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Preliminary Roadmap for Industrial Decarbonization – Kenya

Final Report

United Nations Industrial Development Organization (UNIDO)

INDUSTRIAL DECARBONIZATION ACCELERATOR

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Acronyms

ARPA	Accelerated Partnership for Renewables in Africa
BF	Blast Furnace
BOF	Basic Oxygen Furnace
CaCO3	Calcium carbonate or limestone
CAGR	Compounded Annual Growth Rate
CaO	Calcium Oxide or lime
CCUS	Carbon Capture, Utilisation and Storage
CH	Clean Hydrogen
CO2	Carbon dioxide
CTC	Clinker to cement
DRI	Direct Reduced Iron
EAF	Electric Arc Furnace
EE	Energy Efficiency
EMA	Energy Management Awards
EMS	Energy Management Systems
EPRA	Energy and Petroleum Regulatory Authority
EU	European Union
GCF	Global Climate Fund
GDP	Gross Domestic Product
GESIP	Green Economy Strategy and Implementation Plan
GH	Green Hydrogen
GHG	Greenhouse Gas
GTAF	Global Technical Assistance Facility
GVA	Gross Value Added
HFC	Hydroflouro Carbons
HFO	Heavy Fuel Oil
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IPMVP	International Performance and Measurement Protocol
ISO	International Standards Organization
KAM	Kenya Association of Manufacturers
Kcal	kilo calories
KES	Kenyan Shilling
KIRDI	Kenya Industrial Research and Development Institute
KNBS	Kenya National Bureau of Statistics
KPA	Kenya Ports Authority
kWh	Kilowatt hour
LA	Line of Action
LCPDP	Least Cost Power Development Plan
LULUCF	Land Use, Land-Use Change and Forestry
MEPS	Minimum Energy Performance Standards
MMT	million metric tonnes
MoECCF	Ministry of Environment, Climate Change and Forestry
MoEP	Ministry of Energy and Petroleum
MT CO2e	Million Tonnes Carbon dioxide equivalent
MTAR	Mitigation Technical Analysis Report
MTPA	million tonnes per annum
MW	Mega Watt
NAMA	Nationally Appropriate Mitigation Action
NDC	Nationally Determined Contributions
NEECS	National Energy Efficiency and Conservation Strategy
NEMA	National Environment Management Authority
NGO	Non-government Organization
NMVOC	Non-methane volatile compounds
NPK	Nitrogen, Phosphorous, Potassium
PCI	Pulverized Coal Injection
PCS	Process Control Systems
PPP	Public-Private Partnership
R&D	Research and development
RE	Renewable Energy
REFiT	Renewable Energy Feed in Tariff Policy
SCM	Supplementary Cementitious Materials
SREP	Scaling up Renewable Energy Programme
TJ	Terra Joule
TMT	thousand metric tonnes
VAT	Value added Tax

Executive Summary

Kenya's industrial sector plays a pivotal role in the country's socio-economic development. It accounts for 17% of the country's GDP and employs a significant fraction of Kenya's labour force. The strong regulatory reforms, improved ease of access and the rich mineral resources in the country indicate towards strong growth prospects in the coming years. The sector consumes nearly 50% of the total electricity generated in the country but contributes only 3.5% of the total GHG emissions of Kenya. Nearly 90% of Kenya's electricity is generated from renewables, which includes a significant portion of hydro and geothermal technologies.

GHG emissions from the industrial sector include process related and energy related emissions. In 2020, cement production was the leading cause of the process related emissions while electricity generation was the main contributor to the energy related emissions. As the manufacturing sector expands, fuel related emissions, currently low, are expected to grow as are the energy needs. The iron and steel and chemicals sub-sectors, currently consume small fractions of energy and have low GHG emissions due to limited production capacity, however, these are expected to grow in the coming years.

The objective of this report is to analyse the industrial sector of Kenya and develop a preliminary decarbonization roadmap by:

- Understanding the industrial landscape and identifying key industrial sub-sectors
- Identifying emissions pathways and decarbonization potential of key industrial sub-sectors
- Proposing a set of actions, specific activities to enable low-carbon industrial growth.
- Defining the time horizon for implementation of proposed actions and activities in the short, medium, and long term.

In this study, the current situation and the future landscape of the Kenyan industrial sector were mapped through both literature and data analysis. Stakeholder inputs helped identifying the barriers and bottlenecks that limit the adoption of alternatives and potential opportunities. Based on these, a series of public policy recommendations, development instruments, technologies, and regulations capable of enabling decarbonization in the short, medium, and long term have been suggested.

The main decarbonization strategies identified for the cement, iron and steel, and chemicals (fertilizer) industries are:

- Improving material efficiency through measures such as grinding, milling, increasing scrap material use.
- Enhancing energy efficiency through improved equipment, implementing energy management systems, waste heat recovery.
- Expanding renewable energy technologies such as solar, geothermal and wind.
- Adopting clean hydrogen to power industries, particularly fertilizer production.
- Promoting carbon capture, utilization, and storage (CCUS) through research and pilot projects.

The suggested technology, policy, and market measures are identified based on the short and long-term economic impacts, social impacts, viability, fiscal impacts, as well as the current status of the measure. The roadmap also highlights the need for focused research and development of low-carbon technologies as well as the training of human resources to achieve and develop viable decarbonization actions in addition to the availability of adequate financial resources.

Kenya will benefit from new and green markets by maintaining a low-carbon development path. This will spur economic growth, attract investments, open new markets, create jobs, and lower exposure to fuel price shocks and supply chain disruptions. Additionally, green public procurement can create an enabling support framework that would drive an increase in carbon savings. Further, a cohesive decarbonization strategy for the industrial sector in Kenya requires a collaborative approach between all stakeholders, access to technology, and financial support.

The landscape for decarbonization is ripe in Kenya with supportive legislations and roadmaps in place with specific objectives related to tapping into carbon markets, improving efficiency, and attracting more investments for development of domestic markets. By implementing these recommendations, Kenya will tap into opportunities in the new and green markets created by the global trend to reduce greenhouse gas emissions. This will not only help Kenya grow its economy but also reduce its carbon footprint.

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1. Introduction

1.1. Industries in Kenya

The Kenyan industrial sector is a key player in ensuring job security and enabling economic development in the country. The sector plays a pivotal role in the socio-economic development and urbanization. The industrial sector employs 8% of the labour force and has strong growth prospects as the Government of Kenya has enacted strong regulatory reforms to simplify foreign and local investments. The country was ranked 56th in ease of doing business in 2020 (World Bank rating), up from 61st in 2019. As seen in Figure 1, the industrial sector contributes a significant 17% to the country's GDP.

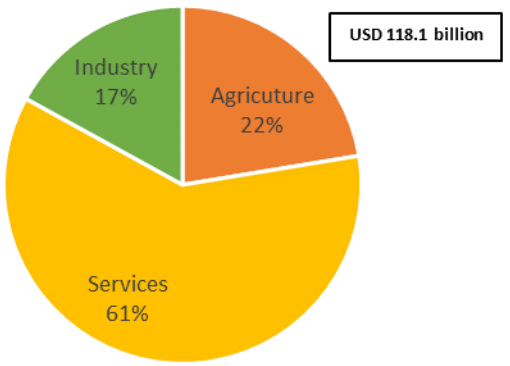

Figure 1: Sectoral contribution to Kenya's GDP in 2021

Furthermore, the manufacturing sector, which accounts for a 7.2% share of the GDP, accounts for nearly half of industrial output and includes production of non-metallic mineral products like cement, leather, and related products, as well as dairy products.

Table 1 provides the quantum indices of specific outputs of the manufacturing sector in 2021 relative to 2017. Cement production, the largest manufacturing sub-sector, grew by 44.3% compared to 2017 levels in terms of quantity produced at a compounded annual growth rate (CAGR) of nearly 10%. However, most of the growth took place in 2020 and 2021.

Table 1: Cement Production and Utilization, 2017-2021 (Thousands of Tonnes)

Year	Production	Imports	Consumption and Stocks	Exports
2017	6,230	14.7	5,858	388
2018	6,070	23	5,949	144
2018	6,163	26.4	6,129	60
2020	7,464	22	7,376	120
2021	9,248	23.6	9,098	173

Kenya has numerous ores and industrial minerals, which are believed to be in substantial quantities. Although detailed exploration work has been limited to date, the Ministry of Mining reports that the country contains viable quantities of coal, iron ore, fluorspar, titanium, gypsum, limestone, soapstone, gemstones, soda ash, diatomaceous earth, lead, gold, silicon oxide, and marble[1]. The recent findings of oil, gas, and **rare earth minerals further enhance the potential for resource-based industries to thrive, particularly in the iron and steel, cement, buildings and construction, chemical, and ornamental industries. These sectors are integral to the economic pillar of Vision 2030 and are expected to significantly influence the future GHG emission profile of the industrial sector.**

The development of the mining and quarrying sectors is anticipated to fuel the growth of the construction and manufacturing industries. The cement as well as iron and steel industries are poised for growth driven by domestic and regional infrastructure projects. The chemical and fertilizer sectors are also noteworthy for their role in Kenya's industrial landscape. The manufacture of chemicals, including fertilizers, is a key component of the industrial sector and is linked to the agricultural productivity of the country. The production processes in these industries are sources of GHG emissions, which means that, as these sectors expand, there needs to be an increased focus on adopting cleaner and more sustainable production technologies.

1 https://oxfordbusinessgroup.com/relaying-the-foundation-new-exploration-efforts-and-reformed-legislation-set-the-stage-for-future-projects/

1.2. Energy Consumption in Industries

The energy sector is critical to paving the path for Kenya's industry sector decarbonization journey. This will require comprehensive changes in how the energy supply is managed in addition to overseeing the energy demand of various sectors.

In 2020, Kenya's industrial sector accounted for 8% of the total energy consumption. Based on the Energy Matrix by Energy and Petroleum Regulatory Authority (EPRA), Kenya's industrial sector indicated an increase in total energy consumption up to 2019. However, it decreased significantly during the COVID-19 pandemic. Post 2020, as the sector began to recover, there was a gradual resumption in energy consumption as pandemic-related restrictions eased (**Figure 2**).

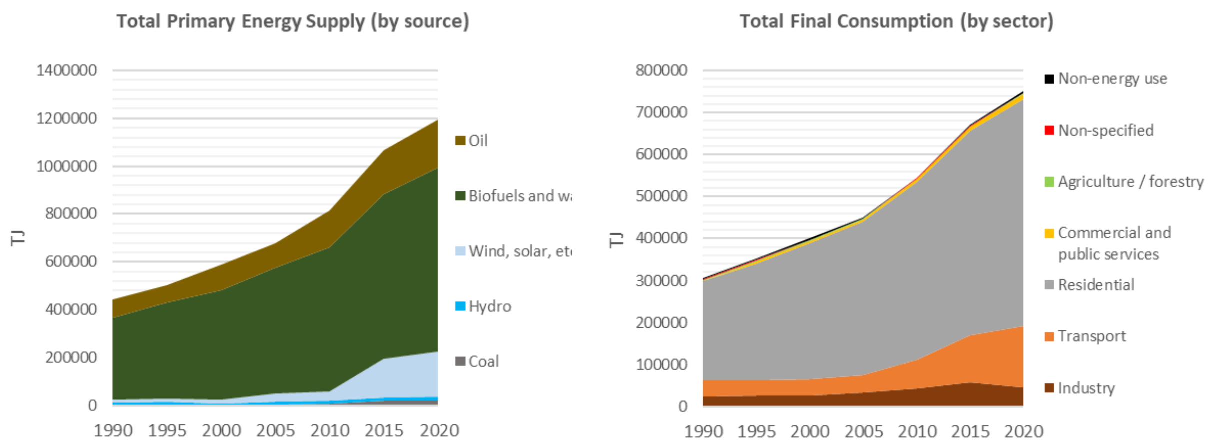

Figure 2: Total Primary Energy Supply by source and Total Energy Consumption by sector in Kenya.

Nearly 75% of the energy consumption within the industrial sector is from electricity **(Figure 3)**.

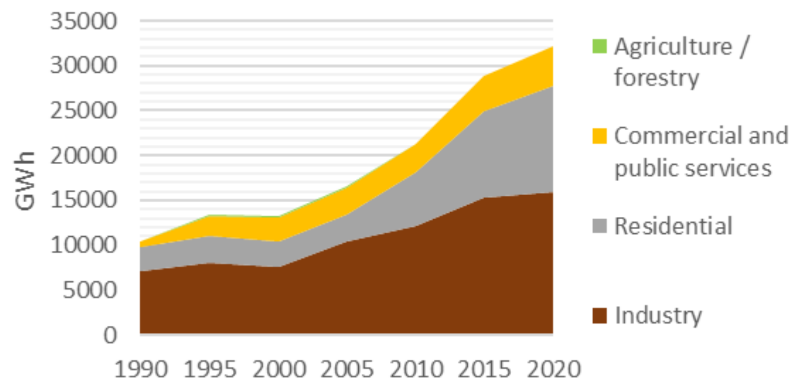

Figure 3: Electricity consumption by sector in Kenya.

In fact, as seen in **Figure 4**, in 2020, the industrial sector is the largest consumer of electricity (50%), followed by the residential sector (36%) and commercial sector (14%).

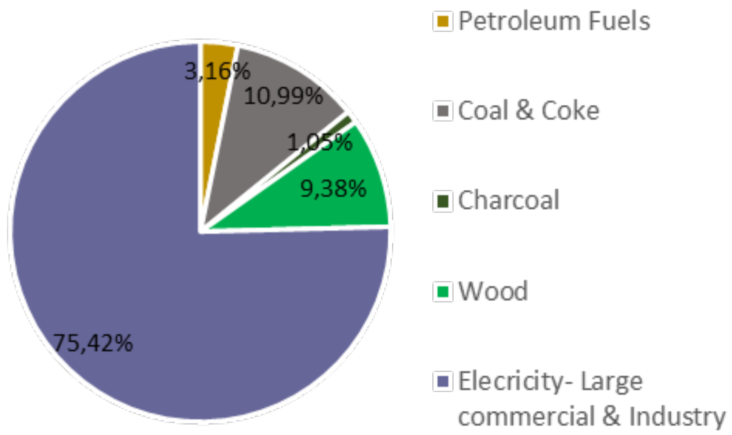

Figure 4: Energy Consumption in the Industrial Sector (TJ) (KNBS, 2021

In Kenya, renewable sources accounted for 90% of total electricity generation in 2020 (Figure 5), giving the country one of the lowest carbon-intensive power systems in the region (0.33 gCO2/ kWh). This can be attributed to the significant penetration of hydro- and geothermal technologies.

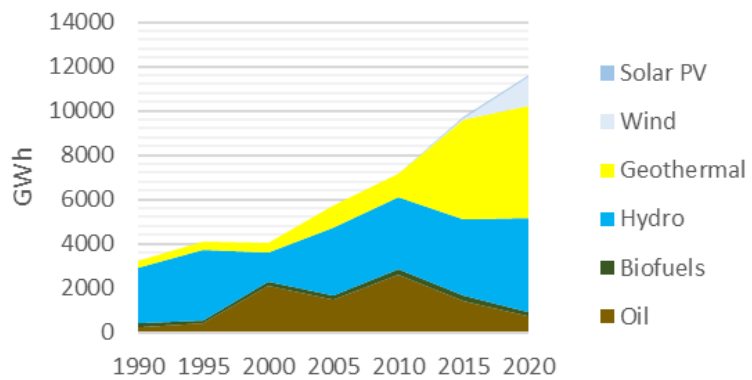

Figure 5: Electricity generation by source.

In recent years, coal consumption in industry has increased steadily, nearly quadrupling in the last decade **(Figure 6)**, and its growth prospects pose a challenge for the decarbonization of the sector.

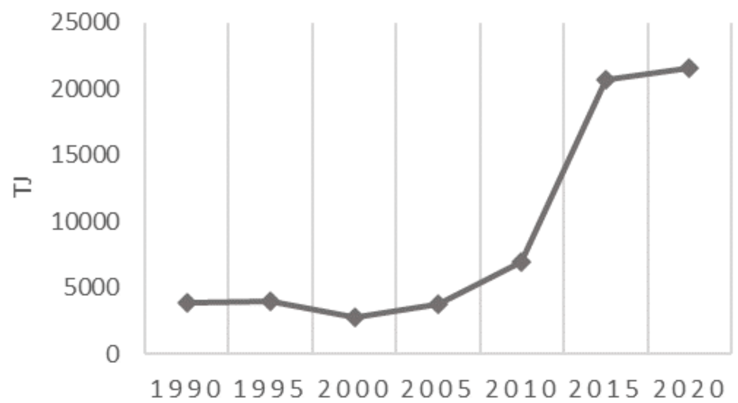

Figure 6: Coal consumption by the industrial sector.

1.3. GHG emissions of the industry sector

The industrial sector GHG emissions include both process-related emissions involving chemical and/or physical change of inputs, and production and use of hydrofluorocarbons (HFC) as well as energy related emissions (**Figure 7**). Kenya's industrial sector (excluding direct fuel combustion) contributed 3.8 % (3 Mt CO_2e per year) to the total national GHG emissions (80 Mt CO_2e per year) in 2015. Industry sector emissions are projected to increase to 4.2% (6 Mt CO_2e per year) by 2030. This is because of the significantly larger contributions by LULUCF, energy and agriculture sectors, as well as the fact that Kenya produces insignificant amounts of industrial gases, such as perfluorocarbons and hydrofluorocarbons, which have high global warming potentials (5,000 to 10,000 times the global warming potential of CO_2). With direct fuel combustion emissions included, the absolute emissions from Kenya's industry sector are projected to grow from 5.4 Mt CO_2eq. in 2015 to 9.9 Mt CO_2eq. in 2030, with their proportion to the total national emissions remaining constant at around 7% through the period.

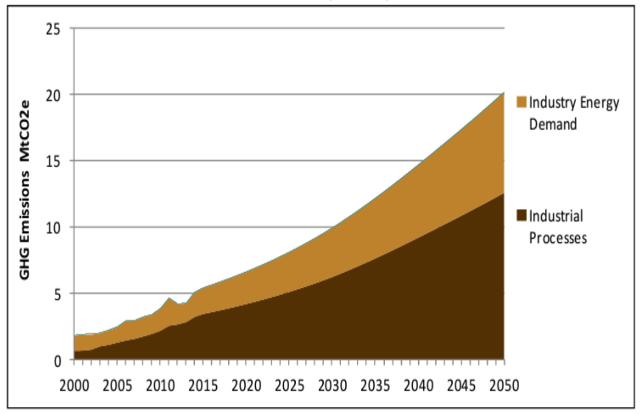

Figure 7: Process-related and energy related Industrial emissions (Source: MTAR, 2018)

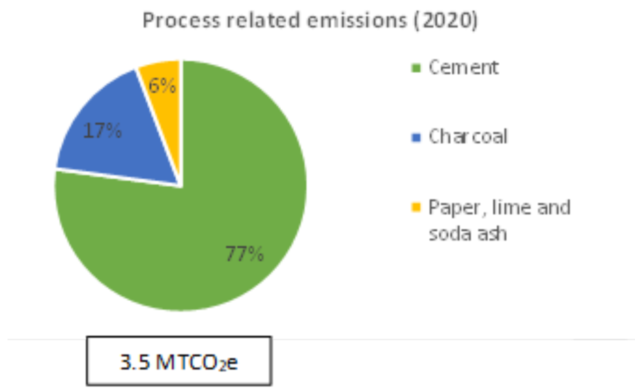

Figure 8: Industry GHG emissions (process related) (Source: Author's analysis)

Process related emissions: These are non-energy related emissions from industrial activities (e.g., direct CO2 emissions from chemical transformations in materials being processed). In 2020, cement production accounted for 77% of total process emissions of the industrial sector, where the CO2 is released as a by-product during clinker production in which limestone (CaCO3) gets converted to lime (CaO) (Figure 8). CO2 is also emitted during cement production by fossil fuel combustion and is accounted in energy related emissions. Additionally, charcoal production contributes 17% to total process related emissions with significant mitigation opportunities, estimated at 1.56 MTCO2eq. of emission per year by 2030 (MTAR, 2018). Furthermore, GHG intensive industries, like metals and chemicals, currently have limited production activities but are expected to grow significantly in the coming years.

Fuel-related emissions: These are emissions associated with the combustion and use of fuels (from fossil or non-fossil sources) for thermal energy needs. Total fuel-related emissions have only 22% of energy related emissions including the use of petroleum fuels, coal and coke, charcoal, and wood. Emissions are estimated through total primary energy supply to the industrial sector and Intergovernmental Panel on Climate Change (IPCC) emission factors for each fuel.

Fuel-related emissions are fewer in Kenya due to the cement industry being the only energy intensive industry with high thermal energy requirements. Majority of the coal imports in the country are used by the cement sector for clinkering process.

1.4. Key industries

Cement manufacturing, the leading emitter of greenhouses in the industrial sector in Kenya, is identified as a core industrial sub-sector, with a growing demand from both within Kenya as well as from neighbouring countries. Other industrial processes sub-sectors such as chemical industry and metal production were determined to have no significant production activities leading to greenhouse gas emissions (MTAR, 2018). However, emissions from these sub-sectors are expected to grow in the coming years. Direct and indirect greenhouse gas emissions in the industrial sector are a result of cement production, lime production and soda ash production. HFC emissions are related to the import of HFCs into Kenya through products and bulk imports. In both the respects, process and energy, Kenya's road to industrial decarbonization is tied to its cement sector. This study will focus on the above for industrial decarbonization, while also briefly delving into potentially upcoming industries such as iron and steel production as well as chemicals.

1.5. Need for Decarbonization

As a developing nation, the industrial sector is a vital contributor to Kenya's GDP and a significant source of employment. However, the sector is also a notable contributor to the overall GHG emissions, primarily due to reliance on fossil fuels and energy-intensive manufacturing processes.

Kenya's commitment to the Paris Agreement underscores the need to decarbonize its industries. Decarbonization in Kenya would imply a reduced dependence on imported fossil fuels, fostering energy security, and promoting the adoption of renewable energy sources. This shift will enhance the resilience against the volatility of global oil prices as well as the physical impacts of climate change, which can disrupt energy supplies and industrial productivity. Moreover, embracing cleaner technologies and green energy will open up new markets, attract investment, and create more jobs.

A collaborative approach involving government, industry, NGOs, and civil society is essential to drive decarbonization. Stakeholder engagement is critical in aligning policies, investments, and innovations toward sustainable industrial practices. By mapping out key players and their roles, Kenya can develop a cohesive strategy that not only addresses the climate crisis but also positions its industrial sector for long-term sustainability and growth in alignment with its global commitments.

2. Objectives of the industrial decarbonization Preliminary Roadmap for Kenya

2.1 Overall objective

Analysis of the industrial sector of Kenya to develop a decarbonization roadmap for a climate compatible industry with short term, medium term and long-term targets.

2.2 Specific objectives

Specifically, the Preliminary Roadmap considers the following aspects:

1. Identify and prioritize the key industrial sectors in the context of development of Kenya's industrial decarbonization roadmap.
2. Propose a set of policy and technology actions, key pathways and specific activities designed to promote the development and implementation of industrial decarbonization in Kenya.
3. Identify stakeholders whose participation will be required for the promotion and implementation of this industrial decarbonization roadmap in Kenya.
4. Define the time horizons to implement the proposed actions and activities in the short, medium and long term; and
5. Propose an approach for the progressive implementation of this Preliminary Roadmap.

3. Scope of the study

3.1. Background

In the past decade, Kenya has grappled with an increasing frequency of extreme weather events such as droughts, floods, and heatwaves. These events have had an estimated negative annual economic impact of 2.5% on the country's GDP (CPI, et al., 2021). Such extreme weather events require diverting resources for disaster relief services, resources that would otherwise be used in development projects. Furthermore, the Kenyan economy relies heavily on climate sensitive sectors such as agriculture, forestry, and fisheries that comprise a combined 34% of Kenya's GDP (CPI, et al., 2021).

Kenya submitted its updated NDC with a slightly improved target in 2020, committing to reducing emissions by 32% below the business-as-usual (BAU) scenario by 2030 (including land use, land use change, and forestry, LULUCF). To accomplish this goal, the country plans to enhance energy and resource efficiency across different sectors, transition to renewable energy sources, and implement sustainable waste management practices. These actions are crucial to achieve low-carbon and climate-resilient development in the industrial sector, in line with Kenya's Vision 2030. Further, such actions need to be supported by the domestic legislations and institutional frameworks as part of the country's broader climate change strategy.

3.2 Literature Review

The following sources were utilized in developing an understanding of Kenya's industrial sector and legislature, policies and programmes which can support decarbonization of the sector in the DDA report.

- **Kenya Agenda 2030**: Kenya Vision 2030 is a long-term development blueprint that aims to transform Kenya into a newly industrializing, middle-income country providing a high quality of life to all its citizens by 2030 in a clean and secure environment. The vision is based on three pillars: economic, social, and political.

- **Economic Surveys, Kenya National Bureau of Statistics – 2017-2020**: The Kenya National Bureau of Statistics publishes an annual report called the Economic Survey, which provides a comprehensive analysis of the Kenyan economy. The report covers various sectors such as agriculture, manufacturing, tourism, and finance, and provides data on key economic indicators such as GDP growth, inflation, imports, exports, and employment.

- **The Climate Change (Amendment) Act, 2023 and the Climate Change (Carbon Markets) Regulations, 2023**: Kenya's The Climate Change (Amendment) Act, 2023 is an amendment to the 2016 Climate Change Act. The Act defines various terms such as carbon budget, carbon credits, carbon market, carbon project, carbon offset, carbon standards, community, mitigation outcomes, nature-based solutions, non-market approaches, reduced emissions from deforestation and forest degradation, share of proceeds, and more. The amendment provides guidance in the development and implementation of carbon markets, reviewing and recommending the level of compliance with international climate commitments, and identifying past, current, and projected sector-based greenhouse gases emission profile. The amendment also introduces a new section focusing on the regulation of carbon markets, including trade in carbon markets, participation in carbon markets, promoting the mitigation of greenhouse gas emissions, while fostering sustainable development, environmental impact assessment, provision of social and environmental benefits, public land-use projects, dispute resolution, fees, offences, and penalties. The Climate Change (Carbon Markets) Regulations, 2023 seeks to set regulations for domestic carbon markets. The new law will also bolster Kenya's ability to mobilize resources to strengthen its capacity for climate resilience initiatives.

- **Energy Act, 2019**: The Energy Act, 2019 is a Kenyan law that establishes an Energy and Petroleum Regulatory Authority to regulate the generation, importation, exportation, transmission, distribution, supply, and use of electrical energy. The Act also provides for a Feed-in Tariff System aimed at catalysing the generation of electricity through renewable energy sources. The Energy Act has consolidated the laws relating to energy in Kenya.

- **National Climate Change Action Plan, 2018-2022**: Kenya's National Climate Change Action Plan (NCCAP) 2018-2022 is a five-year plan that aims to guide Kenya's climate change actions, including the reduction of greenhouse gas emissions. The plan is based on the progress achieved during the implementation of NCCAP 2013-2017 and is built on three pillars: mitigation, adaptation, and cross-cutting issues. The mitigation pillar aims to reduce greenhouse gas emissions through various measures such as promoting renewable energy, energy efficiency, and sustainable transport. The adaptation pillar aims to enhance the resilience of communities and ecosystems to the impacts of climate change through measures such as climate-smart agriculture, water resource management, and disaster risk reduction. The cross-cutting issues pillar aims to address issues such as gender, youth, and public participation in climate change actions. The NCCAP 2018-2022 sets out bold measures to ensure that Kenya's development remains sustainable in the event of any adverse climate change impacts, including droughts, floods, and other extreme climate events that have in the recent past occasioned far-reaching negative implications on the economy.

- **Mitigation Technical Analysis Report, 2018-2022**: The Mitigation Technical Analysis Report (MTAR) provides the evidence base for prioritized climate change mitigation actions in the National Climate Change Action Plan (NCCAP) 2018-2022. This report, which is an integral part of the NCCAP, outlines proposed mitigation actions across various sectors in Kenya, including agriculture, energy, forestry, industry, transport, and waste.

- **Environment Management and Coordination Act, 1999, amended 2009 and 2015**: Kenya's Environment Management and Coordination Act, 1999 is a Kenyan law that establishes the National Environment Council, the National Environment Management Authority, the National Environment Trust Fund, the Environment Restoration Fund, the National Environment Action Plan Committee, the Standards and Enforcement Review Committee and the National Environment Tribunal. The law also regulates various matters relating to the institutions established and various matters relating to protection of the environment including environmental impact assessment, environmental audit and monitoring of the environment. The law is the framework law on environmental management and conservation in Kenya.

- **National Energy Efficiency and Conservation Strategy, 2020**: Kenya's National Energy Efficiency and Conservation Strategy (NEECS) 2020 aims to achieve energy efficiency goals that will have an overall positive impact on Kenya's economy. The strategy seeks to reduce the demand for fossil fuels and related greenhouse gas emissions by promoting renewable energy, energy efficiency, and sustainable transport. The NEECS 2020 is based on the Ministry of Energy, the Kenya Association of Manufacturers, and other stakeholders' efforts to champion energy efficiency in Kenya since the early 2000s in both the public and private sectors. The strategy provides a roadmap towards achieving energy efficiency goals that will have an overall positive impact on Kenya's economy. The NEECS 2020 will help reduce the demand for fossil fuels and related greenhouse gas emissions, enhance the potential of renewable energy sources to meet a larger portion of the country's energy needs, and contribute to achieving the Paris Agreement and Sustainable Development Goal 7.

- **Energy Management Regulations, 2012**: Kenya's Energy Management Regulations, 2012 is a regulation that seeks to promote energy efficiency and conservation in Kenya. The regulations require the owner or occupier of industrial, commercial, and institutional facilities using any form of energy to develop an energy management policy that outlines measures of efficiency and conservation. The regulations also mandate the submission of energy audit reports, the development of an energy investment plan, and the demonstration of its implementation in a phased manner. The regulations establish that a commission shall carry out energy consumption rating for all facilities and mandates the owner or occupier of large facilities to appoint an energy officer. The regulations also provide for the establishment of a fund to support energy efficiency and conservation initiatives. The Energy Management Regulations are a valuable resource for policymakers, researchers, and investors who are interested in promoting energy efficiency and conservation in Kenya.

- **Renewable Energy Feed in Tariff Policy (REFiT), 2008 (Amended 2010, 2012 and 2021)**: The Renewable Energy Feed-in Tariff Policy (REFiT) was introduced in Kenya in 2008 to promote the generation of electricity from renewable energy sources. The policy provides a guaranteed payment for electricity generated from renewable energy sources such as wind, solar, and geothermal. The policy has been amended several times since its introduction, with the most recent amendment in 2021. The amendments have introduced new tariffs for different renewable energy sources, standardized power purchase agreements, and established a framework for the development of renewable energy projects. The REFiT policy has been instrumental in promoting the development of renewable energy projects in Kenya and has helped the country to achieve its renewable energy targets. The policy has also attracted significant investment in the renewable energy sector and has created employment opportunities in the country.

- **Green Hydrogen Strategy, 2023**: Kenya's Green Hydrogen Strategy and Roadmap for 2023-2032 has been developed by the European Union Global

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Technical Assistance Facility (GTAF) for Sustainable Energy, in close cooperation with the Delegation of the European Union to Kenya (EU), the Ministry of Energy and Petroleum (MoEP) for Kenya, and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). The strategy aims to develop the green hydrogen industry in Kenya in three phases: 2023-2027, 2028-2032, and 2032 and beyond. During 2023-2027, the domestic market will be developed, and the first commercial scale green hydrogen projects are expected to be operational. The strategy focuses on domestic market development and growth, exports, and includes specific objectives related to emission reduction, job creation, and direct investments. The Green Hydrogen Strategy and Roadmap for Kenya is a valuable resource for policymakers, researchers, and investors who are interested in the Kenyan energy sector.

- **National Policy on Climate Finance, 2016**: aims to position Kenya strategically to access climate finance through various mechanisms. By doing so, it contributes to advancing the Kenya Vision 2030 agenda. The policy recognizes the critical role of climate finance in addressing climate change challenges. It aligns with international frameworks, including the UNFCCC (United Nations Framework Convention on Climate Change) guidelines. It strengthens the legal provisions related to climate finance and promotes transparency and accountability in climate finance management.
- **Draft National Green Fiscal Incentives Policy Framework**: The Draft National Green Fiscal Incentives Policy Framework aims to steer Kenya's economy onto a low-carbon climate-resilient green development pathway through a variety of fiscal and economic mechanisms. The policy document is organized into five chapters, with the first chapter providing the policy background. The second chapter outlines the policy goals and guiding principles while chapter three provides a situational analysis of green fiscal reforms across key sectors in Kenya and internationally. Chapter four outlines green fiscal policy interventions for each sector based on international experience and the current Kenyan context described in chapter three. The fifth chapter concludes with an overview of the governance structures to implement the policy. The policy proposes key policy tools that include the use of carbon tax, rebates, subsidies, tax exemptions, ecological fiscal transfers, research grants, concessional loans, guarantees, interest rate subsidies, and the creation of a green bank among others. The policy framework addresses a wide array of areas including policy goals and guiding principles, situational analysis of green fiscal reforms across key sectors in Kegreen fiscal policy interventions.
- **Scaling up Renewable Energy Programme (SREP) – Investment Plan for Kenya**: The Scaling up Renewable Energy Programme (SREP) – Investment Plan for Kenya is a program that aims to scale up the deployment of renewable energy solutions and expand renewable markets in the world's poorest countries. The program is funded by the Strategic Climate Fund (SCF), one of the two Climate Investment Funds (CIF). The program aims to develop the green hydrogen industry in Kenya in three phases: 2023-2027, 2028-2032, and 2032 and beyond. During 2023-2027, the domestic market will be developed, and the first commercial scale green hydrogen projects are expected to be operational. The program focuses on domestic market development and growth, exports, and includes specific objectives related to emission reduction, job creation, and direct investments.
- **Least Cost Power Development Plan (LCPDP), 2017-2037**: Kenya's Least Cost Power Development Plan (LCPDP) is a 20-year rolling plan that provides a framework for the generation and transmission of electricity in Kenya. The plan aims to ensure that the country has a reliable, affordable, and sustainable power supply while minimizing the cost of electricity to consumers. The LCPDP 2017-2037 recommends the renegotiation of power purchase agreements for large power plants to introduce operational flexibility and optimize energy costs. The plan also promotes the development of renewable energy sources such as wind, solar, and geothermal.
- **Kenya Green Economy Strategy and Implementation Plan**: Kenya's Green Economy Strategy and Implementation Plan (GESIP) is a policy framework aimed at facilitating a transition to a green economy and outlines the need to mainstream and align green economy initiatives across the economic, social, and environmental spheres. The GESIP provides the overall policy framework to enhance low-carbon, resource-efficient, equitable, and inclusive socio-economic transformation. The plan focuses on binding socio-economic constraints towards attaining Kenya Vision 2030 and is aligned with the outcomes of the United Nations Conference on Sustainable Development (Rio+20).
- **The Kenya Energy Transition & Investment Plan (ETIP)**: plays a crucial role in shaping Kenya's energy transition and attracting investment. The ETIP helps Kenya frame an energy transition agenda that attracts investment while ensuring a just transition while supporting the country's rapid economic growth trajectory.
- **VAT Act, 2013 and VAT (Amendment) Act, 2014**: Under the VAT Act, 2013 and VAT (Amendment) Act 2014, Kenya offers an exemption from value added tax (VAT) and import duties for supplies imported or bought for the construction of a power-generating plant or for geothermal exploration, as well as certain plant and machinery. According to the Acts, solar cells and modules that are not equipped with elements such as diodes, batteries or similar equipment are free from import duty and exempt from VAT. PV semi-conductor devices including PV cells and light-emitting diodes, together with wind-powered generating sets that have already been assembled, are subject to a 5% import duty and 16% VAT. Wind engines (wind mills) are free from import duty and exempt from VAT. Hydraulic turbines and water wheels are free from import duty but pay 16% VAT. These exemptions and reduced rates are expected to promote the development of renewable energy projects in Kenya and attract investment in the renewable energy sector.
- **Finance Act (enacted annually)**: while the Finance Act does not explicitly focus on climate action, it plays a crucial role in shaping the country's financial landscape, including aspects related to environmental sustainability. The act includes measures such as tax incentives for renewable energy projects, carbon pricing mechanisms, and funding allocations for climate resilience programs.

3.3. Methodology

3.3.1 Introduction

In this study, the current situation and future trends of Kenya's industrial sector have been mapped. Further, the barriers or bottlenecks that limit the adoption of alternatives and potential opportunities have been identified. Based on the analyses conducted, a series of public policy recommendations, development instruments, technologies, and regulations capable of enhancing emissions reduction in short medium and long term have been suggested.

3.3.2 Stakeholder Interviews

To better understand the challenges of industrial decarbonisation, a cross-section of stakeholders were identified. A list was generated of individuals and institutions that would have an impact on decarbonisation efforts across the country. These were then categorised based on their roles and influence on decarbonisation, where their influence on decarbonisation efforts were ranked. Once this was done, a list was generated that encompassed government, industry representatives, academia, and the NGO sector.

Interviewees were provided with a questionnaire to fill which was followed up with a call to clarify responses as well as provide an opportunity to provide further information. Their opinions and suggestions were expressed regarding actions and barriers to decarbonizing the industry to meet the country's commitments under the Paris agreement and the NDCs. The stakeholders interviewed are listed in the following Table 2:

Table 2: Stakeholder consulted for the development of the Preliminary Roadmap

Institution	Contact Person and Designation
Ministry of Environment, Climate Change and Forestry (MoECCF)	Mr Augustine Kenduiwo, Deputy Director, Climate Change Knowledge Management
Ministry of Energy and Petroleum	Mr Stephen Nzioka, Deputy Director, Renewable Energy
Ministry of Investments, Trade and industry	Ms Purity W. Kamau, Deputy Director Industries
Kenya Industrial Research and Development Institute (KIRDI)	Dr Kelvin Khisa, Principal Research Scientist
Kenya Association of Manufacturers (KAM)	Ms Georgina Wachuka, Regulatory & Compliance Executive
Institute of Energy Studies and Research	Dr Jeremiah Kiplagat, Director
National Environment Management Authority (NEMA)	Dr Anne Omambia, Deputy Director, Programs and Projects and NDA
SNV Kenya	Mr Victor Gathogo, PM

Stakeholder inputs, based on an initial guiding questionnaire, were grouped into 6 categories: Barriers, Policies, Financial Resources, Programs and Success Factors, Innovation and Technology and General Considerations, as summarized in Table 3.

Table 3. Policies, financial resources, programs and success factors, innovation and technology and general considerations for addressing the Industrial decarbonization barriers in Kenya based on stakeholder inputs.

Barriers	Policies	Sources of finance	Innovation and Technology
High cost of green/ clean hydrogen transition	• Implement subsidies and tax incentives for clean hydrogen production. • Establish a carbon pricing mechanism to make clean hydrogen more competitive. • Create regulations that mandate a certain percentage of clean hydrogen in industrial processes. • Establish a dedicated government agency to oversee the subject matter of clean hydrogen in the country	• Attract international climate funds like the Green Climate Fund. • Public-private partnerships to share the financial risks. • Incentivize local and foreign direct investment in clean hydrogen technology.	• Invest in R&D for more efficient electrolysis processes. • Develop local manufacturing capabilities for electrolysers and related technology. • Partner with countries leading in clean hydrogen technology for knowledge and technology transfer.
High cost of Carbon Capture Utilization and Storage (CCUS) applications in cement production and high temperature heat processes	• Introduce regulatory frameworks for safe and effective CCUS implementation. • Provide grants or tax benefits for industries investing in CCUS technologies. • Collaborate with other nations for standardized CCUS policies and technology sharing.	• Utilize funds from environmental taxes for CCUS research and implementation. • International loans and grants specifically for sustainable industrial practices. • Crowd-sourcing and green bonds targeted towards environmental projects.	• Collaborate with global research institutions for advanced CCUS technologies. • Focus on incremental innovation to improve existing CCUS methods. • Pilot projects to test and demonstrate the effectiveness of CCUS in local industries.
Immature market and high capital cost of heat pumps for low-temperature heat processes	• Introduce incentives for the adoption of heat pumps in industries. • Establish minimum energy performance standards for industrial heating equipment. • Encourage research and development in heat pump technology through government funding. • Introduce emission trading scheme for micro, small and medium enterprises that manufacture heat pumps	• Facilitate low-interest loans for businesses investing in heat pump technology. • Grants and subsidies for small and medium-sized enterprises to adopt new technologies. • International development assistance programs focused on sustainable industrial technology. • Revenue generated by selling credits to peers (and/or other enterprises)	• Invest in R&D for more efficient pumps. • Develop local manufacturing capabilities for efficient heat pumps. • Partner with countries leading in efficient heat pump technology for knowledge and technology transfer.
High cost of upgrading existing industrial processes	• Develop regulations that gradually phase in mandatory upgrades, giving industries time to adapt. • Facilitate easier approval processes for modernization projects.	• Offer financial incentives, such as tax breaks or grants, for industries upgrading their processes. • Access international funding dedicated to sustainable development and industrial modernization. • Develop government-funded programs specifically aimed at industrial process upgrades. • Encourage local banks to offer favourable loan conditions for sustainable upgrades.	• Promote partnerships with technology providers for cost-effective solutions. • Invest in domestic research to develop more affordable upgrade technologies. • Implement pilot projects to demonstrate the feasibility and benefits of upgrades.
Lack of disclosure and transparency	• Enforce mandatory sustainability reporting for industries. • Create a transparent platform for industries to report and share information. • Establish clear guidelines and standards for environmental and sustainability disclosures.	• Government-funded programs to develop and implement transparency platforms. • Corporate social responsibility (CSR) funds from industries benefiting from increased transparency.	• Develop digital tools for easy reporting and data analysis. • Use blockchain or other secure technologies to ensure data integrity and transparency.

Barriers	Policies	Sources of finance	Innovation and Technology
Lack of awareness among various stakeholders, particularly industry owners and workforce	• Initiate government-led awareness campaigns about the benefits of green technologies. • Integrate sustainability and green technology education in vocational and tertiary education.	• Utilize a portion of environmental taxes to fund awareness campaigns. • Seek funding from international organizations promoting sustainable development. • Collaborations with NGOs and private sector for co-financing awareness programs.	• Use digital platforms and social media for widespread information dissemination. • Develop interactive tools and simulations to educate about green technologies.
Need to improve collaboration between government, industries, industrial associations, business associations	• Create formal platforms for dialogue between government, industry, and associations. • Encourage joint projects and partnerships among these entities. • Provide policy incentives for collaborative efforts.	• Government budgets allocated for industrial and economic development. • International development agencies providing funds for public-private partnership initiatives. • Contributions from industry associations and large corporations through CSR initiatives.	• Utilize digital collaboration tools to facilitate communication and project management.
Limited research and development activities currently	• Increase government funding for R&D in green technologies. • Develop digital tools for easy reporting and data analysis. • Use blockchain or other secure technologies to ensure data integrity and transparency.	• Government allocations for science, technology, and innovation. • Grants from international science and technology funds. • Private sector investment, particularly from industries that would benefit from R&D outcomes.	• Foster innovation hubs and incubators focusing on green technology. • Encourage academia-industry partnerships for practical research applications.
Limited skilled workers and professionals	• Invest in education and training programs specifically tailored to green technologies. • Create apprenticeship programs in collaboration with industries. • Offer scholarships and incentives for studies in relevant fields.	• Government funding for educational and vocational training programs. • International educational grants and scholarships. • Investment from industries in sector-specific training programs for their workforce.	
A significant portion of the industrial sector is informal	• Develop programs to gradually formalize informal sectors with incentives. • Tailor specific outreach and support programs for informal sector businesses.	• Microfinance and small business loans targeted at the informal sector. • Government funds aimed at supporting small and medium enterprises (SMEs). • International aid and development funds focused on economic inclusivity and SME support.	• Develop simple, low-cost technological solutions suitable for the informal sector.
Accessibility to land for setting up pilot plants	• Simplify land acquisition processes for sustainable industrial projects. • Offer government-owned land at subsidized rates for pilot projects. • Develop clear guidelines and support systems for land acquisition for green projects.	• Government infrastructure and development funds for land acquisition and preparation. • Investment from private sector partners interested in pilot plant outcomes. • International grants and loans for sustainable industrial development projects.	• Use GIS and other land-use planning tools to identify suitable locations for pilot plants.

There are various cross-cutting programmes and enabling factors that will play a critical role in addressing the barriers. Indicative list of such factors, based on stakeholder inputs is provided below.

- High share of renewable energy in Kenya's energy supply mix
- Push from the government to develop eco-industrial zones and special economic zones.
- Access to emerging green markets
- Investment-friendly governance
- The carbon-intensive sectors such as cement, iron and steel, and fertilizers (among others) are in their nascency, thus enabling early adoption of low-carbon technologies in the hard-to-abate sectors

3.3.3 Sectoral Data Analysis

Based on the data collected, mathematical and Deep Dive Analysis (DDA) statistical models (Annex 2) were applied to estimate greenhouse gas emissions and energy consumption associated with each industrial segment. These models were then calibrated using historical values and behaviour patterns identified from the available macroeconomic variables. The analysis correlates aggregate patterns by industrial segment with economic growth, energy consumption and greenhouse gas emissions, aiming to build a robust model.

The analysis of industrial segments made it possible to examine various sources of emissions in the sector, ranging from emissions related to fuel and electricity generation to emissions from industrial processes. Based on these emission sources, low-carbon opportunities were identified that could have the greatest impacts. These opportunities include industrial decarbonization solutions, such as energy efficiency technologies and processes, renewable energy generation, use of alternative fuels, and carbon capture and storage, among others. The opportunities considered cover mature technologies with proven results, aiming to promote a sustainable transition with low environmental impact in the industrial sector.

3.3.4 Conceptual Design of the Preliminary Roadmap

Kenya's industrial sector has seen a rise in greenhouse gas emissions, notably from the cement industry, which is followed by the fabrication of metals (steel and iron), agro-processing, chemicals, and fertilisers. Over the past 12 years, the country's cement production has more than doubled due to increased exports to adjacent nations and infrastructural development.

By 2040, the nation's total energy consumption is expected to have increased by approximately a factor of five, leading to an increase in GHG emissions. This calls for stepping up efforts to mitigate and adapt to climate change. Development and decarbonisation must therefore coexist as illustrated in Kenya's Nationally Determined Contribution (NDC)[2].

The Preliminary Roadmap was designed by first identifying the threats and weaknesses of the industrial sector. This information was then used to identify primary barriers that must be addressed to achieve the goal of decarbonizing the industrial sector by 2050. These barriers to industrial decarbonisation were identified in the DDA report as limited competition in electricity distribution, supply and demand misalignment, a growing informal sector that is not highly regulated, inadequate infrastructure and access to land for industries to set up sustainable supply chains. Additionally, the report identified high operational costs, weak policy implementation, limited research capabilities and a lack of awareness on climate change impacts at industrial level[3]. A set of actions was developed to address these barriers, focusing on two primary strategic axes: development and implementation. These action pathways are designed to guide and maximize efforts in the short, medium, and long term. The conceptual framework and rationale for the Preliminary Roadmap can be seen in the **Figure 9**.

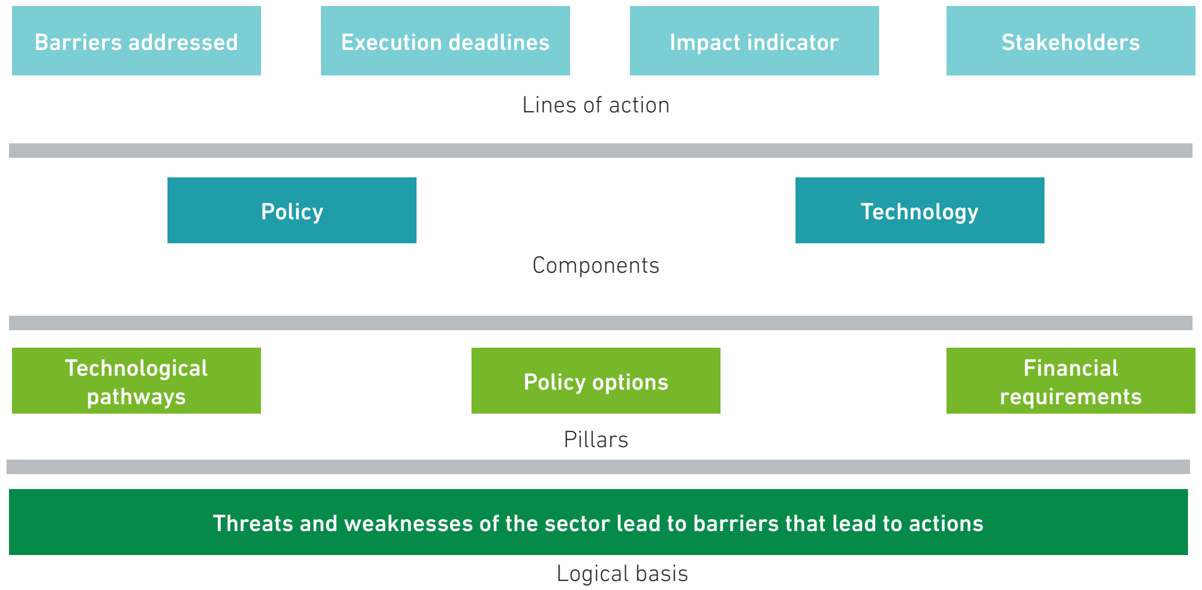

Figure 9. Conceptual structure for designing the Preliminary Roadmap

2 https://www.climatewatchdata.org/ndcs/country/KEN/full

3 Deep Dive Analysis (DDA) report, UNIDO 2023

3.4 Key Pillars of the Preliminary Roadmap

In 2020, Kenya's industries continue to make a vital contribution to the country's economy, while accounting for around 7% of overall CO2 emissions in Kenya (Source: IEA). Industrial sector emissions are attributed to a combination of sources and the mitigation potential is assessed accordingly.

In this report, the main decarbonization strategies (see **Figure 10**) and their status within the Kenyan industrial landscape will be explored.

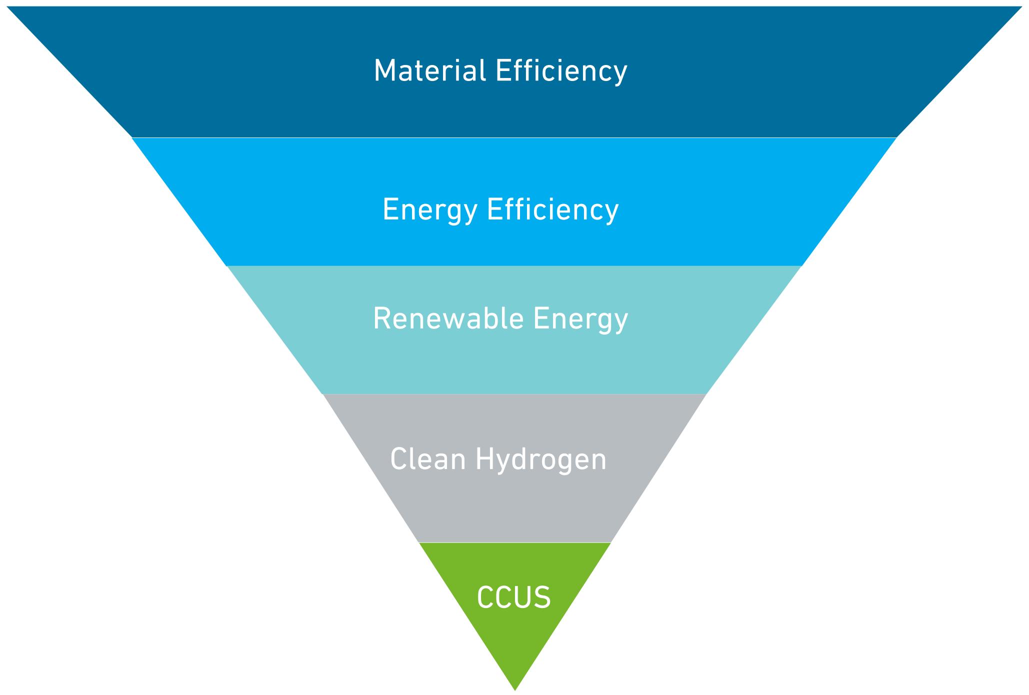

Figure 10. Pillars for the decarbonization of the industrial sector in Kenya.

3.4.1 Material Efficiency

The industrial landscape in Kenya is undergoing significant changes, and material efficiency stands out as a crucial factor in this transformation. This shift must be driven by collaborative efforts from both the government and the private sector to foster sustainable practices. The Kenyan government demonstrates a proactive stance in promoting material efficiency through strategic programs and policies:

- National Material Efficiency Strategy (NMES): Much like the National Energy Efficiency and Conservation Strategy (NEECS), the NMES serves as a comprehensive guide for enhaning material efficiency across various sectors, including industry.
- Regulatory Framework: Kenya has implemented Minimum Material Performance Standards (MMPS) to regulate the material efficiency of products used in various sectors, including industry. These standards aim to minimize waste and optimize resource use.
- Transition to a Circular Economy: The Kenya Private Sector Alliance (KEPSA) Foundation has published a report on Kenya's efforts to transition to a more sustainable and circular economy. The report[4] provides an overview of the status of circular economy trends in Kenya, existing gaps, and available opportunities.
- **Cleaner Production Technologies**: The industrial sector in Kenya has embraced cleaner production technologies through technical assistance by the Kenya National Cleaner Production Centre.[5]
- **Sustainable Waste Management**: Kenya has proven itself a leader on circularity through the Sustainable Waste Management Bill and Policy, the KenyaPlastics Action plan, and banning single-use plastic bags.[6]

4 Kenya Transitioning to a Circular Economy: KEPSA Report - Business Today Kenya

5 Green Economy Booklet.pdf (nema.go.ke)

6 Green Economy Booklet.pdf (nema.go.ke)

3.4.2 Energy Efficiency

The Kenyan industrial sector is undergoing a transformation and energy efficiency is a pivotal aspect of this change, propelled by a mix of government and private sector initiatives. The government has been proactive in promoting energy efficiency through various programs and strategies. The Kenya National Energy Efficiency and Conservation Strategy (NEECS) serves as a comprehensive roadmap for enhancing energy efficiency across multiple sectors, including industry. Key initiatives and highlights include:

- **Minimum Energy Performance Standards (MEPS)**: The number of household appliances under MEPS increased from six to ten, to promote energy efficiency in domestic power consumption. This expansion includes appliances commonly used in the industrial sector, such as computers and cookers.
- **Bioenergy Strategy**: A separate Bioenergy Strategy is being developed to complement the NEECS, focusing on the use of efficient biomass cook stoves. It envisages 50% adoption in households currently using biomass. This strategy has implications for the industrial sector, particularly in agro-processing and other industries reliant on biomass energy.
- **Energy Management Awards (EMA)**: These awards, organized by the Kenya Association of Manufacturers, recognize industrial companies that have made significant strides in energy conservation and efficiency.
- **Energy (Energy Management) Regulations, 2012**: These regulations mandate energy audits for large energy consumers, including industrial facilities, and the implementation of energy-saving measures.
- **Energy (Appliances' Energy Performance and Labelling) Regulations, 2016**: Informs the consumers, including industrial buyers, about the energy performance of appliances, promoting the purchase of energy-efficient equipment.
- **Public-Private Partnerships (PPPs)**: The strategy encourages PPPs to leverage private sector resources and expertise in implementing energy efficiency projects.
- **Capacity Building and Training**: There is a need for continuous training and capacity building to ensure that industry professionals are equipped with the latest knowledge and skills.

The Kenyan government recognizes the importance of energy efficiency in achieving its development goals, including the Vision 2030, the Big Four Agenda and Bottom-Up Economic Transformation Agenda (BETA). Energy efficiency is seen as a key enabler for these goals, providing a more sustainable and cost-effective energy supply for the industrial sector.

3.4.3 Renewable Energy

Kenya is making significant strides in the realm of renewable energy, leveraging its unique geographical advantages and natural resources to foster a sustainable energy future. Figure 11 shows the contribution of various sources in electricity generation in Kenya. The graph shows that in 2020, geothermal, hydro and wind are the leading contributors to electricity generation in the country.

Below is an overview of the Kenya's renewable energy landscape:

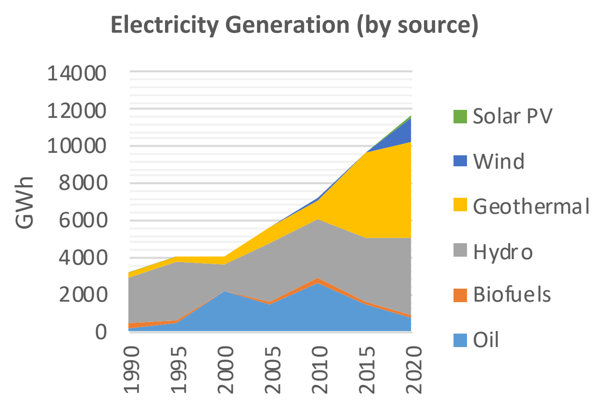

Figure 11. Electricity generation by source in Kenya

- **Geothermal Power**: Kenya's Great Rift Valley, with its vast geothermal potential, has positioned the country as a leader in geothermal energy in Africa. The government has been capitalizing on this resource and generates a stable supply of electricity, affordable energy costs, and mitigate the environmental impacts of fossil fuel use.
- **Solar Energy**: Blessed with high solar insolation, Kenya is harnessing this resource to expand its energy portfolio. Solar power is particularly pivotal in rural electrification, providing energy to remote areas that are not connected to the grid. The government has implemented policies to encourage the adoption of solar technologies, both at small scales in homes and at larger scales in solar farms.
- **Wind Energy**: The Lake Turkana Wind Power project, among others, exemplifies Kenya's commitment to wind energy. The country's diverse topography offers numerous sites suitable for wind farms, which contribute help in reducing the carbon footprint.
- **Bioenergy**: Generating energy by utilizing agricultural residues and municipal waste, Kenya is exploring bioenergy to diversify its energy sources. Biogas programs are being promoted to provide clean cooking solutions and reduce reliance on wood fuels.
- **Hydropower**: Although hydropower has been a traditional source of energy in Kenya, the country is exploring ways to mitigate the impacts of climate change on water levels by diversifying into other forms of renewable energy.

Kenya's renewable energy initiatives are focused enhancing energy security but are also tied to its industrialization and climate action goals. The country is committed to achieving 100% renewable power by 2030 and fuelling green industries by 2040. Through the Accelerated Partnership for Renewables in Africa (APRA), initiated in 2023, Kenya is spearheading efforts to mobilize finance, provide technical assistance, and engage the private sector in renewable energy development.

3.4.4 Clean Hydrogen

Clean Hydrogen (CH), derived from renewable energy, is emerging as a pivotal component in Kenya's decarbonization strategy, particularly for sectors with high greenhouse gas emissions. As the global community strives to meet climate objectives, CH is poised to become a key player in transport, industry, and power generation. It also aligns with the international climate commitments. Kenya, with its strategic initiatives and commitment to renewable energy, is gearing up to carve out a significant niche in the growing CH markets.

Kenya has significant potential for CH production, bolstered by its rich renewable energy resources. Kenya's Green Hydrogen Strategy and Roadmap[7] were unveiled during the Africa Climate Summit (in September 2023), marked by the signing of a significant agreement wherein the European Union (EU) pledges to support Kenya's green economy initiatives.

Currently, in Kenya, hydrogen production costs are estimated to be between approximately $3.65 and $9.77 per kilogram, depending on the chosen location for production.[8] The areas for production that are most economical are in the southern and south-eastern regions near Lake Turkana. Findings suggest that ammonia produced in Kenya could be competitive in the current market, especially considering the ongoing energy crisis, and Kenya could potentially export hydrogen at costs of around $7 per kilogram. With expected technological and economic advancements, the costs for producing hydrogen across Kenya could decrease to between $1.77 and $2.96 per kilogram by 2030. Kenya's investments in renewable energy infrastructure, such as geothermal, wind, and solar, are laying the groundwork for competitive CH production.[9]

Further, the government and private sector are actively exploring the potential of CH through initiation of pilots at strategic locations across the country. Investments are being channelled into renewable energy projects that not only contribute to the overall sustainability of the energy system but also support the direct production of CH (Ref. Kenya Green Hydrogen Strategy 20+++). Further, the Kenyan government agencies will be instrumental in fostering a conducive environment for CH through policy development, regulatory instruments, and incentives. Development banks, energy regulatory authorities, and policy-making bodies are among the key players driving the GH agenda.

The successful deployment of the CH value chain in Kenya requires concerted and collaborative efforts from a complex ecosystem of stakeholders including public and private sector entities, government bodies, academic institutions, and research organizations. International partnerships in the form of technology and expertise transfer and investments are also important for Kenya's CH strategy.

Kenya is formulating a comprehensive legal framework for green (clean) hydrogen, with ongoing discussions aimed at establishing policies that capitalize on the country's renewable energy resources. The development of this regulatory framework is key to supporting clean energy transition in Kenya.

3.4.5 Carbon Capture, Utilization, and Storage (CCUS)

In Kenya, the exploration and development of Carbon Capture, Utilization, and Storage (CCUS) technology are at a nascent stage. The discourse around CCUS is centred on the potential establishment of hubs that would serve as collective facilities for the capture, transportation, and sequestration of carbon dioxide (CO_2) emissions.

The Kenyan government is making strides in carbon market regulation, as evidenced by the recent legislative developments. The Climate Change (Amendment) Act, 2023 is a landmark in Kenya's legal landscape, aiming to provide a structured approach to carbon capture and storage (CCUS) projects and the

7 https://www.eeas.europa.eu/sites/default/files/documents/2023/GREEN%20HYDROGEN%20EXEC_0209_0.pdf

8 Green hydrogen production and use in low- and middle-income countries: A least-cost geospatial modelling approach applied to Kenya -ScienceDirect

9 PtX-Baseline_Study-KE_Report.pdf (energypedia.info)

broader carbon trading market. This Act is expected to lay down the legal certainty needed to foster the development of CCUS hubs.

Research and feasibility studies are also underway to identify potential zones for CCUS hubs in Kenya. These hubs could benefit from government incentives such as direct financial participation, subsidies, or tax credits to stimulate their development and operation. Box 1 summarizes some case examples from other countries.

For successful deployment of CCUS, the industry's growing interest needs to be matched with public sector backing to offset costs and enhance the competitiveness of CCUS solutions. Moreover, establishing stringent regulations and managing the risks associated with CO_2 storage is also essential.

Box 1: How countries are incentivising CCUS:

- Canada: The Canadian government offers a 45Q tax credit that covers 50% of the capital cost of CO2 capture projects between 2022 and 2030. It also supports the development of a national carbon capture and storage (CCS) knowledge sharing hub to collect and curate best practices and lessons learned from Canadian CCS projects.
- United States: The US government also provides a 45Q tax credit that as of 2021 gives $36 per ton of CO2 stored in geological reservoirs or $24 per ton of CO2 used in enhanced oil recovery or other purposes. It also offers direct government grants and loan guarantees for CCUS projects.
- Europe: The European Union has established an Innovation Fund that supports low-carbon technologies, including CCS, with a budget of around €10 billion for the period 2020-2030. It also has an Emissions Trading System that puts a price on carbon emissions and creates a market incentive for CCS.
- China: The Chinese government has been actively promoting CCUS through various policy measures, including the inclusion of CCUS in its national five-year plans and the establishment of a national CCUS demonstration project.
- Middle East: In the Middle East, countries like Saudi Arabia and the United Arab Emirates have been investing in CCUS as part of their efforts to diversify their economies and reduce their carbon emissions. They have been partnering with international oil companies and technology providers to develop and deploy CCUS projects.
- New Zealand: The New Zealand government has been supporting CCUS research and development through its clean energy fund and has been considering the introduction of a carbon pricing scheme.

4. Technologies for Industrial Segments (Cement and Steel)

4.1. Cement Manufacturing

In many respects, Kenya's path to decarbonization is tied to its cement industry and the technology choices made.[10] Cement production recorded significant growth in the last decade occasioned by expansions to meet the increased demand in the construction sector. Cement production doubled between 2010 and 2020 from 3,710 thousand tonnes in 2010 to 7,474 thousand tonnes in 2020 and reached 9,248 thousand tonnes in 2021. More than 90% of produced output is consumed domestically and the balance is exported within East Africa. The major cement companies include Bamburi Cement, Mombasa Cement, East Africa Portland Cement, Savannah Cement, Athi River Mining Cement and National Cement. Bamburi Cement accounts for a third of Kenya's national cement production and is the leading producer in East Africa.

10 https://www.mckinsey.com/~/media/mckinsey/business%20functions/sustainability/our%20insights/africas%20green%20 manufacturing%20crossroads/africas-green-manufacturing-crossroads-choices-for-a-low-carbon-industrial-future.pdf

4.1.1 Energy Demand

Coal is the primary fuel for the cement industry in Kenya. **Figure 12** shows the share of final energy use in the cement industry, while **Figure 13** shows the share of different energy types used in cement manufacturing in 2020. The total energy demand is estimated based on the heat from fuel combustion, which accounted for 87% of total final energy consumption and electricity use accounting for the remaining 13%. The major emissions are from pre-calciner for clinker production where the CO2 comes from decomposition of the calcium/ magnesium carbonates.

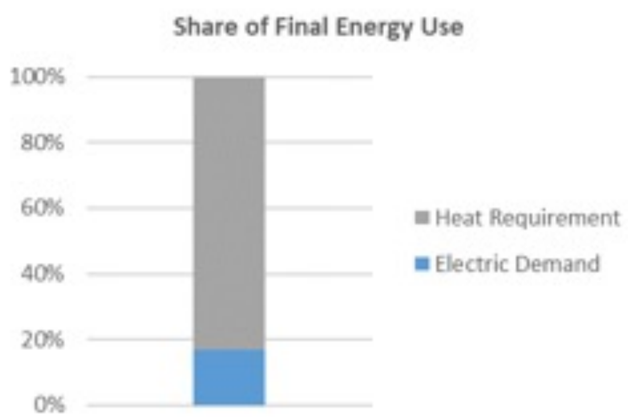

Figure 12. Share of final energy use in the cement industry (Source: Author's analysis)

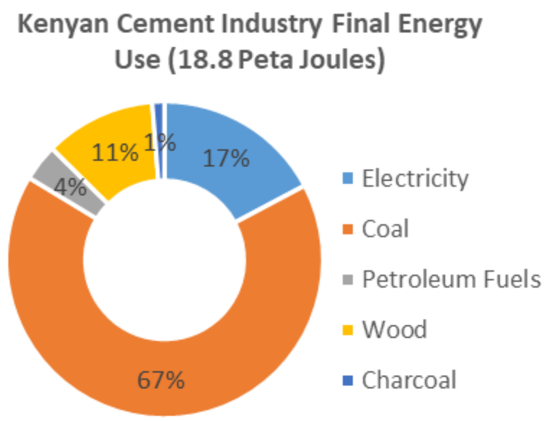

Figure 13. Cement industry energy use in Kenya (2020) (Source: Author's analysis)

The energy demand for cement industry is estimated based on the production volume in 2020 and can be broken down into energy requirement for clinker production and then cement manufacturing. The clinker to cement (CTC) ratio is estimated at 0.76 against the global average of 0.71 (IEA). The total clinker consumed in the country in 2020 was approximately 6 MT of which 3.9 MT was produced domestically while approximately 2 MT was imported.

The energy consumption values of 900 kcal/kg of clinker and 120 kWh/ton of cement were considered for energy saving potential determination.[11] Furthermore, the target for specific energy consumption was set up at 750 kcal/kg of clinker and 90 kWh/ton of cement, i.e., near to global average. This means that overall, a technical potential for thermal energy savings of 200 kcal/kg of clinker (21%) in clinker production and

11 https://documents1.worldbank.org/curated/en/743581468188046789/pdf/80746-FinalReportAfricaCementSector090420-Box-

electricity savings of 30 kWh/ton of cement (25%) could be assumed.

The energy mix for the cement industry is assessed based on the fuels used in the manufacturing industry (KNBS, 2021). There is a discrepancy in the coal consumption data, so the coal share for energy supply is assumed for the remainder thermal energy requirement after accounting for other sources. The assumption is judicious as most of the coal used in the country is for cement production.

4.1.2 GHG Emissions

In 2020, the total emissions from cement sector were 4.5 MT CO2eq., 60% of which were process-related emissions (see **Figure 14**). Therefore, decarbonization in the cement industry cannot be achieved by the best available energy-efficient technologies or fuel switching alone.

Deployment of abatement technologies like CCUS and innovative chemistry including reduced share of clinker will be imperative to achieve near zero GHG emissions from cement industry. The control of other pollutants (SO2, NOx, or NMVOC) emitted at the time of cement manufacturing, which contribute to adverse health impacts locally should also be considered.

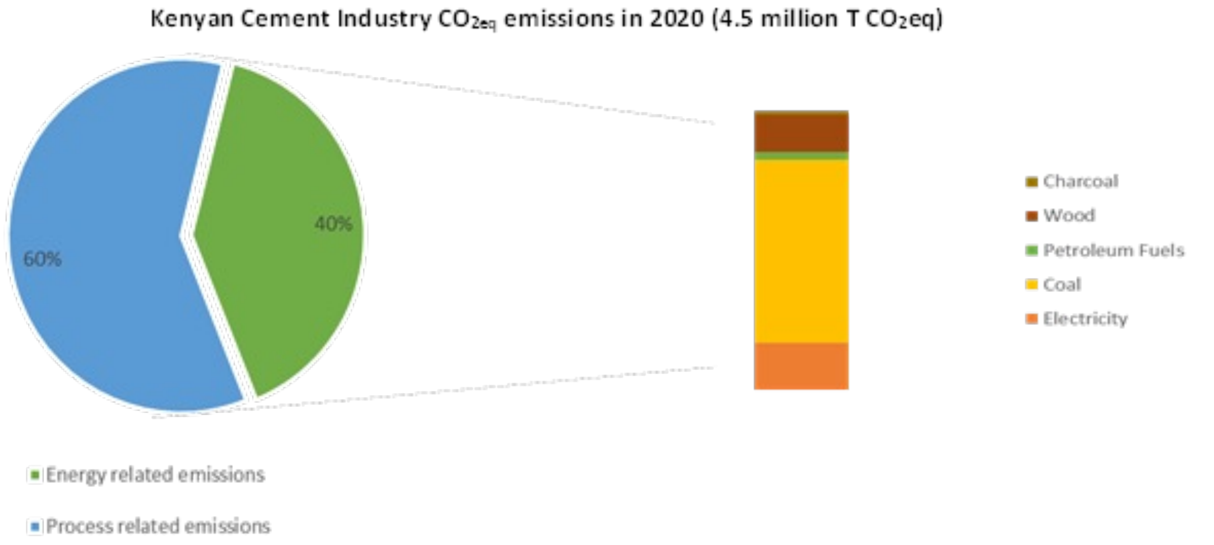

Figure 14. Cement industry GHG emissions in 2020 (Source: Author's analysis)

4.1.3 Energy and GHG Emissions Performance Assumptions

The **Table 4** details the assumptions and factors utilised in estimating energy and GHG estimations for the cement industry.

Table 4. Assumptions for energy and GHG estimations for cement industry

Parameters	Value
Baseline specific thermal energy use	950 kcal/ kg
Projected specific thermal energy use	750 kcal/kg
Emission factors for coal and heavy fuel oil (HFO burnt in kilns)	Coal: 0.0946 tCO¬2/ GJ / HFO: 0.0774 tCO2/GJ
Baseline specific electricity use	120 kWh/ton of cement
Target electricity use	90 kWh/ton of cement
Grid electricity emission factor	0.3322 kg CO2/kWh
Clinker to cement ratio	0.76

4.1.4 Projections

Trends of cement production per capita with per capita overall Gross Domestic Product (GDP) and industrial Gross Value Added (GVA) have been examined. Both trends show a strong correlation between quantities. With the linear regression trends, values obtained in the future for cement production per capita are 225 kg/capita in 2030, and 660kg/ capita in 2050 (**Figure 15**). For reference, per capita cement production values for other countries are shown in **Table 5**.

Table 5. Per capita cement production in different regions

Region	Production per capita	Unit
US	279	kg/capita
UK	173	kg/capita
EU	307	kg/capita
Brazil	261	kg/capita
World	563	kg/capita
China	1529	kg/capita

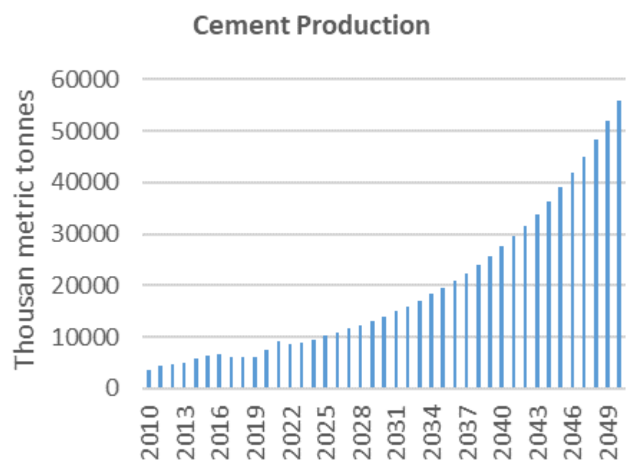

Figure 15. Cement Production Projections in KenyaAuthor's analysis)

4.1.5 Decarbonization Strategies for Cement Industries

With advanced technologies like carbon capture, alternative cements, and efficiency improvements, the cement industry has the potential to reduce its carbon emissions by around 20-40% by 2030, according to estimates by the International Energy Agency (IEA). The interventions that can result in reduced carbon intensity of cement production are discussed below.

4.1.5.1 Energy and Material Efficiency

Improvements in energy efficiency can be made at various stages of the cement production process. These include high efficiency kilns, adopting pre-heaters and pre-calciners, waste heat recovery, combined heat and power, advanced grinding and milling technologies, and implementing Energy Management Systems and Process Control Systems among. The specific energy consumption could be improved to 750 kcal/ kg of clinker production from current level of 950 kcal/ kg offering the potential to increase by 21%, and electricity consumption could be reduced by 25% to 90 kWh/ ton of cement from 120 kWh/ ton.

4.1.5.2 Innovative chemistry

Supplementary Cementitious Materials (SCMs) are materials that can be blended with cement to enhance its properties while reducing the need for clinker. Common SCMs include fly ash, slag, and natural pozzolans among others. These materials react with calcium hydroxide produced during cement hydration, forming additional cementitious compounds that contribute to the strength and durability of concrete. By replacing a portion of the clinker, SCMs reduce both energy consumption and carbon emissions associated with clinker production (**Figure 16**).

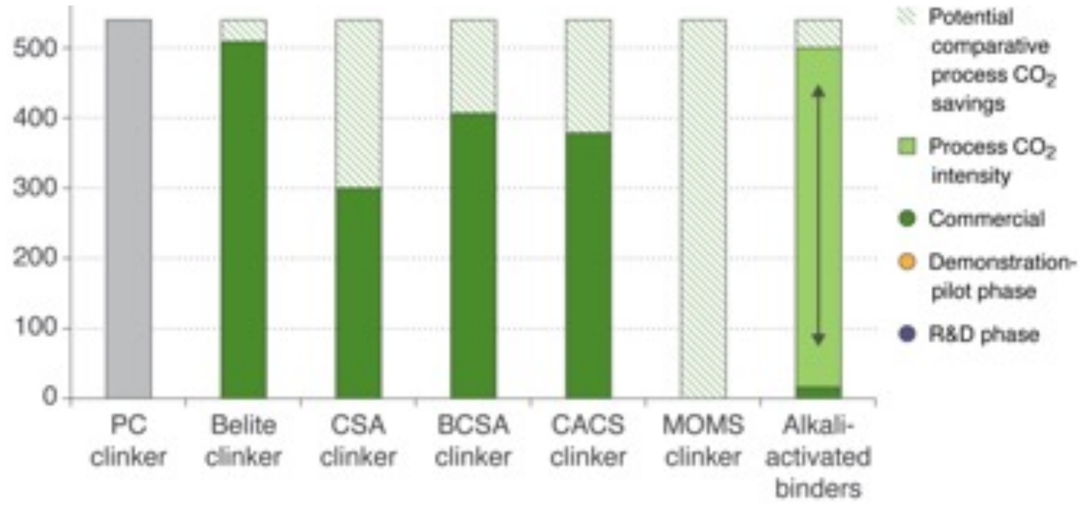

Figure 16. Process CO_2 emissions intensity for cement binding materials (US DoE, 2022)

4.1.5.3 Alternative fuels for Clinker production

The major source of GHG emissions from the cement industry is the calcination process at the time of clinker production. The CO2 intensity using different type of fuels and technologies is presented in Figure 17. Biomass materials such as rice husk, agriculture residue, solid recovery fuels from non-recyclable plastics, municipal solid waste and industrial wastes, rubber waste, and waste oils can help reduce emissions with waste management co-benefits.

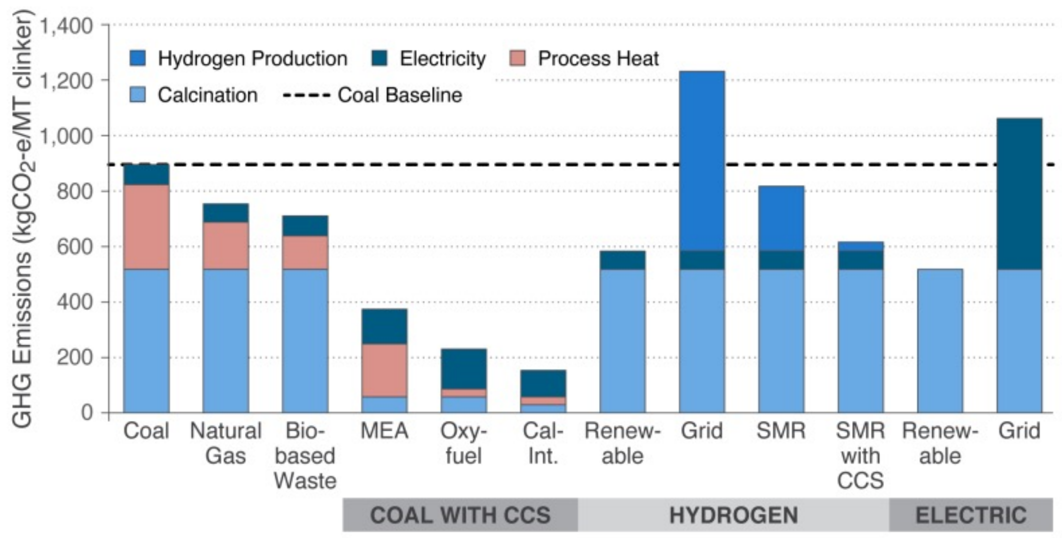

Figure 17. Carbon intensity of clinker produced by using different fuel. (Source: US DoE, 2022)

4.1.5.4 Carbon, Capture, Utilisation and Storage

The process emissions from calcination process are unavoidable even with the cleanest form of energy used. The process related carbon dioxide emissions hence are required to be captured, and stored underground or if applicable can be utilized in other applications as well. **Figure 18** shows that reduction of clinker to cement ratio and integration of carbon capture in cement production have the highest potential in cumulative CO2 emissions reduction.

4.2 Steel Production

In Kenya, the steel-making process is centred on melting steel scrap in induction furnaces, the manufacture of wire and wired products, pipes, cold-rolled steel products, and downstream finishing processes such as galvanization. The amount of steel imported into Kenya together with some of the steel which is currently imported by Kenya's neighbouring countries - presents an immediate steel production opportunity.

4.2.1 Growing Demand and Developments in Steel sector

While the local iron ore deposits exist in Taita, Meru, Kilifi, and Samia regions of Kenya, they are yet to attract commercial interests. Imports of iron and steel have risen steadily over past 5 years at a CAGR of 10.9 per cent from 1.63 MMT in 2017 to 2.47 MMT in 2021 (Kenya Ports Authority, 20+++), indicating towards a rising demand.

Rising demand for steel products have led to huge investments in the sector. Recently, Devki Steel Mills Ltd. opened a KES 50 billion state-of-the-art raw steel production factory, to produce 0.5 million tonnes of steel annually.[12] The integrated steel plant utilises blast furnace technology and two direct reduced iron (DRI) plants, which will require coal for its thermal energy needs while a 55 MW power plant is being installed for electricity requirements. Hence, it is critical to integrate a decarbonization strategy in the steel sector while the sector is taking off in Kenya.

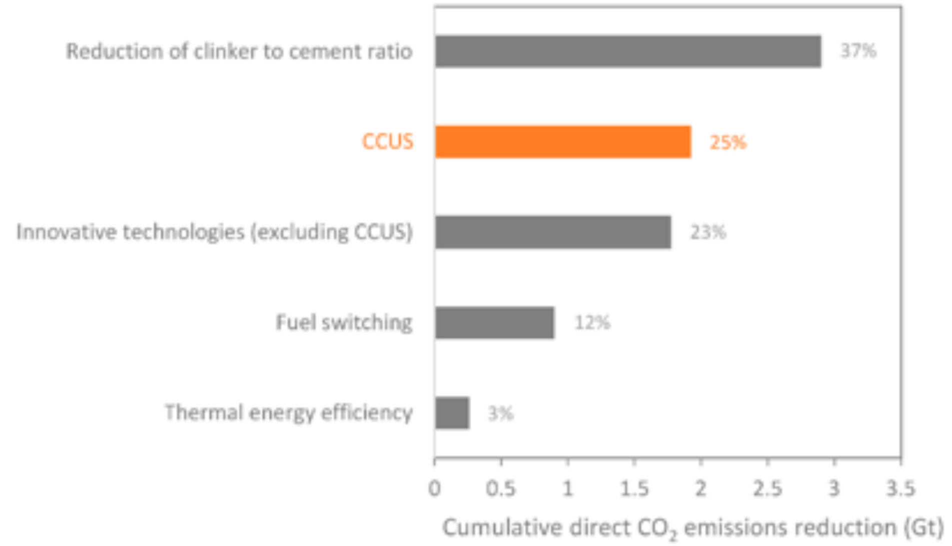

Figure 18. Potential of various technologies for global cumulative reductions in cement production by 2050 (Source: IEA, 2018)

12 Devki Steel

4.2.2 Projections

The iron and steel production sector in Kenya is expected to grow significantly due to identification of mineral sites and development of the mining and quarrying sector. Figure 19 shows the potential growth the iron and steel sector up to and beyond 2050; the production is expected to grow five-fold in this timeframe.

4.2.3 Decarbonization of iron and steel production

Decarbonizing the steel manufacturing process in Kenya can be achieved through a combination of energy efficiency, renewable energy, clean hydrogen, and carbon capture utilization and storage (CCUS) technologies.

4.2.3.1 Energy and material efficiency measures

Can be implemented to reduce the energy consumption of the steel manufacturing process. This can be achieved by optimizing the use of energy in the production process, such as using energy-efficient equipment and processes, increasing share of iron and steel scrap in raw material to reduce use of coal, increasing use of fuel injection, though, for example, pulverized coal injection (PCI), natural gas, plastics, biomass, or hydrogen (as an additional reagent on top) and reducing energy waste. Further ensuring the adoption of scrap-based electric arc furnaces (EAF) over integrated blast furnace (BF)/basic oxygen furnace (BOF) as steel manufacturing expands will not only ensure decreased energy use but also improve circularity in the steel sector

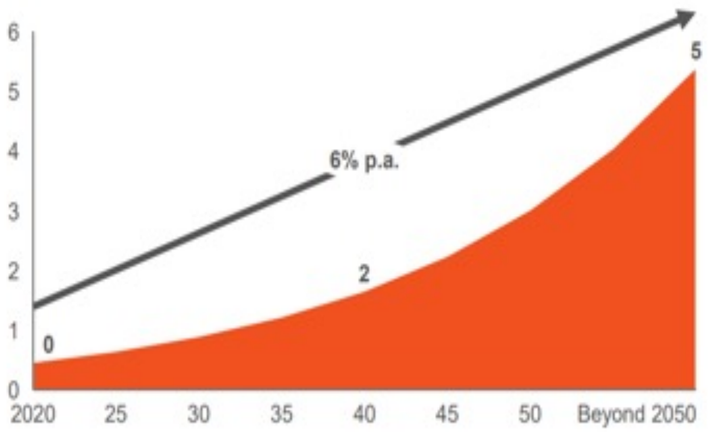

Figure 19. Iron and steel production projections (in Mtpa)

by significantly increasing utilization of scrap metal in the manufacturing process. [13]

4.2.3.2 Renewable energy

Sources such as solar, wind, and geothermal can be used to power the steel manufacturing process. Kenya has abundant renewable energy resources, and the government has already taken steps to increase the use of renewable energy in the country. [14]

4.2.3.3 Clean hydrogen

Can be used as a clean fuel source in the steel manufacturing process. Hydrogen can be produced using renewable energy sources such as solar, geothermal and wind power. It can be used as a substitute for fossil fuels in the steel manufacturing process for producing Direct Reduced Iron (DRI).[15] Hydrogen-based (H2) steel production can be implemented either in forthcoming (greenfield) sites or existing (brownfield) facilities. The latter opportunity requires existing equipment to either be retrofitted or for the facility to possibly be completely rebuilt in order to implement a decarbonized production process.6

4.2.3.4 Carbon capture utilization and storage (CCUS) technologies

Can be used to capture carbon dioxide emissions from the steel manufacturing process and store them underground. This technology can help reduce the carbon footprint of the steel manufacturing process. However, carbon-capture projects at steel plants in other parts of the world are still at the pilot stage. It will require significant investment to lower the cost of carbon capture enough to make it viable as a large-scale solution.

13 https://www.mckinsey.com/industries/metals-and-mining/our-insights/decarbonization-challenge-for-steel

14 https://www.mckinsey.com/~/media/McKinsey/Industries/Metals%20and%20Mining/Our%20Insights/Decarbonization%20challenge%20for%20steel/Decarbonization-challenge-for-steel.pdf

15 https://www.weforum.org/agenda/2022/11/green-hydrogen-energy-opportunity-decarbonization-countries/

4.3 Fertilizer Manufacturing

Kenya's fertilizer industry has witnessed a significant transformation in recent years, moving from a history of heavy reliance on imports to fostering local production. The Toyota Tsusho plant in Uasin-Gishu and the NPK Compound Granulation facility in Nakuru are pioneering this change, with a combined initial production capacity of 250,000 tonnes per year, which will significantly contribute to the national supply and benefit millions of farmers. Such strategic investments are set to enhance local manufacturing capabilities, tailored to Kenya's unique agricultural needs, and are expected to catalyse further growth in the sector. Fertilizer manufacture is a high GHG emissions industry. However, exploration of green/clean hydrogen as a clean alternative for ammonia production in fertilizers will contribute to low-carbon development in the sector.

4.3.1 Projections

The chemicals production sector in Kenya is expected to grow significantly up to and beyond 2050, as evidenced by the gross value added (in $bn) to Kenya's economy in Figure 20. This in turn implies growth in fertilizer manufacturing in the country.

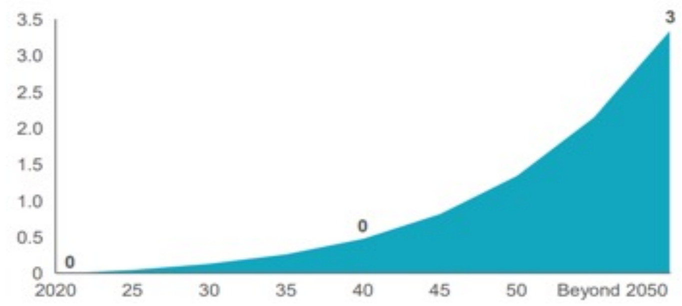

Figure 20. Chemicals industries in Kenya - projections for Gross Value

Based on an assessment of Economic Survey by Kenya's National Bureau of Statistics, import of chemical fertilizers into Kenya has grown at a rate of 6.26% as shown in Figure 21. Projecting the demand, and assuming reliance only on imports (lack of domestic production capacity), by 2050, approximately, 4.9 million tonnes of fertilizer imports could be moving into the country.

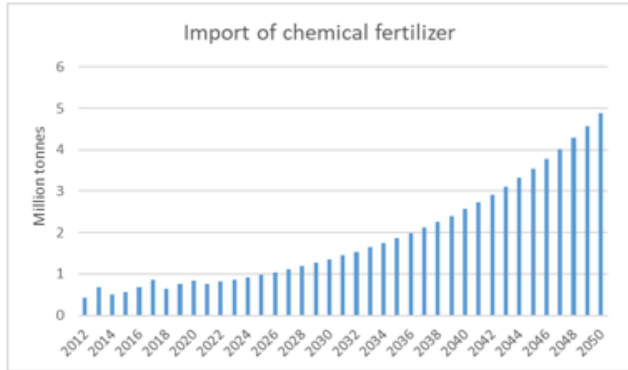

Figure 21. Growth and projection of fertilizer imports (assuming lack of domestic production capacity)

4.3.2 Decarbonization of fertilizer production

It may be possible to bring down emissions from the fertilizer manufacturing sector drastically by 2030 while tripling Kenya's output of fertilizers.[16]

4.3.2.1 Renewable energy

Kenya has abundant renewable energy resources, such as solar, wind, and geothermal and the government has already taken steps to increase the use of renewable energy in the country.[17] These sources can be used to power the fertilizer manufacturing process.

4.3.2.2 Clean hydrogen

Hydrogen, as a clean fuel source, can be produced using renewable energy sources such as solar and wind power and can be used as a substitute for fossil fuels in the fertilizer manufacturing process.[18]

4.3.2.3 Organic fertilizers

16 Maire Technimont Group starts Preliminary work | Stamicarbon

17 For Kenyan farmers, organic fertilizer bokashi brings the land back to life (mongabay.com)

18 A life-changing fertilizer for rural farmers in Kenya | MIT News | Massachusetts Institute of Technology

Can also help reduce the carbon footprint of the fertilizer manufacturing process. Organic fertilizers are made from mainly from natural sources. They can be produced locally and can help reduce the dependency on imported fertilizers.

4.4 Decarbonization potential of selected industrial sub-sectors

This section explores the decarbonization scenarios for the industrial sub-sectors identified in this report. A detailed sectoral breakdown of the energy consumptions in Business As Usual (BAU), Alternate scenarios and the savings provided is found in Annex 2. Decarbonization in the industrial sector will potentially drive an overall shift in fuel consumption, as outlined in **Figure 22**. While coal will play a key role in the fuel mix in 2050, carbon capture and storage will help enhance low carbon development in the sector.

4.4.1 Cement Industry

4.4.1.1 Specific Energy Consumption/ Efficient Technologies

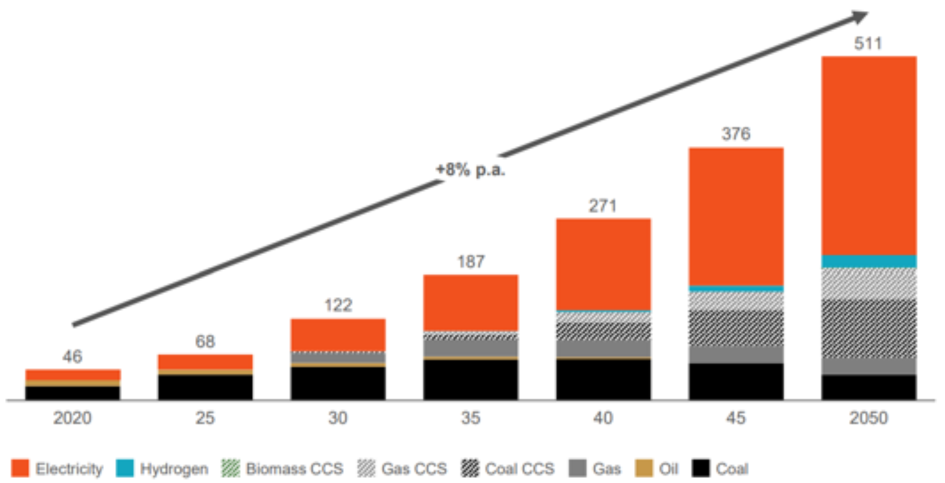

Figure 22. Fuel Mix Projection for the Growing Industrial Sector in Kenya (in PJ)

Assumptions for specific energy consumption and efficiency are given in **Table 6**.

Table 6. Specific energy consumption assumptions

	Baseline (2050)	Alternate (2050)
Cement	279	kg/capita
Electricity consumption	120 kWh/ ton	90 kWh/ ton
Thermal Energy Consumption	950 kcal/ kg	750 kcal/kg

4.4.1.2 Clinker to Cement Ratio

Assumptions for clinker to cement ratio are given in **Table 7**.

Table 7. Clinker to cement ratio assumptions

Baseline (2050)	Alternate (2050)
0.76	0.5

4.4.1.3 Fuel Mix

The fuel mix in the baseline scenario have been assumed same as that in 2020, i.e., grid-based electricity for electricity consumption (90% renewable energy) and the use of coal, petroleum fuels, wood, and charcoal for thermal energy requirement.

In the alternate scenario, all the electricity has been assumed to come from 100% renewable grid, and hydrogen (100%) as the alternate fuel to meet the thermal energy requirement. Also, the coal with CCUS is explored as well in the alternate scenario.

4.4.1.4 Abatement technology

No CCUS is assumed in baselines scenario, however, 100% of CCUS installation is assumed in the alternate case.

4.4.1.5 Energy Savings

The final energy demand for cement production could be reduced by approximately 50%, using alternate materials that can be blended with clinker. The clinker

to cement share of 0.50 from current level of 0.76 could result in nearly 50 petajoules (PJ) of energy savings. Additionally, the improvement in efficiency to the global benchmarks resulting in reduced specific energy consumption, could lead to savings of roughly 45 PJ (see **Figure 23**).

4.4.1.6 GHG emissions reduction

Baseline Scenario: The overall emissions will nearly double in 2030 to 9.7 MT CO2eq. and increase by around 9 times in 2050 to 39 MT CO2eq. from the current levels in 2020. The same level of specific

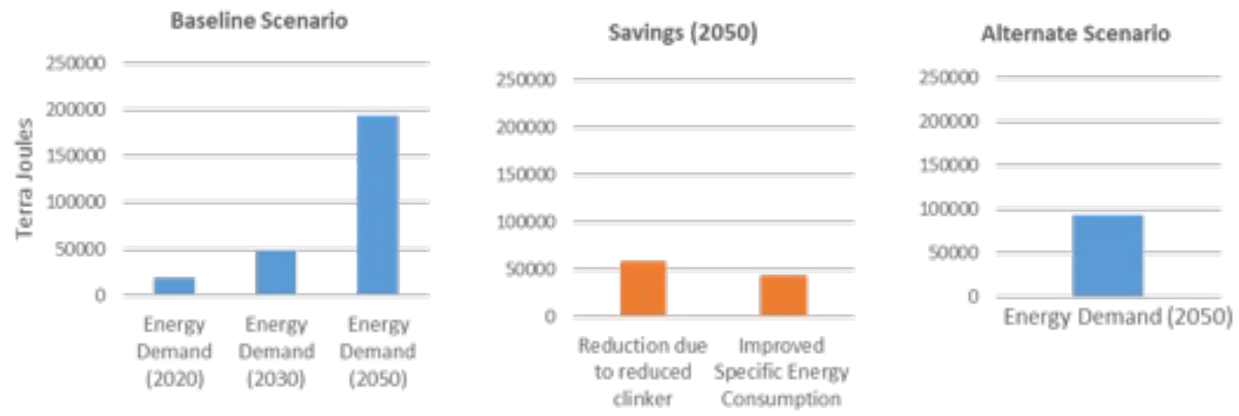

Figure 23. Energy Savings in cement industry under alternate scenario (Source: Author's analysis)

energy consumption and share of fuel mix is assumed in the baseline scenario having largest share of coal from energy related emissions (see **Figure 24**).

Alternate Scenario: Various interventions have been adopted in the alternate scenario. The maximum savings could be observed by reducing the clinker share with cement that resulted in both process and energy related emissions savings. With the energy

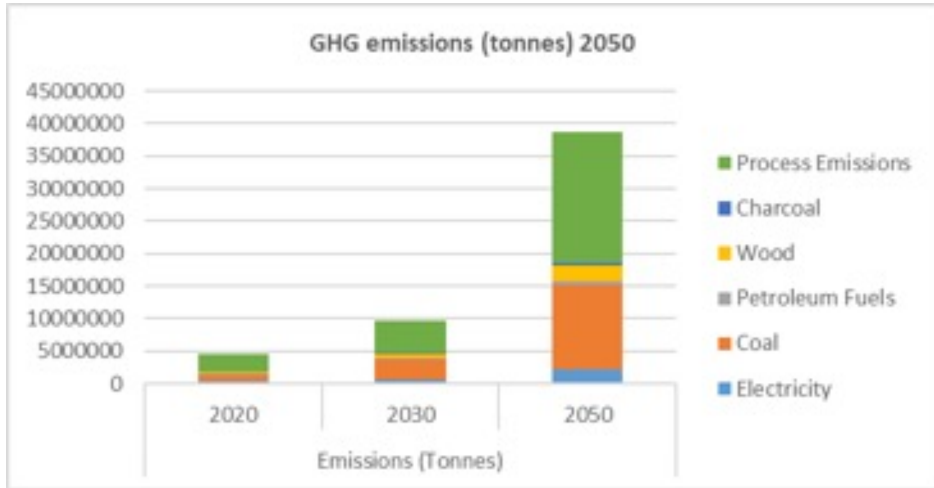

Figure 24. GHG emissions by source (Source: Author's analysis)

efficiency improvement, reduced use of clinker with cement, 100% RE based electricity, residual emissions will be reduced to 5% of the baseline emissions if coal with CCUS is used for process heat, or 18% of the baseline emissions if green/clean hydrogen is used (see **Figure 25**).

4.4.2 Iron and steel manufacturing.

4.4.2.1 GHG emissions

Devki mills steel production plant with an annual production capacity of 0.5 MT in November 2022. Based

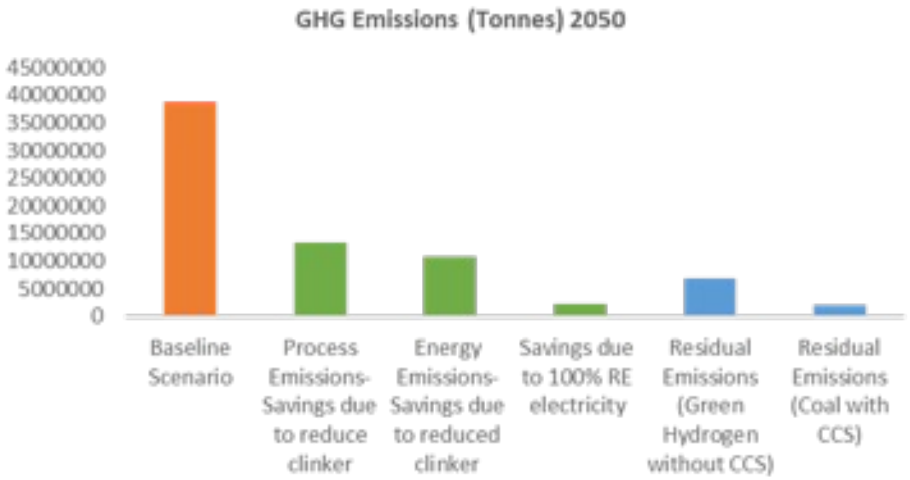

Figure 25. GHG emissions savings and residual emissions under alternate scenario (Source: Author's analysis)

on the projected growth rate of 6%, the production capacity in Kenya in 2030 and 2050 is expected to rise to 0.84 MT and 2 MT, respectively. Under a business-as-usual scenario (BAU), where the technology used for steel production continues to be blast furnace-basic oxygen furnace[19], as is currently in practice, the GHG emissions may be as high as 1.95 MT CO2 in 2030 and 4.7 MT CO2 in 2050.

Transition to electric arc furnace (EAF) combined with in direct reduced iron (DRI)[20] or scrap steel[21] have the potential to significantly cut emissions versus BAU scenario.

Further adoption of renewable energy and green/clean hydrogen production for powering steel production in combination with carbon capture utilization and storage technologies, have the potential to reduce energy related GHG emissions from steel production to zero.

4.4.3 Fertilizers production

4.4.3.1 GHG emissions

Based on lack of available data, it is not possible to estimate GHG emissions for the fertilizer sector and only a qualitative analysis could be done. The current production capacity is 250,000 tonnes per annum from two production facilities in the country. With the impetus on domestic fertilizer production growing, this production capacity is expected to grow. **Figure 21** (as presented earlier in section 3.4.3) gives a high-level estimate of the projected demand.

Studies suggest that for every tonne of chemical fertilizer produced at least 3 tonnes of CO2 is emitted.[22] Based on this assumption, if the GHG emissions for the projected fertilizer demand may exceed 14 million tonnes of CO2 per annum. However, ensuring growth of the fertilizer industry in tandem with green/clean hydrogen technology as a power source, can ensure minimal GHG emissions from the production process.

19 Average GHG emissions of steel manufacture using BF/BOF is 2.33 tonnes CO2 per tonnes of crude steel manufactured.

20 Average GHG emissions of DRI EAF is 1.39 tonnes CO2 per tonnes of crude steel manufactured.

21 Average GHG emissions of Scrap EAF is 0.66 tonnes CO2 per tonnes of crude steel manufactured.

22 https://pubs.acs.org/doi/abs/10.1021/acs.energyfuels.2c00238#:~:text=Given%20that%20most%20of%20the,2%20per%20tonne%20of%20fertilizer.

5. Preliminary Roadmap

5.1 Resources for Preliminary Roadmap Implementation

The adoption of specific policies for the development of low-carbon technologies, as well as the training of human resources to achieve and develop viable decarbonization actions in a sustainable manner, in addition to the availability of adequate financial resources in volume and feasibility conditions, are key elements to achieve decarbonization of Kenya's industrial sector.

Some indications point to the need for training and structuring industries in:

- Energy Management Program (ISO 50001), to enable the perpetuation of the results obtained with the initial investments.
- Training of professionals trained in the International Performance Measurement and Verification Protocol (IPMVP).
- Specialization in the adoption of energy efficiency practices in thermal systems (heat and cold), since the potential for improving energy efficiency in this segment is much higher than that of the electrical part, mainly due to recent technological advances.
- Technical assistance for the development of sectoral performance indicators, possibly breaking down by company size.

5.2 Strategic Framework for the Preliminary Roadmap

Based on the analyses carried out, this Roadmap was developed with a set of actions identified for short, medium, and long-term approaches to achieve carbon neutrality in the industrial sector by 2050).

This section provides information about how efforts can be directed by the intended users of this document. A series of recommendations for the implementation of suggested actions have been highlighted along with a prioritization of actions (based on desk research and stakeholder inputs) based on two general criteria: the level of effort involved in implementing the lines of action and the impact they can achieve.

5.3 Recommendations for the Preliminary Roadmap

16 actions have been proposed for the Preliminary Roadmap. For practical purposes, each is identified by the acronym LA (Line of Action), followed by its consecutive number (1, 2, 3...), and referred to by the initial of the component to which it corresponds (T: Technology / P: Policy) and below are some aspects that are recommended to be considered for its implementation (Table 10). The timeline is also indicated for actions that must be implemented in the short (until 2030), medium (until 2040) and long (until 2050) term.

Table 9. Lines of Action and Recommendations for implementation of the Preliminary Roadmap

Component	Line of action	Timeline (short (ST), medium (MT), long (LT) term)	Recommendation
Technology	LAT1/LA1T: Promote transition to high-performance motors, variable frequency drive and other energy efficient equipment.	ST	Conduct an assessment in each industrial subsector to determine the number of old and inefficient equipment. Develop an action plan to replace this equipment with high-efficiency products that align with international standards.
	LAT2/LA2T: Expanding and introducing new renewables technologies like wind (on-shore and off-shore), geothermal and solar photovoltaic.	MT	Determine the potential for renewable energy generation and calculate electricity generation needs from new RE. Develop an action plan for installing new technologies.
	LAT3/LA3T: Clean Hydrogen plants.	MT	Identify opportunities in industrial sub-sectors to install low-carbon hydrogen plants and select some facilities to develop pilot projects, particularly prioritizing clean hydrogen for fertilizer production (as highlighted in the Green Hydrogen Strategy of Kenya published in September 2023) among other manufacturing activities.
	LAT4/LA4T: CCUS pilot projects.	LT	Identify opportunities in industrial sub-sectors to install CCUS plants and select some facilities to develop pilot projects.
	LAT5/LA5T: Optimize process to reduce the amount of primary material consumption and enhance energy management systems.	ST	Carry out a life cycle assessment of the most consuming industrial sub-sectors and determine the actions to be taken to minimize the use of primary materials and processes that require the implementation of energy management systems.
	LAT6/LA6T: Promote waste heat recovery	ST	Identify opportunities for waste heat recovery and identify industry-specific processes and technologies to implement the same
	LAT7/LA7T: Implement mandatory leak detection and repair requirements on compressed air and steam pipe networks	ST	Carry out regular audits and assessments to identify opportunities for optimization and leakages of GHG emissions.
Policy	LAP1/LA1P: Creation of an energy efficiency certification scheme for energy intensive industries	ST	Based on the best international standards and practices, such as PAT (Perform Achiever and Trade) scheme in India for energy efficiency certificates, to reduce the specific energy consumption (SEC) of energy intensive industries such as cement and steel sectors
	LAP2/LA1P: Green Public Procurement (GPP) policy support for hard to abate energy intensive industry sectors such as cement and steel.	ST	The hard to abate energy intensive industry sectors of Kenya such as cement and steel will require public policy support in their decarbonization journey. GPP is a policy tool that has been gaining a lot of importance worldwide in this context. Determine the actions to be undertaken for the development of GPP in Kenya through a consultation process with key stakeholders and identify the relevant GPP measures such as minimum requirement regulations or preferential buying obligations for low cement and steel procurement by the public sector in Kenya.
	LAP3/LA3P: Disseminate and support the adoption of ISO 50001 (Energy Management) by industries as a way of promoting EE.	ST	Organise awareness campaign(s) aimed at the industry with the involvement of financial institutions involved in the financing mechanisms for the decarbonization of the industry. Through a national industry survey, determine the capacity needs of industrial companies and define a training program.
	LAP4/LA4P: Creation of sub-sector specific (such cement, key industry sub-sector in Kenya) standards and targets for EE	ST	Build on international experience and through a process of consultation with industry representatives, define the EE targets for specific sub-sectors. Develop a Monitoring and Verification system to assess the industry's progress in meeting the EE target and establish penalties for non-compliance.
Policy	LAP5/LA5P: Develop a specific roadmap for each industrial subsector/ Develop short-midterm infrastructure plans (especially around new-value chains) to enable private-sector players to anticipate decarbonization options available	ST	Each industrial subsector must have its own roadmap. An assessment of each subsector may be necessary to determine specific actions and also identify facilities that need to be prioritized to meet international commitments.
	LAP6/LA6P: Develop framework to enable green premium capture (e.g. mandating transparency and certification in production processes)	ST	Industries must be mandated to disclose their GHG emissions and other environmental impacts and by implementing certification schemes to verify the sustainability of production process. Further, an incentive mechanism must be developed to encourage adoption and disclosure of sustainable practices.
	LAP7/LA7P: Develop incentive schemes that mitigates unprofitable share of investments in new clean technologies (such as CCUS applications)	ST	Development of strategies to promote adoption of new and cleaner technologies such as carbon capture and storage particularly for industries like cement and steel.
	LAP8/LA8P: Promoting capacity building, upskilling and industry specific training to create skilled workforce	ST	To ensure sustainable action towards industrial decarbonization, the skilling needs of the workforce needs to be enhanced to ensure ease of transition in adopting newer technologies, process, and practices. Further, this will also support future research and development activities in the industrial sector.
	LAP9/LA9P: Explore establishment of Super ESCO to ensure energy efficiency measures in industries	ST	Energy Service Companies can help support industries in coordination with government and business sectors to identify opportunities and means of improving energy efficiency.

5.3.1 Prioritization Matrix

The prioritization matrices (see **Table 11**, **Table 12**, **Table 13**, **Table 14**) are presented in the context of three main subsectors (cement, steel and fertilizers) and is structured into the following elements:

- **Current Status**: status of technology and policy in the country
- **Technology relevance**: technologies impacted by policy options explored.
- **Policy relevance**: policies impacting application of technology options explored.
- **Decarbonization contribution**: GHG mitigation potential
- **Short- and long-term economic impacts**: static and dynamic abatement of costs
- **Social impact**: generation of employment opportunities and improving standard of living.
- **Viability/practicality**: feasibility of proposed solutions based on existing conditions.
- **Fiscal impact**: impact on fiscal revenues and expenditures
- **Maturity**: of the technology and policy actions recommended

Further, in section 5.3.2, a timeline is indicated for actions that must be implemented in the short (until 2030), medium (until 2040) and long (until 2050) term.

5.3.2 Timeline of implementation

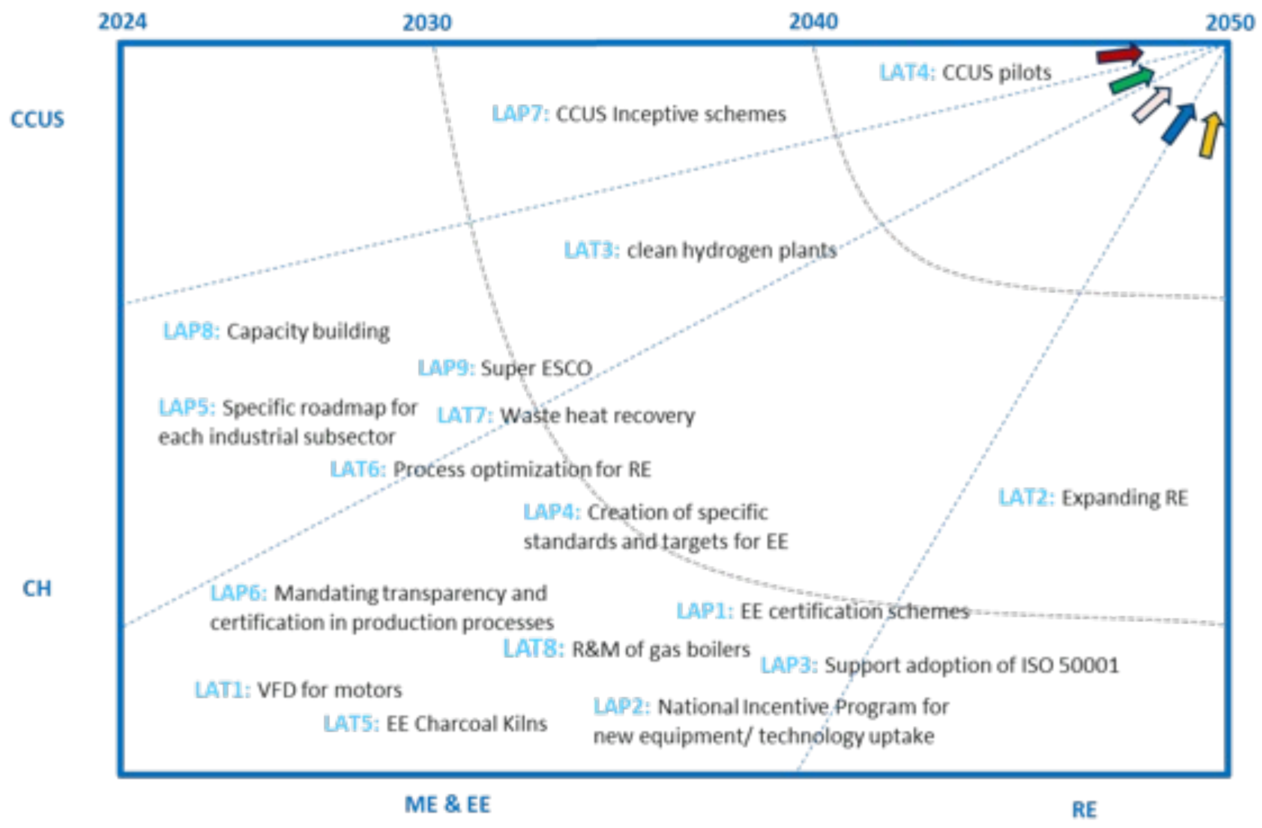

Table 10. Prioritization matrix for policy instruments for industrial decarbonization in Kenya[23]

Policy/ Instruments	Status (Existing or New/Needed)	Technology Relevance	Decarbonization contribution	Short term economic impact	Long term economic impact	Social impact	Viability/ Practicality	Fiscal impact	Maturity
Data collection on and transparency on sustainable industrial practices	Needed	Will support uptake of renewable energy technologies, energy efficiency	High GHG reduction potential	Low costs	Lower costs resulting in economic savings	Moderate job creation potential	High priority across countries worldwide	Some positive contribution to the GDP	Adopted in many countries worldwide
Promoting implementation of clean hydrogen technology	Existing	Will support further uptake of RE, GH and Electrification of Heat Production	High GHG reduction potential	High costs	Lower costs resulting in economic savings	High job creation potential	High priority across countries worldwide	Potential for significant contribution to GDP	Fairly new
Green Public Procurement (GPP) policy	Needed	Will support decarbonization of hard to abate energy intensive industry sectors of Kenya such as cement and steel	High GHG reduction potential	High costs	Lower costs resulting in economic savings	High job creation potential	High priority across countries worldwide	Potential for significant contribution to GDP	Fairly new
Emission Trading Schemes	New (planned)	Will support further uptake of RE, GH and CCUS	High GHG reduction potential	Low costs	Lower costs resulting in economic savings	Low job creation potential	Adopted in many countries worldwide	Some positive contribution to the GDP	Adopted in many countries worldwide
Ambitious binding GHG reduction targets	Existing	Will support EE, RE, GH and CCUS	High GHG reduction potential	High costs	Lower costs resulting in economic savings	High job creation potential	High priority across countries worldwide	Potential for significant contribution to GDP	Adopted in many countries worldwide
Renewable Energy Certificates	Existing	Will support RE and GH	High GHG reduction potential	Low costs	Lower costs resulting in economic savings	Low job creation potential	Adopted in many countries worldwide	Some positive contribution to the GDP	Adopted in many countries worldwide
Tax incentives and carbon taxation	Needed	Will support EE, RE, GH and CCUS	Moderate GHG reduction potential	High costs	Slightly higher costs but resulting in some economic savings in the long term	Moderate job creation potential	High priority across countries worldwide	Limited impact on GDP	Adopted in many countries worldwide
Carbon trading	Existing	Will support EE, RE, GH and CCUS	Moderate GHG reduction potential	High costs	Slightly higher costs but resulting in some economic savings in the long term	High job creation potential	High priority across countries worldwide	Potential for significant contribution to GDP	Adopted in many countries worldwide
Set incentives for reuse and recycling to reduce the need to produce primary materials with higher emissions and improve the integration of supply chains to facilitate these strategies	Needed	Energy and material efficiency	Moderate GHG reduction potential	Moderate costs	Slightly higher costs but resulting in some economic savings in the long term	High job creation potential	Adopted in many countries worldwide	Potential for significant contribution to GDP	Adopted in many countries worldwide

23 Significance of the colour coding in the context of the different KPIs: GREEN – positive impact; YELLOW – moderate impact; RED – negative impact

Policy/ Instruments	Status (Existing or New/Needed)	Technology Relevance	Decarbonization contribution	Short term economic impact	Long term economic impact	Social impact	Viability/ Practicality	Fiscal impact	Maturity
Promote research and development of energy and material efficient, renewable energy and other sustainable technologies for industries	Needed	Will support EE, ME, RE, GH and CCUS	High GHG reduction potential	Moderate costs	Lower costs resulting in economic savings	High job creation potential	Adopted in many countries worldwide	Potential for significant contribution to GDP	Adopted in many countries worldwide
Define performance standards and introduce rating systems for various industries and equipment in terms of emissions and energy use	Needed	Will support EE, ME, RE, GH and CCUS	High GHG reduction potential	Moderate costs	Lower costs resulting in economic savings	Moderate job creation potential	High priority across countries worldwide	Potential for significant contribution to GDP	Adopted in many countries worldwide
Develop frameworks for training, capacity building and upskilling	Needed	Will support EE, ME, RE, GH and CCUS	High GHG reduction potential	Moderate costs	Lower costs resulting in economic savings	High job creation potential	High priority across countries worldwide	Potential for significant contribution to GDP	Adopted in many countries worldwide

Table 11. Prioritization matrix for technologies for cement industry decarbonization in Kenya

Technology	General Policy Relevance	Decarbonization contribution	Short term economic impact	Long term economic impact	Social Impact	Viability/ Practicality	Fiscal impact	Maturity
Improving energy efficiency of kilns through adoption of high-efficiency fans and variable speed drives, pre-grinding, pre-heaters and pre-calciners	National Energy Efficiency and Conservation Strategy, 2020 National Climate Change Action Plan (NCCAP), 2018 – 2022 Energy Management Standards, 2018 Energy Management Regulations, 2012	High GHG reduction potential	EE options already have high-cost savings potential with short payback times.	EE options will continue to high-cost savings potential (even while targeting longer payback times)	High job creation potential	High priority across countries worldwide	EE gains can lead to an increase in economic output.	Proven technologies with constant innovation
Improving energy efficiency through technologies such as multichannel burners								
Adoption of high efficiency coolers for clinkers								
Optimizing pre-heaters and promoting waste heat recovering								
Electrification of heat production	National Energy Efficiency and Conservation Strategy, 2020 Energy Act (2019)	Moderate GHG reduction potential	Electrification is a high-cost activity but has relatively short payback time	High-cost savings	Low job creation potential	High priority across countries worldwide	Can lead to increase in economic output	Proven technologies with constant innovation
Renewable Energy	Energy Act (2019) Renewable Energy Feed in Tariff Policy (REFiT)	High GHG reduction potential	RE capital costs are high however the technologies have become increasingly cost-competitive in recent years	RE helps reduce long term energy related costs	Moderate job creation potential	High priority across countries worldwide	Can lead to increase in economic output	Constant innovation and and efficiency improvements in technologies with proven impacts
CCUS	The Climate Change (Amendment) Act, 2023	High GHG reduction potential	CCUS technology is at a pilot stage and requires high capital inputs	If the technology is viable the economic impacts can come down	Moderate to low job creation potential	Technology I still in pilot stage in many countries	Economic impact is conditional on successful implementation of CCUS	Pilot stage only

Technology	General Policy Relevance	Decarbonization contribution	Short term economic impact	Long term economic impact	Social Impact	Viability/ Practicality	Fiscal impact	Maturity
Clean Hydrogen	The Climate Change (Amendment) Act, 2023 Green Hydrogen Strategy, 2023 Scaling up Renewable Energy Programme (SREP) – Investment Plan for Kenya	High GHG reduction potential	GH is currently expensive, however with large scale deployment the costs are expected to reduce	As GH becomes widespread the costs are expected to reduce	Moderate job creation potential	The technology is being prioritized in many countries	Can lead to increase in economic output	Nascent stage in most countries
Co-combustion with biomass, plastics	National Energy Efficiency and Conservation Strategy, 2020	Low GHG reduction potential	Lower costs due to abundance of biomass resource	High-cost savings	High job creation potential	large-scale biomass cultivation & bio refining is well researched and constantly evolving	Can lead to increase in economic output and improve circularity	Proven technologies with constant innovation

Table 12. Prioritization matrix for technologies for steel industry decarbonization in Kenya

Technology	General Policy Relevance	Decarbonization contribution	Short term economic impact	Long term economic impact	Social Impact	Viability/ Practicality	Fiscal impact	Maturity
Electrification of heat production	National Energy Efficiency and Conservation Strategy, 2020	Moderate GHG reduction potential	Electrification is a high-cost activity but has relatively short payback time	High-cost savings	Low job creation potential	High priority across countries worldwide	Can lead to increase in economic output	Proven technologies with constant innovation
Renewable Energy	Energy Act (2019) Renewable Energy Feed in Tariff Policy (REFiT)	High GHG reduction potential	RE capital costs are high however the technologies have become increasingly cost-competitive in recent years	RE helps reduce long term energy related costs	Moderate job creation potential	High priority across countries worldwide	Can lead to increase in economic output	Constant innovation and efficiency improvements in technologies with proven impacts
Energy efficiency measures such as efficient pumps and motors, variable frequency drives, energy efficient materials for cooling fans	National Energy Efficiency and Conservation Strategy, 2020 National Climate Change Action Plan (NCCAP), 2018 – 2022 Energy Management Standards, 2018 Energy Management Regulations, 2012	High GHG reduction potential	EE options already have high-cost savings potential with short payback times.	EE options will continue to high-cost savings potential (even while targeting longer payback times	High job creation potential	High priority across countries worldwide	EE gains can lead to an increase in economic output	Proven technologies with constant innovation
Fuel injection such as pulverized coal, natural gas, hydrogen, plastics and biomass								
Pre-treating iron ore by pre-heating and palletisation								
Promote adoption of waste heat recovery								
Adoption of Electric Arc Furnace particularly in combination with direct reduced iron and scrap feeding								
Clean Hydrogen	The Climate Change (Amendment) Act, 2023 Green Hydrogen Strategy, 2023 Scaling up Renewable Energy Programme (SREP) – Investment Plan for Kenya	High GHG reduction potential	GH is currently expensive, however with large scale deployment the costs are expected to reduce	As GH becomes widespread the costs are expected to reduce	Moderate job creation potential	The technology is being prioritized in many countries	Can lead to increase in economic output	Nascent stage in most countries
CCUS	The Climate Change (Amendment) Act, 2023Scaling up Renewable Energy Programme (SREP) – Investment Plan for Kenya	High GHG reduction potential	CCUS technology is at a pilot stage and requires high capital inputs	If the technology is viable the economic impacts can come down	Moderate to low job creation potential	Technology l still in pilot stage in many countries	Economic impact is conditional on successful implementation of CCUS	Pilot stage only

6. Conclusions

The Preliminary Roadmap for Industrial Decarbonization in Kenya provides a clear and actionable plan for reducing the carbon footprint of the industrial sector. By following this roadmap, Kenya will achieve significant environmental benefits, enhance its economic competitiveness, and contribute to global efforts to combat climate change. The commitment and concerted efforts of all stakeholders will be crucial in turning this vision into reality, paving the way for a sustainable and prosperous future for Kenya. This roadmap marks a pivotal step toward addressing the pressing need for sustainable industrial development in the country. As outlined in this comprehensive study, the roadmap identifies key industries - cement, steel, and fertiliser manufacturing - that significantly contribute to greenhouse gas (GHG) emissions and outlines targeted strategies for reducing these emissions.

Key Insights and Strategic Directions

1. Industry-Specific Strategies:

- Cement Manufacturing: The roadmap highlights the potential for energy and material efficiency, innovative chemistry, alternative fuels, and carbon capture, utilisation, and storage (CCUS) to significantly reduce emissions.
- Steel Production: Emphasis is placed on energy efficiency measures, renewable energy adoption, the use of clean hydrogen, and CCUS technologies.
- Fertilizer Manufacturing: Focus areas include transitioning to renewable energy sources, utilising clean hydrogen, and promoting the use of organic fertilisers.

2. Decarbonisation Potential

The roadmap quantifies the decarbonisation potential of each industrial sub-sector, providing a clear picture of the energy savings and GHG emissions reductions achievable through the implementation of efficient technologies and practices.

3. Implementation Resources and Strategic Framework

The roadmap outlines the necessary resources and strategic framework required for effective implementation. This includes financial investments, technological advancements, policy support, and stakeholder engagement.

4. Recommendations and Prioritisation

Detailed recommendations are provided, including a prioritization matrix and a timeline for implementation. These recommendations are designed to ensure a systematic and phased approach to decarbonization, maximizing the impact while minimizing disruption to industrial operations.

The successful implementation of this preliminary roadmap relies on the collaborative efforts of government agencies, industry stakeholders, and the international community. By leveraging Kenya's existing strengths and addressing its unique challenges, the country can position itself as a leader in sustainable industrial practices in Africa. Kenya should focus on strengthening policies and regulations to incentivize and support decarbonization efforts. Additionally, investment in new technologies and innovative solutions that drive energy efficiency and emission reductions should be encouraged. This roadmap proposes that the capacity of industry players should be enhanced through training and awareness programs to ensure a smooth transition to low-carbon practices. Finally, robust monitoring and evaluation mechanisms to track progress, identify challenges, and make necessary adjustments to the roadmap should be established.

7. Next steps

In addition to offering suggestions for technical and policy actions, the Preliminary Roadmap points out the next steps to be followed. This strategic direction is essential to ensure that the technical and policy measures presented are not limited to the initiatives and industrial segments initially addressed (cement sector mainly) but are integrated into a broader development and implementation process, which includes other industrial segments, such as the Steel and Chemical sectors.

The partnership with the United Nations Industrial Development Organization (UNIDO), an institution recognized internationally as an entity dedicated to sustainable industrial advancement and the promotion of partnerships between public and private sectors to achieve common objectives, offers a significant advantage by providing technical expertise, resources, and a global perspective. UNIDO can play a key role in facilitating international dialogue, sharing best practices, and promoting global cooperation in the industrial sector. This helps to position national initiatives in a broader context, enabling the exchange of knowledge and experiences with other nations facing similar challenges.

Subsequent project design should be a participatory process, involving ongoing consultations with relevant stakeholders, including representatives from the private sector, academics, non-governmental organizations, and other key actors. This inclusive approach ensures that the project is shaped by a variety of perspectives, making it more robust, adaptable, and acceptable to all involved.

By clearly indicating these next steps, the Draft Roadmap not only provides a strategic vision, but also establishes a tangible path towards practical implementation of the proposals presented. This action-oriented approach is crucial to transform recommendations into tangible results, such as detailed advice for each subsector, including the Cement, Steel and Chemical sub-sectors, as well as the development of roadmaps by each of these sub-sectors.

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