

European Union's Carbon Border Adjustment Mechanism: risks or opportunities for Brazil?

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Abstract

This article analyzes the risks and opportunities for Brazil posed by the European Union's Carbon Border Adjustment Mechanism (CBAM). Brazilian exporting companies, without a strong system to measure, report, and verify (MRV) carbon emissions at the individual product and plant levels, face higher compliance costs due to reliance on CBAM default values. It also presents regulatory gaps regarding indirect carbon emissions, biogenic carbon, and the allocation and accountability of total carbon emissions. However, opportunities arise from accelerating the implementation of Brazil's regulated carbon market, with MRV obligations aligned with international best practices, to retain carbon pricing revenues domestically and support national industrial decarbonization. Brazil should lead efforts in global climate governance forums to mitigate the risk of CBAM regulatory gaps, thereby strengthening the competitiveness of energy-intensive exports, particularly in the iron/steel and aluminium sectors, and making CBAM a fairer and more legitimate mechanism for Global South countries.

Introduction

In 2021, the European Commission published the *Fit for 55 package*, a legislative package comprising 50 initiatives to reduce greenhouse gas (GHG) emissions by at least 55% below 1990 levels by 2030, towards achieving climate neutrality by 2050, as promised in 2019 by the *European Green Deal*. Among these measures is the reform of the European Union Emissions Trading System (EU ETS). Established in 2005 as the world's first major carbon market, the EU ETS allocates a set of free emission allowances to EU producers to ensure they remain competitive with foreign producers not subject to the same carbon taxation rules. Through Directive 2023/959, the EU revamped the EU ETS, aligning it with the stricter climate targets of the *Fit for 55 package* and establishing a timetable for the phase-out of free emission allowances for industry: 2026 (97.5%), 2030 (51.5%), and 2034 (0%). In 2026, the end of free emission allowances for energy-intensive industrial sectors by four years (from 2034 to 2038), aiming to alleviate competitive pressure on industrial sectors regulated by the EU ETS (European Commission 2026).

To prevent carbon leakage, the risk of European companies relocating production to countries with less stringent environmental policies, and unfair competition from foreign companies that do not meet the same climate standards, the Carbon Border Adjustment Mechanism (CBAM) was established by Regulation (EU) 2023/956. It is applied to imports of a list of 250 products, classified under the Combined Nomenclature (CN), and belong to the upstream value chain of six energy-intensive industrial sectors: cement, iron/steel, aluminium, fertilizers, electricity, and hydrogen.

Countries outside the EU that already have instruments equivalent to the EU's ETS, such as Iceland, Liechtenstein, Norway, and Switzerland, are excluded. The future expansion of the CBAM is planned to include downstream products from these sectors, as well as products from new sectors (organic chemicals/polymers, glass, etc.) (Clora et al. 2023).

The CBAM regulations detail the obligations of European importers, establish the format and content of reports, and the methodology for accounting for the actual values of carbon emissions embedded in

imported products. This includes direct emissions (scope 1) from all regulated sectors and excludes indirect emissions (scope 2) from the purchase of electricity for the iron/steel and aluminium sectors. Furthermore, it permits the deduction of carbon payments in the country of origin from the amount payable to CBAM. However, if exporting companies are unable to report the actual carbon intensity of their products, the CBAM-related costs increase because they are calculated based on the difference between default values, reflecting the average emission intensity of the exported products in the EU, based on the country of origin, and benchmark values, referenced to the production of these products in the EU (Böhringer et al. 2022).

Considered the first regulatory mechanism to impose climate change-related restrictions on the international trade of a range of energy-intensive commodities through a border carbon adjustment (BCA) rate, the EU's adoption of the CBAM provoked reactions of Global South countries, classifying it as a form of green protectionism that transfers disproportionate climate burdens to them (Salim et al. 2025). At COP28 in 2023, on behalf of the BASIC group of countries (Brazil, China, India, and South Africa), Brazil expressed concerns about unilateral trade measures related to climate change, such as the CBAM, and their potential adverse impact on climate justice. Adopting a reactive strategy, the country classified the CBAM as an unfair instrument, inconsistent with World Trade Organization (WTO) rules and at odds with the principle of common but differentiated responsibilities (CBDR) enshrined in the Paris Agreement (IETA 2024).

Academic literature on CBAM can be classified into three major analytical approaches (Zhong & Pei 2024). The legal approach focuses on qualitative studies examining the compatibility of CBAM's regulatory architecture, which incorporates environmental costs into international trade, with WTO rules that emphasize free trade and non-discrimination (Selicato 2022; Schippers & Dewit 2022; Salim et al. 2025).

The environmental approach, the focus is on qualitative studies that examine the effects of the CBAM on global emissions reduction, the allocation and fair accountability of carbon, taking into account historical emission disparities among countries according to their level of development, the role of market mechanisms in global climate governance, and the responses, in terms of climate policies, adopted by exporting countries located outside the EU to mitigate the effects of the CBAM (Eicke et al. 2021; Mehling et al. 2022; Beaufils et al. 2023; Ren, Liu & Shi 2023; Zhong & Pei 2024). The economic approach, mostly comprised of quantitative studies that utilize general equilibrium models, input-output matrices, and game theory to estimate, through simulations, the effects on carbon leakage, fair competition, and changes in international trade resulting from the CBAM (Mörsdorf 2022; Acar et al. 2022; Korpar et al. 2023; Clora et al. 2023; Perdana & Vielle 2022; Li et al. 2026) and its potential impacts on the competitiveness of non-EU countries exposed to the mechanism, especially the BRICS (Bashmakov 2022; Zhao et al. 2024; Song 2024; Perdana, Vielle & Oliveira 2024; Chen et al. 2025).

Despite the growth in the number of academic works on the CBAM, mainly from 2023, with the final approval of the EU regulation and the beginning of the transition phase, there is still a need for new

research that discusses the implications of the CBAM in countries of the Global South, such as Brazil, notably based on recent data regarding default and benchmark values and the official price of the carbon certificate, published in 2026 by the EU (European Commission 2026, Magacho, Espagne, & Godin 2024; Wirdyansyah 2025).

Ranked by Kardish et al. (2021) among the 10 non-EU countries most exposed to the CBAM, Brazil allocates 12.5% of its iron/steel exports and 16% of its aluminium product exports to the European market (World Bank 2025; Hidayat 2026). A preliminary analysis by the National Confederation of Industry (CNI 2024) indicates that the CBAM would impact Brazilian exports to the EU by more than US\$3 billion.

Given this context, this research aims to answer the following question: What are the main risks and opportunities of the CBAM for Global South countries that export energy-intensive products to the EU, such as Brazil? This article aims to analyze the main risks and opportunities for Brazil arising from the EU's implementation of the CBAM. It is expected that this research will help mitigate the knowledge gap in the literature on this subject and support the implementation of policies in Brazil to address CBAM adequately. The findings may also provide insights for other Global South countries facing similar challenges and opportunities in adapting to the EU's carbon border regulation.

CBAM as a regulatory instrument for carbon import at the EU border.

Designed as an instrument to prevent carbon leakage in the EU (Böhringer et al. 2022; Mörsdorf 2022), the CBAM requires companies importing carbon-intensive products to purchase CBAM certificates that reflect the carbon price that would have been paid if those goods had been produced in the EU under its carbon pricing rules. The mechanism seeks to “level the playing field” by equalizing the carbon price on imports from outside the EU to the price paid for goods produced in the EU, and capture more than 50% of emissions from sectors covered by the EU ETS (European Commission 2026).

The CBAM governance system is decentralized, with responsibility for the competent national authorities designated by each EU member state. It initiated its three-year transitional phase in 2023 and came into full force in 2026, when it entered its regular phase. During the transitional phase, considered a learning stage, the objective was to collect data on the carbon intensity of imported products and give EU importing companies time to prepare for the regular phase, which importers will need to annually declare the quantity of goods imported into the EU in the previous year, the amount of embedded carbon, and the corresponding number of CBAM certificates acquired, valued at the EU ETS carbon price. For the 1st and 2nd quarters of 2026, the official prices of the CBAM certificate were set at €75.36/tCO₂e and €75.28/tCO₂e, respectively, reflecting the weekly averages of the EU ETS emission allowance auctions. Effective payment will begin in 2027, when the sale of CBAM certificates to cover the carbon emissions embedded in 2026 imports will commence (Fastmarkets 2026).

In addition to the price of carbon on the European market, the calculation of the cost of CBAM certificates depends on the difference between the actual and verified carbon-intensity values of

products reported by exporting companies from outside the EU and the benchmark values. Based on the EU ETS, the benchmark values represent carbon intensities for each technological route used to produce imported products, derived from the performance of the most efficient industrial facilities in the EU (Wolpe 2026).

The final cost of the CBAM certificate depends on the difference between the emissions factor embedded in the product and the benchmark value adjusted by the gradual elimination factor of the free allocations of the EU ETS, the price of the CBAM certificate, and the discount on the carbon price paid in the country of origin:

$$C_{CBAM} = [(EF - (BV \times \alpha)) \times P_{CBAM}] - CP \quad (1)$$

where C_{CBAM} is a CBAM cost per ton of product (€/t), EF is an embedded carbon emissions factor (tCO₂e/t), BV is the CBAM benchmark value (tCO₂e/t), and α denotes the phase-in rate for free allocations under the EU ETS. P_{CBAM} is the price of the CBAM certificate (€/tCO₂e), and CP is the carbon price paid in the country of origin (€/t). If an exporting company cannot provide real, third-party-verified primary data, the EF values may be replaced with default values, based on reliable secondary data of the country of origin. The default values are punitive, higher than the actual carbon intensities of the most efficient industrial facilities, and these values are increased by a markup that varies over time: from 10% in 2026 to 30% in 2028, depending on the exported product. The intention is to encourage exporting companies to provide real, third-party-verified primary data (Carbon Chain 2026).

Methodology

A qualitative, bibliographic, and documentary study was conducted. To understand the state of the art on the topic, the first stage involved a bibliographic search in the Web of Science and Scopus databases, encompassing high-impact journals and a multidisciplinary approach.

Next, documentary research was conducted through content analysis of documents (legislation, guides, technical studies, and policies papers, databases, etc.) about the CBAM in UE (Directorate General of TAXUD - Taxation and Customs Union of the European Commission) and in Brazil (Ministries of Environment and Climate Change - MMA, Development, Industry, Trade and Services - MDIC and Finance - MF). These documents were complemented by sectoral studies and position papers from industrial associations, including the World Steel Association, European Aluminium, European Metals, CEFIC (European Chemical Industry Council), and the National Confederation of Industry (CNI), among others.

In the third stage, secondary data extracted, mainly from the TAXUD of the European Commission (2026) and Eurostat (2026) – International Trade in Goods (ITG) database – are used to estimate the costs of purchasing CBAM certificates and discuss the Brazil's relative position compared to major non-European exporting countries, by providing two illustrative examples of Brazilian products exported to the EU: i) a family of iron/steel products used in the construction of railway tracks (CN 7302); ii) primary (raw) aluminium (CN 7601). These two examples were chosen to illustrate the discussion on the risks and

opportunities of CBAM for Brazil, as they represent two product families (a more elaborate product - railway tracks- and a basic product - raw aluminium), belonging to the Brazilian industrial sectors most exposed to the mechanism.

The three stages of the research are summarized in Figure 1.

To estimate the compliance costs of purchasing CBAM certificates for these two product families and discuss the Brazil's relative position compared to other exporting countries outside the EU, a critical scenario was considered: i) the use of default values established for Brazil by CBAM, replacing the actual values of carbon intensity embedded in these two products; ii) the use of a markup factor to increase the default values, set at 10% for iron/steel and aluminium products in 2026; iii) the official price of the CBAM certificate for the first quarter of 2026, set at €75.36/tCO₂e; iv) a factor for eliminating free allocations from the EU ETS of 97.5% for 2026; v) the absence of prior payment for carbon in Brazil.

$$C_{CBAM} = [(DV \times \Delta) - (BV \times \alpha)] \times P_{CBAM} \quad (2)$$

where C_{CBAM} is a CBAM cost per ton of product (€/t), DV is the default value for the embodied emissions factor in the product (tCO₂e/t), and Δ is the markup factor of the default value. BV is the CBAM benchmark value (tCO₂e/t), α denotes the phase-in rate for free allocations under the EU ETS, and P_{CBAM} is the price of the CBAM certificate (€/tCO₂e).

Results and discussion

The results revealed that the CBAM implies risks for developing countries in the Global South that export energy-intensive products to the EU, such as Brazil, while developed countries with carbon pricing systems equivalent to the EU ETS, such as Norway and Switzerland – positioned by Kardish et al. (2021) among the EU's top 10 trading partners in the import of products covered by the CBAM – benefit from a comparative advantage by being exempt from complying with the regulatory mechanism.

The potential risks of the CBAM for Brazil, notably in the iron/steel and aluminium sectors, would stem from a possible reduction in competitiveness, especially for Brazilian exporting companies with higher carbon intensity. Their products destined for the EU will face additional compliance costs, as European importers will need to acquire CBAM certificates equivalent to the carbon emissions embedded in them. Therefore, these companies would see their products become more expensive, which could lead them to lose market share to competitors from outside the EU with lower carbon intensities, or to European countries exempt from the CBAM. These findings are consistent with previous studies by Li et al. (2026), who analyzed the impact of CBAM on international trade using China as a case study.

Another risk associated with CBAM is the compliance cost of developing robust MRV systems at the individual product and industrial-plant levels to account for the carbon emissions embedded in products exported to the EU, using reliable primary data and third-party-verified reports. This requires Brazilian

exporting companies to move beyond traditional corporate emissions inventories, and the annual MRV costs are estimated at €45,000-€75,000 (Wolpe 2026).

Although it is EU importers who will have to declare the carbon emissions embedded in imported goods, Brazilian exporting companies must be prepared to provide third-party-verified reports on the carbon intensity of their products. Exporting companies that fail to do so run a greater risk of losing business partners to competitors, as the importer will have to pay CBAM through a higher, punitive default value, making the product less competitive in European markets (APEX 2024).

The risks that some Brazilian exporting companies may face with CBAM also represent opportunities for others. An exporter that already has MRV capacity to account for, report, and verify carbon emissions from the production of its goods has a comparative advantage over those who are not prepared for this. Furthermore, exporting companies that can demonstrate, through MRV, the use of cleaner technological routes and low-carbon energy sources to decarbonize their production processes can gain market share by better positioning their products in the EU, as they will incur lower CBAM-related costs. Low-carbon-intensive exports, with products emitting less carbon per unit produced, will be more economically attractive to European importers, as they will need to purchase fewer CBAM certificates during the import process. Therefore, Brazilian exporting companies are doubly challenged: i) to reduce the carbon intensity of their products, initially using the benchmark values established by the European Commission for CBAM as a reference; ii) to prove this carbon emission reduction through an MRV at individual product and industrial plant levels, under penalty of default values being applied (Savi et al. 2026).

To anticipate and assess future regulatory risks, this mandatory MRV applied to products regulated by CBAM tends to induce a broader movement of measurement, reporting, and verification of carbon emissions, including by Brazilian exporting companies that have not yet been requested by European importers or whose products are not yet covered by the mechanism, such as the chemical industries (CEFIC 2026).

This movement has the positive aspect of increasing the number of Brazilian companies that are beginning to measure, report, and verify the carbon intensities of their products and production facilities, strengthening emissions management and climate transparency, considering that granular MRV, at the individual product and industrial plant levels, is still incipient in Brazil. Most Brazilian companies report carbon emissions only at the corporate or sectoral level (INETTT 2026). These results are consistent with the investigations by Eicke et al. (2021), who argue that, with CBAM, MRV capacity at product and industrial-plant levels becomes a determinant of international competitiveness.

Estimates by Carbon Chain (2026) show that the use of default values for the main Brazilian products exported to the EU implies an increase in costs between 2026 and 2030, due to the purchase of CBAM certificates of €40 to €250/t (aluminium), €120 to €400/t (iron-chromium/nickel alloys) and €40 to €280/t (other iron/steel products), depending on the technological route adopted in production.

Figure 2 illustrates the gaps between the default values established for Brazil by CBAM regulations and the benchmark value for the routes used to manufacture iron/steel products exported to the EU, which are used to construct railway tracks (CN 7302).

As shown in Figure 2, the default values for Brazil, referring to the family of iron/steel products used in railway track construction (CN 7302), are always the same (2.992 tCO₂e/t), regardless of the three main technological routes used in production: BF-BOF (conventional blast furnace-converter technology), DRI/EAF (direct reduction of iron ore in an electric arc furnace), and Scrap/EAF (the use of scrap – recycled steel – associated with the electric arc furnace). The benchmark values are lower the cleaner the technology used in production: the Scrap/EAF route value is 82.79% lower than that of the DRI/EAF route and 93.85% lower than that of the traditional BF/BOF route.

The logic employed here is to impose the highest costs on exporting companies that fail to declare, after a third-party audit, the actual primary data on the carbon intensities of their products exported to the EU, even if they use cleaner technologies (see Figure 3).

As shown in Figure 3, considering the CBAM certificate price for the first quarter of 2026 of €75.36/tCO₂e and default values for Brazil, the compliance costs relating to CN 7302 iron/steel products for the SCRAP/EAF (€219.07/t) and DRI/EAF (€188.25/t) routes are higher when compared to the BF/BOF conventional technology (€121.25/t).

Brazil's main strategy for decarbonizing the BF-BOF route is to replace coke or coal with charcoal, which is used in less than 1% of cases worldwide. About 11% of national crude steel production uses biomass-BF-BOF, and 25% Scrap-EAF. These two routes could reduce Brazilian steelmaking emissions by 65% until 2050 (Souza & Pacca 2021; Hebeda et al. 2023).

However, there is a regulatory gap in the CBAM framework that limits the potential use of biomass as a decarbonization strategy for the Brazilian iron/steel industry and represents a regulatory risk for exporting companies in this sector: CBAM establishes different rules for recognizing the zero factor of biogenic carbon, depending on the use of biomass. For example, all charcoal used in the BF-BOF route as a bio-reducing agent, i.e., the process's main stoichiometric input, receives an emission factor of zero, without requiring any sustainability certification. The existence of biogenic carbon is proven through a stoichiometric method or by laboratory analysis of Carbon-14, carried out by a laboratory that is economically independent of the exporting company, preferably ISO 17025-accredited, and critically evaluated by an accredited CBAM verifier (European Commission 2026).

Charcoal, used secondarily in the iron/steel industry as an energy vector, even when sourced from Forest Stewardship Council (FSC)-certified planted forests, can only receive zero-emission factor if it meets the compliance requirements with the sustainability and GHG savings criteria, compared to fossil fuels, of the EU Renewable Energy Directives: 2018/2001 (RED II) and 2023/2413 (RED III).

According to CBAM regulations, FSC certification, although recognized as a standard for responsible forest management and widely used in Brazil, is not sufficient to replace RED sustainability certification for the secondary use of biomass for energy purposes in the iron/steel industry. The FSC chose not to seek formal recognition from the European Commission as a RED certification scheme (FSC 2026).

This occurs not because the predominant use of charcoal as a reducing agent in the iron/steel industry is necessarily more sustainable, but because the sustainability and GHG-savings RED-criteria, adopted by CBAM, were designed for biomass energy consumption rather than for the bio-reduction process. Consequently, a planted eucalyptus forest in Brazil, without RED certification—and potentially even without FSC—could, in theory, supply charcoal as a process input for steelmaking, whose biogenic carbon fraction is considered zero-rated for the CBAM. For this, it is only necessary that the exporting company can prove, through a Carbon-14 laboratory report verified by an independent third party, that the charcoal used as a reducing agent is effectively biomass and that there is no mixture with fossil carbon.

Therefore, under the current regulatory framework of CBAM, if an export company lacks third-party verifications of sustainability and GHG-savings RED-certifications for biomass used as biofuel, and laboratory carbon-14 analysis for use as a reducing agent, the fraction of charcoal emissions attributable to biogenic carbon is considered fossil.

Unlike biofuel supply chains, particularly ethanol, which can rely on RED-recognized sustainability certification schemes, such as Bonsucro-RED and International Sustainability and Carbon Certification (ISCC) EU, the Brazilian iron and steel sector currently lacks an equivalent RED-recognized certification pathway for demonstrating the sustainability of biomass used as a strategy of industrial decarbonization (Cezar et al. 2026). Thus, the fact that CBAM recognizes biogenic carbon from energy biomass in compliance with RED poses a risk for Brazilian companies exporting iron/steel products to the EU. Adopting a conservative approach, CBAM will treat the biogenic fraction of emissions from biomass used as biofuel as fossil carbon whenever exporting companies fail to meet the sustainability and GHG-savings RED criteria, thereby increasing compliance costs by failing to remunerate biogenic carbon.

Even if a Brazilian exporting company produces iron/steel with low carbon emissions, due to the use of biomass as a decarbonization strategy and a cleaner technological route, it is penalized by CBAM if it cannot measure, report, and demonstrate this in a way verifiable by a third party. These findings are in line with Eicke et al. (2021)'s argument that the MRV deficit can generate economic losses even for relatively efficient industrial facilities.

However, if we compare the gaps between the default values and the benchmark value for the CN 7302 product family, for the BF/BOF route, Brazil is well positioned relative to other EU trading partners for the import of iron/steel products, such as China, India, and Turkey (see Figure 4):

While these three Asian countries show default values exceeding 300% of the EU benchmark value, Brazil, Canada, and the United States show between 107 and 118% gaps, indicating lower risks and,

consequently, greater opportunities for these three American countries to increase their market share in exporting CN 7302 product family to the EU.

The data in Figure 4 suggest a potential comparative advantage for Canadian, Brazilian, and North American exporting companies that report verified emissions below the default values and as close as possible to the EU benchmark value for imports of iron and steel products used in railway track construction (1.383 tCO₂e/t). These results are consistent with the findings of Perdana, Vielle & Oliveira (2024), who argue that CBAM, rather than causing adverse effects, tends to enhance the competitiveness of Brazilian companies exporting energy-intensive products.

Another CBAM regulatory gap related to the recognition of indirect emissions poses a risk to Brazil, as it could limit the conversion of its environmental comparative advantages into competitiveness. Despite the country possessing the one of the world's lowest-carbon electricity matrix, with low-carbon sources accounting for approximately 90% of electricity generation in 2024 (IEA 2025), controversially, the current CBAM methodology focuses primarily on direct emissions (scope 1), failing to recognize the differentials in indirect emissions linked to the purchase of clean electricity (scope 2), precisely for the two Brazilian sectors most exposed to the mechanism. This penalizes exporting companies that already have low embedded carbon emissions in their iron/steel products and, notably, aluminium. These findings are in line with the studies of Mörsdorf (2022), which show that CBAM, limited to scope 1 direct emissions, can significantly underestimate the effective carbon intensity of products exported to the EU whose production is heavily dependent on electricity.

The share of electricity in total emissions across global aluminium production chains, a highly electricity-intensive sector, is 60%, while in Brazil it falls to 30% (Hidayart 2026). In the iron and steel sector, electricity has less weight in the calculation of carbon intensity (10-15% globally and 5-8% in Brazil), as most emissions continue to be associated with the iron ore reduction process using coal (scope 1), via the conventional BF-BOF technology route, which remains predominant (over 70%), both globally and in Brazil. Consequently, Brazil's comparative advantage from clean electricity is much smaller in the iron and steel sector than in the aluminium sector (World Steel Association 2023).

European industry associations linked to these sectors oppose the inclusion of indirect emissions in the CBAM, arguing that European producers under the EU ETS bear indirect carbon costs due to higher electricity prices and the specific functioning of European energy markets, and that these cannot be accurately replicated through a BCA. Therefore, including indirect emissions in the CBAM would increase European companies' production costs without imposing equivalent burdens on foreign competitors, and increasing carbon leakage. They defend the exclusion of indirect emissions from the CBAM and the maintenance of the ICC (Indirect Cost Compensation) until 2030, a subsidy scheme within the EU ETS where companies are compensated with state aid for the indirect costs, as the most appropriate measure to prevent carbon leakage (European Metals 2026; European Aluminium 2025).

This issue lies not only in whether CBAM reduces carbon leakage, but in discussing whether its regulatory architecture allows for the accurate, verifiable, and non-discriminatory recognition of actual

differences in carbon intensity among producers and countries, without disproportionately shifting the costs of a unilateral European climate policy into the developing economies of the Global South (Böhringer et al. 2022).

Even considering this regulatory gap in the CBAM, Figure 5 shows that for primary aluminium (CN 7601), Brazil is positioned in a group of non-European exporting countries to the EU that have greater comparative advantages, including Malaysia, Saudi Arabia, and Oman.

Brazil and the other 3 non-EU countries with default values of 1.87 tCO₂e/t show the smallest default-to-benchmark value gap (31.4%) and, consequently, the lowest costs, estimated at €36.37/t, given the price of the CBAM certificate for the first quarter of 2026, €75.36/tCO₂e. Meanwhile, the costs for the other countries range from €50.46/t (for the group of 5 countries with a default value of 2.057 tCO₂e/t) to €160.56/t for Mozambique (the country with the highest default value, 3.518 tCO₂e/t).

These results are in line with the competitiveness study carried out by Fastmarkets (2026) for the 20 main exporting countries of products regulated by CBAM, considering the default-to-benchmark value gap: Brazil is among the three most competitive exporting countries to the EU for aluminium and iron/steel products.

If CBAM regulations allowed accounting of indirect emissions for aluminium, Figure 6 shows that Brazil has the lowest default value (0.096 tCO₂e/MWh), second only to Mozambique. The African country, in turn, has the disadvantage of the largest direct-emissions default-to-benchmark value gap – see Figure 5. This puts Brazil in a better position within the cluster comprising Malaysia, Saudi Arabia, and Oman, all of which have much higher default values for indirect emissions than Brazil.

This analysis for aluminium considers the same criteria established by CBAM for indirect emissions from other product families (e.g., cement and fertilizers), where this accounting is permitted: default values calculated based on the simple arithmetic mean of the emission factors of the electricity grid in the country of origin for the five most recent years, mainly using reliable data from the International Energy Agency (IEA). CBAM only allows the use of the real value of the electricity source's emission factor in two situations: i) self-generation of electricity, through a direct technical connection between the production facility and the electricity generation source; ii) direct purchase from an electricity producer, through a long-term Power Purchase Agreement (PPA) (European Commission 2026).

It is observed that the default value established for Brazil (see Figure 6) is 76% higher than the national grid's emission factor in 2024 (0.0545 tCO₂e/MWh) and 108.2% higher in 2025 (0.0461 tCO₂e/MWh) (MCTI 2026). Thus, the CBAM systematically overestimates the indirect emissions of companies exporting energy-intensive products to the EU that are located in countries with low-carbon electricity matrices, thereby preventing the correct valuation of clean electricity, since the average emission intensity of national grids may not accurately capture electricity generation with lower emissions (Menkes 2025).

These results are in line with the INTTT (2026), which argues that the CBAM regulatory framework disadvantages exporting countries to the EU with abundant renewable energy resources, such as Brazil: a country with a cleaner electricity matrix than the world average, and the use of biomass both as an energy vector (biofuels) and as a bio-reducing agent in the iron/steel industry.

This disadvantage in relation to Brazil's specificities occurs due to regulatory gaps in the CBAM through the adoption of different rules in at least two situations: i) recognition of indirect scope 2 emissions for four of the six regulated industrial sectors, leaving out the iron/steel and aluminium sectors; ii) on the one hand, the requirement of RED sustainability certification for the recognition of zero factor of biogenic carbon in biomass used as an energy vector, but on the other hand, the lack of a requirement for any equivalent certification scheme to recognize the zero factor of biogenic carbon in the same biomass when used as a bio-reducing agent in steelmaking, a relevant Brazilian strategy to industrial decarbonization.

This is not about advocating for the automatic and unrestricted recognition of biogenic carbon from biomass as sustainable, whether for energy or bio-reduction purposes, since the abundance of renewable energy in countries of the Global South does not, in itself, imply sustainability or GHG savings (Matušík & Kočí 2022). However, by adopting the same rules as the EU ETS, with the aim of "leveling the playing field", the RED requirement only for energetic biomass, CBAM creates a regulatory inconsistency, notably for the Brazilian iron/steel sector, which mainly uses biomass as a reducing agent and secondly as an energy vector.

Thus, instead of encouraging the reduction of GHG emissions through the use of technological routes for industrial decarbonization based on sustainable biomass, this CBAM regulatory gap creates uncertainties for Brazilian exporting companies that already use charcoal as a reducing agent and acts as a regulatory disincentive to the full exploitation of the climate function of sustainable biomass as a legitimate comparative advantage for this country and other biomass-rich Global South countries.

This argument aligns with the work of Hebeda et al. (2023), which analyzes the industrial experience of the Brazilian iron/steel industry with biocarbon. They argue that there is no single universal route for producing low-carbon fossil iron/steel and that the use of biomass as an effective industrial decarbonization strategy, already available in Brazil, should not be underestimated. It is a unique technological route, distinct from those predominant in Europe, with a primary focus on electrification and green hydrogen.

It is expected that Brazilian commodities with high energy intensity will be positioned even better in the European market if the regulatory gaps in the current CBAM framework, which pose risks for exporting companies, were mitigated. Thus, if Scope 2 indirect emissions were accounted for by CBAM, the carbon intensity of Brazilian aluminium would be about 2.5 times lower than the global average (Hidayat 2026). A similar effect can be expected in the Brazilian iron and steel sector, where scrap-based EAF and charcoal-based BF-BOF constitute important pathways for reducing embedded carbon emissions, leveraging Brazil's availability of low-carbon electricity and biomass resources (Hebeda et al. 2023; de

Souza & Pacca 2021). Lower embedded emissions would, in turn, reduce the number of CBAM certificates required for exports to the EU and consequently the carbon costs.

Despite these regulatory gaps regarding indirect emissions and biogenic carbon, CBAM creates an opportunity to decarbonize the Brazilian industry by incentivizing the setting of sectoral targets to reduce carbon emissions and by regulating the domestic carbon market. Thus, the carbon price paid in Brazil can be deducted from the amount needed for importers to purchase CBAM certificates in the EU and used to create a fund to finance investments in cleaner technologies and energy efficiency aimed at green industrialization, making the country a leading trading partner of the EU in the export of energy-intensive products.

This agenda is underway in Brazil, but its implementation needs to be accelerated: i) The Climate Plan, launched at the end of 2025 and developed with the participation of several ministries, serves as a guide for Brazilian climate policy, aiming to achieve targets for reducing GHG emissions by 53% by 2030, compared to 2005 emissions, with a view to achieving net-zero emissions by 2050. To this end, this public policy instrument has 7 sectoral target plans, including industry and mining (MMA 2026). ii) The carbon market is currently undergoing regulation until 2026, under the responsibility of the MF, after Law 15.042, of December 2024, established the Brazilian Greenhouse Gas Emissions Trading System (SBCE). The iron/steel and aluminium sectors are among the first to be covered by the SBCE, with MRV obligations starting in 2027, but the carbon price is only expected to be defined from 2028/29 onwards (Brazil 2024; MF 2026).

These results are aligned with the study conducted by Zhang & Sovacool (2025), which argues that the CBAM generates a "pressure-opportunity paradox" for the Global South: while imposing risks due to compliance costs, the mechanism catalyzes institutional reforms, technological innovation, and the structuring of national carbon pricing and MRV systems, opening windows of opportunity for the competitiveness of countries that anticipate the energy transition and industrial decarbonization.

Another finding of the research, in line with the studies by Li et al. (2026), Wirdyansyah (2025), Magacho, Espagne & Godin (2024), Ren, Liu & Shi (2023), Menkes (2025) and Do (2025), revealed that the implementation of the current CBAM framework represents a risk for countries in the Global South by amplifying existing asymmetries in the allocation and accountability for carbon emissions in international trade.

This occurs because, under the CBAM regulations, exporting countries of products subject to the mechanism, such as Brazil, are entirely responsible for the carbon emissions resulting from their production. In other words, carbon emissions are allocated and accounted for exclusively by the producing and exporting countries—mostly developing countries—which have historically borne little responsibility for global carbon emissions, rather than by the developed EU countries, which are importers and consumers. This is a regulatory limitation of the CBAM that goes against the CBDR principle, central to environmental agreements, and raises concerns about the application of the principles of climate justice and international cooperation that is crucial on global climate governance,

especially for Global South developing countries like Brazil, but notably: i) countries with smaller and less developed economies (low share of global GHG emissions); ii) more exposed countries (weight of CBAM exports in total exports to the EU); iii) more vulnerable countries (weight of CBAM exports to the EU in total exports to other regions). For example, Mozambique is among the countries most exposed and vulnerable to the EU CBAM (Magacho, Espagne & Godin 2024). Approximately 97% of its aluminium exports are destined for the EU. In comparison, CBAM-related exports to the EU accounted for approximately 5.5% of GDP in 2024, with aluminium accounting for most of this trade. It is the country with the highest exposure (>56%) and vulnerability (15.35%) among the developing countries (Maliszewska et al. 2023; World Bank 2025). This high CBAM exposure contrasts sharply with Mozambique's negligible contribution to global GHG emissions, of approximately 0.06%.

Is it legitimate for a unilateral climate policy, such as CBAM, to generate adverse effects in poor countries without a portion of the revenues being directed to support their decarbonization? (Perdana & Vielle 2022). The environmental effectiveness of the CBAM depends heavily on its regulatory architecture and the capacity to distribute its impacts more symmetrically between the EU and its trading partners, a factor of particular relevance for developing countries in the Global South (Mehling et al. 2022; Korpar et al. 2023; Beaufils et al. 2023). The risk of CBAM regulatory gaps exacerbated these asymmetries, aligning with the investigations by Eicke et al. (2021) and Zhong & Pei (2024), and converging with the reactive responses of some countries in the Global South to the CBAM, such as India.

In the CBAM support index for countries outside the EU, developed by Sabyrbekov & Overland (2025), Brazil ranks 50 on a scale of 1 to 100, while India ranks 18. Thus, Brazil, not being considered a strong opponent and given its environmental comparative advantage, could lead the diplomatic negotiations with the EU to make the CBAM a fairer and legitimate carbon-related import regulatory instrument, particularly for the most vulnerable countries in the Global South.

Final remarks and implications for policies

Brazil must perceive CBAM not only as a risk that increases the costs of exporting companies but also as an opportunity to innovate, reduce carbon emissions, build a robust MRV system, and enhance competitiveness. Especially in the iron/steel and aluminium sectors, the country is well-positioned. It has a comparative advantage over other exporting countries outside the EU in handling the additional costs arising from the CBAM, even in a critical scenario, if its trading partners in Europe must pay for CBAM certificates at the European Commission's punitive default values. These extra compliance costs will be avoided by the best-prepared companies, which manage carbon emissions more effectively and offer more preventive and effective responses to CBAM. Thus, Brazilian exporting companies that anticipate and adopt sustainable practices will be able to use the CBAM as a quality seal, gaining a larger share of the European market.

It is recommended to accelerate the implementation of SBCE, aligned with the execution of industrial public policies led by the MDIC, to stimulate the energy transition and green industrialization through

technological innovation, thereby increasing energy efficiency and the adoption of cleaner technologies and energy sources, towards a low-carbon and more competitive economy. The rapid implementation of the SBCE and its interoperability with the EU ETS play a fundamental role in the CBAM response, because, while Brazil does not have a domestic carbon pricing mechanism, the deductions corresponding to carbon values already paid locally remain close to zero for exporting companies. The CBAM-related costs will be paid in full to European governments, generating revenue for the EU rather than being invested in decarbonization, efficiency, and the energy transition of national industry.

Therefore, advancing the regulation of the SBCE, including the institutional capacity to implement a MRV infrastructure aligned with international best practices – the main pillar of credibility for a regulated carbon market – is very important for retaining carbon pricing revenues in the country and reducing the risk of exposure to the CBAM, not only in the EU, but also to other initiatives for implementing BCA mechanisms being developed in other countries, such as the United Kingdom, Norway, Japan, Australia, etc.

To contribute to a fairer CBAM, it is recommended that Brazil actively engage in international forums for global climate governance and, together with other exporting countries in the Global South, negotiate with EU diplomacy to overcome the currently existing regulatory gaps: i) Recognizes indirect carbon emissions from scope 2 in the calculation of the number of CBAM certificates for all industrial sectors regulated by the mechanism. The environmental comparative advantages of Brazil and Mozambique, for example, by using predominantly renewable sources, are not reflected in the calculation of CBAM certificates, which constitutes a substantial limitation for measuring the carbon intensity of products and reduces the incentive for investments in clean electricity. It contradicts the objective of CBAM to stimulate the global decarbonization; ii) Recognizes sustainability criteria for biogenic carbon from the use of biomass as a bio-reducing agent, in common agreement with countries that already use this strategy for decarbonizing the iron/steel sector. This would make the CBAM more coherent and reduce uncertainties for exporters in the Global South, allowing the full conversion of the legitimate comparative advantage of biogenic carbon into a competitive advantage of low fossil carbon and preventing the biomass-rich countries from being at a disadvantage in the industrial energy transition; iii) Promotes a fairer allocation and accountability for carbon emissions embedded in products imported by UE, according to the CBDR principle, with part of the revenues collected by CBAM be allocated to technical assistance and the financing of investments in cleaner technologies in the less developed countries of the Global South that are more exposed and vulnerable to the mechanism.

These measures, which Do (2025) termed CBAM-plus, could help Brazil and other countries in the Global South respond more proactively to CBAM, given the synergies between climate and trade policies and the principles of climate justice and international cooperation that are central to global climate governance.

It is expected that this article will support and influence Brazilian public organizations in accelerating the implementation of carbon pricing, decarbonization, and energy transition policies. This research may

also encourage exporting companies to innovate to reduce the carbon intensity of their products, adopt a low-carbon economy, and implement robust MRV systems at the individual product and plant levels.

This study is limited by its exclusive use of secondary data to estimate CBAM-related costs and to position Brazil relative to other exporting countries outside the EU, based on only two product families in the iron/steel and aluminium sectors. It is suggested that future broader studies expand the list of products and industrial sectors analyzed and conduct interviews with Brazilian companies and institutional actors, as well as with European importers and representatives of the agencies and bodies responsible for CBAM in the EU. Further research is also recommended to evaluate CBAM as a climate policy instrument, using data reported by European importers and exporting companies outside the EU during the transition phase (2023-2025), which will be published shortly by the European Commission.

Declarations

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Author Contribution

C.A.: conceptualization, methodology, investigation, data curation, wrote the main manuscript text; A.S. and E.F.: review & editing, conducted some analysis and made adjustments to the text; E.B, J.F., A.N., and D.P.: review & editing, made some comments to the text;

Data Availability

The data used in this article are all in the public domain.

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Figures

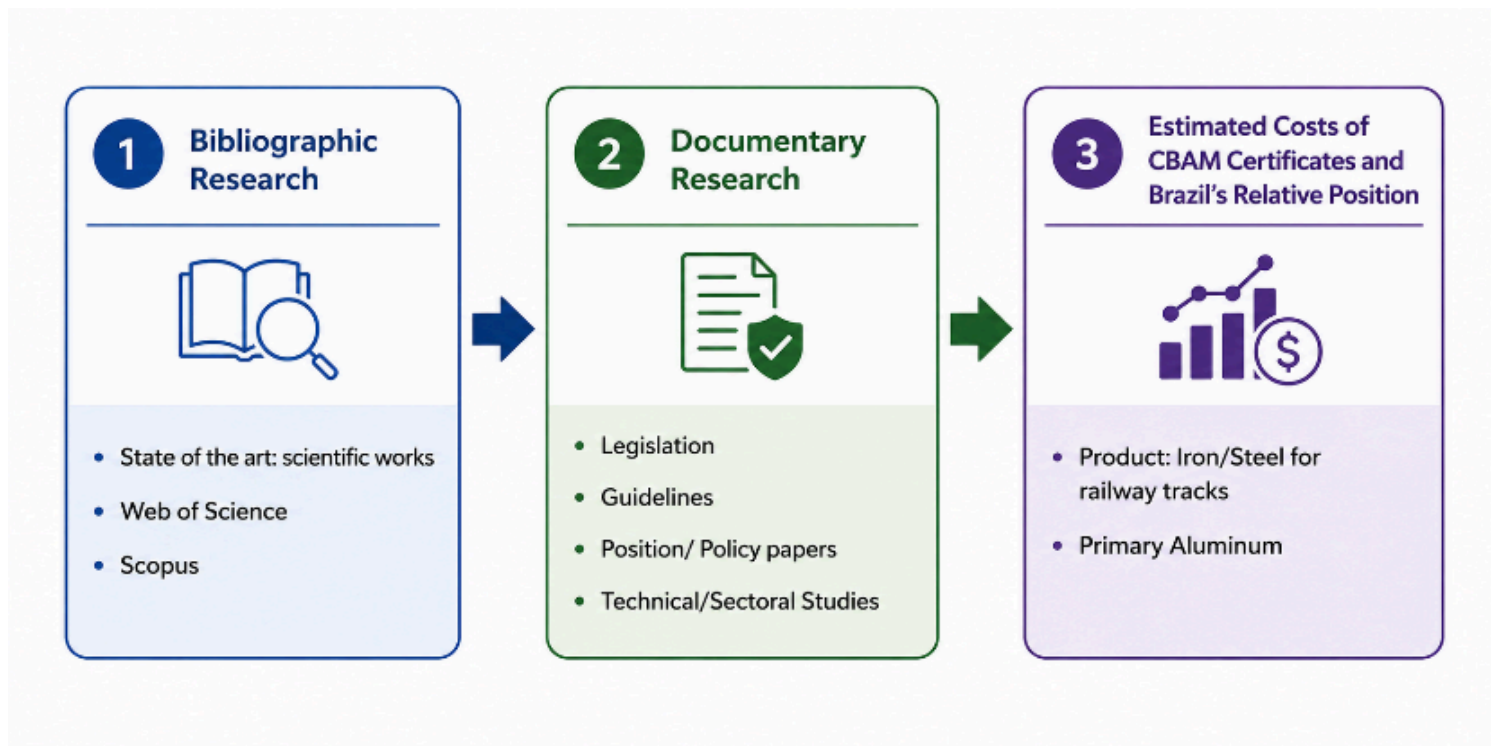


Figure 1

Methodological Steps of the Investigation

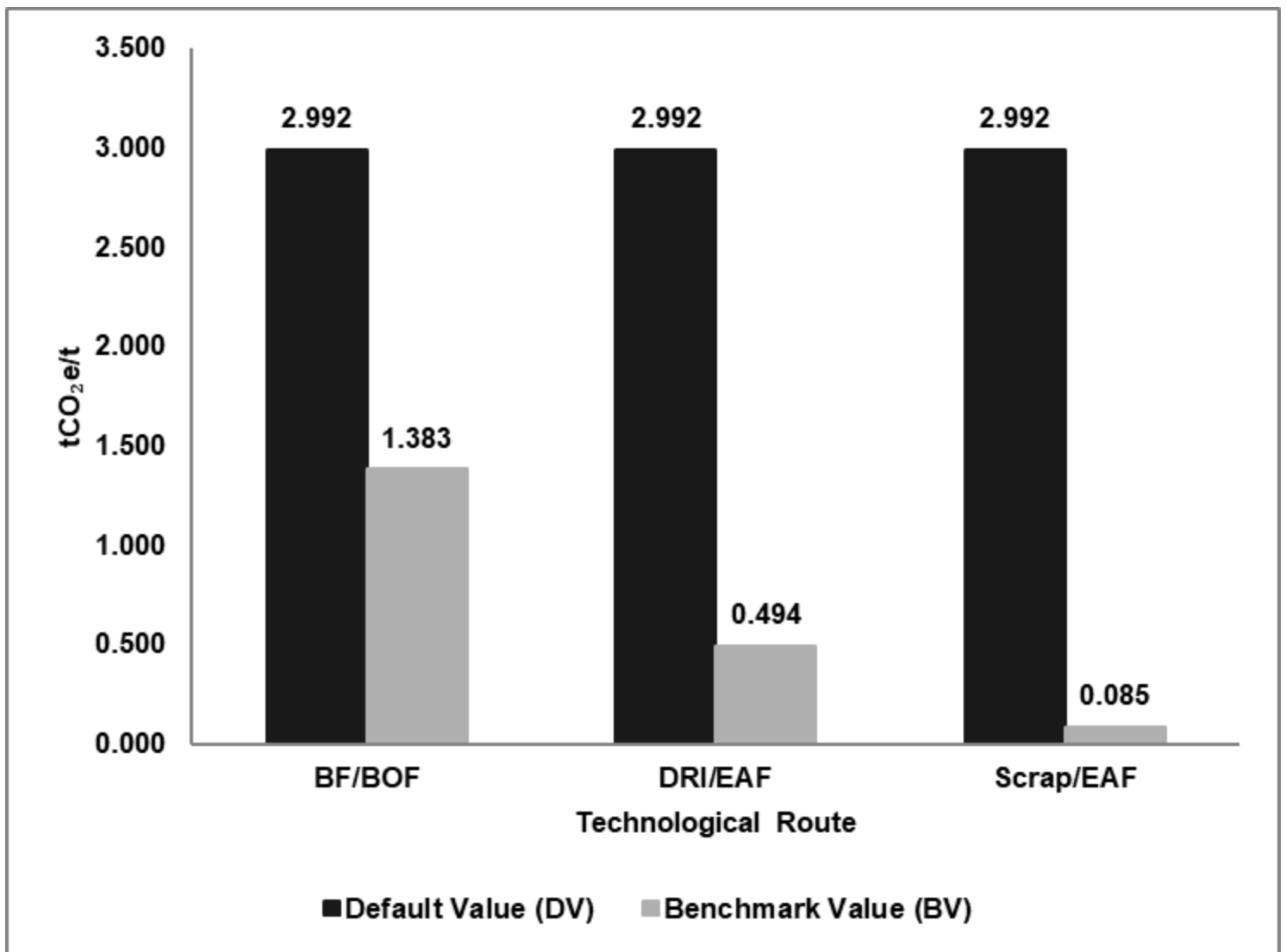


Figure 2

CN 7302: CBAM default-to-benchmark value gaps for Brazil by technological route.

Source Prepared by the authors based on European Commission (2026)

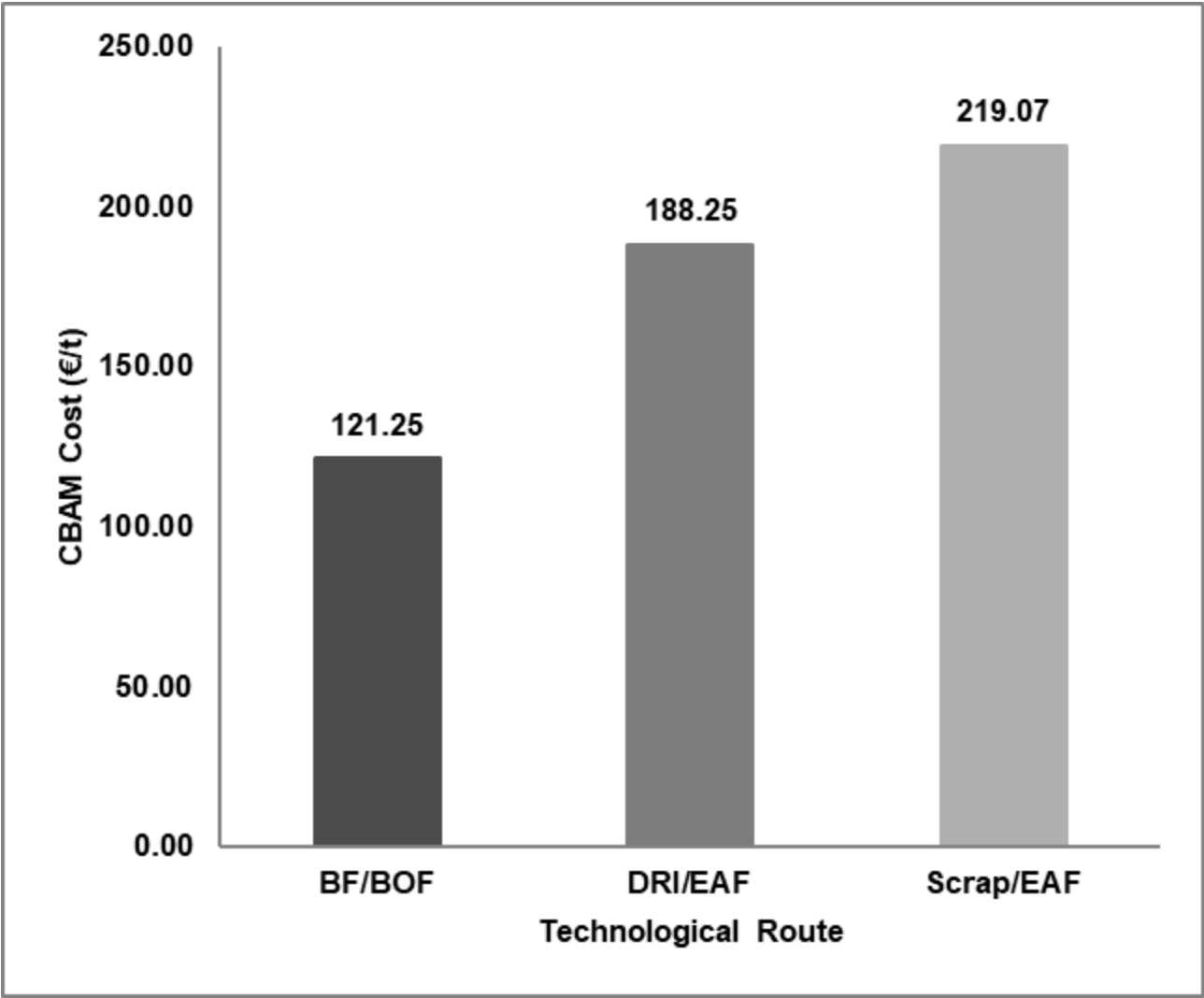


Figure 3

CN 7302: CBAM Certificate costs by technological route for Brazil using default values

SourcePrepared by the authors based on the European Commission (2026).

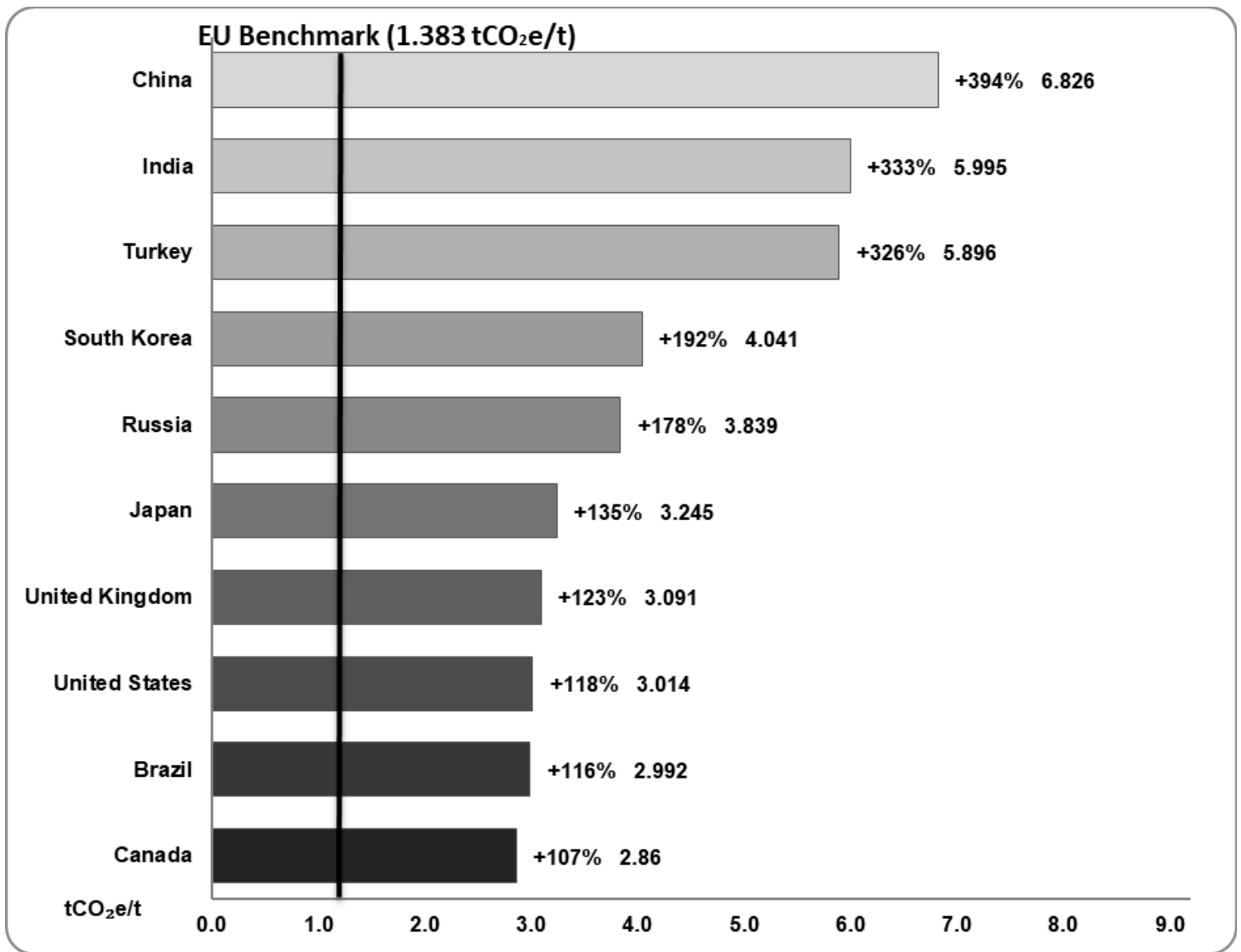


Figure 4

CN 7302: CBAM default-to-benchmark value gaps, BF/BOF route, EU Trading Partner Countries.

Source Prepared by the authors based on the European Commission (2026) and Eurostat (2026).

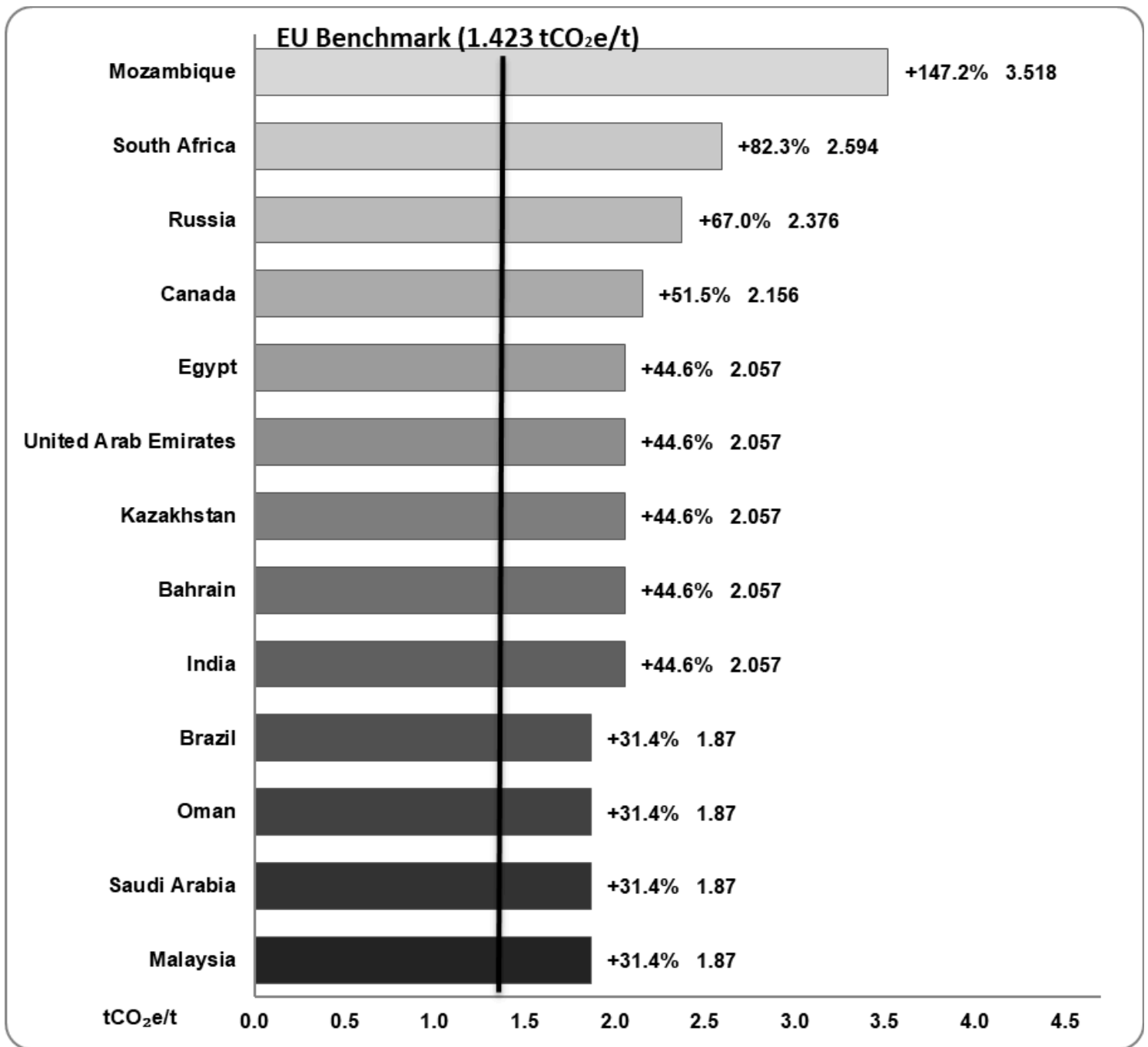


Figure 5

CN 7601: CBAM default-to-benchmark value gaps, Main Non-European Exporting Countries.

Source Prepared by the authors based on the European Commission (2026) and Eurostat (2026).

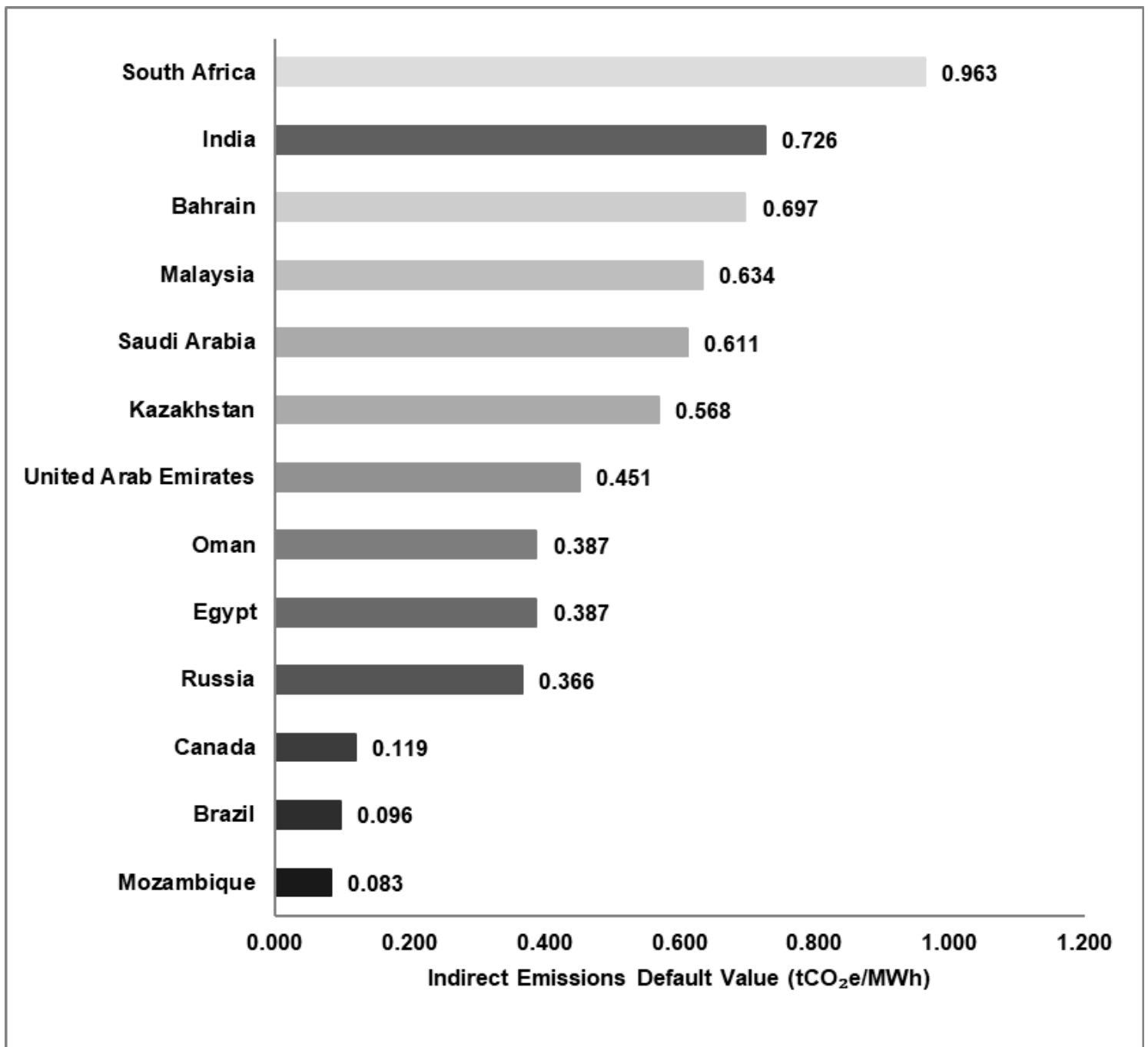


Figure 6

CN 7601: Default values of Indirect Emissions from Electricity Purchases, Main Non-European Countries Exporting to the EU.

Source Prepared by the authors based on European Commission (2026)