

SCOPING STUDY ON

PAKISTAN'S CEMENT SECTOR A ROAD TO DECARBONIZATION

March 2024



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Pakistan's Cement Sector: A Road to Decarbonization

Saleha Qureshi, Ubaid ur Rehman Zia, and Noman Bashir

March 2024



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Abbreviations

ALCCC	Alliance for Low Carbon Cement and Concrete
APCMA	All Pakistan Cement Manufacturers Association
ATP	Advanced Technology and Policy
BAU	Business as Usual
CAGR	Compound Annual Growth Rate
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilization
CCUS	Carbon Capture, Utilization and Storage
CCG	Carbon Capture and Utilization
COGS	Cost of Goods Sold
CPEC	China Pakistan Economic Corridor
CSI	Cement Sustainability Initiative
CSO	Civil Society Organization
EE	Energy Efficiency
EPS	Energy Policy Scenario
ETS	Emission Trading Scheme
GDP	Gross Domestic Product
GCCA	Global Cement and Concrete Association
GHGs	Greenhouse Gases
IEA	International Energy Agency
KII	Key Informative on Interviews
LC3	Limestone Calcined Clay Cement
LCS	Long Term Capacity Support
LSM	Large Scale Manufacturing
MTOE	Million Tons of Oil Equivalent
NDC	Nationally Determined Contributions
NEECA	National Energy Efficiency and Conservation Authority
NEPRA	National Electric Power Regulatory Authority
OPC	Ordinary Portland Cement
ORC	Organic Rankine Cycle
PCA	Portland Cement Association

PB	Portland Blast
PSDP	Public Sector Development Programme
PSQCA	Pakistan Standards and Quality Control Authority
RE	Renewable Energy
RDF	Refuse Derived Fuel
SCM	Supplementary Cementitious Material
SMEs	Small and Medium Sized Enterprises
TDF	Tires Derived Fuel
TRL	Technical Readiness Level
UNFCCC	United Nations Framework Convention on Climate Change
UNCTAD	United Nations Conference on Trade and Development
VFD	Variable Frequency Drives
VSD	Variable Speed Drives
WHR	Waste Heat Recovery

Executive Summary

Driving the change: Private sector commitments are increasing to shape the global net-zero target.

Amid the current multifaceted crises the world is faced with, countries are unveiling their strategies for low-carbon development, sustainable economic recovery, as well as their pledges and commitments to achieve net zero emissions as part of their energy and climate initiatives. In addition to national objectives, the corporate sector is actively showing its commitment to advancing low-carbon development, with a specific focus on transitioning to low-carbon fuels. This allows them to not only improve their corporate standing, consumer preferences, mandatory and voluntary reporting mechanisms, and performance tracking but also keep their market competitive and make a stronger case for positive socio-economic and environmental impact. Although concerted efforts have been made under the umbrella of net zero transition, it is still a challenge, particularly for hard-to-abate sectors such as concrete and cement in the developing countries like Pakistan.

While global efforts are increasing, the cement sector lags behind and developing countries remains off-track to meet the decarbonization targets and goals.

Cement is globally the second most consumed product with around 4.5 billion tons of production yearly worth almost \$350 billion. It is the main component of concrete that is used in construction of key infrastructure. In 2021, the Asia Pacific region dominated global production, contributing over 70% of the total share. Among the top 10 cement producers globally, four hail from Asia, namely China, Vietnam, India, and Indonesia. Unlike China, which primarily consumes much of its domestically produced cement, Vietnam stands out for exporting a significant portion of its cement, with the construction sector being the primary beneficiary of this ample supply.

At the same time, cement is also recognized as one of the most hard-to-abate sectors due to emissions resulting from the unavoidable highly emission intensive calcination process. As of 2020, the cement sector was responsible for 7% of global CO₂ emissions (i.e. 25% of total emissions from the industrial sector) with highest emissions generated per \$ of the revenue. Nonetheless, the net zero pathways of International Energy Agency and other research studies highlight that in principle, the cement industry could reduce its emissions by more than three folds (from 2017 level) by 2050. Significant strides have been made to produce green cement, clinker substitution, and use of alternative materials; these efforts are still limited in underdeveloped and developing countries due to the absence of a strong business case that currently exists.

Scoping decarbonization of Pakistan's cement sector

Against this backdrop, this study aims to conduct a scoping of opportunities and challenges that currently exist in decarbonization of Pakistan's cement sector. Taking leap from Pakistan's updated Nationally Determined Contributions (NDCs) and a potential netzero scenario, it uses a mixed-method approach driven by primary and secondary data to analyze decarbonization efforts across five key levers: i) energy efficiency, ii) alternate fuels, iii) clinker substitution, and iv) carbon capture and storage. Along with desk review, the modeling assumptions, data inputs, policy interventions and key challenges are analyzed based on data collected after discussions with the stakeholders.

Pakistan's cement industry: The largest consumer of coal in Pakistan

In 2021, the cement sector of Pakistan consumed 8.5 Mtoe of coal as final energy. This constitutes a share of 68.7% in total industrial sector final use of coal and 51.4% in total net primary energy supplies of Pakistan. Between 2016-21, the annual consumption of coal in the cement sector increased from 3.4 Mtoe to 8.5 Mtoe, depicting an annual compound growth rate of 13.2%.

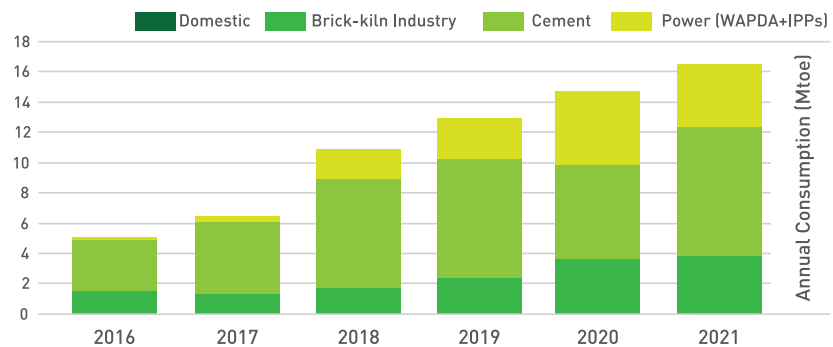


Figure ES1: Annual consumption and share of different sectors for coal use in Pakistan

On the process end, coal constitutes around 85% of total energy consumption of the cement sector (against a global average of around 70%), followed by 15% from natural gas (mainly being used for plant startups) and some portion of electricity and alternate fuels (biomass). Given this high reliance on coal, cement is essentially a key component of industrial emissions. As of 2021, cement sector is currently contributing to around 44.5% - 52% of Pakistan's total industrial emissions and around 10% of the country's total emissions. Along with environmental challenges, the high reliance on coal has also led to economic uncertainties for the cement sector as most of it is being imported. Currently, the cement sector is using around 550,000 tons of coal per month, which is imported from South Africa, Russia, Ukraine, Indonesia, and Afghanistan. Given the recent economic turmoil, the cement sector has also faced uncertainty in the coal supply chain and price instability. Only between August 2021 - March 2022, the prices of imported coal increased from \$140/ton to \$375/ton.

Limited Discourse around decarbonization efforts in cement sector of Pakistan

Despite a high reliance on imported fossil fuels, a very limited discourse currently exists for decarbonization of cement sector in Pakistan. Key challenges pertaining to this are identified in Figure ES2.



Figure ES2: Challenges hindering the decarbonization efforts in cement sector of Pakistan

While Pakistan's updated Nationally Determined Contributions (NDCs) have given a target of 50% emission reductions by 2030 (baseline of 2015) -a major share of which is to come from industrial sector- there are no specific targets identified for the cement sector. Apart from the 2023 energy efficiency target for cement prescribed under NEECA's strategic plan for 2023, no policy or regulatory target is defined for energy saving or decarbonization efforts of the cement industry. Further, the country is still missing an emission reporting mechanism as well as a repository to enable industry to undergo a proper emission monitoring and reporting procedure. In absence of these, the cement sector remains open to issues and concerns around provision of data as it could lead to compromising their competitive advantages and data hacks, eventually leading to trust deficits.

Secondly, the business case for decarbonization in industrial sectors in Pakistan is mainly driven by their export competitiveness and global demand for the green products. While Pakistan's textile sector has followed the trend, the similar case for cement sector does not exist as most of the export destinations (trade channels) are already carbon-intensive (such as Sri Lanka, Afghanistan, etc.). Even, globally the demand of green cement from consumer end is limited. Lastly, the cost associated with decarbonization efforts in cement sector is comparatively much higher-given cement industry is a hard-to-abate sector-than the fiscal space available in the backdrop of increasing energy prices. Power wheeling reforms remain unaddressed in Pakistan, further limiting the industry to opt for cheap renewable energy sources. Hence, while decarbonization makes a better socio-economic case for the cement sector, a strong policy and regulatory push would be required to drive industry's transition towards low-carbon growth.

Opportunities and current efforts of cement sector to support low-carbon development in Pakistan

Despite several challenges in decarbonization pathways, several opportunities exist that can enable long-term decarbonization goals of the cement industry. Pakistan's cement industry has already made significant strides in improving energy efficiency of the plants, particularly using Waste Heat Recovery Systems (WHRS). Many of the cement plants in Pakistan are operating at high efficiency (low energy intensity) rates, using most up to date technologies. The industry has also initiated pilot projects for using sugar mud as an alternative fuel, and are expanding the project to include other materials such as rice husk, wheat husk, Maze, and Corn crop. Most of the cement industries have installed solar plants ranging from 7 MW to up to 20 MW. However, despite these efforts, various opportunities currently exist which have not been tapped; not only by the cement; but majority of industrial sub-sectors in Pakistan as depicted in Figure ES3.



Figure ES3: Unaddressed opportunities for decarbonization of cement industry in Pakistan

Modeling the decarbonization pathways for cement sector in Pakistan

Based on socio-economic indicators, data insights and global targets, this study has modelled four decarbonization scenarios for Pakistan's cement sector: i) Business-As-Usual (BAU), ii) Frozen Scenario (FS), iii) Energy Policy Scenario (EPS), iv) NDC scenario (unconditional-15% reductions), and v) Net zero scenario. Energy and environmental scenarios are modelled using a bottom-up optimized approach through Low Emissions Analysis Platform (LEAP) model. Figure ES4 indicates the energy and economic profile of Pakistan's cement sector under the BAU scenario.

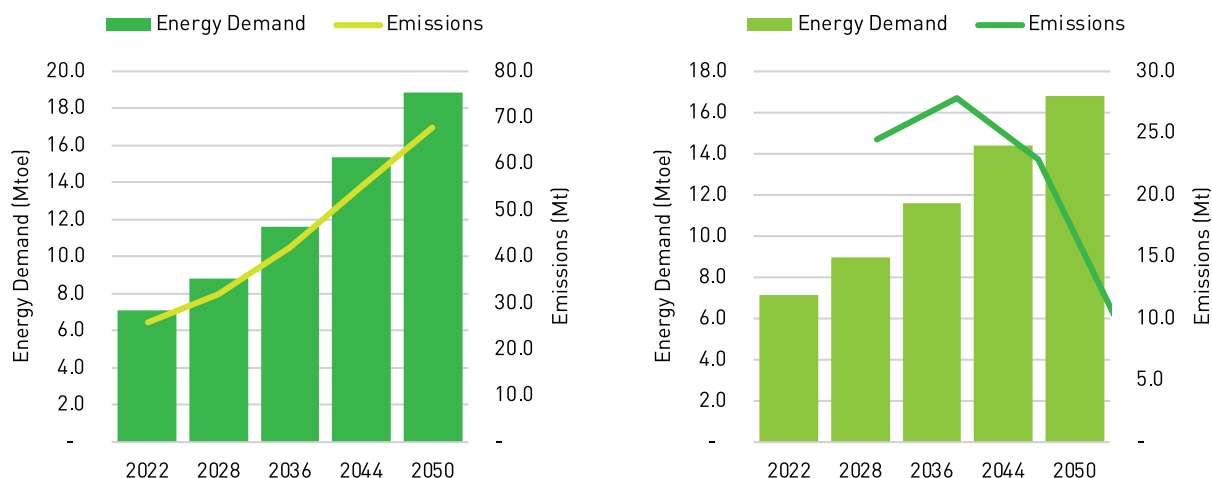


Figure ES4: Energy and emission profile of Pakistan's cement sector under i) BAU (left) and ii) Net zero scenario.

Under the BAU scenario, the energy demand of cement sector is expected to increase from 7.6 Mtoe in 2023 to 18.8 Mtoe by 2050, indicating an ACGR of 3.53%). For frozen scenario, the 2050 figures indicate a demand of 23.2 Mtoe which further highlights that the historic trend of energy intensity improvements will lead to energy savings of around 600 ktoe by 2030 and 4400 ktoe by 2050. In EPS, NEECA's strategic plan is the only guiding document that will lead to additional energy savings of around 186.3 ktoe. The NDC scenario follows the same plan as that of **Energy Policy Scenario (EPS)**, while the net zero scenario leads to the least energy intensive case. Driven by globally aligned intensity figures, it depicts that the energy demand would increase to 16.8 Mtoe by 2050, indicating energy saving potential of 2000 ktoe as compared to the BAU scenario.

For emission profile, the BAU scenario indicates an increase from 25.6 Mt in 2023 to 68 Mt by 2050, highlighting an ACGR of 3.4%. In the frozen scenario, these emissions increase to 83 Mt by 2050, indicating an emission reduction potential of 16 Mt by 2050. This emission reduction is driven by improvements in energy intensity and fuel switching from coal to alternate energy sources. Under the NDC scenario, the emissions are further dropped to around 38 Mt, highlighting the percentage drop of 14.1% by 2030 and 44% by 2050. Under the net zero scenario, the emission trajectory follow the same pattern as NDC scenario, however, further drops to a net zero by 2050, following a pathway accompanied by high use of carbon capture and storage technologies. However, the net zero scenario is optimized for Carbon Capture and Storage (CCS), which represents that under the user defined constraints, the emission reductions required to achieve net zero (apart from the proposed measures under other decarbonization levers), the remaining emissions will be abated through these technologies. In principle, this does not highlight the potential but a condition that a net zero scenario for cement sector would require the deployment of CCS technologies.

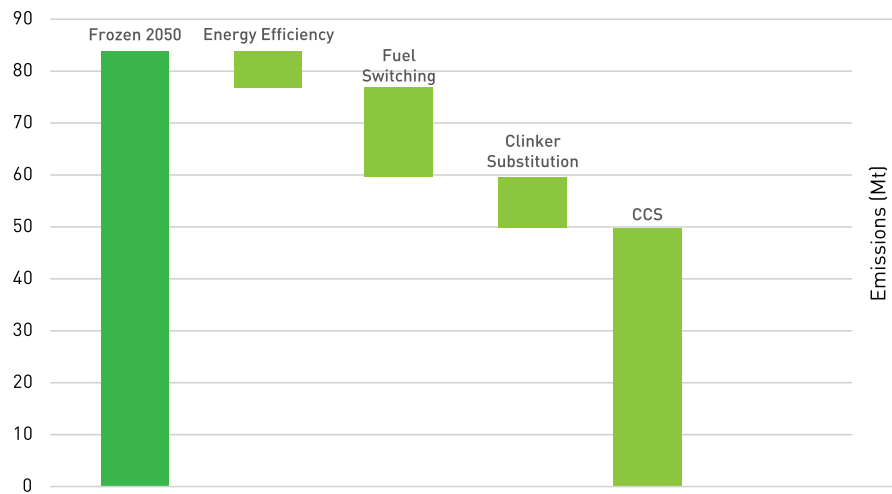


Figure ES5: Need assessment of decarbonization levers to achieve net-zero targets of Pakistan's cement sector.

Based on figure ES5, each lever of decarbonization would play a critical role in decarbonization pathway of cement sector in Pakistan, however, the net zero scenario would require a very critical role to be played by the CCS. However, currently this technology lacks proper commercialization in most parts of the world due to high cost, and around only 500 projects have been globally implemented. Alternate scenarios for net zero would certainly be possible, however, they would demand more ambitious targets to be achieved for fuel switching, clinker substitution, energy efficiency, and rapid shift towards green cement production.

The economic side of this transition also demonstrates a similar trend. Cement decarbonization requires large-scale investments from the companies in advancing technological development, reducing both fuel and process emissions. Clinker substitution is currently the only lever that has a negative abatement cost (\$10-40/ton CO₂). Using alternate fuels such as waste or biomass has positive abatement cost ranging up to \$100/ton CO₂. CCUS has the highest abatement cost (negative), extending beyond \$200/tonCO₂. However, these figures depict the global average and could differ substantially for the local context of Pakistan.

In addition to the decarbonization strategies outlined in this study, there are additional options available for reducing the carbon dioxide emissions associated with cement and concrete production. For instance, employing alternative raw materials and products in the manufacturing of cement and concrete, which are not reliant on Portland cement, can significantly contribute to the reduction of CO₂ emissions within the cement industry. Moreover, the incorporation of alternative materials in construction projects can play a crucial role in diminishing the need for cement and concrete products, thereby further mitigating their environmental impact. Bringing circularity in the cement

industry would also play a substantial role and is being explored globally, and for which Pakistan needs to conduct a thorough scoping.

In either case, the decarbonization of cement in Pakistan is currently an uphill task and a right set of policies and national/international partnerships between the stakeholders. The government should enhance the strategic approach for the cement industry, including the implementation of a robust policy framework offering inducing financial incentives to promote the adoption of alternative fuels. In this regard, the collaborative efforts among industry stakeholders [(All Pakistan Cement Manufacturers Association (APCMA), State Cement Corporation of Pakistan (SCCP), consumers, suppliers, Environmental Protection Agency (EPA)] are essential to enforce stringent quality standards, ensuring consistent high-quality production and aligning with environmental objectives. To enhance investor confidence in the renewable energy sector, the government should establish a transparent tariff structure, integrate grid balancing technologies, and engage with stakeholders for policy formulation. More importantly, international collaborations should align national efforts with global climate commitments, opening avenues for international investments and partnerships.

Section I

Introduction



Section I - Introduction

1.1 Background

The Paris Agreement has spurred global efforts to limit Greenhouse Gas (GHG) emissions and keep global temperature rise below 1.5 degrees Celsius. Recognizing the need to mitigate the adverse effects of rising emissions, countries have now realized that comprehensive decarbonization is essential that require transformation across all sectors of the economy, including energy generation, production and goods and services delivery, and land management (Mekala Krishnan et al. 2022). Though the developed world, i.e. historically responsible for higher emissions, possesses the necessary technologies to curb emissions, the developing world faces challenges due to limited financial resources, technology, capacity, and political will, despite being relatively lower emitters with growing economies (United Nations Conference on Trade and Development 2021)

Over 70% surge has been recorded in industrial emissions since 2000 due to rising global demand for goods, limited energy efficiency gains, and a post-pandemic rebound, necessitating a rapid annual reduction of about 3% to meet Net Zero Scenario targets by 2030 (Scott & Gösling 2021).

In 2021, the International Energy Agency (IEA) reported that industries worldwide relied on coal for 38% of their energy consumption, followed by oil at 32% and natural gas at 20%. The remaining 10% of industrial energy consumption came from alternative sources like renewables and nuclear fuel (United Nations Conference on Trade and Development 2021). Notably, the specific usage percentages of coal, oil, and natural gas exhibited variations across countries. For instance, China heavily relied on coal, which comprised 67% of its industrial energy consumption, whereas in the United States, oil accounted for 35%, natural gas for 33%, and coal for 22% of energy consumption within the industrial sector (World Energy Outlook 2020).

Addressing the imperative of decarbonization in hard-to-abate sectors entails striking a delicate balance between fulfilling global commitments, capitalizing on economic drivers, and surmounting the challenges associated with the transition.

In order to meet global commitments, especially in industries (such as cement, textiles, and steel) decarbonization is of utmost importance due to its heavy reliance on fossil fuels. Though challenging, the transition to clean energy sources has positive economic drivers, including climate change mitigation, green job creation, economic growth, and a sustainable future, provided sustainable economic growth and technological penetration. However, recent events such as the Russia-Ukraine conflict have led to a sharp increase in

energy prices and disrupted global supply chains, posing additional obstacles for developing countries in their transition to a low-carbon economy and accessing the necessary technologies and resources for decarbonization.

The developing world faces a challenge, primarily related to fuel switching. Though green hydrogen is anticipated to emerge as a prominent alternative, its widespread implementation is still a distance away.

The decarbonization of hard-to-abate sectors is driven primarily by consumer demand for green products, particularly evident in the textile industry. However, other industries such as cement and steel have yet to experience significant consumer awareness regarding decarbonization. (Siemens Energy 2022) There was an increasing trend in the stock market in 2023 compared to 2022, driven by the adoption of renewable energy technologies, Carbon Capture, Utilization, and Storage (**CCUS**), energy efficiency measures, and other decarbonization technologies. This trend is propelled by global inflation concerns and the urgent need to address climate change impacts.

Investing in renewable energy and decarbonization technologies has become increasingly appealing in the stock market due to the following strategic factors.

- These investments serve as a robust hedge against inflation, offering stability amidst the unpredictable fluctuations of fossil fuel prices. By reducing reliance on fossil fuels, renewable energy projects provide investors with consistent cash flows and secure long-term contracts, ensuring resilience in the face of market volatility.
- The imperative to address climate change has led to heightened awareness and proactive measures. Investors are drawn to these technologies as they facilitate the essential transition to a low-carbon future. In alignment with environmental, social, and governance (ESG) principles, these investments not only mitigate climate-related risks but also unlock new markets and growth opportunities.
- Supportive policies and regulations further enhance the appeal of these investments. Incentives such as tax credits, subsidies, and mandates for green energy and electric vehicles encourage substantial investments in renewables. Concurrently, disincentives targeting fossil fuels, including carbon taxes and emissions trading schemes, underscore the viability of renewable energy in the stock market.

These factors collectively position renewables as an attractive and strategic choice for investors navigating the evolving landscape of sustainable investments.

Pakistan NDC 2021 entails the bold commitment of GHG emissions by 2030 (United Nations Framework for Climate Change Convention, 2022).

Pakistan, as a signatory to the Paris Agreement, has demonstrated its commitment to climate action through the submission of its updated Nationally Determined Contributions (NDCs). The NDCs for 2021 outline Pakistan's

ambitious target of achieving a 50% reduction in projected emissions by 2030. This reduction will be accomplished through a combination of measures, including a 15% reduction utilizing domestic resources and an additional 35% reliance on international financial support. However, the NDCs doesn't provide specific details about how industries will reduce their emissions. It's crucial to have a clear plan for industries because they play a vital role in these emission reduction efforts. Being clear about how industries can help will be essential for Pakistan to achieve its climate goals.

Decarbonizing the cement sector is essential for countries to meet their NDCs and net-zero targets under the Paris Agreement (United Nations Framework for Climate Change Convention, 2017).

In 2022, Pakistan GHG emissions were 525.2 Mt of CO₂ equivalent. Among different sectors, manufacturing industries account for almost 70 Mt, while IPPU emits around 5.5% of total emissions.

This sector alone contributed to over 49% of Pakistan's total CO₂ emissions. Over the past two decades, fossil fuels have been the dominant energy source in the industrial sector due to its affordability and availability compared to other sources. As a result, CO₂ emissions from industries increased significantly, rising from 17.21 million tons to 95.2 million tons between 1990 and 2019. The growing energy demand driven by economic development has been the key factor behind the increase in CO₂ emissions (Sarwar, 2023).

"In Pakistan, cement constitutes around 44.5% - 52% of total industrial emissions while utilizing around 68-73% of country's total coal."

Cement production globally contributes to 6-8% of CO₂ emissions, making it a significant factor in achieving net-zero goals. Pakistan's cement industry, with an annual production capacity of 69 million tons, accounts for 5.3% of the country's economy and can play a substantial role in the net-zero mission (Haroon 2023).

The above statistics show that the industrial sector, particularly the cement industry, holds considerable potential to make decarbonization efforts impactful. It is imperative to address the environmental concerns associated with the sector both at the national and global level.

In the pursuit of a global net zero scenario, as outlined by the International Energy Agency (IEA), the industrial sector is confronted with the challenging task of reducing its CO₂ emissions from 8.5 Gt to 0.5 Gt within a span of 30 years (Chakrabarty et al. 2019). Within this context, the cement sector emerges as an important player. Presently, cement production exhibits an emission intensity of 0.59 tCO₂ per tons of cement produced in 2021, necessitating a reduction to 0.43 tCO₂ per tons of cement produced by 2030 to align with the net zero targets.

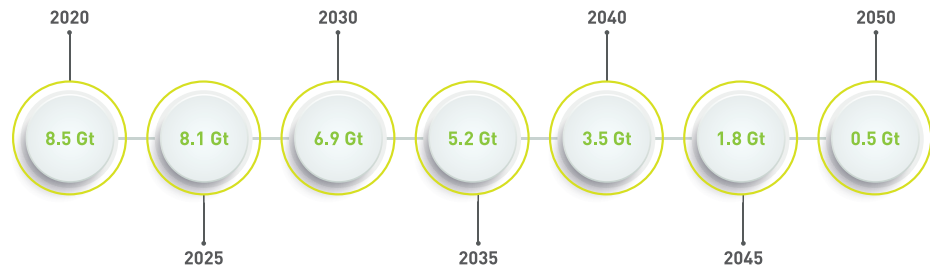


Figure 1: Road to Net Zero (For Industrial Sector) - (IEA, 2021)

The active engagement of the cement sector in achieving “Net Zero” objectives and aligning with NDCs assumes utmost importance for Pakistan. One significant challenge is fulfilling NDCs. The sector confronts substantial hurdles due to the escalating demands associated with rapid urbanization and industrialization. Cement retains its pivotal role as an indispensable construction material for modern infrastructure development, thereby further complicating efforts aimed at emission reduction. Consequently, the cement industry finds itself categorized as a hard-to-abate sector, necessitating the adoption of innovative strategies to effectively curtail emissions by 75-90% from 2010 levels by 2050 (Gerres, 2022)

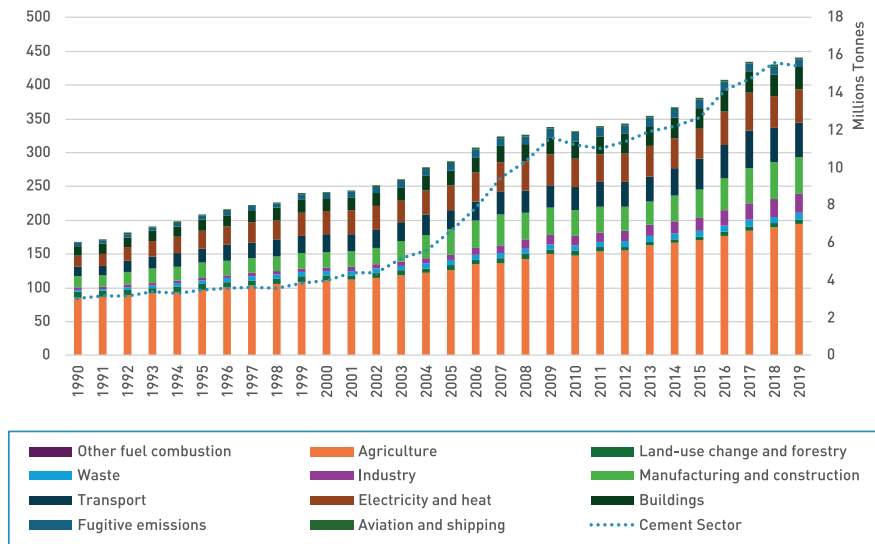


Figure 2: Annual GHG Emissions (CO₂eq) and Emissions from Cement Sector in Pakistan (Our World in Data, 2022)

1.2 Significance of Cement in the Construction Industry

1.2.1 Cement Industry in Global and South Asian Construction Sectors

In 2022, global cement production reached approximately 4.1 billion tons, marking a significant increase from 1.39 billion tons recorded in 1995. This substantial growth reflects the expansion of the construction industry over the years. (Statista, 2022), as indicted in Figure 3.

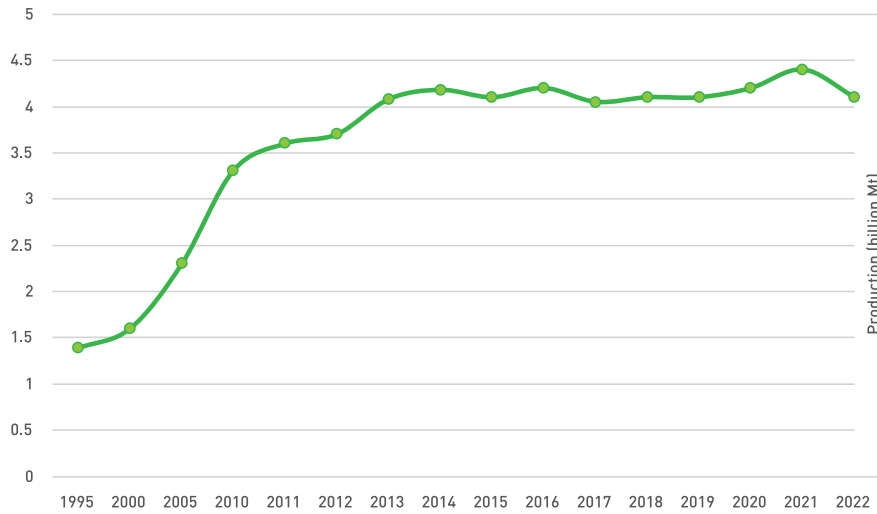


Figure 3: Production of cement in Billion Metric Tons per year (worldwide) (Statista, 2022)

1.2.2 Trade channels

In 2021, cement emerged as a significant global commodity, ranking 271st in terms of total trade value, which amounted to \$14.8 billion. Notably, its exports experienced a notable growth of 16.6% between 2020 and 2021, rising from \$12.7 billion to \$14.8 billion (Overseas Employment Corporation, 2021.). The demand for cement and clinker has witnessed a shift towards emerging regions, driven by rapid urbanization and the resulting opportunities for regional companies to excel. This trend has given rise to the emergence of regional champions that contribute to value creation.

However, the year 2022 presented challenges in seaborne trading markets, marked by weakening demand and soaring production costs. Projections indicate a potential decline of 5-10% in imports for 2023, leading to a subsequent decrease in export prices. It is expected that shipments to major markets such as the US and China will see reductions, while other regions may experience only marginal growth. Producers benefiting from subsidized energy costs are anticipated to gain market share as shown in Figure 4.

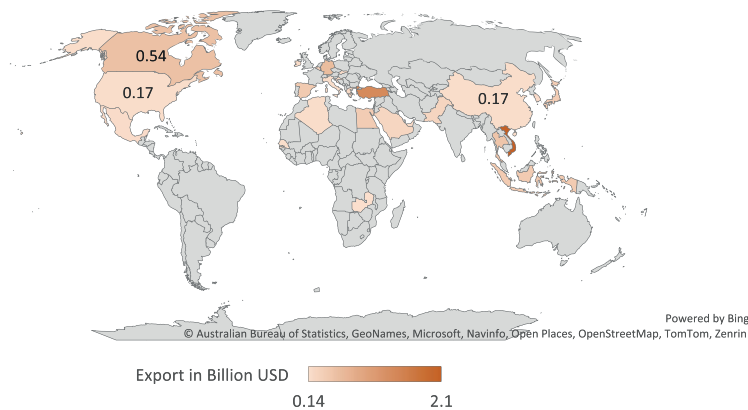


Figure 4: Top 25 Exporters of Cement in year 2021 (World's Top Exports, 2022)

Asia dominates the global cement market, contributing over half of the total demand and production. China, India, Vietnam, Indonesia, and Japan stand as leading cement producers in the region. The surge in cement demand in Asia is propelled by rapid urbanization, industrialization, infrastructure projects, and population growth.

Cement trade in Asia operates through domestic and international channels. Local producers and distributors serve domestic markets, leveraging extensive networks of plants, warehouses, terminals, and transport facilities. Meanwhile, international markets involve exporters and importers navigating complex trade regulations, tariffs, quotas, and standards across various countries.

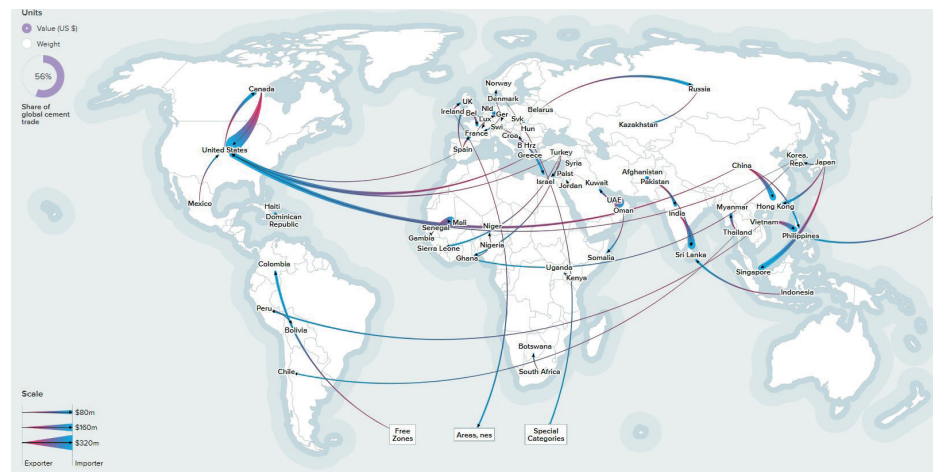


Figure 5: Global Cement Suppliers (ARIJCO, 2022)

1.3 Leading Cement Production Companies

The top five countries contribute around 68.6% of the global clinker production capacity, which stood at approximately 3.8 billion metric tons in 2022 (Statista 2022).

China, with its dominant presence and significant influence, emerges as the preeminent participant in the global cement market, commanding approximately 51% of the world's total cement production (IEA, n.d.). China notably leads in both capacity and actual production, capturing more than half of the global market share, while India follows with a market share of less than 10% in global cement production (Statista, 2022). (Table 1 Annexure)

1.4 Scope and Objective of the Study

Industries in Pakistan contribute 40% share of the country's GHG emissions, with the cement sector emerging as a prominent player, accounting for 22% of emissions during the manufacturing process (Energy and Clean Air Program, 2021).

As the country grapples with the need to build infrastructure for a growing population, the demand for cement is rising. In 2022, at least 53 million tons of coal and one million cubic feet of gas per day was consumed by cement sector of Pakistan (Pakistan Bureau of Statistics 2022). Although there are alternatives to coal, they face challenges in terms of availability, cost, and quality. This continued dependence on fossil fuels leads to increasing GHG emissions, necessitating urgent climate reparations and causing harmful environmental consequences. To overcome this challenge, there is a need to move towards using less energy and producing fewer emissions.

In this backdrop, this study scopes the current status of cement sector in Pakistan, its decarbonization efforts, and challenges and opportunities to delve into a decarbonization journey. Key objectives of the study include:

- i. To analyze the status quo of cement sector and examine how the energy use in Pakistan's cement industry has been changing over time.
- ii. To benchmark mitigation strategies of Pakistan's cement sector with best practices and globally identified decarbonization levers.
- iii. To identify financing needs and frame the decarbonization pathway of Pakistan's Cement Sector under different scenarios of policy commitments.
- iv. To analyze the challenges and opportunities for cement sector to strategize its decarbonization goal in line with Pakistan's NDCs and net zero commitment.

To achieve these objectives, this study uses the following methodological approach.

- **Desk Review Assessment:** An extensive desk review was conducted with a thorough assessment of the cement industry's emissions landscape in Pakistan, including baseline emission levels, key emission sources, existing mitigation efforts and policy landscape.
- **Consultative Discussion and Key Informant Interviews (KIIs):** Through a desk review and consultative discussions, key stakeholders and cement industries were interviewed to gain insights into the challenges faced by the industry. The purpose of these interviews was to understand the policy and regulatory support required to facilitate their operations and to assess the progress made in implementing energy efficiency and decarbonization measures in the cement industry.

Along with various consultative discussions around initial scoping and preliminary findings, the public consultations conducted under this study include the Public Private Dialogue on “Decarbonizing Pakistan’s Cement Sector: Pathways to lever Net Zero Commitments” and Special Lecture with Power Cement titled: Charting the course of Decarbonization Drivers in Cement Industry of Pakistan.

- **Low-Emission Analysis Platform (LEAP) Modelling:** The study will then develop various **scenarios** based on the outlined objectives. These scenarios include the Business-as-Usual Scenario (BAU), the Advanced Policy Scenario, and the Net Zero Scenario. These scenarios will serve as the foundation for analyzing the potential outcomes and impacts of different approaches and policies on the cement industry’s emissions and decarbonization efforts.

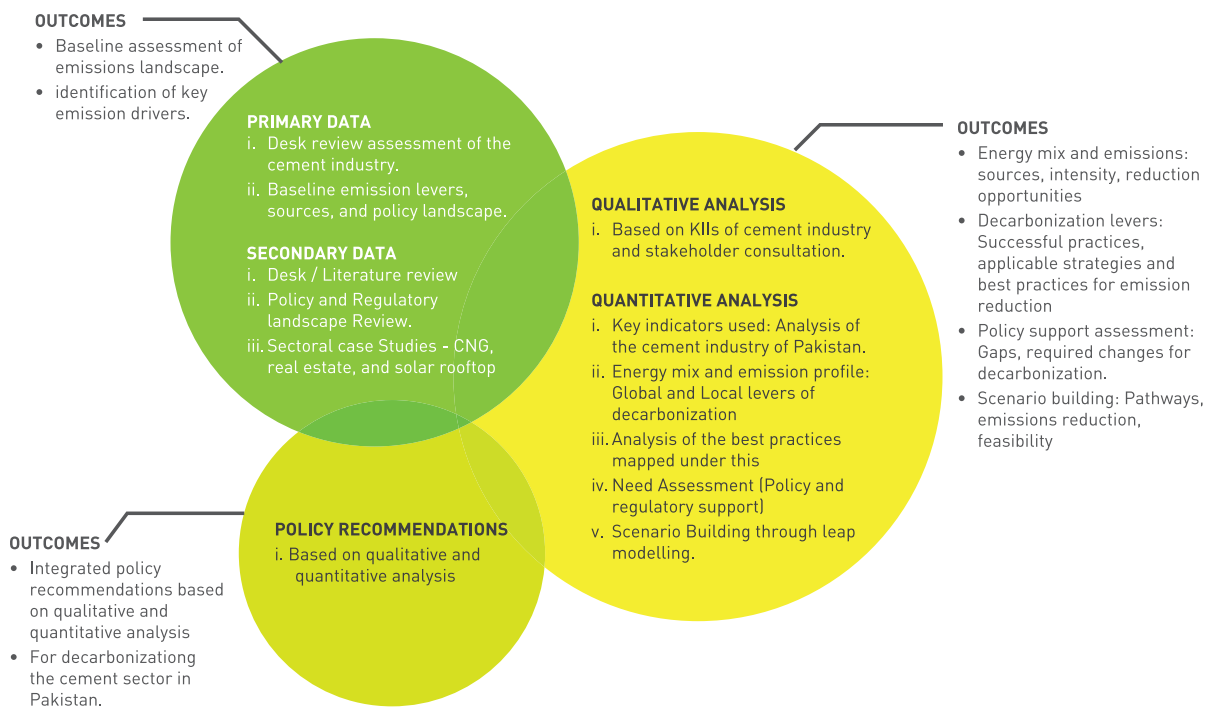


Figure 6: Methodological Framework

Section I I

An overview of Pakistan's Cement Sector



Section II: An overview of Pakistan's Cement Sector

In FY 2022, Pakistan's economy saw significant growth, with the nominal GDP reaching around PKR 67 trillion. Industrial activities contributed about 20% to the GDP, experiencing a positive year-on-year growth rate of around 7.2%. Manufacturing, which accounted for approximately 65% of the industrial value, grew at a rate of about 9.8%. Figure 7 further highlights some of these statistics.

Pakistan has ample reserves of raw materials, but cement production remains energy-intensive, with coal accounting for 40% of production costs. Geographical location impacts transportation costs and export opportunities.

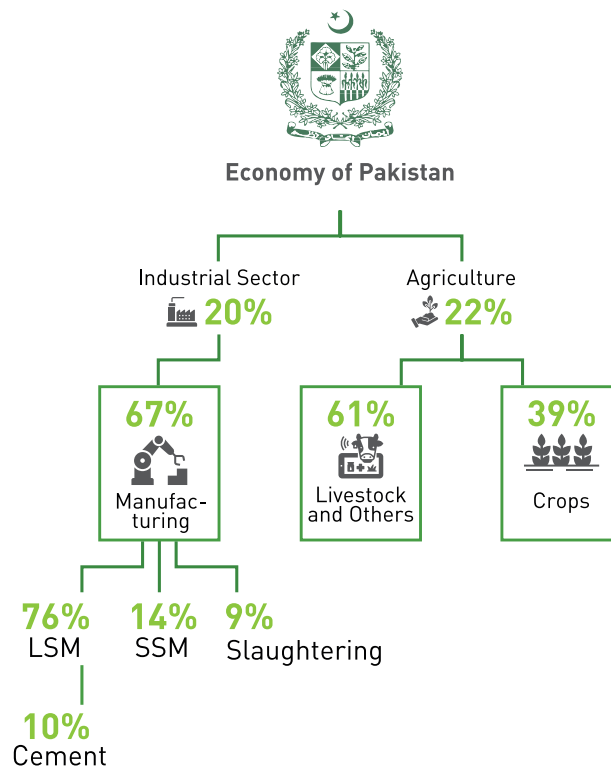


Figure 7: Share of Cement Industry in Economy of Pakistan (Source: Economic Survey of Pakistan 2021-2022)

2.1 Situational Analysis of Cement Industry in Pakistan

In FY 2021-22, **All-Pakistan Cement Manufacturers Association (APCMA)** reported a decline in total cement dispatches to 52.89 million tons, down by 7.9% from the previous fiscal year. Domestic consumption contracted marginally to 47.63 million tons while exports experienced a significant drop of 43.6% to 5.25 million tons.

Forecast indicates a promising growth trajectory for Pakistan’s local cement consumption. With a projected CAGR of 7% until 2025, annual consumption is expected to reach a robust average of 65 million tons. However, cement exports are expected to remain relatively stable at approximately 5 million tons per year, with an additional export potential of 3 to 4 million tons per annum from clinker. (Hussain, 2019)

While it has witnessed remarkable growth in production capacity, currently standing at 69 million tons per annum, compared to 16 million tons per annum at the beginning of the millennium, the current progress has slowed due to limited industrial development and country-wide growth. Per capita cement consumption has increased from 72 kg/head in 2001 to 233 kg/head in 2021. (Pakistan Gulf Economist, 2021) However, it is still below the global average of 540 tons per capita. This disparity indicates a substantial room for growth in cement demand within the country, presenting an avenue for potential expansion and heightened consumption in the foreseeable future.

The cement industry in Pakistan faces challenges at the onset of FY23, including inherited vulnerabilities and a devastating flood. However, despite these hurdles, there are investment opportunities supported by government initiatives and a recovering GDP.

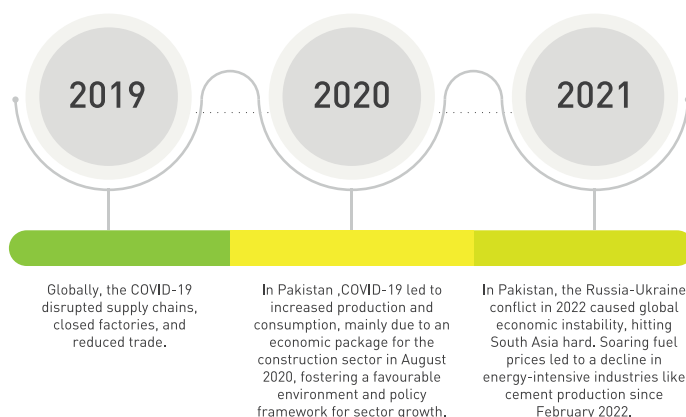


Figure 8: Cement Industry in Unusual Times

The economic crisis in the country has led to a decline in domestic and export demand for cement. Geopolitical tensions and rising fuel costs have further disrupted the industry, resulting in decreased plant utilization and production levels. Nevertheless, Pakistan has witnessed significant growth in per capita cement consumption, indicating untapped potential for expanding domestic consumption. The cement sector is a significant employment provider, contributing to socio-economic development across various skill levels. The industry’s presence in the northern regions, propelled by projects related to the China-Pakistan Economic Corridor (CPEC), has fostered regional development, improved infrastructure, and reduced poverty. Additionally, the industry has actively engaged in community development initiatives, supporting education and healthcare.

2.2 Production and Utilization Pattern

The cement industry in Pakistan comprises 27 cement plants with a total production capacity of 70,061 thousand metric tons (Details attached in Table 1 Overview of Cement Production/Manufacturing Facilities at Annexure 1). The industry is divided into the Northern and Southern zones with the Northern Zone accounting for 80% of production and relying mainly on Afghanistan and India for exports. In contrast, the Southern Zone benefits from access to multiple export markets via sea transportation. The industry’s expansion is driven by the CPEC-related projects and the government’s focus on development spending. The Northern Zone contributes 51,316 thousand metric tons, while the Southern Zone contributes 18,745 thousand metric tons to the overall success of the industry.

With the undergoing expansion and plans to add approximately 18 million tons of capacity in coming years, most of these expansions are focused on the northern region. The government’s housing initiatives, infrastructure projects, and the resumption of CPEC activities are driving construction and cement sales. Lower interest rates and accessible financing options have further facilitated industrial growth.

Such initiatives have increased demand in industry, anticipate sustained demand growth and intend to establish new cement plants to meet future requirements. While challenges related to costs and project completion times persist, the overall outlook for the cement industry in Pakistan remains positive as it continues to contribute to the country’s economic development (Jamal, 2021).

As per Figure 9, the production and utilization capacity in the cement sector during FY2017 to FY2022 indicates a consistent upward trend. However, the current economic condition in Pakistan has slowed down this growth trajectory, specifically during 2023.

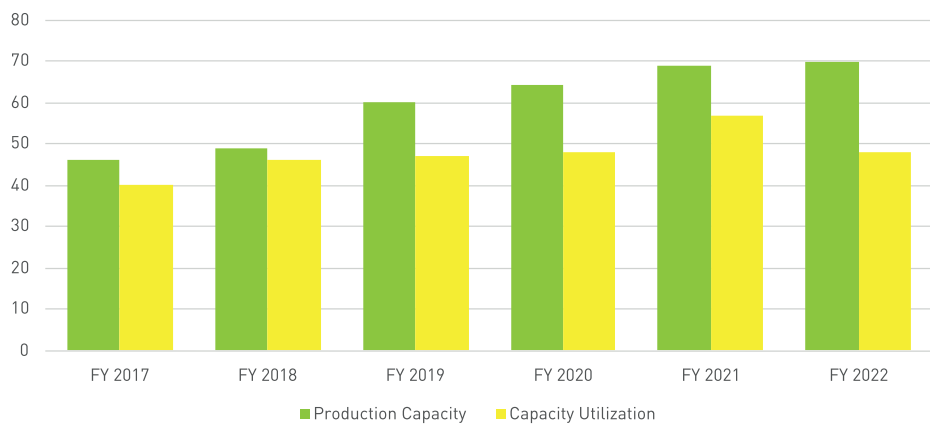


Figure 9: Production Capacity vs Capacity Utilization of Pakistan’s Cement Industry in (mtn MT) from FY 2017 to FY 2022 (APCMA)

In the fiscal year 2022, Pakistan experienced a substantial increase in the export value per 50kg bag of cement, witnessing a significant rise from PKR 308 in the previous fiscal year to PKR 401. This remarkable surge of 34.1% exceeded the growth observed in clinker exports. Despite the premium price associated with white cement, its contribution to the overall export mix remained modest, accounting for less than 0.2% of the total. In FY22, the export value per 50kg bag of clinker in Pakistan reached PKR 299 compared to PKR 233 in FY21 (Cement, 2022).

During the initial months of FY23, the cement industry observed a noteworthy increase in the export value per metric ton of cement, with a significant rise of approximately 26% in USD terms and around 70% in PKR terms. This exceptional growth can be attributed to the changing dynamics of energy costs, which have reshaped the industry’s landscape.

The cement sector relies heavily on imported coal; the increasing cement production and the establishment of coal-fired power plants have led to a surge in coal imports, underscoring the significant influence of imported coal on shaping the operational framework of the industry.

These developments highlight the evolving trends and strategic considerations within the export domain of the cement industry. They emphasize the importance of acquiring a comprehensive understanding of market preferences, optimizing product offerings, and establishing strong trade alliances to capitalize on growth prospects in different regions.

2.3 Import and Export Scenario of Cement Industry

Regarding the production of Clinker and Ordinary Portland Cement (OPC) in fiscal year 2022, its been observed the clear trends and notable export partners over the last 10 years, as shown in Figure 10.

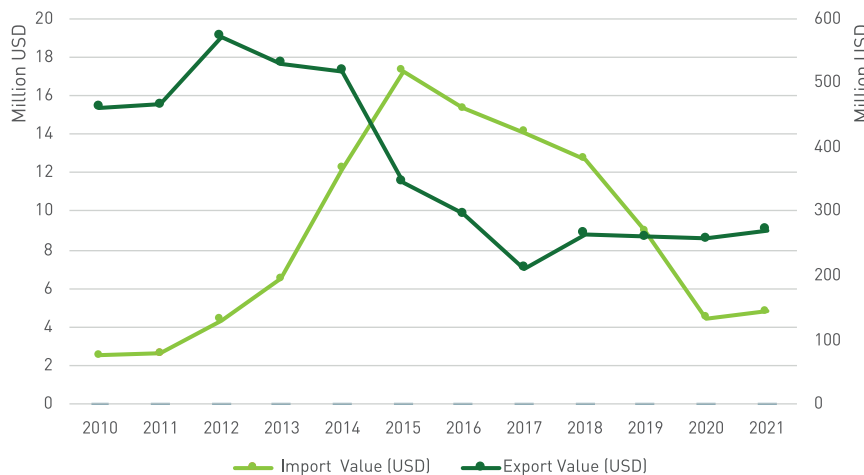


Figure 10: Import and Export trends in last 10 years

Table 2&3 indicate the clinker and Ordinary Portland Cement (OPC) export dynamics in FY 22. Bangladesh emerges as the primary export partner for clinker, capturing a substantial market share in terms of both volume and value, closely followed by Sri Lanka. Other countries, including Qatar, contribute to the remaining export volumes and values. Cement from Pakistan is being exported to countries with low regulatory and environmental standards.

Similarly, in the case of OPC exports, Afghanistan takes the lead as the largest export partner, followed by Sri Lanka. Oman and other countries also play a significant role in the export volumes and values of OPC. Notably, the average PKR value per metric ton varies across these export partners, reflecting distinct market dynamics and pricing considerations.

Table 2 Key figures for Export of Clinker in FY 22

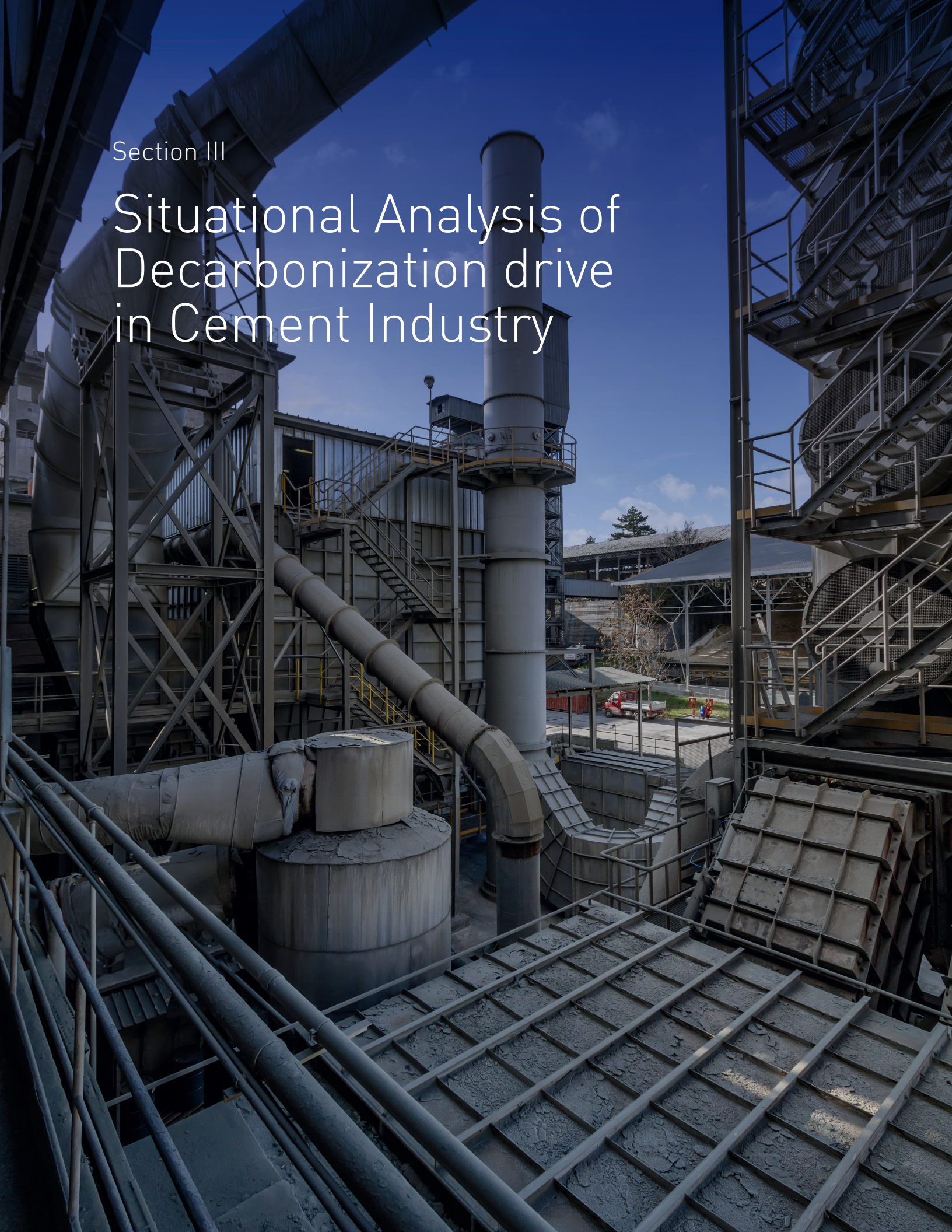
Clinker FY [22]						
Sr No.	Export Partner	Exports (MT 000')	Exports (PKR mln)	Share (Vol.)	Share (PKR Value)	PKR Value/ MT
1	Bangladesh	1469	8396	44%	43%	5717
2	Sri Lanka	981	5860	30%	30%	5973
3	Qatar	320	2077	10%	11%	6482
4	Others	537	3409	16%	17%	6349
Total		3307	19741	100%	100%	5970

Table 3 Key figures for Export of Ordinary Portland Cement in FY 22

Ordinary Portland Cement FY [22]						
Sr No.	Export Partner	Exports (MT 000')	Exports (PKR mln)	Share (Vol.)	Share (PKR Value)	PKR Value/ MT
1	Afghanistan	962	6938	40%	36%	7210
2	Sri Lanka	684	6646	28%	34%	9711
3	Oman	478	3630	20%	19%	7596
4	Others	294	2188	12%	11%	7450
Total		2418	19402	100%	100%	8023

Section III

Situational Analysis of Decarbonization drive in Cement Industry



Section III: Situational Analysis of Decarbonization drive in Cement Industry

3.1 Overview

The concurrent challenge of reducing CO₂ emissions in cement production while meeting the escalating demand presents a complex undertaking. To cut CO₂ emissions from the cement production process necessitates the implementation of decarbonization levers and the advancement of near-zero emission production routes. Achieving the net zero emissions goal entails the deployment and development of requisite technologies. Notwithstanding the offsetting effect of market expansions, the emissions intensity of production has exhibited an upward trajectory since 2015, primarily propelled by an elevated global clinker-to-cement ratio as shown in Figure 11 and Figure 12.

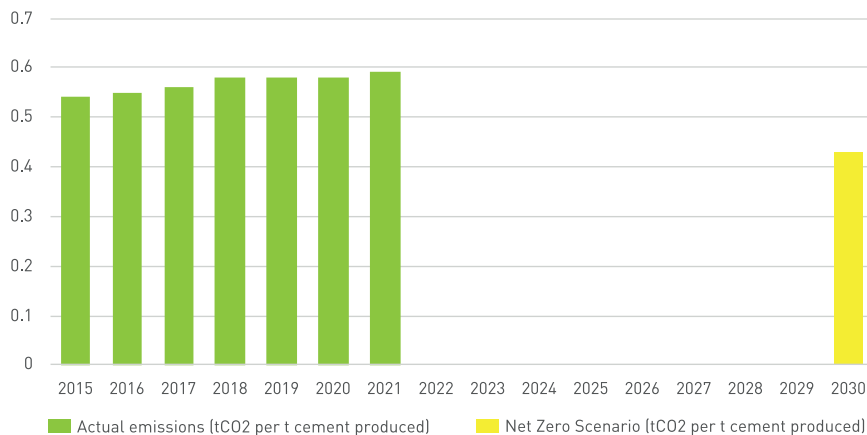


Figure 11: Global Direct emissions intensity of cement production in the Net Zero Scenario, 2015-2030 (International Energy Agency (IEA), 2021)

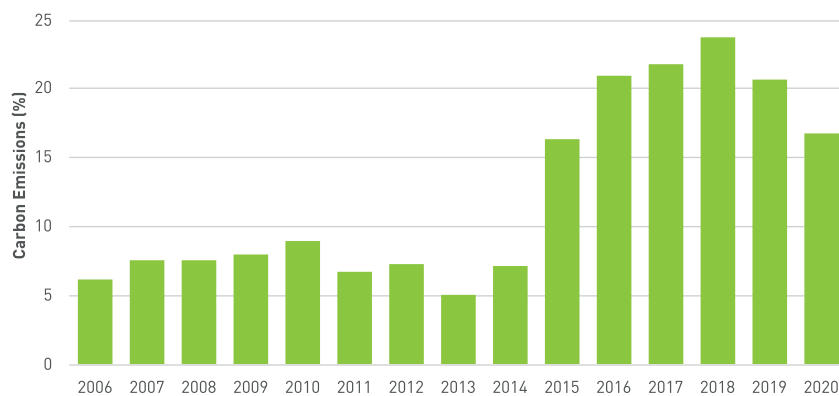


Figure 12: Carbon emissions by cement production in Pakistan (Statista 2022)

Figure 12 indicates that the carbon emissions in cement production from 2006 to 2020 highlights a substantial upward trend. During this period, carbon emissions significantly increased. This increase underscores the rapid growth in energy demand and the consequential escalation of consumption-induced carbon emissions in Pakistan. The linkage between industrialization and environmental pollution is well-established, with the production of Portland cement (clinker) identified as the primary source of carbon emissions due to extensive reliance on carbon fuels. Currently, the cement industry in Pakistan heavily relies on coal as its primary energy source, driven by its cost-effectiveness.

3.2 Pakistan's Cement Energy Value Chain

The energy value chain of the Cement production involves high temperatures and the release of carbon dioxide as a byproduct. Globally, the dry process utilizes 3.40 GJ of specific energy per ton of clinker production, while the wet process requires 5.29 GJ/t and most of the plants in Pakistan use the dry process. Cement Manufacturing process is mentioned below;

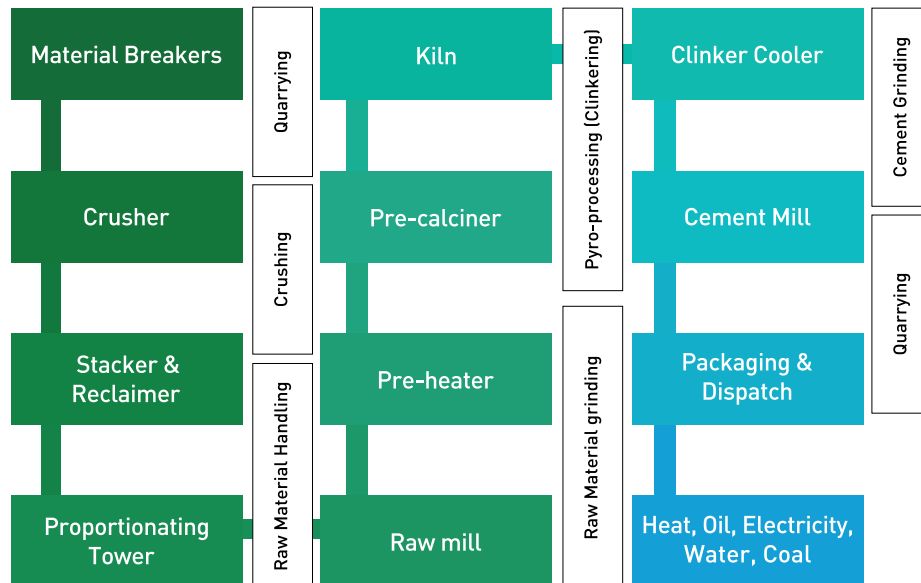


Figure 13: Cement Manufacturing process is mentioned

The clinker to cement ratio in Pakistan's cement production is 0.95, which is higher than both the global average (0.72) and the target for the Net Zero Scenario by 2030 (0.65). A higher clinker to cement ratio implies a higher proportion of clinker, the main carbon-intensive component, in the final cement product. This indicates that Pakistan's cement industry may have opportunities to reduce carbon emissions by optimizing the use of clinker.

Pakistan's emissions intensity in cement production is reported as 0.79 t-CO₂ per ton of clinker (t-cl), which is higher than the global average of 0.6 t-CO₂/t-cl. Although the specific target for the Net Zero Scenario by 2030 is not provided, the higher emissions intensity highlights the importance of reducing carbon emissions in the cement industry. Lowering emissions intensity is crucial for achieving environmental sustainability goals.

Table 4: Energy Profile of Cement Sector			
	Pakistan	Global Average	For Net Zero scenario by 2030
Thermal Energy Consumption (GJ/t-cl)	3.9	3.45	3.2
Electrical Energy Consumption (kWh/t-cement)	90	100	84
Clinker to Cement Ratio	0.95	0.72	0.65
Emissions Intensity (t-CO ₂ /t-cl)	0.79	0.6	

The table 4 provides a deeper insight on the type of resource (including energy) being used at various stages in the process of cement production in Pakistan.

3.3 Energy mix of the cement sector

Figure 14 and 15 are as follows;

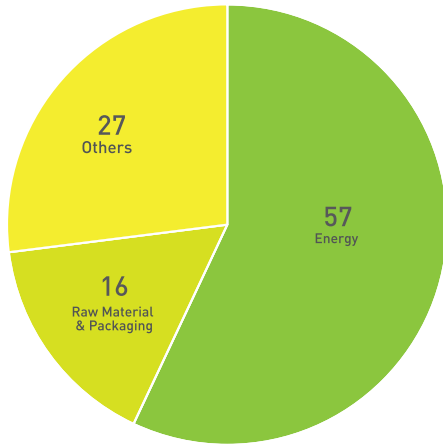


Figure 14: COGS Breakup FY 21- APCMA

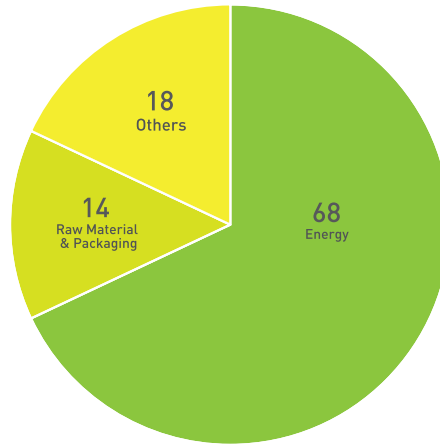


Figure 15: COGS Breakup FY 22 - APCMA

Pakistan's cement industry relies primarily on coal, natural gas, furnace oil, and electricity for its energy mix. Although coal is chosen for its affordability and accessibility, its widespread use leads to high carbon emissions and leaves the industry vulnerable to supply disruptions and price fluctuations. **Energy expenses constitute approximately 63 per cent of the total production costs, with coal being the primary fuel used in cement production. Specifically, for Ordinary Portland cement, fuel costs contribute to about 46 per cent of the cost of goods sold (COGS).** Furthermore, fuel costs make up a significant portion, approximately 73 per cent, of the total energy cost for cement production. **The manufacturing process of cement is known for its high energy intensity, with the production of one metric ton of clinker necessitating 4.6 million British thermal units (Btu) of energy, which is equivalent to burning approximately 160 kilograms of bituminous coal.** Additional associated costs can be found in Annex 3.



Figure 16: Fuel mix of the cement industry of Pakistan

The utilization of alternative energy sources such as biomass and waste-to-energy remains negligible at a mere 0.02 per cent as shown in Figure 15. Consequently, the cement industry in Pakistan exhibits an energy-intensive nature, leading to emissions surpassing the global average by 45 per cent (Figure 16).

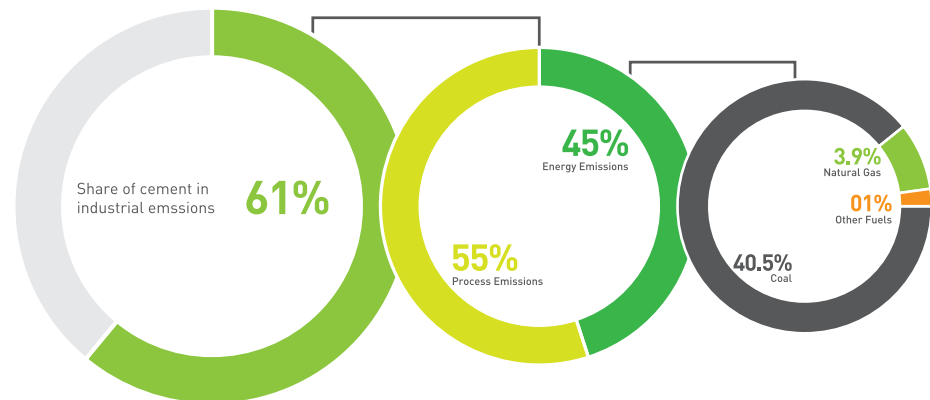


Figure 17: Breakdown of Emissions from Cement Sector of Pakistan

Within Pakistan’s industrial landscape, the cement sector holds a prominent position, consuming 33 per cent of the country’s industrial energy.

Furthermore, the cement industry’s energy consumption constitutes 12.1 per cent of Pakistan’s overall energy consumption. This underscores the significant impact of the cement industry on the country’s energy landscape and highlights the imperative for implementing sustainable energy practices.

Table 5 highlights key aspects of the cement industry’s energy mix and emissions. The clinker to cement ratio is higher than the global average, indicating potential for optimizing clinker usage. The substantial share of coal in the energy mix contributes to a significant carbon footprint, while the relatively lower use of natural gas suggests room for improvement. The limited utilization of biomass and waste in the energy mix indicates an opportunity for increasing the use of alternative fuels. These findings underscore the importance of addressing clinker ratios, exploring cleaner energy sources, and promoting the adoption of biomass and waste-derived fuels to reduce emissions in cement production.

Table 5 Key Energy Mix Indicators of Cement Industry in Pakistan vs Global Cement Industry

Indicator	Average of Sample Plants	Global Average
Clinker to Cement Ratio	0.95	0.72
Share of Coal in Energy Mix	85%	70%
Share of Natural Gas in Energy Mix	12%	24%
Share of Biomass/Waste in Energy Mix	0.08%	6%

Pakistan’s thermal energy consumption in cement production is measured at 3.9 GJ per ton of clinker (t-cl). This value is higher than the global average of 3.45 GJ/t-cl and even higher than what is needed for net zero by 2030. The higher thermal energy consumption suggests potential inefficiencies in the cement production process in Pakistan. Reducing thermal energy consumption is crucial for improving energy efficiency and mitigating carbon emissions.

Pakistan’s electrical energy consumption in cement production is reported at 90 kWh per ton of cement (t-cement). This value is lower than the global average of 100 kWh/t-cement and relatively close to the target of 84 kWh/t-cement for the Net Zero Scenario by 2030. The lower electrical energy consumption indicates that the cement industry in Pakistan has made progress in adopting energy-efficient practices.

The higher emission intensity of country's cement industry can be attributed to several key factors, including a higher clinker to cement ratio compared to the global average, a significant reliance on coal as the primary energy source, a lower utilization of natural gas, and limited incorporation of biomass and waste in the energy mix. To enhance the industry's environmental performance, it is imperative to adopt cleaner technologies and explore alternative fuel options. By implementing these measures, emissions can be effectively mitigated, paving the way for a more sustainable and environment-friendly cement sector.

3.4 Involvement of key SMEs in cement supply chain

During FY22, Pakistan's cement industry experienced a decrease in its coal consumption, which accounted for approximately 24% of the country's total coal supply. Although coal imports dropped by around 4% compared to the previous fiscal year, the value of imports surged by a significant 80.2% due to escalating global energy prices and currency devaluation. The primary source of coal for the industry was South Africa, with South African bituminous coal representing 59% of the total imports in FY22. To mitigate energy costs, local cement manufacturers in Pakistan sought alternative solutions by importing coal from Afghanistan, ensuring uninterrupted operational efficiency.

Small and medium-sized enterprises (SMEs) associated with the cement industry play vital roles in supporting and contributing to the overall production process. SMEs specializing in cargo and transportation ensure the efficient and timely delivery of raw materials. Additives to SMEs enhance the properties and performance of cement. Packaging SMEs provide essential services for the storage and transportation of cement. Mining and mineral SMEs supply crucial raw materials, while steel SMEs contribute to construction projects and the development of cement plants. Coal SMEs provide the necessary thermal energy.

Figure 18 is as follows;

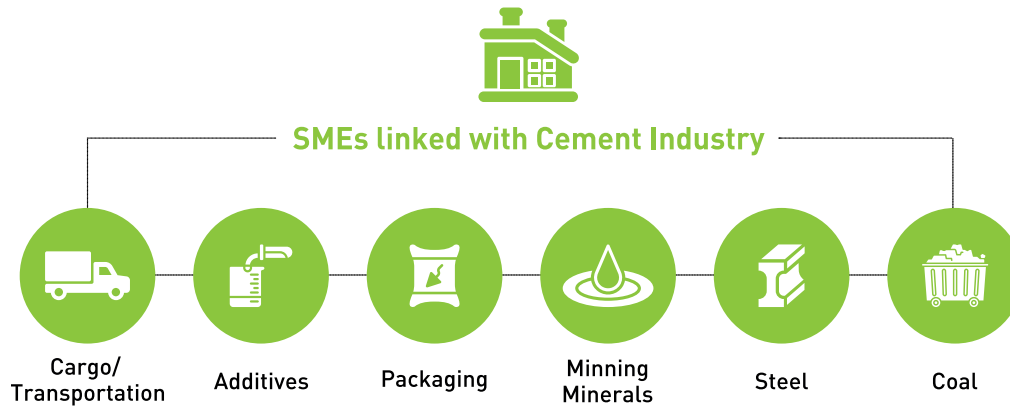


Figure 18: SMEs related with Cement Industry



Section IV

Mapping Global Progress/ Initiatives around Cement Decarbonization

Section IV: Mapping Global Progress/ Initiatives around Cement Decarbonization

4.1 Progress around the decarbonization efforts

Cement manufacturing is a key focus for decarbonization efforts due to its substantial emissions. **In addition to the environmental impact of CO₂ emissions, increasing financial costs are associated with carbon-pricing systems, projected to reach up to €180 billion worldwide by 2050.** (World Bank 2023). Despite these challenges, cement remains the most widely used building material, with a staggering annual production of four billion metric tons. The growing trend demands for environment-friendly alternatives particularly green cement, which supports the need for lower-carbon construction materials. Across the world, a multitude of measures and levers have been employed to accelerate progress in this area, as shown in Figure 19.

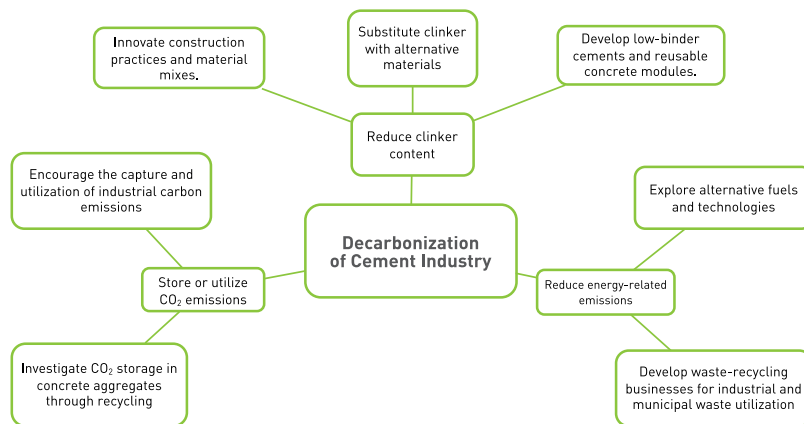


Figure 19: Strategies for Decarbonizing the Cement Industry (Global Efficiency Intelligence, 2021)

The decarbonization of cement industry is a global imperative. As regards, concerted efforts are being made to reduce carbon emissions and transition towards sustainable practices. To accomplish these ambitious goals, a range of promising technologies and strategies are being explored. Driving down the use of clinker, a key component in cement production, is recognized as a viable pathway towards decarbonization (Habert et al. 2020). Additionally, the deployment of carbon capture and storage (CCS) technologies holds significant potential for reducing emissions. Cement plants are actively testing carbon-capture solutions and electric kilns to achieve substantial emission reductions (Bahman et al. 2023).

Energy efficiency improvements play a crucial role in decarbonizing the cement sector. Enhancing energy efficiency through advanced technologies and operational optimizations is a priority (Dinga & Wen 2022). Furthermore, innovative approaches such as greener cement chemistries and materials substitution, including the utilization of fly ash, slag, and wollastonite-based components, offer opportunities for emission reduction and sustainable production.

Carbon pricing has emerged as a powerful driver of decarbonization efforts, with governments at the forefront of incentivizing change in the cement industry (Rissman et al. 2020). They can effectively create incentives through carbon pricing mechanisms, promote green procurement practices for public projects, and encourage the widespread adoption of low-carbon cement.

Fig 20 and fig 21 is shown below;



Figure 20: Global Policies and Incentives to Support Cement Decarbonization.

Furthermore, policy support and off-take agreements offer valuable risk mitigation strategies to produce low-carbon cement. To propel the industry's transition to net-zero emissions, robust policy instruments must be in place, addressing various aspects of the cement value chain. Strategic deployment of carbon capture and storage (CCS) technologies and low-carbon electricity can meet the technical requirements for efficient CO₂ transport.

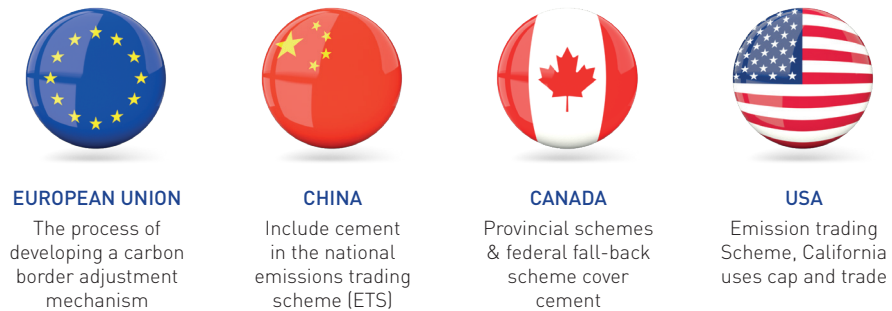


Figure 21: Successful examples from the globe on Carbon pricing to push the cause of Cement Decarbonization.

4.2 Global Best Practices in Net-Zero Initiatives for Cement Industry

Global cement industries have taken initiatives to decarbonize their operations by implementing policies, levers, and legislations with the goal of achieving net-zero emissions within specific timelines. One successful example is the implementation of a comprehensive carbon pricing system that includes a steadily increasing carbon tax. This incentivizes cement companies to reduce their emissions and invest in low-carbon technologies. These efforts, combined with collaborative partnerships, knowledge exchange, and research, demonstrate that with the right policies, legislation, and collective efforts, cement industries worldwide can make significant progress in decarbonization and work towards achieving net-zero emissions. Here are the successful examples worldwide.

Table 6 is as follows;

Table 6: Global Best Practices for net-zero initiative for cement industry			
Countries with Best Practices	Initiatives taken	Progress around Levers to Decarbonize	Other initiatives and incentives (finances, policies) or Barriers
United Kingdom	The UK government pledges to assist the cement sector in decarbonization through innovation, investment, and global collaboration as part of its net-zero agenda.	The government aims for net-zero greenhouse gas emissions by 2050 and has a Cement Industry Roadmap to aid emission reduction efforts (Carver & Walker 2023).	The roadmap involves boosting low-carbon fuel usage, enhancing energy efficiency, and developing carbon capture and storage technologies.
Germany	Germany aims for a 55% reduction in cement industry emissions by 2030 through alternative fuels, energy efficiency, and low-carbon technologies, with a net-zero emissions goal by 2050 (Clean Energy Wire, 2019).	Germany aims for climate neutrality by 2045, with a target to cut cement industry carbon intensity by 50% by 2030.	Investing in new technologies such as CCS and using waste heat from cement kilns to generate electricity.

Table 6: Global Best Practices for net-zero initiative for cement industry

Countries with Best Practices	Initiatives taken	Progress around Levers to Decarbonize	Other initiatives and incentives (finances, policies) or Barriers
United States	The US cement industry, led by the Portland Cement Association (PCA), targets carbon neutrality by 2050, focusing on alternative fuels, energy efficiency, and low-carbon technology. The PCA's Carbon Footprint Reduction program supports emission cuts, aligning with the nation's goal of 50-52% greenhouse gas reduction below 2005 levels by 2030.	United States has set a target of reducing cement production by 10% by 2030, and is also promoting the use of alternative fuels, such as biomass, in the cement industry	The US adopts low-carbon cement tech, using waste as coal substitute and energy-efficient motors, supported by policies promoting sustainable practices in cement production.
China	China targets peak carbon emissions by 2030 and carbon neutrality by 2060, emphasizing the adoption of alternative fuels and low-carbon technologies in the cement industry (Kumar et al., 2022) to reduce greenhouse gas emissions.	China aims to achieve a 40% reduction in carbon intensity and a 10% decrease in cement production by 2025, showcasing its proactive commitment to environmental mitigation and sustainable practices in the cement industry.	China invests in CCS and promotes CCUS technologies through policies such as carbon tax, renewable energy targets, and emission reporting. They provide tax breaks for renewable energy investments and grants for low-carbon cement research.
France	France is committed to achieving net zero emissions by 2050. The French government has set a target of reducing the carbon intensity of the cement industry by 60% by 2030. (Global Cement 2021)	France has set a target of reducing its emissions from cement production by 40% by 2030. To achieve this target, France is investing in alternative fuels, improving energy efficiency, and using clinker substitutes.	France promotes alternative fuels, implements a carbon tax, and sets renewable energy targets to drive decarbonization in the cement industry. Financial incentives like tax breaks and grants support investments in renewable energy and low-carbon cement research.

Table 6: Global Best Practices for net-zero initiative for cement industry			
Countries with Best Practices	Initiatives taken	Progress around Levers to Decarbonize	Other initiatives and incentives (finances, policies) or Barriers
Sweden	Sweden has set a target of reducing its emissions from cement production by 80% by 2030. (UNFCCC 2017)	To achieve this target, Sweden is investing in alternative fuels, improving energy efficiency, and using clinker substitutes.	Sweden enforces carbon tax, renewable energy targets, and emissions reporting for cement producers, while incentivizing investments in renewable energy, low-carbon cement research, and offering tax breaks. Biomass replaces coal in cement kilns, advancing sustainability.
India	In India, the cement industry is committed to reducing greenhouse gas emissions by 33-35% by 2030 (Business Today 2015), through the adoption of alternative fuels, energy efficiency improvements, and low-carbon technology development. The Cement Sustainability Initiative (CSI) India has devised a roadmap for achieving carbon neutrality in the industry by 2050.	India implements initiatives and incentives to support its cement industry’s sustainability goals, including tax breaks, grants, and promotion of alternative fuels. The government sets renewable energy targets to drive renewable adoption in cement production.	India recognizes the importance of sustainable practices in the cement sector and is actively working towards decarbonization through a combination of technological advancements, energy efficiency measures, and supportive policies and incentives.

It is evident that the government policies and incentives have been successful globally in expediting the decarbonization process. However, it is worth noting that low-income countries face certain challenges that hinder their ability to accelerate progress in this regard.

Despite the continued efforts, there are challenges that demand attention, the rapid scaling up the deployment of renewable energy technologies, energy efficiency stands as a paramount necessity across all sectors of the economy. Furthermore, the development and implementation of innovative carbon capture and storage technologies must be pursued earnestly. Additionally, ensuring an equitable and fair transition to a low-carbon economy remains a critical imperative.

Though there are encouraging developments in decarbonization within the global energy sector, the share of renewable energy in global electricity generation has witnessed an increase from 24% in 2010 to 29% in 2021.

4.3. Road to Net-Zero for Cement Industry

1. Carbon capture and utilization/storage:

- a. Carbon capture at cement plants

This action involves the capture of carbon dioxide (CO₂) emissions from cement plants, with subsequent utilization or storage to prevent its release into the atmosphere. In Pakistan, 60% of coal is used for making cement and tinker, but globally, companies aim to replace 30% of coal with other fuels, such as agricultural waste, domestic waste, forestry waste, and oil waste.

2. Efficiency in concrete production:

- a. Optimized mix design
- b. Optimization of constituents
- c. Continued industrialization of manufacturing
- d. Quality control

These measures aim to enhance the efficiency and sustainability of concrete production. They encompass optimizing mixture designs, selecting appropriate constituents, streamlining manufacturing processes through continued industrialization, and ensuring rigorous quality control standards.

3. Decarbonization of electricity:

- a. Decarbonization of electricity used at both cement plants and in concrete production.

This initiative specifically focuses on transitioning to low-carbon or carbon-free electricity sources for powering cement plants and concrete production operations.

4. Saving in Cement and Binders

- a. Portland clinker cement substitution/ clinker binder ratio
- b. Alternatives to Portland clinker cements

A 9% focus on "Savings in cement and binders." This includes substituting Portland clinker cement with alternative materials and exploring non-Portland clinker cements. The goal is to reduce carbon emissions and improve sustainability in cement production.

5. CO₂ Sink Recarbonation

Decarbonation, accounting for 6%, involves the natural uptake of CO₂ in concrete, making it a carbon sink. This process helps mitigate emissions and promotes sustainability in the construction industry.

In 2021, LafargeHolcim, the world's largest cement producer, unveiled plans to invest \$3 billion in low-carbon cement production technologies by 2030. In 2022, the Global Cement and Concrete Association, the global trade association for the cement industry, initiated the "Cement 2050 Roadmap" to expedite decarbonization efforts.

6. Efficiency in design and construction

- a. Client brief to designers to enable optimization,
- b. Design optimization,
- c. Construction site efficiencies,
- d. Re-use and lifetime extension.

Efficiency in design and construction, accounting for 22%, focuses on optimizing the design process through clear client briefs, design optimization, and enhancing construction site efficiencies. Additionally, promoting re-use and lifetime extension minimizes waste and improves sustainability in the industry.

In the context of achieving a net-zero future in the cement and concrete industry, the following breakdown illustrates the various actions and factors contributing to this goal, accompanied by their respective percentages denoting their importance or contribution:

Fig 22 is shown below;

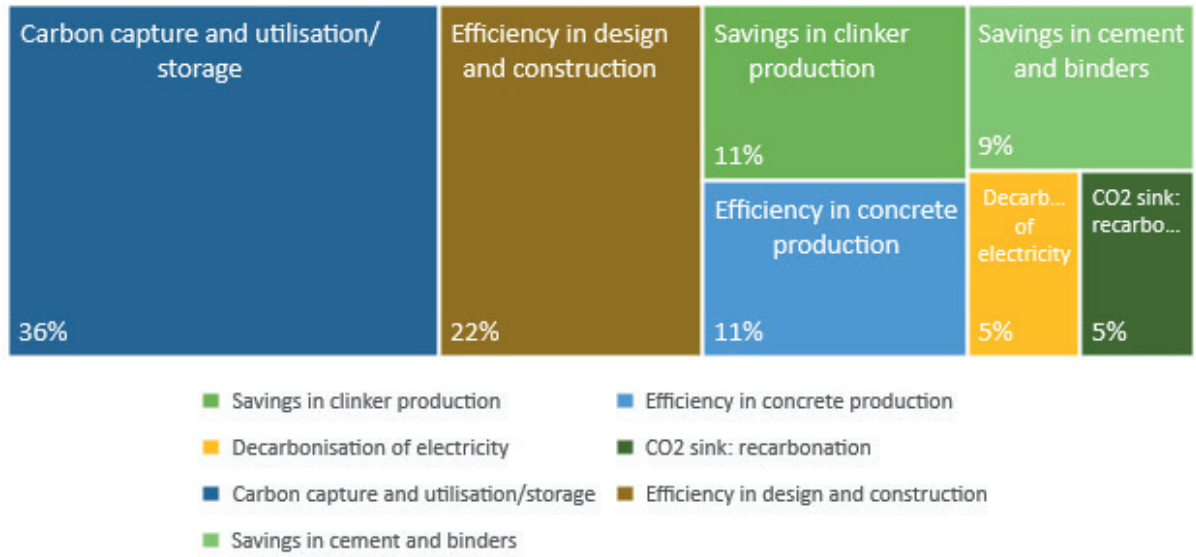
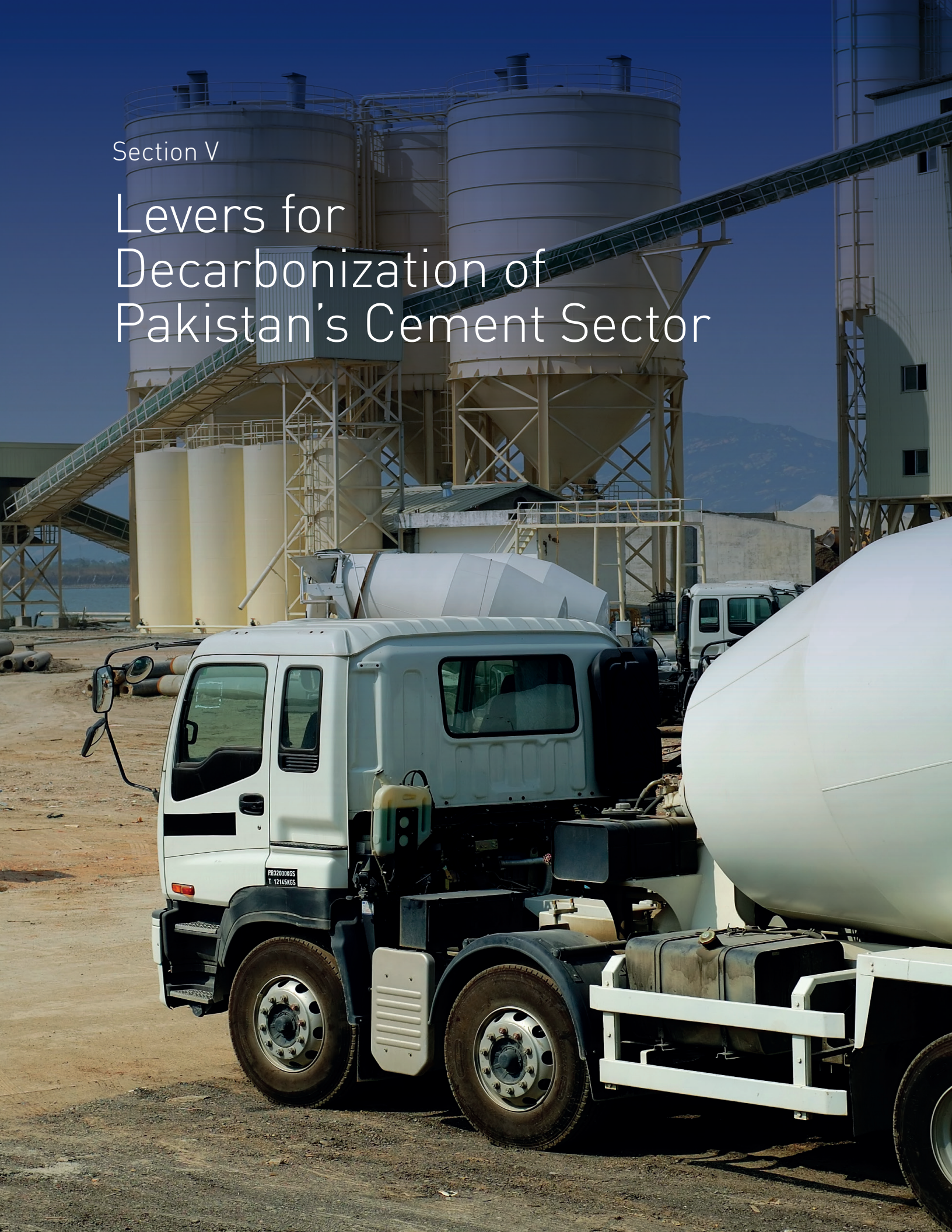


Figure 22: Actions to Net-Zero (Global Cement and Concrete Association (GCCA), 2021)

Section V

Levers for Decarbonization of Pakistan's Cement Sector



Section V: Levers for Decarbonization of Pakistan's Cement Sector

5.1 Existing Landscape for Decarbonization of Cement Industry in Pakistan

Pakistan's carbon emissions are projected to experience a staggering 300% increase by 2030 (Hussain et al. 2020), which necessitates an urgent action. To navigate this complex landscape, a comprehensive decarbonization system must be implemented. The World Bank has explored potential pathways for Pakistan to achieve deep decarbonization, aiming for net-zero emissions by 2070 without compromising its development goals (World Bank 2021). Notably, the Nationally Determined Contributions (NDCs) serve as a pivotal roadmap for decarbonizing various industrial sectors, including cement industry, within Pakistan's strategic framework.

The decarbonization of Pakistan's cement sector entails a multi-faceted approach that encompasses reducing clinker use, capturing process emissions, and implementing transformative technologies like carbon capture and storage. To enable this transition, government support and targeted incentives are essential drivers. Measures such as import facilitations, tax exemptions, and tailored incentives can create a favourable environment for the cement industry to lead the nation towards a low-carbon economy.

5.2 Potential Levers for the Decarbonization in Pakistan

Figure 23 is shown below;

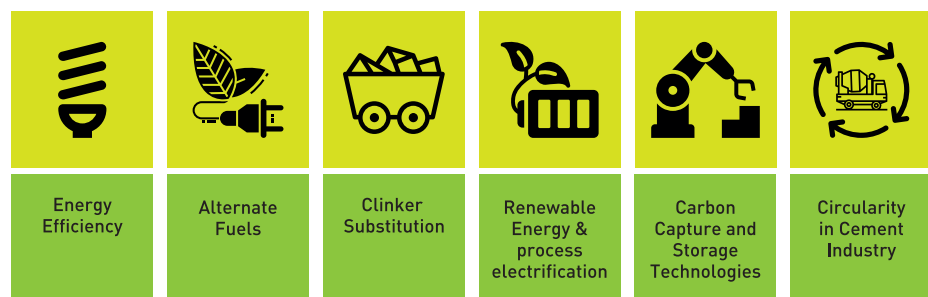


Figure 23: Potential levers for Decarbonization

5.2.1 Potential of Emission Reduction under these Pathways

Table 7 is shown as below

Table 7: Potential Emission Reduction pathways					
Pathways	Impact on CO ₂ emissions	Application			Cost of Application
		Hard	Medium	Easy	
Energy Efficiency	4-8%			•	Low
Alternative Fuels•	35-40%	•			Medium-High
Clinker Substitution	70-90%		•		Low
Novel Cements	90-100%	•			High
Carbon Capture and Storage	95-100%	•			Very High

Decarbonization Strategies in the Cement Industry in Pakistan

During the stakeholder discussion with key stakeholders, the role of key levers in the overarching drive towards decarbonization was brought to the forefront. This included a particular focus on the challenges posed by using alternate fuels, with complexities arising from lower calorific values in boilers and steam applications. Highlighting the need for technological updates, the discussion emphasized the strategic shift from coal to biomass, while acknowledging the substantial costs associated with such a transition.

Amidst these challenges, a compelling alternative arises through clinker substitution strategies, providing a promising avenue to reduce carbon footprints without compromising operational efficiency.

However, the commercial viability of these strategies faces hindrances, including the high cost of Carbon Capture Usage and Storage (CCUS) implementation, the absence of underground storage facilities, regulatory gaps, technical risks, and barriers in deployment. Examining the global landscape, the viability of CCUS emerges as a constrained yet crucial consideration, with optimal feasibility primarily observed in the UK and the US.

A notable aspect in the fuel mix is the current 7 to 8% contribution of Tire-Derived Fuels (TDF) in the cement industry. However, a deeper dive is essential to comprehensively analyze the potential impact, efficiency, and scalability of TDF.

Furthermore, successful case studies of Waste to Heat Recovery systems have been observed in Pakistan, with widespread deployment in most of the country’s cement industry. Additionally, solar initiatives have been witnessed in many cement industries as part of their sustainability efforts.

Further detail of the levers of decarbonization are discussed below.

5.3. Energy Efficiency

Unlike many developing countries, the cement industry in Pakistan has made notable strides in enhancing energy efficiency, particularly through thermal energy efficiency measures. Although cement plants have already embraced efficient technologies, there is always room for improvement.

Recent changes in electricity and gas tariffs, along with exchange rate fluctuations, have created uncertainties and financial implications for industries, hindering decarbonization investments. The lack of a regulatory regime for cleaner technologies and a shortage of trained energy auditors and managers poses barriers to comprehensive energy audits and effective energy management. Investment in capacity building programmes and exploring innovative financing mechanisms like energy saving certificates and conservation bonds can attract private investments. Pakistan needs to catch up with other countries' decarbonization efforts by benchmarking against global best practices and formulating effective strategies and policies. Energy demand and consumption by industry depends on various factors. The main factors behind high energy consumption in cement production can be characterized by the factors in Figure 24.

Pakistan's Energy Efficiency Roadmap stresses the imperative of enhancing energy use efficiency and implementing fuel-efficient technologies across sectors like buildings, industry, and transport. Sectorial variations in energy consumption and optimizing energy intensity can contribute to achieving future efficiency targets. Promotion of Renewable Energy and Energy Efficiency Concepts project aims to bolster sustainable power supply through improved efficiency and increased use of renewable sources. The cement industries sector holds significant potential for energy conservation by adopting integrated management and enhanced efficiency practices; Successful implementations include the integration of waste heat recovery power plants at renowned cement plants, leveraging untapped energy sources.

By implementing energy-efficient measures in 22 cement production plants, the cement industry has the potential to save approximately 0.18 million tons of oil equivalent (MTOE) by 2025. To achieve this goal, \$500 million is required, which can be obtained through the Public Sector Development Program (PSDP), the proposed Energy Efficiency Surcharge by the National Energy Efficiency and Conservation Authority (NEECA), microfinancing options, and donor assistance from various development partners for the Renewable Energy Loan Facility (National Energy Efficiency and Conservation Authority, 2020).

The cement industry has successfully implemented several efficient technologies to optimize its operations. These include the utilization of efficient rotary kilns with multi-stage preheaters and pre-calciners, efficient gate coolers, and steam Rankine-based waste heat recovery (WHR)

systems. Furthermore, the industry has adopted efficient vertical roller mills for grinding and advanced mechanical transport systems. However, there are still potential areas for improvement. One such area is the implementation of low-temperature WHR systems like the Organic Rankine Cycle (ORC), which remains relatively underutilized. Another critical focus should be on enhancing the energy efficiency of auxiliary equipment, such as motors, fans, and pumps, as they consume a significant portion of the industry's energy, accounting for approximately 90%. Other opportunities for improvement include the utilization of hydraulic drives, the adoption of single pipe conveyors, and the installation of Variable Frequency Drives (VFDs) or Variable Speed Drives (VSDs). By addressing these areas, the cement industry can further enhance its energy efficiency and contribute to sustainable practices.

5.4 Carbon Capturing and Storage

The implementation of carbon capture and storage (CCS) technology in Pakistan's cement sector has the potential to significantly reduce CO₂ emissions. However, its viability hinges on the availability of a complete CCS chain, including infrastructure for CO₂ transport, suitable storage sites, and a robust legal framework governing CO₂ transport, storage, monitoring, verification, and licensing.

CCS is a crucial technology for achieving sustainability in the cement industry. However, there are challenges to its adoption in Pakistan cement industry. Commercial feasibility is a key determinant, as implementation is contingent on economic viability. Many cement industry players have already taken proactive measures without external funding or government support.

In the case of most of the developing countries such technologies are either in the demonstration stage or currently expensive, necessitating substantial efforts and overcoming various obstacles for successful integration into cement production processes.

However, to foster sustainability in the Pakistan cement industry, the implementation of carbon pricing mechanisms is essential. These mechanisms can incentivize the industry through tax incentives, investments in low-carbon technologies, and subsidies to facilitate the adoption of CCS. Table 8 is shown on next page;

Table 8: Evaluation of Carbon Capture and Utilization Options for Cement Industry

Recommended Option	TRL	Cost (USD/t-CO ₂)	Emission Impact	Energy Impact
Cement Specific CCUS	6-7	250	Up to 95%	60% heat, 70% kWh
Low TRL heat (electric and H ₂ in kiln)	4-5	200	Up to 40%	N/A (low TRL)
Alternate Cement Chemistries (dependent on Chemistry)	4-9	<50	15% to 70%	Vary with Chemistry

CCUS (Carbon Capture, Utilization, and Storage) technologies are recognized as a crucial element in accelerating the transition towards a low-carbon future. In the context of the cement industry in Pakistan, stakeholders highlighted that the implementation of CCUS can yield significant benefits for decarbonization. The estimated cost for implementing CCUS in 6-7 cement plants is reported to be around \$250/t-co₂, resulting in a remarkable 95% reduction in emission impact and notable improvements of 60% in heat and 70% in kWh energy consumption. **Despite the potential, the adoption of low-carbon technologies faces technological and financial barriers. Insufficient incentives and the absence of specific regulatory approaches hinder the widespread deployment of such technologies.**

While the Pakistan cement industry has implemented certain technologies focused on material efficiency, fuel switching (such as electrification and green hydrogen), CCUS, and circular economy practices like recycling of concrete, it faces several barriers in reducing its high carbon emissions. Process emissions and reliance on fossil fuels for thermal energy contribute to these challenges. Moreover, the strong customer demand for carbon-intensive Ordinary Portland Cement (OPC) in Pakistan and the perception of alternative cement chemistries as inferior in strength hinder progress.

5.5 Use of Less Carbon Intensive Materials

Certain cement industries in Pakistan are incorporating fly ash and limestone, up to 5% in their production processes, as performance enhancers. However, the precise current utilization of fly ash and limestone in the country's cement industry remains unclear. Further information is required to assess the extent to which these materials are being utilized. Pakistan's clinker to cement ratio of 0.95% as of 2023 exceeds the global average of 0.72% and falls short of the targeted net-zero threshold of 0.65% by 2030. Therefore, the optimization of raw material utilization and enhancement of production process efficiency emerge as pivotal drivers in curbing clinker consumption within the cement sector.

Nevertheless, there are various opportunities for the Pakistan cement industry to embrace less carbon-intensive technologies, as indicated in Figure 24.

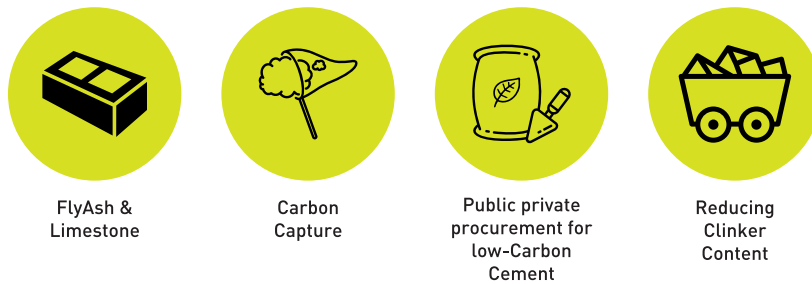


Figure 24: Opportunities to embrace less carbon-intensive technologies.

The limited adoption of green cement is due to a lack of customer awareness and insufficient implementation of legislation discouraging the use of OPC in certain applications, where high-end cement is unnecessary.

Despite the Pakistan Standards and Quality Control Authority (PSQCA) standardizing LC3 (Limestone Calcined Clay Cement), which has a theoretical reduction potential of 30% in CO₂ emissions per ton of cement produced compared to OPC, the market's acceptance of green cement remains low. Full-scale production has not been initiated due to the lack of demand, but small-scale trial production has been conducted on trial basis. Implementing supportive policies for the transition to green cement is a significant challenge. Customer mindset changes are slow, with costs often taking priority over environmental considerations. For example, customers prefer lower-cost options like Portland Blast (PB) furnace cement despite the availability of higher-quality alternatives.

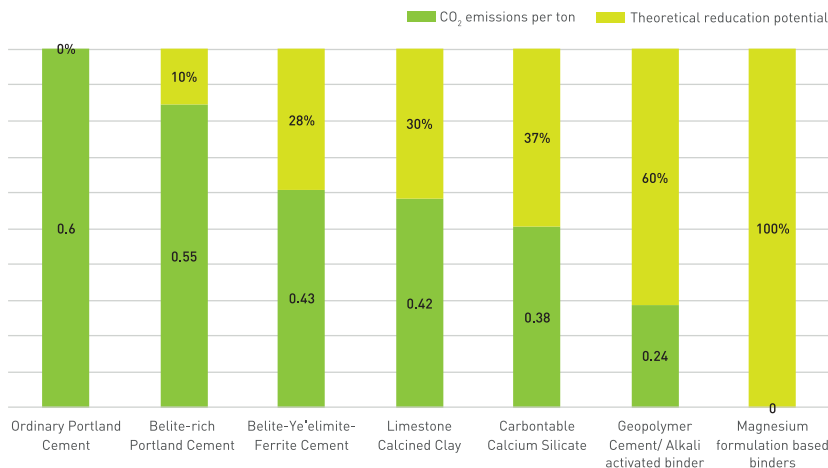


Figure 25: carbon dioxide reduction potential of various low carbon cement (Third Derivative, 2022)

5.6 Use of bagasse in sugar industry & biogas digestors

In Pakistan, bagasse is predominantly utilized as a fuel source in the sugar industry, paper and pulp industry, textile industry, and food processing industry. However, its use as a fuel in the cement industry is not widespread (Kumar et al. 2018). The high temperatures required in cement manufacturing process, reaching up to 1,450 degrees Celsius, necessitate fuels with specific properties to ensure efficient and controlled combustion.

It should be noted that certain cement plants in specific regions or circumstances may explore alternative fuels, including biomass, as part of their energy diversification strategies. However, other biomass sources like agricultural residues, wood chips, or biomass pellets are more commonly considered in these cases due to their better alignment with the energy content and combustion characteristics required for cement kiln operations.

Some cement plants in Pakistan has conducted a smaller pilot using sugar mud as an alternative fuel, and they plan to expand the pilot to include other materials such as rice husk, wheat husk, maize, and corn crop. They believe that within the next year, they can reduce their coal consumption by at least 10% by using alternative fuels.

5.7 Renewable energy and process of electrification

Lucky Cement, DG Khan Cement, and Fauji Cement have demonstrated commendable efforts in transitioning towards sustainable energy practices through the implementation of solar power plants. Lucky Cement achieved a significant milestone by successfully commissioning a **34 MW captive solar power plant at its manufacturing site in Khyber Pakhtunkhwa (KP)**, (The Express Tribune 2022). This initiative not only ensures an annual electricity production of approximately 48 GWh but also translates into considerable cost savings for the company and a noteworthy reduction of around 29,569 tons of CO₂ equivalent emissions per year. (Kumar et al. 2022)

Pakistan's cement industry is characterized by its traditional nature, often exhibits a reluctance to embrace alternative pathways. However, it is crucial to acknowledge that industry has access to viable technological solutions that can effectively address environmental concerns. Notably, the utilization of solar, wind, and biomass energy sources has proven successful in powering cement kilns, and wind energy for grinding operations.

The integration of solar power enhances the reliability of the power system and signifies a notable advancement in Pakistan's nascent energy storage market, positioning Lucky Cement as a pioneer in adopting innovative renewable energy solutions within the country's industrial sector (Lucky Cement 2022).

DG Khan Cement accomplished the installation of a 7 MW on-grid solar power plant at its Khairpur site. By embracing solar energy, DG Khan Cement aims to reduce its power cost mix, curtail carbon footprints, and decrease reliance on expensive fossil fuels. This proactive approach aligns with DG Khan Cement's standing as a prominent cement manufacturer in Pakistan (DG Cement installs 2023).

Fauji Cement inaugurated an 8.8 MW solar power plant at its Wah cement factory, demonstrating its commitment to achieving energy self-sufficiency and adopting environmentally friendly energy sources. The installation of this solar facility is expected to yield a reduction of approximately 10,000 tons of CO₂ emissions, equivalent to the environmental benefit of planting 15,000 trees. With 60% of its total power requirements being fulfilled by renewable sources, Fauji Cement exemplifies its dedication to sustainable practices (CEMNET 2023).

Waste Heat Recovery (WHR) and renewable energy (RE) sources have the potential to meet up to 35% of the cement industry's electricity demand, equivalent to 3% of primary energy consumption (Siemens Energy 2021). In a specific plant example, RE contributes 20 MW and generates 20 GWh/year, accounting for 11% of electricity production (1.1% of primary energy). Energy efficiency (EE) measures and conservation practices offer immediate opportunities for improvement.

Renewable energy technologies, including solar photovoltaic systems, concentrated solar thermal collectors, and wind turbines, have a relatively small share of around 10% in primary energy usage due to their capital expenditure (CAPEX) requirements (Kumar et al. 2022). Exploring fuel switching options such as sustainable biomass, waste as fuel, and green hydrogen availability, along with assessing their supply chain and economic viability, present alternative avenues.

Bestway Cement has been making noteworthy strides in solarizing their plants. They have successfully installed over 80 MW capacity of solar plants on their cement facilities, with a target of expanding it to 120 MW. As a result, they often generate surplus power during the day from these solar plants, which they can sell by leveraging power wheeling technologies (CEMNET 2022).

5.8 Circular Economy

Due to the low calorific value of alternative fuels such as chemical wastes, agricultural waste, healthcare waste, consumer products, industrial municipal solid waste (MSW), and whole or shredded scrap tires, they are being utilized in the cement industry of Pakistan for thermal energy. This approach provides an intrinsically safe method to dispose of community waste due to the relatively long residence times and high temperatures in the kiln burning process, which creates favorable conditions for the complete combustion of organic material,

exemplified by community waste. This initiative presents an opportunity to embrace waste utilization as a circular economy practice, thereby contributing to the reduction of power bills.

The utilization of Reused Derived Fuel (RDF) brings benefits to both the community and the cement industry. The combustion of RDF in cement manufacturing kilns results in a reduction compared to conventional combustible fuels like coal. It helps prevent resource depletion of valuable non-renewable fossil fuels, enhances energy recovery from wastes, ensures safe disposal, and eliminates the need for the construction of dedicated incineration facilities and landfill sites.

However, a significant challenge arises due to the lack of a proper waste segregation mechanism, making the separation of high calorific-value components from MSW difficult. Developed nations are adopting circular processes in the cement industry by using waste products to substitute fossil fuels, thus reducing the negative environmental impact of fossil fuels.

In the context of Pakistan, an agrarian economy where over 37.4% of the population works in the agriculture sector contributing 22.7% of the GDP (Pakistan Bureau of Statistics, 2022), the use of agricultural waste in the cement industry becomes a sustainable circular practice. Crops such as rice, wheat, sugarcane, cotton, and maize generate substantial residue in the form of rice husks, straws, bagasse, cotton straw, and corn stover.

The mixture of coal and bagasse emerges as an environmentally viable option with lower greenhouse gas (GHG) emissions. Furthermore, the co-firing of coal with bagasse proves economically cheaper compared to other alternatives, albeit hindered by the lack of regulatory support from the government in advancing circular economy practices. Additionally, alternative fuels often contain lime, silica, alumina, or iron oxides, primary components in clinker production.

5.9 Mapping Pakistan's progress on levers of Decarbonization

The substitution of clinker with other substances like fly ash or kozelana can reduce carbon emissions in cement production. The electrical and thermal energy consumption of cement plants cannot be reduced beyond a certain point, even in brand new plants, which typically have an electrical consumption of 75 to 80 and a thermal energy consumption of 680 to 700. This means that cement production will continue to require a significant amount of electricity and coal.

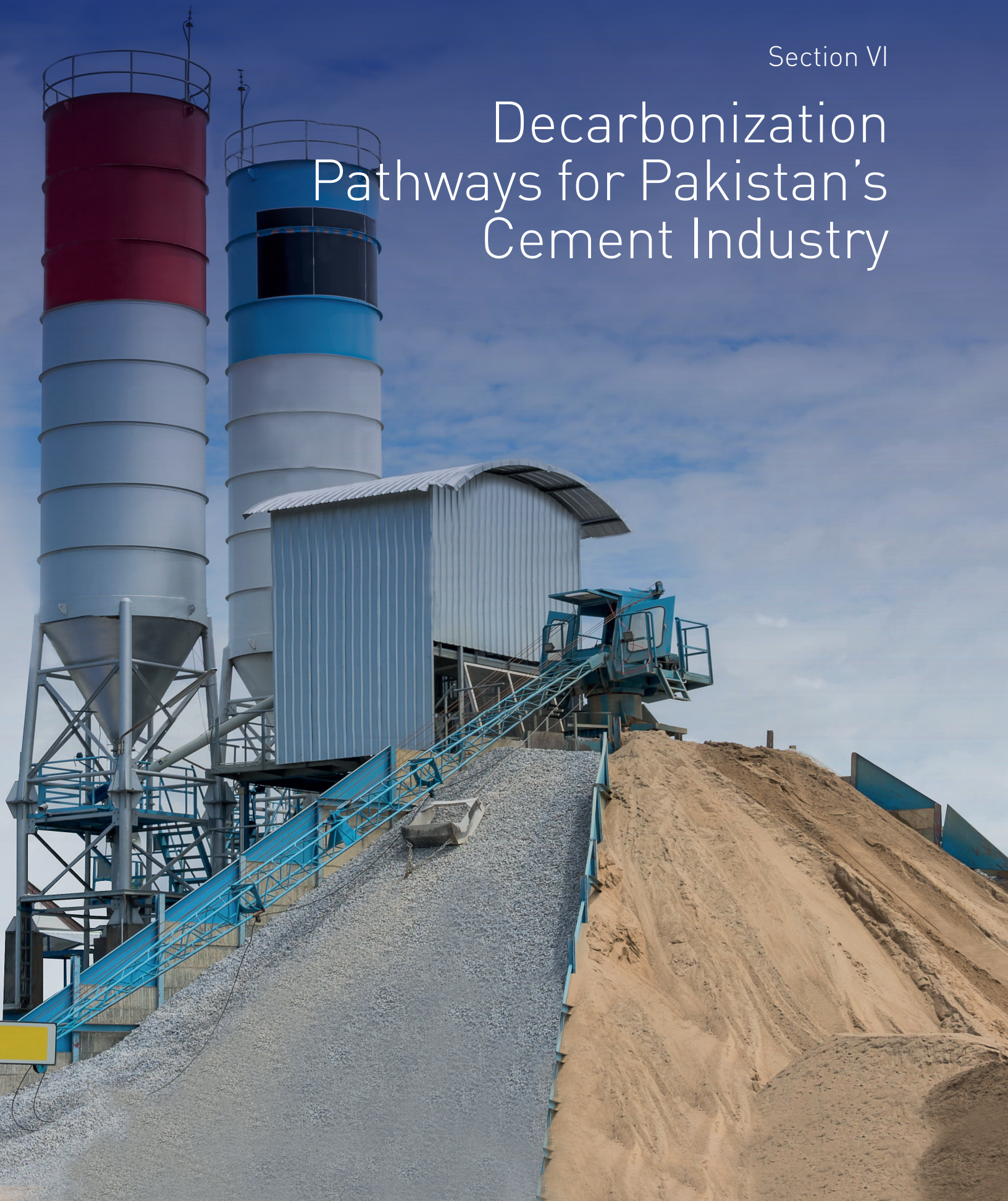
The prevailing conditions in the Pakistani cement industry call for a multifaceted approach to drive the progress of reducing clinker usage, capturing additional heat and process emissions, and embracing transformative zero-carbon technologies.

Despite the cement industry's partial adoption of renewable energy technologies, its reliance on non-renewable sources remains prevalent, highlighting significant avenues for improvement. Cost emerges as a prominent barrier impeding wider adoption, emphasizing the need for economic viability and competitiveness vis-à-vis fossil fuel alternatives. Furthermore, the intermittent nature of renewable sources, particularly solar and wind, presents a challenge. However, integrating energy storage technologies, such as batteries, can effectively mitigate this issue, while recognizing the limited availability of wind potential.

Electrification of heat and the adoption of electric kilns in cement production are promising but still at a low Technical Readiness Level (TRL), necessitating a sufficient supply of green electricity (Qazi, 2022). Lastly, circular economy practices encompassing concrete recycling and the utilization of fly ash and slag as raw materials depend on their availability and customer demand, offering additional technological options for the industry.

Section VI

Decarbonization Pathways for Pakistan's Cement Industry



Section VI: Decarbonization Pathways for Pakistan’s Cement Industry

This section analyzes the impact of policy, regulatory, and technology interventions to enable the achievement of decarbonization pathways for the cement sector in Pakistan. Based on the status quo and environment/energy intensity figures, this develops a scenario-based model under a framework described in Figure 26.

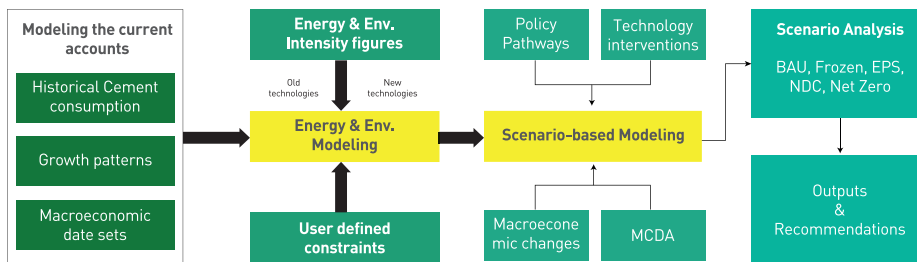


Figure 26: Framework of Scenario based model

The Low Emissions Analysis Platform (LEAP) model has been used as the tool to conduct scenario assessment. The analysis begins by developing the whole demand side model of Pakistan’s energy sector, including all sectors and sub-sectors of the cement sector. This approach would allow to identify the pathways for cement sector, and at the same time assist in analyzing the relative share to be played by cement in overall decarbonization of Pakistan’s Industrial sector to achieve NDC and net-zero targets.

Thus, following two perspectives were targeted using LEAP modeling:

1. Potential of each lever described in previous chapters to limit emissions from the cement sector.
2. Analyze the potential role of cement sector to achieve Pakistan’s NDC and a net zero target by 2050.

6.1 Current Account Setting or Base Year Data

The energy demand assessment in the model is carried out through a bottom-up approach using “energy intensity” and “activity levels” of different subsectors and technologies within. This demand is then influenced through different demand drivers, i.e. Industrial Gross Domestic Product, Commercial space,

population growth, and urbanization.

Given that the whole demand sector of Pakistan has been modeled for conducting a broader analysis, the key indicators and base-year values for them are provided in Annexure B.

For final energy intensity in the current accounts, the values used for different fuels are: i) Coal (0.004271 toe/USD), ii) Oil (0.000247 toe/USD), iii) Natural Gas (0.000004545 toe/USD), iv) Electricity (0.0002773 toe/USD).

6.2 Scenario-based modeling

This section describes different scenarios used in the study along with key assumptions used in each of them. The year 2021 is taken as the base year given that it has the most recent and updated information while 2050 is taken as the end year. Five different scenarios have been modeled as described below:

1. **Business as Usual (BAU):** Under BAU scenario, the economy and the cement sector are expected to grow following the historical demand. It does not take into account the energy efficiency of emission mitigation measures as announced in different policies. In each sector, the fuel share mix is considered the same as its growth over the past years, extrapolated to either 2030 or 2050. This scenario is developed to depict a case as to what would happen if no new policy measures put in place.
2. **Frozen Scenario:** In the frozen scenario, the energy mix of the cement sector, energy intensity and emission factors, and use of carbon capturing technologies is kept same as that in the base year. The rest of the growth patterns are kept the same as that in BAU scenario.
3. **Current Policy Scenario:** This scenario follows the implementation of key measures taken by the cement industry of Pakistan and the roadmap put forward by National Energy Efficiency and Conservation Authority (NEECA) for 2023 and extrapolated further.
4. **NDC Scenario (15% & 50%):** Under this scenario, the emissions from energy sector are reduced by 50% till 2030 through user defined constraints: i) global energy intensity targets by 2030, ii) global target of energy mix, and iii) CCUS to mitigate the remaining GHG emissions required to achieve NDC targets of Pakistan.
5. **Net-Zero Scenario:** In the Net-zero scenario, user defined constraints are changed as to achieve net-zero by 2050. The scenario follows the global net-zero target values for the cement sector and describes what interventions would be required in each lever of the decarbonization in Pakistan.

Table C shows different indicators and how they are projected under different scenarios. The macro-economic indicators that are kept same in each scenario are given below:

- **GDP Growth:** GDP growth is assumed to be 3% between 2023-2025, 4.5% till 2030, and 5.5% 2030 onwards. This is assumed to remain the same for each scenario.
- **Population Growth & Urbanization:** The annual population growth of Pakistan is kept same in each scenario, i.e. 2%. Based on this population increase, the household demand (and consequently the demand of construction materials) is expected to increase to approximately 45 million by 2030 and 67 million by 2050. Household size is kept constant throughout the modeling timeframe.
- **Commercial Space:** Commercial space growth with 8% till 2030 and 5.7% till 2050.

The growth of key levers under these scenarios are described in Table 9.

Table 9: growth of key levers under potential scenarios				
Scenario	Energy Efficiency	Fuel Switching	Clinker Substitution	CCUS
Business as Usual	Historical Energy intensity improvements. 7% improvement by 2030 and 19% by 2050.	Switch to 10% alternate fuels (TDF/RDF/etc.) by 2030 and 20% by 2050.	No clinker substitution	No utilization of CCUS till 2050.
Frozen Scenario	No improvements	Same fuel mix	No clinker substitution	No utilization of CCUS till 2050.
Energy Policy Scenario	NEECA strategic plan	Same as BAU	Same as BAU	No utilization of CCUS till 2050.
NDC Scenario (50%)	Same as BAU	Switch to 20% alternate fuels by 2030 and 30% by 2050	Clinker to cement ration reduced to 0.85 by 2030 and 0.7 by 2050.	Optimized
Net-Zero scenario	Energy intensity improvements of 10% by 2030 and 30% by 2050	Switch to 30% alternate (biomass) fuels by 2050 and 30% natural gas by 2050	Clinker to cement ration reduced to 0.85 by 2030 and 0.7 by 2050.	Optimized

6.3 Key modeling assumptions and data tables

6.3.1 General Parameters

Economic Parameters		Growth Patter	
GDP	Population	Population	225 million
PPP (2021 at 2017 dollar)	Population growth rate	Population growth rate	2%
Growth rate	Total households	Households & size	38 million (6 people per household)

6.3.2 Other targets and assumptions

- Economic growth will be at 4.3% as described under Pakistan's Indicative Generation and Capacity Expansion (IGCEP) plan.
- Commercial floor space will be the direct index of Pakistan's GDP.
- Industrial activity will increase as per the GDP and share of industrial sector in it.
- Energy efficiency measures in energy policy scenario are based on NEECA strategic plan 2021. For Net Zero Scenario, energy efficiency improvements will be doubled.
- The NEECA targets for cement sector indicate 100 ktoe reduction by 2023 through overall energy efficiency, modelled as 2.5 per cent energy intensity reduction for cement.

6.4 Modeling Results

Energy Demand Projections

Figure A represents the energy profile of cement sector under different scenarios.

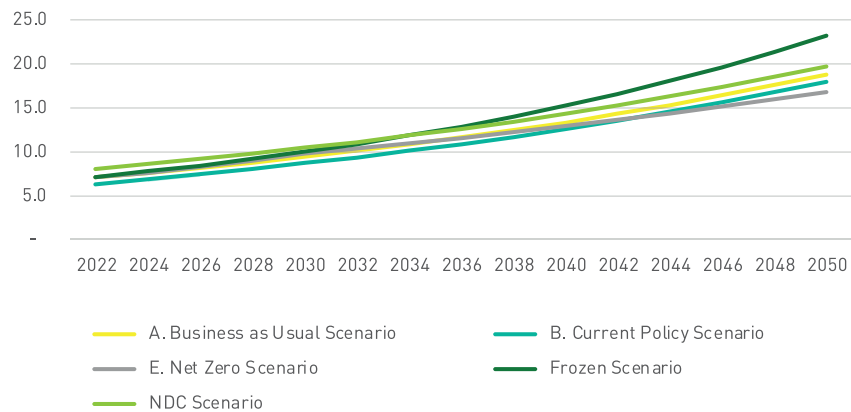


Figure 27: Energy demand of cement sector under different scenarios

Figure 27 indicates that:

- Under BAU scenario, energy demand from cement sector is expected to increase from 7.6 Mtoe in 2023 to around 9.5 Mtoe by 2030 and 18.8 Mtoe by 2050, depicting an annual compound growth rate of 3.53% till 2050.
- The energy demand growth under frozen scenario indicates a much higher value of around 10 Mtoe by 2030 and 23.2 Mtoe by 2050. This indicates that the historic improvements in the energy intensity trend of the cement sector and a switch to biomass would lead to energy savings of around 600 ktoe by 2030 and 4400 ktoe by 2050.
- Given the lack of policy interventions for energy efficiency improvements in the cement sector (apart from NEECA plan), the figure represents almost the similar trend BAU and CPS. The only minor difference comes for the year 2023 where CPS indicates energy savings of around 186.3 ktoe, while in BAU, the energy savings are limited to around 94 ktoe.
- The NDC scenario also indicates a similar trend as that by CPS, as there are no additional energy efficiency improvement measures provided in the updated NDC document for cement sector.
- The net-zero scenario indicates the lowest energy demand profile, depicting annual energy demand of 9.4 Mtoe by 2030 and 16.8 Mtoe by 2050. This indicates the impact coming from increased energy efficiency measures i.e., energy intensity figures in line with global requirements for net-zero scenario for the cement sector (also indicated in Figure 28).

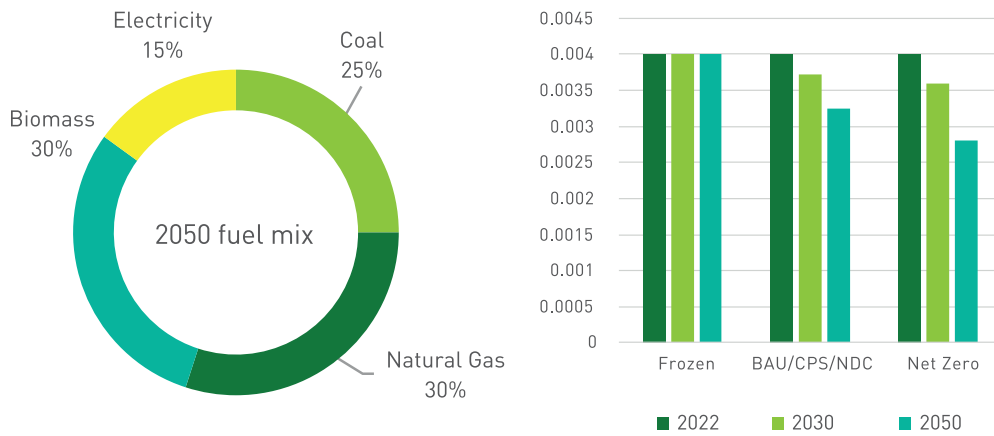


Figure 28: Fuel share mix and energy intensity values by 2050

Figure B further indicates that the total energy demand by 2050 in cement sector under a net-zero scenario should be met by almost 30% utilization of biomass, 15% electricity-based power, and a higher dependence on natural gas as a resource. The consumption of coal under the net-zero would drop from 85% in 2022 to around 25% in 2050.

Emission Profiles

Figure 29 represents the emission profile of cement sector under different scenarios.

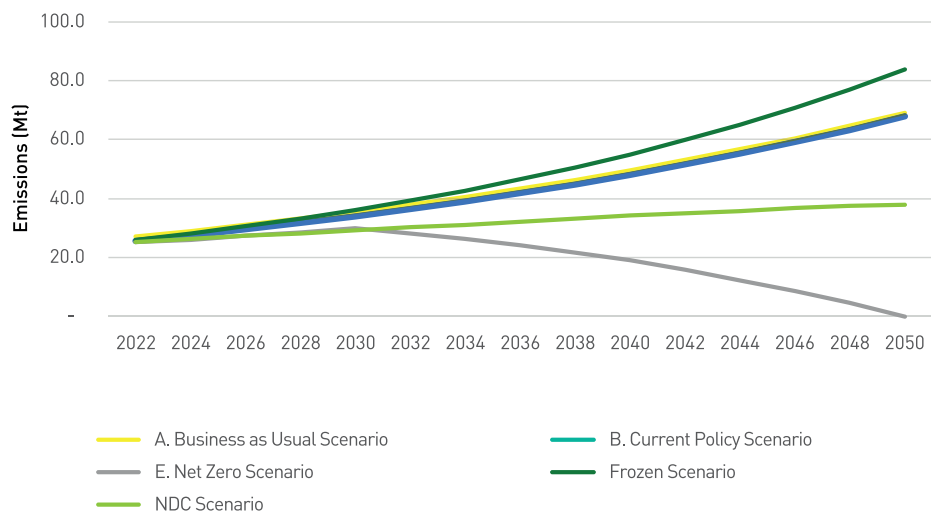


Figure 29: Emission profiles of cement sector under different scenarios

Figure 29 indicates that:

- Under BAU scenario, emissions from cement sector of Pakistan are expected to increase from 25.6 Mt in 2022 to 34 Mt by 2030 and 68 Mt by 2050. This indicates an ACGR of 3.4% till 2050.
- In frozen scenario, the emissions increase to 36 Mt by 2030 and 83 Mt by 2050. This indicates that energy efficiency improvements and switching from coal to energy alternatives under the BAU scenario would lead to emission reductions of 2.1 Mt and 16 Mt by 2030 and 2050 respectively.
- The current policy scenario indicates the same trend as the BAU scenario.
- In NDC scenario, the emissions increase to 29.2 Mt by 2030 and 38 Mt by 2050. This indicates an emission reduction of 5 Mt by 2030 and 30 Mt by 2050. As compared to BAU scenario, this indicates an emission reduction of 14.1% and 44% by 2030 and 2050 respectively.
- Under the net-zero scenario, the emission follows the same trajectory as NDC scenario till 2030, and then reduces to zero by 2050.

6.5 Decarbonization through different levers

6.5.1 Energy efficiency impact

Various research studies have identified opportunities to enhance energy efficiency within the global cement industry through the adoption of readily available technologies and practices. This is primarily because approximately 60% of the total CO₂ emissions in the cement industry stem from process-related emissions during calcination, which are unrelated to energy consumption. Consequently, energy efficiency measures only influence roughly 40% of the CO₂ emissions produced by cement manufacturing.

Among the array of energy efficiency technologies and measures, one major development in cement sector of Pakistan has been the waste heat recovery (WHR) systems for power generation in cement plants. This technology harnesses a portion of the medium-temperature waste heat (ranging from 200-400°C) generated by kiln flue gases to produce electricity. While it doesn’t reduce the overall electricity consumption at a cement plant, it efficiently utilizes excess heat that would otherwise go to waste, generating electricity for on-site use or export to the grid.

Typically, WHR power generation technology yields approximately 10-25 kWh per ton of clinker produced, with the electricity output dependent on factors like kiln configuration, raw material moisture content, and preheater setup. Several countries, including China, India, Japan, and South Korea, have embraced WHR power generation technology, with installation rates ranging from 30% to 90% of each nation’s cement production capacity. Notably, China leads the way with the highest adoption of WHR power generation technology in the cement industry, as approximately 90% of its domestic clinker production capacity incorporates this technology.

Figure 30 represents the energy efficiency impact across different scenarios of the model.

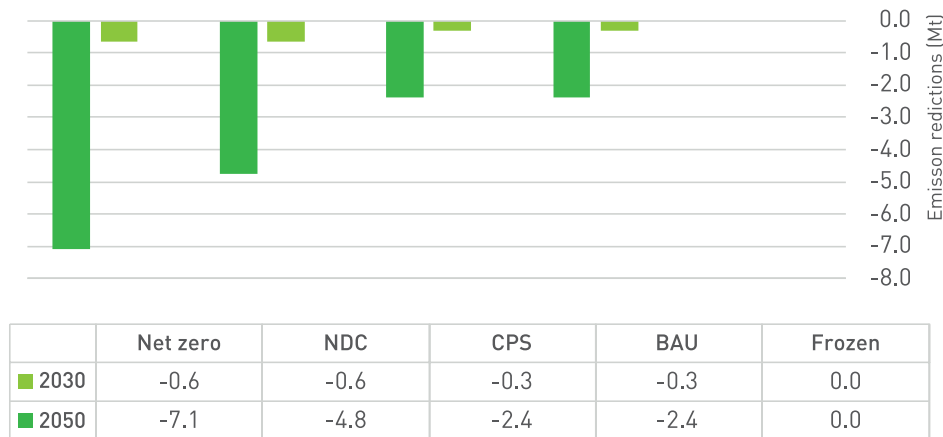


Figure 30: Impact of energy efficiency on decarbonization efforts of cement sector in Pakistan

Figure D further indicates that energy efficiency improvements in cement sector of Pakistan could lead to a maximum emission reduction of around 7.1 Mt (corresponding to 30% improvements in energy intensity by 2050 under NDC scenario).

6.5.2 Fuel Substitution Impact

Coal and petroleum coke are among the most carbon-intensive fuel options available. Shifting away from these two fuels towards less carbon-intensive alternatives, such as natural gas, can have a substantial impact on reducing GHG emissions in the cement industry. The primary fuel-switching option involves transitioning from coal and petroleum coke to natural gas, which is readily available in large quantities and can be easily integrated into existing cement plants with current technology. Notably, the CO₂ emissions intensity of natural gas (measured in kgCO₂/GJ) is less than 60% of that of coal and petroleum coke.

Given the price projections for coal and natural gas in the wake of, recent regional turmoil and rising energy costs, it is improbable that market forces alone will prompt a shift from coal to natural gas in Pakistan's cement industry. Hence, there is a pressing need for policy interventions that incentivize this transition. One potential policy measure could involve the implementation of a carbon tax or carbon credit system. It's important to note that, unlike coal and petroleum coke, natural gas does not require significant preparation, such as coal grinding, before it can be used in kilns. Nevertheless, in cases where cement plants lack adequate natural gas transport infrastructure, retrofits may be necessary to install the required natural gas pipelines, and in some instances, new kiln burners may be required.

Another critical consideration in Pakistan is the adoption of Tyre-derived fuel and Refuse-Derived Fuel (RDF) as substitutes for coal. Many cement industries in the country have already taken steps in this direction. However, due to the high costs associated with waste segregation and collection, making this transition will also necessitate robust policy support and fiscal incentives. Figure 31 indicates the emission reduction potential through fuel switching in cement sector of Pakistan.

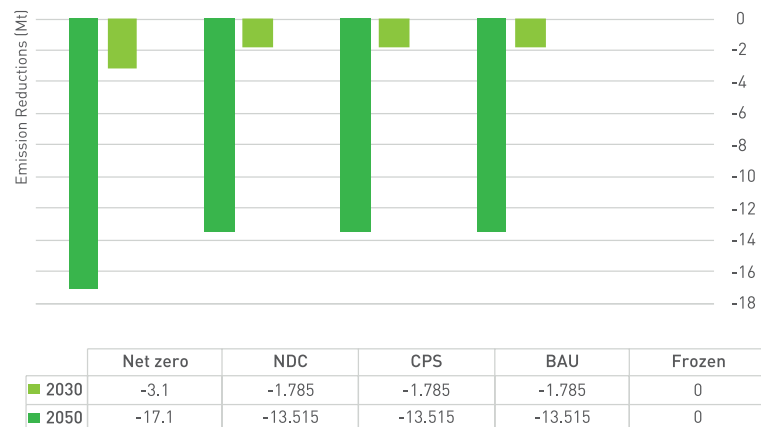


Figure 31: Impact of fuel switching on decarbonization efforts of cement sector in Pakistan

6.5.3 Clinker Substitution

Currently, the clinker-to-cement ratio in cement plants on average in Pakistan is around 0.95. In a cement plant, fuel consumption and approximately 60% of electricity usage are primarily attributed to clinker production, which includes activities like raw material grinding, fuel preparation, and the operation of cement kilns. A higher clinker-to-cement ratio leads to increased energy and fuel consumption per ton of cement produced. The substitution of clinker with Supplementary Cementitious Materials (SCMs) such as fly ash, blast furnace slag, natural pozzolans, ground limestone, and calcined clay offers a viable solution to markedly reduce energy intensity per ton of cement manufactured.

Various types of SCMs can be integrated into cement or concrete production. The most prevalent SCMs include fly ash, ground-granulated blast-furnace slag (GGBFS), and ground limestone. Additionally, other SCMs like natural pozzolans and calcined clay hold substantial potential for utilization in both cement and concrete applications. It’s important to recognize that, although fly ash and GGBFS have been used as SCMs worldwide for many years, environmental concerns regarding their eco-toxicity have been raised by environmentalists. As a result, it is imperative to establish and adhere to prescribed protocols for the handling and processing of these two SCMs to mitigate any adverse environmental consequences.

While the clinker substitution in Pakistan poses a good potential, as the current ratio is very high, nothing much has been done around it due to limited support provided to the industries. Based on the model, the clinker substitution impact is slightly visible in the NDC and mainly in the net-zero scenario. However, this impact given the model complexity has been separately modeled (dummy variable in the model).

Figure 32 represents the emission reduction potential through clinker substitution in cement sector of Pakistan.

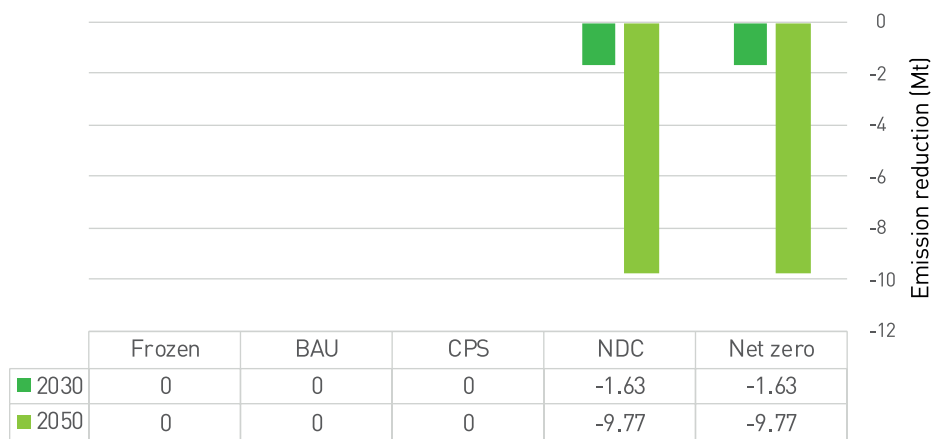


Figure 32: Impact of clinked substitution on decarbonization efforts of cement sector in Pakistan

6.5.4 Use of carbon capture and storage technologies

CCUS technologies are emerging in the cement industry for capturing and compressing CO₂ emissions. While carbon capture technologies are still in pilot stages, some carbon utilization technologies, like Carbon Cure, have been fully commercialized. These technologies are valuable for reducing CO₂ emissions from cement production, particularly through post-combustion CO₂ capture. Captured CO₂ can be stored geologically or used commercially in various applications such as concrete curing, material production, and fuel synthesis. Although most carbon utilization technologies are in development, some are advancing towards scale-up.

Commercial-scale deployment of carbon capture technologies in cement is slow until 2030, while certain carbon utilization technologies are more advanced. For example, CarbonCure has implemented its technology in around 100 North American concrete plants. Widespread adoption of CCUS technologies in cement and concrete relies on significant policy support, especially for capital-intensive post-combustion CCS technologies. Adequate infrastructure for storing the captured carbon is essential, as carbon utilization alone may not absorb all the captured carbon. Suitable geological storage sites are required for cement plant emissions.

In the LEAP model used for this study, CCUS utilization is optimized under two conditions: i) to meet NDC target of 2030 and ii) to meet net-zero emission reduction target by 2050. Figure 33 represents the emission reduction that is to be achieved by using CCUS in an optimized mode.

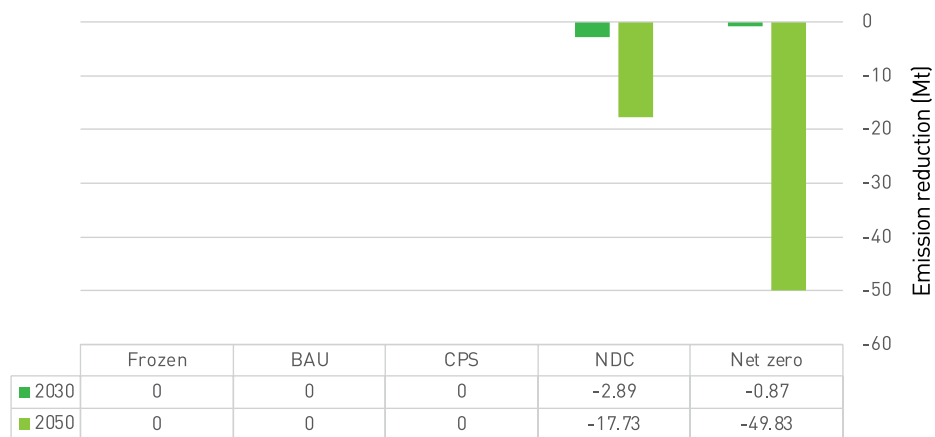


Figure 33: Emission reduction achieved through the use of CCUS

Section VII

Challenges and Recommendations for Cement Industry Low Carbon Development



Section VII: Challenges and Recommendations for Cement Industry Low Carbon Development

Energy efficiency Improvements

Challenges and Limitations

- **Issue 1- The informal sector:** While processing within the plant has improved, the informal sector of the supply chain (mainly the small-scale quarrying, waste collectors, transportation systems) is still energy and environment intensive, leading to energy waste and carbon leaking.
- **Issue 2- Outdated systems still exist:** While most of the cement plants in Pakistan are using updated technologies with adequately high efficiencies, some industries have still not adopted the advanced solutions (such as waste heat recovery systems).
- **Issue 3- Absence of benchmarks and performance standards:** While NEECA is currently working on the MEPs, there is no existing technology standard or benchmark in place to gauge or enforce the efficiency improvements in cement industry of Pakistan. This is particularly important for the utilization of industrial waste and geopolimer in the construction industry which is hindered by inadequate benchmarks and technological upgrades.

Policy Recommendations

- To further improve efficiency in manufacturing process, Ministry of Industries and Production (MoIP) in collaboration with Engineering Development Board (EDB), NEECA and EPA should develop a “**Strategic Plan**” aimed at energy intensity improvements, particularly through the installation of energy management systems, upgrading preheaters, exploring hybrid energy solutions, and optimizing operational efficiency.
- To enable an early shift from outdated technologies, NEECA (in collaboration with provincial EE&C authorities) can develop and enforce **Minimum Energy Performance Standards (MEPS)** and benchmarks for any future cement powerplant while also providing a target year for improvements in the existing ones. These benchmarks will also allow cement manufacturers to compare their energy performance against industry standards.
- To enable transformation towards advanced technologies, the GoP must facilitate **Public-Private Partnerships (PPPs)** that encourage the collaboration between MoIP, NEECA, PEC, and the private sector for adoption of energy efficient technologies and best practices.

Use of Alternate Materials

Challenges and Limitations

- **Issue 1- Supply chain of TDF/RDF:** While the use of Reuse-derived Fuel (RDF) and Tyre-derived fuel (TDF) is considered a locally viable solution for cement industry, the need for a waste management supply chain results in additional cost for the industry. Given that no such formal medium of conveyance exists in Pakistan, the industry is reluctant to make the transition away from a comparatively low-cost fuel source, i.e. coal.
- **Issue 2 – Fiscal or regulatory support for the use of TDF/RDF:** Currently, no financial incentives (tax rebates, subsidies, etc.) or regulatory support is being given to the private sector to replace coal with alternate sources. Further, there is an absence of quality standards and regulations for waste categorization and RDF production to be used in industrial boilers.
- **Issue 3 – Technological Limitations:** Use of alternate materials also requires the availability of necessary technology for its efficient working. While some of the new cement plants (such as the one being operated by Power Cement) are using updated technologies, many still rely on boilers that cannot efficiently process the waste and tariff reforms. Hence, significant technological upgrades are required to use a blend of biomass and coal for burning.
- **Issue 4 – High temperature and intensity needs:** The calcination process in cement manufacturing requires high-temperatures during production, which needs rapid combustion. However, as of now, limited solutions and alternatives exist that can replace the use of coal or fossil fuels to provide those operating conditions.
- **Issue 5 – Electric Kilns still a distant solution:** While induction or electric kilns are being proposed as an alternate solution, the technology has not yet reached a fully commercial scale even in the developed countries due to its high cost.

Issue 6 – Clinker Substitution

Policy Recommendations - Waste derived fuel

- To expedite the transition from coal to waste-derived fuel, the GoP must provide regulatory and fiscal support (incentives, tax breaks, subsidies, or tipping fee) to the manufacturers, thus providing an economic case for transition.
- NEECA, in collaboration with private sector, industry regulators, APCMA, and waste management agencies, can develop and enforce quality standards for use of alternate fuels. A centralized testing facility can be established to verify the composition and burning characteristics of fuel components, addressing challenges related to R&D samples.
- MoCC&ED, in collaboration with waste management authorities, should put forward policy provisions for responsible handling and utilization of waste-derived fuels in cement industry.
- The public sector, in collaboration with development partners, can establish a joint platform that can facilitate technology transfer by partnering with developed countries. This platform may also serve to share knowledge among cement manufacturers, encouraging the exchange of best practices and lessons learned.
- NEECA, in collaboration with CSOs and private sector, should scope the feasibility of using green hydrogen as an alternate to natural gas in the cement industry.

Policy Recommendations - Clinker Substitution

- The Ministry of Industries and Production (MoIP), in collaboration with NEECA (and provisional EE&C authorities), should initially devise a policy roadmap, enabling a gradual increase in use of blended cement. The roadmap (or policy) must point to new standards and codes and encourage the use by providing requirements in public procurement policy.
- Pakistan Engineering Council, in liaison with academic institutes, should initiate pilot R&D projects that allow the cement industries to work jointly with academic institutes to scope the feasibility and potential use of blended cement in a wide range of applications. The discourse around this may further be developed by engaging development partners and civil society.
- To build the discourse around socio-economic significance of clinker substitution, NEECA (along with provincial EE&C authorities) in collaboration with CSOs and Academia should initiate a series of training sessions and seminars highlighting the acceptable alternate solutions, best practices, and global trends, and understanding the regulatory need assessment to enable the transition.

Renewable Energy Integration

Challenges and Limitations

- **Issue 1- Power wheeling constraints:** To support the offtake of RE in the corporate sector, power wheeling reforms can provide a driving push, however, there has been a major disagreement on wheeling or use of system charges between NEPRA, CPPA, DISCOs, and the private sector.
- **Issue 2 - Slow offtake of competitive market regime:** While Pakistan has made a transition from single to a multi-buyer model, there is a slow offtake or progress to support RE development.

Policy Recommendations

- CCOE must open communication channels (such as special taskforce) to address the power wheeling issues in a consolidated and holistic manner.
- The International Monetary Fund (IMF), through its bailout programme for Pakistan, should consider offering tax credits or exemptions for investments in renewable energy infrastructure and technologies, including solar panels, wind turbines, and energy storage systems.

Carbon Capture and Storage Technologies

Challenges and Limitations

- **Issue 1- Commercial viability:** While there is a growing focus on the use of CCS to limit carbon emissions, there are very limited projects globally deployed (less than 600) to address the solution. CCS particularly for developing countries is not a short-term solution to mitigate emissions from hard to abate sectors.
- **Issue 2- High Cost:** Deployment of CCS entails high capital investment, which in the short run is not economically viable, especially in the backdrop of economic turmoil leading to a limited fiscal space for private sector.

Policy Recommendations

- The Ministry of Climate Change and Environmental Coordination, in collaboration with development partners and NEECA, should provide a long-term plan (2035 or 2040) for CCS in updated NDCs and LT-LEDs. Such plans should also demonstrate Pakistan's vision to either pilot or commercialize the technology by 2030 or 2035.
- PEC, in liaison with academic institutes and private sector, should increase the R&D for post combustion CCS. This would require an increase in the government funding to support such initiatives.

Circularity in the Cement Industry

Challenges and Limitations

- **Issue 1- Supply chain management:** Circular solutions require the industry to adapt and build new supply chains and technologies. Achieving circularity in the built environment will require supportive regulations and industry-wide standards.
- **Issue 2-** Technological development and availability: Most of the technologies are relatively new and have not yet been deployed at scale.
- **Issue 3-** Limited discourse and developments in policy landscape

Policy Recommendations

- The Ministry of Climate Change and Environmental Coordination, in collaboration with development partners and NEECA, should provide a long-term plan (2035 or 2040) for CCS in updated NDCs and LT-LEDs. Such plans should also demonstrate Pakistan's vision to either pilot or commercialize the technology by 2030 or 2035.
- PEC, in liaison with academic institutes and private sector, should increase the R&D for post combustion CCS. This would require an increase in the government funding to support such initiatives.

Other key messages for enabling the transition

- To develop discourse around low carbon development, **decarbonization of cement industry should be made a part of Pakistan's updated NDCs** and Long-term low emission development strategy (LT-LEDs).
- To address data challenges, there is a need to provide an **emission accounting framework** and a legal cover to the cement industry, which shields them from data hacks and leads to competitive disadvantage.

7.1 Driving Platforms for Cement Sector Decarbonization

A) Business case and global commitments

Cement Industries in Pakistan are not completely open to discussion and more importantly are reluctant of "targets" such as appraisals like "Net zero".

Global Enterprises are receptive to engaging in dialogue but exhibit apprehension towards commitments such as "Net Zero" targets due to concerns over the potential implications. To bring them around the global commitments, there is a need to come up with commercially viable solutions that could support the operations of the industry along with the global climate commitments fulfillment.



Figure 34: Strategic measures implemented for decarbonization to make commercial sense

B) Opportunities for Pakistan Cement Industry to decarbonize: Business Case

Decarbonization efforts, especially within hard-to-abate sectors in developing economies marked by economic instability, a comprehensive evaluation of commercial viability is imperative. Emphasizing key factors that underscore the initiative's environmental, financial, and social benefits is essential. Such an analysis is pivotal for highlighting the feasibility of decarbonizing industries, showcasing its potential to drive sustainable business growth amidst complex economic landscapes.

In the context of the Pakistan cement industry, adopting a comprehensive approach towards decarbonization is not just an environmental responsibility but a strategic necessity for sustainable business growth. Addressing several key aspects can significantly contribute to building a compelling business case for decarbonization. Firstly, emphasizing the role of decarbonization in mitigating climate change is crucial. By reducing GHG emissions, especially carbon dioxide, industry can contribute significantly to global efforts in combatting climate change, aligning with international agreements like the Paris Agreement.

Fortera has joined the Alliance for Low Carbon Cement and Concrete (ALCCC) to support decarbonization in the cement and concrete sectors. The ALCCC aims to decrease the carbon footprint by promoting low-carbon materials and technologies, influencing policy and standards, and revising building standards. The alliance includes established material designers, producers, startups in biotechnology and sustainable construction, and collaborates with international NGO ECOS. By uniting industry experts and advocating for change, the ALCCC strives to reduce CO₂ emissions and make low-carbon cement and concrete the standard choice.

The **Global Cement and Concrete Association (GCCA)** promotes sustainability in the cement industry through its guidelines and roadmap for reducing emissions by 2050. It emphasizes responsible leadership in sourcing, manufacturing, and use of cement and concrete, while prioritizing health, safety, and monitoring performance. The GCCA aims to establish concrete as the preferred sustainable building material to address global challenges.

Figure 35: International Collaboration and platform

Moreover, focusing on **air quality improvement** is essential. Decreasing emissions not only benefits the environment but also enhances public health, which is a critical concern in densely populated countries like Pakistan. Additionally, considering the stringent emission standards and the potential impact of **carbon pricing** mechanisms is vital. Adhering to regulations and preparing for future policies ensures regulatory compliance and helps the industry adapt to evolving market demands.

Another key aspect in that sense is understanding **market dynamics**. With a rising demand for sustainable products, companies investing in decarbonization can align with **consumer preferences**, gaining a competitive edge and

bolstering their brand image. Collaborations with **research institutions** and advancements in **green cement** technologies demonstrate innovation, attracting socially responsible investors and positively influencing stock prices.

Operational efficiency and cost savings are paramount. Implementing **energy-efficient processes** not only reduces operational costs but also establishes resilience in the supply chain, vital in the face of climate-related disruptions. Decarbonization efforts, when measured through specific KPIs such as carbon emissions reduction, energy efficiency, sustainable material usage, and renewable energy adoption, provide a clear framework to track progress. This data-driven approach not only showcases tangible results but also facilitates access to green financing options, enhancing the industry's financial viability.

Another key idea to enhance the business case would be the **Carbon Capture and Storage (CCS)** technology can capture carbon dioxide emissions from cement production and store them underground, which would prevent them from entering the atmosphere. CCS technology is a relatively new technology, but it has the potential to significantly reduce GHG emissions from the cement industry. In fact, the International Energy Agency (IEA) has estimated that CCS technology could reduce GHG emissions from the cement industry by up to 60%. Investing in CCS technology would be a significant investment for a cement producer in Pakistan. However, there are a number of potential benefits to investing in CCS technology, including reduced regulatory risk, improved brand reputation, access to new markets.

A cement producer in Pakistan could develop new cement products with lower carbon footprints in a number of ways. For example, the company could use alternative fuels, such as biomass or waste-derived fuels, in the cement production process. This would reduce the amount of fossil fuels used, which would lead to lower GHG emissions, use supplementary cementitious materials (SCMs) in the cement production process. **SCMs** are materials that can be added to cement to improve its properties and reduce its carbon footprint. Some common SCMs include fly ash, slag, and silica fume develop new cement formulations that are more efficient and have lower carbon footprints. For example, researchers are developing new types of cement that can be produced at lower temperatures, which would reduce energy consumption and GHG emissions.



Figure 36: Commercial Viability for Pakistan Cement Industry to decarbonize

C) Ammonia as fuel in the cement decarbonization

The global adoption of ammonia as a fuel in the cement industry is witnessing a notable upswing, as reported by the International Energy Agency (IEA). This trend reflects a growing shift towards cleaner alternatives to traditional fossil fuels in cement production. Countries that have embraced ammonia, such as the Netherlands and Sweden, have showcased remarkable reductions in carbon emissions within their cement industries. This environmentally friendly approach not only contributes to emission reduction goals but also proves to be cost-effective for cement manufacturers. The significant cost savings observed in nations adopting ammonia as a fuel underscore its economic viability, making it a compelling choice for sustainable and economically prudent cement production practices on a global scale.

International Case Studies

AUSTRALIA: with its abundant natural resources and renewable energy potential, is poised to emerge as a key global exporter of green ammonia. The country is actively exploring domestic uses of ammonia, including the H2-Hub project, focusing on integrated hydrogen and ammonia production for both transportation and industry. Australia is also engaged in international collaborations with nations like Japan and South Korea, working towards establishing standardized global supply chains for green ammonia.

EUROPE: Vital decarbonization solution in Europe, not just for fertilizers but also as a clean fuel. It's promising for heavy transport, serving as an energy source for long-haul voyages. Challenges like toxicity and flammability can be managed with solutions like scrubbers. Green ammonia production from renewables is crucial. Europe seeks to enhance ammonia's role in decarbonization through low-carbon synthesis, carbon capture and storage, and its use as storage for renewable electricity and a hydrogen carrier. Strong regulations and international collaboration are vital to drive ammonia's market readiness.

JAPAN: The use of ammonia as a next-generation energy source involves co-firing it at coal-fired power plants and direct combustion in gas-turbine power generation. In the cement industry, co-firing ammonia at coal-fired plants is a key strategy. By implementing 20% co-firing across all coal-fired plants, Japan could cut CO₂ emissions by 40 million tons. If these plants shifted entirely to ammonia firing, the reduction would be 200 million tons, half of Japan's power sector emissions. Japan is actively building a stable ammonia supply chain to facilitate widespread adoption in sectors like cement manufacturing.

Pakistan is uniquely poised to tap into the potential of ammonia as a cleaner fuel for cement production. With a burgeoning emphasis on sustainability, the nation can explore eco-friendly alternatives within the cement manufacturing landscape. Encouragingly, government initiatives are indicative of a growing interest in sustainable technologies. The way forward for Pakistan hinges on crafting a comprehensive strategy for the integration of ammonia as a fuel in cement production. By aligning with global decarbonization endeavors and drawing inspiration from successful international models, Pakistan can significantly curtail carbon emissions within its cement industry. This transition not only addresses environmental concerns but also promises cost-effective operations, thus propelling sustainability in this critical sector.

Ammonia can be used as a fuel in the cement decarbonization in Pakistan in such ways

Co-firing ammonia with coal can be co-fired with coal in existing cement kilns to reduce the amount of coal used and the associated CO2 emissions. This is a relatively low-cost and low-risk option for cement producers, as it does not require significant modifications to existing infrastructure.	Ammonia as a feedstock for synthetic fuels can be used as a feedstock for the production of synthetic fuels, such as hydrogen and methanol. These synthetic fuels can then be used as fuels in cement kilns, either on their own or in combination with coal or natural gas. This option requires more investment in new infrastructure, but it has the potential to achieve deeper CO2 reductions.	Ammonia as a fuel for ox fuel combustion is a process in which cement kilns are operated with a mixture of pure oxygen and recycled flue gas, instead of air. This creates a CO2-rich flue gas that can be easily captured and stored. Ammonia can be used as a fuel in ox fuel combustion systems, either on its own or in combination with coal or natural gas. This option is still under development, but it has the potential to achieve very high CO2 reductions.
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Figure 37: Ammonia as an option for the cement industry to decarbonize

The global adoption of ammonia as a fuel in the cement industry serves as a compelling testament to the viability and efficacy of this innovative strategy. Notably, nations such as the Netherlands and Sweden have not only reduced carbon emissions significantly but have also achieved substantial cost savings, while ensuring the sustainability of their cement production processes. Drawing inspiration from these international successes, Pakistan stands at the threshold of a transformative opportunity. By emulating the strategies that have proven successful in these countries, Pakistan can embark on a sustainable and eco-friendly trajectory within its cement industry. This shift aligns seamlessly with global decarbonization objectives and positions Pakistan as a proactive contributor to the shared goal of environmental preservation on an international scale.

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Annexures

Table 1 Top ten Cement Companies in the world on annual cement Production 2023				
Sr. No	Company Name	Origin country	Annual Revenue	Annual Cement Production (mt/yr)
1.	Holcim Group/ LafargeHolcim	Switzerland	28.525 billion USD	286.6 mt / yr
2.	Anhui Conch Cement	China	22.24 billion USD	217.2 mt / yr
3.	China National Building Material(CNBM)	China	42.957 billion USD	176.22 mt / yr
4.	Heidelberg Cement	Germany	18.713 billion USD	18.713 billion USD
5.	Cemex	Mexico	15.351 billion USD	87.09 mt / yr
6.	Italcementi	Italy	4 billion USD	76.62 mt / yr
7.	China Resources Cement	China	5.604 billion USD	71.02 mt/yr
8.	Taiwan Cement	Taiwan	3.670 billion USD	63.72 mt / yr
9.	Eurocement Group	Russia	50 billion Russian Rubles	45.18 mt / yr
10.	Votorantim Group	Brazil	54.4 million tons of cement per year	45.02 mt / yr

Table 2: Overview of Cement Production/Manufacturing Facilities					
Sr. No	Company	Manufacturing process	Technology-process employed	# of Plants	Production Capacity FY 2022 (000 MT)
1	Lucky Cement Limited	Dry process	Pre-heater, pre-calciner, and vertical roller mills	2	12,150
2	Bestway Cement Limited	Dry process	Pre-heater, pre-calciner, vertical mills, and ball mills	4	10,274
3	D.G Khan Cement Company	Dry process	Pre-heater, pre-calciner, and vertical mills	3	6,720
4	Maple Leaf Factory Limited	Dry process	Pre-heater, pre-calciner, vertical roller mills, and ball mills	2	5,700
5	Pioneer Cement Limited	Dry process	Classifiers and vertical roller mills	1	5,195
6	Kohat Cement Company Limited	Dry process	Pre-heater and vertical roller mills	2	4,913
7	Cherat Cement Company Limited	Dry process	Pre-heater, roller press, and ball mill	1	4,536
8	Fauji Cement Company Limited	Dry process	Vertical mills ,Pre-heater, vertical roller mill, and classifier	3	6,363
9	Power Cement Limited	Dry process	Vertical roller mills	1	3,371
10	Dewan Cement	Dry process	Pre-heater, pre-calciner, and vertical mill	2	2,940
11	Attock Cement Pakistan Limited	Dry process	Pre-heater, pre-calciner, and vertical mill	1	3,027
12	Gharibwal Cement Limited	Dry process	Vertical mill	1	2,010
13	Fecto Cement Limited	Dry process	Pre-heater, pre-calciner, and ball mills	1	945
14	Flying Cement Company Limited	Dry process	Pre-heater, pre-calciner, and vertical roller mills	1	720

15	Thatta Cement Company Limited	Dry process	Dry and wet process	1	576
16	Dandot Cement	Dry process	Data not available	1	504
Total				27	70,061

Table 3: Cement Cost of Good Sold (COGS) FY22						
Major COGS Breakup (FY 22)						
S.No	Company	Raw Material (%)	Packaging (%)	Fuel (%)	Power (%)	Others (%)
1	Attock Cement	8	6	46	15	25
2	Bestway Cement	7	9	48	18	17
3	Cherat Cement	7	9	43	16	25
4	DG Khan Cement	2	7	51	19	21
5	Dewan Cement	6	8	51	19	15
6	Fauji Cement	8	7	45	18	23
7	Flying Cement	3	10	43	29	15
8	FECTO Cement	5	6	49	19	20
9	Gharibwal Cement	4	5	53	11	26
10	Kohat Cement	5	9	49	22	14
11	Pioneer Cement	7	9	54	20	10
12	Maple Leaf Cement	7	8	49	18	19
13	Power Cement	10	6	50	18	15
14	Thatta Cement	9	7	52	19	13
15	Lucky Cement	6	8	55	20	10
Cement Industry Average		6	8	46	17	23

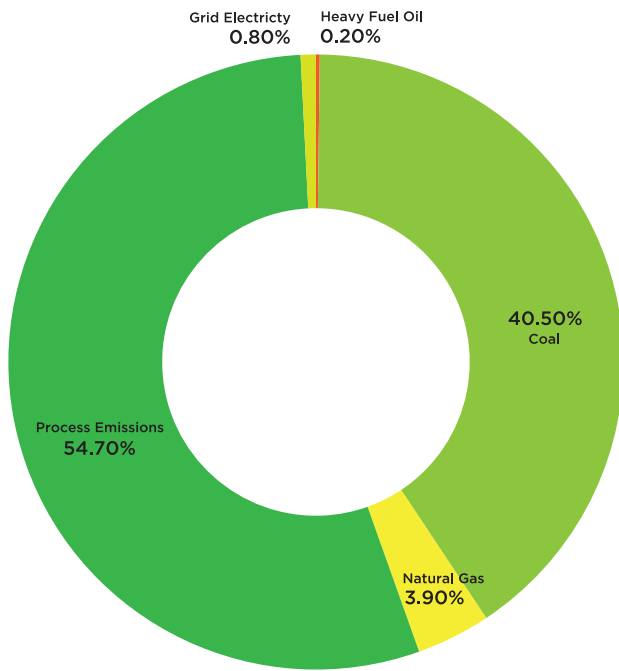


Figure 1: Break down of emissions from cement sector of Pakistan

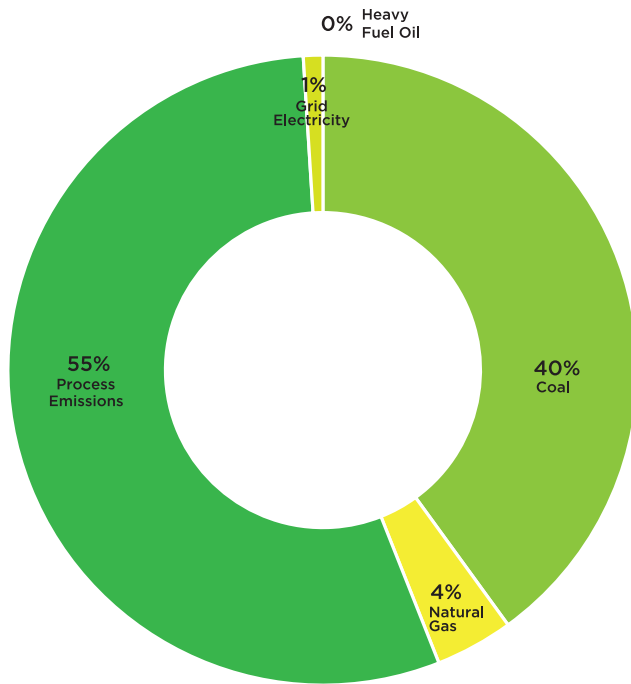


Figure 2: Manufacturing Cost Break up of Cement Industry in Pakistan



Plot # 10, Taimur Chambers, Fazl-ul-Haq Rd, G-6/2 Blue Area, Islamabad

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