegetable fats and oils and their cleavage products; prepared animal fats; animal or vegetable waxes**		**243,586,057**	**2.7%**
	1507 Soya-bean oil and its fractions; whether or not refined, but not chemically modified	*243,586,057*		
8	**Fruit and nuts, edible; peel of citrus fruit or melons**		**155,959,010**	**1.7%**
	801 Nuts, edible; coconuts, Brazil nuts and cashew nuts, fresh or dried, whether or not shelled or peeled	*155,959,010*		
10	**Cereals**		**90,771,860**	**1.0%**
	1008 Buckwheat, millet and canary seeds; other cereals	*90,771,860*		
			Share:	**89.3%**

Merchandise eports from Colombia, 2019 (USD current)		Bolivianos per USD in 2020:		**6.9013**
sectoral de minimus cut off: 1% of merchandise exports at 4-digit level				
TOTAL	**All Commodities**	**39,489,359,461**		
		394,893,595		
27	**Mineral fuels, mineral oils and products of their distillation; bituminous substances; mineral waxes**		**21,560,515,961**	**54.6%**
	2709 Petroleum oils and oils obtained from bituminous minerals; crude	*12,979,915,800*		
	2701 Coal; briquettes, ovoids and similar solid fuels manufactured from coal	*4,883,977,407*		
	2710 Petroleum oils and oils from bituminous minerals, not crude; preparations n.e.c, containing by weight 70% or more of petroleum oils or oils from bituminous minerals; these being the basic constituents of the preparations; waste oils	*2,912,291,580*		
	2704 Coke and semi-coke; of coal, lignite or peat, whether or not agglomerated; retort carbon	*784,331,174*		
9	**Coffee, tea, mate and spices**		**2,363,170,296**	**6.0%**
	901 Coffee, whether or not roasted or decaffeinated; husks and skins; coffee substitutes containing coffee in any proportion	*2,363,170,296*		
71	**Natural, cultured pearls; precious, semi-precious stones; precious metals, metals clad with precious metal, and articles thereof; imitation jewellery; coin**		**1,746,835,077**	**4.4%**
	7108 Gold (including gold plated with platinum) unwrought or in semi-manufactured forms, or in powder form	*1,746,835,077*		
6	**Trees and other plants, live; bulbs, roots and the like; cut flowers and ornamental foliage**		**1,474,824,457**	**3.7%**
	603 Flowers; cut flowers and flower buds of a kind suitable for bouquets or for ornamental purposes, fresh, dried, dyed, bleached, impregnated or otherwise prepared	*1,474,824,457*		
8	**Fruit and nuts, edible; peel of citrus fruit or melons**		**934,276,317**	**2.4%**
	803 Bananas, including plantains; fresh or dried	*934,276,317*		
72	**Iron and steel**		**545,101,180**	**1.4%**
	7202 Ferro-alloys	*545,101,180*		
87	**Vehicles; other than railway or tramway rolling stock, and parts and accessories thereof**		**432,011,606**	**1.1%**
	8703 Motor cars and other motor vehicles; principally designed for the transport of persons (other than those of heading no. 8702), including station wagons and racing cars	*432,011,606*		
39	**Plastics and articles thereof**		**394,959,863**	**1.0%**
	3902 Polymers of propylene or of other olefins, in primary forms	*394,959,863*		
			Share:	**74.6%**

Merchandise exports from Ecuador, 2019 (USD current)		Pesos per USD in 2020:		**3,333.3333**
sectoral de minimus cut off: 1% of merchandise exports at 4-digit level				
TOTAL	**All Commodities**		**22,329,378,718**	
27	**Mineral fuels, mineral oils and products of their distillation; bituminous substances; mineral waxes**		**8,677,248,749**	**38.9%**
	2709 Petroleum oils and oils obtained from bituminous minerals; crude	*7,731,162,685*		
	2710 Petroleum oils and oils from bituminous minerals, not crude; preparations n.e.c, containing by weight 70% or more of petroleum oils or oils from bituminous minerals; these being the basic constituents of the preparations; waste oils	*946,086,064*		
3	**Fish and crustaceans, molluscs and other aquatic invertebrates**		**3,901,558,585**	**17.5%**
	306 Crustaceans; in shell or not, live, fresh, chilled, frozen, dried, salted or in brine; smoked, cooked or not before or during smoking; in shell, steamed or boiled, whether or not chilled, frozen, dried, salted or in brine; edible flours, meals, pellets	*3,901,558,585*		
8	**Fruit and nuts, edible; peel of citrus fruit or melons**		**3,310,588,274**	**14.8%**
	803 Bananas, including plantains; fresh or dried	*3,310,588,274*		
16	**Meat, fish or crustaceans, molluscs or other aquatic invertebrates; preparations thereof**		**1,187,323,717**	**5.3%**
	1604 Prepared or preserved fish; caviar and caviar substitutes prepared from fish eggs	*1,187,323,717*		
6	**Trees and other plants, live; bulbs, roots and the like; cut flowers and ornamental foliage**		**879,778,942**	**3.9%**
	603 Flowers; cut flowers and flower buds of a kind suitable for bouquets or for ornamental purposes, fresh, dried, dyed, bleached, impregnated or otherwise prepared	*879,778,942*		
18	**Cocoa and cocoa preparations**		**657,272,145**	**2.9%**
	1801 Cocoa beans; whole or broken, raw or roasted	*657,272,145*		
			Share:	**83.4%**

Merchandise exports from Peru, 2019 (USD current)		currency: soles. Soles per USD in 202		**3.4948**
sectoral de minimus cut off: 1% of merchandise exports at aggregated 4-digit level				
TOTAL	**All Commodities**		**46,131,564,759**	
26	**Ores, slag and ash**		**17,052,226,139**	**37.0%**
	2603 Copper ores and concentrates	*12,191,877,269*		
	2601 Iron ores and concentrates; including roasted iron pyrites	*978,982,236*		
	2607 Lead ores and concentrates	*977,934,948*		
	2608 Zinc ores and concentrates	*1,634,039,033*		
	2613 Molybdenum ores and concentrates	*644,683,122*		
	2616 Precious metal ores and concentrates	*624,709,531*		
71	**Natural, cultured pearls; precious, semi-precious stones; precious metals, metals clad with precious metal, and articles thereof; imitation jewellery; coin**		**6,750,540,738**	**14.6%**
	7108 Gold (including gold plated with platinum) unwrought or in semi-manufactured forms, or in powder form	*6,750,540,738*		
27	**Mineral fuels, mineral oils and products of their distillation; bituminous substances; mineral waxes**		**2,991,030,188**	**6.5%**
	2710 Petroleum oils and oils from bituminous minerals, not crude; preparations n.e.c, containing by weight 70% or more of petroleum oils or oils from bituminous minerals; these being the basic constituents of the preparations; waste oils	*2,365,596,965*		
	2711 Petroleum gases and other gaseous hydrocarbons	*625,433,223*		
8	**Fruit and nuts, edible; peel of citrus fruit or melons**		**2,795,164,027**	**6.1%**
	804 Dates, figs, pineapples, avocados, guavas, mangoes and mangosteens; fresh or dried	*1,024,913,245*		
	806 Grapes; fresh or dried	*880,423,045*		
	810 Fruit, fresh; n.e.c. in chapter 08	*889,827,737*		
74	**Copper and articles thereof**		**1,623,092,957**	**3.5%**
	7403 Copper; refined and copper alloys, unwrought	*1,623,092,957*		
23	**Food industries, residues and wastes thereof; prepared animal fodder**		**1,529,323,291**	**3.3%**
	2301 Flours, meal and pellets, of meat or meat offal, of fish or of crustaceans, molluscs or other aquatic invertebrates, unfit for human consumption; greaves	*1,529,323,291*		
79	**Zinc and articles thereof**		**739,387,973**	**1.6%**
	7901 Zinc; unwrought	*739,387,973*		
3	**Fish and crustaceans, molluscs and other aquatic invertebrates**		**697,195,824**	**1.5%**
	307 Molluscs; whether in shell or not, live, fresh, chilled, frozen, dried, salted or in brine; smoked molluscs, whether in shell or not, cooked or not before or during the smoking process; flours, meals and pellets of molluscs, fit for human consumption	*697,195,824*		
9	**Coffee, tea, mate and spices**		**636,834,747**	**1.4%**
	901 Coffee, whether or not roasted or decaffeinated; husks and skins; coffee substitutes containing coffee in any proportion	*636,834,747*		
			Share:	**75.5%**

Annex B: Methodology, Caveats

The two main steps to the assessment are 1) attributing national emissions directly to economic production sectors (i.e., Scope 1 emissions) and 2) Estimating Scope 2 and Scope 3 emissions associated with the Scope 1 emissions that are passed through output to either other industries, final consumption expenditures, capital formation or exports.

Direct emissions that are reported in national Inventory common reporting format (CRF) tables that are submitted to the UNFCCC are mapped to the input-output economic industry sectors identified in available national tables and to households.

The objective is to map national emissions that are of the same year as the input-output tables, but a variance of several years was allowed for some countries as this was the only data available (see specific country method descriptions in section 2). Input-Output tables are sometimes available for different countries at different levels of disaggregation, but because some countries only had industry disaggregation for 70-100 industries, input output tables were selected at this level of disaggregation for all countries.

Mapping of direct emissions: Mapping of direct (Scope 1) emissions to industry or households was based on a preferential list of allocation methods:

1. **Direct allocation** (emissions all to a single industry sector) were used when these emissions clearly belonged to a single industry category. For example, emissions in the NIR categorized as fossil fuel burning emissions for the production of electricity could all be directly linked to the electricity industry sector category.
2. **Indirect allocation based on sector output** activity data. If emissions are known to belong to a number of different industry categories, it can be possible to split emissions based on economic activity from the input output table. For example, energy emissions associated with the chemical industry could be split amongst multiple chemical sector categories (e.g., basic chemicals, pharmaceuticals, rubber and plastic products) by using the respective intermediate output demand for refining products and natural gas services for each of these industries to determine the split of emissions.
3. **Indirect allocation based on total economic sector output**. If emissions are known to belong to a number of different industry categories, emissions are split based on the total economic output activity of the sectors. For example, N_2O emissions from agricultural soils associated with agriculture industry categories could be split amongst multiple industry categories (e.g., coffee production, grain production, banana production) by using the respective total output of these sectors to determine the split of emissions.

Note that where it is clear that Scope 1 emissions are part of household activities that are only indirectly attributed to industry activity (i.e., the emissions are downstream Scope 3 emissions for industry not Scope 1 emissions directly attributed to industry activity), then they are mapped to household expenditures. The two primary and most important examples of this are residential fuel heating emissions and household personal passenger transportation emissions. While the fuel products are sold to households, the actual direct emissions are not Scope 1 industry emissions and therefore not part of Scope 1 emission liability for the associated fuel distributor and refining sectors.

LULUCF emissions or sinks were associated with economic sectors only where there was an apparent direct correlation with an industry economic activity. LULUCF emissions and sinks associated with wetlands and settlements were never associated with industry activity (unmapped emissions). Emissions or sinks from cropland were always associated with prmiary agriculture and specifically crop production categories. If there were multiple crop production industry sectors (e.g., coffee, bananas, etc), they were sub-allocated based on output or land area. Grassland emissions or sinks were always associated with animal production (i.e.., grazing), or agriculture if there was not a separate animal production industry designation. For forest land emissions and sinks, where possible we identified emissions and sinks that were from managed forests and these were directly linked to the forestry industry sector.

In addition, Land-Use, Land-Use Change and Forestry (LULUCF) emissions and sinks are not always mapped to industrial activity and sectors. In these sectors emissions and sinks are related to the change in biomass, either as a result of a change in the stock of carbon for existing land-uses or as a result of a change of land-use from one type to another. Attribution to industrial sectors was only done where there was an apparent direct correlation with an industry economic activity. LULUCF emissions and sinks associated with wetlands and settlements were never associated with industry activity (unmapped emissions). Emissions or sinks from cropland were always associated with primary agriculture and specifically crop production categories. If there were multiple crop production industry sectors (e.g., coffee, bananas, etc), they were sub-allocated based on output or land area. Grassland emissions or sinks were always associated with animal production (i.e., grazing), or agriculture if there was not a separate animal production industry designation. For forest land emissions and sinks, where possible we identified emissions and sinks that were from managed forests and these were directly linked to the forestry industry sector.

LULUCF emissions and sinks have a high degree of uncertainty as they are not only difficult to measure, but methodologies are also inconsistent between countries. They are also subject to very large annual changes due to conditions that are not necessarily directly correlated to industry activities in a given year. This uncertainty is discussed further below.

Indirect emissions: Once Scope 1 emissions have been attributed to industry sectors, it is possible to trace these Scope 1 emissions through the economy, using input-output tables or use tables until their eventual embodiment in final use categories. These final use categories include Final Consumption (i.e., household and government expenditures), Capital Formation (emissions embodied in equipment, buildings, infrastructure, or intellectual property) or Exports. Embodied emissions are essentially Scope 2 and Scope 3 emissions that are passed on from upstream industry. Industry can pass on not only Scope 1 emissions, but because Industry consumes output, industry also passes on Scope 2 and Scope 3 emissions that are related to their inputs (i.e., upstream emissions).

The use tables define how much output is consumed by intermediate industries and how much is passed on to Final Consumption, Capital Formation and Exports. There is a general assumption here that for every industry sector, emissions pass through at the same emission intensity, so for example, a dollar of output of electricity consumed by households or consumed by the steel sector, has the same emission intensity (e.g., $50 tCO2e/million$ of output). This is simplification, as for example the household sector might get electricity from a different grid (with a different emission intensity) then the steel sector, but the construct allows us to trace and pass through all emissions as the input-output tables are balanced.

Because a portion of direct emissions flows through output that is purchased by other industry sectors, the model uses an iterative approach (10 iterations) until all Scope 2 and Scope 3 emissions are allocated to final consumption or use (i.e., final consumption, capital formation or exports). The allocation of emissions is based on the dollar value of the output in the use table. The result is essentially equivalent to the often-used method of inverting the input-output matrices, as after enough iterations the results will asymptotically approach the inverted matrix results. Our tests showed that 10 iterations was enough to result in statistically insignificant differences in the numbers for final attributed emissions.

This model can then be used to not only sum Scope 1, Scope 2 and Scope 3 emissions and emission intensities associated with all industry output sectors (i.e., tCO2e/$ of output it can also express this for expenditures, capital formation or exports (i.e., tCO2e/$ expenditure). The model can also trace from whence Scope 2 and 3 emissions originate – so that for any industry sector we can summarize the contributing sectors to emissions that are embodied in its output.

There are several key things to note. Output must be expressed as domestic output only. In other words, the contribution of imports to total economic output must be subtracted. The reason for this is that imports could be embodied with completely different emission intensities, and from a carbon competitiveness perspective we are interested in only understanding the emission intensity of domestic production. While some imports may be re-exported, for country comparisons of carbon competitiveness it is better to consider only a domestic view. There is a simplifying assumption that a dollar imported has the same effect on final output as a dollar of domestic production.

Further caveats:

1. Allocation of emissions using input-output tables is imperfect, as each sector will have differentiated output of different emission intensities. As a result, some intermediate inputs will have higher emission intensity than others.
2. Allocation of LULUCF emissions and sinks is highly uncertain. The direct contributions of industry activity to LULUCF emissions and sinks in a given year are difficult to determine. There are also widely different accounting methodologies for LULUCF emissions. Because these emissions and sinks can be very large, they can overwhelm direct emissions from the energy, waste, IPPU and agriculture sector categories, leading to Scope 1 and 3 emission intensities that have significantly greater uncertainty.
3. Some emissions are associated with the combustion of fuels or use of products that have been purchased by households. The most significant emission sources residential fuel use and personal transportation fuel use have been allocated in this methodology to households. There are other emissions that should also be allocated to households, like non-energy products from fuels and solvent use and product uses as substitutes for ozone-depleting substances could also be associated with household product usage.

Annex C: Climate-Based Market Exposure Indices

5 largest export destinations by sector, merchandise exports from Bolivia, 2019 (USD current)							
sectoral de minimus cut off: 1% of merchandise exports							
TOTAL	**All Commodities**	**8,924,397,790**					
				Income	**Country risk (CR)**	**Climate Action Tracker rating**	**Market risk index (/100)**
27	**Mineral fuels, mineral oils and products of their distillation; bituminous substances; mineral waxes**	**2,823,654,905**	**31.6%**				
	Brazil	1,457,756,209		2	0	3	21.8
	Argentina	1,267,666,340		2	0	3	19.0
	Saint Lucia	21,483,108		2	0		0.3
	Paraguay	19,662,497		2	0		0.2
	Peru	19,567,935		2	0	4	0.3
							42
26	**Ores, slag and ash**	**2,049,137,799**	**23.0%**				
	Japan	709,548,853		3	1	3	24.2
	China	350,127,407		2	0	3	7.2
	Rep. of Korea	312,663,154		3	0	2	7.1
	Australia	159,619,897		3	1	3	5.5
	Belgium	146,149,645		3	2	4	6.7
							51
71	**Natural, cultured pearls; precious, semi-precious stones; precious metals, metals clad with precious metal, and articles thereof; imitation jewellery;**	**1,972,351,074**	**22.1%**				
	United Arab Emirates	848,896,164		3	0	3	23.0
	India	739,931,467		1	0	3	11.7
	USA	149,130,424		3	2	3	6.6
	Italy	77,643,910		3	2	4	3.7
	Turkey	72,185,885		2	0	1	1.1
							46
23	**Food industries, residues and wastes thereof; prepared animal fodder**	**468,575,760**	**5.3%**				
	Peru	229,126,165		2	0	4	23.9
	Colombia	170,976,170		2	0	3	15.4
	Chile	32,974,751		3	0	4	4.2
	Ecuador	22,268,525		2	0		1.6
	Myanmar	5,450,328		1	0		0.2
							45
15	**Animal or vegetable fats and oils and their cleavage products; prepared animal fats; animal or vegetable waxes**	**287,733,603**	**3.2%**				
	Colombia	163,990,409		2	0	3	24.1
	Ecuador	101,455,330		2	0		11.8
	Peru	15,672,047		2	0	4	2.7
	Chile	6,004,747		3	0	4	1.3
	Argentina	265,594		2	0	3	0.0
							40
80	**Tin; articles thereof**	**285,211,678**	**3.2%**				
	USA	150,328,858		3	2	3	45.7
	Netherlands	78,502,841		3	2	4	25.7
	Spain	42,521,979		3	2	4	13.9
	Mexico	5,735,824		2	0	2	0.7
	Japan	2,496,520		3	1	3	0.6
							87
8	**Fruit and nuts, edible; peel of citrus fruit or melons**	**186,823,710**	**2.1%**				
	Netherlands	49,920,745		3	2	4	24.9
	Argentina	28,536,503		2	0	3	6.4
	United Kingdom	24,945,962		3	2	4	12.5
	Germany	24,448,184		3	2	4	12.2
	USA	22,431,953		3	2	3	10.4
							66
10	**Cereals**	**99,407,809**	**1.1%**				
	USA	39,583,459		3	2	3	34.5
	France	10,241,446		3	2	4	9.6
	Germany	8,520,604		3	2	4	8.0
	China	6,437,091		2	0	3	2.7
	Canada	5,760,739		3	2	2	4.6
							59

Merchandise exports from Colombia, 2019 (USD current)							
de minimus cut off: USD 10M							
TOTAL	**All Commodities**	**39,489,359,461**					
				income	**Country risk (CR)**	**Climate Action Tracker rating**	**Market risk index (/100)**
27	**Mineral fuels, mineral oils and products of their distillation; bituminous substances; mineral waxes**	**21,631,821,238**	**54.8%**				
	USA	7,281,085,818		3	2	3	29.2
	China	4,045,052,350		2	0	3	7.9
	Panama	2,049,330,693		3	0		3.2
	Turkey	1,135,402,419		2	0	1	1.5
	Saint Lucia	867,236,727		2	0		0.9
							43
9	**Coffee, tea, mate and spices**	**2,376,441,108**	**6.0%**				
	USA	1,061,985,566		3	2	3	38.7
	Germany	193,024,029		3	2	4	7.6
	Japan	184,324,457		3	1	3	5.4
	Canada	176,465,222		3	2	2	5.9
	Belgium	122,289,991		3	2	4	4.8
							62
71	**Natural, cultured pearls; precious, semi-precious stones; precious metals, metals clad with precious metal, and articles thereof; imitation jewellery; coin**	**1,961,815,996**	**5.0%**				
	USA	590,955,050		3	2	3	26.1
	Italy	456,032,284		3	2	4	21.7
	Free Zones	319,154,749					0.0
	United Arab Emirates	155,597,741		3	0	3	4.2
	Switzerland	145,702,571		3	0	3	4.0
							56
6	**Trees and other plants, live; bulbs, roots and the like; cut flowers and ornamental foliage**	**1,495,636,125**	**3.8%**				
	USA	1,166,308,687		3	2	3	67.6
	Japan	52,988,980		3	1	3	2.5
	United Kingdom	45,469,609		3	2	4	2.8
	Netherlands	39,359,480		3	2	4	2.5
	Canada	38,666,494		3	2	2	2.1
							77
39	**Plastics and articles thereof**	**1,471,826,462**	**3.7%**				
	Brazil	415,451,201		2	0	3	11.9
	USA	179,132,875		3	2	3	10.5
	Ecuador	126,890,654		2	0		1.9
	Mexico	114,977,204		2	0	2	2.8
	Peru	111,341,626		2	0	4	3.7
							31
8	**Fruit and nuts, edible; peel of citrus fruit or melons**	**1,158,487,472**	**2.9%**				
	Belgium	216,627,629		3	2	4	17.5
	United Kingdom	193,911,204		3	2	4	15.6
	Netherlands	170,035,007		3	2	4	13.7
	USA	169,150,452		3	2	3	12.7
	Italy	127,361,327		3	2	4	10.3
							70
87	**Vehicles; other than railway or tramway rolling stock, and parts and accessories thereof**	**656,726,355**	**1.7%**				
	Ecuador	318,387,373		2	0		10.8
	Mexico	144,450,555		2	0	2	7.8
	Argentina	55,308,026		2	0	3	3.6
	USA	41,669,324		3	2	3	5.5
	Chile	36,278,454		3	0	4	3.3
							31
72	**Iron and steel**	**604,934,500**	**1.5%**				
	China	398,811,761		2	0	3	27.8
	China, Hong Kong SAR	35,787,084		3	0		2.0
	Japan	33,421,910		3	1	3	3.9
	Netherlands	28,240,701		3	2	4	4.4
	Germany	28,171,937		3	2	4	4.3
							42
15	**Animal or vegetable fats and oils and their cleavage products; prepared animal fats; animal or vegetable waxes**	**524,791,369**	**1.3%**				
	Netherlands	135,640,395		3	2	4	24.1
	Ecuador	98,952,960		2	0		4.2
	Spain	46,004,575		3	2	4	8.2
	Mexico	45,427,798		2	0	2	3.1
	Germany	34,888,932		3	2	4	6.2
							46
17	**Sugars and sugar confectionery**	**484,634,736**	**1.2%**				
	USA	97,624,624		3	2	3	17.5
	Peru	80,791,370		2	0	4	8.2
	Chile	51,722,494		3	0	4	6.4
	Ecuador	35,614,107		2	0		1.6
	Haiti	22,456,146		1	0		0.5
							34
33	**Essential oils and resinoids; perfumery, cosmetic or toilet preparations**	**483,056,313**	**1.2%**				
	Peru	118,130,038		2	0	4	12.0
	Ecuador	96,618,067		2	0		4.4
	Mexico	80,667,370		2	0	2	5.9
	Chile	39,921,248		3	0	4	5.0
	Dominican Rep.	21,073,757		2	0		1.0
							28
38	**Chemical products n.e.c.**	**476,850,060**	**1.2%**				
	Brazil	137,468,978		2	0	3	12.2
	Ecuador	76,063,021		2	0		3.5
	Mexico	55,682,151		2	0	2	4.2
	Peru	41,847,037		2	0	4	4.3
	Argentina	22,414,105		2	0	3	2.0
							26
85	**Electrical machinery and equipment and parts thereof; sound recorders and reproducers; television image and sound recorders and reproducers, parts and accessories of such articles**	**475,268,460**	**1.2%**				
	USA	110,867,700		3	2	3	20.2
	Ecuador	74,436,603		2	0		3.5
	Peru	66,601,615		2	0	4	6.9
	Mexico	28,957,828		2	0	2	2.2
	Chile	28,700,854		3	0	4	3.6
							36
84	**Nuclear reactors, boilers, machinery and mechanical appliances; parts thereof**	**413,338,146**	**1.0%**				
	USA	98,828,173		3	2	3	20.7
	Ecuador	75,968,802		2	0		4.1
	Peru	36,486,257		2	0	4	4.3
	Mexico	29,648,754		2	0	2	2.6
	Guatemala	24,475,324		2	0		1.3
							33

5 largest export destinations by sector, merchandise exports from Ecuador, 2019 (USD current)							
sectoral de minimus cut off: 1% of merchandise exports							
TOTAL	**All Commodities**	**22,329,378,718**					
				Income	**Country risk (CR)**	**Climate Action Tracker rating**	**Market risk index (/100)**
27	**Mineral fuels, mineral oils and products of their distillation; bituminous substances; mineral waxes**	**8,746,465,196**	**39.2%**				
	USA	4,017,336,525		3	2	3	40
	Panama	1,873,834,876		3	0		11
	Chile	1,214,510,377		3	0	4	8
	Peru	610,611,303		2	0	4	3
	China	261,623,564		2	0	3	1
							64
3	**Fish and crustaceans, molluscs and other aquatic invertebrates**	**4,241,981,442**	**19.0%**				
	China	2,133,243,358		2	0	3	21
	USA	712,119,253		3	2	3	15
	Viet Nam	328,248,915		1	0	1	1
	Spain	250,426,713		3	2	4	6
	France	189,760,256		3	2	4	4
							47
8	**Fruit and nuts, edible; peel of citrus fruit or melons**	**3,490,732,648**	**15.6%**				
	Russian Federation	643,853,810		2	0	2	7
	USA	580,706,109		3	2	3	14
	Turkey	232,049,280		2	0	1	2
	China	220,466,132		2	0	3	3
	Germany	171,621,717		3	2	4	5
							30
16	**Meat, fish or crustaceans, molluscs or other aquatic invertebrates; preparations thereof**	**1,207,336,602**	**5.4%**				
	Spain	290,422,948		3	2	4	22
	Netherlands	155,794,249		3	2	4	12
	USA	150,918,700		3	2	3	11
	Colombia	140,693,180		2	0	3	5
	Italy	91,707,046		3	2	4	7
							57
6	**Trees and other plants, live; bulbs, roots and the like; cut flowers and ornamental foliage**	**887,030,032**	**4.0%**				
	USA	402,279,326		3	2	3	39
	Russian Federation	128,237,237		2	0	2	5
	Netherlands	75,829,838		3	2	4	8
	Italy	32,236,220		3	2	4	3
	Spain	26,911,612		3	2	4	3
							59
18	**Cocoa and cocoa preparations**	**763,896,885**	**3.4%**				
	Indonesia	168,810,687		2	0	3	9
	USA	140,853,946		3	2	3	16
	Netherlands	109,521,886		3	2	4	13
	Malaysia	72,331,464		2	0		3
	Mexico	60,084,093		2	0	2	3
							45
44	**Wood and articles of wood; wood charcoal**	**463,742,189**	**2.1%**				
	China	132,405,584		2	0	3	12
	USA	91,176,054		3	2	3	17
	Colombia	75,411,989		2	0	3	7
	India	51,569,303		1	0	3	3
	Peru	45,547,340		2	0	4	5
							44
20	**Preparations of vegetables, fruit, nuts or other parts of plants**	**215,807,031**	**1.0%**				
	USA	96,132,633		3	2	3	39
	Netherlands	26,421,591		3	2	4	11
	France	18,643,662		3	2	4	8
	Chile	16,697,694		3	0	4	5
	Spain	9,269,562		3	2	4	4
							67

5 largest export destinations by sector, merchandise exports from Peru, 2019 (USD current)							
sectoral de minimus cut off: 1% of merchandise exports at 2-digit level							
TOTAL	**All Commodities**	**46,131,564,759**		**Income**	**Country risk (CR)**	**Climate Action Tracker rating**	**Market risk index (/100)**
26	**Ores, slag and ash**	**17,052,540,713**	**37.0%**				
	China	10,618,328,858		2	0	3	26
	Rep. of Korea	1,459,146,405		3	0	2	4
	Japan	1,224,976,943		3	1	3	5
	Germany	567,113,321		3	2	4	3
	Brazil	418,622,913		2	0	3	1
							39
71	**Natural, cultured pearls; precious, semi-precious stones; precious metals, metals clad with precious metal, and articles thereof; imitation jewellery; coin**	**7,194,265,931**	**15.6%**				
	Switzerland	2,253,045,186		3	0	3	17
	Canada	1,846,838,541		3	2	2	21
	India	1,499,474,455		1	0	3	6
	United Arab Emirates	964,243,845		3	0	3	7
	USA	483,706,492		3	2	3	6
							57
8	**Fruit and nuts, edible; peel of citrus fruit or melons**	**3,412,708,766**	**7.4%**				
	USA	1,346,818,966		3	2	3	34
	Netherlands	767,567,087		3	2	4	21
	United Kingdom	241,352,735		3	2	4	7
	Spain	171,919,244		3	2	4	5
	China	152,075,010		2	0	3	2
							68
27	**Mineral fuels, mineral oils and products of their distillation; bituminous substances; mineral waxes**	**3,169,075,463**	**6.9%**				
	USA	510,050,916		3	2	3	14
	Brazil	394,986,198		2	0	3	5
	Panama	394,970,064		2	0		4
	Japan	325,376,293		3	1	3	7
	Rep. of Korea	282,636,084		3	0	2	4
							35
74	**Copper and articles thereof**	**2,086,453,903**	**4.5%**				
	China	1,001,671,959		2	0	3	20
	Italy	267,037,677		3	2	4	12
	Brazil	197,578,926		2	0	3	4
	Rep. of Korea	180,395,108		3	0	2	4
	USA	160,730,690		3	2	3	7
							47
23	**Food industries, residues and wastes thereof; prepared animal fodder**	**1,759,942,233**	**3.8%**				
	China	1,119,737,083		2	0	3	27
	Ecuador	227,358,964		2	0		4
	Japan	116,385,826		3	1	3	5
	Viet Nam	65,670,750		1	0	1	1
	Germany	46,941,786		3	2	4	2
							39
3	**Fish and crustaceans, molluscs and other aquatic invertebrates**	**1,204,590,650**	**2.6%**				
	Spain	225,603,057		3	2	4	17
	China	197,169,335		2	0	3	7
	USA	180,603,999		3	2	3	13
	Rep. of Korea	109,061,883		3	0	2	4
	Japan	68,142,380		3	1	3	4
							46
61	**Apparel and clothing accessories; knitted or crocheted**	**914,126,970**	**2.0%**				
	USA	625,692,592		3	2	3	59
	Brazil	51,062,695		2	0	3	2
	Germany	27,981,944		3	2	4	3
	Chile	26,419,168		3	0	4	2
	Canada	25,455,845		3	2	2	2
							68
79	**Zinc and articles thereof**	**796,507,283**	**1.7%**				
	USA	163,357,469		3	2	3	18
	Belgium	75,290,793		3	2	4	9
	Other Asia, nes	64,143,323					0
	Germany	56,082,081		3	2	4	7
	Thailand	46,218,904		2	0	1	2
							35
9	**Coffee, tea, mate and spices**	**775,377,114**	**1.7%**				
	USA	229,008,311		3	2	3	26
	Germany	147,196,147		3	2	4	18
	Belgium	64,127,156		3	2	4	8
	Sweden	38,461,338		3	2	4	5
	Canada	37,459,238		3	2	2	4
							60
7	**Vegetables and certain roots and tubers; edible**	**679,211,459**	**1.5%**				
	USA	374,913,101		3	2	3	48
	Spain	62,317,900		3	2	4	9
	United Kingdom	51,696,462		3	2	4	7
	Netherlands	46,677,490		3	2	4	6
	Japan	18,035,810		3	1	3	2
							72
20	**Preparations of vegetables, fruit, nuts or other parts of plants**	**582,148,560**	**1.3%**				
	USA	263,737,959		3	2	3	39
	Spain	103,129,572		3	2	4	17
	Netherlands	44,974,856		3	2	4	7
	France	33,606,505		3	2	4	5
	Brazil	30,183,342		2	0	2	2
							70
39	**Plastics and articles thereof**	**549,750,888**	**1.2%**				
	Colombia	86,517,045		2	0	3	7
	USA	85,126,624		3	2	3	13
	Bolivia (Plurinational State of)	71,549,018		1	0		2
	Chile	65,064,876		3	0	4	7
	Ecuador	55,729,148		2	0		3
							33
15	**Animal or vegetable fats and oils and their cleavage products; prepared animal fats; animal or vegetable waxes**	**507,632,664**	**1.1%**				
	Canada	77,583,097		3	2	2	12
	Denmark	72,144,449		3	2	4	13
	Belgium	58,832,895		3	2	4	11
	China	48,024,315		2	0	3	4
	Chile	42,307,697		3	0	4	5
							45