



DECARBONIZING HEAVY INDUSTRY: Global Trends, Technological Pathways and Policy Challenges

Muhammad Usman, Sana Noor, Sana Affan & Amna Karim Bajwa

1. INTRODUCTION

Heavy industry drives roughly 30% of global CO₂ emissions, with steel, cement and chemicals alone accounting for close to a quarter of the world total. The technologies to cut that footprint- electric arc furnaces, waste heat recovery, clinker substitution, and green hydrogen are largely proven; the remaining question is deployment speed and who pays for the transition.

Pakistan's industrial sector emitted 86 MtCO₂e in 2022, 16% of national emissions. That is small next to China, which alone accounts for around 60% of global steel-sector emissions and over half of world cement and aluminium output, but it is

concentrated in cement, steel and textiles, sectors that now sit directly in the path of Europe's carbon border regime and Pakistan's own NDC 3.0 commitments.

Two pressures converge on this industrial base. The EU's Carbon Border Adjustment Mechanism (CBAM) entered its definitive phase on January 1, 2026, with a planned extension to chemicals and textiles that would hit Pakistan's largest export categories. And Pakistan's NDC 3.0, submitted in September 2025, commits to cutting projected 2035 emissions by 50% relative to business-as-usual, 17% unconditionally, and 33% conditionally on international finance. Industry sits inside both tracks, a compliance cost abroad and a mitigation target at home.

This article maps Pakistan's industrial emissions landscape, the pathways realistically available to cement, steel and textiles, the policy instruments now in motion, and the barriers, capital cost above all, standing between current practice and net zero.

2. PAKISTAN'S INDUSTRIAL EMISSIONS LANDSCAPE

Globally, cement is roughly twice as carbon-intensive per dollar of output as steel due to clinker calcination, while steel remains the largest absolute industrial emitter, accounting for around 11% of global CO₂ emissions. Pakistan broadly follows this pattern, with cement as the heavier emitter and steel smaller but strategically important.

Cement is Pakistan's largest industrial emitter. Estimates range from about 16 MtCO₂ in 2023 to nearly 25 Mt based on plant-level clinker data, highlighting gaps in monitoring, reporting and verification (MRV). With installed capacity of around 69 Mt/year projected to reach 77.5 Mt by 2030, absolute emissions could continue rising despite efficiency gains. Steel emits an estimated 1.9–2.5 MtCO₂ annually. Unlike many countries, Pakistan relies mainly on induction and electric arc furnaces, with induction furnaces accounting for over 85% of production. This gives the sector a lower-emission advantage, but weak MRV and product-level carbon certification limit its ability to demonstrate this advantage in regulated export markets.

Textiles represent the major trade exposure. They account for roughly 53–60% of Pakistan's exports and around three-quarters of exports to the EU. While only about 1.23% of current exports fall under CBAM, its planned 2026–2030 expansion to textiles and apparel could bring Pakistan's largest export sector under direct carbon pricing.

3. CORE DECARBONIZATION PATHWAYS

The pathways available to Pakistan's industry are the same ones scaling elsewhere: efficiency and electrification first, fuel switching and material substitution next, carbon capture and new feedstocks as longer-term bets, just applied at a different starting point and a different pace.

3.1 Energy efficiency and waste heat recovery

Cement kilns discharge exhaust gas at high temperature and volume; waste heat recovery captures that stream to generate a meaningful share of a plant's own power needs. It is the cheapest lever available and does not require new chemistry, but it needs upfront capital that many mid-sized producers cannot self-finance without concessional support.

3.2 Renewables and captive power

Solar and wind are already being deployed at plant level. Lucky Cement's captive solar and wind portfolio at its Pezu and Karachi plants now produces over 212 GWh annually and displaces more than 100,000 tonnes of CO₂ a year, and the World Bank estimates that solar PV on under 1% of Pakistan's land area could meet the country's entire electricity demand, resource enough to power EAF steelmaking on clean grid or captive power rather than fossil-fired induction furnaces.

3.3 Fuel switching and alternative fuels

Cement kilns can co-fire refuse-derived fuel (RDF), biomass and industrial waste oils in place of coal. Scenario modelling for Pakistan's cement sector finds that fuel switching alone could avoid roughly 17 Mt of CO₂ under a 2050 net-zero pathway, but this depends on a formal RDF and alternative-fuel market that does not yet exist, along with quality-assured biomass supply chains.

3.4 Clinker substitution and material efficiency

Blending clinker with supplementary cementitious materials, fly ash and slag among them, cuts embodied carbon per tonne of cement without new capital plant. On the steel side, the existing scrap-based induction and EAF base gives Pakistan more room here than most developing steel producers; the constraint is domestic scrap collection infrastructure, not technology.

3.5 Carbon capture

CCUS remains distant for Pakistan's industry, capital cost and the absence of storage infrastructure rule it out at scale for now, but it stays relevant for the calcination-linked process emissions that efficiency and fuel switching cannot reach.

3.6 Green hydrogen for fertilizer

Fertilizer, not steel or cement, is where green hydrogen has the clearest near-term case in Pakistan. The sector already runs on ammonia produced from natural gas, so swapping in electrolytic hydrogen is a feedstock substitution rather than a new industrial process. Punjab's draft green hydrogen policy targets 100 kilotonnes a year of green hydrogen and ammonia capacity by 2030, backed by electricity duty exemptions and capital subsidies for early biomass-to-hydrogen projects. Pakistan's gas reserves are depleting and increasingly import-dependent, which gives green ammonia an energy-security rationale on top of its climate one, though cost remains the constraint until domestic renewable power and electrolyzer prices fall further.

4. POLICY AND ECONOMIC INSTRUMENTS

CBAM is the sharpest edge of a broader global shift toward carbon pricing and border measures, but it is not the only one; Indonesia, Japan and Vietnam are each standing up their own carbon markets, and US disclosure requirements are tightening in parallel. For an export economy like Pakistan's, that trend means compliance costs are unlikely to stay confined to the EU market alone.

4.1 CBAM exposure

CBAM's compliance requirement, embedded-emissions reporting per product, is where Pakistan is least prepared. Industry representatives have publicly flagged the country as under-equipped for the 2026 standard, and the steel sector in particular lacks a formal MRV framework despite using comparatively low-emission EAF and induction technology. Building that verification capacity, and expanding

Pak-EPA's legal mandate to cover it, is a precondition for capturing any competitive advantage from the sector's existing technology mix.

4.2 NDC 3.0 and green finance

NDC 3.0 puts a price tag on the transition: an estimated USD 565.7 billion in investment is needed to meet the 2035 target, alongside a planned shift to 60% renewable electricity and a 30% increase in electric vehicle adoption. The Securities and Exchange Commission of Pakistan's revised ESG disclosure guidelines, aligned to the new Pakistan Green Taxonomy, are the first domestic instrument meant to channel private capital toward these targets, industrial decarbonization included.

4.3 Digital compliance requirements

Beyond carbon pricing, the EU's Digital Product Passport will require textile exporters to document material origin, production stage and environmental performance for every shipment. For an export base still building basic emissions MRV, that is a second, parallel compliance burden layered on top of CBAM.

5. BARRIERS AND CHALLENGES

Capital cost is the binding constraint across all three sectors. Waste heat recovery, solar retrofits and clinker substitution all carry high upfront cost against thin margins, and Pakistan's cement and steel producers operate in a market without a domestic carbon price to make the low-carbon option commercially preferable.

Institutional capacity is the second constraint. Pakistan currently lacks the MRV systems, third-party certification protocols and international compliance alignment that CBAM will demand, a gap that a research assessment attributes to weak regulatory frameworks and an absence of transition incentives, not a shortage of viable technology.

Trade competitiveness is the third. India's pending free trade agreement with the EU threatens to erode Pakistan's tariff advantage in textiles just as compliance costs are rising, meaning exporters face

margin pressure from two directions simultaneously, market access and carbon cost.

Stranded asset risk sits underneath all three. Pakistan's post-2022 energy crisis pushed the government toward expanding domestic coal capacity to cut reliance on imported gas, and coal already supplies roughly 60% of the power sector fuel mix. Industrial electrification bets on a grid that is still being decarbonized on its own separate, slower timeline, meaning a cement or steel plant that switches from direct coal firing to grid electricity today may only be trading one fossil-linked emissions source for another until the power sector's own renewable buildout catches up.

6. CASE STUDY: LUCKY CEMENT'S RENEWABLE TRANSITION

Lucky Cement, roughly 18 to 19% of national cement output, released about 7.3 million tonnes of CO₂ across its Pezu and Karachi plants in FY2025. Its renewable build-out, a 42.8 MW solar plant with battery storage at Pezu, a 31.5 MW solar project at Karachi, and a 28.8 MW

wind project, is now Pakistan's largest on-site captive solar installation and avoided over 100,000 tonnes of CO₂ in a single year. It demonstrates that captive renewables are commercially viable for large integrated producers today; the open question is whether that model can be financed down to the mid-sized plants that make up the rest of the sector.

7. PATHWAYS TO 2030/2035

NDC 3.0's indicative 2035 target is to cut projected emissions from 2,559 MtCO₂e to 1,280 MtCO₂e economy-wide, with industry named explicitly alongside energy, agriculture and transport. Meeting that for cement, steel and textiles will depend less on any single breakthrough technology and more on whether MRV capacity, concessional finance for waste heat and renewable retrofits, and CBAM-readiness converge before the EU's compliance clock runs out. Pakistan's structural advantage, an EAF- and induction-furnace-dominated steel sector and demonstrated captive renewable models in cement, gives it a genuine head start. Converting that head start into certified, exportable low-carbon products is the work still ahead.

Muhammad Usman, Sana Noor, Sana Affan & Amna Karim Bajwa, National Disaster Management Authority, Islamabad, Pakistan.