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DECARBONIZATION FOR INDUSTRIALIZATION

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Abstract

Pakistan's industrial sector, predominantly dependent on coal, oil, and natural gas, encounters substantial decarbonization challenges crucial for adhering to international climate commitments and fostering economic resilience. Despite significant emissions from key industries such as cement and textiles, there exists considerable potential for advancement through modernization, the adoption of renewable energy, and establishing international trade frameworks, including the EU's Carbon Border Adjustment Mechanism. Strategic approaches involve enhancing energy efficiency, especially within the textile industry, transitioning to renewable energy sources such as solar power and biofuels, substituting clinker in industrial processes, and implementing carbon capture technologies. Progress is impeded by issues such as outdated machinery, frequent power outages, restricted access to finance, and the high costs associated with renewable technologies. To address these obstacles, it would be beneficial to give financial incentives for modernization, promote decentralized renewable energy systems, improve vocational training, and ensure regulatory compliance. Subsidies for renewable projects and the creation of a green financial framework are critical.

1. Introduction

Since 2000, industrial emissions have surged by over 70% due to rising global demand for goods, limited energy efficiency gains, and a post-pandemic rebound. This trend necessitates a rapid annual reduction of about 3% to meet Net Zero Scenario targets by 2030 (Scott & Gössling, 2021). According to the International Energy Agency (IEA) in 2021, industries worldwide primarily relied on coal (38%), oil (32%), and natural gas (20%) for energy consumption, with the remaining 10% from alternative sources like renewables and nuclear fuel (United Nations Conference on Trade and Development, 2021). The usage of these energy sources varies across countries, with China heavily relying on coal and the United States on oil and natural gas (World Energy Outlook, 2020).

Decarbonizing hard-to-abate sectors such as cement, textiles, and steel is crucial for meeting global commitments, despite challenges like the Russia-Ukraine conflict which has increased energy prices and disrupted global supply chains (Siemens Energy, 2022). Decarbonization drives economic growth by attracting green investments and developing sustainable sectors that stimulate economic activity and create jobs. This shift is critical for developing economies like Pakistan, where sustainable industrialization can enhance economic resilience and support long-term prosperity.

Energy security is also a main challenge for Pakistan's industrial sector, with limited access to sustainable energy resources causing operational disruptions. Therefore, it is significant to speed up the transition to renewable energy, enhance energy efficiency, and improve competitiveness. By decreasing reliance on imported fossil fuels, Pakistan can mitigate risks associated with global energy price fluctuations and geopolitical uncertainties.

Pakistan's commitments under international climate agreements, such as the Paris Agreement, necessitate the decarbonization of its industrial sector. Achieving these commitments is crucial not only for global environmental objectives but also for maintaining market access and avoiding potential trade barriers. Pakistan, a signatory to the Paris Agreement, submitted NDCs in 2016 and 2021 aiming to reduce emissions by 2030, combining reductions through domestic resources and an additional 35% through international financial support (United Nations Framework for Climate Change Convention, 2022). However, the NDCs lack specific plans for industrial emissions reductions.

Given the significant role of industries in the country's carbon footprint, addressing this gap with clear plans for industrial emissions reductions will be essential for Pakistan to achieve its climate goals, leveraging economic opportunities from green technologies and improving global market competitiveness. Industrial decarbonization presents economic opportunities for Pakistan. Investments in green technologies promote economic growth and create jobs in sectors focused on environmental sustainability. This transition enhances Pakistan's export competitiveness, particularly under initiatives like the EU's Carbon Border Adjustment Mechanism (CBAM). Successful examples from countries like Germany and Japan show that robust decarbonization strategies can lead to increased efficiency, innovation, and economic resilience.

1.1 Current State of Pakistan's Industrial Sector

The industrial sector in Pakistan is emerging as a cornerstone of the country's economic recovery, showing signs of revival despite ongoing obstacles. Large-Scale Manufacturing (LSM) has demonstrated some growth, with a 3.63% increase month-on-month in November 2023 and a 1.59% increase year-on-year. However, historically, the sector has struggled with low productivity and a declining contribution to GDP. In FY24, the industrial sector contributed 18% to Pakistan's GDP.

One major issue is that Pakistan's industrial policies have often been reactive rather than proactive, leading to inconsistent growth and underperformance. For instance, the contribution of manufacturing to GDP has declined from 19.11% in 2022 to 18.22% in 2024. This declining trend is partly due to the lack of significant manufacturing output growth and low or negative productivity in existing industries.

To improve the situation, there is a need for better regulatory oversight, institutional improvements, and investments in innovation and technology. The Pakistan Business Council advocates for a "Make-in-Pakistan" thrust to promote employment, value-added exports, and import substitution. This strategy aims to leverage the size of Pakistan's domestic market to develop scale and competitiveness, which could also address global demand.

1.2 Challenges and Opportunities in Pakistan's Industrial Sector

Pakistan's industrial sector faces several key challenges that hinder its growth and competitiveness. Many industries, particularly in textiles, are operating with outdated machinery and technology, which reduces efficiency and competitiveness. For instance, textile machinery imports increased by 82% from 2020 to 2021, reflecting a pressing need for modernization to keep up with global competitiveness. However, this trend has not sustained, as in 2023 and 2024, textile machinery imports in Pakistan have experienced significant fluctuations, mirroring broader economic uncertainties and sector-specific hurdles. The textile industry alone suffered an estimated $70 million loss due to power outages in 2023.

Additionally, there is a significant shortage of trained and skilled workers, attributed to inadequate technical education and training facilities. Approximately 80% of Pakistan's youth labor force has low levels of education and a poor skills base. Compliance and quality control issues are also prevalent, with many factories struggling to meet international standards in social compliance, working conditions, and quality management systems. Political instability and security concerns, including terrorism, sectarian violence, and political unrest, create an uncertain environment for businesses. This instability has led to reduced foreign investment and weak institutions5. Moreover, there is insufficient focus on research and development (R&D), with Pakistan investing only 0.16% of GDP in R&D, limiting innovation and the development of new products and processes.

Despite these challenges, Pakistan's industrial sector has several opportunities that can be leveraged for growth. The country benefits from preferential trade agreements, such as the EU's Generalized Scheme of Preferences (GSP), which provides duty-free access for many products. Since 2014, Pakistan's exports to the EU have increased by 65%. Pakistan also has an abundant supply of raw materials, supported by extensive agricultural production8. The China-Pakistan Economic Corridor (CPEC) is expected to bring in $50 billion in energy and infrastructure investments over the next 10-15 years, further boosting industrial growth.

To capitalize on these opportunities and overcome the challenges, Pakistan needs to invest in modernizing its industries, improve energy supply, enhance technical education, and create a stable political and security environment conducive to business. By addressing these areas, Pakistan can significantly enhance its industrial sector's productivity and competitiveness.

2. Global Decarbonization Accelerator

In 2023 the Conference of Parties (COP28), President Dr. Sultan Al Jaber unveiled the Global Decarbonization Accelerator (GDA), marking a significant step towards accelerating the global energy transition and drastically reducing emissions. The GDA represents a comprehensive plan for systemic change, addressing both the demand and supply sides of the energy sector simultaneously.

2.1 Overview of GDA Pillars

2.1.1 Rapidly Scaling the Energy System of Tomorrow

The Global Renewables and Energy Efficiency Pledge has been signed by 116 countries, aiming to triple the worldwide installed renewable energy generation capacity to at least 11,000 gigawatts and double the global average annual rate of energy efficiency improvements to more than 4% per year by 2030.

2.1.2 Decarbonizing the Energy System of Today

The Oil and Gas Decarbonization Charter (OGDC), signed by 50 companies representing over 40% of global oil production, aims to decarbonize the oil and gas sector. Additionally, the Industrial Transition Accelerator (ITA) has been launched to expedite decarbonization across key heavy-emitting sectors.

2.1.3 Targeting Methane and Other Non-CO2 Greenhouse Gases

The GDA aims to reduce methane emissions and other non-CO2 greenhouse gases across economies, with a $1 billion mobilization for methane abatement projects.

3. Significance of Decarbonization for Pakistan

Decarbonization is crucial for Pakistan, considering its economic dependence on industries like cement, textiles, and steel. These sectors are significant contributors to the country's GDP and employment but are also major sources of greenhouse gas emissions. By decarbonizing these industries, Pakistan can reduce its carbon footprint and improve its environmental sustainability (UNCTAD, 2023).

Pakistan's acute climate vulnerability severely impacts its economy. Consequently, reducing GHG emissions is imperative to meet global commitments. Decarbonizing key sectors such as cement, steel, and textiles is crucial. Emission reductions in these industries can significantly mitigate climate impacts and contribute to global efforts to limit temperature rise. (World Bank, 2022).

With the aim of enhancing export competitiveness the EU's Carbon Border Adjustment Mechanism (CBAM) provides an economic opportunity for the world to develop its trade in the global market. The CBAM imposes a carbon price on imports into the EU, ensuring that imported goods are subject to the same carbon costs as those produced within the EU. This mechanism encourages Pakistan's industries to adopt cleaner technologies and reduce their carbon emissions to maintain access to the EU market (European Commission, 2023). Additionally, decarbonization attracts international investment in clean technologies, fostering innovation and economic growth (McKinsey, 2023).

To capitalize on these opportunities and overcome the challenges, Pakistan needs to invest in modernizing its industries, improve energy supply, enhance technical education, and create a stable political and security environment conducive to business. By addressing

these areas, Pakistan can significantly enhance its industrial sector's productivity and competitiveness (World Bank, 2023).

Objectives:

- Evaluate the economic and environmental impacts of CBAM on Pakistan's industrial sector.
- Analyze policy frameworks to facilitate seamless integration of CBAM into Pakistan's industrial strategy.
- Explore technological pathways and innovation strategies to enhance industrial decarbonization efforts, identifying opportunities for sector-specific advancements.

4. Methodology

This study uses a mixed-methods approach, integrating quantitative data analysis with qualitative insights and contextual analysis. The methodology incorporates insights from key industry experts and utilizes statistical data from industry reports. The data covers various aspects, including GDP contribution, power outages, machinery imports, and R&D investment. This approach provides an entire overview of Pakistan's contemporary industrial sector by combining quantitative and qualitative data. It explains the sector's difficulties and identifies possible areas for growth.

5. Discussion and Analysis

5.1 Pakistan's Industrial Emission Levels and Trends

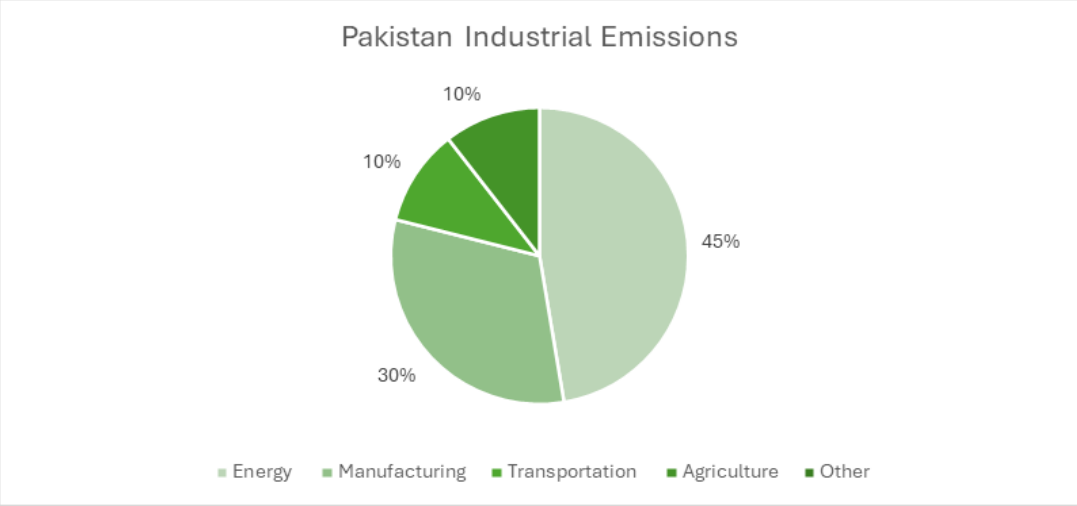

Fig 1: Pakistan Industial Emissions

Pakistan's industrial sector is a significant contributor to greenhouse gas emissions. Key sectors like cement and textiles while secondary steel making process being used in Pakistan. The current emission levels highlight the urgent need for effective decarbonization strategies.

Pakistan's industrial sector is a major contributor to the country's greenhouse gas emissions, accounting for 28.1 million tons of CO_2 emissions in 2019, with emissions continuing to rise (Our World in Data, 2023). In 2019, the industrial sector was responsible for approximately 34% of net anthropogenic GHG emissions (UNFCCC, 2023). Key sectors contributing to these

emissions include cement, textiles, and steel. The cement sector, with an energy demand of 250.1 Ktoe, emitted 0.91 $MtCO_2$-e of GHGs and had a production capacity of 67.44 million tons per year as of 2021 (Statista, 2024).

The textile sector, the largest manufacturing sector in Pakistan, had an energy demand of 359.3 Ktoe and emitted 1.45 $MtCO_2$-e, contributing 8.5% to GDP and employing over 15 million people (World Bank, 2023). Although smaller, the steel industry still contributed to overall emissions, with a production capacity of around 6.5 million tons in 2021 (Statista, 2024). In 2022, Pakistan's fossil fuel use and industrial activities generated nearly 200 million metric tons of CO_2 emissions, and in 2018, the country's GHG emissions were 428.6 million tons of CO_2 equivalent, ranking it the world's 18th largest emitter.

Although the Government of Pakistan has set a target to reduce emissions by 50% by 2030, with 15% of the reduction achieved through domestic resources and 35% contingent on receiving $101 billion in financial support from developed countries (UNFCCC, 2023). The National Clean Air Program (NCAP) has been launched to reduce air pollution through improved industrial emissions standards, promotion of cleaner transportation, and enhanced monitoring and enforcement (Climate & Clean Air Coalition, 2023). However, significant challenges remain, including the high cost of renewable technologies, limited access to finance, and constrained capacity for energy efficiency improvements (World Bank, 2023). Addressing these challenges will be crucial for Pakistan to achieve its emissions reduction targets and transition to a more sustainable industrial sector (UNDP, 2023).

Implementing a carbon tax and carbon pricing mechanism in Pakistan's industrial sector is essential for several reasons. Firstly, a carbon tax incentivizes industries to reduce emissions and adopt cleaner technologies, yielding significant environmental benefits and potential cost savings through enhanced efficiency. Revenue generated from a carbon tax can support green industrial development, innovation, and worker retraining, fostering a transition to a sustainable economy. Additionally, aligning with global trends in carbon pricing and sustainability enhances Pakistan's competitiveness in export markets, making its industries more attractive internationally.

The potential economic impacts, both positive and negative, require careful consideration. While industries may face increased production costs, potentially affecting competitiveness, especially if major trading partners do not implement similar policies, a well-designed carbon pricing mechanism can mitigate these challenges. Targeted support or exemptions for energy-intensive and trade-exposed industries, such as cement and steel, can help manage the transition. Achieving broad political support and stakeholder engagement is crucial, as previous attempts to introduce a carbon tax in Pakistan encountered significant resistance.

5.2 Key Initiatives Under the GDA with Relevance to Pakistan

5.2.1 Global Renewables and Energy Efficiency Pledge

The GDA's Global Renewables and Energy Efficiency Pledge aims to triple renewable energy capacity and double energy efficiency improvements by 2030. This initiative aligns well with Pakistan's commitment to increasing renewable energy as outlined in its Nationally Determined Contributions (NDCs). Specifically, Pakistan targets having 60% of its energy produced from renewable resources by 2030. This alignment is crucial for reducing greenhouse gas emissions, improving air quality, and enhancing energy security in Pakistan. The pledge can also support Pakistan's Vision 2025 and sectoral growth targets, offering potential cost savings, energy security, environmental benefits, and economic growth.

5.2.2 Commitments from 116 Countries

The GDA has garnered commitments from 116 countries, highlighting a global consensus on the urgency of decarbonization. For Pakistan, participation in such a global effort underscores its dedication to international climate goals and the shared responsibility of mitigating climate change. The international support and cooperation can bolster Pakistan's efforts to achieve its ambitious climate targets, including a 50% reduction in projected greenhouse gas emissions by 2030.

5.2.3 Oil and Gas Decarbonization Charter

The Oil and Gas Decarbonization Charter, which involves commitments from major oil companies to achieve net-zero operations and eliminate routine flaring by 2030, presents a significant opportunity for Pakistan. Despite the Charter's limitations, such as its focus on upstream operations and the lack of commitments on scope three emissions, it provides a framework for reducing emissions in Pakistan's oil and gas sector. Addressing these limitations and encouraging participation from state-owned enterprises can enhance the effectiveness of Pakistan's decarbonization efforts.

5.2.4 Methane and Non-CO2 Greenhouse Gas Reduction Initiatives

Pakistan can benefit from the GDA's methane and non-CO2 greenhouse gas reduction initiatives through funding and projects for methane abatement. In the agriculture and waste sectors, reducing methane emissions from livestock manure and agro-industrial wastewater can generate biogas for energy use. Additionally, capturing methane from landfills and wastewater treatment plants can reduce greenhouse gas emissions and provide a clean energy source. These initiatives align with Pakistan's goals of enhancing climate resilience and promoting sustainable practices.

6. Opportunities for Pakistan

6.1 Expanding Renewable Energy and Energy Efficiency

By participating in the GDA's pledge to expand renewable energy and improve energy efficiency, Pakistan can achieve significant cost savings, reduce dependence on imported fuels, and stimulate economic growth. These efforts will also contribute to achieving Pakistan's goal of 60% renewable energy by 2030, creating a more sustainable and resilient energy sector.

6.2 Methane Abatement and Waste Management

The GDA's focus on methane abatement offers Pakistan the opportunity to improve waste management practices and reduce emissions from agriculture. Implementing anaerobic digestion systems and capturing methane from landfills can provide clean energy and support the country's climate goals.

6.3 Reducing Coal Dependency and Exploring Nuclear Energy

While the GDA emphasizes renewables and energy efficiency, it is also crucial for Pakistan to reduce its coal dependency and explore nuclear energy as a reliable and clean energy source. This approach can mitigate environmental impacts, enhance energy security, and support sustainable development.

7. Levers of Decarbonization in Pakistan

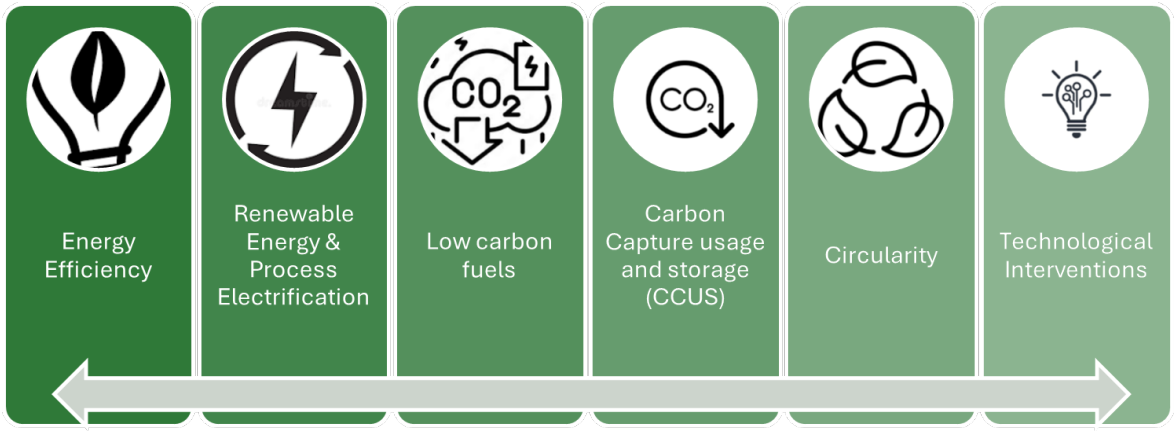

Fig 2: Pakistan Industrial decarbonization levers

Improving energy efficiency is a critical lever for decarbonizing Pakistan's industrial sector, with particular emphasis on the textile industry. Enhancements in compressor efficiency, heat transfer, recovery systems, power factor correction panels, process control, steam system optimization, lighting, and motors can lead to substantial energy savings. These measures not only reduce energy consumption but also lower operational costs, increasing industrial competitiveness while significantly decreasing carbon emissions.

The transition to renewable energy sources is another essential decarbonization strategy. Moving away from domestic coal and integrating renewable energy sources such as solar photovoltaic systems (PVs) into the energy mix can substantially reduce carbon emissions. This transition supports sustainable energy production and aligns with global trends towards cleaner energy solutions, enhancing Pakistan's energy security and resilience against fossil fuel price volatility.

Incorporating low-carbon fuels, such as biofuels for power and heat generation, provides another pathway for mitigating carbon emissions. Biofuels offer a renewable alternative to conventional fossil fuels, reducing the carbon footprint of industrial processes and contributing to overall emissions reductions.

lever In Pakistan's industrial sector, alternative fuels such as chemical wastes, agricultural waste, healthcare waste, consumer products, industrial municipal solid waste (MSW), and whole or shredded scrap tires are increasingly utilized for thermal energy due to their low calorific value. This approach safely disposes of community waste through high temperatures and long residence times in kiln burning processes, ensuring complete combustion of organic material and reducing power bills by embracing circular economy practices. Reused Derived Fuel (RDF) offers benefits by reducing reliance on conventional combustible fuels like coal, preventing the depletion of nonrenewable fossil fuels, enhancing energy recovery from waste, ensuring safe disposal, and eliminating the need for dedicated incineration facilities and landfill sites.

However, the lack of proper waste segregation poses a significant challenge in separating high calorific-value components from MSW. Developed nations mitigate the environmental impact of fossil fuels by adopting circular processes in various industries, substituting waste products for fossil fuels. In Pakistan, where agriculture employs over 37.4% of the population and contributes 22.7% of the GDP, using agricultural waste such as rice husks, straws, bagasse, cotton straw, and corn stover is a sustainable circular practice. The mixture

of coal and bagasse presents an environmentally viable option with lower greenhouse gas (GHG) emissions and economic advantages, though it is hindered by the lack of regulatory support for advancing circular economy practices. Additionally, alternative fuels often contain essential components like lime, silica, alumina, or iron oxides, which are crucial for various industrial process.

The substitution of clinker with substances like fly ash or pozzolana can significantly reduce carbon emissions in various industrial processes, including cement production. Despite efforts to reduce energy consumption, the electrical and thermal energy needs of industrial plants cannot be minimized beyond a certain point. For example, brand new cement plants typically consume 75-80 kWh of electricity and 680-700 kCal of thermal energy per ton of clinker. This indicates that significant electricity and coal will continue to be necessary across industries. In Pakistan, reducing clinker usage, capturing additional heat and process emissions, and adopting zero-carbon technologies are crucial for progress.

While some industries have partially adopted renewable energy technologies, reliance on non-renewable sources remains prevalent, highlighting opportunities for improvement. Cost is a significant barrier to wider adoption, emphasizing the need for economic viability compared to fossil fuel alternatives. The intermittent nature of renewable sources, such as solar and wind, presents challenges; however, integrating energy storage technologies like batteries can mitigate this issue, considering the limited wind potential in Pakistan. Electrification of heat and the use of electric kilns are promising but currently at a low Technical Readiness Level (TRL), requiring a sufficient supply of green electricity. Lastly, circular economy practices, including recycling materials like concrete and utilizing fly ash and slag, depend on availability and customer demand, offering additional technological options for the industrial sector.

Technological interventions are also pivotal in decarbonizing the cement sector. Strategies such as reducing clinker usage, capturing additional heat along with process emissions, and deploying advanced technologies like carbon capture and storage (CCS), electrification, and enhanced energy efficiency are crucial. These technological pathways not only reduce emissions but also foster innovation and efficiency within the sector.

However, several challenges hinder the implementation of these decarbonization strategies. The high cost of renewable technologies, limited access to finance, inadequate capacity for energy efficiency improvements, and insufficient technological advancements present significant barriers. Addressing these challenges requires coordinated efforts, including financial incentives, international support, and policy frameworks that promote sustainable industrial practices. By leveraging these decarbonization levers and overcoming associated challenges, Pakistan can transition towards a more sustainable and resilient industrial sector.

8. Comparative Analysis of Decarbonization Levers in Pakistan's Industrial Sector

8.1 Energy Efficiency Impact

Approximately 40% of CO2 emissions in industrial processes can be reduced through energy efficiency measures, with the remaining emissions being process related. Waste Heat Recovery (WHR): WHR systems capture medium-temperature waste heat from industrial processes to generate electricity. This technology does not reduce overall electricity consumption but harnesses excess heat to produce additional electricity for on-site use or export, thereby improving energy efficiency.

8.2 Fuel Substitution Impact

Transitioning from coal and petroleum coke to natural gas can significantly reduce GHG emissions due to natural gas having less than 60% of the CO2 emissions intensity of coal and petroleum coke.

Economic and policy interventions, such as carbon taxes or carbon credits, are necessary to incentivize the shift from coal to natural gas, given the cost barriers and market dynamics.

The use of Tyre-Derived Fuel (TDF) and Refuse-Derived Fuel (RDF) as substitutes for coal can further reduce emissions. However, the high costs associated with waste segregation and collection require robust policy support and fiscal incentives.

8.3 Material Substitution

Using supplementary materials such as fly ash, blast furnace slag, natural pozzolans, ground limestone, and calcined clay can reduce energy intensity in various industrial processes. These materials substitute for more energy-intensive components, decreasing overall fuel consumption. There is substantial potential for the use of supplementary materials to reduce energy intensity. However, limited support and infrastructure have hindered widespread adoption.

8.4 Carbon Capture and Storage (CCS) Technologies

Emerging technologies for capturing and compressing CO2 emissions are becoming more viable. Some technologies, like Carbon Cure, have been commercialized for specific applications. Significant policy support and infrastructure development are essential for the widespread adoption of CCUS technologies. Adequate infrastructure for geological storage is crucial, as carbon utilization alone cannot absorb all captured carbon.

9. Feasibility and Effectiveness of Carbon Pricing Mechanisms

9.1 CBAM: An Opportunity for Emission Reduction in Pakistani Industries

Different carbon pricing mechanisms, such as carbon taxes or cap-and-trade systems, are being evaluated in Pakistan. These mechanisms can provide financial incentives for reducing emissions and promoting clean technologies. Industrial sustainability through decarbonization is particularly urgent for Pakistan's export sector in light of the EU's Carbon Border Adjustment Mechanism (CBAM). As Pakistan embarks on this ambitious journey, the introduction of CBAM presents both a challenge and a unique opportunity.

Global best practices focus on reducing emissions in challenging sectors through innovative technologies and regulatory measures. The EU's regulatory mechanisms are becoming stricter over time to ensure climate compliance and protect domestic industries. For instance, CBAM, which began on October 1, 2023, aims to level the playing field by ensuring that imported goods face the same carbon costs as those produced within the EU. By 2026, this mechanism will be fully operational and will cover a wider range of sectors.

This convergence of efforts from the EU represents a critical step in balancing Pakistan's industrial growth and climate change commitments. It underscores the need for international cooperation and a balanced approach that considers both environmental and economic imperatives. By making a strong economic case for decarbonization and capitalizing on policies like CBAM, countries in the global south, particularly Pakistan, can turn the challenge of climate change into an opportunity for sustainable development and economic growth.

CBAM specifically targets businesses outside the EU that lack equivalent carbon pricing measures. Importantly, countries participating in the EU Emissions Trading System (ETS) or having linked systems, like those in the European Economic Area and Switzerland, are exempt. Special provisions also apply to countries integrating their electricity markets with the EU, although full integration and compliance with EU decarbonization strategies are prerequisites for exemption.

The CBAM reporting system mirrors the EU ETS framework, relying on a carbon credit system. This involves assessing the carbon content of imports, pricing emissions based on the EU ETS, and requiring importers to purchase CBAM certificates. These certificates validate the carbon pricing of imported goods, ensuring parity with EU-produced goods.

For Pakistan, understanding and adapting to CBAM is crucial. The policy underscores the necessity for robust carbon pricing mechanisms and sustainable production practices. As Pakistani industries prepare to meet these new standards, CBAM could serve as a catalyst for accelerated industrial decarbonization, making Pakistani exports more competitive in the EU market.

Moreover, CBAM is part of the broader European Green Deal, which aspires to achieve climate neutrality by 2050. Announced in December 2019, the Green Deal reinforces the EU's commitment to environmental management through innovative policies like CBAM and the reformed EU ETS.

The implementation of CBAM marks a decisive moment in global carbon pricing and climate policy. For Pakistan, aligning with these new regulations offers a strategic advantage, promoting industrial innovation and sustainability. As the world gravitates towards greener economies, Pakistan's proactive adaptation to CBAM can pave the way for a more resilient and competitive industrial sector.

10. Challenges for Industries to Decarbonize and Policy Recommendations

Challenge 1: Lack of coordination between government industrial policies, academic research, and industrial practices, leading to inefficient resource allocation and duplicative efforts in decarbonization.

Policy Recommendation:

- Develop a National Decarbonization Strategy that integrates inputs from policymakers, academia, and industry. This framework should define shared goals, funding mechanisms, and timelines for achieving decarbonization targets.

Challenge 2: Academic institutions often focus on theoretical research, which is not aligned with industry needs and government focused areas resulting in a disconnect between academia, government and industrial applications.

Policy Recommendation:

- Higher Education Commission and Ministry of Industry and Production should Create centers of excellence in key academic institutions, supported by government funding, to serve as hubs for research, industry collaboration, and policy advisory.
- Develop public-private partnerships (PPPs) to co-fund research and development (R&D) initiatives on decarbonization technologies, including energy-efficient industrial processes, carbon capture, and circular economy models.

Challenge 3: Many industries, particularly in textiles, operate with outdated machinery that is energy-inefficient and environmentally harmful. This not only reduces their productivity and competitiveness but also leads to higher operational costs and carbon emissions.

Policy Recommendation:

- Introduce a government-backed financial incentive program by the Ministry of Industry and Production (MOIP) to support the modernization of industrial machinery. Provide low-interest loans or grants for companies investing in energy-efficient technologies and equipment upgrades.

Challenge 4: Frequent power outages and load shedding disrupt industrial operations, causing significant productivity losses and increasing operational costs. This unreliable power supply also discourages investment in energy-efficient technologies.

Policy Recommendation:

- Ministry of Energy and power division should set mechanism to Invest and promote decentralized renewable energy systems such as solar PV and wind power to ensure a reliable and continuous power supply. Implement policies to improve grid stability and reduce power outages.

Challenge 5: The industrial sector faces a significant shortage of trained and skilled workers

due to inadequate technical education and training facilities. This skills gap hinders the adoption of new technologies and efficient practices.

Policy Recommendation:

- Ministry of Science and Technology with Pakistan Standards & Quality Control Authority (PSQCA) should develop comprehensive vocational training programs in collaboration with industry stakeholders. Provide incentives for industries to offer apprenticeships and on-the-job training to bridge the skills gap.

Challenge 6: Many factories struggle to meet international standards in social compliance, working conditions, and quality management systems. This non-compliance can lead to lost business opportunities and reputational damage.

Policy Recommendation:

- Ministry of Energy (MoE) Strengthen regulatory frameworks and enforcement mechanisms to ensure compliance with international standards. Provide training and support to industries to help them implement best practices in quality management and social compliance.

Challenge 7: Political instability and security concerns create an uncertain environment for businesses, discouraging both domestic and foreign investment. This uncertainty can delay or halt decarbonization efforts.

Policy Recommendation:

- Ministry of Planning development and special Initiatives should establish a stable political environment through policy continuity and security reforms. Encourage public-private partnerships to enhance investment security and economic resilience.

Challenge 8: The limited focus on R&D in the industrial sector restricts innovation and the development of new products and processes. This hampers the industry's ability to adopt cutting-edge technologies and remain competitive.

Policy Recommendation:

- Increase government funding for R&D in industrial sectors and create incentives for private sector investment in innovation. Establish research hubs and innovation centers focused on developing low-carbon technologies.

Challenge 9: The high initial cost of renewable technologies limits their adoption by industries, which often operate on tight budgets. This financial barrier slows down the transition to cleaner energy sources.

Policy Recommendation:

- Implement subsidies and tax incentives for renewable energy projects. Facilitate access to international funding and financial mechanisms to reduce the initial investment costs for industries adopting renewable technologies.

Challenge 10: Many industries face challenges in accessing finance for decarbonization projects due to stringent lending criteria and lack of tailored financial products. This restricts their ability to invest in necessary upgrades and innovations.

Policy Recommendation:

- Create a green financing framework that includes green bonds, loans, and credit facili-

ties specifically for industrial decarbonization projects. Engage with international financial institutions to provide financial support and risk mitigation tools.

Challenge 11: Industries often lack the technical capacity and expertise to implement energy efficiency improvements. This can result in missed opportunities for cost savings and emissions reductions.

Policy Recommendation:

- Launch energy efficiency programs that offer technical assistance and capacity-building workshops for industries. Encourage energy audits and the adoption of energy management systems through regulatory incentives.

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