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Decarbonizing at the Border:

Assessing the Readiness of MENA's Steel Sector for the EU's Carbon Border Adjustment Mechanism

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Abstract

The European Union's Carbon Border Adjustment Mechanism (CBAM) will redefine trade in carbon-intensive goods, posing significant challenges for steel exporters in the Middle East and North Africa (MENA). Addressing a major gap on the region's exposure to climate-linked trade policy, this study quantifies CBAM-related costs for MENA steel through 2035 by combining life-cycle-assessment-based emission intensities with scenario simulations that incorporate carbon-price trajectories, export elasticities, and emission-reduction pathways. Results show that under high-price scenarios, rising EU ETS prices nearly double regional CBAM costs, while price-responsive exports moderate these effects depending on elasticity. Paris-aligned emission reductions reduce exposure by up to 40 percent by 2035. The integrated scenario—assuming mid-price and mid-elasticity conditions with gradual decarbonization—reveals clear asymmetries: Türkiye remains the largest contributor due to scale, Egypt faces the highest market exposure, and Morocco benefits from cleaner energy use. Overall, the study provides an evidence-based assessment of CBAM exposure under current trade structures, highlighting how production technology and emission profiles shape regulatory vulnerability in an increasingly carbon-conditioned trade environment.

Keywords: Carbon Border Adjustment Mechanism (CBAM); life cycle assessment (LCA); MENA countries; decarbonization pathways; steel sector; climate policy impacts; GHG emission targets of MENA countries

1 Introduction

The European Union (EU)'s Carbon Border Adjustment Mechanism (CBAM) represents a landmark shift in global climate governance. By pricing carbon at the border for selected carbon-intensive goods, the EU seeks to prevent carbon leakage while maintaining the integrity of its internal Emissions Trading System (ETS) (European Commission: Directorate-General for Taxation and Customs Union, 2023). The steel sector, as one of the initial CBAM-covered sectors, is especially impacted due to its high emissions intensity and global trade exposure (Lin & Zhao, 2023; Mehling et al., 2019).

Steel is among the most carbon-intensive industries worldwide, contributing roughly 7–9% of global energy-related CO_2 emissions (International Energy Agency, 2020). This stems primarily from the dominance of coal-based production routes, particularly the blast furnace–basic oxygen furnace (BF–BOF) process, which relies on coke and iron ore and remains the backbone of global primary steelmaking (Kim et al., 2022). Although alternative pathways such as the electric arc furnace (EAF), which is largely scrap-based, and direct reduced iron (DRI) with EAF offer lower-carbon options, their diffusion is uneven across regions and strongly dependent on resource availability, infrastructure, and electricity grid decarbonization (Zhang et al., 2025). With global crude steel production surpassing 1.8 billion tons annually (World Steel Association, 2025), the sector's emissions profile has drawn increasing scrutiny under international climate policies. Efforts to curb emissions through efficiency gains, recycling, carbon capture, and the introduction of green hydrogen are advancing, yet their adoption faces major cost, technology, and policy challenges (Kazmi et al., 2023). This backdrop explains why the EU's inclusion of steel in the CBAM is particularly significant: it targets one of the hardest-to-abate sectors while sending a strong signal for the decarbonization of heavy industry worldwide.

Between 2008 and 2024, the EU's imports of iron and steel (HS 72) and articles of iron or steel (HS 73) fluctuated markedly, ranging between approximately US $185 billion and US $360 billion as shown in Figure 1 (UN Comtrade Database, 2025). After peaking in 2008, imports fell sharply during the global financial crisis, then recovered unevenly throughout the 2010s amid alternating phases of demand expansion and price corrections. A pronounced surge occurred in 2021–2022—driven by post-pandemic restocking, global supply bottlenecks, and higher input prices—before moderating again in 2023–2024. These oscillations reflect the combined effects of cyclical commodity price movements, pandemic disruptions, and post-2022 geopolitical shocks.

For countries like Türkiye, which accounted for approximately 15.5 million tons of steel exports in 2024 (U.S. Department of Commerce, 2025), or Egypt and Algeria, whose trade volumes are also non-negligible, the scale and volatility of EU demand translate into significant exposure to multiple sources of disruption. On top of price fluctuations and geopolitical shocks, a new layer of regulatory shock—embodied by the CBAM—has emerged. Even modest adjustments in EU tariff policy or carbon pricing could now trigger substantial swings in export revenues for these economies.

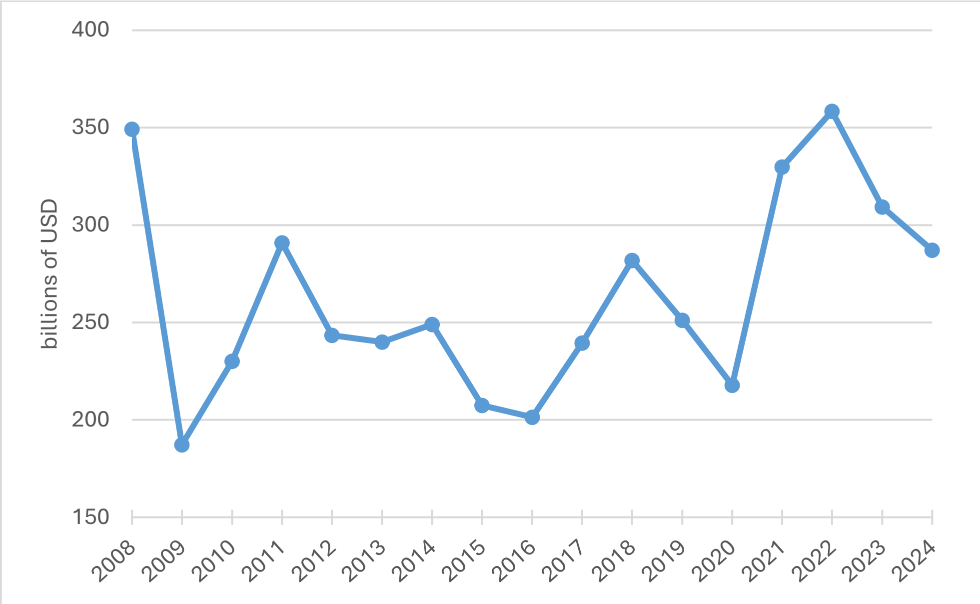


Figure 1. EU Imports of Iron and Steel (HS72+HS73) (UN Comtrade Database, 2025)

CBAM introduces a fundamental compliance challenge: exporters will be required to measure, report, and ultimately reduce embedded emissions in their products or face cost penalties tied to the EU ETS carbon price. This is particularly critical for MENA countries where low-cost energy has historically driven production advantages, but where emissions monitoring infrastructure and decarbonization investments remain limited (Mattera et al., 2025).

Existing literature on CBAM's implications for steel exporters is growing but largely macro in scope. Several studies suggest that developing economies could face asymmetric adjustment burdens (Bassi et al., 2025; Cosbey et al., 2019; Mehling et al., 2019; Takeda & Arimura, 2024). Additional studies indicate that CBAM could reduce embodied carbon emissions in EU steel imports by up to 25.9 million tons, particularly affecting major producers like China, Korea, and Vietnam (Lee et al., 2024; Li et al., 2023, 2024; Yue et al., 2025).

Empirical research on steel's technical readiness suggests that while basic emissions data are available, many MENA producers remain far from meeting EU benchmarks (Basson, 2025; IEEFA, 2024; International Energy Agency, 2020). In the MENA region, CBAM may exacerbate challenges for exporters, given high reliance on fossil fuels and limited renewable integration, though opportunities exist in green steel production leveraging regional advantages in hydrogen and renewables (Ghoneim, 2024; World Economic Forum, 2023). Moreover, (Joltreau & Sommerfeld, 2017) stress that effective carbon pricing must be coupled with structural reform to avoid competitiveness losses and carbon leakage. Recent analyses reinforce this, showing that carbon pricing paired with compensation mechanisms can mitigate leakage risks, while border adjustments like CBAM aim to address competitiveness concerns in high-emission sectors (Basaglia et al., 2025; Habibi, 2025; Tamba et al., 2024; Teusch et al., 2024).

However, while global analyses offer broad insights into CBAM's effects, region-specific studies on the MENA steel sector remain limited, often overlooking the unique interplay of its heavy reliance on fossil fuels, abundant renewable resources, and potential for leadership in green steel through hybrid DRI-EAF systems and green hydrogen integration (Basirat, 2025; IEEFA, 2024). This gap is critical, as MENA exporters could capitalize on CBAM to expand EU market share by adopting lower-emission technologies, potentially offsetting economic risks from carbon-intensive grids and phasing out free allowances, but only with targeted structural reforms and investments to mitigate Scope 1 and 2 emissions.

The current study addresses this crucial gap by focusing specifically on the MENA steel sector's technical and economic readiness for CBAM. It integrates engineering-based emissions profiling with trade exposure data and policy scenario simulations. Our research question is: *How prepared is the MENA steel sector for CBAM compliance, and what are the economic implications of delayed decarbonization?*

2 The Steel Industry in MENA and CBAM

The steel industry plays a pivotal role in the economic structure of the MENA region, serving as a cornerstone of industrialization, employment, and export performance. Several countries in the region are among the world's leading steel producers, collectively accounting for a significant share of global crude steel output. As shown in Table 1, Türkiye and Iran are the dominant producers, ranking eighth and tenth globally, respectively, with annual crude steel production exceeding 30 million tons each. Egypt and Saudi Arabia follow as mid-sized producers, while Algeria, the United Arab Emirates, Oman, Iraq, and Morocco maintain smaller but steadily growing capacities. Overall, the MENA region's steel production landscape reflects a mix of mature and emerging producers, driven by access to energy resources, domestic demand from construction and infrastructure projects, and export orientation toward European and Asian markets.

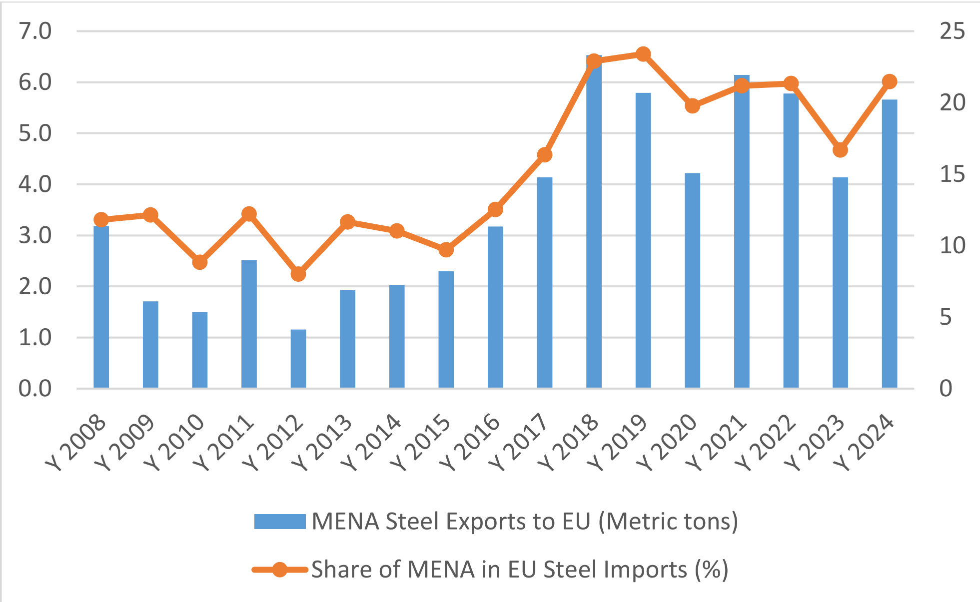
Table 1. Selected Steel Producing Countries in MENA (million tons, crude steel production)

	2024		2023	
	Rank (World)	Tonnage	Rank (World)	Tonnage
Türkiye	8	36.9	8	33.7
Iran	10	31.4	10	30.7
Egypt	19	10.7	18	10.4
Saudi Arabia	20	9.6	20	9.9
Algeria	30	4.5	34	4.4
United Arab Emirates	38	3.7	39	3.8
Oman	40	3.0	41	2.9
Iraq	41	3.0	42	2.8
Morocco	49	1.4	49	1.5

Source: World Steel Association (2025)

Despite this industrial significance, MENA's steel sector faces mounting challenges from the global decarbonization agenda. The CBAM, which entered its transitional phase in October 2023 and will become fully operational by 2026, introduces a new cost structure for carbon-intensive exports to the EU. The CBAM is designed to equalize the carbon price between the EU producers subject to the EU ETS and foreign producers exporting to the EU. This ensures that European firms are not disadvantaged by importing goods from regions with less stringent climate policies and, at the same time, discourages “carbon leakage” — the relocation of carbon-intensive production to jurisdictions with weaker environmental regulations.

The CBAM’s relevance for the MENA region is particularly pronounced given the region’s export dependency on EU markets, especially for iron and steel products. As depicted in Figure 2, several MENA countries—most notably Türkiye, Egypt, and Algeria—have substantial steel export flows to the EU. These exports represent not only a vital component of their industrial base but also a key source of foreign exchange earnings. Consequently, the implementation of CBAM poses significant competitiveness risks for MENA exporters whose production processes are more carbon-intensive than their EU counterparts. Although Iraq is among the 50 largest steel producers in the World, they do not have exports to EU. Therefore, we exclude Iraq from our analysis.



Source: Eurofer (2025)

Figure 2. Steel Exports of MENA Countries to the EU

Beyond the immediate trade implications, CBAM has the potential to serve as an external pressure mechanism that may accelerate the region’s green transition. Countries with established decarbonization roadmaps—such as Türkiye’s alignment with the EU Green Deal, Egypt’s low-carbon industrial zones, and the Gulf states’ renewable energy investments—may turn this regulatory challenge into an opportunity to upgrade production technologies, increase energy efficiency, and attract green financing. In this context, CBAM operates not merely as a trade instrument but as a catalyst for industrial decarbonization and policy convergence between the EU and its neighboring MENA economies.

3 Methodology and Analysis

3.1 Data and LCA Framework

Given its scale and reliance on different production routes, the steel sector has a considerable influence on both the regional economies and environmental performance of MENA. Understanding these technological and structural characteristics provides the foundation for assessing how the region's steel sector may respond to the decarbonization pressures introduced by the EU's CBAM.

To move from context to measurement, this study applies life-cycle assessment (LCA) calculations using the Ecoinvent database (Wernet et al., 2016) with SimaPro software (Database & Support team at PRé Sustainability, 2022) to quantify the emission profiles of the three principal steelmaking methods employed in the region: Blast Furnace–Basic Oxygen Furnace (BF-BOF), Electric Arc Furnace (EAF), and Direct Reduced Iron combined with Electric Arc Furnace (DRI+EAF). These pathways vary greatly in their raw-material requirements, energy consumption, and greenhouse-gas emissions; therefore, a comparative life-cycle assessment becomes essential for shaping realistic decarbonization strategies and anticipating CBAM-related cost implications.

The BF-BOF route, which relies on iron ore and coke in a blast furnace followed by oxygen-based refining, is the most carbon-intensive method due to its dependence on coal (Anjun et al., 2022). In contrast, the EAF route, which primarily uses recycled scrap melted with electricity, offers considerably lower emissions, although its overall footprint is strongly influenced by the carbon intensity of the power grid (Hu et al., 2025; L. Yang et al., 2023). Between these two extremes lies the DRI+EAF process, which produces sponge iron with natural gas before melting it in an EAF (Suer et al., 2022; L. Z. Yang et al., 2025). For the MENA context, this approach is particularly relevant in countries with abundant natural-gas resources, indicating that resource endowments shape not only production choices but also each country's potential pathway toward cleaner steelmaking.

Building on these technological distinctions, the next step is to translate process characteristics into measurable environmental outcomes. To this end, the study quantifies life-cycle emissions for each production route and integrates them with national production data to assess CBAM exposure at the country level. Emission intensities for each production route were calculated per functional unit (1 t crude steel) within cradle-to-gate system boundaries. Life-cycle data from the Ecoinvent 3.9 database were processed in SimaPro following ISO 14040/44 procedures. National production shares from the World Steel Association (2025) and electricity emission factors from the IEA (2024) were used to compute weighted-average country intensities. These were then matched with Eurofer export data to the EU to estimate embedded emissions in traded volumes. Finally, projected CBAM liabilities were simulated by multiplying embedded emissions by EU ETS carbon-price trajectories under alternative policy scenarios.

Taken together, this integrated LCA–trade framework enables a consistent comparison of environmental performance and policy exposure across MENA steel exporters, providing the analytical foundation for the cross-regional benchmarking presented in the next section.

3.2 LCA Results: EU vs. Rest of the World

Building on the methodological framework described above, this section presents the LCA results that benchmark MENA's major production routes against global patterns, focusing on the contrast between the EU and the rest of the world (ROW). The results, summarized in Table 1, highlight significant variation in carbon intensities across steel production routes and geographical contexts, with emissions expressed per ton of crude steel produced.

Unsurprisingly, the BF–BOF pathway exhibits the highest global warming potential, exceeding 2.1 tCO_2 per ton of crude steel in both the EU and ROW. This reflects its dependence on coke and iron ore, underscoring why BF–BOF remains the most carbon-intensive production method globally. In contrast, EAF steelmaking demonstrates considerably lower emissions when based on scrap input, with European averages around 0.55 tCO_2 per ton, nearly four times lower than BF–BOF. However, EAF production outside the EU shows much higher emissions—about 1.42 tCO_2 per ton—revealing the critical influence of grid electricity carbon intensity on this route's environmental performance.

The DRI–EAF represents an intermediate pathway, producing roughly 1.15–1.59 tCO_2 per ton, depending on regional conditions. Its emissions are lower than BF–BOF but higher than scrap-based EAF, positioning it as a transitional technology, especially suited for gas-rich economies such as those in the MENA region. These values align with global benchmarks (e.g., ~2.32 tCO_2/t for BF-BOF, ~0.70 tCO_2/t for EAF, ~1.43 tCO_2/t for DRI+EAF (Basson, 2025)) confirming the robustness of the comparative approach.

Beyond climate change, the LCA results show that different production pathways also carry distinct environmental trade-offs. In categories such as stratospheric ozone depletion and terrestrial acidification, BF-BOF production generally exhibits higher impacts than EAF and DRI-EAF, reflecting the more resource- and emission-intensive nature of blast furnace operations. However, the EAF route in the EU records elevated ionizing radiation impacts, which can be traced to the reliance on nuclear power within the regional electricity mix, a reminder that decarbonization strategies are highly context-dependent.

Toxicity-related categories show particularly striking differences: while EAF achieves lower impacts in many categories, human carcinogenic toxicity is disproportionately high in both European and non-European EAF due to upstream processes linked with alloying and scrap recycling. Similarly, terrestrial ecotoxicity remains highest in BF-BOF, but notable burdens persist across all pathways. Resource-related categories also demonstrate variation, with BF-BOF leading in fossil resource scarcity and land use, whereas mineral resource scarcity is especially pronounced for DRI-EAF given its dependence on direct reduced iron inputs. Water consumption shows a mixed picture, with relatively higher demand in EAF outside the EU due to electricity-related withdrawals.

Taken together, these results underline that reducing CO_2 emissions alone is insufficient—comprehensive decarbonization policies must consider multidimensional environmental trade-offs, especially for water-stressed MENA exporters.

Table 1. LCA Results for the Production of 1 t Crude Steel with Different Production Techniques

Impact category	Unit	BF-BOF (EU)	BF-BOF (ROW)	EAF (EU)	EAF (ROW)	DRI-EAF (EU)	DRI-EAF (ROW)
Global warming	kg CO2 eq	2193.35	2279.79	546.25	1419.57	1149.60	1588.96
Stratospheric ozone depletion	kg CFC11 eq	0.00031	0.00032	0.00014	0.00029	0.00015	0.00022
Ionizing radiation	kBq Co-60 eq	66.45	42.75	130.34	49.51	73.85	30.20
Ozone formation, Human health	kg NOx eq	4.71	4.96	1.27	3.24	2.36	3.25
Fine particulate matter formation	kg PM2.5 eq	3.32	3.73	0.88	2.50	1.52	2.40
Ozone formation, Terrestrial ecosys.	kg NOx eq	4.84	5.07	1.32	3.38	2.42	3.35
Terrestrial acidification	kg SO2 eq	5.76	6.22	1.59	4.04	2.74	3.97
Freshwater eutrophication	kg P eq	1.69	1.57	0.35	0.95	0.56	0.74
Marine eutrophication	kg N eq	0.059	0.052	0.019	0.119	0.031	0.074
Terrestrial ecotoxicity	kg 1,4-DCB	13617.28	13978.79	1530.01	5339.25	1287.82	3203.43
Freshwater ecotoxicity	kg 1,4-DCB	639.64	636.15	441.38	352.97	246.39	198.65
Marine ecotoxicity	kg 1,4-DCB	845.84	841.47	653.16	519.71	360.90	289.31
Human carcinogenic toxicity	kg 1,4-DCB	6319.13	6437.82	32202.67	23483.23	16161.29	11798.59
Human non-carcinogenic toxicity	kg 1,4-DCB	17973.45	17848.23	1635.69	2399.24	1792.39	2056.88
Land use	m2a crop eq	56.57	62.08	19.67	32.21	24.28	32.32
Mineral resource scarcity	kg Cu eq	134.12	134.75	3.03	29.47	37.85	51.05
Fossil resource scarcity	kg oil eq	499.86	516.55	123.92	337.42	268.52	367.91
Water consumption	m3	14.25	14.76	8.37	18.48	5.84	10.89

Electricity-Related Carbon Emissions in the EU and MENA

To explain part of the observed variability in EAF emissions, Figure 3 examines differences in the carbon intensity of electricity generation across countries and regions. Europe stands out with the lowest emission factor, at 0.340 kg CO_2-eq/kWh, reflecting its high share of renewable energy and reduced reliance on fossil fuels. In contrast, most MENA countries exhibit considerably higher values, largely driven by fossil-based generation, particularly oil and natural gas.

At the country level, Saudi Arabia (0.999 kg CO_2-eq/kWh) and Morocco (0.937 kg CO_2-eq/kWh) show the highest intensities, nearly three times the European average. Egypt (0.697), Türkiye (0.610), and the UAE (0.606) perform relatively better than the MENA average but still record almost double the European level, illustrating how the electricity mix directly constrains decarbonization gains from EAF steelmaking.

Algeria (0.750) and Iran (0.715) also demonstrate above-average emission factors compared to Egypt and Türkiye, again reflecting limited integration of renewables. Regionally, both the Middle East (0.823 kg CO_2-eq/kWh) and Africa (0.783 kg CO_2-eq/kWh) show values more than twice the European benchmark, confirming that electricity-sector decarbonization is a prerequisite for industrial transition.

From a policy standpoint, these findings highlight the urgency of accelerating power-sector reforms in MENA to close the emissions gap with Europe and meet international climate targets. In countries like Egypt and Türkiye—where steel relies heavily on EAF—the carbon intensity of the grid significantly inflates overall steel emissions. Hence, while EAF technology provides structural advantages, its environmental payoff ultimately depends on parallel progress in energy-system decarbonization.

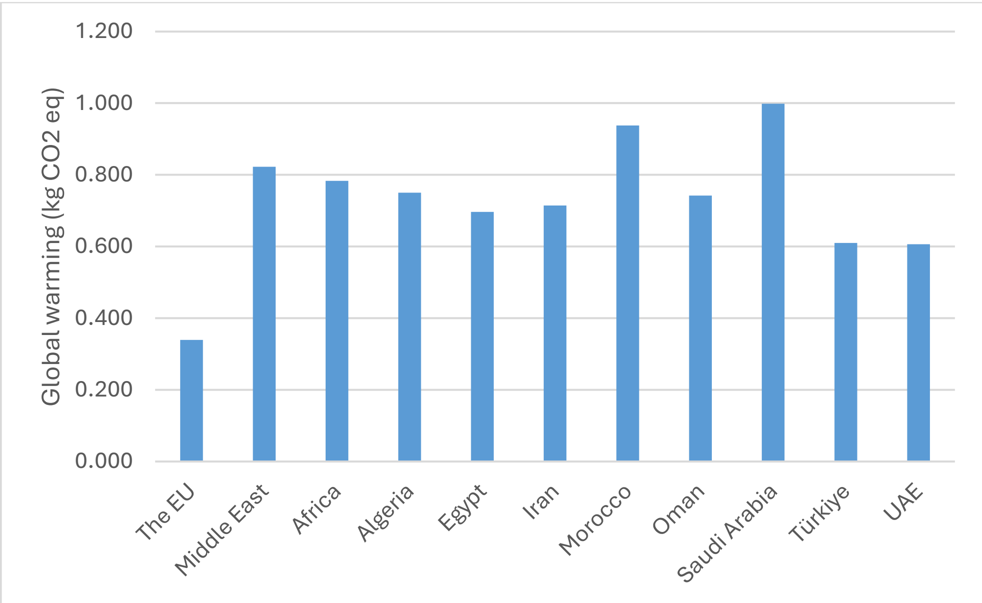


Figure 3. Global Warming Potential of 1 KWh Electricity Generation (kg CO_2-eq per kWh) (Ecoinvent, medium voltage)

3.3 Country-Specific LCA of Steel Production in the EU and MENA

Building on the regional electricity analysis, this section integrates national data to estimate total emissions and potential CBAM exposure. As illustrated in Table 1, different production techniques produce different emissions. Therefore, the production technology used in each country derives the emissions. National reports of Steel associations in countries provide the technology composition of the countries. Table 2 provides the assumptions used in the analysis for the technology of the MENA countries.

Table 2. Steel Technology Composition of MENA Countries (%)

	BF-BOF	EAF	DRI+EAF
Algeria	35	25	40
Egypt	8	92	-
Iran	25	15	60
Morocco	5	95	
Oman	-	10	90
Saudi Arabia	2.5	15	82.5
Türkiye	30	62.5	7.5
UAE	-	15	85

To maintain comparability across countries, emissions linked to electricity use were calculated using country-specific values. The LCA covers the entire steel production cycle—from raw-material extraction to crude-steel output—and evaluates global warming potential alongside other environmental indicators.

The environmental and economic implications of steel production in major MENA countries, summarized in Table 3, reveal significant variations in emission intensity and potential exposure to CBAM. In constructing this table, the proportion of each steel production method per country was identified, and emission profiles were computed using the Ecoinvent database within SimaPro. This step allows for a more granular understanding of how technology choices, electricity mixes, and trade volumes jointly determine CBAM vulnerability.

Table 3. The Environmental and Economic Implications of Steel Production in Selected MENA Countries, 2024

Country	Crude Steel Production (million t)	Exports to the EU (t)	Share of the EU Exports in Production (%)	Emissions (t CO2/t steel)
Algeria	4.5	272,108	6.05	1.64
Egypt	10.7	1,212,073	11.33	1.04
Iran	31.4	4,048	0.01	1.58
Morocco	1.4	10,226	0.73	1.24
Oman	3	47,961	1.60	1.38
Saudi Arabia	9.6	181,034	1.89	2.20
Türkiye	36.9	3,844,934	10.42	1.30
UAE	3.7	86,222	2.33	1.32

Source: *Crude steel production data of 2024 is taken from World Steel Association (2025). Exports to the EU data of 2024 is from The European Steel Association (2024). Emissions are calculated by the authors.*

The data highlight both the scale of production and the variation in carbon intensities, directly determining CBAM exposure. Türkiye stands out as the largest producer in the region with almost 37 million tons of crude steel, of which nearly 3.8 million tons are exported to the EU. Egypt, the second-largest exporter to the EU with over 1.2 million tons, benefits from a lower emission factor due to its EAF dominance, making its per-ton CBAM burden smaller than that of peers. Nevertheless, the carbon intensity of Egypt's EAF production remains significantly higher than most European producers, primarily due to its fossil-fuel-based grid.

In contrast, Saudi Arabia shows one of the highest emission intensities in the region. Even though its export volumes are modest, the high carbon content of its steel means each ton faces a substantial CBAM levy, illustrating how high-emission producers may lose competitiveness even with small trade exposure.

Countries such as Algeria and Iran, with emission intensities above 1.4 t CO_2/t steel, also face barriers to EU exports, though their current export volumes are limited. Morocco stands out as the most competitive case, with the lowest emission factor (0.73 t CO_2/t), positioning its steel exports at a clear advantage under CBAM despite smaller traded volumes. Oman and the UAE display moderate emissions, making them more competitive than Saudi Arabia or Algeria but still lagging behind Egypt and Morocco. These cross-country contrasts emphasize that technological mix and power-sector decarbonization together define each country's readiness for a carbon-constrained trade regime.

3.4 Scenario Analysis

Having established the emission intensities and trade exposure of MENA steel exporters, this section presents a forward-looking scenario analysis that quantifies how the EU CBAM may shape regional trade and emission outcomes through 2035. Three complementary simulations explore different dimensions of adjustment:

i. carbon price scenarios,
ii. price-responsive export scenarios, and
iii. emission-reduction scenarios.

Together, they offer a comprehensive perspective on how policy, market, and behavioral factors jointly determine CBAM exposure.

i. Carbon Price Scenarios

The first scenario examines how alternative EU carbon-price paths influence the total CBAM cost for MENA steel exporters. Each country's embedded emissions—calculated using steel exports to the EU and route-specific carbon intensities—were multiplied by projected EU ETS prices, starting from €80 per tCO_2 in 2025.

Three trajectories were modeled as follows:

- Low: +5 % annual increase
- Mid: +7 % annual increase
- High: +9 % annual increase

This simulation isolates the pure effect of carbon-price escalation, keeping trade volumes and production technologies constant.

Figure 4 shows that even moderate price growth substantially raises the region's cumulative CBAM burden. The total regional cost rises from roughly €0.6 billion in 2025 to €1.1 billion by 2035 in the mid-price path, while the high-price path pushes it close to €1.4 billion.

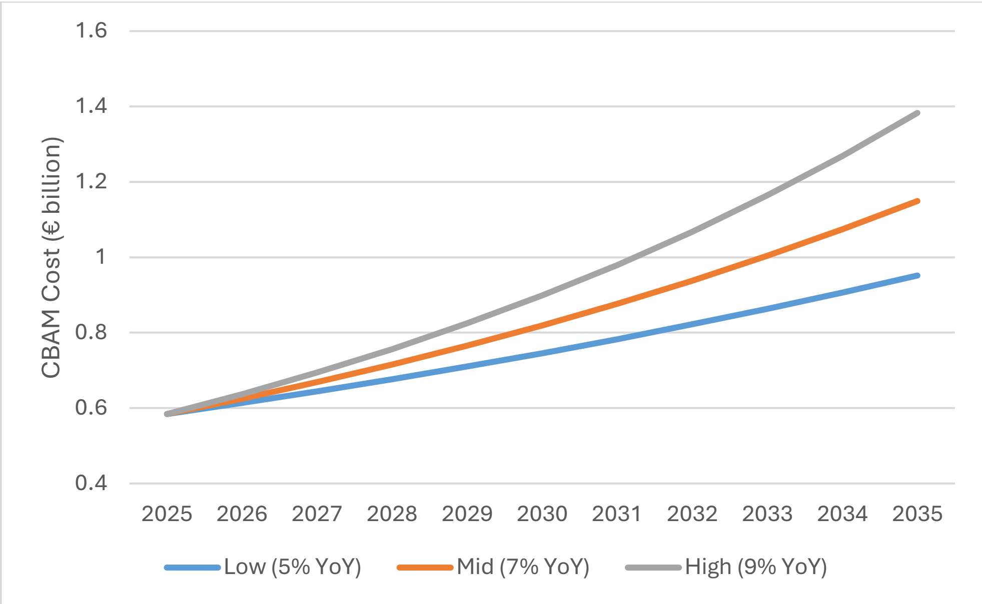


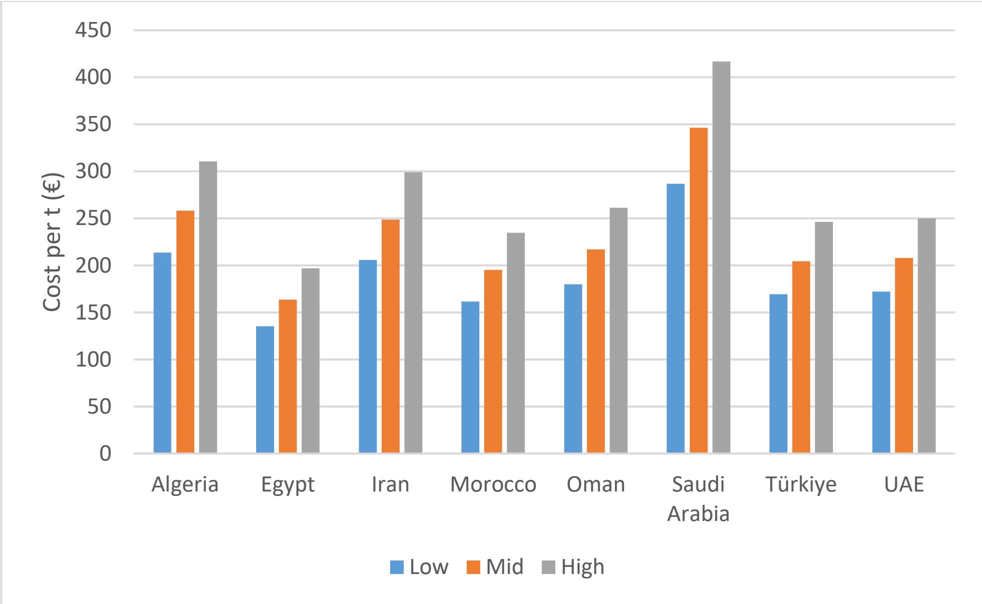
Figure 4. Total CBAM Cost of MENA Countries under Different Carbon Price Scenarios

Figure 5 compares the CBAM burden across MENA steel exporters under alternative carbon-price scenarios, distinguishing between unit-level costs (Panel a) and aggregate macroeconomic exposure (Panel b).

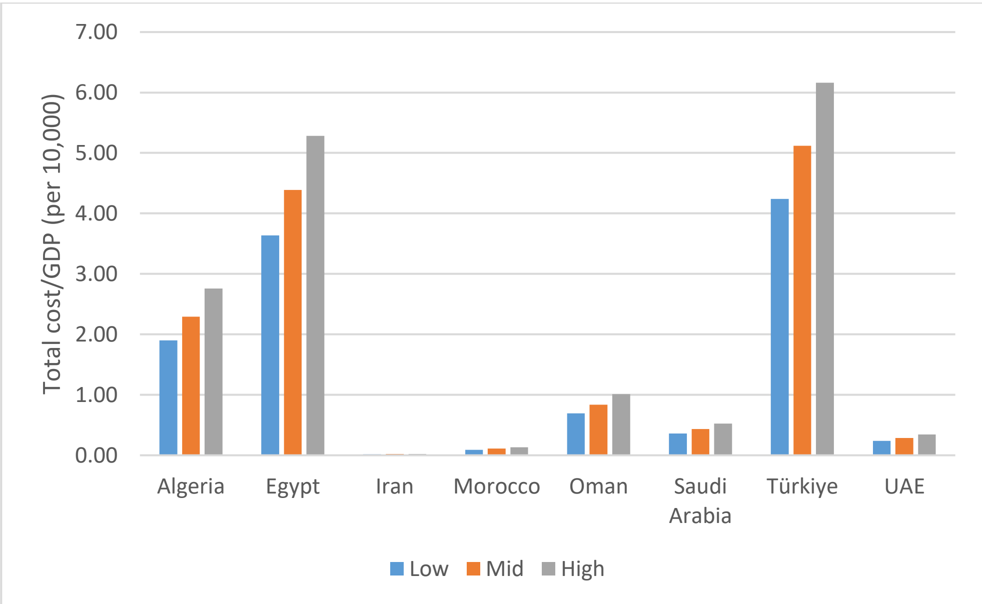
In Panel (a), Saudi Arabia, Algeria, and Iran stand out with the highest cost per ton of exported steel. Their elevated unit costs reflect both the predominance of more carbon-intensive production routes and the high carbon footprint of their energy systems. Even where DRI + EAF technologies dominate, as in Saudi Arabia, the continued reliance on fossil-based electricity substantially raises the effective CBAM rate. In contrast, Egypt, Türkiye, Oman, and the UAE show comparatively lower per ton costs, consistent with greater use of electric-arc or hybrid routes and, in some cases, cleaner power mixes.

Panel (b) shifts the focus to economy-wide exposure, revealing that Türkiye and Egypt bear the heaviest CBAM burden when measured as a share of GDP. This outcome is not driven by emission intensity but by export dependence on the EU market and the scale of production, which magnify total liabilities despite lower unit costs. By comparison, Algeria, Iran, and Saudi Arabia face high marginal costs but limited macroeconomic exposure due to smaller export volumes, while Morocco, Oman, and the UAE remain only marginally affected.

Taken together, the two panels underscore a dual vulnerability pattern: some countries are penalized primarily for their carbon intensity, others for their trade exposure. The findings also highlight that mitigating CBAM risks requires an integrated strategy combining energy-system decarbonization, technological upgrading, and diversification of export markets.



Panel a. Cost per t of Exported Steel



Panel b. Total Cost as a share of GDP

Figure 5. CBAM Burden Country Comparisons for Different Carbon Price Scenarios

ii. Price Responsive Export Scenarios

The second scenario, depicted in Figure 6, introduces price elasticity of exports to evaluate how rising prices might alter export volumes and CBAM revenues. The analysis assumes an annual 7 % increase in steel prices—corresponding to the mid-price trajectory—and applies three elasticity levels to reflect alternative responsiveness levels:

- −0.7: Low responsiveness (inelastic exports)
- −1.0: Moderate responsiveness

- –1.3: High responsiveness (elastic exports)

Elasticity effects were applied each year from 2026 to 2035, producing a compounding decline in exports over time. Consequently, CBAM costs decline compared to the price scenarios.

Under low elasticity (–0.7), exports decrease only marginally, and the region's total CBAM costs continue to rise throughout the period. Under moderate elasticity (–1.0), export declines offset much of the price effect, keeping aggregate CBAM payments broadly stable. Under high elasticity (–1.3), export volumes shrink rapidly, resulting in a pronounced fall in total CBAM revenues by 2035.

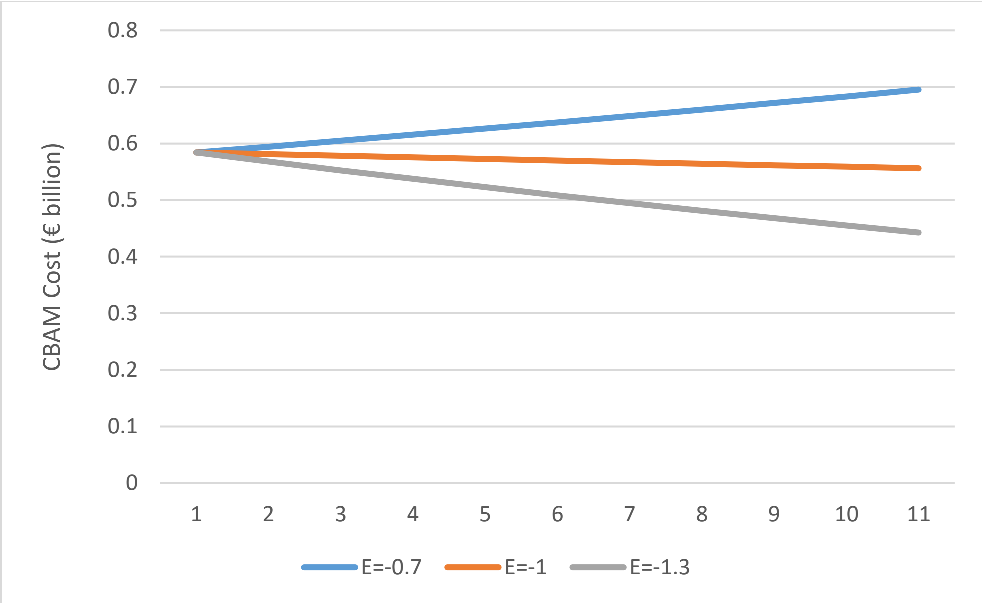
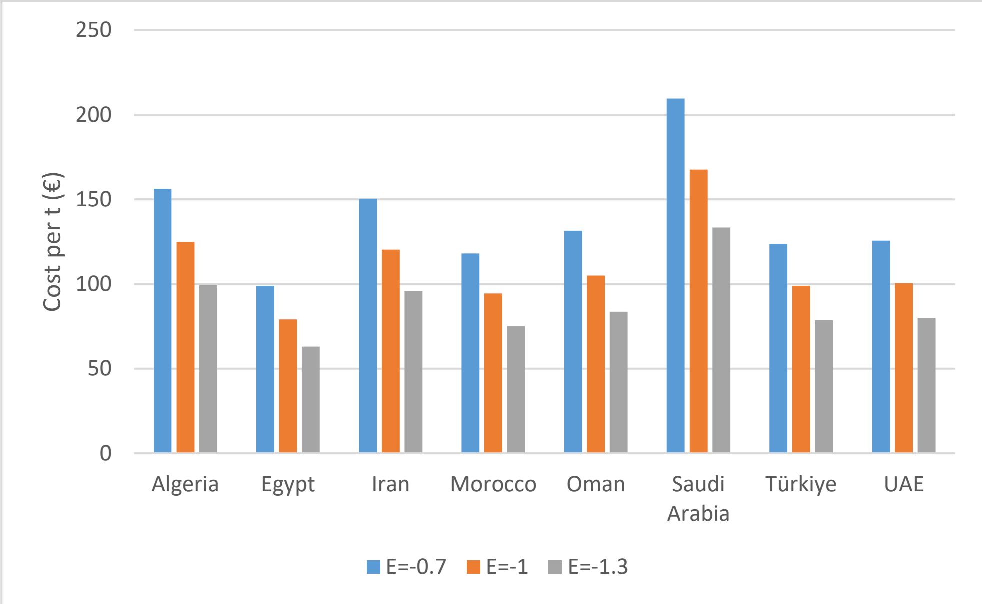


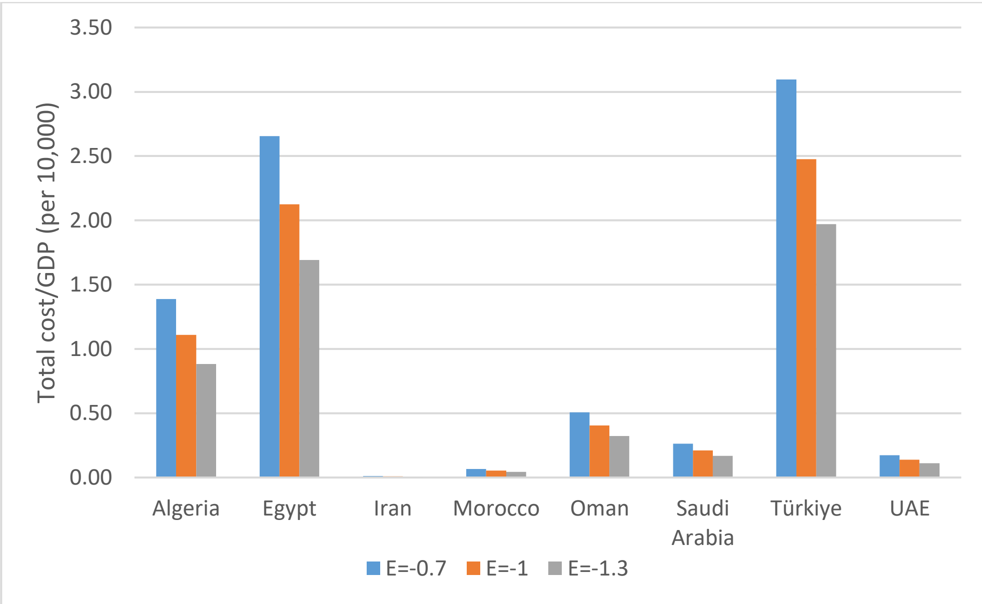
Figure 6. Total CBAM Cost of MENA Countries under Different Carbon Price Elasticity Scenarios

Figure 7 illustrates how alternative carbon-price elasticity assumptions (E = –0.7, –1, –1.3) influence the distribution of CBAM costs across MENA steel exporters. Panel (a) shows that the ranking of countries by cost per ton remains broadly similar to Figure 5—Saudi Arabia, Algeria, and Iran continue to face the highest unit costs, while Egypt and Türkiye exhibit lower levels. The downward shift in unit cost with higher elasticity values reflects smaller effective export volumes rather than technological change.

Panel (b) reveals that macroeconomic exposure declines markedly for Türkiye and Egypt relative to Figure 5, as higher export responsiveness reduces total CBAM liabilities. Countries with limited EU trade, such as Iran, Oman, and the UAE, show only marginal variation, confirming that elasticity effects operate mainly through trade dependence. Overall, greater export elasticity moderates CBAM vulnerability but also implies reduced export revenues, pointing to a structural trade-off between short-term cost containment and long-term competitiveness in the EU market.



Panel a. Cost per t of Exported Steel



Panel b. Total Cost as a share of GDP

Figure 7. CBAM Burden Country Comparisons under Different Carbon Price Elasticity Scenarios

iii. Emission Reduction Scenarios

The final scenario integrates national and global decarbonization pathways to assess how emission-reduction policies can mitigate CBAM exposure. This analysis builds on the mid-price (7 %) and moderate elasticity (–1.0) assumptions but allows emission intensities to decline annually according to alternative trajectories.

Three pathways are examined:

- Business-as-Usual (BAU): No change in emission intensity.
- National Targets: Country-specific unconditional or conditional targets annualized and extrapolated to 2035.
- Global (Paris) Pathway: A 29 % global emission reduction by 2030, aligned with Paris Agreement expectations, extended linearly to 2035 at the same rate of decline.

Table 4 presents the national reduction commitments applied in the model. Although most targets are economy-wide, they provide a credible proxy for potential steel-sector decarbonization. Annualizing these reductions assumes that emission intensity improves each year at a constant pace, continuing beyond 2030 until 2035.

Table 4. Emission Targets for Selected MENA Countries

Country	Target Year	Base Year	Unconditional Target (%)	Conditional Target (%)	Sector	Source
Algeria	2030	2021	7	22	All GHG emissions	The World Bank, 2023
Egypt	2030	2021	-	37	Electricity	Climate Action Tracker, 2023b
Iran	2030	2015	4	12	All GHG emissions	Climate Watch, 2015; Ghadaksaz & Saboohi, 2020
Morocco	2030	2021	18.3	45.5	All GHG emissions	Climate Action Tracker, 2023a
Oman	2030	2021	2	7	All GHG emissions	International Energy Agency, 2024; Oman, 2022
Saudi Arabia	2030	2018	30		All GHG emissions	Crippa et al., 2021; Saudi & Middle East Green Initiatives, 2021
Türkiye	2030	2021	41		All GHG emissions	The Government of the Republic of Türkiye, 2023
UAE	2035	2019	47		All GHG emissions	United Arab Emirates Ministry of Climate Change and Environment, 2024

Figure 8 illustrates the aggregate regional trend. Under BAU, total CBAM costs rise steadily through 2035, led by Türkiye, Algeria, and Saudi Arabia. Under National Targets, costs decline noticeably—by about 20–25 % relative to BAU—reflecting accelerated decarbonization in countries such as Türkiye, Egypt, and Morocco. The Paris-aligned pathway generates the strongest effect, with total regional CBAM liabilities falling by nearly 40 % by 2035, highlighting the cumulative impact of consistent global emission reductions.

Figure 9 evaluates how alternative carbon-emission reduction pathways—business-as-usual (BAU), national targets, and the global Paris-aligned trajectory—reshape the CBAM burden across MENA steel exporters.

Panel (a) shows a clear downward trend: CBAM costs per ton of exported steel fall systematically from BAU to national targets and further under the Paris pathway, reflecting the direct effect of declining embodied carbon. While the overall ranking of countries remains similar, the scale of reduction varies according to the ambition of national commitments. Türkiye, Morocco, and Egypt stand out with highly ambitious national targets that already approach the Paris-aligned trajectory, leading to limited additional cost reductions between the two pathways. In contrast, Iran and Algeria, whose commitments are comparatively modest, show only minor improvements even under the global scenario.

Panel (b) translates these effects into macroeconomic terms. The CBAM burden as a share of GDP declines sharply for Türkiye and Egypt, whose substantial EU export exposure amplifies the benefits of lower emission intensity. For smaller exporters such as Oman and the UAE, the overall impact remains limited regardless of the decarbonization pathway.

Taken together, Figure 9 underscores that ambitious emission-reduction policies can substantially mitigate CBAM exposure. However, the results also reveal considerable heterogeneity across the region, emphasizing the need to align national climate targets, industrial strategy, and trade orientation to ensure that decarbonization efforts translate into tangible competitiveness gains.

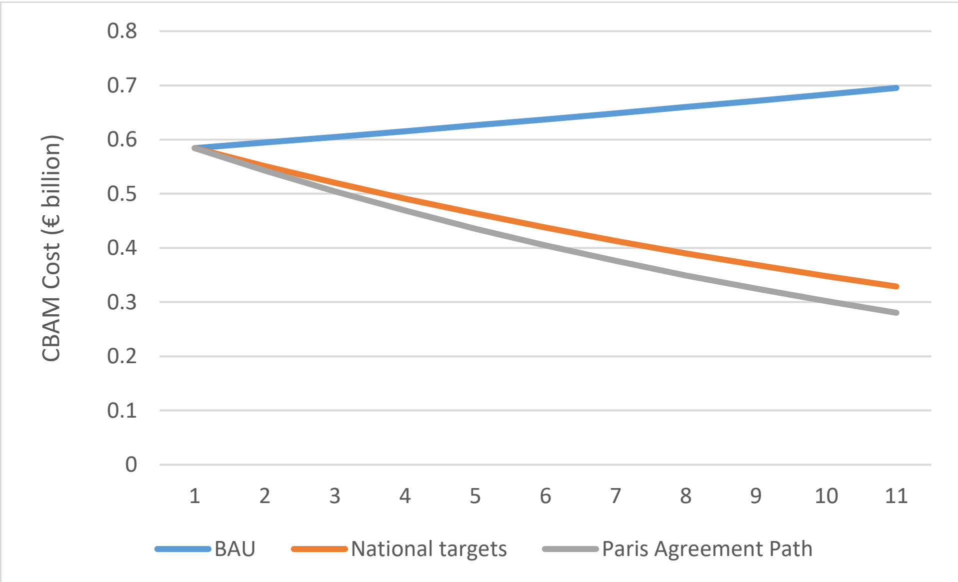
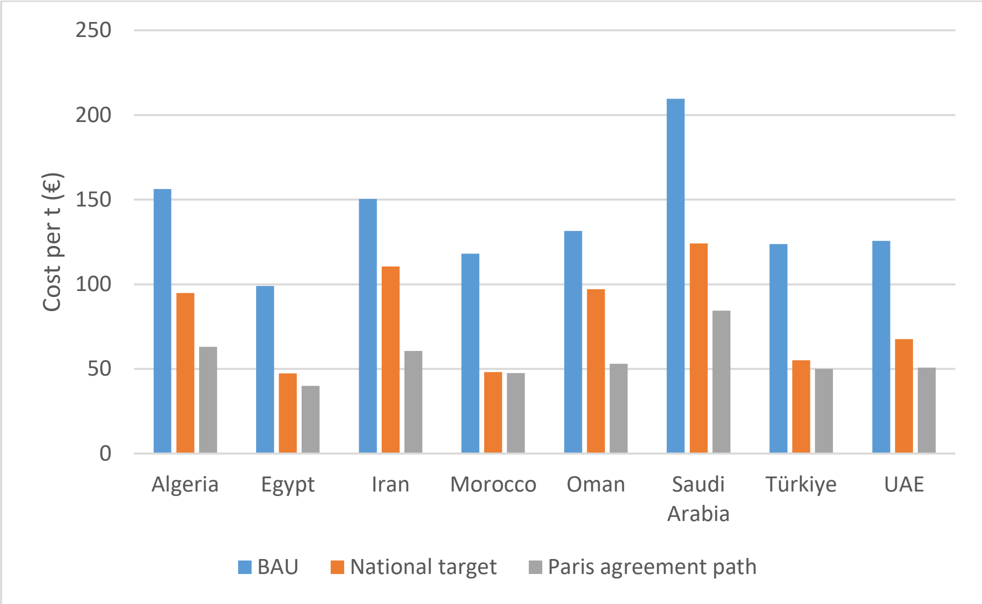
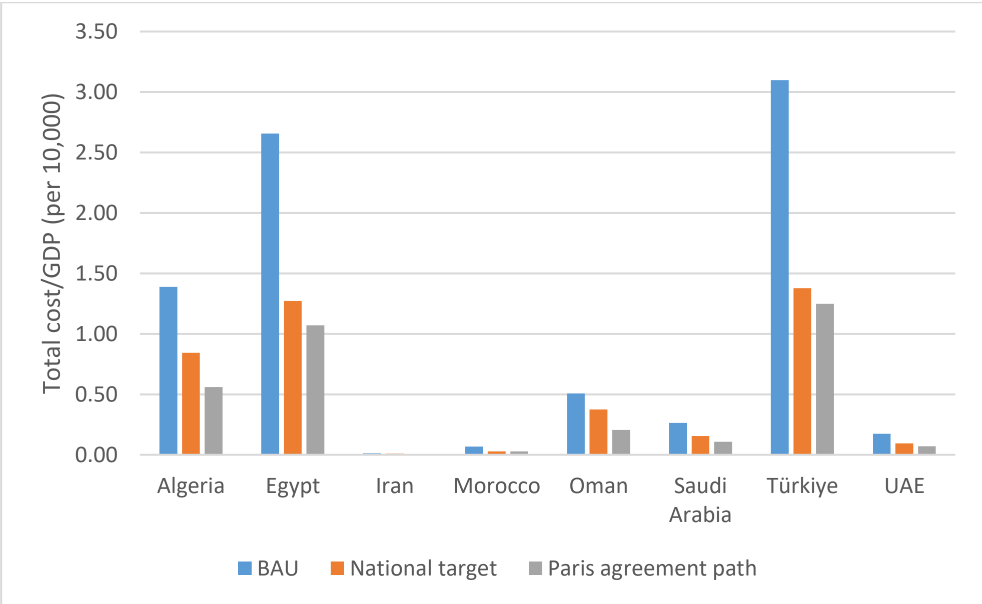


Figure 8. Total CBAM Cost of MENA Countries Under Different Carbon Emission Reduction Scenarios



Panel a. Cost per t of Exported Steel



Panel b. Total Cost as a share of GDP

Figure 9. CBAM Burden Country Comparisons Under Different Carbon Emission Reduction Scenarios

4 Conclusions and Policy Implications

This study integrates process-based LCA analysis with trade exposure and scenario simulations to evaluate how the Middle East and North Africa's steel sector will be affected by the EU's CBAM. By combining technology-specific emission profiles with export data and alternative carbon-price and elasticity assumptions, it provides a comprehensive mapping of the region's potential CBAM liabilities through 2035. The analysis links engineering-based emissions data to trade exposure, illustrating how production structure and carbon pricing jointly determine the scale of regulatory risk under a carbon-constrained trading regime.

The scenario analysis reveals three complementary adjustment margins. First, under alternative carbon-price trajectories, regional CBAM costs rise sharply with higher ETS prices, but the distribution of the burden remains uneven—Türkiye dominates regional exposure due to export scale, Egypt faces the highest market dependence, and Saudi Arabia bears the greatest carbon-intensity risk. Second, introducing export-price elasticity demonstrates that responsiveness to higher carbon costs can significantly mitigate macroeconomic exposure, especially for EU-dependent exporters such as Türkiye and Egypt, though at the expense of reduced export revenues. Third, emission-reduction scenarios indicate that alignment with national or Paris-consistent pathways can reduce total CBAM liabilities by up to 40 percent by 2035, with Türkiye, Morocco, and Egypt already approaching Paris-level ambition. Collectively, these scenarios confirm that both technological decarbonization and trade elasticity act as critical buffers against CBAM-related risks.

From a trade-policy perspective, CBAM represents a new layer of adjustment beyond tariffs or conventional non-tariff measures—it reintroduces environmental performance as a condition for market access. The mechanism effectively transforms carbon pricing into a component of international competitiveness, with implications for how comparative advantage is perceived and priced. In the EU–MENA steel corridor, this dynamic reframes trade exposure as a function not only of cost and productivity but also of emission efficiency.

Technologically, efficiency upgrades and the expansion of scrap-based EAF capacity remain the most feasible short-term response, particularly for Egypt and Morocco. Carbon capture and storage (CCS) technologies appear costly at current ETS prices, while hydrogen-based DRI routes offer long-term potential for gas-rich economies such as Saudi Arabia and Oman. Yet these technological options must be complemented by policy measures—power-sector decarbonization, national scrap traceability systems, credible measurement–reporting–verification frameworks, and access to green finance—to ensure that industrial investments translate into durable trade competitiveness.

In sum, CBAM exposes the structural carbon asymmetry between MENA and the EU but also opens a pathway for industrial renewal. The quickest way to reduce CBAM-related liability is to lower the "carbon intensity per exported dollar" through cleaner inputs, electrification, and transparent emissions accounting. Whether CBAM becomes a constraint or a catalyst for MENA's steel sector will ultimately depend on how effectively the region aligns its trade and industrial strategies with the accelerating global shift toward carbon-conditioned market access.

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