Ministry of Climate Change
and Environmental Coordination
Government of Pakistan

SPAR6C
Supporting Preparedness for
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Sectoral Study

Decarbonization of Pakistan's Cement Sector: Technologies, Policy Options, and Carbon Market Opportunities

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Abbreviations

AJK	Azad Jammu and Kashmir
APCMA	All Pakistan Cement Manufacturer Association
BAU	Business As Usual
BEV	Battery Electric Vehicle
BMWK	German Ministry for Energy and Climate Action
CBAM	Carbon Border Adjustment Mechanism
CCS	Carbon Capture and Storage
CPEC	China-Pakistan Economic Corridor
CPP	Captive Power Plants
CREA	Centre for Research on Energy and Clean Air
EAC	Electric Arc Calciner
EPA	Environmental Protection Agency
EOR	Enhanced Oil Recovery
EPD	Environmental Product Declaration
ER	Emissions Reductions
EV	Electric Vehicle
GCCA	Global Cement and Concrete Association
GCF	Green Climate Fund
GHG	Greenhouse Gas
GPP	Green Public Procurement
IDDI	Industrial Deep Decarbonisation Initiative
IEA	International Energy Agency
ITMOs	Internationally Transferred Mitigation Outcomes
JCM	Joint Crediting Mechanism
KPK	Khyber Pakhtunkhwa
LCA	Life Cycle Assessment
LC3	Limestone Calcined Clay Cement
MoCC	Ministry of Climate Change and Environmental Coordination
MoU	Memorandum of Understanding
MSW	Municipal Solid Waste
NDC	Nationally Determined Contributions
OPC	Ordinary Portland Cement
PA	Paris Agreement

PCF	Product Carbon Footprint
PCR	Product Category Rules
PKR	Pakistani Rupee
PPP	Public-Private Partnership
PSQCA	Pakistan Standard and Quality Control Authority
R&D	Research and Development
RFP	Request of proposal
ROI	Return on Investment
SCM	Supplementary cementitious materials
SDG	Sustainable Development Goals
SPAR6C	Supporting Preparedness for Article 6 Cooperation
tCO2e	Tons of Carbon Dioxide Equivalent
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
VCM	Voluntary Carbon Markets
VCS	Verified Carbon Standard
WBCSD	World Business Council on Sustainable Development
ZETI	The Zero-Emission Technology Inventory

Executive Summary

Carbon markets offer a path to improve people's lives while preserving the earth's environment by mitigating carbon emissions and reducing improving resiliency to the adverse impacts of climate change. Like many countries across the globe, Pakistan seeks to improve living standards for its growing populations while at the same time achieving the carbon mitigation goals laid out in the country's commitments under the Paris Agreement on the Climate. Specifically, under its Nationally Declared Contributions (NDCs), Pakistan has committed to a 50% reduction of its projected emissions by 2030.[1] Carbon markets, and especially Article 6 of the Paris Agreement, could be a source for the funds needed to reach this goal. This is particularly true for the cement sector, as cement is very carbon-intensive industry that will need to tap into all available sources to finance capital-intensive investments in its quest for deep decarbonization.

Background: A Modern, Efficient Industry

Cement (together with steel) is essential for the housing and infrastructure of modern life, and the cement sector plays a crucial role in any country's industrial, economic and social progress. However, greenhouse gas (GHG) emissions from cement production are very large. It has been noted that if the cement industry were considered a country, it would rank as the third or fourth largest contributor to carbon dioxide (CO_2) emissions globally; in 2022, cement production generated 1.6 billion metric tons of CO_2, accounting for roughly 8% of the world's total emissions. Pakistan's Nationally Declared Contributions (NDCs) include cement as a strategic sector for GHG reductions.[2]

The Cement Industry in Pakistan is formed of 16 active companies which are operating 24 plants. The industry is characterized by technological advancement and operational efficiency. Its focus on sustainability and energy efficiency is evident in the widespread implementation of Best Available Technology (BAT), and the pervasive use of the state-of-the-art equipment and manufacturing processes. Further, pollution abatement technologies are standard in both new and upgraded cement plants across the country.

Rising energy costs in Pakistan and favorable rates of return have spurred significant investments in Waste-Heat Recovery (WHR) plants, and renewable (solar and wind) energy, with major players like Bestway Cement, DG Cement, Lucky Cement and Fauji Cement leading the way. However, reaching ambitious deep decarbonization goals in the industry would require the mobilization of large amounts of additional financial resources, and carbon markets could provide the critical funding sources and mechanisms needed.

The Role of Carbon Markets for Pakistan's Cement Industry to Reach Paris Agreement Climate Goals

Pakistan's cement industry largely uses modern technology, but it needs to adopt advanced techniques for producing low-carbon cement. This shift would reduce sector

[1] Government of Pakistan (2021). UPDATED NATIONALLY DETERMINED CONTRIBUTIONS. https://unfccc.int/sites/default/files/NDC/2022-06/Pakistan%20Updated%20NDC%202021.pdf
[2] Ibid.

emissions and help maintain economic competitiveness as global demand for low-carbon cement rises.

Pakistan is actively seeking ways to reduce its GHG emissions to meet its NDC targets. Pakistan's updated NDCs include cement as a strategic sector for GHG reductions, not least because the sector accounted for 65% of industrial coal consumption in 2018, and the NDCs seek to "completely ban imported coal."[3] The cement sector, a significant source of emissions, presents both opportunities and challenges under Article 6 of the Paris Agreement.

Article 6 provides a framework for the sale and purchase of Internationally Transferred Mitigation Outcomes (ITMOs). ITMOs are units of GHGs that can be verified against national carbon registries and sold to other entities. Article 6.2 lays the groundwork for countries to exchange ITMOs for financial compensation. For example, if a country required ITMOs to meet its commitments for carbon emissions reductions under the Paris Agreement, it could purchase them from a country that is overly-compliant in this regard (i.e., that country is meeting its Paris Agreement requirements and has excess GHG emissions reductions that it can offer on the carbon market). Meanwhile, under Article 6.4 establishes a "Supervisory Body" that develops and supervises the processes needed to establish mechanisms for the new international carbon crediting mechanism of Article 6.[4] While the details of the mechanism are still being defined, some carbon market players foresee that emissions reductions under Article 6.4 will be available for purchase by countries or private entities.[5]

Pakistan's cement industry has previously successfully engaged carbon markets to spur mitigation projects, notably under the Clean Development Mechanism (CDM, the predecessor of Article 6). A total of 10 projects in the sector were successfully completed under the CDM, 7 for Waste Heat Recovery and 3 for Alternative Fuels, for total annual estimated reductions of 724,408 metric tons of CO_2.[6]

Pakistan's cement sector has substantial potential to support the nation's climate goals through Article 6 mechanisms. However, realizing this potential requires overcoming several challenges. Chief among these needs is increased capacity for financial investment, as very high interest rates in Pakistan constrain the ability of companies to invest in expensive technologies at cement plants. Further, domestic demand for low-carbon cement should increase. The government can play a key role in overcoming these challenges by creating the conditions for carbon financing of projects in the cement sector and increasing demand for "green" cement. In this way, Pakistan can effectively leverage carbon markets to increase low-carbon cement production, cut emissions, and advance sustainable development.

The following are some ways carbon markets can help reduce emissions from the cement sector in Pakistan:

[3] Government of Pakistan. (2021). Pakistan: updated nationally determined contributions 2021. P. 10. New York: UN Framework Convention on Climate Change. https://unfccc.int/sites/default/files/NDC/2022-06/Pakistan%20Updated%20NDC%202021.pdf
[4] https://unfccc.int/process-and-meetings/bodies/constituted-bodies/article-64-supervisory-body
[5] https://carbonmarketwatch.org/2022/11/02/cop27-faq-article-6-of-the-paris-agreement-explained/
[6] Authors' calculations from https://cdm.unfccc.int/

Emissions offset/Baseline and Credit schemes

Under these types of arrangement, which include Articles 6.2 and 6.4 of the Paris Agreement, Pakistani cement firms could engage in baseline-and-credit activities to generate Internationally Transferred Mitigation Outcomes (ITMOs). Pakistani cement companies will first measure baseline emissions related to cement production, then implement carbon mitigation measures. The measurable difference between the baseline emissions and the emissions mitigated by the project will be offered for sale to countries to meet their emissions targets.

Emissions-trading Systems (ETS)

ETSs usually use a cap-and-trade system, which sets an overall emissions cap to achieve emissions reductions. Using emissions reduction targets based on previous emissions, emissions permits are auctioned or provided to participants. ETSs are mandatory/compliance mechanisms that create domestic and international markets for carbon mitigation from public and private entities.

Although Pakistan does not currently have and ETS, creating one would incentivize the adoption of cleaner technologies or alternative materials like low-carbon cement, or seek offsets for their own emissions, and companies may be able to purchase offsets under Article 6 of the Paris Mechanism in the future.

GHG Emissions from Cement Production in Pakistan

Up to 95% of GHG emissions from the cement sector in Pakistan can be subdivided into two subgroups: Process emissions and coal consumption[7]. Process emissions (55% of emissions) come from the calcination of limestone (limestone is used to create clinker). Next, 41% of emissions come from the combustion of fuels to heat both the calcination and sintering process (kilns). In Pakistan, 86% of fuel used to power these processes is coal.

The emissions estimate for cement production in Pakistan provided in this report uses the amount of cement produced per year (from the APCMA - All Pakistan Cement Manufacturer Association), multiplied by an emission factor of 0.9 tons of CO_2 per ton of cement (Hasanbeigi et al. 2010).[8] The historical emissions from cement production shown below largely follow economic cycles in Pakistan. For example, a current economic crisis in the country has led to decreased cement production in recent months; this caused a dip in emissions to 40.1 million tons in 2023-2024 from a high of 51.6 million tons in 2021-2022.

[7] Qureshi, S, Zia, U, Bashir, N 2023., Pakistan's Cement Sector: A Road to Decarbonization 2023, SDPI.
[8] Hasanbeigi A, Price L, Lu H, Lan W (2010) Analysis of energy efficiency: opportunities for the cement industry in Shandong Province, China: a case study of 16 cement plants. Energy 35:3461–3473

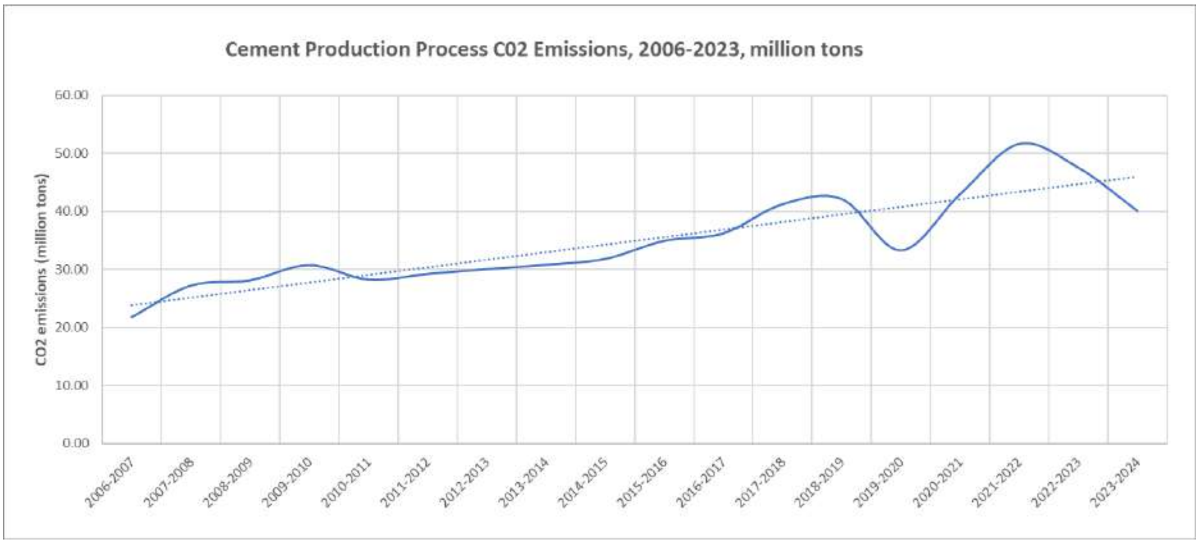


Figure 1: Article 6 of the Paris Agreement

However, the downturn in domestic consumption of cement has been somewhat ameliorated by increases in exports. For example, year-to-year from July 2023 to July 2024, while domestic production declined 11.4%, exports increased 21.7%.

Nonetheless, despite low utilization of installed capacities at cement plants in recent years, Pakistan's cement industry has promising future growth potential as per capita cement consumption has increased from 72 kg/head in 2001 to 233 kg/head in 2021 and is still well below the global average of 550 tons per capita.[9] As the country's population increases in coming years, and as housing and other infrastructure are built to accompany this population growth, emissions from the sector are very likely to increase in the absence of initiatives to mitigate emissions from the sector. Using an average growth rate of previous years (2006-2023), emissions from the sector will total 69.2 million tons of CO_2 by 2040, in the absence of mitigation measures.

Technologies for Deep Decarbonization of Cement in Pakistan

Achieving the needed reductions in CO_2 emissions from the cement sector will require a broad range of technological solutions. The solutions identified in this report include ones that are incremental (technologies that are currently widely used, but not necessarily in Pakistan) and transformational (these may have started industrial-scale production recently, in pilot phases or under development). The identified solutions can be implemented in the short term (e.g., using cements with lower clinker content, increasing renewable energy capacity, alternative fuels – such as agricultural waste), medium term (Municipal Solid Waste as alternative fuel, electrification of transport vehicles) and long term (electric kilns, carbon capture, use and storage). In addition to outlining these technological solutions, this report identifies data needs for in-depth and accurate planning for implementing these technologies.

[9]https://www.pakistangulfeconomist.com/2021/10/11/cement-industry-steering-through-the-pandemic/

The solutions identified in this report include technologies that can be implemented in the **short-term**, such as:

Supplementary cementitious materials (SCMs)-based cement – These are cements with lower clinker content than the commonly used Ordinary Portland Cement (OPC), which is currently the standard in Pakistan. These cements (such as CEMII) are commonly used outside of Pakistan. For example, CEM II is the most common cement in Austria, Finland, Portugal and Switzerland, with 90% usage rates.[10] Based on the type of cement, carbon reductions for SCM-based cements can range from 10-40%.

Alternative Fuels can be used instead of coal for calcination and to heat the kilns. The cement industry in Pakistan began exploring the use of alternative fuels (AFs) in the early 2000s, experimenting with agricultural waste like rice husks, as well as poultry waste, sugar mud, tires, and municipal solid waste (MSW).

Medium-term:

Limestone calcined clay cement (LC^3) – This innovative, low-carbon cement is made by replacing half of the clinker in cement with calcined clay and ground limestone, which don't release carbon when heated. It has the potential to lower CO_2 emissions by as much as 40%. LC^3 is also less pervious to water and salt, making concrete roads and bridges more durable.[11]

Electrifying transport and other logistics - While representing less than 5% of carbon emissions from cement, electrifying these activities could be strategic for emissions reductions in the sector, especially as Pakistan's cement firms' capacity for energy generation from renewable sources grows, and as the availability of battery-electric heavy-duty trucks and other industrial vehicles increases in coming years.

Long-term:

Carbon Capture, Storage and Use - The carbon emitted from cement production can be captured and stored permanently. This has been implemented in Norway, where Brevik cement has implemented the "Big Catch," which has a capacity of over 400,000 tons of CO_2 per year[12]. However, the cost is also quite high (e.g., ca. 1 billion EUR over 5 years for Norcem Brevik[13]). As such, carbon markets could help cement firms in Pakistan gain access to this very promising, but still expensive, technology. However, an even more interesting possibility is the permanent storage of CO_2 in other products, such as building materials, thereby providing an extra revenue stream for cement firms. This reuse of CO_2 is currently being implemented by numerous startups.

[10] https://www.globalcement.com/news/item/13870-alternative-raw-materials-in-europe-projects-and-perspectives#:~:text=CEM%20II%20is%20the%20norm,of%20cement%20despatched%20in%202021.
[11] https://lc3.ch/2023/11/20/the-future-of-construction-with-more-sustainable-cement/#:~:text=LC3:%20the%20innovation%20changing%20the,replacing%20half%20of%20the%20clinker.&text=LC3%20is%20functional%2C%20too.,%2C%20up%20to%2025%25%20lower.
[12] https://akercarboncapture.com/offerings/big-catch/
[13] https://www.geos.ed.ac.uk/sccs/project-info/1781

Direct industrial electrification represents an extremely efficient way of transitioning towards sustainable industrial practices. In the case of electrifying the calcination part of the cement process, a significant decrease in emissions can already be achieved by electrifying the calcination part of a cement plant. Electric kilns are currently being piloted and should reach maturity in coming years, especially as the drive for decarbonization of the sector picks up steam. Electric kilns produce nearly pure CO_2, which greatly enables the storage or re-use of the gas.

Creating incentives for Carbon Finance under Article 6

The government of Pakistan can stimulate the uptake of carbon mitigation projects that can create investment opportunities under Article 6. The government could create a "Green Cement" initiative that would involve major line ministries, the cement industry, research institutes and academia.

This initiative could begin by **improved and standardized baselines for emissions calculations.** While data on cement production is available from the APCA, and each cement company in Pakistan includes information on cement production and aspects of related emissions, there is no standardized approach that provides the disaggregated data that would provide a more solid basis for mitigation projects. An initiative to supply this type of data could provide data on:

- **Types of cement produced at each plant –** this would include data on the clinker production and content of cement, enabling more accurate emissions calculations.
- **Kiln energy consumption** – this includes the fossil fuels used (coal, oil, natural gas), alternative fuels (e.g., tires, municipal solid waste and agricultural waste)
- **Transportation** and other cement-related processes, which, although they are less than 5% of overall emissions in the sector, may provide opportunities for abatement.

Green procurement - A simple and game-changing way the government of Pakistan could create demand for low-carbon cement in Pakistan would be to specify the use of such cements in public projects. Such a green procurement policy would create a demand for the mitigation measures outlined below, thereby creating additional incentives for projects that could attract carbon financing.

Key Recommendations

With such important potential for carbon emissions reductions, the cement sector should be an integral part of Pakistan's carbon market approach. Further, given the high cost of many of the available technologies, the ability to tap into financing and additional revenue streams and enabling technology transfer (a key characteristic of Article 6) make carbon markets an obvious choice for helping abate emissions in the cement sector in Pakistan. Key recommendations in the sector study include:

- A government-led initiative to promote "green cement" involving the private and public sectors, and academia, to enhance the sector's ability to leverage climate finance opportunities
- "Green procurement" for low-carbon cement from the public sector
- Fast-tracking low carbon cement production by linking sustainable cement initiatives to climate finance opportunities
- Pursuing the creation of low-carbon cements with Environmental Product Declarations (EPDs) to increase exports to markets, including the Clean Ministerial Industrial Deep Decarbonisation Initiative (IDDI)[14] countries (including the UK, United States, Canada, Saudi Arabia, Germany, UAE, Japan, and Sweden)

Given the impressive the ability of the Pakistani cement sector to implement state-of-the-art, sustainable technologies, as well as the successful track record of mitigation projects under the CDM, no existing or potential technology in the cement industry in Pakistan should be ruled out for carbon markets.

Finally, spurring the production of low-carbon cement in Pakistan through climate finance can also contribute to reaching the Sustainable Development Goals (SDGs) of the United Nations,[15] including:

- SDG1: No Poverty - Lower cost cement low-carbon cements will provide material for more affordable and higher-quality (more durable) housing and infrastructure
- SDG11 – Sustainable Cities & Communities - Environmental and health benefits from decreasing the use of fossil fuels
- SDG13: Climate Action - Mobilize financial resources to support climate change mitigation for developing countries

[14] https://www.unido.org/IDDI
[15] https://sdgs.un.org/goals

1. Background

1.1 The Paris Agreement and Article 6

The 2015 Paris Agreement (PA), under the UNFCCC, aims to limit global temperature increases to below 2°C, ideally 1.5°C, above pre-industrial levels.[16] Reaching this goal requires comprehensive actions across all sectors, including cement, a major source of global greenhouse gas (GHG) emissions. The Agreement also emphasizes enhancing climate resilience and aligning financial flows with low-GHG pathways.

To fulfill these goals, the PA requires Parties to submit nationally determined contributions (NDCs) detailing domestic emission reduction plans. Well over half of the submitted NDCs (83%[17]) reference carbon markets as a means to meet GHG targets, making them vital tools for cost-effective emission cuts, especially in sectors like cement. Carbon markets allow trading of GHG reduction units, providing flexible pathways for emissions reductions at both international and domestic levels.

The text of Article 6 of the Paris Agreement[18] outlines ways countries and other entities can voluntarily cooperate to reach the climate goals established in NDCs. Through this framework, nations can transfer carbon credits generated from GHG emission reductions to assist other countries in meeting their climate objectives.

Within this framework, **Article 6.2** provides a foundation for trading GHG emission reductions, referred to as "internationally transferred mitigation outcomes," (ITMOs) across nations. **Article 6.4** resembles the Kyoto Protocol's Clean Development Mechanism and establishes a "mechanism" that "shall be supervised by a body"[19] for trading GHG reductions by public and private entities, under the oversight of the Conference of Parties, the decision-making body of the UNFCCC. Meanwhile, Article 6.8 focuses on non-market approaches, fostering collaboration for GHG emissions "while fostering sustainable development"[20] through financial support, technology sharing, and capacity building without involving emission reduction trading.

Article 6 of the Paris Agreement – Paragraphs		
6.2	6.4	6.8
Creates the possibility of voluntary collaboration for countries to use ITMOs to reach NDC goals, further sustainable development in a way that preserves environmental integrity and	Establishes a mechanism overseen by supervisory body of the Conference of the Parties of the Paris Agreement under which public and private entities	Provides the possibility of non-market approaches to achieve NDC mitigation goals and adaptation outcomes through finance, technology transfer and capacity building activities

[16] https://unfccc.int/most-requested/key-aspects-of-the-paris-agreement#:~:text=The%20Paris%20Agreement's%20central%20aim,further%20to%201.5%20degrees%20Celsius.
[17] https://www.wri.org/insights/understanding-ndcs-paris-agreement-climate-pledges
[18] United Nations (2015). Paris Agreement. https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf#page=9
[19] Ibid
[20] Ibid

transparency, and avoids double counting	can achieve achieve mitigation goals while contributing to sustainable development	

1.2 Carbon markets and Article 6 Operationalization

While Article 6 activities refer to the mechanism established by Paris Agreement to meet NDC goals, "carbon markets" is a more general term that includes Article 6 and other types of schemes to create market mechanisms that provide frameworks and financing for carbon mitigation activities.

Carbon markets can be categorized into both compliance-driven and voluntary regimes. Compliance-based actions fulfill regulatory requirements like NDCs or regional schemes such as the EU's Emissions Trading Scheme (ETS) and Carbon Border Adjustment Mechanism (CBAM). While the EU ETS is a cap-and-trade system designed to reduce emissions withing the trading block, the CBAM was designed to encourage cleaner industrial practices in non-EU countries by putting "a fair price" on carbon-intensive goods produced outside the region.[21]

In compliance markets, the cement sector's targets are typically part of national or sectoral NDCs rather than specific entities. An example is the use of ITMOs under Article 6.2, such as Japan's use of its Joint Crediting Mechanism (JCM) to achieve its NDC goals. Under the JCM, Japan acquires ITMOs from projects in other countries. While these ITMOs are counted to reducing Japan's requirements from its NDCs, the same emissions reductions cannot be counted toward the required emissions reductions in the host country (i.e., there cannot be "double counting").

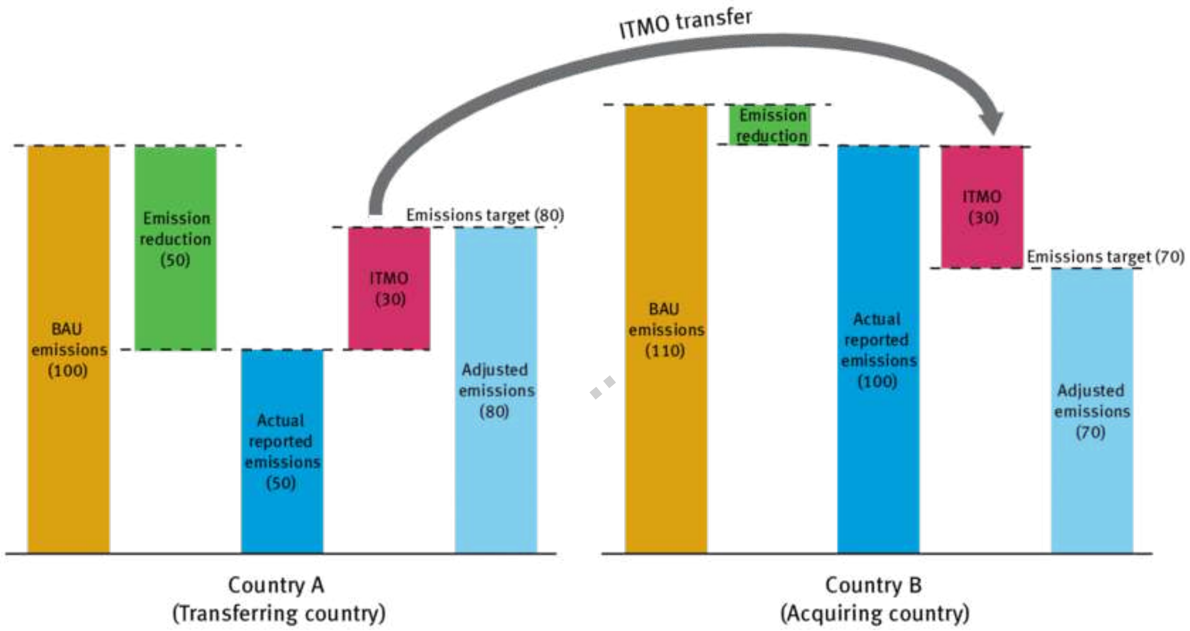
Lazarus, Schneider, and Broekhoff (2016), provide an example of how Article 6.2 could be operationalized for a country to meet its NDC emissions goals.[22] In this illustrative case, Country A (transferring country) has a BAU emissions projection of 100 Mt CO2e and pledged in its NDC to limit emissions to 80 Mt CO2e. Country B (acquiring country) has a BAU projection of 110 Mt CO2e and pledged to cap emissions at 70 Mt CO2e. Together, their combined target is 150 Mt CO2e.

Through a cooperative approach, Country A transfers 30 Mt CO2e in mitigation outcomes to Country B. Under this arrangement, Country A adds the transferred amount to its reported GHG emissions, while Country B subtracts it. Country A reduces emissions by 50 Mt CO2e, transferring 30 Mt CO2e and reporting adjusted emissions of 80 Mt CO2e, meeting its target. Country B reduces emissions by 10 Mt CO2e and uses the 30 Mt CO2e from Country A to meet its target, also reporting 80 Mt CO2e.

This approach ensures total emissions remain 150 Mt CO2e, with no double counting.

[21] https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism_en
[22] Lazarus, M., Schneider, L., & Broekhoff, D. (2016). Robust Accounting of International Transfers under Article 6 of the Paris Agreement, P. 28. https://www.researchgate.net/publication/321057839_Robust_Accounting_of_International_Transfers_under_Article_6_of_the_Paris_Agreement_Discussion_Paper/download?_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6Il9kaXJlY3QiLCJwYWdlIjoiX2RpcmVjdCJ9fQ

Figure 2 - Applying ITMOs to NDC Emissions Targets[23]



The operational details and specific procedures of Article 6 are continually being refined, particularly at the annual Conference to the Parties (COP) meetings (e.g., at COP 29 in Baku, in Baku, Azerbaijan, from 11 to 22 November 2024). However, many countries have already engaged in Article 6 activities. According to the UNFCCC, as of November 2024, 56 countries have entered into bilateral agreements for Article 6.2 activities, and there are 141 recorded pilot projects.[24] ITMO acquiring countries that have engaged in bilateral agreements include Australia, Japan, Norway, Singapore, South Korea, Sweden and Switzerland. Section 5.2.2. Article 6 (below) contains further details on the status of Article 6.2 and project activities around the world.

Voluntary carbon markets (VCMs) primarily involve private organizations and support their sustainability goals like carbon neutrality or net-zero targets. Under VCMs, carbon credits are created in registries that are offered by organizations such as Gold Standard, Verra, or Climate Action Reserve. VCMs operate without centralized governance, with transactions occurring internationally through direct agreements or exchanges, reflecting their flexible, decentralized nature. The same principles that apply to the generation of ITMOs under Article 6, including environmental integrity, transparency and no double-counting, apply to carbon credits generated under VCM registries.

[23] Ibid, P. 28.
[24] https://unepccc.org/article-6-pipeline/

1.3 The importance of carbon finance and Article 6 to decarbonize the cement Sector

Together with steel, GHG emissions from the cement sector are often considered to be particularly "hard-to-abate."[25] Reasons for this include:

- The process to create cement is still inherently carbon-intensive, centering around crushing and processing limestone and necessitating high temperatures that can still only be achieved by using fossil fuels (both processes release large amounts of GHGs)
- Technological solutions to reduce carbon emissions in the sector involve large, complex and technologically sophisticated machinery and processes that require highly skilled professionals to implement and operate. In short, solutions to reduce carbon emissions from cement production involve high capital and operational expenditures (CAPEX and OPEX).

Given the high capital needs and technical difficulty of decarbonizing the cement sector, carbon finance will be a critical source of the funding needed to implement these solutions. This is particularly true in Pakistan, where interest rates are high and access to large amounts of finance for non-essential activities is not necessarily forthcoming.

However, this study argues that in addition to reducing carbon emissions, carbon finance can be used to strategically make Pakistan's cement industry more competitive. This is particularly true as cement-importing countries, trade blocks (such as the EU), and coalitions, (such as the Clean Ministerial Industrial Deep Decarbonisation Initiative (IDDI)[26] focus on procuring imported cement that is low-carbon or zero-carbon. With a demonstrated capacity for implementing state-of-the-art technologies and energy efficient solutions, Pakistan's cement industry is poised to take full advantage of the financing opportunities created by carbon markets.

1.4 Pakistan's Climate Goals and Framework for Article 6

Article 6 of the Paris Agreement enables Parties to voluntarily cooperate to achieve collective climate goals. Pakistan continues to pursue its climate objectives as outlined in its 2021 updated NDCs, committing to reduce projected GHG emissions by 50% by 2030 from a business-as-usual baseline. The NDCs point to "international grant finance"[27] as a source of 35% of these reductions, contingent upon international support, technology transfer, and capacity building (the other 15% would be financed by Pakistan's own resources). Achieving these targets requires actions across all sectors, including agriculture, forestry, land use, and waste management, energy, and industry (notably cement). The cement sector, as a major contributor to Pakistan's GHG emissions, offers a key opportunity for reduction efforts.

[25] World Economic Forum. (2023). https://www.weforum.org/stories/2023/01/davos23-decarbonization-developing-economies-steel-cement/
[26] IDDI countries include the UK, United States, Canada, Saudi Arabia, Germany, UAE, Japan, and Sweden. https://www.unido.org/IDDI
[27] Government of Pakistan. (2021). Pakistan: updated nationally determined contributions 2021. P. 10. https://unfccc.int/sites/default/files/NDC/2022-06/Pakistan%20Updated%20NDC%202021.pdf

As with any country that seeks to begin activities under Article 6, Pakistan will need to create the regulatory and procedural framework for the issuance of ITMOs that can be created and sold. These elements include:

- Robust national carbon registries. These should include detailed emissions accounting by sector. This is necessary to ensure that emissions reductions (ERs) that are offered for sale under Article 6 are not included in a country's mitigation actions toward achieving the goals set forth in the NDCs (double counting).
- Clear Standard Operating Procedures for the submission and approval of Article 6 projects, and the subsequent monitoring of the carbon mitigation achieved by these projects.
- Strong guidance for project developers, including requiring the use of rigorous methodologies and Monitoring, Verification and Reporting (MRV) systems, with third party verification, for tracking of emissions mitigations achieved.
- Enhanced transparency of all projects that generate ERs, with key project documents made publicly available, including those created under Article 6 and VCM schemes.

With these elements in place, countries can begin to tap into opportunities to finance projects that not only reduce carbon emissions, but improve sustainability, resilience, and quality of life for their populations, while at the same time achieving the climate goals set out in the country's NDCs.

1.5 Purpose and Scope of this Report

This report, created for the Government of Pakistan, analyzes the cement sector's current conditions, challenges, and carbon market opportunities under Article 6 of the Paris Agreement. It supports the development of strategies to help the sector meet emissions targets while unlocking new carbon finance, offering insights for policymakers on reducing emissions and attracting investment for sustainable practices in cement.

This work is part of the Supporting Preparedness for Article 6 Cooperation (SPAR6C) Program,[28] which prepares countries for participation in international carbon markets. Pakistan, one of SPAR6Cs four focus countries, aims to strengthen its regulatory frameworks and enhance private sector engagement, benefiting significantly from this program.

This report details the findings of SPAR6C's experts for the decarbonization of the cement industry in Pakistan. The objective of this report is to identify the technologies and strategies for the transformational change needed for a substantial reduction in carbon emissions in cement the sector. The qualitative and quantitative data used in this report comes from desk research, meetings with industry leaders, and two workshops held with cement sector stakeholders in April 2024, one in Lahore, and another in Karachi. The audience of this study includes government policymakers, cement industry professionals, students, and international climate change-related organizations, and financial institutions.

[28] www.spar6c.org/

2. Current Overview of the Sector and GHG Emissions

Together with steel, cement is the backbone of the housing and infrastructure (roads, bridges, damns) of contemporary society, and the cement sector plays vital role in any country's industrial, economic and social progress. However, this material is also an important source of carbon emissions worldwide and in Pakistan, and the country's Nationally Declared Contributions (NDCs) include cement as a strategic sector for GHG reductions.[29] Since Pakistan's independence in 1947, cement production capacity has increased from 0.5 million tons/annum in 1947 by 4 cement plants to 83.2 Million tons/annum in 2023 by 27 cement plants, according to the All Pakistan Cement Manufacturer Association (APCMA)[30].

The Cement Industry in Pakistan is formed of 16 active companies. The sector is divided into two industrial regions located in the North and the South of Pakistan. The northern industrialized region covers the Punjab, KPK (Khyber Pakhtunkhwa) and AJK (Azad Jammu and Kashmir) whilst the southern region including areas of Sindh and Balochistan. Throughout the cement industry, the main manufacturing process is dominated by dry manufacturing (**Table 1**). Such a process, compared to a wet process which mixes water with all the processed materials, is significantly (ca.40%) less energy intensive, has lower operational and capital costs and decreases the production of wastewater during cement production[31].

[29] Government of Pakistan (2021). UPDATED NATIONALLY DETERMINED CONTRIBUTIONS. https://unfccc.int/sites/default/files/NDC/2022-06/Pakistan%20Updated%20NDC%202021.pdf

[30] https://www.apcma.com/data_productioncapacity.html

[31] Ohunakin, O.S., Leramo, O.R., Abidakun, O.A., Odunfa, M.K. and Bafuwa, O.B., 2013. Energy and cost analysis of cement production using the wet and dry processes in Nigeria. *Energy and Power Engineering*, *5*(9), p.537.

Total cement production capacity is estimated at ca 70 to 80 million metric tons as of 2022, with the Northern region concentrating the bulk of cement production capacity (52.6 million tons) compared to the Southern Region (16.5 million tons)[33]. A list of cement plants and capacity are found in **Table 1**. The production capacity is moreover projected to reach 81 million tons in 2024[34] and up to 99 million tons before 2030[35].

The rapid growth of Pakistan's population, which has expanded from approximately 35 million in 1951 to nearly 280 million by 2023[36], has significantly increased the demand for cementation, particularly in major urban centers like Karachi, Lahore, and other burgeoning cities. This demographic surge has led to a substantial rise in the number of vehicles (Figure 4), especially light vehicles like motorcycles, which are a preferred mode of cement due to their affordability and maneuverability in congested urban environments. As a result, cities like Karachi and Lahore have seen an exponential increase in motorcycle usage, contributing to traffic congestion and heightened emissions. Meanwhile, the rise in heavy vehicles, such as trucks and buses, reflects the growing need for freight cement and public transit options to support the expanding urban economy and population (Figure 5).

[32] Rasheed, R., Tahir, F., Afzaal, M. and Ahmad, S.R., 2022. Decomposition analytics of carbon emissions by cement manufacturing–a way forward towards carbon neutrality in a developing country. Environmental Science and Pollution Research, 29(32), pp.49429

[33] The Pakistan Credit Rating Agency Limited PACRA Research, March 2021 Report

[34] https://www.cemnet.com/News/story/173686/pakistani-producers-to-expand-cement-capacities.html

[35] https://www.globalcement.com/news/item/12381-pakistan-s-cement-production-capacity-to-increase-to-99mt-yr#:~:text=Upon%20completion%2C%20the%20current%20projects,Mt%2Fyr%20in%20Southern%20Pakistan.

[36] https://finance.gov.pk/survey/chapter_24/Economic_Survey_2023_24.pdf

N°	Name of Cement Factory	Region	Province	Annual Cement Production Capacity (Mt)	Technology	Manufacturing Process
1	Attock Cement Pakistan Limited - Hub Chowki, Lasbela	South	Baluchistan	3.027.150	Pre-heater, pre-calciner, and vertical mill	Dry process
2	Bestway Cement Limited - Hattar	North	KPK	3.654.000	Pre-heater, pre-calciner, and vertical mills	Dry process
3	Bestway Cement Limited - Chakwal	North	Punjab	3.600.000	Pre-heater, pre-calciner, vertical mills, and ball mills	Dry process
4	Bestway Cement Limited - Farooqia	North	KPK	2.976.750	Pre-heater, pre-calciner, and vertical mills	Dry process
5	Bestway PakCem Limited - Kalar Kahar	North	Punjab	2.299.500	Pre-heater, pre-calciner, and vertical mills	Dry process
6	Bestway Cement Limited - Pai Khel	North	Punjab	2.268.000		
7	Cherat Cement Company Limited-Nowshera	North	KPK	4.536.000	Pre-heater, roller press, and ball mill	Dry process
8	Dandot Cement Limited - Jehlum	North	Punjab	504.000	unknown	Dry process
9	Dewan Hattar Cement Limited - Hattar	North	KPK	1.134.000	Pre-heater, pre-calciner, and vertical mill	Dry process
10	Dewan Cement Limited - Dhabeji	South	Sindh	1.953.000	Pre-heater, pre-calciner, and vertical mill	Dry process
11	D.G.Khan Cement Limited - D.G.Khan	North	Punjab	2.110.500		
12	D.G.Khan Cement Limited - Chakwal	North	Punjab	2.110.500	Pre-heater, pre-calciner, and vertical mills	Dry process
13	D.G.Khan Cement Limited - Hub	South	Baluchistan	2.835.000	Pre-heater, pre-calciner, and vertical roller mills	Dry process
14	Fauji Cement Limited - Wah	North	Punjab	1.102.500	Pre-heater, classifier	Dry process
15	Fauji Cement Limited - Nizampur	North	KPK	3.748.500	Pre-heater, vertical roller mill, and classifier	Dry process
16	Fauji Cement Company Limited - Fateh Jang	North	Punjab	3.503.640	Vertical mills	Dry process
17	Fecto Cement Limited - Sangjani	North	Punjab	945.000	Pre-heater, pre-calciner, and ball mills	Dry process
18	Flying Cement Limited - Lilla	North	Punjab	1.197.000	Pre-heater, pre-calciner, and vertical roller mills	Dry process
19	GharibWal Cement Limited - Jehlum	North	Punjab	2.110.500	Vertical mill	Dry process
20	Kohat Cement Company Limited - Kohat	North	KPK	5.017.500	Pre-heater and vertical roller mills	Dry process
21	Lucky Cement Limited - Pezu	North	KPK	9.645.000	Pre-heater, pre-calciner, and vertical roller mills	Dry process
22	Lucky Cement Limited, - Indus Highway, Karachi	South	Sindh	5.309.625	Pre-heater, pre-calciner, and vertical roller mills	Dry process
23	Maple Leaf Cement Factory Limited - Daudkhel	North	Punjab	8.190.000	Pre-heater, pre-calciner, vertical roller mills, and ball	Dry process
24	Pioneer Cement Limited - Khushab	North	Punjab	5.454.225	Classifiers and vertical roller mills	Dry process
25	Power Cement Limited - Nooriabad, Dadu	South	Sindh	3.370.500	Vertical roller mills	Dry process
26	Thatta Cement Limited - Thatta	South	Sindh	577.080	Pre-heater, Pre-calciner, and ball mill	Dry and wet process
2023 Data from APCMA				83.179.470		

Table 1: Factories, production capacities and manufacturing technologies in cement industry in Pakistan.

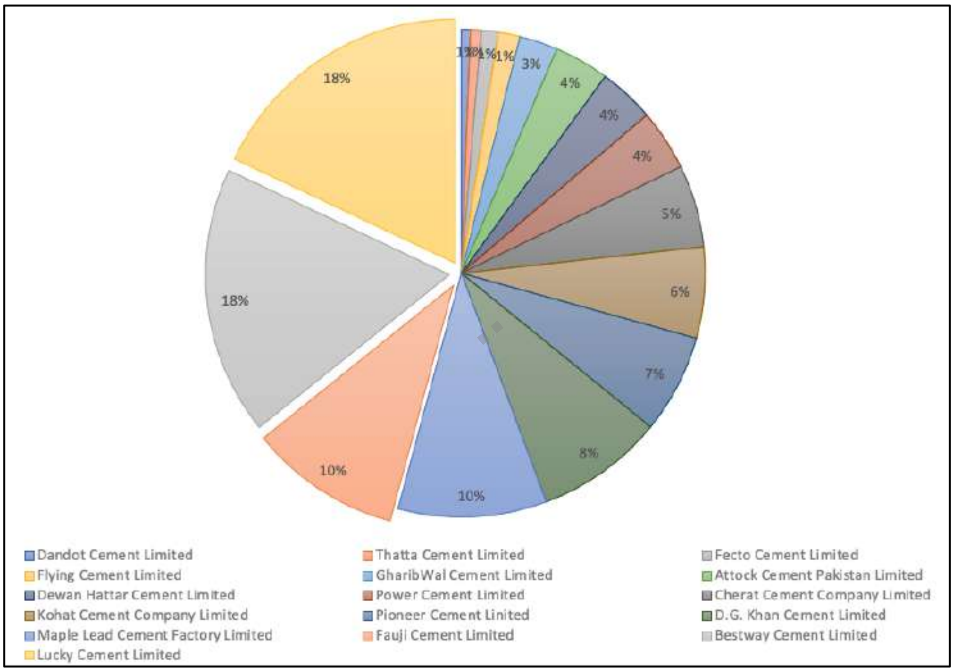


Figure 3: Annual cement Production Capacity subdivided by company

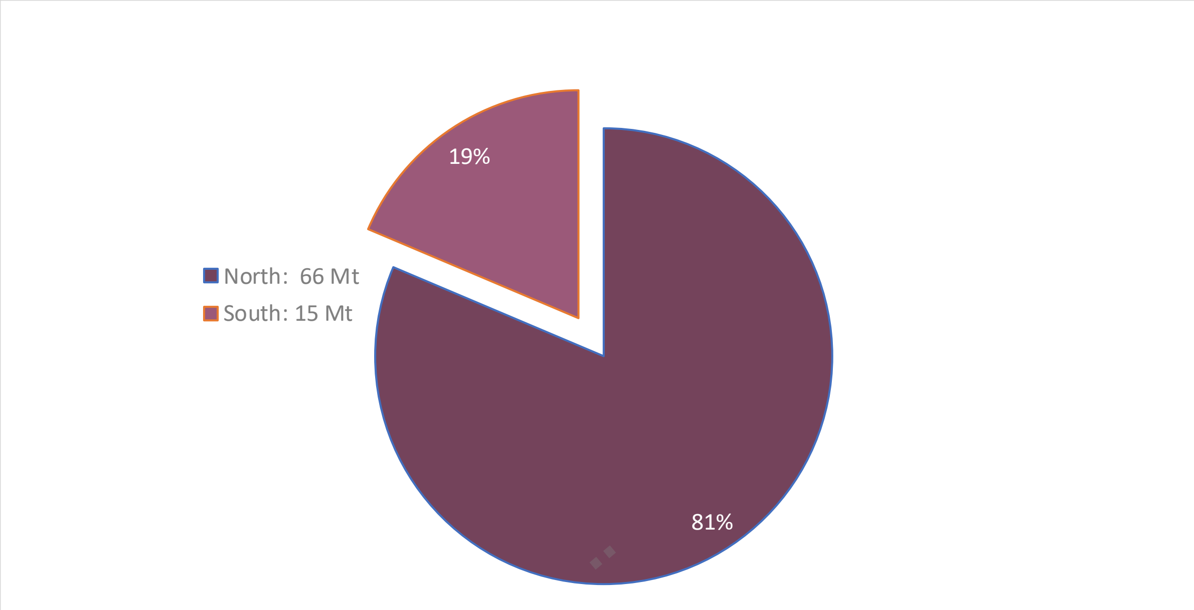


Figure 4: Annual Cement Production Capacity (in % and millions of tons) and Location of Plants

The significant increase in cement capacity however will likely only exacerbate the issue of overcapacity in cement production in Pakistan as the capacity utilization has historically varied between 70-80%[37] and the cement industry is currently facing significant challenges, with projected capacity utilization decreasing below 70% by 2024[38]. Indeed, cement manufacturers produced 44.6 million tons of cement during the 2023 financial year, down 16% from 52.9 million tons in the previous financial year. Moreover, exports dropped by 13% to 4.57 million tons from 5.26Mt[39]. This suggests that the capacity utilization in this past fiscal year has already dropped to a historical low of 65% (assuming an installed capacity of ca. 80 million tons).

Industries in the South benefit from cheaper transportation costs due to their close proximity to ports, implying cheaper coal imports for use in kilns and easier access to export markets. On the other hand, more expensive transport costs for the Northern Industrial region is counterbalanced by easier access to export markets in Afghanistan and India (*note however, that there are several challenges to export markets for both the southern and northern regions*).

2.1 A modern, efficient industry

The cement industry in Pakistan stands as a testament to the country's commitment to technological advancement and operational efficiency. Under private ownership, the industry has consistently demonstrated a keen sense of business acumen by adopting

[37] Pakistan Economic Survey 2019-2020, Government of Pakistan Finance Division, https://www.finance.gov.pk/survey/chapter_20/03_Manufacturing_and_Mining.pdf
[38] https://www.cemnet.com/News/story/173401/cement-capacity-outpaces-production-in-pakistan.html
[39] https://www.globalcement.com/news/item/15965-pakistani-cement-despatches-decline-in-2023-financial-year

cutting-edge technologies and cost-effective measures. The widespread implementation of Best Available Technology (BAT) across the industry highlights its focus on sustainability and energy efficiency. The exclusive use of the "Dry Process" in cement production (mentioned above), coupled with widespread integration of energy-efficient Vertical Mills (VMs) for raw meal and finish grinding, state-of-the-art burning guns, and high-efficiency coolers, underscores the industry's dedication to reducing energy consumption and environmental impact (including carbon emissions). Additionally, pollution abatement technologies are standard in both new and upgraded cement plants across the country.

Moreover, the industry's commitment to energy conservation is evident in the near-universal installation of Waste Heat Recovery (WHR) power plants, which contribute significantly to meeting the energy needs of these plants. This proactive approach extends to the adoption of Variable Frequency Drives (VFDs) and energy audits, further enhancing efficiency. The rising energy costs and favorable rates of return have also spurred significant investments in solar energy, with major players like Bestway Cement, DG Cement, Lucky Cement and Fauji Cement leading the way (more on renewable energy below). This shift towards renewable energy not only reduces operational costs but also alleviates pressure on the national grid, positioning Pakistan's cement industry as a leader of modern industrial practices and sustainability in the country.

2.2 Cement Sector Stakeholders

This section briefly outlines the key cement sector stakeholders, in addition to the 16 cement firms mentioned above.

2.2.1. Private Sector

A key player in the industry is the All Pakistan Cement Manufacturer Association (APCMA), which is the association for 16 cement-producing firms. Among other functions, the APCMA collects and reports annual data on cement production in Pakistan, including dispatches of cement production for domestic use and export.

2.2.2. Public Sector

PSQCA

The Pakistan Standards and Quality Control Authority (PSQCA) is the main government body responsible for regulating and controlling products manufactured and marketed in Pakistan. Established by Act-VI of 1996, PSQCA provides streamlined services for standardization and conformity assessment.[40]

[40] https://www.psqca.com.pk/about-us/

Historically, cement produced under the PS mark adhered to British Standard #12. In 2008, for the first time in Pakistan's cement history, PSQCA adopted Indian Standards for 43 and 53 grade cement under the marking PS-232:2008®. This change was made to facilitate increased cement exports to India and to avoid the need for double testing at production units.

PSQCA has since taken a proactive approach in approving various global cement standards as adopted standards for Pakistan, reducing legal barriers for production and marketing. A complete list of approved standards in Pakistan is provided below (in the Section 4.1.1. Supplementary cementitious materials (SCMs)-based cement).

National Government
The public sector bodies identified below are mainly ministries and related bodies. While this list is not exhaustive, it does contain many of the key players potentially related to efforts to decarbonize cement from the national-level government of Pakistan.

Ministry of Industries & Production (MoI&P): MoI&P plays a crucial role in fostering industrial growth in Pakistan. It is responsible for national industrial planning and coordination, formulating industrial policies, and promoting industrial productivity. The ministry also oversees federal agencies that focus on industrial product testing and special studies to enhance industrial efficiency. This ministry's work directly impacts the cement industry by creating policies and an environment conducive to growth and productivity.

Engineering Development Board (EDB): The EDB is under the MoI&P and serves as the primary policy-making and implementation body for Pakistan's engineering industry. It functions as an apex decision-making entity, focusing on the development and growth of the engineering sector. For the cement industry, EDB's policies and decisions are pivotal in shaping the technological advancements and infrastructural support required for industry expansion.

Ministry of Science and Technology (MoST): MoST drives technological advancement in Pakistan, focusing on industrial development, renewable energy, and innovation. By integrating technology from research institutions into industries, MoST enhances production efficiency and competitiveness. For the cement industry, this means access to advanced technologies and materials that boost growth and sustainability.

Ministry of Planning Development & Special Initiatives: The mission of this is to is “To manage Pakistan's socio-economic development in a strategic and sustainable manner."[41] The ministry manages Pakistan’s socio-economic development with a focus on strategic growth. Through the Planning Commission, it formulates policies and oversees infrastructure expansion. Vision 2025, the ministry’s development plan, emphasizes areas like energy and infrastructure, directly impacting the cement industry by creating opportunities for growth and modernization.

[41] https://www.pc.gov.pk/web/ministry

Ministry of Climate Change & Environmental Coordination (MOCC&EC): The MOCC&EC is responsible for developing and implementing policies to address climate change and environmental sustainability in Pakistan, including the NDCs and Long Term Strategy (LTS) for decarbonization. It focuses on reducing the environmental impact of industries, including the cement sector, by promoting eco-friendly practices and enforcing environmental regulations. The ministry's efforts are crucial in guiding the cement industry towards sustainable production methods that minimize pollution and conserve natural resources, aligning with national and global environmental goals.

Pakistan Environmental Protection Agency (Pak-EPA): Managed by the MOCC&EC, the Pak-EPA is responsible for establishing and enforcing the National Environmental Quality Standards (NEQS) to protect Pakistan's environment. It promotes research and technological development to prevent pollution and encourages sustainable development practices. The cement industry must comply with Pak-EPA's regulations to minimize environmental impact, ensuring cleaner production processes.

Provincial Government

Pakistan is divided into four provinces and one special zone, Gilgit Baltistan. The cement industry is primarily located in Punjab, Sindh, and Khyber Pakhtunkhwa (KPK), with two plants in Baluchistan, and no production facilities in Gilgit Baltistan or Azad Jammu & Kashmir. As such, the provincial governments of Punjab, Sindh, KPK, and Baluchistan are important actors to engage regarding the decarbonization of the cement industry.

The Provincial-level governments have bodies that correspond to many of the above-mentioned ministries (for example, the Government of Punjab has a Planning & Development Board that coordinates with the ministry cited above).

Of particular importance to the cement industry are the **Provincial EPAs.** These Agencies enforce environmental standards specific to the local context, including those related to emissions, waste management, and resource usage in the cement industry. Provincial EPAs play a crucial role in monitoring and regulating the environmental impact of cement production, ensuring that plants operate within the legal frameworks to protect local ecosystems. Their oversight helps to mitigate pollution, conserve natural resources, and promote sustainable industrial practices at the provincial level.

The Provincial Environment Protection Agencies (EPAs) have issued "Smart Rules" for monitoring and reporting emissions.[42] The cement industry falls under Category "A" as per S.R.O.No.528(1)/2001D, requiring monthly environmental monitoring reports and records of startup and upset conditions. Please note that for this report, the authors did not find publicly available EPA data for analyzing the current environmental conditions at cement plants.

Research and Educational Institutions

[42] https://epd.punjab.gov.pk/system/files/NEQS_SMART_Rules_2001_0.pdf. SELF MONITORING & REPORTING RULES.doc (punjab.gov.pk)

Pakistan is home to numerous prestigious research and education institutions with talented and experienced professionals. Many of these institutions are presently very active regarding cement-related research, and educating the next generation of professionals who can lead the charge to decarbonize the sector. The below list is not meant to be exhaustive by any means and mentions just three of these as examples (of course, there are many more such institutions that make critical contributions to the sector):

Global Climate-Change Impact Studies Centre (GCCISC): The GCCISC is Pakistan's leading research institute focused on climate change. It conducts national-level research, provides policy analysis, and supports planners in understanding the impacts of climate change on key sectors like water, agriculture, energy, and health. The Centre also plays a crucial role in developing adaptation and mitigation strategies to address these challenges, helping to guide sustainable development in the country.

NED University of Engineering & Technology (NED): NED University of Engineering & Technology is one of Pakistan's premier institutions for engineering education and research. The university plays a vital role in developing the country's technical expertise by offering programs in various engineering disciplines. It also engages in research and collaboration with industries, including the cement sector, to drive innovation and improve industrial practices. NED's focus on producing skilled engineers and conducting applied research supports Pakistan's broader goals of industrial growth and technological advancement.

University of Engineering & Technology, Lahore (UET) The University of Engineering & Technology, Lahore (UET), is a leading engineering institution in Pakistan, renowned for its contributions to technical education and research. UET plays a crucial role in producing highly skilled engineers and conducting research that supports industrial innovation. Through its programs and partnerships, the university directly influences sectors like cement production by advancing engineering practices and fostering technological growth, helping to drive Pakistan's industrial development.

2.3 Economic Analysis, Risks and Challenges

Despite the inherent competitiveness and efficiency of Pakistan's cement sector (outlined above), the industry nonetheless faces risks, especially as the global demand for low-carbon cement will grow. The cement sector in Pakistan is highly organized and oligopolistic, with a market capitalization for the sector estimated at PKR 690bln. The growth of the sector is primarily driven by economic growth, government spending on infrastructure projects and increasing access to export markets[43]. We detail the risks and opportunities in this section.

According to a 2023 investment and scenario analysis of BMA Capital[44], three main cement companies in Pakistan have particularly promising financial outlooks, namely Lucky Cement Company[45] (diversified income stream, cash rich balance sheet and in-

[43] AHL Research, 2021, link
[44] https://res.bmacapital.com/dailyreports/sod/pdfs/3814.pdf
[45] https://www.lucky-cement.com

house power generation), Kohat Cement Company Limited[46] (low debt level and cheap valuation) and Fauji Cement Company Limited[47] (expansions of 2 manufacturing facilities and amalgamation of Askari Cement).

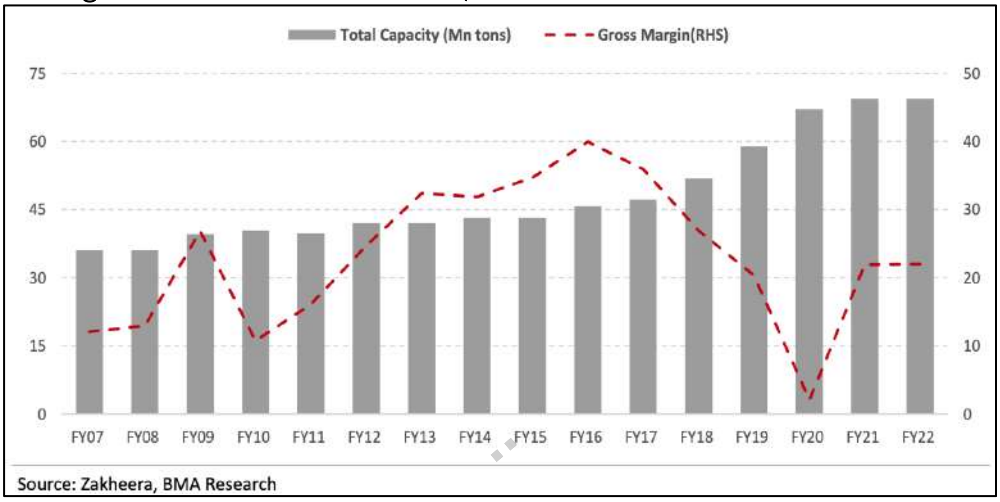


Figure 5: Capacity of the Cement industry (vertical axis, left, in million tons) and Gross margin (vertical axis, right). Figure from BMA Research (see text for reference).

The Pakistan cement industry is pushing forward with a significant expansion in cement production capacity, and this has, aside from the COVID-19 years, not significantly affected the gross margins (in RHS). However, recent economic challenges, as well as the lack of spending on infrastructure (2.1% of GDP compared to 8-10% of GDP in other countries as per the State Bank of Pakistan[48]) are likely to be a challenge to the cement industry in upcoming years. Indeed, the Cement industry is currently facing significant challenges, which includes recent extensive PKR (Pakistani Rupee) devaluation, sluggish demand for cement, import constraints, limited government spending on infrastructure projects, and recent policy changes. These challenges are outlined in more detail below and in **Figure 6.**

[46] http://www.kohatcement.com
[47] https://fccl.com.pk/en/our-profile/
[48] https://www.thenews.com.pk/print/1050018-pakistan-s-infrastructure-spending-lowest-in-region-sbp-governor

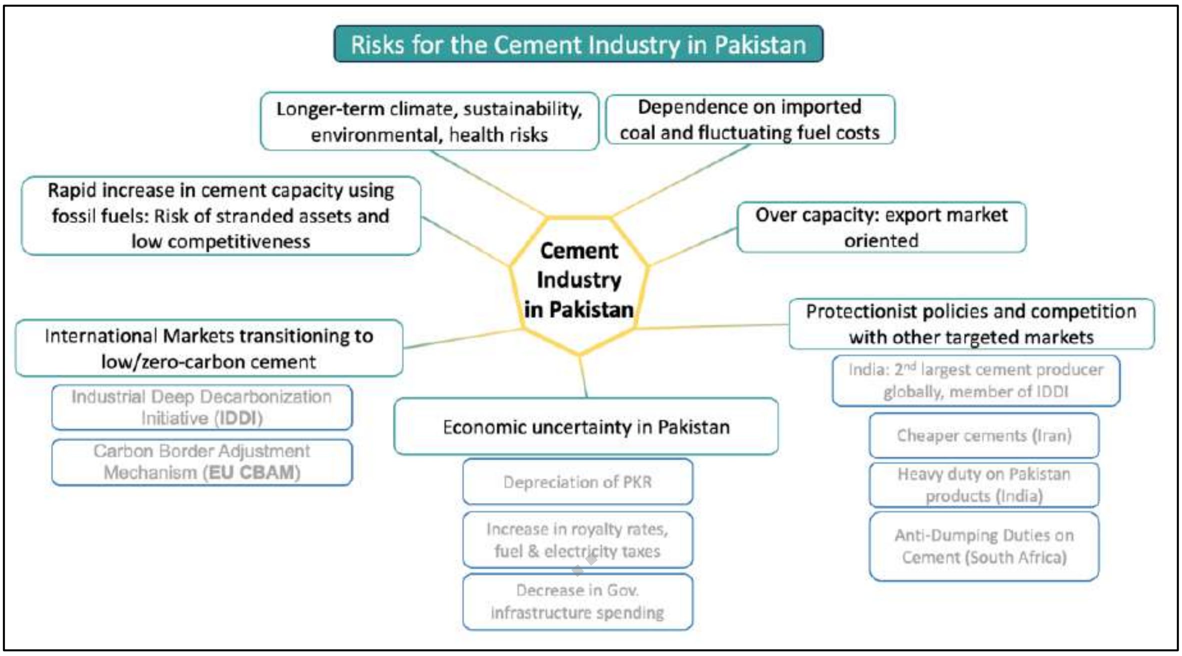


Figure 6: Risks to the cement industry in Pakistan. Note that these risks and challenges can also be used as opportunities to transform the cement sector (see main text).

1. The current economic crisis in Pakistan has driven the Pakistan government to increase royalty rates from PKR 115 to PKR 250 per ton of cement (US$ 0,41 to 0.88/ton of cement), thereby increasing cement production costs.

2. The crisis has also driven the government to increase electricity and fuel rates, thereby increasing the cost of cement production and freight cost.

3. The cement industry is vulnerable to the price of coal and although coal has dropped significantly from a peak in 2022 after having gone through a very volatile period (100 to >400USD/ton), it remains somewhat higher than historical values. Currently, the drop in coal price is helping cement manufacturers counter the hiked in rates. However, it is important to note that the cement industry is fundamentally dependent on coal imports, with coal constituting about 40% of the total cost of production of cement[49].

4. A deteriorating economic landscape and tight fiscal position has prevented the Pakistani government from spending on infrastructure, thereby decreasing the demand for cement. Cement industries produced 44.6Mt of cement during the 2023 financial year, which is down by 16% year-on-year from 52.9Mt in the 2022 financial year[50].

[49] The Pakistan Credit Rating Agency Limited PACRA Research, March 2021 Report
[50] https://www.globalcement.com/news/item/15965-pakistani-cement-despatches-decline-in-2023-financial-year

5. There is currently an over-capacity of cement production in Pakistan[51,] which will potentially reach 99 million metric tons in the near future[52]. It is expected that the capacity utilization, historically between 72-86%, will drop significantly below 70% if there is no up-turn in the cement market (*note that our current study already suggests current utilization rate of ca. 65%*). Moreover, these installations are not built using state-of-the-art sustainable technologies which implies that significant investments will be required in the foreseeable future to refurbish them and transition them towards sustainable practices (e.g., electric kilns, usage of waste, LC^3, CCS).

6. Due to an overcapacity in cement production and flagging internal demand, the cement industry is pushing to expand the export market. However, protective policies implemented by India (heavy duty taxes on Pakistan Products) and South Africa (anti-dumping duties on cement from Pakistan) remain a significant challenge, whilst the export market to Afghanistan has been hampered by cheaper cement from Iran. Nevertheless, cement exports in 2023 and 2024 seem to be recovering from a significant downturn in 2022 for both northern and southern industries[53].

7. 2022 and 2023 saw the first cement exports (which will total 600´000 tons) to the United States[54] as demand for cement in the United States has significantly increased following the passage of the Inflation Reduction Act[55]. Pakistani cement producers are also actively exporting to Afghanistan, and Africa, and continue to locate new markets, including the UK, to where it began exporting in January 2024.[56] However, opening the Pakistan export market might lead to further challenges (or opportunities). Indeed, a key low- to zero-cement initiative is currently under development under The Clean Ministerial Industrial Deep Decarbonisation Initiative (IDDI)[57], which is co-led by the UK and India, and whose members include the United States, Canada, Saudi Arabia, Germany, UAE, Japan, Sweden, and Brazil. This initiative is aiming for participating nations to start using low-emission and zero-emission cement (and steel) in their Public Procurement (PP) policies as of 2030. International initiatives such as IDDI are pushing governments to transition towards sustainable cement practices. IDDI has unveiled The Green Public Procurement (GPP) Pledge[58] which recognizes the power of governments to secure long-term demand for low carbon materials:

- The importance of decarbonising the global steel and cement sectors
- The role of governments to lead by example and incentivise the adoption of energy efficiency and low emission technologies;

[51] https://www.cemnet.com/News/story/173686/pakistani-producers-to-expand-cement-capacities.html
[52] https://www.globalcement.com/news/item/12381-pakistan-s-cement-production-capacity-to-increase-to-99mt-yr#:~:text=Upon%20completion%2C%20the%20current%20projects,Mt%2Fyr%20in%20Southern%20Pakistan.
[53] https://www.cemnet.com/News/story/175321/pakistan-started-with-a-massive-growth-in-cement-dispatches-in-1mfy23-24.html
[54] https://www.cemnet.com/News/story/174178/pakistan-exports-to-the-usa-for-the-first-time.html#:~:text=Pakistan%27s%20DG%20Khan%20Cement%20Co,Fazal%2C%20executive%20director%2C%20DGKCC.
[55] https://www.whitehouse.gov/briefing-room/statements-releases/2023/08/16/fact-sheet-one-year-in-president-bidens-inflation-reduction-act-is-driving-historic-climate-action-and-investing-in-america-to-create-good-paying-jobs-and-reduce-costs/
[56] https://www.globalcement.com/news/item/17280-update-on-pakistan-april-2024
[57] https://www.unido.org/IDDI
[58] https://www.cleanenergyministerial.org/content/uploads/2023/04/the-gpp-pledge-brochure-iddi.pdf

- The benefits of measuring and reporting the embodied carbon in the highest-emitting construction materials;
- The importance of encouraging efficient use of construction materials and deployment of available and transformative decarbonisation technologies and best practices to reduce carbon intensity, and accelerate near zero emission production of these materials;

The commitments under the IDDI pledge are highlighted in **Figure 8**:

Figure 7: The 4 levels of commitments under the Green Public Procurement pledge developed under the Industrial Deep Decarbonization Initiation. See text for reference.

The risk for countries who do not participate in such an initiative therefore is two-fold: **i)** decreasing opportunities in export markets after 2030 if using current/outdated cement producing technologies based on fossil fuels; **ii)** lack of knowledge and skills as well as structures in place at an industrial, regulatory and policy level to develop guidelines for green public procurement and/or analysis of embodied carbon in materials produced in Pakistan cement plants (Product Category Rules – PCRs, Life Cycle Assessments – LCA , Environmental Product Declarations – EPDs and Product Carbon Footprints – PCFs). Therefore, initiatives such as IDDI can be either seen as a risk (decreasing opportunities in export markets) or as an opportunity. An expansion of Green Public Procurement (GPP) policies and a need for green cement could imply that ambitious refurbishment of cement plants towards low- to net-zero cements could open up markets for low-CO_2 cements with a green premium. The cement industry remains a laggard (globally) amongst hard-to-abate sectors in terms of decarbonisation strategies, implying that there is a significant opportunity to produce low- to net-zero CO_2 cement and open new market opportunities. Potential agreements with foreign actors for long-term purchase agreements of green cement and concrete might go a long way to securing export markets for Pakistan as well as ensure substantial investments required to fully decarbonize cement plants.

8. Finally, the European Carbon Border Adjustment Mechanism (CBAM[59]) will enter into force starting in 2023 (with a transition period) and will apply – amongst others – to cement products to prevent carbon leakage by forcing EU importers to pay for embedded carbon emissions (if such emissions have not already been paid for). Such policies could, if expanded, cause additional issues in the long term if there is no significant change in cement production in Pakistan.

9. Investments in renewable energy are currently deemed too risky due to the current economic situation in Pakistan in addition to the renewable energy market in Pakistan not being mature yet. Indeed, a request of proposal (RFP) for a flagship 600 MW solar project under the Pakistani Fast Track Solar Initiatives has received limited interest as of mid-2023[60]. Moreover, due to the cost of natural gas, Pakistan is increasing investments in coal power plants functioning on locally mined coal[61]. Coal expansion has been exacerbated by the China-Pakistan Economic Corridor (CPEC) which has financed a significant expansion of coal-fired power plants, with coal-fired electricity generation increasing from 61 GWh in 2012 to 15,774 GWh in 2018[62]. This likely will have significant consequences on the ability to expand renewable energy if the Pakistan Government is not in a position to renegotiate long-term contracts (power purchase agreements and capacity charge) with these new fossil fuel power plants. In addition, significant investments in a more flexible electric grid – as well as grid extension – will be required to accommodate a significant increase in renewable energy.

10. Finally, coal mining and coal consumption result in significant environmental and health hazards in Pakistan. Negative impacts on health affects both for miners working in coal mines[63] (e.g., respiratory diseases, irritation of the body, gastrointestinal problems, musculoskeletal harms, and headache) and local populations which are consequently a significant burden to the local healthcare system. A recent study has shown that the closure of a coal-plant leads to rapid – and significant- health benefits for the surrounding population[64]. Note that these impacts do not take into consideration medium- to long-term impacts as a result of CO_2 emissions from the consumption of coal for cement production.

2.4 Overview of the Cement Sector Emissions

As mentioned above, reducing emissions from the cement sector is crucial for Pakistan to meet its goals under the country's NDCs. Up to 95% of GHG emissions from the

[59] https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism_en
[60] https://ieefa.org/resources/choosing-right-incentive-pakistans-renewable-energy-industry
[61] https://www.reuters.com/business/energy/pakistan-plans-quadruple-domestic-coal-fired-power-move-away-gas-2023-02-13/
[62] Bhandary, R.R. and Gallagher, K.S., 2022. What drives Pakistan's coal-fired power plant construction boom? Understanding the China-Pakistan Economic Corridor's energy portfolio. *World Development Perspectives*, *25*, p.100396
[63] Ayaz, M., Jehan, N., Nakonieczny, J. and Mentel, U., 2022. Health costs of environmental pollution faced by underground coal miners: Evidence from Balochistan, Pakistan. *Resources Policy*, *76*, p.102536
[64] Yu, W. and Thurston, G.D., 2023. An interrupted time series analysis of the cardiovascular health benefits of a coal coking operation closure. *Environmental Research: Health*, *1*(4), p.045002

cement sector in Pakistan can be subdivided into two specific subgroups: Process emissions and coal consumption[65] **(Figure 9)**.

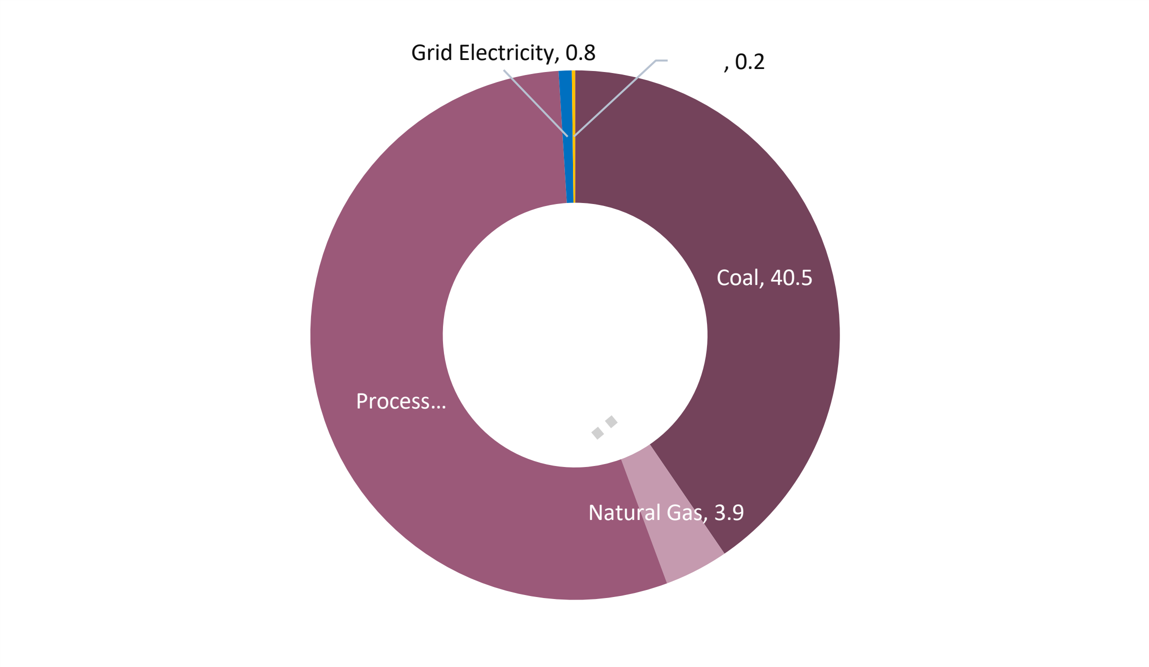


Figure 8: Emissions from the cement sector in Pakistan. See text for reference.

Process emissions (calcination of limestone) have been continuously rising as cement production has increased. Calcination of cement typically produces 0.526kg CO_2 per kg of clinker produced, a value which remains relatively constant[66] as the fundamental ingredient of clinker and cement remains limestone. These represent emissions that remain unavoidable. Although these emissions can be somewhat decreased by decreasing the ratio of clinker/cement, overall, this data implies that about 25 million tons of CO_2 emissions would need to be stored permanently yearly **(Figure 10)**. Moreover, as the capacity of cement production is expected to reach between 81 and 99 million tons per year between 2024 and 2030, it is likely that process emissions will increase to ca. 30 million ton per year (assuming a 70% capacity utilization, which is within the lower end of historical trends).

[65] Qureshi, S, Zia, U, Bashir, N 2023., Pakistan's Cement Sector: A Road to Decarbonization 2023, SDPI.
[66] Damtoft JS, Lukasik J, Herfort D, Sorrentino D and Gartner EM (2008) Sustainable development and climate change initiatives. Cement and Concrete Research 38(2): 115–127.

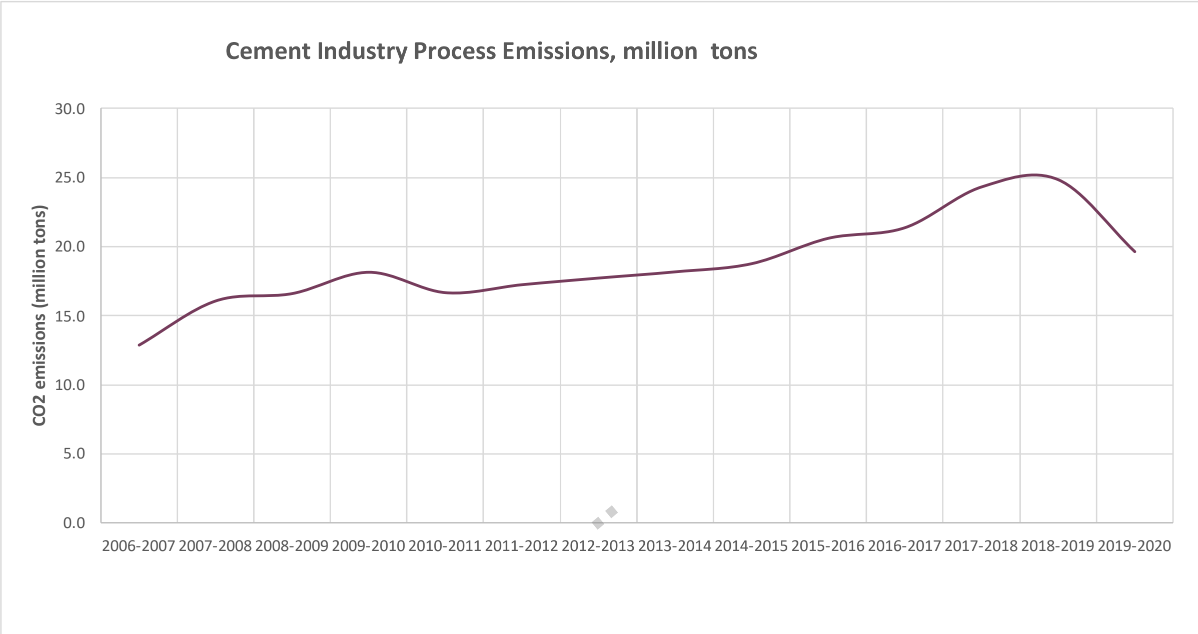


Figure 9: CO_2 emissions resulting from the calcination of limestone during clinker production[67] (Scope 1 emissions, see Section 3). Note that these process emissions do not take into account fuels used nor any other emissions related to the manufacturing process (eg., scope 2 and 3 emissions). Data is based on the amount of cement produced per year and an emission factor of 0.53kg CO_2 per kg of clinker produced.

The second largest contributor to emissions in the cement industry is the combustion of fuels to heat both the calcination and sintering process (kilns). In Pakistan, the majority of fuel used to power these processes is coal (86%). According to a recent study by the Centre for Research on Energy and Clean Air (CREA, see **Figure 11** for data and reference), coal consumption for the cement industry has significantly increased in recent years, leading to a sharp increase in CO_2 emissions. According to the CREA report, about 23.6 million tons of coal were consumed by the cement industry in 2021-2022[68]. These values are significantly higher than Governmental reports (Pakistan Economic Survey 2021-2022, Government of Pakistan Finance Division) indicating that coal consumption for the cement industry reached 7.8 million tons (metric) in fiscal year 2020-2021 and decreased significantly to 5.3 million tons in 2021-2022[69]. Even though there are *significant* discrepancies in provided datasets, cement GHG emissions are exceedingly high due to the reliance on coal as a source of fuel (the cement industry in Pakistan switched from furnace oil to coal as a calcination fuel source in 1990's due to increased furnace oil prices). Moreover, it is important to note that these emissions do not take into account additional "embodied carbon" and environmental impacts derived from emissions resulting from mining and transporting coal from coal-producing countries to Pakistan. The current decrease in coal price and high natural gas prices (due in part to depleting natural gas resources in Pakistan) likely means that coal consumption for

[67] https://ourworldindata.org/co2/country/pakistan
[68] https://lookerstudio.google.com/reporting/2dd0581b-aaa5-4fea-b6ad-2e3abb62aa43/page/t3DTC
[69] https://www.finance.gov.pk/survey/chapter_22/PES14-ENERGY.pdf

cement production will remain high in the upcoming years. It is important to note that the cement industry burns about 50% of all coal consumed in Pakistan, followed by power production and kilns for brick manufacturing.

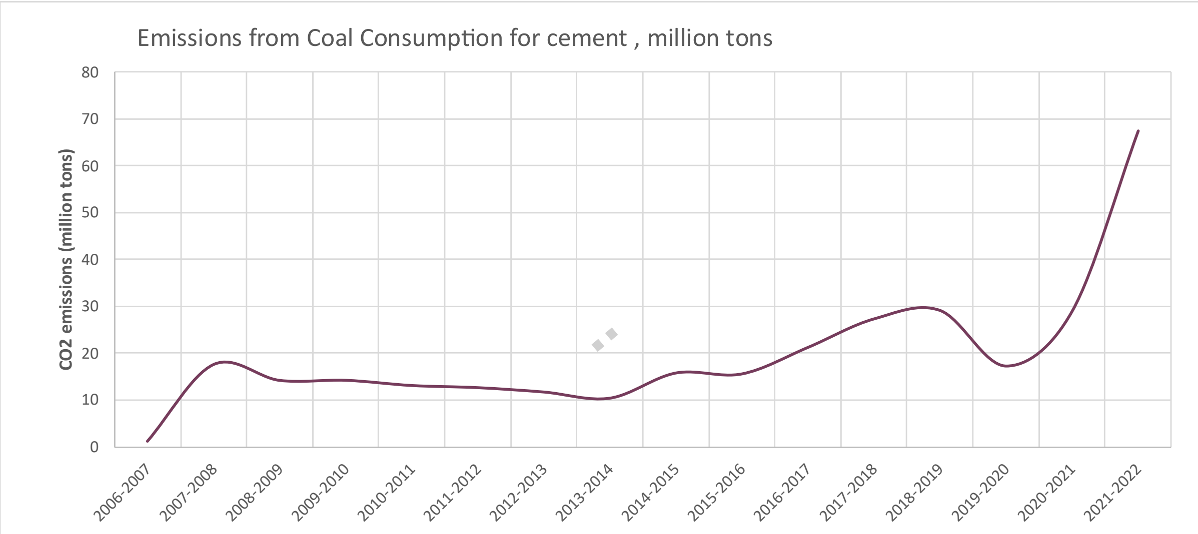


Figure 10: CO_2 Emissions resulting from the use of coal in the production of cement. Data from [70]. (note that these data represent maximum estimate – see text for explanation)

Regarding Scope 2 and 3 emissions, it is worth noting that the Pakistan cement industry mainly relies on high CO_2 emitting road transportation (diesel trucks instead of rail, etc.). That is the main cause of Scope 3 emissions which are not yet accounted for in any existing study, to the authors' knowledge.

[70] CREA, CO_2 Emissions from Pakistan´s Energy Sector, July 2021, Dawar Butt, Lauri Myllyvirta and Sunil Dahiya, https://energyandcleanair.org/wp/wp-content/uploads/2021/07/CO2-Emissions-from-Pakistans-Energy-sector_30_07_2021.pdf

3. BAU Scenario until 2040 in the Absence of New Interventions

Given the discrepancy is available data, this report employs a conservative approach to calculating overall CO_2 emissions from cement production. The emissions estimate for cement production in Pakistan provided below uses the amount of cement produced per year (from the APCMA), multiplied by an emission factor of 0.9 tons of CO_2 per ton of cement (Hasanbeigi et al. 2010).[71]

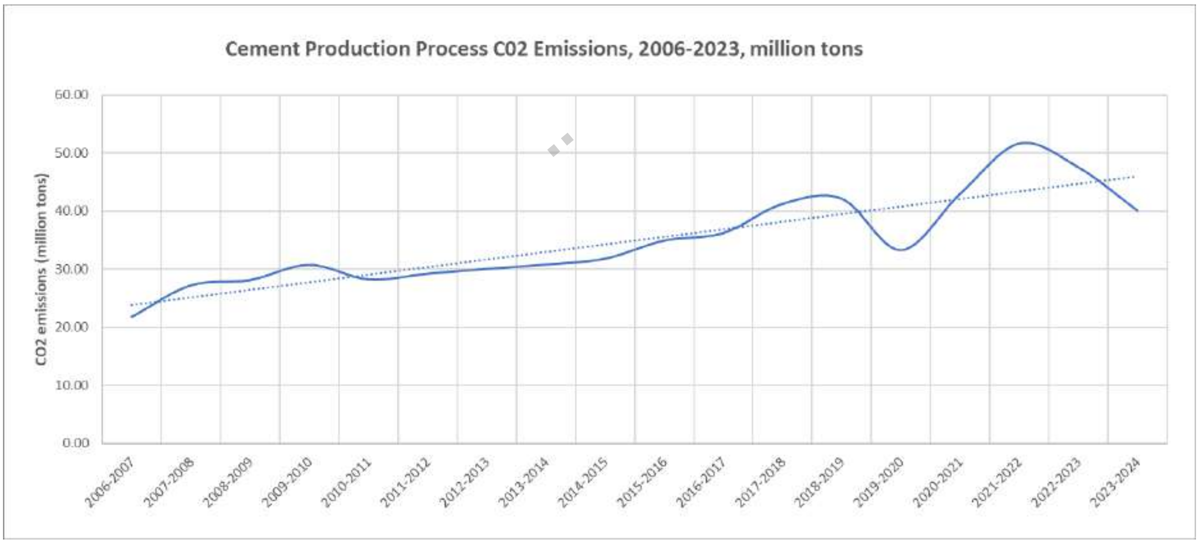


Figure 11 : CO2 Emissions from Cement Production in Pakistan (sources in text)

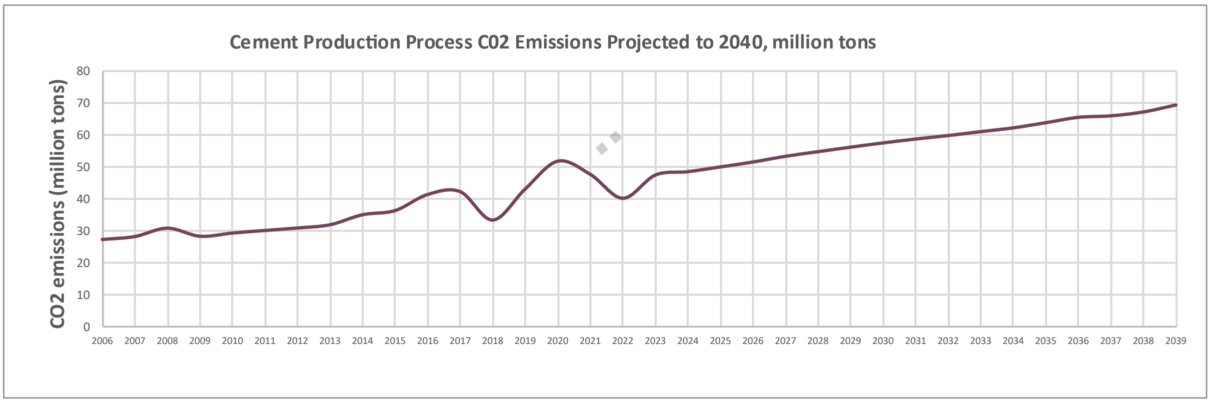
The historical emissions from cement production shown above largely follow economic cycles in Pakistan. For example, a current economic crisis in the country has led to decreased cement production in recent months. According to the data released by APCMA, cement dispatches dropped by 6.81% in July 2024, marking the 11th consecutive month of declining domestic sales.[72]

However, the downturn in domestic consumption of cement has been somewhat ameliorated by increases in exports. For example, year-to-year from July 2023 to July 2024, while domestic production declined 11.4%, exports increased 21.7%. Please note that the data shown in the figure above includes total cement production in Pakistan, which includes exports.

Nonetheless, despite low utilization of installed capacities at cement plants in recent years, Pakistan's cement industry has promising future growth potential as per capita cement consumption has increased from 72 kg/head in 2001 to 233 kg/head in 2021, and is still well below the global average of 550 tons per capita. [73]

[71] Hasanbeigi A, Price L, Lu H, Lan W (2010) Analysis of energy efficiency: opportunities for the cement industry in Shandong Province, China: a case study of 16 cement plants. Energy 35:3461–3473
[72] https://mettisglobal.news/cement-dispatches-drop-6-81-in-july-2024/
[73]https://www.pakistangulfeconomist.com/2021/10/11/cement-industry-steering-through-the-pandemic/

To calculate the BAU scenario for Pakistan's emissions up to 2040, a linear regression model was applied based on historical emission data from 2006 to 2023. The BAU scenario assumes that current trends continue without additional interventions or policy changes. Using the "forecast" function in excel, predicted values for years 2024-240 were calculated and plotted on the below chart. This approach provides an estimate of future emissions levels under the assumption of unchanged conditions and growth patterns, serving as a baseline scenario for understanding potential future outcomes and the need for mitigation strategies.



Using the historical trend of cement production emissions from 2006 to 2023 (when emissions reached 40.1 million tons of CO2 (down from a historical high of 51.6 million tons in 2020), the model predicts steady growth between 2024 and 2040, reaching 69.2 million tons in the latter year.

As mentioned above, the cement industry in Pakistan is relatively modern and efficient, and many plants use state-of-the-art technology. This fact, and the widespread implementation of Best Available Technology (BAT) in Pakistan, suggests that emissions from cement may increase at a lower rate than in the above model, even in the absence of the more aggressive carbon-reducing measures outlined in this report. On the other hand, the reliance of the cement industry in Pakistan on coal for heating kilns suggests that emissions may remain stable, as the above model suggests.

4. Decarbonization Technologies and their Applications in Pakistan and Abroad

This report follows the widely used definition of Scopes 1,2, and 3 emissions developed by the Greenhouse Gas (GHG) Protocol Corporate Standard.[74] It divides direct and indirect emissions into three distinct categories, referred to as emission scopes (as illustrated in the figure below):

Scope 1: This includes all direct greenhouse gas (GHG) emissions, such as those produced by a kiln.

Scope 2: This encompasses indirect GHG emissions that result from the consumption of purchased electricity, heat, or steam, for instance, the emissions linked to the electricity bought for cement production.

Scope 3: This covers other indirect emissions, including those from the extraction and production of purchased materials and fuels (like clinker), transportation activities in vehicles not owned or operated by the cement company, electricity-related activities such as transmission and distribution losses that are not included in Scope 2, as well as outsourced activities, waste disposal, and more.

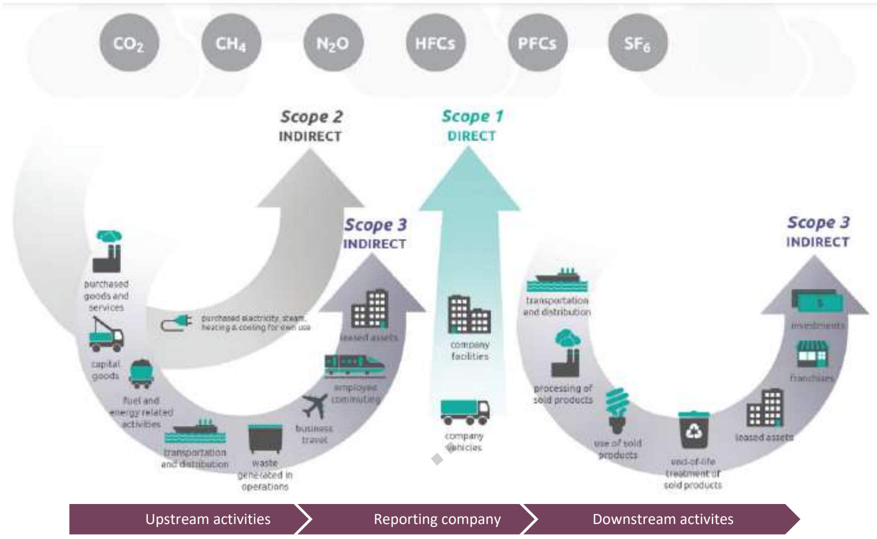


Figure 12: Scope 1, 2, and 3 Emissions per GHG Protocol[75]

Please note that due to time and resource constraints, this report focusses almost exclusively on Scope 1 and Scope 2 emissions from Pakistan's cement sector.

[74] https://ghgprotocol.org/corporate-standard
[75] WBCSD (October 2016). Cement Sector Scope 3 GHG Accounting and Reporting Guidance, p. 2. https://www.wbcsd.org/wp-content/uploads/2023/12/Cement-Sector-Scope-3-GHG-Accounting-and-Reporting-Guidance.pdf

4.1 Scope 1 Emissions

These emissions include the CO_2 released by the calcination of calcium carbonate (limestone) into free lime (calcium oxide) (ca. 526 kg CO_2/kg clinker) and the fuel combustion for the thermal processes ((pre)-calcination and sintering). In addition, non-kiln fuels used for the production of cement are also incorporated into Scope 1 emissions and include fuels for thermal process equipment (material drying), on-site and cement company-owned and operated vehicles (e.g., trucks), room heating/cooling and on-site power generation. As limestone will remain the main ingredient for cement for the foreseeable future, these emissions can only be mitigated by CCUS, whilst CO_2 emission mitigation from fuel combustion can be addressed in several ways as highlighted below:

4.1.1. Supplementary cementitious materials (SCMs)-based cement

In 2014, the Pakistan Standards and Quality Control Authority (PSQCA) approved the manufacturing and marketing of Supplementary Cementitious Materials (SCM)-based cement by adopting the EN-197 standard, enabling the production of CEM-II cement in Pakistan. A list of all approved cement standards in Pakistan with their designated markings is provided below.

Sr.	Code No.	Type
1	PSS-232:2008	OPC (BIS. Adopt)
2	PSS-5313:2014	Common Cement (EN-197)
3	PSS-5314:2014	Masonry Cement (EN-413, BS-5224/95 & ASTM C91)
4	PSS-612:2014	SR Cement
5	PSS-1630:2014	White Cement
6	PSS-232:2015	OPC with EN Strength
7	PPS-5586:2023	LC-3 Cement

Cement types marked in green (including EN-197) may be designated as Green Cement, as they allow the addition of Supplementary Cementitious Materials (SCMs) or Performance Improvers (PIs) with clinker, apart from gypsum. This reduces the clinker factor in cement and proportionally decreases the CO2 footprint.

The EN-197 standard includes 27 types of cements, with different clinker contents. These 27 types of cement are grouped into 5 categories, from CEM I-CEM V, as illustrated in the table below.

Type of cement	Description	Clinker content
CEM I	Portland cement	>95%
CEM II	Portland-composite cement	65-94%
CEM III	Blastfurnace cement	5-64%
CEM IV	Pozzolanic cement	45-89%
CEM V	Composite cement	20-64%

Table 2: Categories of EN 197-1 Cement and Clinker Content[76]

Cements lower in clinker content, like CEM II, are extensively used in Europe, where the EN 197-1 standard, which includes CEM II and CEM III (as well as other cements that are lower in clinker content), was first developed. EU countries have a high adoption rate of SCM-cements due to stringent environmental regulations and a strong emphasis on reducing CO_2 emissions. For example, CEM II is the go-to cement in Austria, Finland, Portugal and Switzerland, with 90% usage rates.[77] Meanwhile, in the Netherlands, CEM III blast furnace slag cement with a clinker factor below 65% predominates, as it offers improved protection against corrosion of steel reinforcement in marine environments. Based on the type of cement, carbon reductions for SCM-based cements can range from 10-40%.

Supplementary cementitious materials (SCMs) theoretically offer an efficient way of decreasing CO_2 emissions of cement production by reducing the clinker factor. Materials which are either already in use or which could be potentially used as SCMs to manufacture blended cements (i.e., CEM II) include: Fly ash, blast furnace slag, natural pozzolan, silica fume, rice husk ash. However, as highlighted in **Figure 14** (from [78]), one significant challenge with "classical" SCMs is the lack of sufficient quantity of high quality SCMs locally available to reduce the clinker factor. Moreover, the expected phasing out of coal plants globally (or their decreasing capacity utilization) and the expected transition of Blast-Furnace steel making towards alternative production methods (e.g., Hydrogen-based Direct Reduced Iron and use of scrap steel), implies that the source of traditional SCMs will likely decrease with time. Moreover, the geographical distribution of coal and steel plants is not necessarily correlated with the location with cement production facilities, which implies a potential geographical mismatch for the demand of SCMs in the cement industry.

[76] https://cembureau.eu/about-our-industry/cement/
[77] https://www.globalcement.com/news/item/13870-alternative-raw-materials-in-europe-projects-and-perspectives#:~:text=CEM%20II%20is%20the%20norm,of%20cement%20despatched%20in%202021.
[78] Scrivener, K., Martirena, F., Bishnoi, S., Maity, S., 2018, Calcined Clay Limestone Cements (LC3), Cement and Concrete Research, 114, pp.49-56, doi: 10.1016/j.cemconres.2017.08.017

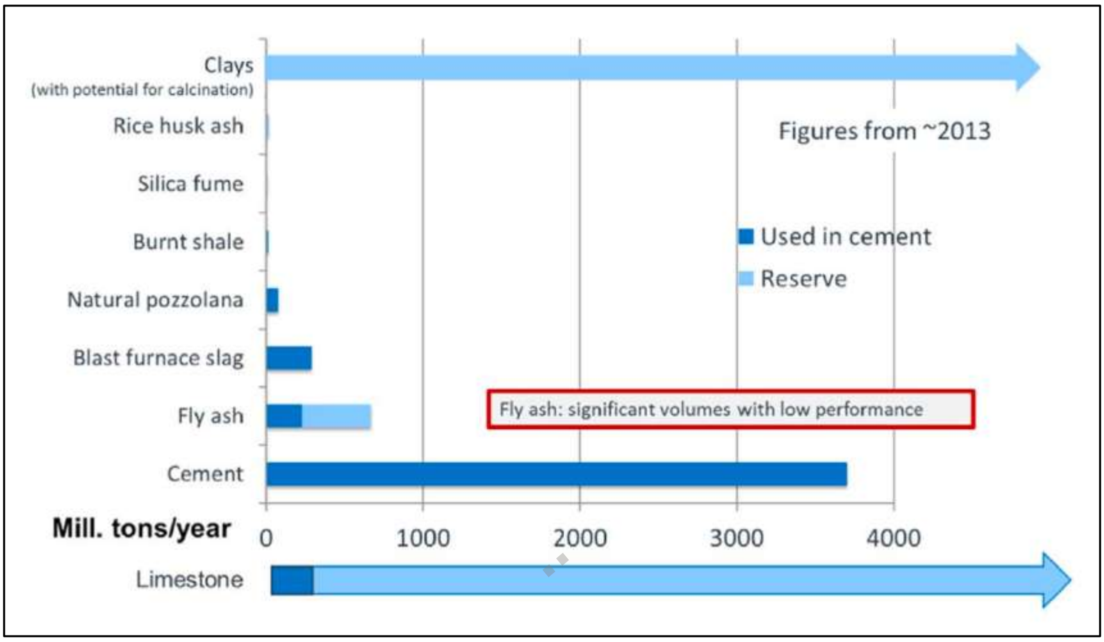


Figure 13: Scaling up the use of SCMs is constrained by a lack of blast furnace slag and fly ash, which are the typical SCM currently in use. Clays, however, offer an alternative. See text for reference.

However, SCM-based cement uptake has been slow in Pakistan (more information below, in section 4.1.1. Supplementary cementitious materials (SCMs)-based cement). Further, an alternative source of SCMs has been identified in the form of *clays* (outlined below).

4.1.2. Limestone Calcined Clay Cement (LC3)

Limestone calcined clay cement (LC^3) is based on the widespread availability of limestone and clays (with potential for calcination; i.e. having a specific proportion – ca. 40% – of Kaolinite) as opposed to the limited availability of other SCMs[79] **(Figure 14)**. Moreover, as illustrated in the publication of Ito and Wagai (2017)[80], kaolinite-bearing clays are found globally, and are widespread throughout developing countries, including Pakistan. The abundant availability of kaolinite-bearing clay deposits in Pakistan which could be utilized for the production of LC^3 was confirmed as recently as in 2023[81]. LC^3 cements therefore offers the opportunity to decrease CO_2 emissions by 40%[82] by reducing the clinker content of an Ordinary Portland Cement (OPC) down to 50% (LC^3-50).

The use of calcined clay as a replacement for clinker decrease GHG emissions through three different routes: 1) clays are calcined at a temperature of 700-800°C instead of 1400-1500°C for the manufacturing of clinker; 2) clays reduce the proportion of clinker

[79] Scrivener, K., Cement and Concrete Research (2018), https://doi.org/10.1016/j.cemconres.2017.08.017
[80] Ito, A. and Wagai, R., 2017. Global distribution of clay-size minerals on land surface for biogeochemical and climatological studies. Scientific data, 4(1), pp.1-11, DOI: 10.1038/sdata.2017.103
[81] Hussain, S.M.F., Sheikh, M.D., Jamil, T., Khan, A.U.R., Ayub, T. and Hu, C., 2023. Initial search for low grade clay in Pakistan for producing LC3 ecofriendly cement. Low-carbon Materials and Green Construction, 1(1), p.15, doi: 10.1007/s44242-023-00016-4
[82] www.LC3.ch, 2022, LC3: A sustainable alternative for the cement industry, 2022

to 50%, significantly decreasing process emissions derived from the transformation of limestone into CaO (lime) and CO_2 during calcination; 3) calcined clays reduce the energy needed for grinding compared to clinker, thereby decreasing electricity consumption for grinders (as well as - *possibly* - maintenance costs due to less wear and tear).

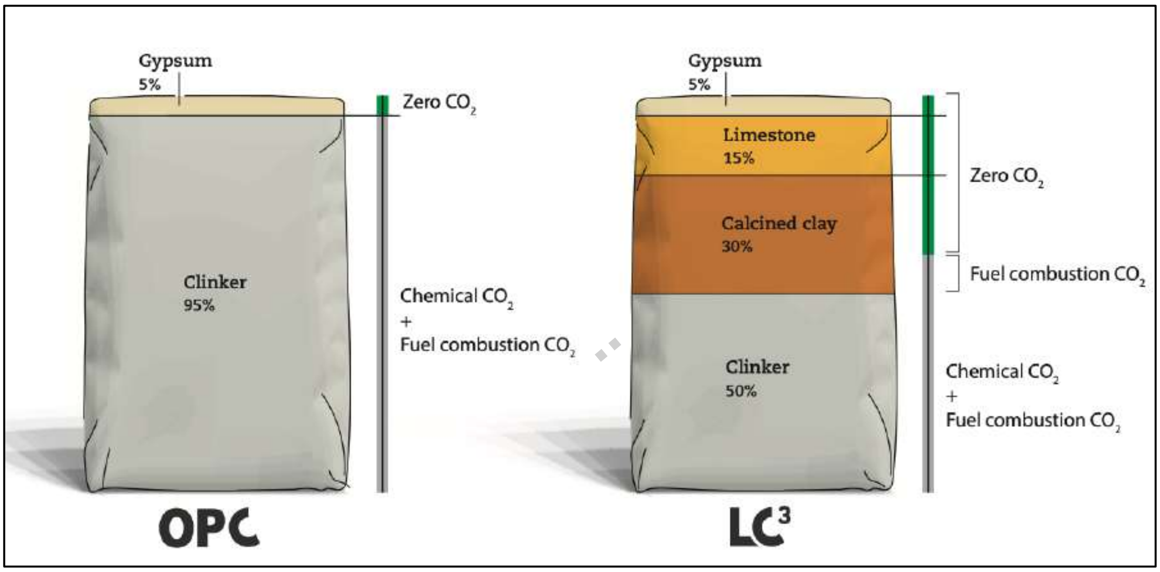


Figure 14: Proportion of clinker and other materials (gypsum, limestone, calcined clay) in an Ordinary Portland Cement (OPC) and a LC^3 cement (see text for reference).

CAPEX investments are related to retrofitting of a conventional cement plant, including a calcination unit (retrofitting an existing rotary kiln or a flask calciner), retrofitting the grinding unit and the storage units (silos). As no new technology is required to scale-up LC^3, this should enable a rapid Return on Investment (ROI). Importantly, initial studies have shown that LC^3 cements are commercially viable alternatives to OPC [83,84], indicating a ROI of 1 to 7 years. Not only are LC^3 cements generally cheaper to manufacture, but they also provide additional benefits, including:

1) High chloride penetration resistance
2) Dense microstructure with high resistivity making LC^3 cements and concretes ideal for harsh conditions like in marine or desert environment.
3) Highly suitable for use with reactive aggregates.
4) Use of non-ceramic grade clays
5) Similar strengths compared to OPC
6) Improved durability compared to OPC
7) Opportunities to use waste limestone of various compositions

[83] Joseph, S., Bishnoi, S. and Maity, S., 2016. An economic analysis of the production of limestone calcined clay cement in India. Indian Concr. J, 90(11), pp.22-27.
[84] Scrivener, K., Dekeukelaere, A., Avet, F., Grimmeissen, L., 2019, Financial Attractiveness of LC3. EPFL, Cementis, SDC.

Current countries scaling up the production of LC^3 are Cuba, Columbia, Ghana, India, Malawi, France and Denmark[85]. However, current challenges to scaling up of LC^3 lies not primarily with technology/manufacturing process, but in ensuring that regulations are in place that enable the use of LC^3 cements. LC^3 cement with 50% clinker (LC3-50) is accepted under cement standards[86] applicable in Europe, India[87], USA, Cuba and parts of South America. However, current complexities of national standards and building codes continue to impede the adoption of LC^3 cements by being too prescriptive and containing legacy requirements for durability which are not keeping up with technological innovation (e.g., limitation on kaolinite purity, minimum clinker content)[88]. Even after approval of LC^3 cement standards, there is no guarantee that use of LC^3 cements can be widespread. For example, in Pakistan, as specifications for projects almost exclusively call for OPC. A shift away from prescriptive to performance-based standards for cement and concrete is a key requirement to scale up low-carbon cements such as LC^3. Stronger synergies between academic research institutions, regulators, policy makers and industrial partners is required to streamline the development of new flexible standards and building codes which can drive a significant decrease in embodied carbon emissions of cement and concrete.

However, the global and local landscape should change in favor of using the lower-carbon LC3 cement in coming years. For example, in early 2023, the global cement player Holcim began large-scale LC3 production at its plant in Saint-Pierre-la-Cour plant, France. With a maximum production capacity of 500,000 tons of cement per year (or 1,515 tons per day), Holcim claims to reduce carbon emissions by 50% versus standard CIM I cement.[89] Next, in Pakistan, LC3 is currently approved by the PSQCA for manufacture and use (code: PSS-5586:2023) SPAR6C heard from several cement firms that they were very interested in beginning to produce LC3, and that the requisite standards were in place in the country to allow for its production. Taken together, this evidence suggests that LC3 has the potential become more commonplace in the future.

4.1.3. Alternative Fuels: Municipal and Agricultural Waste

Pakistan generates approximately 49.6 million tons of solid waste a year, which has been increasing by more than 2.4 % annually[90]. Processing of municipal and industrial waste or crop residue in cement kilns instead of landfills can provide a cost-effective way of decreasing CO_2 emission in the short term[91], whilst potentially decreasing the

[85] https://rmi.org/unleashing-the-potential-of-limestone-calcined-clay-cement/
[86] https://www.cemnet.com/Articles/story/172916/lc3-in-codes-and-standards.html
[87] IS 18189 : 2023 Portland Calcined Clay Limestone Cement Specification (21-06-2023), Bureau of Indian Standards
[88] Kanavaris, F., Vieira, M., Bishnoi, S., Zhao, Z., Wilson, W., Tagnit Hamou, A., Avet, F., Castel, A., Zunino, F., Visalaksh, T. and Martirena, F., 2023. Standardisation of low clinker cements containing calcined clay and limestone: a review by RILEM TC-282 CCL. Materials and Structures, 56(9), p.169.
[89] https://www.holcim.com/media/media-releases/first-calcined-clay-cement-operation
[90] https://www.trade.gov/country-commercial-guides/pakistan-waste-management
[91] Khan, M. M. H., Havukainen, J., & Horttanainen, M. (2021). Impact of utilizing solid recovered fuel on the global warming potential of cement production and waste management system: A life cycle assessment approach. Waste Management & Research, 39(4), 561–572. https://doi.org/10.1177/0734242X20978277

amount of waste landing up in landfills worldwide. This might be an effective step which can help decrease, in the short term, CO_2 emissions from the cement sector, considering that coal accounts for 86% of primary energy use in cement plants in Pakistan. Use of waste is relatively widespread in the cement industry, with biomass and alterative waste reaching 46% in Europe in 2017 (30% waste and 16% biomass).[92] However, these values are significantly lower in Pakistan (likely around 1%, relevant data for Pakistan not found). It is important to note that although the International Energy Agency (IEA) indicates that 20% of overall heat energy could be produced by such waste and biomass worldwide by 2050, this implies that additional methods and technologies are required to bring the cement industry to net-zero (or even in order to simply half the emissions). State-of-the-art technologies currently being marketed, such as the HOTDISK combustion technology by FLShmidt[93], enable up to 80% of fuel replacement in a traditional kiln, with high flexibility in terms of type of waste used. The investments required typically range between USD5 million and USD18 million for a cement plant[94]. Such investments do not take into account the significant investments needed in waste pre-processing facilities and setting up a waste management infrastructure. Indeed, typically, pre-processing and treatment of waste are required to make the waste ready for co-processing in cement kilns, meaning that effective regulatory and institutional frameworks are critical to ensuring that co-processing has no harmful environmental or social impacts[95]. Finally, it is crucial to ensure that the use of specific types of materials as an incineration product is not preventing the sustainable re-use and re-purposing of waste materials in a circular economy; in such a case, increasing the use of waste for kiln incineration could hamper the development of additional value chains.

The use of biofuels from agricultural waste to replace coal in cement kilns, including but not limited to rice husk, rice paddies, corn stover, and wheat straw is championed by some stakeholders in Pakistan. Proponents argue that these biofuels can effectively replace 20-35% of coal in kiln operations.[96] However, like MSW, there are questions about the availability and consistency of the supply of these fuels (for example, rice husks have already established a supply chain and are used in the energy generation industry, and crops are usually only seasonably available). As such, these fuels should be further studied to determine if they are indeed viable options for the cement industry, and/or to what degree they could in fact replace coal.

[92] https://setis.ec.europa.eu/system/files/2021-02/jrc120570_decarbonisation_of_cement_fact_sheet_2.pdf
[93] https://www.flsmidth.com/-/media/brochures/brochures-products/pyro/2000-2017/hotdisc-combustion-device.pdf
[94] International Finance Corporation, 2017, Increasing the use of alternative fuels at cement plants: international best practices
Cembureau, 1997b. Best Available Techniques for the Cement Industry, Brussels: Cembureau.
[95] Hasanbeigi, A., Lu, H., Williams, C. and Price, L., 2012. International best practices for pre-processing and co-processing municipal solid waste and sewage sludge in the cement industry (No. LBNL-5581E). Lawrence Berkeley National Lab.(LBNL), Berkeley, CA (United States).
[96] Khokhar, M. F. et al (April 2024), Decarbonizing Cement Production, Exploring Pathways to Net-zero in Pakistan, https://acjce.com/wp-content/uploads/2024/05/Decarbonizing-the-Cement-Industry-R06.pdf

4.1.4. Kiln Electrification

Direct industrial electrification represents the most efficient way of transitioning towards sustainable industrial practices and most technologies are present to drive this transition forward. For instance, current technologies in Europe could electrify 78% of industrial energy demand[97]. Electric powered technologies heating up to 1000°C or more are already present in heavy industry (e.g., electric boilers, resistance furnace, induction furnace, microwave & radio frequency heaters), however these have not yet been established in the cement industry. The particular challenge of the cement industry is that heating occurs as a two-step process, namely i) (pre)-calcination which reaches about 900°C and where free lime (CaO) is produced, and 2) sintering in the rotary kiln, which occurs at ca. 1450°C where clinker is produced. Temperatures of 1400°C are more challenging to reach with electric kilns.

A 2019 feasibility study has shown that that electric calcination (i.e., *electrified rotary calciners with resistance-based heating*) is competitive with alternative technologies, such as amine-based CCS and post-combustion CCS[98]. Moreover, electric kilns are used as indirect heating systems, which means that the material (limestone) is heated in an isolated system. This implies that the flue gas which is then produced is ca. 99% CO_2 as it is not mixed/diluted with air (*as opposed to current flue gas CO_2 concentrations in cement plants which vary between 14% and 33%*)[99]. Thus, such a technology can therefore rely fully on renewable energy and circumvent the need to install additional carbon capture technology, such as amine-based capturing, which itself is energy intensive. The high purity CO_2 gas can then be directly transported and stored in long-term storage places or used on-site for producing additional building material as shown in **Sections 5 and 6**.

In case of electrifying the calcination part of the cement process, a significant decrease in emissions can already be achieved by electrifying the calcination part of a cement plant as:

i) **The calcination step requires 60% of all fuel energy in comparison to the rotary kiln** (clinker production at 1400-1450°C), which requires the remaining 40% of energy.

ii) The calcination step involves the chemical reaction where limestone ($CaCO_3$) breakdown into CO_2 and CaO (free lime). This implies that the bulk of process CO_2 emissions, which amount yearly to ca. 20-25 million metric tons as seen in **Figure 32** can be fully captured, as the flue gas produced reaches ca. 99% CO_2 and contains no additional gases.

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[97] Madeddu, S., Ueckerdt, F., Pehl, M., Peterseim, J., Lord, M., Kumar, K.A., Krüger, C. and Luderer, G., 2020. The CO2 reduction potential for the European industry via direct electrification of heat supply (power-to-heat). Environmental Research Letters, 15(12), p.124004

[98] Tokheim, L.A., Mathisen, A., Øi, L.E., Jayarathna, C.K., Eldrup, N.H. and Gautestad, T., 2019. Combined calcination and CO2 capture in cement clinker production by use of electrical energy. In *TCCS–10. CO2 Capture, Transport and Storage. Trondheim 17th–19th June 2019. Selected papers from the 10th International Trondheim CCS Conference*.

[99] Anderson, S. and Newell, R., 2004. Prospects for carbon capture and storage technologies. Annu. Rev. Environ. Resour., 29, pp.109-142.

Developments in electric kilns are outlined below:

• A Consortium spearheaded by VTT (Decarbonate initiative) and which include cement suppliers (e.g., Finnsementti) has developed a 10-meter electrically heated rotary kiln for the indirect calcination of limestone[100] at 875-1050°C, which produces nearly pure CO_2 gases at more than 90% calcination rate[101]. The capacity of the electric rotary kiln is currently of 100 kg/hour. Pilot tests took place in 2021 and 2022, with VTT currently aiming to scale-up the technology further.

• Vattenfall and Cementa implemented a Feasibility Study between 2017 and 2019 (CemZero Project, Sweden) and have showcased that electrification of cement kilns is technically feasible. The consortium is currently exploring the possibility of building a pilot plant[102]. Initial findings, based on a plasma-based technology, is that the cost of cement is doubled compared to current technologies. However, electrification simplifies the process of capturing CO_2 and brings the additional cost of CCS down significantly.

• LEILAC2 (A European Consortium including HeidelbergCement, Calix) is a pilot demonstration plant alongside an operational cement plant which will allow 100kt of pure CO_2 to be captured per year. This Project is supported by 16 million Euros of EU funding, for a total budget of ca. 35 million Euros (years 2020-2025). The vertical, indirect calcination technology is based on the Project LEILAC1 and produces a near-pure CO_2 flue gas[103] without the need for further processing. Particularly interesting is that the proposed technology can also be retrofitted in a modular form at any scale and use any fuel or energy source for heating purposes.

• Finnish-Dutch company Coolbrook has developed a new electric-powered technology called RotoDynamic Heater[104] which can be implemented in a variety of heavy industries in order to decarbonise heat processes (up to 1700°C) and can replace fossil-fuel kilns in the cement industry. The technology, based on accelerating an internal gas to supersonic speeds through rotating blades, is expected to be fully commercial by 2024 and is currently partnering with cement company CEMEX to implement the technology in the cement industry. A current 0.8MW pilot plant is under construction, with the aim of reaching 1700°C in 2024 and reach an electric-to-heat conversion efficiency of 90-95%. The small footprint and modular nature of this technology indicates that the system can be easily retrofitted in current cement plants in both a fully electric

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100 https://www.vttresearch.com/en/ourservices/electric-rotary-kiln
101 https://www.decarbonate.fi/wp-content/uploads/2022/06/Decarbonate_Final_report.pdf
102 https://www.umu.se/en/research/projects/cemzero---carbon-dioxide-free-products-based-on-electrified-manufacturing---reactivity-of-cement-clinker-with-secondary-cementitious-materials/#:~:text=The%20CemZero%20projects%20aims%20to,which%20are%20suitable%20for%20CCS.
103 https://cordis.europa.eu/project/id/884170
104 https://coolbrook.com/industries/

system of hybrid approach depending on the cement plant and the decarbonisation timelines[105].

• Swedish company SaltX has developed an Electric Arc Calciner (EAC) to calcinate limestone and produce quicklime using electric plasma torches (Scan Arc). Following a smaller pilot test of the technology, the company is operating a test facility in Sweden to test this technology at industrial scale (2MW, operational since the fall of 2023)[106] as well as establishing full-scale industrial facilities with different industrial partners. In June 2023, SaltX signed an MoU (Memorandum of Understanding) to implement the EAC technology in and Indian Cement production facility (Dalmia Cement).

4.1.5. Logistics electrification

The exponential increase in electrified transport, reaching 10 million electric vehicles sold globally in 2022 (for a total of 14% of all cars sold globally)[107] implies that electrification of vehicles in industrial sectors represent an effective way of mitigating CO_2 emissions. Moreover, current innovations in electric vehicles, electric trucks, construction and mining equipment and charging infrastructure implies a maturing of technologies which can be rapidly scaled up if sufficient financial and policy support is present. First-mover country Norway has mandated that all new trucks in 2030 must be zero emissions (i.e., BEV, hydrogen, or biogas)[108], indicating that the phasing out of fossil fuel trucks is gathering pace. Indeed, according to The Zero-Emission Technology Inventory (ZETI) [109], 843 zero-emission medium- to heavy-duty truck models have been announced as of 2023, of which 794 are fully electric (not hydrogen-powered/fuel-cells). The cement industry in North America Lafarge Canada (subsidiary of Holcim) is currently transitioning its vehicle fleet to electric vehicles to decrease Scope 1 emissions using Vicinity Motor Corp. (VMC 1200) trucks[110,111] while Volvo Trucks delivered, in early 2023, the first electric heavy-duty concrete mixer truck to CEMEX for operation in Germany[112]. In 2024, India launched a pilot project involving the deployment of ca. 150 electric vehicles in the cement sector (*e-trucks available in India including: BYD Q1R Pure Electric* , *Olectra Greentech - Meghaetron Electric 6x4 Tipper, IPL Tech - IPLT Rhino 5536*)[113].

Additional electrification of construction equipment is gathering pace, as shown by the recently unveiled Volvo EC230 Electric 23-ton excavator[114] which will be commercially

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[105] https://www.globalcement.com/magazine/articles/1269-coolbrook-harnessing-electricity-for-cement-production
[106] https://www.saltxtechnology.com/files/REPRINT-ICR-APRIL-2024-HR-SaltX-Electric-kilns-3p-MB.pdf
[107] IEA (2023), Global EV Outlook 2023, IEA, Paris https://www.iea.org/reports/global-ev-outlook-2023, License: CC BY 4.0
[108] https://elbil.no/na-far-norge-et-nullutslipps-mal-ogsa-for-lastebiler/
[109] https://globaldrivetozero.org/tools/zeti-data-explorer/
[110] https://www.lafarge.ca/en/lafarge-canada-pioneers-all-electric-trucks-setting-bar-sustainable-operations-north-america , Accessed 18th August 2023.
[111] https://www.vmcpioneerelectrictruck.com, Accessed 18th August 2023.
[112] https://www.volvotrucks.com/en-en/news-stories/press-releases/2023/feb/volvo-delivers-the-first-heavy-duty-electric-concrete-mixer-truck-to-cemex.html
[113] https://www.globalcement.com/news/item/17397-india-s-cement-industry-pilots-ev-trucks
[114] https://www.volvoce.com/europe/en/products/electric-machines/ec230-electric/

available in 2024. Electrification of vehicles represent a relatively effective way of reducing Scope 1 emissions whilst also decreasing operational costs *(in particular when combined with cheap solar power and on-site battery storage).* Moreover, the projected decrease in battery costs (currently expected to decrease by 40% by 2025 from 2022[115]), development in new battery chemistries and increase in battery energy density will only continue to drive the cost of electric vehicles down in the foreseeable future[116]. Depending on the size of the truck fleet, bi-directional charging could provide an additional financial incentive to the cement industry (i.e., selling electricity back to the grid or "Vehicle-to-grid") and enable grid operators to use these large vehicles as decentralized storage units to stabilize the electric grid in times of need[117].

A 2024 study published by the Confederation of Indian Industry and the Cement Manufacturers Association in India has shown that although CAPEX of BEV trucks can be up to 3 times as high as traditional fossil fuel powered trucks, substantial operational savings imply that the return on investment is reached after 5 to 6 years, assuming a truck driving 8´000 km /month[118].

4.1.6.Change to on-site power generation

Electrification, installation of renewable energy – and if needed combined with battery storage – could be maximized in order to decrease the use of fossil fuel power generation on-site. According to Bloomberg NEF (2023)[119], onshore wind and solar power are now the cheapest new-build technologies in countries covering 82% of global electricity generation **(Figure 16)**. Moreover, a study by the National Renewable Energy Laboratory (NREL) published in 2023[120] projects capital cost reductions of 16-49% by 2030 and 28-67% by 2050 for utility-scale battery storage. It is important to note that Pakistan has a striking potential for renewable energy, particular solar energy[121,122]. Such changes are already underway in the cement industry in Pakistan[123]. In 2023, Lucky Cement, a leading cement manufacturer in Pakistan, installed a 34 MW solar array with Li-ion battery storage at their cement plant at Pezu, (Northern industrial sector, Khyber Pakhtunkhwa) which is expected to produce about 48GWh of energy and cut CO_2 emissions by 29,569 tons per year[124]. Other cement industries in Pakistan, such as such as Fauji Cement Company Ltd (FCCL) and Bestway cement are equipped

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115 https://www.goldmansachs.com/intelligence/pages/electric-vehicle-battery-prices-falling.html
116 https://theicct.org/publication/cost-ev-vans-pickups-us-2040-jan22/
117 Solanke, T.U., Ramachandaramurthy, V.K., Yong, J.Y., Pasupuleti, J., Kasinathan, P. and Rajagopalan, A., 2020. A review of strategic charging–discharging control of grid-connected electric vehicles. Journal of Energy Storage, 28, p.101193.
118 Confederation of Indian Industry (CII) and Cement Manufacturers' Association (CMA), May 2024, Greening Logistics: electrification in cement & raw material transport,
119 https://about.bnef.com/blog/cost-of-clean-energy-technologies-drop-as-expensive-debt-offset-by-cooling-commodity-prices/
120 Cole, W., & Karmakar, A., 2023, Cost Projections for Utility-Scale Battery Storage: 2023 Update, National Renewable Energy Laboratory Technical Reports NREL/TP-6A40-85332, https://www.nrel.gov/docs/fy23osti/85332.pdf
121 Global Photovoltaic Power Potential by Country, The World Bank and the Energy Sector Management Assistance Program (ESMAP), June 2022, *https://openknowledge.worldbank.org/server/api/core/bitstreams/8a711495-4034-52d3-a5cc-3fcbc98d0738/content*
122 Zaidi,Hassan Jafar; Dreesmann,Gerwin; Marz,Tobias; Bilal,Muhammad Umair; Ahmed,M. Farooq; Ali,Abrar; Fatima,Rida. *Variable Renewable Energy Locational Study : Main Report (English).* Washington, D.C. : World Bank Group.http://documents.worldbank.org/curated/en/883241610741226840/Main-Report
123 Qureshi, S, Zia, U, Bashir, N 2023., Pakistan's Cement Sector: A Road to Decarbonization 2023, SDPI.
124 https://www.brecorder.com/news/40217528 , accessed 18th of August 2023.

with solar power generation (and waste heat recovery plants) to power cement manufacturing facilities[125] in order to bring down costs, decrease CO_2 emissions and increase energy reliability. For instance, Bestway Cement recently commissioned 7,200 tons per day cement plant in Mianwali covers 50% of its energy requirement from solar renewable power generation[126].

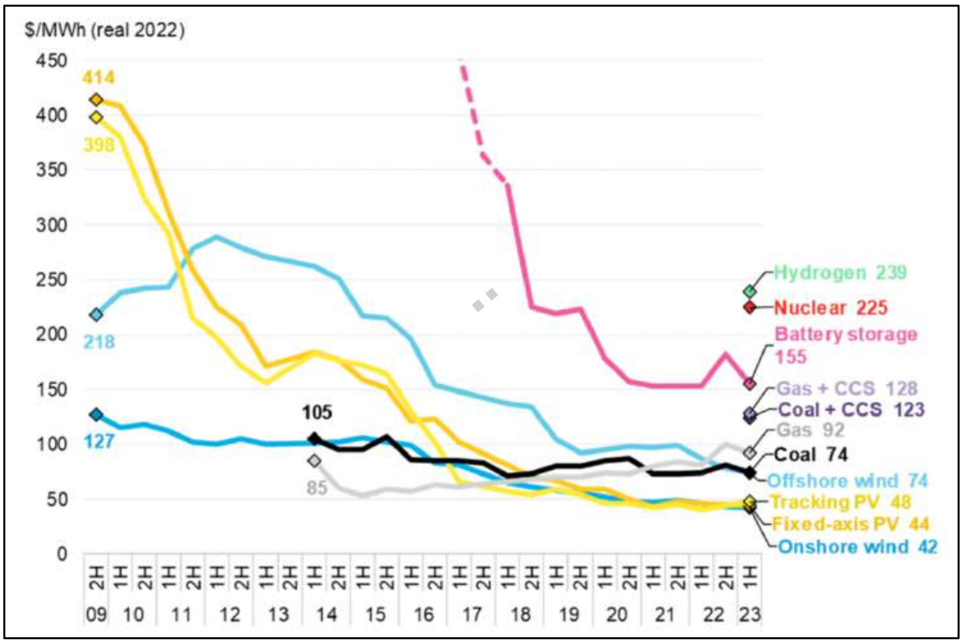

Figure 15: Global levelized cost of electricity benchmarks, 2009-2023 (BloombergNEF, June 2023)

4.2 Scope 2 Emissions

These are typically indirect emissions from the generation of electricity which is consumed in the company's owned or controlled equipment. In the case of electrification of the cement industry, electricity consumption is going to increase significantly. Thus, scope 2 emissions can be decreased through the following pathways:

4.2.1. Increasing Energy Efficiency

Energy efficiency is typically focused on transforming cement plants to use a dry manufacturing process as well as multi-stage pre-heaters, pre-calciners, efficient grate coolers as well as vertical roller mills, the later replacing ball mills (*offer energy savings of 6-7 kWh per ton of raw materials*[127] *which are currently estimated at 10-17 kWh per ton of clinker*). However, Pakistan cement plants, as seen from Table 1, typically operate such state-of-the-art technologies already. The key therefore is not to replace the specific technology but increase the efficiency of both these technologies and additional auxiliary equipment such as fans, conveyors, blowers, motors, pumps and compressors which are ubiquitous in the cement industry. Overall, these measures are estimated to decrease CO_2 emissions by 2-5kg CO_2 per ton of clinker.

[125] https://www.cemnet.com/News/story/166812/fauji-cement-co-commissions-12-5mw-solar-power-plant.html
[126] Haroon, M.; Ayub, A. Role of the Pakistan Cement Industry towards the Achievement of Net Zero Goal by Mid-Century: A Review from a Waste Heat Recovery Perspective. Eng. Proc. 2023, 45, 45. https://doi.org/10.3390/ engproc2023045045
[127] Cembureau, 1997. Best Available Techniques for the Cement Industry, Brussels: Cembureau.

Waste heat recovery (WHR), typically through a Kalina Cycle system, Steam-driven or Organic Rankine cycles can lead to savings of up to 25kWh per ton of clinker[128]. Emissions are estimated to decrease by 5-10kg CO_2 per ton of clinker[129], with about 20%–30% of the required electricity for cement production being derived from the waste heat[130]. We encountered published evidence of 11 Waste Heat Recovery systems installed at 9 cement plants throughout Pakistan **(Table 3)**, for a total of >100MW of capacity, with a potential of an additional capacity of 50-100 MW as of 2014[131]. However, all Pakistani cement firms, with the exception of one firm (Dandot Cement), have implemented WHR at their plants. This implies that the potential for WHR is rather limited in Pakistan, consistent with our stakeholder engagement with cement actors who did not show any particular interest in pursuing this mitigation technology. Note that many of these WHR systems were financed through the Clean Development Mechanism (CDM), showcasing the effectiveness of climate finance in decarbonizing the cement sector.

Table 3 Waste Heat Recovery Systems in Pakistan[132,133]

Cement Industry	Kiln Type/No of Lines/ Capacity (tpd)	Total Installation Cost (USD)	WHR Capacity (MW)	Net Zero Goal in Terms of CO_2 Savings (t/y)	Power Generation (MWh/y)
D.G Cement (D.G. khan Plant)	4/5 stage preheater/2/6700	15 million	10.4	40,332	70,088
(Khairpur plant)	Rotax 2/1/6700	11.8 million	8.5	28,542	61,301
Cherat Cement	Rotary/1/3200	9.3 million	7	25,761	41,730
Attock cement (Hub Plant)	4 × 64 Rotary/2/5200	18.6 million	12	37,908	58,320
Fecto Cement	Dry/1/2600	7.2 million	6	19,584	38,400
Karachi Plant	Rotary/2/6600	9.1 million	10	33,820	58,291
Lucky Cement	Dry/3/9000	12.54 million	15	42,992	87,437

4.2.2. Increasing use of Renewable Energy

The electric grid in Pakistan is dominated by coal, leading to an elevated grid factor, due to heavy investments in coal-power plants in recent decades. Instead, cement companies have, in part, started to produce their own renewable energy, thereby decreasing their dependence on a coal-dominated electric grid (known as Captive Power Plants, CPP). Thus, one alternative is for cement companies to scale-up vertically and become energy producers as CPPs (see section 3.1.6). Lucky Cement uses 100 % captive power generation, DG Khan Cement uses 40 % and Maple Leaf Cement uses 45 %[134]. Alternatively, cement industries could set-up virtual power purchase agreement (PPAs) with

128 IEA 2018
129 ECRA and CSI (2017)
130 International Finance Corporation: IFC. Review of existing installations and assessment of remaining potential waste heat recovery in Turkish cement industry. Washington, DC. 2018, http://documents.worldbank.org/curated/en/772541525345168887/Waste-heat-recovery- in-Turkish-cement-industry-review-of-existing-installations-and-assessment-of-remaining-potential.
131 Waste Heat Recovery for the Cement Sector. Market and Supplier Analysis, a report by: Institute of Industrial Productivity and International finance corpora- tion World Bank group; 2014.
132 Haroon, M.; Ayub, A. Role of the Pakistan Cement Industry towards the Achievement of Net Zero Goal by Mid-Century: A Review from a Waste Heat Recovery Perspective. Eng. Proc. 2023, 45, 45. doi:10.3390/ engproc2023045045
133 Zeb, K.; Ali, S.M.; Khan, B.; Mehmood, C.A.; Tareen, N.; Din, W.; Farid, U.; Haider, A. A survey on waste heat recovery: Electric power generation and potential prospects within Pakistan. Renew. Sustain. Energy Rev. 2017, 75, 1142–1155.
134 International Finance Corporation, 2017, Increasing the use of alternative fuels at cement plants: international best practices

grid operators and electricity providers in Pakistan to only purchase renewable energy, thereby giving an incentive to the Pakistani government and grid operators to invest and scale up renewable energy capacity. It is noteworthy that solar panel prices are expected to decrease by 40%, with solar module prices reaching a record low of USD 0.1/W by the end of 2024[135]. Average electricity consumption ranges between 90 to 130 kWh per ton of cement, implying that power represents up to 50% of direct cement production cost[136]. This implies that the cement industry is highly vulnerable to the fluctuating cost of coal, 67% of which was imported into Pakistan in 2021[137]. Soaring energy costs have strongly impacted industrial activity recently[138].

4.3 Scope 3 Emissions

Additional indirect emissions which include the CO_2 released through the sourcing/purchase of raw materials and trade of intermediate products, transport-related activities with vehicles not owned or controlled by the cement company, waste disposal and other outsourced activities. Note that for the cement industry, Scope 1 and 2 account for the large majority of emissions[139]. Scope 3 emissions will not be covered due to the scarcity of data at this point.

4.4 Mitigation Costs and Feasibility of Technologies

Two successful workshops held by SPAR6C in Pakistan in April 2024 showcased significant interest from cement manufacturing companies in Pakistan to invest in ambitious climate mitigation technologies. In response to these workshops in Lahore and Karachi, several cement companies developed additional draft PINs aimed at scaling up LC^3 cements, electric trucks and/or agricultural waste as an alternative fuel. These actors already have a successful track record of having implemented WHR systems through the CDM methodology, implying that additional initiatives are required for a substantial decrease of GHG emissions of cement production in Pakistan. From engagement with the cement industry and current state-of-the-art technologies, this report provides the following analysis:

1) Using cements lower in clinker content that can already be readily produced in Pakistan with no (or small) additional capital investments, such as CEM II (outlined in 4.1.1. Supplementary cementitious materials (SCMs)-based cement) 4.1.1. Supplementary cementitious materials (SCMs)-based cement This could potentially provide an excellent cost-benefit, as clinker content of such cement in 65-89% lower, leading to considerable carbon reductions. As such cements are currently widely used in Europe, it would appear that the only obstacle to adopting this cement is cultural. As such, educational campaigns/awareness raising with organizations that procure cement, and/or a targeted lobbying effort would be all that is needed to make use of such cements commonplace in Pakistan.

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[135] https://www.pv-magazine.com/2023/11/23/solar-module-prices-may-reach-0-10-w-by-end-2024/
[136] International Finance Corporation, 2017, Increasing the use of alternative fuels at cement plants: international best practices
[137] Malik, A., 2023, Local coal for power generation in Pakistan, The Pakistan Development Review, v. 62:4, pp. 573-589.
[138] https://tribune.com.pk/story/2458599/soaring-energy-costs-stall-growth-at-029#
[139] http://docs.wbcsd.org/2016/11/Cement_Sector_Scope3.pdf

2) The use of MSW as a fuel could solve substantial environmental and health issues in local communities in Pakistan by ensuring the safe disposal of waste. Consultations with the cement industry has shown a willingness to invest in MSW (and other types of waste) as a way of decreasing their reliance on (typically imported) coal, including setting up certain waste processing facilities (i.e., drier, shredder) on-site. However, substantially barriers remain related to the lack of efficient waste management process at the municipal/city level (i.e., waste collection, segregation, transportation, processing, shredding, drying) which can provide substantial amounts of MSW on a consistent and long-term basis and with sufficient quality to be used in cement kilns (e.g., low moisture). A lack of financing for waste treatment plants and poor infrastructure, lack of awareness and capacity throughout the waste value chain and bureaucratic hurdles compound these challenges[140]. The substantial investments needed to develop these entire processing systems and the number of additional actors involved (e.g., public and private waste companies, municipalities, cities, etc.) imply that such MSW might not be an effective mitigation option in the *short-term*. An initial phase based on carbon and/or concessional financing for the development of waste processing facilities which could provide clarity and certainty could pave the way for cement companies to then invest in the use of MSW over the medium-term.
3) The use of agricultural waste (including rice husk, corn stover, wheat straw, sugar bagasse, and rice paddy) for biofuels could have an excellent cost-benefit value, if these materials can substitute a sufficient proportion of coal, and provide a reliable source of energy. The adoption of these fuels could result in excellent value, especially if, as some sources suggest, that adopting alternate fuels requires little or no capital expense.[141] However, as pointed out previously in this report, the reliability of these sources of fuels is not guaranteed and must be determined on a case-by-case basis.
4) Transitioning cement plant lines to LC^3 cement production would substantially decrease CO_2 emissions (up to 40%). Kaolinite-bearing clay deposits have been identified in Pakistan which are suitable for the production of LC^3, and both local research institutes and cement companies have already implemented sample analysis and quality tests on clays and potential LC^3 cements. Transitioning towards LC^3 cements would likely imply lower production costs and lower operational costs which could lead to a decrease in infrastructure costs and increasing access to affordable housing in Pakistan. Pay-back time for the transition from OPC to LC^3 cement plants for six different scenarios has been suggested to be as short as 1.4 to 7.1 years[142]. Although there is a clear willingness of the cement industry to transition towards LC^3 cement in Pakistan there are two key issues that need to be addressed : i) High CAPEX remains a substantial barrier: ensuring affordable and accessible financing (through carbon and/or concessional finance) is crucial, ii) Ensuring an enabling environment by securing a long-term demand for LC^3 cements through green public and private procurements and other actions (awareness raising events, capacity building workshops, performance-based

[140] Asif, M., Laghari, M., Abubakar, A.M., Suri, S.K., Wakeel, A. and Siddique, M., 2025, Review on Municipal Solid Waste, Challenges and Management Policy in Pakistan, Portugaliae Electrochimica Acta, 43, 249-258.
[141] Khokhar, M. F. et al (April 2024), Decarbonizing Cement Production, Exploring Pathways to Net-zero in Pakistan, https://acjce.com/wp-content/uploads/2024/05/Decarbonizing-the-Cement-Industry-R06.pdf
[142] Scrivener, K., Dekeukelaere, A., Avet F., Grimmeissen, L., 2019, Financial Attractiveness of LC3, LC3-Project/École Polytechnique Fédérale de Lausanne, Lausanne

standards). However, substantial data gaps remain, including how many cement lines per plant could be converted, type of calciner to be installed (new or repurposed, flash calciner or rotary kiln) location and quality of kaolinite-bearing clay deposits. Indeed, a key issue – aside from the actual CAPEX and installation costs - in ensuring the financial attractiveness of LC3 cements remains the distance of clay deposits from the cement production facility.

5) Currently, the global transition towards BEVs implies that the CAPEX of vehicles and electric charging infrastructure is expected to decrease significantly in the near future, which, combined with expected ROIs of 5-6 years for BEVs, suggests that electrification of transport vehicles in the cement sector represents an effective mechanism to rapidly decarbonize the logistics of cement manufacturing. Electrification of logistics could be particularly beneficial for cement facilities operating as CPPs and produce their own solar energy. A combination of scaling up onsite solar power plants with charging infrastructure and battery storage facilities might be financially attractive. However, substantial data gaps (see section 6.1.2) remain, including the type and quantity of trucks, type and length of routes, kms travelled per months and potential location of chargers. This implies that more detailed analysis of the costs associated with electrification of specific parts of the logistics of cement production cannot be provided and will have to be developed on a case-by-case basis for specific cement plant operators wishing to identify potential financing opportunities through climate and concessional finance to support the upfront costs (additional benefits from electrification can be found in **Table 4**).

6) Long-term engagement with a variety of industrial and governmental actors should pave the way to identify the potential for CO_2 storage in Pakistan with a suggested high-level strategy highlighted in **Figure 17**. Overall, the expected high costs of capturing CO_2 (as shown by the costs of the Norcem Brevik CCS facility in Norway) combined with the requirements of identifying suitable CO_2 storage sites implies that engaging early on with a variety of actors is crucial. Moreover, the potential benefits of storing CO_2 in specific rock formations found in Pakistan could open the way for other industrial actors to engage with the cement industry. As such, CO_2 should not be seen as a simple waste product, but as a potential asset to produce additional resources required for the energy transition.

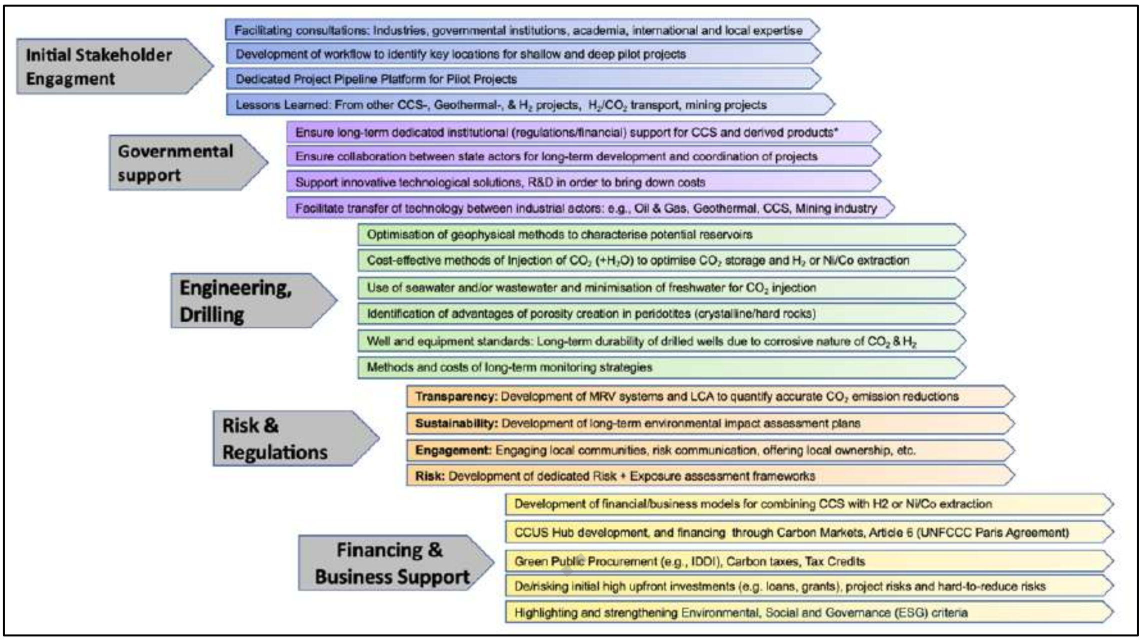


Figure 16 : High-level long-term strategy to setting up a permanent carbon storage infrastructure in Pakistan.

7) Finally, as stated previously, one key aspect of decarbonizing the cement sector by phasing-down or phasing-out fossil fuels is the substantial health benefits which Pakistan will benefit from, and therefore consequently economic benefits. For instance, the direct correlation between coal consumption and a range of health issues implies that an early phase out of coal plants *globally* could help avoid over 14.5 million premature deaths over the next three decades, which is estimated to deliver an economic benefit of US$16.3 trillion[143]. **Table 4** highlights the benefits under SDGs which would result from the implementation of these technologies, and incudes implementation cost and timeframe estimates. **Table 5** is a subset of the previous table and contains technologies that are most feasible to implement in the short and medium terms.

[143] Powering Past Coal: The State of Global Action to End Emissions from Coal Power, November 2022, Powering Past Coal Alliance.

Table 4: Summary of potential mitigation technologies, estimated costs and GHG mitigation potential as well as SDG Impact and challenges/Barriers.

Technology	Cost & time-frame	Estimated cost to implement per plant	GHG Mitigation Potential	SDG potential	SDG impact	Challenges/Barriers (context and technology-related)
SCM Cements (with lower clinker content, e.g., CEM II)	Low/ Short-term (0-5 years)	To be determined (some plants already have this capacity)	High: 10-40% (based on type of cement)	Elevated: SDG1: No Poverty; SDG9 – Industry, Innovation & Infrastructure; SDG11 – Sustainable Cities & Communities; SDG12 – Responsible Consumption & Production; SDG13: Climate Action; SDG17 – Partnership for the Goals.	1) Lower cost cement will provide lower cost housing (affordable housing materials); 2) Resilient infrastructure: Higher quality of LC3 compared to OPC; 3) Environmental and health benefits of decreasing the use of coal; 4) Promotion of sustainable and innovative technologies; 5) Upgrade infrastructure and retrofit industries to make them sustainable	1) Cultural barriers and complexities of national standards and building codes that impede the uptake of lower-clinker cements; 2) Prescriptive instead of Performance-based cements; 3) Lack of awareness and conservativeness amongst users (procurement, engineers, architects) 4) Availability of SCMs in Pakistan to be determined
LC3	Medium cost/Short-term (0-5 years)	Medium: Ca. 10 to 40 Million EUR per new line (1200 tons/days); *Costs vary substantially depending on investments required (i.e., existing integrated plant replacement part of OPC production for LC3 or greenfield plant)*	High: 40% GHG Reduction.	Elevated: SDG1: No Poverty; SDG9 – Industry, Innovation & Infrastructure; SDG11 – Sustainable Cities & Communities; SDG12 – Responsible Consumption & Production; SDG13: Climate Action; SDG17 – Partnership for the Goals.	1) Lower cost cement will provide lower cost housing (affordable housing materials); 2) Resilient infrastructure: Higher quality of LC3 compared to OPC; 3) Environmental and health benefits of decreasing the use of coal; 4) Promotion of sustainable and innovative technologies; 5) Upgrade infrastructure and retrofit industries to make them sustainable; 6) Enhance scientific research, upgrade the technological capabilities of industrial sectors; 7) Support domestic technology development, research and innovation in developing countries	1) Complexities of national standards and building codes which impede the uptake of LC3 cements; 2) Prescriptive instead of Performance-based cements; 3) Upfront investments costs (CAPEX); 4) Lack of awareness and conservativeness amongst users (procurement, engineers, architects); 5) lack of secured, long-term demand (e.g., GPP policies); 6)Early-age strength (24h) differs from OPC

Increased Renewable energy	Low/Short-term (0-5 years)	5-15 million USD (ca. 500´000USD per MW)	Low to Medium (ca. 10%)	SDG11 – Sustainable Cities & Communities	1) Environmental and health benefits of decreasing the use of fossil fuels;	1) Ensuring stable, 24h-long source of RE remains a challenge, however battery-storage technology is becoming cost-competitive as well.
Electric transport	Low-medium/Short-term (0-5 years)	Estimated 3 times the cost of individual fossil fuel trucks (not including charging infrastructure). *Total investment costs depending on size and type of fleet.*	Low (ca. 3-5%)	Elevated: SDG9 – Industry, Innovation & Infrastructure; SDG11 – Sustainable Cities & Communities; SDG12 – Responsible Consumption & Production; SDG13: Climate Action; SDG17 – Partnership for the Goals.	1) Environmental and health benefits of decreasing the use of fossil fuels (reduced tailpipe emissions, reduced fossil fuel imports, reduced noise pollution); 2) Promotion of sustainable and innovative technologies; 3) Upgrade infrastructure and retrofit industries to make them sustainable; 4) Enhance scientific research, upgrade the technological capabilities of industrial sectors; 5) Support domestic technology development, research and innovation in developing countries	1) Awareness of Electric trucks is low and reluctance to adopt new technologies is high; 2) Availability: heavy-concrete mixers, e-excavators, and other e-vehicles are still scaling up; 3) Charging infrastructure and grid capacity; 4) Up-front investment costs (CAPEX); 5) Lack of charging infrastructure and lower range of trucks implies (at the present) fixed routes and shorter trips; 6) Likely a lack of acquiring spare parts for maintenance
Alternative fuel: agricultural waste (biofuels)	Short-term (0-5 years)	Low: USD1 million for a cement plant*	Potentially high – up to 30% - Depends on availability of agricultural waste	Elevated: SDG9 – Industry, Innovation & Infrastructure; SDG11 – Sustainable Cities & Communities; SDG12 – Responsible Consumption & Production; SDG13: Climate Action; SDG17 – Partnership for the Goals.	1) Environmental and health benefits of phasing out the use of fossil fuels in the production of cement; 2) Reduction of emissions, e.g., air pollution from rice paddy burning	1) Depends on the long term and continuous availability of biofuels from agricultural waste of sufficient quality for use in cement industry; 2) development of local supply chains; 3) Development of biofuels processing infrastructure (collection and conveyor belts, drying, shredding, or gasification)
Alternative fuel: Municipal Solid Waste & biofuels	Medium (5-10 years)	Medium: USD5 million and USD18 million for a cement plant*	Potentially high – up to 30% - Depends on availability of MSW	Elevated: SDG1: No Poverty; SDG9 – Industry, Innovation & Infrastructure; SDG11 – Sustainable Cities & Communities; SDG12 – Responsible Consumption & Production; SDG13:	1) Environmental and health benefits of phasing out the use of fossil fuels in the production of cement; 2) Reduction of emissions, e.g., methane emissions from landfills and air pollution from rice paddy burning	1) Depends on the long term and continuous availability of MSW & biofuels from agricultural waste of sufficient quality for use in cement industry; 2) development of local supply chains; 3) Development of MSW and biofuels processing infrastructure (collection and transport of

				Climate Action; SDG17 – Partnership for the Goals.		MSW/biofuels, processing of waste, installation of. sorting and shredding lines); 1, 2, and 3 are presently outside of the control of cement firms
CCS	High/Long-term (10+ years)	High (e.g., ca. 1 billion EUR over 5 years for Norcem Brevik in Norway[144])	High (ca. 65-70%)	Elevated: SDG9 – Industry, Innovation & Infrastructure; SDG11 – Sustainable Cities & Communities; SDG12 – Responsible Consumption & Production; SDG13: Climate Action; SDG17 – Partnership for the Goals.	1) Environmental and health benefits of phasing out the use of fossil fuels in the production of cement; 2) Promotion of sustainable and innovative technologies; 3)) Enhance scientific research, upgrade the technological capabilities of industrial sectors	1) The cost of Capturing CO_2 remains a key barrier; 2) The current energy requirements (or energy penalty) to capture CO_2 at a cement plant can increase energy requirements by 30-50%; 3) Developing CO_2 transport infrastructure and dedicated storage space; 4) high number of actors involved; 5) lack of clear guidelines and policies for the exploration of CO_2 storage opportunities;
Electric Kilns	High//Long-term (10+ years)	currently unknown	High (Ca. 40%) (assuming kilns are powered by renewable energy)	Elevated: SDG9 – Industry, Innovation & Infrastructure; SDG11 – Sustainable Cities & Communities; SDG12 – Responsible Consumption & Production; SDG13: Climate Action; SDG17 – Partnership for the Goals.	1) Environmental and health benefits of phasing out the use of fossil fuels in the production of cement; 2) Promotion of sustainable and innovative technologies; 3)) Enhance scientific research, upgrade the technological capabilities of industrial sectors	1) Currently, technologies are only at the pilot phase; 2) Integration of electric kiln within a stable electric grid; 3) Upfront costs likely high due to new technology.
Waste Heat Recovery	High	7-20 million USD	Low to medium	SDG9 – Industry, Innovation & Infrastructure; SDG11 – Sustainable Cities & Communities; SDG12 – Responsible Consumption & Production; SDG13: Climate Action; SDG17 – Partnership for the Goals.	1) Decreasing use of fossil-fuel derived electricity to power the cement plant; 2) Environmental and health benefits of phasing out the use of fossil fuels in the production of cement;	1) WHR power plants are already widespread in Pakistan (>50% of plants); 2) Actors in the cement industry are looking at additional mitigation technologies so interest appears low; 3) high CAPEX (note that many WHR power plants were financed through the CDM).

[144] https://www.geos.ed.ac.uk/sccs/project-info/1781

Table 5: Most feasible technologies for short & medium term decarbonization of cement in Pakistan

Technology	Feasibility	Reason for feasibility
Increased renewable energy	Very high	The cement industry has already shown that investing in renewable energy (wind and solar) makes financial sense. Sunshine and wind are abundant in Pakistan, as is the technical expertise to implement and operate renewable energy facilities. The only constraints to increasing this production are financing and available space for solar panels and wind farms.
SCM cements (e.g. CEM II)	Very high	The technical capacity to produce these cements already exists in Pakistan – e.g., CEM II is currently produced and sold for export. A targeted campaign could greatly increase domestic demand for these cements in the short term.
LC3	High	Proponents of LC3 in Pakistan include important cement firms and researchers, as well as international OEMs (original equipment manufacturers). As this type of low-carbon cement becomes more commonly used and produced in the coming years, its acceptance in Pakistan and globally will increase. Pakistan likely has good availability of calcine clay (to be confirmed by further study) and has a track record of successfully implementing state-of-the-art cement facilities.
Alternative fuels: Municipal Solid Waste & biofuels from agricultural waste	Medium	While some cement firms have already installed facilities for processing MSW, these efforts have stalled due to the inability to acquire sufficient-quality MSW. However, with several project underway for the separation of organic waste and implementation of sorting facilities, higher quality MSW should become available. Regarding biofuels, some companies have piloted small-scale programs and facilities, and these could be scaled up. However, questions regarding availability, reliability and cost of these fuels remain and must be confirmed on a case-by-case basis.
Electric transport	Medium	This would dovetail very well with increased renewable energy. Barriers include the high cost of purchasing vehicles and charging infrastructure; however, the former should decrease in coming years as electric truck production scales up.

5. Carbon Market Opportunities and Challenges

Pakistan's cement sector has substantial potential to support the nation's climate goals through Article 6 mechanisms. However, realizing this potential requires overcoming several challenges. Chief among these needs is increased capacity for financial investment, as very high interest rates in Pakistan constrain the ability of companies to invest in expensive technologies at cement plants. Further, domestic demand for low-carbon cement should increase. The government can play a key role in overcoming these challenges by creating the conditions for carbon financing of projects in the cement sector and increasing demand for "green" cement. In this way, Pakistan can effectively leverage carbon markets to increase low-carbon cement production, cut emissions, and advance sustainable development.

This section details the ways carbon markets can catalyze emissions reductions from the cement sector in Pakistan. It first outlines market tools commonly used to achieve carbon mitigation, with emphasis on Article 6. It then shows possibilities for Pakistan's cement industry to harness carbon markets for decarbonisation, including incremental and transformational pathways.

5.1 Emissions-trading Systems (ETSs)

ETSs usually use a cap-and-trade system, which sets an overall emissions cap to achieve emissions reductions. Using emissions reduction targets based on previous emissions, emissions permits are auctioned or provided to participants. ETSs are mandatory/compliance mechanisms that create domestic and international markets for carbon mitigation from public and private entities.

Although Pakistan does not currently have and ETS, creating one would incentivize the adoption of cleaner technologies or alternative materials like low-carbon cement, or seek offsets for their own emissions, and companies may be able to purchase offsets under Article 6 of the Paris Mechanism in the future. Further, in all likelihood an ETS in Pakistan would include cement and other heavy industries.

An Emissions Trading Scheme (ETS) is a structured carbon pricing tool that establishes a cap-and-trade system by setting a cap on total allowable emissions within a sector or multiple sectors, then allocates emission allowances to regulated entities. Each allowance permits the holder to emit one metric ton of CO_2 equivalent (CO2e). Allowances may be distributed for free or sold at auction by regulatory authorities. Entities that exceed their allowances must buy more in the market or face penalties. The European Union's ETS, the largest and longest-running, began in 2005, and is now in its fourth phase (2021-2030).[145] This ETS sets emissions caps across energy, aviation, and industry (including cement) sectors. The EU's ETS carbon pricing is pushing the European cement industry toward full de-carbonization, and the production of net-zero cement.[146]

[145] https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets/what-eu-ets_en
[146] https://www.globalcement.com/magazine/articles/1357-the-future-of-eu-ets-prices

Another example, the South Korean ETS (K-ETS), was launched in 2015. The K-ETS became East Asia's first mandatory, nationwide ETS, covering approximately 89% of South Korea's greenhouse gas emissions. This initiative aligns with the nation's commitment to reach carbon neutrality by 2050, as outlined in the 2021 "Carbon Neutral Framework Act." Encompassing 804 major emitters across sectors like power, industry, buildings, and transportation, the K-ETS requires entities to surrender allowances for all covered emissions, with allocation managed through auctions and free distribution. While at least 10% of allowances must be auctioned, energy-intensive, trade-exposed sectors receive free allocations based on benchmarks for production costs and trade intensity, with expanded participation from financial intermediaries and third parties allowed since 2021.[147] Cement has been included as a subsector for benchmarking-based allocation in all three phases of the ETS (2015-2017, 2018-2020, and 2021-2025).[148]

If Pakistan were to develop an ETS, cement would be a clear sector to include in such a scheme. The establishment of an ETS in Pakistan would spur decarbonization of the sector in multiple, important ways. First, it would require all cement producers to carefully account for all GHG emissions. Next, it would provide financial incentives for GHG reduction, and therefore concrete actions to produce lower-carbon cement. This would likely result in the production of large amounts of low or zero-carbon cement (for example, to the EU), which would, in turn, be attractive to the international market for such cements, therefore opening new opportunities for exports. Further, it would likely create concrete opportunities to sell cement-sector emissions reductions (ERs) under Article 6.

5.2 Emissions offset/Baseline and Credit schemes

Emissions offset schemes use a baseline of emissions, e.g., from a cement plant, and measure the difference in emissions after the implementation of a carbon mitigation project. The emissions mitigated are independently verified (by a third party), and purchased by entities (including countries, companies and individuals) who seek to offset their own emissions. These include compliance and voluntary schemes.

Certification standards of carbon emissions reductions, whether under compliance or voluntary markets, uphold key principles and requirements in carbon finance, including:

- **Additionality:** The project should not be mandated by law, widely practiced, or financially viable without the revenue from credits.

- **Accuracy:** The reduction in CO_2 emissions must be conservative and align with the number of offset credits issued, accounting for any unintended GHG emissions caused by the project (also known as "leakage," or "rebound effects"). The carbon mitigated must be independently verified by a third party.

[147] https://icapcarbonaction.com/system/files/ets_pdfs/icap-etsmap-factsheet-47.pdf
[148] https://eneken.ieej.or.jp/data/11487.pdf

- **Permanence:** The reduction in GHG emissions should be irreversible, leading to a lasting decrease in emissions.

- **Unique claims:** Each metric ton of CO_2 can only be claimed once, with proof of credit retirement provided when the project reaches maturity. Credit reductions must only be counted once (not be double counted).

- **Co-benefits:** Projects must comply with all legal environmental and social requirements and should provide additional co-benefits (e.g., in line with the UN's SDGs).

5.2.1. Clean Development Mechanism (CDM)

Under the CDM, instituted under the Kyoto Protocol, mitigation projects created carbon credits that were sold to countries and companies that used these credits to meet their carbon mitigation obligations. The CDM was the predecessor to the Paris Agreement's Article 6 mechanisms.

Pakistan's cement industry has previously successfully engaged carbon markets to spur mitigation projects, notably under the CDM. A total of 10 projects in the sector were successfully registered under the CDM, 7 for Waste Heat Recovery and 3 for Alternative Fuels (see table below).[149] The projects were registered from 2010 to 2016, and the companies were Bestway, DG Cement, Attock Cement, Maple Leaf Cement, Lucky Cement, Fecto Cement, and Fauji Cement. The total annual estimated reductions of these 10 projects were 724,408 metric tons of CO_2.[150]

Table 6 - CDM Cement Sector Projects in Pakistan (citation in text)

Date	Title	Other Parties	Methodology *	CO2 Reductions **
Aug 2010	Waste Heat Recovery based 15 MW Power Generation Project at Bestway Cement Limited, Chakwal, Pakistan	Japan Sweden	AMS-III.Q. ver. 2	48,060
Nov 2011	DGKCC Waste Heat Recovery and Utilization for 10.4 MW Power Generation at Dera Ghazi Khan Plant	Switzerland	AMS-III.Q. ver. 3	33,845
Oct 2012	Waste heat recovery and utilization for power generation at DG Cement Khairpur Plant	Switzerland	AMS-III.Q. ver. 4	28,542
Nov 2012	Substitution of coal with alternate fuels at DG Khan Cement Company Limited, Khairpur Plant	Switzerland	ACM0003 ver. 7	132,439
Nov 2012	Partial substitution of coal with alternate fuels at DG Cement, Khofli Sattai Dera Ghazi Khan Plant	Switzerland	ACM0003 ver. 7	162,135
Nov 2012	Waste Heat Recovery CDM Project at Attock Cement Pakistan Ltd.	United Kingdom	AMS-III.Q. ver. 4	34,417

[149] Projects identified by searching CDM website - https://cdm.unfccc.int/
[150] Authors' calculations from https://cdm.unfccc.int/

Dec 2012	Waste Heat Recovery and Utilization for Power Generation at Maple Leaf Cement Factory Limited, Iskanderabad, Pakistan	United Kingdom	AMS-III.AL. AMS-III.Q. ver. 4	49,785
Jul 2013	Substitution of coal with alternate fuels at Lucky Cement Limited, Karachi Plant	Switzerland	ACM0003 ver. 7	191,542
Jul 2014	Waste Heat Recovery Power Plant at Fecto Cement Limited.		AMS-III.Q. ver. 5	14,995
Oct 2016	Fauji Cement Company Limited Waste Heat Recovery Project	Germany	AMS-III.Q. ver. 6	2,8648

* ACM - Consolidated Methodologies, AMS - Small scale
** Estimated emission reductions in metric tons of CO2 equivalent per annum (as stated by the project participants)

5.2.2. Article 6

Under these types of arrangement, which include Articles 6.2 and 6.4 of the Paris Agreement (described in greater depth above, in Section 1.1.), Pakistani cement firms could engage in baseline-and-credit activities to generate Internationally Transferred Mitigation Outcomes (ITMOs). Pakistani cement companies will first measure baseline emissions related to cement production, then implement carbon mitigation measures. The measurable difference between the baseline emissions and the emissions mitigated by the project will be offered for sale to countries or firms to meet their emissions targets.

Currently, formal activity under Article 6 has been under Article 6.2, in the form of bilateral agreements (BAs). As of November 2024, 91 BAs have been realized between 56 countries. [151] Altogether, there are 141 recorded pilot projects, with Japan's Joint Crediting Mechanism (JCM) accounting for 119 of these. Other countries that have engaged in BAs include Australia, Japan, Norway, Singapore, South Korea, Sweden and Switzerland.

Among these 141 pilot projects, only five have received Authorization Statements from the UNFCCC[152] (see table below). The participating countries—Ghana (3 projects), Switzerland (4 projects), Thailand, and Vanuatu—have also submitted Initial Reports to the UNFCCC. These projects collectively aim to generate a substantial amount of Mitigation Outcomes.

Table 7 - Article 6.2 Projects that have received Authorization Statements (citation in text)

Project	Countries	Period	Expected CO2 Mitigations
Promotion of climate smart agriculture practices for sustainable rice	Ghana-Switzerland	1 June 2022 to 31 December 2030	1,344,592 tCO2e, at an average of 156,712 tCO2e/year[153]

[151] https://unepccc.org/article-6-pipeline/
[152] Ibid
[153] https://www.bafu.admin.ch/dam/bafu/de/dokumente/klima/klima-kop-ausland-ab-2022/5001_MADD.pdf.download.pdf/5001_MADD.pdf

cultivation in Ghana			
Bangkok E-Bus Program	Thailand-Switzerland	2022-2030	1.5 million t CO_2e until 2030[154]
Electrification of Vanuatu's Inhabited Islands through Solar Power ITMO Programme	Vanuatu-Switzerland	1 April 2022 – 31 December 2030	97,217 tCO2e until 2030[155]
Integrated waste recycling and composting for methane reduction in Ghana	Ghana-Switzerland	1 January 2023 – 31 December 2030	1,598,292 tCO2e until 2030[156]

Example: Renewable Energy for Cement Plant Japan's Joint Crediting Mechanism (JCM) shows how the cement industry can provide carbon offsets under Article 6.2. A JCM project in the Philippines provides 9MW of renewable solar energy to a cement plant (and a ceramics factory) in the country.[157] The project, which began in 2022, substitutes fossil-fuel generated electricity with clean electricity generated by solar panels at the cement plant. Expected annual mitigation from the project is 6,751 tCO2-e.

5.2.3. Voluntary Carbon Markets

Under Voluntary Carbon Markets, entities (such as companies or individuals) can purchase carbon offsets for their own carbon-producing activities. There are multiple registries for VCM offsets, including the American Carbon Registry (ACR), Climate Action Reserve (CAR), Gold Standard, and Verra's Verified Carbon Standard (VCS). These are

[154] https://www.klik.ch/en/international/activities/bangkok-e-bus
[155] https://www.bafu.admin.ch/dam/bafu/de/dokumente/klima/klima-kop-ausland-ab-2022/5005_MADD.pdf.download.pdf/MADD%20Vanuatu%20%E2%80%93%20Solar%20Power%20Electrification%20Programme%20(project%20ID%20number%205005).pdf
[156] https://www.bafu.admin.ch/dam/bafu/de/dokumente/klima/klima-kop-ausland-ab-2022/5035_MADD_public_geschw.pdf.download.pdf/5035_MADD_public_geschw.pdf
[157] https://gec.jp/jcm/projects/22pro_phl_03/
[158] Source : JCM website, Energy Supply Project by 9MW Solar Power System to Ceramic Factory and Cement Plant | JCM The Joint Crediting Mechanism

private, independent, non-governmental organizations. They establish project standards, ensuring adherence to those standards, oversee the issuance and cancellation of credits, and generate income from the offsets they certify.

Most companies that buy carbon offsets are large, multinational corporations, which use the offsets to gain status as "carbon neutral" or in pursuit of decarbonization goals. Examples of companies that purchase these offsets include easyJet, Boeing, Telstra, Chevron, and DPD. The two largest buyers of VCM credits, Delta Airlines and Shell, constitute about 35% of all VCM offsets in a recent study.[159]

The VCM has enjoyed considerable success in Pakistan, not least because of one large project in the state of Sindh. The Delta Blue Carbon Mangroves project is listed on Verra's Verified Carbon Standard and promises to sequester 142,050,139 tCO2e over its 60-year life span[160]. With a project area of 350,000 hectares, the project reports the creation of 21,000 jobs.

A cursory review of a database of all listed VCM projects[161] revealed numerous cement sector VCM initiatives. This database included cementer sector projects involving a diverse range of focuses, including WHR, renewable energy generation, SCM cements, and biomass power generation.

This database includes two VCM projects from the cement sector in Pakistan. These projects are both with Bestway cement and are currently (November 2024) listed on Verra's website as "under validation." One of these projects is for solar energy[162] and another is for a WHR plant[163].

The above-mentioned VCM solar project involves developing renewable energy plants using Solar photovoltaic technology to supply electricity to its factories. The voluntary initiative replaces fossil fuel-based grid power with clean energy, reducing greenhouse gas (GHG) emissions. The project currently includes six Solar PV power plants owned and managed by Bestway Cement, with the potential to add more in the future. All plants will be located in Pakistan, with the initial six expected to reduce emissions by 422,719 tCO2e over 10 years.[164]

5.2.4. Price differences and potential interactions between VCM Carbon Credits and compliance-based schemes (Article 6 and ETSs)

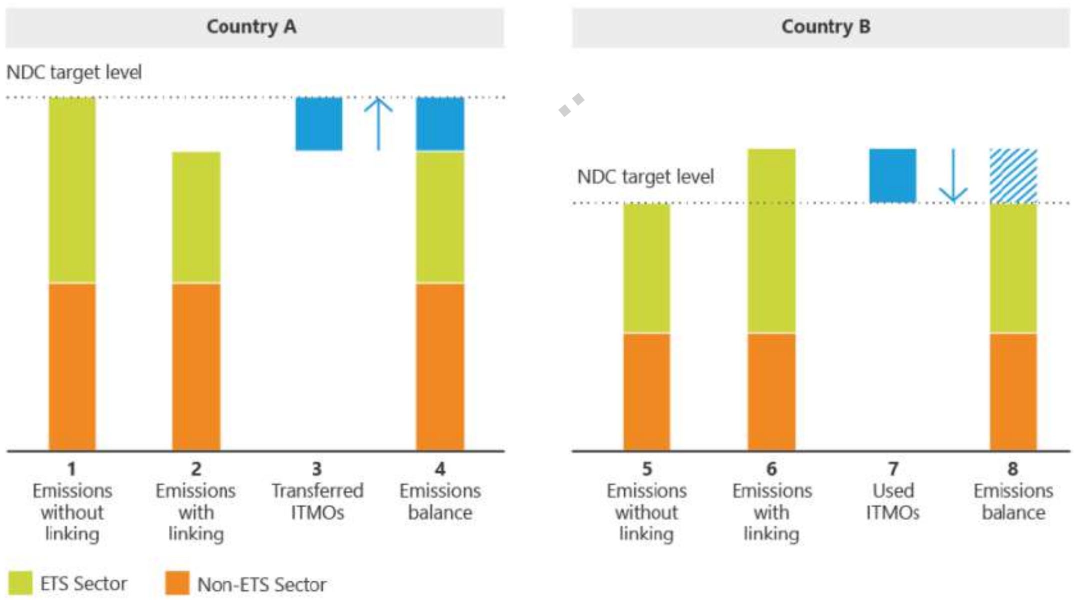
There are currently important differences between carbon prices in compliance-based ETSs (generally higher) and VCM offsets (usually lower). Bloomberg NEF projects that prices for VCM offsets will average $20 per metric ton in 2030, while for ETSs in California, US, and the EU, the prices will be $93 and $162 per metric ton, respectively.[165] The prices of carbon in ETSs is particularly important for mitigation activities under

[159] Trencher et al, 2024. https://www.nature.com/articles/s41467-024-51151-w
[160] https://deltabluecarbon.com/
[161] https://gspp.berkeley.edu/research-and-impact/centers/cepp/projects/berkeley-carbon-trading-project/offsets-database
[162] https://registry.verra.org/app/projectDetail/VCS/5098
[163] https://registry.verra.org/app/projectDetail/VCS/5124
[164] https://registry.verra.org/app/projectDetail/VCS/5098
[165] https://about.bnef.com/blog/global-carbon-market-outlook-2024/

Article 6, as Article 6-based emissions reductions are expected to be connected to ETSs, especially as countries operating under ETSs could link their ETSs. Linking ETSs would facilitate the ability of a country to reach its carbon obligations by purchasing ITMOs from other another country.[166]

The figure below shows how linking ETSs could facilitate the use of ITMOs to reach carbon goals. After linking ETSs, if Country A has emissions that are below its NDC target, it could generate and transfer these ITMOs to Country B (country that receives ITMOs), whose emissions have exceeded the NDC target level in the same period.

Figure 17 - Linked ETSs under Article 6[167]



As Article 6 activities mature, there could very well be interactions between Article 6 and VCM carbon emissions reductions. Indeed, a recent UNDP (January 2024) study suggests that many VCM projects are well-positioned to become imbedded in Article 6 activities.[168] In the case of Pakistan, where there are existing VCM activities underway, the government would need to provide a clear strategy on how VCM credits would be incorporated into Article 6. This would include a national VCM registry that would also report on Emissions Reductions and Removals counted toward Pakistan's NDCs, if the VCMs were to be linked to Article 6.[169]

The figure below shows different options for incorporating VCM credits into Article 6 and shows that the strongest potential is to incorporate VCM activities directly into Article 6.2 (country to country transfer of ITMOs to reach NDC goals).

[166] D. Hynes and L. Schneider. (2023). Applying Rules under Article 6 of the Paris Agreement to Linked Emissions Trading Systems. Berlin: International Carbon Action Partnership, https://icapcarbonaction.com/system/files/document/art-6-and-ets-linking_final-version_0.pdf
[167] Ibid, p. 12
[168] https://www.undp.org/sites/g/files/zskgke326/files/2024-05/UNDP%20-%20Voluntary%20Carbon%20Market%20%28VCM%29%20Report%20-%2005.07.2024.pdf
[169] USAID, February 2024, https://www.climatelinks.org/sites/default/files/asset/document/2024-06/2024.4.10%20Pakistan%20VCM%20Learning%20Guide%20FINAL.pdf

Figure 18 - Modalities of Incorporation of VCM into Article 6[170]

Article 6 only (private actors invest in 6.2 or 6.4 activities)	Article 6	VCM only (with proactive government steering)	VCM only (with minimal guidelines from government)
• For 6.2: Government provides an overall framework or program under which private entities can invest in Cooperative Approaches • For 6.4: Private sector can directly invest in approved activates	• For countries with existing VCM activities, government may develop an Art 6.2 program that covers existing and future VCM activities	• Government identifies which sectors are included or excluded in the VCM and facilitates investments into VCM activities	• Government formulates safeguards and ensures VCM activities are aligned with country priorities • No link to Art. 6

5.2.5.Results-Based Climate Financing (RBCF)

Results-based climate financing (RBCF) is a funding approach where financial support is provided only after specified climate-related outcomes have been achieved and verified. This model contrasts with traditional financing methods, where funds are provided upfront. An example of RBCF opportunities for the cement sector in Pakistan is the World Bank's multi-donor fund called "Scaling Climate Action by Lowering Emissions" (SCALE).[171]172 SCALE's "Pillar II-Sustainable Infrastructure Solutions" are designed for deep decarbonization initiatives in industry, among other sectors. RBCF could be particularly useful for the high CAPEX investments needed to decarbonize cement production, where investments in technology can be particularly expensive.

5.3 Incremental and transformational technologies to transform the cement sector

This section describes two paths forward for decarbonizing the cement industry. It first outlines incremental changes that are well-established solutions in the cement industry but may not be common practice in Pakistan. Next, transformational changes are outlined that have the potential to deeply decarbonize the industry. These transformational changes also entail new business opportunities for the cement industry and other sectors.

Both incremental and transformational technologies should be pursued by stakeholders in Pakistan. Since the technologies for incremental change are already commonly available, these can be thought of as "low-hanging fruit." In the meantime, transformational technologies are more likely to be under development, in pilot phases, and/or not yet widely adopted by the cement industry worldwide. However, traditional/incremental methods of decarbonisation will not be sufficient for the Cement sector to decarbonize thoroughly[173]. As such, it is important for cement industry stakeholders in Pakistan to consider these technologies in medium and long-term planning, so the industry can stay competitive and take advantage of opportunities available for carbon financing, under SPAR6C and other initiatives.

[170] Climate Focus, 2023, in UNDP, 2024: https://www.undp.org/sites/g/files/zskgke326/files/2024-05/UNDP%20-%20Voluntary%20Carbon%20Market%20%28VCM%29%20Report%20-%2005.07.2024.pdf
[171] https://www.worldbank.org/en/programs/scale
[172] https://www.worldbank.org/en/programs/scale
[173] Czigler, T., Reiter, S., Schulze, P., Somers K., 2020. Laying the foundation for zero-carbon cement, McKinsey & Co.

5.4 Incremental technologies

Current initiatives to decrease CO_2 emissions in the cement sector are highlighted in **Figure 21**. Improvements in energy efficiency –are clearly needed and welcome as are initiatives to decrease the proportion of clinker in cement, the more efficient use of cement (and concrete) during construction (of buildings, infrastructure) and the use of waste as a replacement for coal as a fuel.

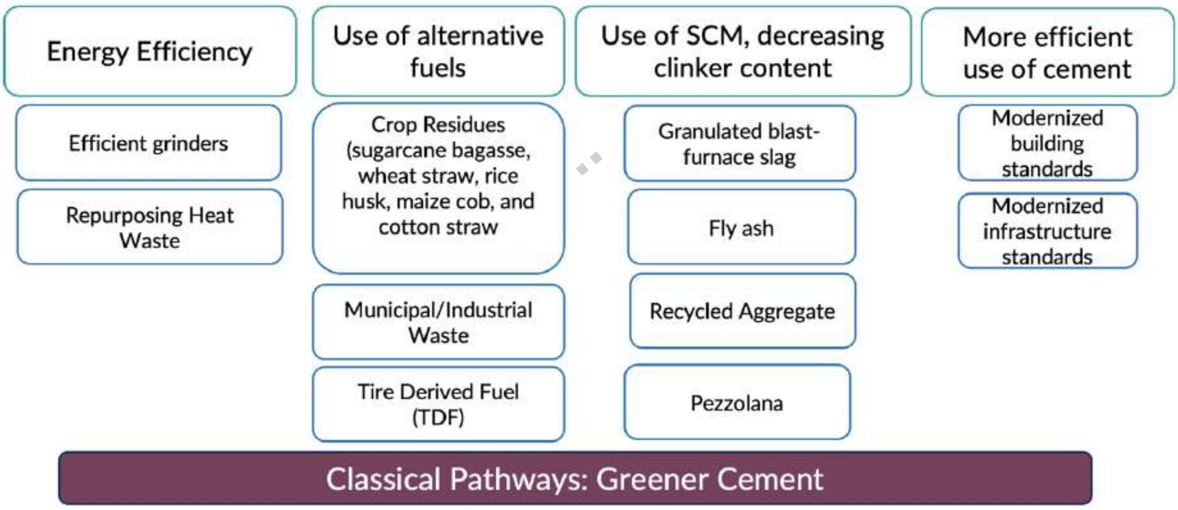


Figure 19 : Classical initiatives for decarbonizing the cement industry. SCMs are supplementary cementing materials.

However, some of these incremental technologies have experienced significant obstacles in Pakistan. Some of these are outlined below.

5.4.1. Alternative Fuels

The cement industry in Pakistan began exploring the use of alternative fuels (AFs) in the early 2000s, experimenting with agricultural waste like rice husks, as well as poultry waste, carbon black, sugar mud, and municipal solid waste (MSW). However, challenges such as the availability of these materials in sufficient quantities, inconsistency in quality, and seasonal dependence have hindered their widespread adoption. Fauji Cement and DG Cement were pioneers in using MSW as an alternative fuel, securing agreements with local authorities to ensure a consistent and uninterrupted supply to their plants in Jhang Bahtar and Chakwal. These companies made significant investments in state-of-the-art refuse-derived fuel (RDF) plants. Unfortunately, these initiatives did not flourish, leading to the shutdown of the RDF plants due to the high moisture content of the supplied MSW, which averaged around 40%. This high moisture level significantly increased internal heat consumption compared to coal, which typically has a moisture content of 10-12%.

Stakeholder engagement has highlighted substantial challenges in acquiring the required amount of high-quality agricultural waste and/or MSW that would be required for processing in a cement plant to replace coal. Thus, although further efforts could be made in scaling up the use of these AFs (based on local feasibility), the focus of decarbonization should also be on additional levers to drive decarbonization (both medium and long term), which outlined below.

5.4.2. Supplementary Cementitious Materials (SCM)-based cement

During the SPAR6C stakeholder workshops held in April 2024, cement industry leaders in Pakistan informed that there were cultural obstacles to using cements with lower clinker content in the country. Participants mentioned that all megaprojects specified the use of Portland cement, and that the standards organizations and construction (housing and infrastructure) industry in general was reticent to deviate from the OPC standard.

Since the EN 197-1 standard (outlined above, in Section 4.1.1. Supplementary cementitious materials (SCMs)-based cement) was adopted in Pakistan in 2014, a few cement plants in the southern region have introduced CEM-II to the local market (exact data on its production is not publicly available). In the northern region, companies like Bestway Cement and Fauji Cement have also attempted to market their CEM-II brands but have not gained significant traction, mainly because there a significant market for such cements did not emerge in Pakistan. However, CEM-II cement has become an integral part of Pakistan's cement exports to countries like Afghanistan and regions in Africa. A switch from the current PS-232:2008® standard to CEM-II cement could increase the capacity of cement production in Pakistan considerably, e.g., to the order of 20-25% with this single decision (an empirical study would be needed for a more precise estimate). A shift to widespread CEM-II use in Pakistan could also potentially reduce carbon emissions, as the clinker content in CEM II is lower than in the typically used OPC, ranging from 65% to 89%, depending on the specific type of CEM II cement. Depending on the clinker content of the type of cement, this could reduce carbon emissions per ton of cement by 10-40%[174] When considering lifecycle emissions for cement (e.g., including mining and transport of coal versus using SCMs), emissions are even lower for cements lower in clinker content.[175]

However, there are some questions around the lower-clinker cements outlined above. Most SCMs are in short supply and are expected to grow scarcer with time as a result

[174] Król, A., Giergiczny, Z., & Kuterasińska-Warwas, J. (2020). Properties of concrete made with low-emission cements CEM II/CM and CEM VI. Materials, 13(10), 2257.
[175] Şanal, İ. (2018). Discussion on the effectiveness of cement replacement for carbon dioxide (CO2) emission reduction in concrete. Greenhouse Gases: Science and Technology, 8(2), 366-378.

of closing coal power plants (decrease fly ash supply) and transitioning of the steel industry towards direct reduced Iron (H_2-DRI) and electric arc furnaces (decrease in blast furnace slag). There may be other technical constraints (e.g., scarcity of SCMs in Pakistan) that lead cement industry stakeholders to favor other solutions, such as LC3. As such, it is necessary to begin developing the technologies outlined below.

5.5 Transformational technologies

One of the main issues that needs to be addressed in the cement manufacturing industry is that cement production will likely *always* emit CO_2 due to the use of limestone. As such, ultimately, transformational technologies will be needed achieve deep decarbonization in the sector. Therefore, in order to develop a clear, ambitious and transformational roadmap to decarbonize the cement sector, the central questions that need to be addressed are:

i) **Q1: Energy consumption:** how to efficiently decrease non-process related emissions?
ii) **Q2: Process emissions:** How to effectively decrease process emissions in cements?
iii) **Q3: Residual process emissions:** How can CO_2 be efficiently captured?
iv) **Q4: Storage:** How and where can CO_2 be efficiently stored?
v) **Q5: New business opportunities:** Which industrial actors can play a role and benefit from such initiatives?

A summary of ambitious decarbonization pathways are detailed in the next pages.

5.5.1. LC3

Modification of current production lines to manufacture LC^3-50 cements, leading to a 40% reduction in CO_2 emissions of production lines. This solution is currently hampered by, on the one hand, a lack of production and supply of LC^3 in Pakistan. Once production is established, and ideally well before, the basis must be laid the large-scale adoption of LC^3-based cement in construction. While there is currently an approved standard for LC^3 in the country, building codes need to incorporate calcined clay-based cement and procurement rules should also be updated to promote use of the low-carbon cement. Note that such shifts towards LC^3 cements could open-up significant international markets where LC^3-cements are accepted. The figure below illustrates the steps for rapid decarbonization via LC3.

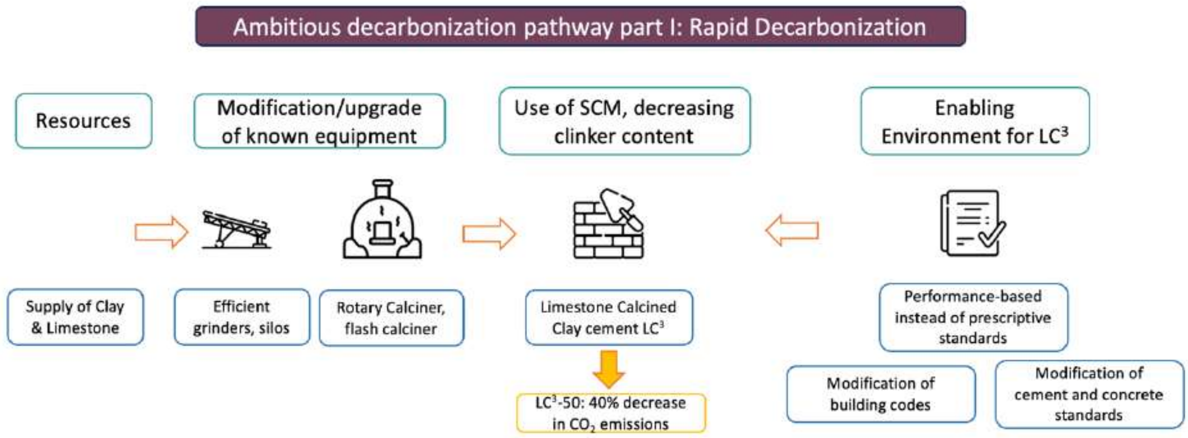


Figure 20: Ambitious Pathway to Decarbonization of the cement industry via LC3

5.5.2.Transport Electrification

Electrification of vehicles and scaling up of solar power represents low-hanging fruit which can efficiently decrease CO_2 emissions due to the rapid rise of electric vehicles in all vehicle categories. Although emission mitigation from electrification of logistics (at the quarry, transport to the facility and final delivery of final products) is rather small (ca. 3% of total emissions at a cement plant[176] - (*note that current data is not available for plants in Pakistan*), vehicle electrification – in combination with in-house solar power generation– represents a low CAPEX solution which is in line with current efforts to electrify transport systems (i.e., *low-hanging fruit*). A 3-step pathway to decarbonise the transport sector of a cement plant (or plants) is shown in **Figure 24.** Please note that while heavy-duty electric trucks may currently be quite expensive, their production is expected to increase significantly from 2024-2030, and OEMs are offering new models for varied industrial applications.[177] As such, the possibility of electrifying transport related to cement production should becoming increasingly more realistic in Pakistan in the coming years.

[176] Czigler, T., Reiter, S., Schulze, P., Somers K., 2020. Laying the foundation for zero-carbon cement, McKinsey & Co.
[177] https://www.grandviewresearch.com/industry-analysis/heavy-duty-electric-trucks-market-report#:~:text=The%20global%20heavy%2Dduty%20electric,20.6%25%20from%202024%20to%202030.

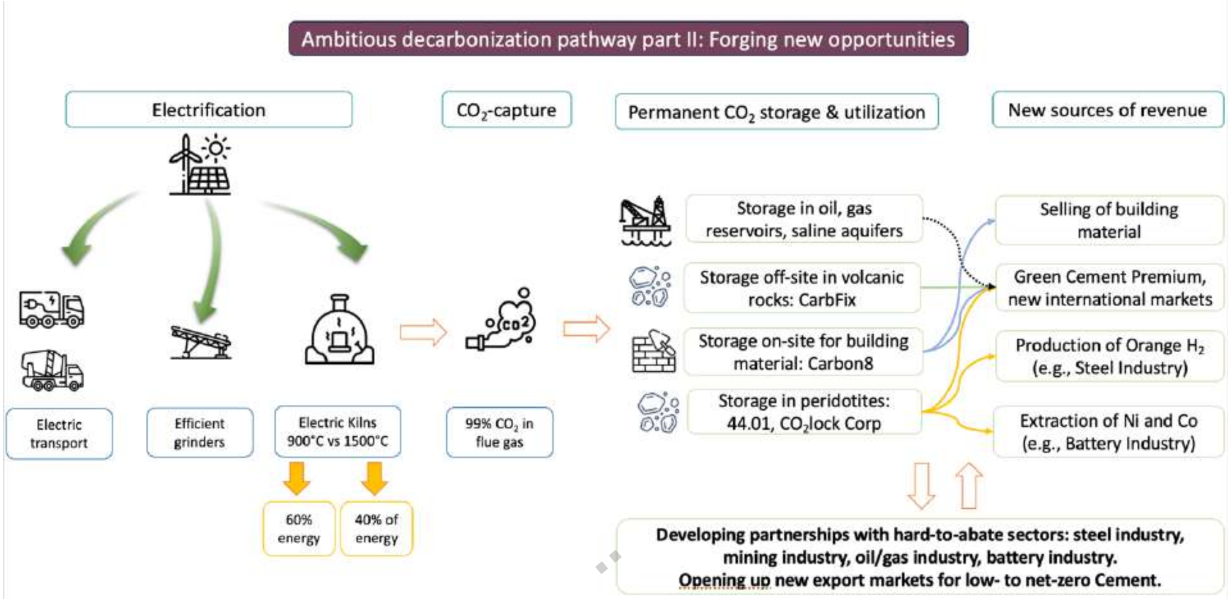


Figure 21: Ambitious decarbonization pathways for the cement sector via full electrification.

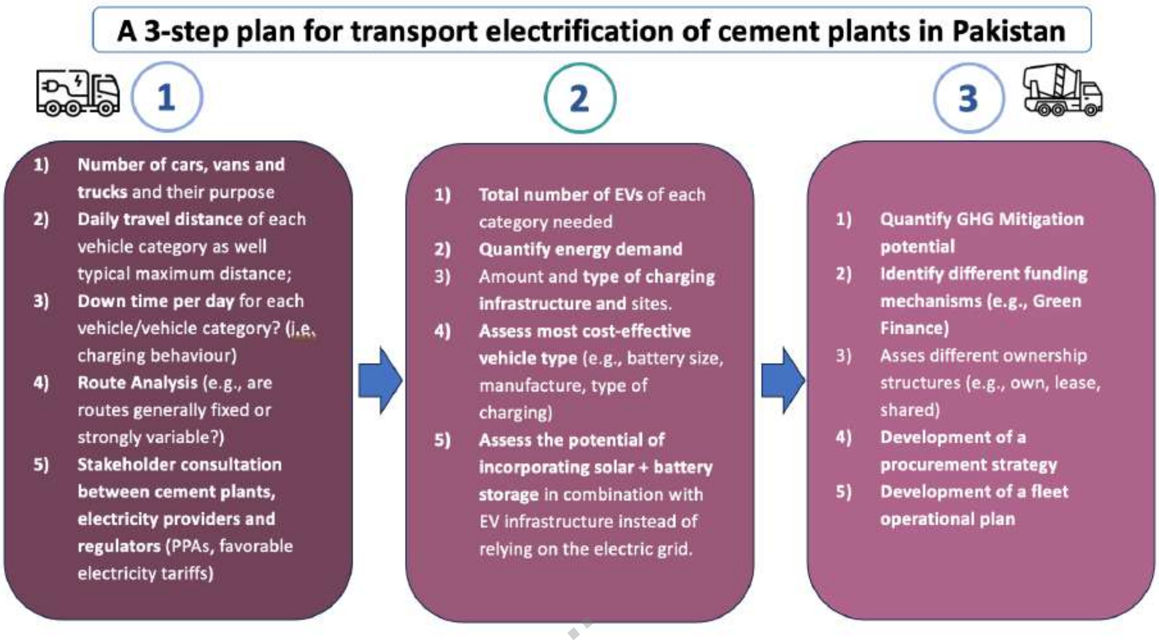


Figure 22: A 3-step program to decarbonize the transport sector in the cement industry

5.5.3. Ambitious electrification

can be addressed through the use of electric kilns as highlighted in previous sections. Not only does such a technology rely exclusively on electricity, it does not rely on additional chemical processes which have also been proposed for the cement industry (e.g., use of Hydrogen and oxy-combustion, both of which require high-purity chemicals, i.e., H_2 or O_2). Instead, electric kilns produce high-purity CO_2 flue gases of ca. 99% CO_2. As stated previously this implies that no additional CCS infrastructure is required (e.g., amine processing, calcium-looping). The flue gas can therefore be used or transported directly. (*Note that alternative technologies using amine-scrubbing are gradually scaling up in the cement sector with the development of the modular Aker Carbon Capture system "Big Catch" which has a capacity of >400´000 tons of CO_2 per year and which has been installed at the Brevik cement CCS facility in Norway*[178]*).*

It is important to note that two types of electric kilns are currently under development:
a) Kilns reaching temperatures of 850-950°C, enabling the transformation of limestone into CaO (lime) and CO_2 (process emissions)
b) electric kilns reaching 1450°C which can be used for sintering and production of clinker.

Therefore, the total GHG mitigation potential depends on whether kilns will be used for calcination alone or calcination + sintering. It is likely that an initial first step will see pilot facilities focusing on scaling up electric kilns to 900°C, leaving the sintering process to be fired by traditional methods (i.e., coal + waste). However, as stated previously, this would allow to replace 60% of the energy used for calcination and sintering by electric power supply, substantially decreasing GHG emissions from fossil fuels.

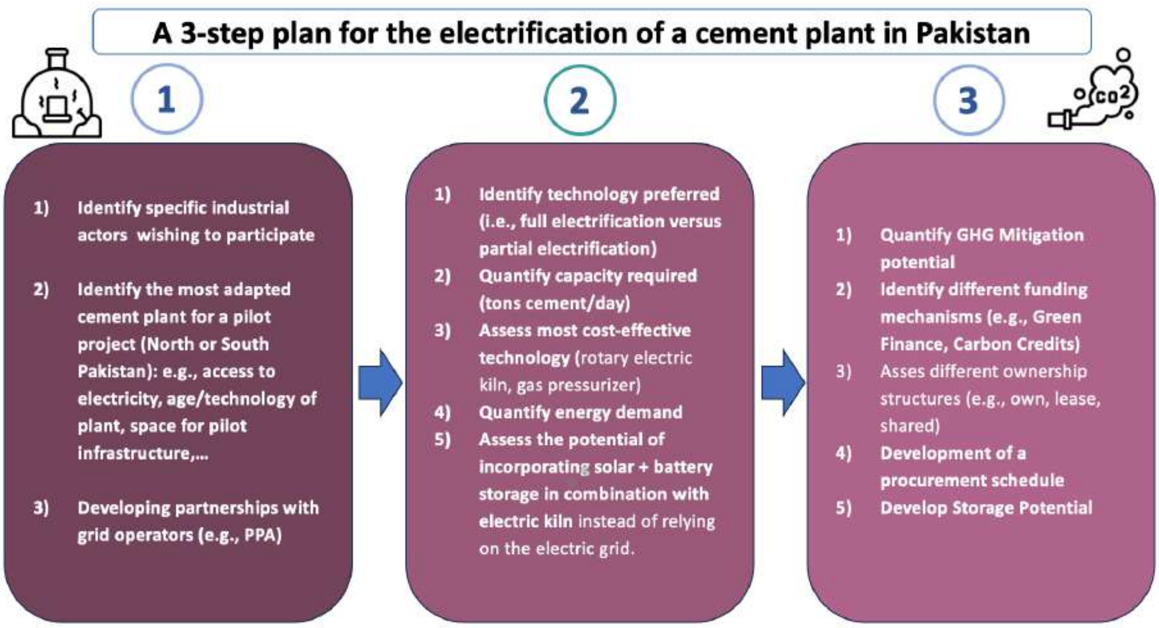


Figure 23: A 3-step plan to develop a pilot project to electrify a cement plant in Pakistan

5.4.4. C02 Storage and use

Carbon capture and use (CCUS) can be directly linked together depending on the type of long-term storage needed or preferred. This report does not include the potential

[178] https://akercarboncapture.com/offerings/big-catch/

for CO_2 for the use in Enhanced Oil Recovery (EOR), methanol and derivatives (i.e.., plastics and jet fuel), Urea (fertilizer), carbonation of drinks and use of CO_2 to promote plant growth. The reason for this is that CO_2 is not stored permanently but is re-emitted at a later stage. What is required are methods for ***permanent storage***, which outlined below:

1. CO_2 can be stored in oil & gas reservoirs and saline aquifers, typically found several km deep in sedimentary formations. Such CO_2 reservoirs are well aligned with point source industrial emissions in Pakistan and could be a location for CO_2 storage, with initial CO_2 storage capacity estimated at 1.7Gt CO_2, which is significantly higher than industrial emissions in Pakistan[179]. However, there is currently no known initiative to develop such CO_2 storage systems in Pakistan. The investments for this type of CCS method are also significant. Therefore, alternative (yet complimentary) storage systems should be explored.

2. Instead of storing CO_2 in sedimentary rocks, CO_2 can be stored as a solid mineral in volcanic rocks such as basalts. In this case, captured CO_2 is transported to thick lava flows where CO_2 can be injected a few hundreds of meters below the surface (*significantly shallower than other methods*). Storage in hard rocks such as basalts offer compelling advantages compared to traditional storage, namely shallower injection and rapid transformation of CO_2 into minerals within weeks to years following injections. This is because Iron, Magnesium and Calcium contained in these rocks rapidly reacts with the incoming CO_2 to form carbonates, thereby decreasing the risks of CO_2 migration and leakage and consequently decreasing long-term monitoring costs. This implies that costs of monitoring the storage system after CO_2 injection is limited in time. CO_2 storage in basalts is currently spearheaded by CarbFix in Iceland, where costs of CO_2 storage in such rocks is estimated at USD 25/ton of CO_2[180], which assuming 25 million tons of CO_2 per year (process emissions) implies a total cost of 625 million per year (at minimum). Such a system would initially require careful identification and mapping of geological formations that would be suitable for CO_2 storage.

3. Due to the estimated cost of storing CO_2, alternative methods should be found where CO_2 can provide additional revenue. One possibility is that CO_2 can be stored directly at the cement manufacturing site. The 99% CO_2-rich flue gas derived from the electric kiln is reacted with industrial and mining waste such as ash, slag, cement bypass dust, cement kiln dust to produce aggregates which can be used in

[179] Holloway, S.G.A.K.M.D.A., Garg, A., Kapshe, M., Deshpande, A., Pracha, A.S., Khan, S.R., Mahmood, M.A., Singh, T.N., Kirk, K.L. and Gale, J., 2009. An assessment of the CO2 storage potential of the Indian subcontinent. *Energy Procedia*, *1*(1), pp.2607-2613.

[180] Gunnarsson, I., Aradóttir, E.S., Oelkers, E.H., Clark, D.E., Arnarson, M.Þ., Sigfússon, B., Snæbjörnsdóttir, S.Ó., Matter, J.M., Stute, M., Júlíusson, B.M. and Gíslason, S.R., 2018. The rapid and cost-effective capture and subsurface mineral storage of carbon and sulfur at the CarbFix2 site. *International Journal of Greenhouse Gas Control*, *79*, pp.117-126.

the building sector. Several start-up companies include Carbon8[181] (United Kingdom) are expanding, where individual CCS systems can capture up to 4´000 tons of CO_2 per year and recycle up to 12´000 tons of industrial waste and transform it into building materials. In North America, Blue Planet[182] is offering similar solutions and is financially supported by cement industries such as Holcim. These methods are significantly cheaper than conventional CCS systems as the CO_2 does not need to be purified, liquified and transported to a storage site and instead is stored on site directly from the flue gas exhaust system. The reacted material can be repurposed and resold as building material, providing additional income for industries. Importantly, many other industrial actors, such as the steel industry, are close to cement industries in Pakistan.

Table 8: Industrial materials which can be used for on-site CO_2 storage (data from Carbon8, see text for reference).

Potential Residues	Industries Targeted
Fly ash	Energy from Waste incinerators, biomass, coal
Cement bypass / kiln dust	Cement, lime production
Ash	Paper & Pulp Industry
Slag	Steel Industry
Mine Tailings	Mining Industry
Concrete fines (recycled concrete aggregate)	Construction and demolition
Sludges	Water Treatment Industry
Drill cuttings	Oil& Gas and Geothermal Industries
Filter Cake	Diverse Industries

4. Carbon-Curing of building materials can lead to the storage of CO_2 in pre-cast concrete slabs or ready-mix concrete, thereby providing additional ways of storing CO_2, a method being pioneered by companies such as CarbonCure[183]. Pre-cast concrete offers the additional benefit of using less material as the concrete slabs are cured in a controlled atmosphere in a factory.

5. Basalts are only one of several hard rocks capable of retaining significant amounts of CO_2. An additional rock type is represented by mantle rocks, dominated by peridotites. These rocks, related to basalts, form a large part of the ocean floor globally and are found in mountain ranges worldwide[184]. Large segments of western Paki-

[181] https://www.carbon8.co.uk
[182] https://www.blueplanetsystems.com/partners
[183] https://www.carboncure.com
[184] McCarthy, A., Tugend, J., Mohn, G., Candioti, L., Chelle-Michou, C., Arculus, R., Schmalholz, S.M. and Müntener, O., 2020. A case of Ampferer-type subduction and consequences for the Alps and the Pyrenees. American Journal of Science, 320(4), pp.313-372.

stan, from the South to the North, are formed of geological formations ("Ophiolites") containing these rocks[185,186]. This implies that CO_2 storage involving peridotites might well be a viable opportunity for Pakistan. Storage costs of around 10$ per ton could be achieved in ideal conditions, depending on the pressure and temperature of storage and the porosity of the rocks, all of which strongly influence the affordability of a given project. Pakistani researchers have identified possible sites to begin CCS.[187]

4a. *CO_2 Storage and Hydrogen production*: The reaction of CO_2 and water (H_2O) with these rocks can lead to the production of Hydrogen (known as Orange Hydrogen) through a natural process of *serpentinization*[188]. The natural consequence of this reaction is that natural wells of hydrogen are found worldwide, and it is estimated that naturally occurring Hydrogen worldwide might currently produce 23 million tons of Hydrogen per year. Each cubic meter (m^3) of peridotite can produce 2-4 kg of H_2 under optimal conditions, which implies that known peridotites worldwide could be the source of 100 trillion tons of Hydrogen. Currently, several companies are exploring naturally occurring Hydrogen wells worldwide[189,190] with one such well already being used by local populations in Mali since 2012[191]. Sustainable hydrogen is likely to be an important component of a sustainable energy transition (e.g., Green Urea, Ammonia, Methanol, steel manufacturing). Therefore, there is a significant potential for industrial synergies where storing CO_2 permanently could produce sustainable Orange Hydrogen for use in other industries[192]. Considering the current cost of green hydrogen (USD 8-10 per kg of H_2) and the limited production of green hydrogen worldwide, the extracted Hydrogen could cover the cost of storing CO_2 in these rocks and provide an alternative (or additional) source of sustainable hydrogen.

4b. ***CO_2 Storage and Nickel (Ni) and Cobalt (Co) extraction***: More recently, R&D has identified the potential for reacting CO_2 with these rocks in order to extract Nickel and Cobalt[193], which are common elements find in elevated concentrations in these rocks. Research published in 2023 indicates that each ton of CO_2 sequestered could recover nearly 98 kg of Nickel and between 2-3 kg of Cobalt (depending on the exact rock type). At current market rates (Nickel: USD 19.5 per Kg, Cobalt: USD 33.5, August 2023), the value of the extracted metals could be as high as 2000 USD

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185 Khan, S.R., Jan, M.Q., Khan, T. and Khan, M.A., 2007. Petrology of the dykes from the Waziristan Ophiolite, NW Pakistan. Journal of Asian Earth Sciences, 29(2-3), pp.369-377.

186 Lemenkova, P., 2021. Mapping topographic, geophysical and gravimetry data of Pakistan–a contribution to geological understanding of Sulaiman Fold Belt and Muslim Bagh Ophiolite Complex. Geophysica, 56(1-2), pp.3-26.

187 Habib, W., Nazeer, A., Ahmed, S., & Ali, I. Carbon capture, storage and sequestration–an overview and feasible geological models in Pakistan.

188 Müntener, O., 2010. Serpentine and serpentinization: A link between planet formation and life. Geology, 38(10), pp.959-960.

189 https://helios-aragon.com/

190 https://www.goldhydrogen.com.au/

191 Maiga, O., Deville, E., Laval, J., Prinzhofer, A. and Diallo, A.B., 2023. Characterization of the spontaneously recharging natural hydrogen reservoirs of Bourakebougou in Mali. Scientific Reports, 13(1), p.11876

192 Osselin, F., Soulaine, C., Fauguerolles, C., Gaucher, E.C., Scaillet, B. and Pichavant, M., 2022. Orange hydrogen is the new green. Nature Geoscience, 15(10), pp.765-769.

193 Wang, F. and Dreisinger, D., 2023. An integrated process of CO2 mineralization and selective nickel and cobalt recovery from olivine and laterites. *Chemical Engineering Journal*, *451*, p.139002.

per ton of CO_2 captured[194]. What these numbers imply is that the cost of transporting (USD 6 – 22 per ton per km) and storing CO_2 (10 – 100 USD per ton)[195] could be partially to fully covered by the extraction of Nickel and Cobalt, elements which are crucial to a sustainable energy transition in the transport sector for example. Indeed, Brazil mining company Vale is expecting a 44% increase in demand for Nickel by 2030[196] whereas consumption of Cobalt has tripled in the past decade and is expected to double again by 2035, driven primarily by the electronic and battery industry[197]. Moreover, production of Nickel and Cobalt as a result of CO_2 storage would significantly decrease the carbon footprint (or embedded carbon) of the metals incorporated into EVs and other electronic equipment. Crucially, Ni-deposits ad Ni-bearing rocks are well-known in Pakistan but remained underexplored[198]. Industrial synergies between the cement industry and mining industry could significantly increase the potential for Pakistan to develop both green cement and sustainable Nickel and Cobalt extraction processes.

[194] Wang, F., Dreisinger, D. and Xiao, Y., 2023. Accelerated CO2 mineralization and utilization for selective battery metals recovery from olivine and laterites. Journal of Cleaner Production, 393, p.136345.
[195] Data from Carbon Capture, Utilisation & Storage in the Energy Transition: Vital but Limited (2022, Energy Transitions Commissions)
[196] https://www.reuters.com/markets/commodities/vale-sees-44-increase-global-nickel-demand-by-2030-2022-09-07/
[197] https://www.mining-technology.com/features/keeping-up-with-cobalt-demand-and-opportunity-in-australia/
[198] Stanin, S.A., Wahid, M.A., and Khan, S., 1975, Geochemical Prospecting for Copper and Nickel in the Wulgai and Tor Tangi areas Southeast of Hindubagh, Quetta Division, Pakistan. Project Report, Pakistan Investigations (IR) PK-5, US Geological Survey, https://pubs.usgs.gov/of/1975/0163/report.pdf

6. Transformational Decarbonization of the Cement Sector: Strategies, Stakeholders, Policies and Data

As explained in the sections above, decarbonizing the cement industry could (potentially) help decarbonize other industrial sectors in Pakistan whilst stimulating the growth of new sustainable jobs, including in the mining-, steel-, building- and battery-manufacturing industries.

6.1 Strategy and Stakeholders

In addition to low-hanging fruit that could reduce carbon emissions in the short-term, a more in-depth overhaul of the industry is needed to reach the zero-carbon goals that are required to drastically reduce GHG emissions. A long-term vision of decarbonizing the cement sector requires new technologies and business models, and ideally would include all existing actors in the sector, as well as involving others that may not currently be involved in decarbonization efforts. Below, is a mapped-out diagram highlighting the actors which could be used to put the Pakistan Cement industry onto the path of transformative and sustainable change (Figure 26). The public sector stakeholders included in Section 2.3 would be considered "policymakers" in the below figure. In addition to industry players just menti6.oned, other stakeholders include financial institutions (including those related to carbon markets), research and development (this would also include the research institutions mentioned in Section 2.3), oil and gas stakeholders (particularly for CCUS), transport (for transport electrification).

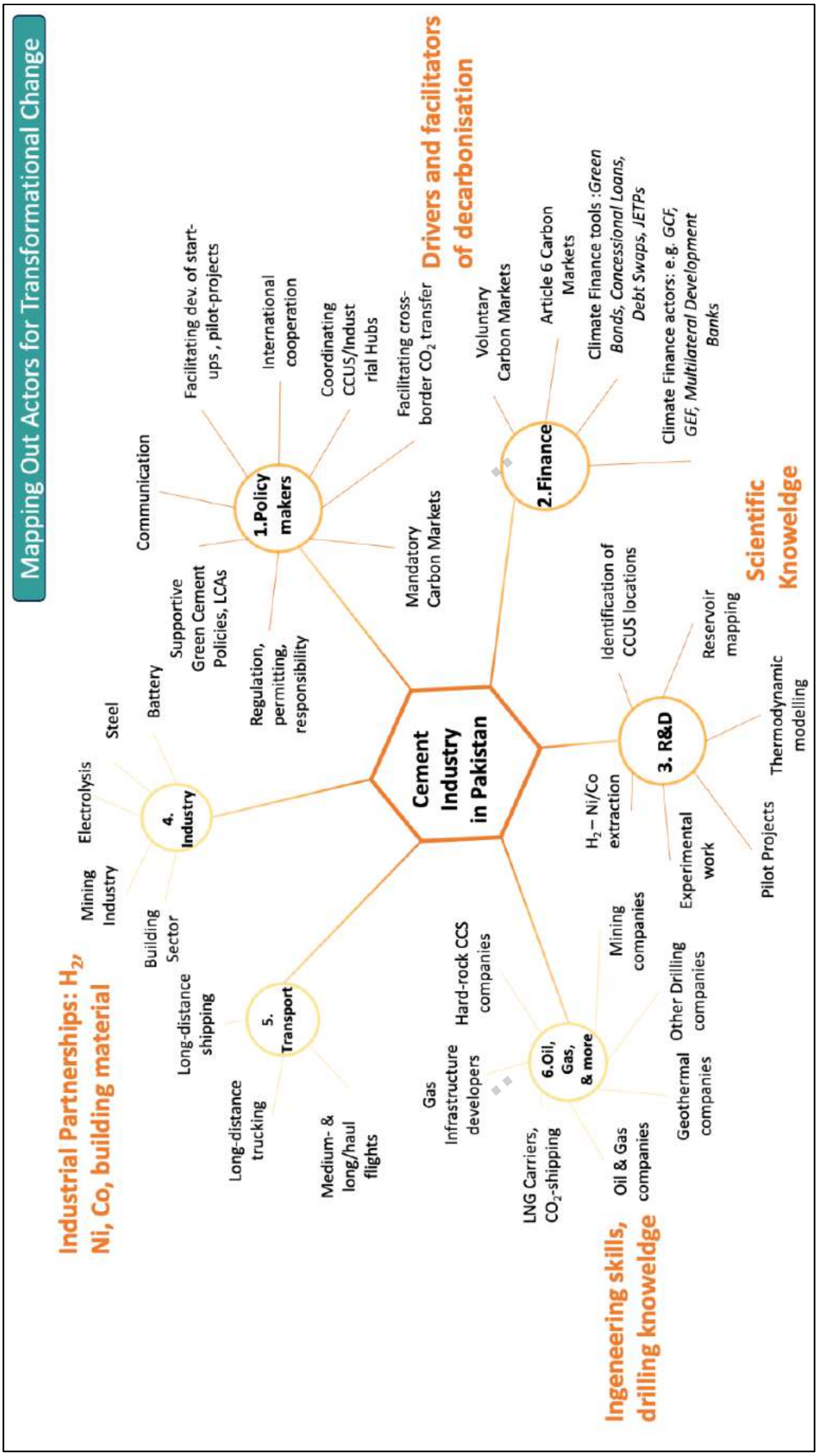

Figure 24: Mapping out actors potentially involved in the transformative decarbonization of the Cement Industry in Pakistan.

In addition to an incremental pathway to decarbonisation which relies on decreasing coal consumption through increasing energy efficiency and reducing coal consumption and clinker content, this report also includes a more transformative approach which leap-frogs incremental change. This transformative approach is focused on full electrification through decreasing costs of renewable energy (solar-wind-battery storage, electric transport), new innovations (electric kilns) and the growth of new industries using ground-breaking permanent CCS technologies (extraction of Nickel and Cobalt and potentially Hydrogen). In this Transformative Framework, near-pure CO_2 gases produced thanks to the use of electric kilns can be seen as an asset which could attract significant investments from other industrial actors (e.g., mining industry, transport sector, steel industry).

Overall, an ambitious, long-term vision of the transformation of the cement sector relies on 3 main pillars: **1)** Policymakers, which enforce supportive policy measures, regulatory measures and drive systematic change; **2)** Financial institutions which can provide significant capital through carbon markets and climate finance. This is particularity important as up-front investments will be significant; **3)** R&D can help link these actors together whilst developing pilot projects, for example, for LC3, electrification, and on the storage of CO_2 in Pakistan.

These three main pillars of transformative change can furthermore stimulate additional investments from three additional groups of actors which can spearhead change through the development of cross-industrial collaborations and the development of Industrial Clusters, namely **4)** heavy industries, from steel manufacturing to mining industry to the manufacturing of batteries and electrolysers for the energy transition; **5)** Actors in the transport sector who are leading in innovative solutions for long-haul shipping, trucking and flights interested in innovative decarbonisation solutions; and **6)** Oil & Gas industries and other actors (e.g., geothermal industry) who are currently innovating in CCUS, transport of CO_2 and drilling practices.

6.2 Policy needs

Strong policy underpinnings from Pakistan's national government would accelerate the deep decarbonization of the cement sector . As also outlined recently in [199], ensuring that The Ministry of Climate Change and Environmental Coordination, in collaboration with development partner and other relevant Pakistani ministries and other public bodies (included in Section 2.3., e.g., Ministry of Industries & Production (MoI&P), Ministry of Science and Technology and PSQCA), should provide long-term plans for low carbon

[199] Qureshi, S, Zia, U, Bashir, N 2023., Pakistan's Cement Sector: A Road to Decarbonization 2023, SDPI.

cements/concrete in updated NDCs and Long-Term Low Emission Development Strategies (LT-LEDs)[200] to demonstrate Pakistan's vision to either pilot or commercialize the technology. Moreover, in order to secure long-term demand for low-carbon cements and concrete, this report recommends that the government of Pakistan joins IDDI and commit to The Green Public Procurement (GPP) Pledge[201]. In order to ensure a transparent framework to compare low carbon materials (i.e., for procurement specialists, engineers, architects, etc.), developing initiatives and regulations to scale up the use of life cycle assessment of materials and buildings (EPDs[202], PCRs and PCFs) could help ensure long-term uptake of low-carbon materials. Financial incentives for cement companies to transition towards the use of waste to phase-out coal could be envisaged as well.

However, in the context of Pakistan's current economic crisis, relying on financial incentives for cement companies to transition from coal to waste-based fuels may be impractical. Given the limited fiscal space, a more viable approach could be to implement stringent regulatory measures and promote technological advancements. In the current economic scenario, establishing clear environmental regulations and standards can drive the industry towards sustainable practices.

6.3 Data needs for sector-wide decarbonisation

Comprehensive data on the cement sector is essential to effectively allocate resources for decarbonization. As indicated above, SPAR6C's efforts to obtain facility-specific high-resolution datasets was of very limited success (an additional report published in 2024 on the state of the cement industry in Pakistan[203] also did not have such data). As such, this report presents solutions for lowering carbon emissions from cement based on the publicly available, high-level data, and qualitative data from SPAR6C interactions with cement industry leaders (e.g., in meetings and stakeholder workshops held in April 2024). However, for future endeavours, more granular, plant-specific data is recommended to have a more accurate picture of potential carbon reductions and costs for Pakistan's cement industry.

Limited datasets are available publicly through annual reports of cement companies published online on their website (8 of 15 companies). It is important to know that the documents are not meant to target highly technical audiences, and therefore, most of the required information and datasets needed to clearly define the mitigation potential of specific technologies at specific plants is still missing.

The published documents vary widely in terms of overall analysis (i.e., presence or absence of financial sensitivity analysis, quarterly performance analysis, economic and financial risks and mitigation strategies, long-term strategies, SDGs, etc.). In terms of data that is directly relevant to quantifying GHG emissions, the following data have been identified:

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[200] (LT-LEDS) are crucial frameworks that guide countries in aligning their developmental goals with the Paris Agreement's objective to limit global warming to well below 2°C. https://www.undp.org/publications/planning-net-zero-future-guidance-how-develop-long-term-low-emission-development-strategy-lt-leds
[201] https://www.cleanenergyministerial.org/content/uploads/2023/04/the-gpp-pledge-brochure-iddi.pdf
[202] E.g.: https://buildingtransparency.org/ec3
[203] Qureshi, S, Zia, U, Bashir, N 2023., Pakistan's Cement Sector: A Road to Decarbonization 2023, SDPI.

Companies	Datasets
Bestway	- Number of Plants - Revenue, profit before tax - Onsite Solar Plants with Capacity - CO_2 mitigation due to RE - Number of WHR power plants
Cherat	- Cement and Clinker production - Use of Refuse Derived Oil and installation of dual-fuel captive power plants - Onsite Solar plant with capacity
DG Cement	- Types of cements produced - Plant Capacity by line (incl. manufacturer) - Solar and Coal plants (incl. manufacturer) - Clinker capacity (tons/day and tons per year) of each factory - Electricity requirements per plant (+type of fuel) - Electricity Generation Capacity per plant (+type of fuel)
Fauji Cement	- Types of cements produced - Plant capacity and actual production (Cement and Clinker) - Solar Power Plants - WHR power plants - Clean energy Production from WHR and Solar plants - CO_2 mitigated from clean energy sources - Use of alternative fuels - Use of Cementitious materials and estimated GHG reduction
Gharibwal Cement	- Yearly capacity and production of clinker - Evidence of WHR power plants (unknown number/capacity/energy produced)
Kohat Cement	- Yearly capacity and production of clinker (incl. grey and white clinker) - Solar Power Plants - WHR power plants
Lucky Cement	- Yearly capacity and production of clinker - local sales of cement and clinker - Solar Power Plants - WHR power plants
Pioneer	- Yearly capacity and production of clinker and cement - WHR power plants

Although certain cement companies, such DG Cement and Fauji Cement, provide more granular data which could be used for a high-level quantification of GHG emissions, it is evident from the above table, that there is a lack of consistency in the type of data published and how accessible the data is. For example, certain annual reports provide data on the amount of GHG avoided due to the use of RE and WHR power plants. However, there is no clarity on the exact calculations and international guidelines used to arrive to those conclusions. The table below includes data relevant to GHG emissions available from the latest annual reports.

	Annual Reports FY 2023						Fuel		
Company & Plant	Capacity Tons	Cement Tons	Clinker Tons	Elect MW	Solar MW	CO2 Red Mtons	Coal Imported	Coal Local	Alt.Fuel
Attock Cement Pakistan Limited - Hub Chowki		1,503,714	1,971,426						
Bestway Cement Limited - Hattar									
Bestway Cement Limited - Chakwal									
Bestway Cement Limited - Farooqia	15,000,000	15,000,000			89.6	-5			
Bestway PakCem Limited - Kalar Kahar									
Bestway Cement Limited - Pai Khel									
Cherat Cement Company Limited-Nowshera		2,882,790	2,643,785						
Dandot Cement Limited - Jehlum	504,000								
Dewan Hattar Cement Limited - Hattar		1,575,000	1,348,000						
Dewan Cement Limited - Dhabeji									
D.G.Khan Cement Limited - D.G.Khan			2,010,000	42					
D.G.Khan Cement Limited - Chakwal			2,010,000	31	6.9		29%	63%	8%
D.G.Khan Cement Limited - Hub			2,700,000	40	1.02				
Fauji Cement Limited - Wah									
Fauji Cement Limited - Nizampur		4,900,000					47%	53%	
Fauji Cement Company Limited - Fateh Jang									
Fauji Cement Company Limited - DG. Khan*									
Fecto Cement Limited - Sangjani		646,530	632,116						
Flying Cement Limited - Lilla									
GharibWal Cement Limited - Jehlum		1,349,789							
Kohat Cement Company Limited - Kohat	4,915,000	3,037,220	2,796,089						
Lucky Cement Limited - Pezu	15,300,000	7,059,899	6,235,310				44%	24%	
Lucky Cement Limited, - Indus Highway, Karach									
Maple Leaf Cement Factory Limited - Daudkhel	7,800,000*	4,266,699	3,928,830						
Pioneer Cement Limited - Khushab	5,194,500	2,741,440							
Power Cement Limited - Nooriabad, Dadu	3,370,000								
Thatta Cement Limited - Thatta									
	*Clinker								

In this table, blank cells indicate that the data is not available. The large number of blank cells is an indicator that data in addition to what is currently publicly available is greatly needed.

Moreover, higher resolution data at the plant level would enable the cement industry to target – at specific sections of the manufacturing plant and value chain – the most cost-effective mitigation technologies which could be implemented through concessional finance of carbon finance. The below section discusses these datasets further.

6.3.1. Data for Financing Decarbonization of Cement Sector

CO_2 emissions monitoring and reporting can have diverse goals, including internal management of environmental performance, public environmental reporting, reporting for taxation schemes, voluntary or negotiated agreements, emissions trading, performance benchmarking and product LCA and publication of EPDs.

By offering a consistent reporting framework for GHG reporting, this will increase transparency and increase attractiveness for financing projects acting through carbon financing and other GHG mitigation initiatives, where a key measure of impact and success remains the quantity of GHG displaced per EUR/USD invested. Moreover, by ensuring that cement industry start acquiring and reporting more granular datasets, this will provide a framework to develop product-specific environmental/carbon footprints or certification schemes, such as internationally recognized EPDs and PCFs, which offer an attractive mechanism to catalyze the demand for green materials, thereby derisking investments into transformative – yet CAPEX intensive – mitigation technologies[204].

In order to get an accurate panorama of Scope 1, 2 and 3 emissions from the cement sector in Pakistan, a concerted effort is needed to collect this data from the cement firms *(i.e., note the discrepancy in data between the figures on GHG emissions from cement production in Pakistan).* This report recommends using a spreadsheet that SPAR6C adapted from the World Business Council's *CO2 and Energy Accounting and Reporting Standard for the Cement Industry*[205], which offers and internationally accepted and harmonized methodology for calculating and reporting CO_2 emissions from the cement industry.

An illustration of the required data is found in **the figure below.** This spreadsheet includes sub-categories for cements with different clinker contents, coal and electricity consumption, and transportation for cement-related processes. This spreadsheet can be downloaded *(here)* and used by future initiatives that seek to characterize emissions in the sector in order to efficiently allocate resources for transformational change in the cement sector. Moreover, integration of such reporting frameworks into national MRV systems could lead to setting long-term, quantifiable GHG reduction goals in national NDCs and LT-LEDS for each specific industrial sector thereby providing long-term certainty for investors and industrial actors.

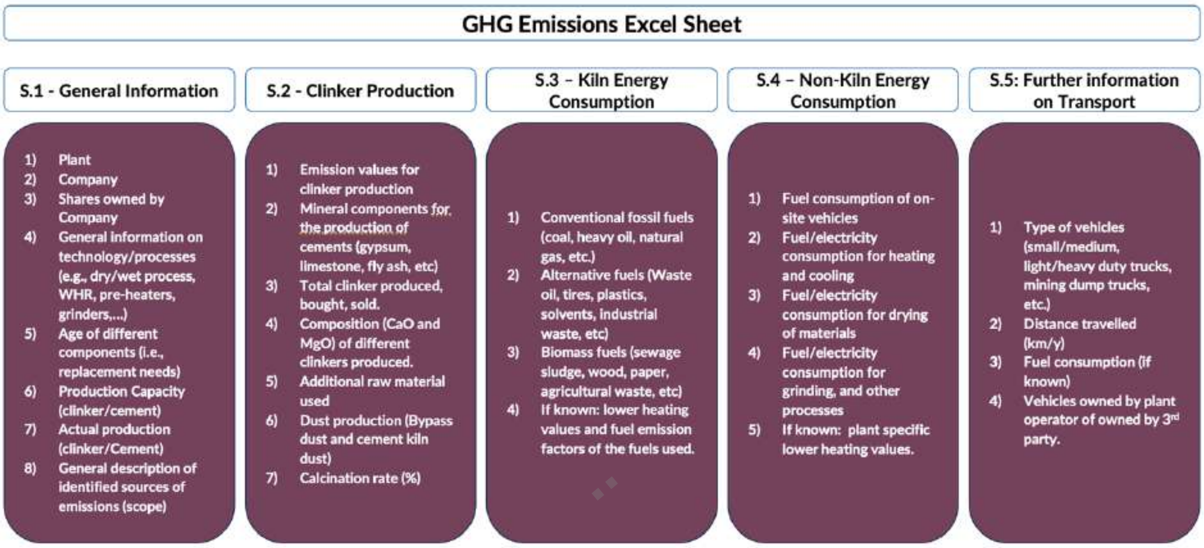

Figure 25: Data needs per cement plant to quantify GHG emissions along the value chain.

[204] Hasanbeigi A., and Shi., D., 2021, Standards and Evaluation Guidelines for Green Public Procurement, White Paper, Clean Energy Ministerial, IDDI, UNIDO and LEADit.
[205] WBCSD, May 2011, https://www.cement-co2-protocol.org/v3/Content/Internet_Manual/download.htm

7. Conclusion

This report has outlined the potential of carbon markets to deeply decarbonize Pakistan's cement sector, including in the short, medium and long term. It has presented mitigation technologies and described the roles of a broad range of stakeholders in this transformation. This conclusion presents some of the most crucial points this report identifies to ensure that carbon markets in general, and Article 6 in particular, can be used to catalyse this decarbonization process.

Potential paths for decarbonizing the cement industry: The cement industry in Pakistan has shown that decarbonization of the value chain can also make financial and business sense, as seen by financing of WHR power plants (carried out by all Pakistani cement firms except Dandot Cement) and scaling up the use of renewable energy under CPPs (including, but not limited to the following cement firms: Bestway, Cherat, DG Khan, Fauji, Kohat, Lucky, Maple Leaf, and Power Cement). Stakeholder engagement during workshops and feedback during the development of PINs has showcased that there is a substantial willingness of cement actors to push for more transformational decarbonization initiatives. Carbon Finance under Article 6 is likely to provide a substantial opportunity to scale up and attract investments due to the potential to decrease GHG emissions substantially (e.g., LC3 cements). In order to provide better facility-based cost-benefit analysis however, substantially more data is required, Indeed, currently available data (i.e., *through annual reports which are publicly available*) do not typically provide enough granularity in terms of emissions, including clinkers quantity produced (capacity versus production), types/composition of clinker, clinker to cement ratio, detailed energy consumption for each equipment along the value chain, type and number of vehicles (incl., daily distance traveled, etc).

This implies that development of PINs and MADDs to assess opportunities under Article 6 will require additional work on a project-basis to clearly identify the best potential GHG mitigation option of a specific plant (further data is also required on potential import tariffs and other taxes which might affect the cost of importing new technologies, such as BEV trucks). Finally, by working with international initiatives, such as the Global Cement and Concrete Association (GCCA), could help spur decarbonization of the sector. For instance, GCCA launched, in 2019, the GCCA Industry Environmental Product Declaration (EPD) Tool to support the publication of EPDs by cement and concrete producers in order to enable *"the (cement/concrete) industry and its customers to better quantify and verify the life cycle environmental impact of existing products and to develop lower-impact products in the future"*[206].

Article 6 Financing: Article 6 of the Paris Agreement is a vital tool for Pakistan to raise private sector capital, enabling technological adoption and emission mitigation while generating revenue. It facilitates carbon financing, which is crucial for decarbonizing Pakistan's cement industry. However, a broader strategy that includes stringent regulatory frameworks is essential for sustained long-term decarbonization. Clarity on the modalities of the implementation of Article 6 under the MoCC in Pakistan are key to ensure that carbon financing can be used to decarbonize the cement industry. Upfront

[206] https://gccassociation.org/news/gcca-launches-industry-epd-tool-as-part-of-ongoing-industry-efforts-to-reduce-environmental-impact-and-support-global-sustainability-goals/

costs (high CAPEX) remain a key challenge which needs to be resolved in order to ensure the financing of decarbonization projects (e.g., through concessional loans, equity, grants, or guarantees). A two-pronged approach is therefore required combining financing and providing technical assistance to support countries in establishing institutional infrastructures and build capacity to operationalize carbon markets.

National Government: The MoCC&EC can play a critical role in facilitating Article 6 Financing. As mentioned above, the ministry can use its position to join international efforts such as the IDDI and The Green Public Procurement (GPP) Pledge, as well as encourage the cement industry to continue to decarbonize, e.g., by joining international initiatives, such as the Global Cement and Concrete Association (GCCA).

Further, the MoCC&EC can use its influence so that the Line Ministries directly involved in the cement sector to spearhead a "Green Cement" or "Net zero cement" (or similarly titled) initiative. Under such an initiative, the MOCC&EC could coordinate public sector stakeholders (including the MoI&P and Ministry of Science and Technology, and influential bodies such as the PSQCA), academia, and in partnership with the cement industry, to accelerate the decarbonization of the sector.

This initiative would be a PPP that would steer the cement industry and government to deep decarbonization practices, as well as ensuring that markets will exist in Pakistan for lower-carbon cements, particularly in public sector projects. Healthy procurement of low-carbon cement by the public sector would certainly convince the private sector to follow suit. Furthermore, strong alignment of public sector players behind decarbonization efforts in the industry would help assure international lenders and firms that this effort has strong underpinnings and will be sustained over time. This is particularly crucial as large investments, and a concerted, sustained effort will be needed to bring carbon emissions from cement to zero (or near-zero).

Such an effort will become critical for the export of Pakistani cement, especially as the EU's Carbon Border Adjustment Mechanism (CBAM) comes into force (the mechanism entered its transitional phase on October 1, 2023 and is scheduled for full implementation on January 1, 2026.). By adhering to EU carbon standards, Pakistan can avoid potential tariffs on carbon-intensive products, ensuring competitiveness in the European market. This comprehensive approach fosters environmental sustainability and secures Pakistan's economic interests in international trade.

Provincial and Municipal Governments: The Provinces and Municipalities can play a crucial role in decarbonizing cement by ensuring that authorities in charge of waste management (e.g., Lahore Waste Management Company) develop and implement waste collection and management strategies (including potential financing under Article 6) that strengthen the entire waste supply chain in order to enable cement facilities to acquire high-quality waste to incrementally lower the amount of coal used (and eventually phase-out coal use all together). Overall, a multi-faceted approach that combines regulatory measures, technological advancements, and collaborative efforts between waste management entities and the cement sector can support sustainable practices in Pakistan's cement industry.

High CAPEX Solutions: these are needed, particularly because many solutions, such as LC3, electrification and CCS require large investments in heavy equipment. However, these types of solutions should be within reach, given the Pakistani cement industries successful track record with large investments (e.g., several high-capacity cement plants have been built in recent years, using state of the art equipment). With government backing and a strong partnership between the public sector and the cement industry, these costly investments should come within reach, especially as the cost of technology declines with global scaling up of these solutions.

Capacity Building: the next generation of cement industry professionals is currently being trained at the country's universities, and ample opportunities exist for these professionals to be trained in the latest technologies for producing high-quality cement with greatly reduced carbon footprints. University leadership in cement include the NED University of Engineering and Technology, Karachi (NEDUET) and the UET University of Engineering and Technology, Lahore. These universities could establish research programs to gather the crucial data needed to efficiently decarbonize the cement industry (outlined in section in above, in Section 6.3.2), and at the same time ensure that training for the creation of low-carbon cement is introduced in the university curriculum, as well as offer short trainings on these topics for professional development of engineers currently working in the industry.

Governance and Transparency: while the cement industry is already considerably transparent in Pakistan, with data made public through the APCA, more granular data could also be made available. For example, the United States Geological Service publishes the different types of cement that are produced in each state of the country, monthly.[207] Governance and transparency could also be further enhanced by robust participation of the cement industry and academia/research institutions in a government led "Green Cement" initiative, and publication of initiative results, and data.

[207] Please see: https://www.usgs.gov/centers/national-minerals-information-center/cement-statistics-and-information

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