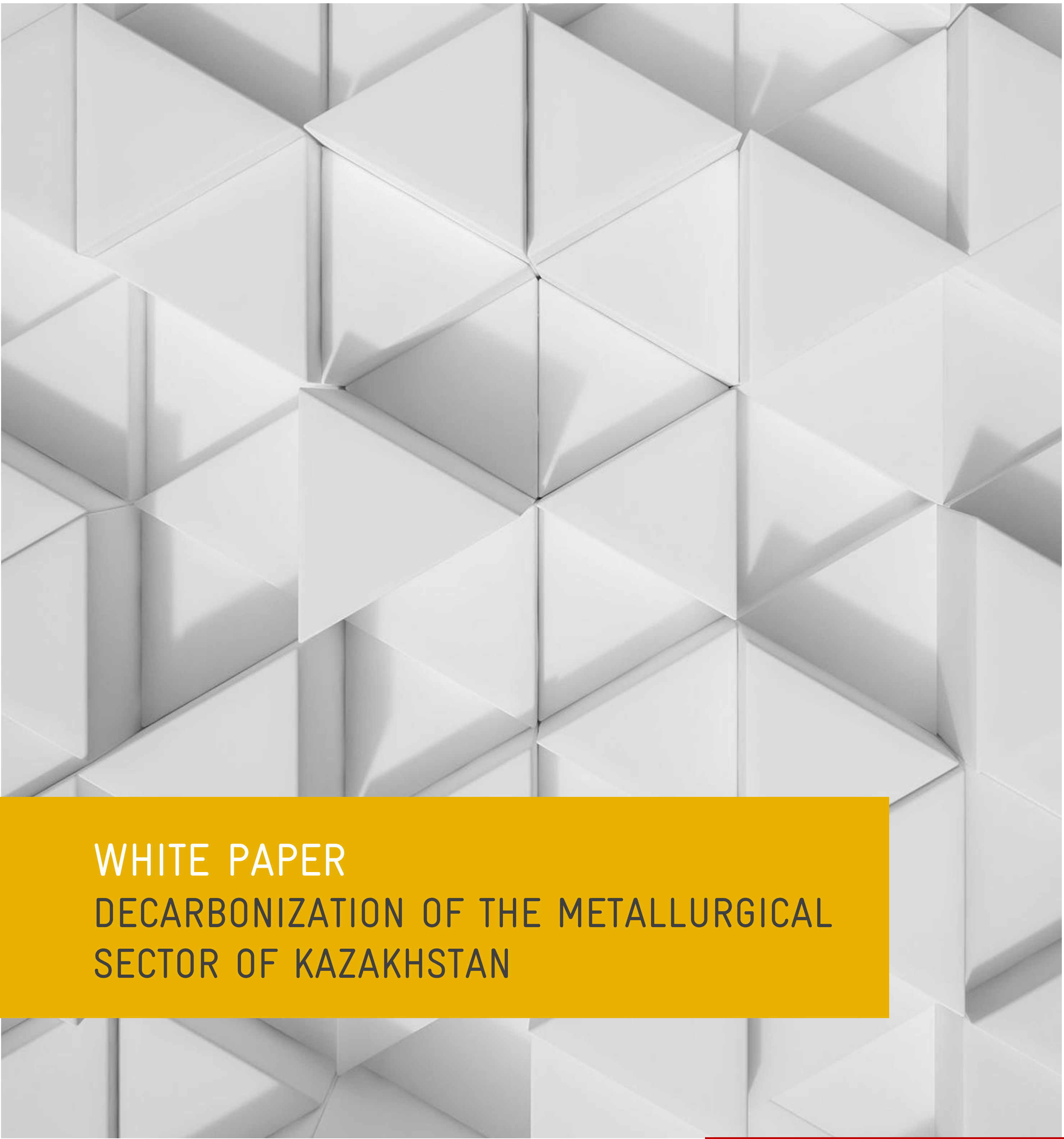

WHITE PAPER
DECARBONIZATION OF THE METALLURGICAL SECTOR OF KAZAKHSTAN

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Project description
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On behalf of
Federal Ministry for Economic Affairs and Climate Action (BMWK)

Kazakhstan 2024

White Paper |

DECARBONIZATION OF THE METALLURGICAL SECTOR OF KAZAKHSTAN

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This publication has been prepared as part of the support provided by GIZ GmbH to Kazakh partners under the individual measure 'Carbon Neutrality Strategy Implementation in the Private Sector of Kazakhstan.' The publication is primarily based on desk research and findings from missions to Kazakhstan. It is therefore intended as a working paper and does not claim to comprehensively cover all financial, entrepreneurial, and technical dimensions of Kazakhstan's metal sector, nor the opportunities and challenges associated with its decarbonization.

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Acronyms

AI	Artificial Intelligence
BAT	Best Available Technology
BAU	Business-as-Usual
BOF	Basic Oxygen Furnace
CAPEX	Capital Expenditure
CAWEP	Central Asia Water & Energy Program
CBAM	Carbon Border Adjustment Mechanism
CCA	Carbon Containing Agglomerates
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilization
CCfD	Carbon Contracts for Difference
CCUS	Carbon Capture, Utilization and/or Storage
CFD	Contracts For Difference
CHP	Combined Heat and Power
CNS	Carbon Neutrality Strategy
DIW	Deutsches Institut für Wirtschaftsforschung
DRI	Direct Reduced Iron
EAEU	Eurasian Economic Union
EAF	Electric Arc Furnace
EBIT	Earnings Before Interest and Taxes
EBITDA	Earnings Before Interest, Taxes, Depreciation and Amortization
ESaaS	Energy Savings as-a-Service
ESF	Electric Smelting Furnace
ETS	Emissions Trading System
EU	European Union
EV	Electric Vehicle
GDP	Gross Domestic Product
HBI	Hot Briquetted Iron
HVAC	Heating, Ventilation, and Air Conditioning
ICMM	International Council on Mining and Metals
IEA	International Energy Agency
IGCC	Integrated Gasification Combined Cycle
IOC	Iron Ore Company of Canada
IoT	Internet of Things
IPPU	Industrial Processes and Product Use

IRR	Internal Rate of Return
KZ	Kazakhstan
LCA	Life-Cycle Assessment
LCEF	Low Carbon Economy Fund
LKAB	Luossavaara-Kiirunavaara Aktiebolag
MRV	Monitoring, Reporting, and Verification
NDC	Nationally Determined Contribution
NGCC	Natural Gas Combined Cycle Plants
NGO	Non-Governmental Organization
NPV	Net Present Value
NZE	Net Zero Emissions
PC	Pulverized Coal
PCI	Pulverized Coal Injection
PKSW	Port Kembla Steek Works
PLC	Programmable Logic Controllers
PPA	Power Purchase Agreement
PRA	Pre-Reduced Agglomerates
R&D	Research and Development
RE	Renewable Energy
RES	Renewable Energy Sources
RoI	Return on Investment
SSAB	Svenskt Stål Aktiebolag (Swedish Steel Corporation)
TCO	Total Cost of Ownership
UaaS	Utilities as a Service
UNIDO	United Nations Industrial Development Organization
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollars

1 INTRODUCTION

Kazakhstan is a nation rich in natural resources and which has seen its economy develop rapidly and largely due to its abundant fossil fuel reserves. Kazakhstan is one of the world's top producers of coal (ranking 10th in 2023)1 and oil (12th in 2023)2 in the world. This heavy reliance on fossil fuels has driven economic growth but also created significant challenges in transitioning to low-carbon technologies. The availability of indigenous fossil fuels makes it difficult to shift away from traditional energy sources, posing a unique challenge for Kazakhstan as it seeks to decarbonize its economy.

However, Kazakhstan is increasingly vulnerable to the impacts of climate change, which has prompted the government to develop a national long-term low emission development strategy. This strategy outlines the investments needed to achieve carbon neutrality by 2060. This White Paper specifically addresses the metallurgical sector, which is a cornerstone of Kazakhstan's economy and plays a crucial role in the country's efforts to reduce greenhouse gas (GHG) emissions.

The importance of the metallurgical industry in Kazakhstan

Kazakhstan's metallurgy industry is a key pillar of the national economy, contributing significantly to the country's Gross Domestic Product (GDP). The sector is deeply rooted in the extraction, processing, and export of metals and metallic materials such as iron concentrate, iron pellets, steel, copper, zinc, and aluminum. The country's vast mineral resources have made it one of the world's top producers of these essential metals, positioning Kazakhstan as a critical player in the global metals market.

The metallurgy industry not only supports the domestic economy but also plays a vital role in international trade. The export of metals and metal products is a major source of revenue for Kazakhstan, making the sector integral to the country's economic stability and growth. However, the industry's environmental impact, aging infrastructure, and need for technological upgrades present significant challenges that must be addressed if Kazakhstan is to achieve its carbon neutrality goals.

[1] Mining Technology, 2024. Coal production in Kazakhstan and major projects. Accessed via: https://www.mining-technology.com/data-insights/coal-in-kazakhstan/#:~:text=According%20to%20GlobalData%2C%20Kazakhstan%20is,up%20by%202%25%20on%202022

[2] United States Energy Information Administration, 2023. Petroleum and other liquids. Accessed via: https://www.eia.gov/international/data/world/petroleum-and-other-liquids/annual-petroleum-and-other-liquids-production?pd=5&p=00000000000000000000000000000002&u=0&f=M&v=mapbubble&a=-&i=none&vo=value&vb=173&t=C&g=0000000000000000000000000000000000000000000000001&l=249-ruvvvvvfvtvnvv1vrvvvvfvvvvvvfvvvou20evvvvvvvvvvvnvvvs0008&s=1701388800000&e=1701388800000&ev=true

Challenges facing Kazakhstan's metallurgical industry

The metallurgy industry in Kazakhstan faces several challenges as it strives to modernize and reduce its environmental footprint. The sector's infrastructure is aging, and there is limited experience in implementing decarbonization initiatives. While some initial efforts are underway to modernize facilities, improve efficiency, and adopt more sustainable practices, these measures are not yet sufficient to meet the demands of a low-carbon future. For Kazakhstan's metallurgy sector to contribute meaningfully to the country's goal of carbon neutrality by 2060, a substantial transformation is required.

Moreover, the global demand for low-carbon metals and metal products is growing. International markets are evolving, with new rules and standards emerging that require metal production companies to reduce their emissions and adopt cleaner processes. Failure to adapt to these changes could limit Kazakhstan's access to key markets, potentially undermining the sector's economic viability. This highlights the urgent need for the metallurgy industry to embrace decarbonization and align with international best practices.

The need for a strategic approach to decarbonization

Decarbonizing energy-intensive processes in the metallurgy industry is a complex and challenging task that requires careful planning and coordination. There are significant benefits to be gained from collaboration across the industry, with a strong role for the government in driving and facilitating decarbonization efforts. However, the involvement of other key sectors, such as the financial and lending sectors, is also essential to ensure that the necessary investments are made, and that decarbonization initiatives are effectively implemented.

A clear strategic approach and well-coordinated actions are crucial for the successful decarbonization of Kazakhstan's metallurgy industry. International experience has shown that sectoral emission mitigation efforts are most effective and cost-efficient when there is a comprehensive plan in place. Such a plan must involve all relevant stakeholders, including the private sector, and provide them with the specific skills, capacities, knowledge, and support needed to achieve emission reduction targets.

The role of the industry White Paper

This Industry White Paper provides a sector-specific analysis of Kazakhstan's metallurgy industry, considering the technoeconomic, regulatory, and political frameworks that shape the sector. The White Paper includes a summary of existing technical, economic, legal, regulatory, political, and environmental frameworks in Kazakhstan, offering a comprehensive overview of the factors that influence the industry's ability to decarbonize.

One of the key features of this White Paper is the identification of barriers to decarbonization within the metallurgical sector. These barriers include outdated technologies, high energy intensity, and the lack of experience with low-carbon initiatives. Additionally, the White Paper provides a decarbonization potential analysis to 2030, 2050, and 2060, aligning with Kazakhstan's National Determined Contributions (NDC) and the country's long-term low emission development strategy.

Economic efficiency, competitiveness, and market dynamics

The White Paper also includes an analysis of the economic efficiency and competitiveness of decarbonization efforts in the metallurgy sector. This analysis takes into account the impacts of the European Union's Carbon Border Adjustment Mechanism (CBAM) on Kazakh industries. The CBAM is designed to impose a carbon price on imports into the EU based on their carbon content, which could have significant implications for Kazakhstan's metal exports.

To remain competitive in international markets, Kazakhstan's metallurgical companies will need to comply with evolving environmental standards and reduce their emissions. The White Paper examines the requirements for Kazakh companies to adapt to these changes, including the applicability of best available technologies and energy efficiency measures. It also explores the potential for integrating renewable energy sources into the metallurgy sector, which could further enhance the sector's environmental performance and economic competitiveness.

Best available technologies and energy efficiency measures

The integration of best available technologies (BAT)[3] and energy efficiency measures is critical for the decarbonization of Kazakhstan's metallurgy industry. The White Paper provides a detailed assessment of the technologies that can be applied to reduce emissions and improve energy efficiency in the sector. This includes advanced smelting and refining processes, waste heat recovery systems, and the use of alternative fuels such as biomass and hydrogen.

Energy efficiency is a key component of the decarbonization strategy, as it can significantly reduce the energy consumption and carbon intensity of metallurgical processes. The White Paper analyzes the potential energy savings that can be achieved through the implementation of energy efficiency measures, as well as the associated cost savings and environmental benefits.

Renewable energy integration and governance issues

The White Paper also addresses the integration of renewable energy (RE) sources into the metallurgy sector. This includes an analysis of the potential for solar, wind, and hydropower to supply the energy needs of metallurgical facilities. The use of RE can reduce the sector's reliance on fossil fuels and lower its carbon footprint, making it an essential component of the decarbonization strategy.

Governance is another critical issue that the White Paper explores in detail. Effective governance is needed to ensure that decarbonization efforts are coordinated and aligned with national and international policies. The White Paper identifies the key governance challenges facing the metallurgy sector in Kazakhstan, including the need for stronger regulatory frameworks, better enforcement of environmental standards, and greater transparency in reporting emissions and progress towards decarbonization goals.

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[3] https://practiceguides.chambers.com/practice-guides/environmental-law-2024/kazakstan/trends-and-developments, New Environmental Policy under Trends and Developments

Lessons learned from international experience

The White Paper draws on international experience to provide insights and recommendations for Kazakhstan's metallurgy sector. It includes case studies of decarbonization efforts in other countries, highlighting best practices and lessons learned that can be applied to the Kazakh context. These case studies demonstrate the importance of a strategic approach to decarbonization, as well as the benefits of collaboration between industry, government, and other stakeholders.

The White Paper also emphasizes the need for capacity development to support the decarbonization of Kazakhstan's metallurgy industry. This includes building the technical skills and knowledge required to implement low-carbon technologies, as well as providing the financial and institutional support needed to facilitate the transition to a low-carbon economy.

Regulatory needs and financing instruments

The successful decarbonization of Kazakhstan's metallurgy sector will require a supportive regulatory environment and access to financing instruments. The White Paper identifies the regulatory reforms needed to promote the adoption of low-carbon technologies, including the development of standards and certifications for energy efficiency and emissions reduction.

Financing is another critical component of the decarbonization strategy. The White Paper outlines various financing instruments that can be leveraged to support the transition to a low-carbon metallurgy sector. Access to affordable financing is essential for enabling companies to invest in new technologies and infrastructure upgrades necessary for reducing emissions.

Decarbonization roadmap and milestones

A key outcome of this White Paper is the development of decarbonization milestones for Kazakhstan's metallurgy sector. The milestones provide a set of targets for reducing emissions in the short, medium, and long term, aligned with Kazakhstan's national plans.

The milestones include specific actions and initiatives that the metallurgy sector can undertake to reduce its carbon footprint. These include the adoption of best available technologies, implementation of energy efficiency measures, and integration of renewable energy sources.

Sectoral nexus and conclusion

The White Paper concludes with a discussion of the sectoral nexus, highlighting the interconnections between the metallurgy industry and other key sectors of the economy. This includes the linkages between metallurgy and the energy sector, as well as the potential synergies between decarbonization efforts in different industries. By adopting a holistic approach to decarbonization, Kazakhstan can maximize the benefits of its low-carbon transition and ensure that all sectors contribute to the country's climate goals.

In summary, the White Paper provides a comprehensive analysis of the challenges and opportunities facing Kazakhstan's metallurgy sector as it seeks to decarbonize. It offers a strategic roadmap for achieving carbon neutrality by 2060, with clear recommendations for industry, government, and other stakeholders. Through the implementation of the set of recommendations outlined in this White Paper, Kazakhstan can position its metallurgy sector in the global transition to a low-carbon economy, ensuring long-term economic competitiveness and environmental sustainability.

2 SECTOR SPECIFIC ANALYSIS OF THE METALLURGICAL INDUSTRY SECTOR IN KAZAKHSTAN

2.1 TECHNICAL FRAMEWORK

- Currently, the Government of the Republic of Kazakhstan has approved 14 Best Available Technology (BAT) handbooks for industrial processes within the Kazakh economy. Of these, 10 BAT handbooks are relevant to the country's metallurgical sector. Specifically, these include handbooks for the production of zinc and cadmium; lead; copper and precious metals (gold); the extraction and beneficiation of non-ferrous metal ores (including precious metals); the production of pig iron and steel; coal mining and beneficiation; production of ferroalloys; further processed products of ferrous metals; aluminium production; and the extraction and beneficiation of iron ores (including black metal ores).4
- The Kazakhstan Government has approved its strategy to achieve carbon neutrality in Kazakhstan by 2060. Specifically, the Strategy of the Republic of Kazakhstan on achieving carbon neutrality by 20605 was approved in 2023, by Decree of the President of the Republic of Kazakhstan of 2 February 2023 No. 121.
- During the process of developing Kazakhstan's 2060 carbon neutrality strategy and Low Emissions Development Strategy (LEDS), in 2021 GIZ realized a study in which potential GHG emissions pathways to 2060 in Kazakhstan were quantitatively modelled. The results of this study have no official status, but were used to inform key aspects of the Kazakhstan government's 2060 carbon neutrality strategy. It is worth underlining several of the important technical assumptions and milestones, as regards production activities and GHG emissions, within the metallurgical sector in the period to 2060, and as considered within GIZ's modelling study (2021). These include the following:
    - A significant portion of steel produced in the period to 2060 will continue to be produced in converters, with an intermediate step of extracting iron from ore in blast furnaces. However, this refers to the baseline scenario only.

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[4] Green Bridge Kazakhstan, 2024. Handbooks on Best Available Techniques. Accessed via: https://green-bridge.kz/en/news/Handbooks+on+Best+Available+Techniques+%28BAT%29/

[5] UNFCCC, 2024. Strategy of the Republic of Kazakhstan on achieving carbon neutrality by 2060. Unofficial translation to English. Accessed via: https://unfccc.int/sites/default/files/resource/Carbon_Neutrlaity_Strategy_Kazakhstan_Eng_Oct2024.pdf

  - In the Carbon Neutrality scenario of the strategy, an active transition to natural gas and hydrogen DRI technologies is projected for steel production between 2030 and 2040. By 2045, almost all blast furnace and sinter production will be replaced by DRI technologies, stabilizing emissions from both IPPU (industrial processes and product use) and energy use despite production growth.
  - In general, current aluminium production processes in Kazakhstan are using the latest technologies. In the baseline scenario, the process of introducing more efficient and low-carbon emissions technologies will start from 2030 onwards, as they are still under development. The Carbon Neutrality scenario assumes the same level of production with modern low-emission technologies such as inert anode technology.
- Some metallurgic plants in Kazakhstan have their own RE sources (solar PV systems, mainly).

2.2 ECONOMIC FRAMEWORK

State support

- Certain policies under the "Kazakhstan 2050 Strategy" focus on sustainable economic growth and diversification of industrial activities in the period to 2050.
- The government has worked to create a favorable investment climate by simplifying regulatory procedures and providing tax incentives for foreign investors.
- Special economic zones offer additional benefits, such as tax exemptions and reduced customs duties.

International networks

- Kazakhstan's membership in the Eurasian Economic Union (EAEU) provides access to a larger market and facilitates trade with member countries.
- Bilateral trade agreements with other countries/regions (i.e., aluminum export to the EU) help to boost exports of metallurgical products.

2.3 LEGAL AND REGULATORY FRAMEWORK

Legal measures in force

- Law on Subsoil and Subsoil Use.[6] This law seeks to regulate the exploration, extraction, and processing of mineral resources in Kazakhstan. Its main components include establishing clear guidelines for obtaining licenses and permits for mining and metallurgical activities. It also ensures environmental protection and sustainable use of natural resources. Furthermore, this law mandates environmental impact assessments for new projects.
- Environmental Code.[7] This code is to protect the environment and ensure sustainable development through stringent environmental regulations. The key components of the code include establishing GHG emissions standards and limits for pollutants from metallurgical operations; requiring regular environmental monitoring and reporting by metallurgical companies; and implementing penalties for non-compliance with environmental regulations.
- Energy Saving and increase of Energy Efficiency Law.[8] This law works to improve energy efficiency and reduce energy consumption across all industries, including metallurgy. The main c*omponents of the law are the m*andating of energy audits for metallurgical facilities; providing incentives for the adoption of energy-efficient technologies and practices; and setting targets for energy reduction and monitoring progress.
- Investment Law.[9] To attract domestic and foreign investments into Kazakhstan's economy, with a focus on strategic sectors like metallurgy. The law sets provisions for offering tax incentives and financial support for investments in the metallurgical sector. Furthermore, it provides legal protections and guarantees for investors; and facilitates public-private partnerships to develop the metallurgical industry.

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[6] Ministry of Justice of the Republic of Kazakhstan, 2024. On subsoil and subsoil use. Accessed via: https://adilet.zan.kz/eng/docs/K1700000125

[7] Ministry of Justice of the Republic of Kazakhstan, 2024. Environmental code of the Republic of Kazakhstan. Accessed via: https://adilet.zan.kz/eng/docs/K070000212_

[8] Ministry of Justice of the Republic of Kazakhstan, 2024. On energy saving and increase in energy efficiency. Accessed via: https://adilet.zan.kz/eng/docs/Z1200000541

[9] Ministry of Justice of the Republic of Kazakhstan, 2024. Accessed via: https://adilet.zan.kz/eng/docs/Z040000576_

Regulations in force

Regulations in force that have a direct or indirect link with metallurgy in Kazakhstan include the following:[10]

- On the approval of the Concept of industrial -innovative development of the Republic of Kazakhstan for 2021 – 2025.
- On approval of the list of own-produced goods (works, services) by kinds of activities meeting the purpose of special economic zones.
- On approval of the rules of expertise for establishing the connection of occupational disease with the performance of labor (official) duties.
- On approval of the Agreement on cooperation of the member states of the Commonwealth of Independent States in mining and metallurgical industry.
- On the Concept of Foreign Policy of the Republic of Kazakhstan for 2020-2030.
- On approval of the Rules for transportation of cargo by railway transport.
- On Subsoil and Subsoil Use.
- On approval of the Rules for Obtaining Refusal from Precious Metals Production Entities or a Confirmation from an Authorized Body on the Existence of Such a Refusal, as well as Conditions for Precious Metals Production Entities.
- On approval of forms of conclusions on possibility (impossibility) and economic expediency (inexpediency) of industrial extraction of precious metals from primary goods in the Republic of Kazakhstan and on economic inexpediency or impossibility of processing primary goods containing precious metals in the Republic of Kazakhstan.
- On precious metals and precious stones.
- On approval of the Rules for Compiling a List of Precious Metals Production Entities.
- On some issues of transportation of scrap and ferrous and non-ferrous metals waste.
- On approval of the Rules for the Enforcement of the State's Priority Right to Purchase Refined Gold to Replenish Assets in Precious Metals.
- On approval of the Rules for transfer for affinage of scrap and wastes of precious metals converted to state property on separate grounds, into ingots of affined gold and receipt thereof after affinage.
- On approval of the Rules for the submission of information on legal entities engaged in the collection of scrap and waste of non-ferrous and ferrous metals, and on individuals carrying out the realization of such scrap and waste, and their forms.

[10] Ministry of Justice of the Republic of Kazakhstan, 2024. Accessed via: https://adilet.zan.kz/eng

- On industrial policy.

Non-ferrous metallurgy

- Amendments to technical regulations are being developed to improve industry standards in non-ferrous metallurgy.[11]

2.4 POLITICAL FRAMEWORK

Relevant institutions

- The key government Ministries and organizations that are relevant for the metallurgy industry in Kazakhstan are:
    - Ministry of Ecology and Natural Resources
    - Ministry of Energy
    - Ministry of Industry and Construction
    - Ministry of Economy
    - Zhassyl Damu [the national operator of Kazakhstan's trading scheme for greenhouse gas emissions (Kazakhstan ETS)

Key metallurgy policies in effect in Kazakhstan

- Kazakhstan has developed several key policies to regulate and promote the metallurgy sector, focusing on sustainability, economic development, and modernization. The national policies are subject to the government's aim of Net Zero for 2060. These policies include:
- Green Economy Concept.[12] To transition to a green economy by promoting sustainable development practices across all sectors, including metallurgy. The main components of this policy include:
    - Encouraging the reduction of greenhouse gas emissions and energy consumption in metallurgical processes.
    - Implementing waste recycling and management strategies.

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[11] The Astana Times, 2024. Kazakhstan targets $3.7 billion in output from 180 new projects in 2024. Accessed via: https://astanatimes.com/2024/07/kazakhstan-targets-3-7-billion-in-output-from-180-new-projects-in-2024/#:~:text=Export%20revenues%20are%20improving%20the,has%20significantly%20increased%2C%20intensifying%20competition

[12] Asia Pacific Energy, 2013. CONCEPT for the transition of the Republic of Kazakhstan. Accessed via: https://policy.asiapacificenergy.org/sites/default/files/Concept%20on%20Transition%20towards%20Green%20Economy%20until%202050%20%28EN%29.pdf

  - Promoting the use of renewable energy sources within the metallurgical industry.

- Strategy of the Republic of Kazakhstan on achieving carbon neutrality by 2060.[5] The overall goal of this strategy is to achieve a low-carbon economy by reducing greenhouse gas emissions and promoting sustainable practices.
- As mentioned above, during the process of preparing Kazakhstan's 2060 carbon neutrality strategy (LEDS), in 2021 GIZ led a study to quantitatively model GHG emissions pathways to 2060 in Kazakhstan. The study results have no offical status, but served as a comprehensive assessment of GHG emissions mitigation pathways for the country. Amongst other topics, the study focused on GHG emissions from fuel combustion in industry by sector and energy intensity of production in individual industries, including ferrous metallurgy and non-ferrous metallurgy. The base year of the modelled scenarios was 2017, and projections were made for the years 2030, 2040, 2050 and 2060 in both "Base" and "Carbon neutrality" scenarios. Furthermore, the elimination of carbon- and heat-based oxidation of ore was considered. The study also defined solutions to decarbonize aluminum and steel production. For instance, in aluminum production, eliminating carbon in smelting by using inert anodes; and in steel production the use of green hydrogen for DRI in combination with electric arc furnaces.

Exports of metallurgy products

- From January to May 2024, Kazakhstan's metallurgical production surged by 54.2%, spurred by heightened production of ferroalloys, raw aluminum, raw lead, and refined copper.
- The growth in export revenues has enhanced the trade balance and augmented foreign currency reserves, with metallurgical exports climbing by 8.3% to $4.7 billion in the initial four months of 2024.[11]
- The metallurgical sector has seen a substantial increase in the number of operating enterprises. According to the Kazakh Bureau of National Statistics, 442 companies are active in the metallurgy industry, with 26 being large-scale operations.[13]
- Recent regulatory developments include the extension of laws governing the collection and processing of scrap metal.[14] The government has created authorities for issuing second-category permits and has tightened export controls to bolster domestic markets. This includes a ban on exporting ferrous scrap and non-ferrous metal waste.

[13] Qazstat, 2024. Statistics of enterprises. Data downloaded and accessed via https://stat.gov.kz/en/industries/business-statistics/stat-org/

[14] GMK Centre, 2024. Kazakhstan extends ban on scrap exports again. Accessed via: https://gmk.center/en/news/kazakhstan-extends-ban-on-scrap-exports-again/

Non-ferrous metallurgy

- Kazakhstan's non-ferrous metallurgy sector advanced in the first half of 2024 through international collaboration. The Ministry of Industry and Construction signed memorandums of understanding with the Chinese Ministry of Commerce and the South Korean Ministry of Trade, Industry and Energy to deepen cooperation in this sector.[15]

Circular economy

- Government strategies: The government has included circular economy principles in national strategies, such as the "Kazakhstan 2050 strategy",[16] which emphasizes sustainable development and the efficient use of natural resources.
- Kazakhstan has established facilities for the collection and recycling of metal scrap and has reinforced regulations on scrap metal collection and recycling.[17] This reduces the need for primary raw materials and lowers environmental impacts.
- Environmental laws and regulations are being updated to include requirements for waste reduction, recycling, and the adoption of cleaner production technologies in the metallurgy sector.

2.5 ENVIRONMENTAL AND CLIMATE IMPACT

GHG emissions

- GHG emissions from the metallurgy sector have fallen somewhat during the last three calendar years:[18]
  - 2021 - 28 440 426 tonnes of CO_2.
  - 2022 - 26 018 847 tonnes of CO_2.
  - 2023 - 24 242 843 tonnes of CO_2.

[15] The Korea Times, 12 June 2024. S. Korea, Kazakhstan sign critical minerals partnership agreement. Accessed via: http://www.koreatimesus.com/s-korea-kazakhstan-sign-critical-minerals-partnership-agreement/

[16] Ministry of Justice of the Republic of Kazakhstan, 2012. Kazakhstan 2050 Strategy. Accessed via: https://adilet.zan.kz/rus/docs/K1200002050

[17] Weartech, 2024. Kazakhstan tightens regulations on scrap metal collection and recycling. Accessed via: https://weartech.kz/en/kazakhstan-tightens-regulations-on-scrap-metal-collection-and-recycling

[18] ECOJER, 2024. Data reported by the Kazakhstan Ministry of Ecology

Water pollution issues

- Mine tailings are a form of waste material produced during mining operations. They often contain hazardous substances that can contaminate water bodies if not properly managed.[19]
- To address the issue of accidental water pollution from metallurgical activities, particularly from mine tailings, Kazakhstan has established the Inter-institutional Working Group on Tailings Safety and the Prevention of Accidental Water Pollution (IIWG).[20] The group aims to strengthen national capacities and develop measures to minimize water-related risks in Kazakhstan.

[19] UNECE, 2023. Kazakhstan takes further measures to prevent accidental water pollution from mine tailings with UNECE support. Accessed via: https://unece.org/environment/news/kazakhstan-takes-further-measures-prevent-accidental-water-pollution-mine-tailings

[20] UNECE, 2022. Kazakhstan to strengthen mine tailings safety and prevent water pollution, with UNECE support. Accessed via: https://unece.org/media/news/365127

3 EXISTING BARRIERS AND DEFICITS FOR DECARBONIZATION OF THE METALLURGICAL SECTOR

This section outlines the barriers that currently hinder the decarbonization of Kazakhstan's metallurgical sector, including: *i)* technical and technological issues, *ii)* regulatory and legal topics, *iii)* economic subjects, *iv)* financial support, *v)* policy and incentive mechanisms, *vi)* availability of raw materials, *vii)* skills, knowledge and workforce capacities, and *viii)* socioeconomic questions.

The most pertinent barriers to decarbonization stem from the high costs of transitioning to low-carbon technologies, challenging market dynamics, the availability of large coal reservoirs, outdated electricity transmission and distribution assets, low prices (consumer tariffs) of electricity, a de facto absence of a carbon emissions market, and limited financing and favourable funding lines for investments in low-carbon and energy efficient production systems.

3.1 BARRIERS TO THE DECARBONIZATION OF THE METALLURGICAL SECTOR

3.1.1 Technical and technological barriers

High energy consumption

- Metallurgical processes, especially in steel and aluminum production, are highly energy intensive. The energy intensity of these processes has to be reduced without compromising productivity or quality. Balancing energy efficiency with operational performance is difficult, making this a significant barrier to decarbonization.

Dependence on fossil fuels and process emissions

- The metallurgical sector relies heavily on coal and natural gas for energy. Relying almost entirely on fossil fuels poses a challenge because decarbonization requires shifting to non-fossil fuels and thus changing equipment and production processes in some cases.
- Transitioning to renewable energy sources or cleaner fuels like hydrogen requires significant infrastructure changes and investment. This is a barrier because of a possible lack of investment funds, potential loss of competitive edge and uncompetitive financing rates from lending institutions due to perceived high risks, for instance. Extensive infrastructure changes and significant investment are both costly and time-consuming, potentially slowing down the shift away from fossil fuels in the metallurgical sector.

- The reduction of iron ore in blast furnaces produces significant CO_2 emissions. Developing and implementing alternative reduction methods, such as hydrogen-based direct reduction, is a big challenge because this technology is still in experimental or early commercial stages.
- Metallurgical processes inherently produce emissions due to chemical reactions, such as CO_2 from limestone in blast furnaces. This poses a challenge because these GHG emissions are hard to abate. These processes are challenging to decarbonize without fundamentally altering them or developing new technologies.

Grid issues: T&D

- Kazakhstan's renewable energy infrastructure is underdeveloped. This poses a challenge because expanding renewable energy capacity and integrating it into the energy supply for metallurgical plants is costly and complex, and using renewable energy is one of the most relevant measures to decarbonize metallurgy.
- In the above-mentioned context, currently 6.47% of total electricity generated in Kazakhstan comes from renewable energy sources.[21] In total, 148 renewable energy facilities with a total installed capacity of 2,903.54 MW were operating in Kazakhstan in mid-July 2024. This is comprised of:
    - 59 wind power plants with a total capacity of 1,409.55 MW.
    - 46 solar power plants with a total capacity of 1,222.61 MW.
    - 40 hydroelectric power plants with a total capacity of 269,78 MW.
    - 3 biogas power plants with a total capacity of 1.77 MW.[22]
- An important challenge to power sector decarbonization relates to the prevalence of outdated and old equipment, systems, etc. into which it may be difficult to incorporate energy efficiency saving / low carbon measures, such as electrification, automation, demand management, etc. There is a need for grid and systems retrofitting, and this poses a significant challenge, due to the large scale of investment needed.
- Challenges in the power transmission grid (technical losses, outages etc.) may complicate balancing and incorporation of variable RE systems. This is a barrier because it may lead to potential instability and inefficiency in energy supply for energy-intensive processes.
- The number of unscheduled outages has been on the rise in recent years. Unscheduled outages are a barrier to decarbonizing metallurgy because they disrupt continuous production processes, leading to inefficiencies and increased reliance on backup systems that are often carbon intensive.

[21] Kazakhstan has the following target indicators for the share of renewable energy generation in the total volume of electricity production: 6% in 2025; 15% in 2030; 50% in 2050; and 80% in 2060.

[22] The Times of Central Asia, 2024. Kazakhstan Reports on Renewable Energy Generation. Accessed via: https://timesca.com/kazakhstan-reports-on-renewable-energy-generation/

Availability of low-carbon technologies

- Advanced technologies for low-carbon metallurgy, such as electric arc furnaces (EAF) or direct reduced iron (DRI) using hydrogen, are not widely available or affordable in Kazakhstan.
- The production, storage, and transportation infrastructure for hydrogen, to support hydrogen-based reduction metallurgical processes, is not developed in the country. Developing this infrastructure is costly and its lack prevents the effective implementation of hydrogen-based reduction processes in metallurgy.
- Many low-carbon technologies are still in the development or early deployment stages, making them less economically viable compared to mature conventional technologies. This is a barrier since high cost and uncertainty deter investment and widespread adoption of low-carbon technologies.
- Researching, developing, and deploying these technologies at scale poses a big challenge, as there is insufficient funding for research and development in low-carbon technologies specific to the metallurgical sector.
- A weak innovative ecosystem hinders the development and deployment of new low-carbon technologies for the metallurgical sector. This poses a challenge because a weak innovative ecosystem limits funding, research, and collaboration, slowing the progress of low-carbon technologies in metallurgy. Without robust support for innovation, new technologies struggle to advance and gain market traction.

Internal disconnection of zones within the country

- The western power system zone is not integrated with the rest of the country and the connection between the northern and southern zones is weak. Internal disconnection of power system zones hampers the integration of renewable energy sources across the country. This can generate that integration of renewable energy in the grid will not impact the system as a whole, but only the part of the grid to which it has been connected. This fragmentation limits the availability of low-carbon electricity for metallurgical processes, making it harder to reduce carbon emissions.

Schedule adjustability

- Thermal power plants have currently very limited technical capability to adjust their schedules to the availability of wind and solar PV electricity. Schedule adjustability of thermal power plants is critical for the effective integration of renewable energy into the power grid. Renewable energy sources are intermittent and variable by nature, meaning their output can fluctuate based on weather conditions and time of day. This is a barrier because this variability introduces challenges for maintaining a stable and reliable power grid. By providing the necessary flexibility to balance supply and demand, adjustable thermal power plants are needed for integrating more renewable energy in Kazakhstan's electricity grid. Thermal plants' schedule adjustability helps in supporting grid stability, enhancing economic efficiency, reducing renewable energy curtailment, and ensuring energy security.

Carbon Capture and Storage

- Lack of complete information on CO_2 storage capacity, geological underground sites, etc. Incomplete information on CO_2 storage capacity and geological sites creates uncertainty about the feasibility and safety of carbon capture and storage (CCS) technologies. This lack of data can deter investment and development in CCS solutions for metallurgy.
- Capturing and utilizing or sequestering carbon emissions efficiently is expensive and CCS technologies are still non-existent in Kazakhstan. This is a barrier to decarbonization because high cost and lack of CCS technologies make it difficult to implement effective post-combustion carbon reduction strategies in metallurgy. Without these technologies, managing and mitigating emissions becomes economically unfeasible.

Limited local technical capacity

- Dependence on foreign technology and expertise for metallurgy sector processes' decarbonization. This is a barrier since dependence on foreign technology and expertise can lead to delays and higher costs due to reliance on external sources. It also risks knowledge gaps and reduced control over technological adaptation.

3.1.2 Regulatory and legal barriers

Decarbonization targets

- Lack of legally binding decarbonization targets, etc. for the metallurgical sector. This is a challenge to decarbonization given that without legally binding decarbonization targets there is little regulatory pressure or incentive for the metallurgical sector to adopt low-carbon technologies. This lack of clear mandates can lead to slower progress and insufficient investment in GHG emission reduction measures. Additional information is presented in Monitor Sustainability no. 02 / 2024 Kazakhstan's energy transition[23] and ABDI Working Paper Series Toward Hydrogen Economy in Kazakhstan[24]

[23] https://www.kas.de/documents/d/guest/monitor-sustainability-kazakhstan

[24] https://www.adb.org/sites/default/files/publication/836516/adbi-wp1344.pdf

- Current emission standards[25],[26] for the metallurgical sector may not be stringent enough to drive significant reductions in greenhouse gas emissions. If current emission standards are not stringent, they may fail to compel the metallurgical sector to invest in and adopt advanced low-carbon technologies. This leniency reduces the urgency for significant emission reductions, hindering progress toward decarbonization goals.

Renewable energy integration

- Incomplete regulatory framework and/or regulatory hurdles for the integration of renewable energy, needed for powering low-carbon metallurgical processes. These barriers can delay the deployment of necessary clean energy infrastructure and create uncertainties for investment.
- Despite the constant decline in the cost of renewable energy, it still cannot compete in terms of levelized cost of generation with coal and hydro plants owned by mining giants.
- Among all RE facilities, only wind power plants are competitive in terms of electricity generation costs. However, their use also rests on the problem of the need for round-the-clock operation of critical mining and processing equipment, which is the basis for both productivity and safety in mining and processing processes.
- Significant parts of mining and metal production equipment, including single-stall systems, ventilation systems, pumps, as well as ore processing plants, must operate continuously to maintain the working process. Sudden stops of equipment lead not only to a decrease in productivity, but also create serious safety risks, potentially blocking miners in mines, or causing the collapse of structures. The same interruptions in ventilation systems can lead to dangerous accumulations of gases, endangering the lives of miners.
- A further obstacle to RE uptake is the high debt burden of mining companies. Many companies invest in coal and stable electrical energy generation from fossil fuel and not from RES. In case of RES the feeding tariffs are too low and pay back period is too long. In case of coal, the payback is short and electrical energy generation is stable. In case of RES the electrical energy generation is less predictable.[27] The high financial obligations and debts of most operating mining companies (including small players) limits their ability to make significant investments outside their industry. As a result, from the point of view of attracting debt financing, it is more profitable for companies to invest in expanding existing energy assets, bringing available capacity to the installed capacity, than to implement RE projects from scratch.

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[25] https://practiceguides.chambers.com/practice-guides/environmental-law-2024/kazakstan/trends-and-developments, Law and Practice - section 14.2

[26] State regulation of greenhouse gases in the Republic of Kazakhstan, ECOJER, 2024

[27] QazaqGreen | Industry News | Overcoming obstacles: why are the leaders of the mining industry in no hurry to switch to renewable energy

- RE uptake is also stymied by problems of the electric power industry: imbalances in the energy system, lack of maneuverable capacities, dependence on neighbouring states, wear and tear of equipment of traditional stations, and isolation of the internal zones of the energy system.
- Thus, metallurgy companies in Kazakhstan have serious obstacles in the transition to renewable energy. High tariffs and instability of energy supply from RE facilities, as well as the high debt burden of the companies, lead to the fact that the integration of renewable energy into the metallurgy sector seems difficult and financially unrealistic.
- Rules place responsibility for balancing renewable energy output on the project developers (i.e., metallurgical companies). This poses a significant burden for them, as they are obliged to install either gas-fired balancing stations or battery storage for balancing purposes, significantly raising total project costs.

Emissions Trading System

- The carbon unit trading system in the Republic of Kazakhstan consists of primary and secondary carbon markets. In the primary market, the operator of the carbon units trading system sells carbon quota units from the corresponding reserve category of the National Quota Plan on auction terms. In the secondary carbon market, subjects purchase and sale carbon units among themselves through a direct transaction or through a commodity exchange.[28]
- A key barrier to decarbonization of the metallurgical sector is the effective absence of a competitive ETS market. The effect of very low prevailing ETS permit prices is to reduce the economic incentive for metallurgical companies to mitigate their GHG emissions. This lack of cost pressure diminishes the motivation for investing in low-carbon technologies.
- There are various deficiencies in the ETS system, such as a lack of binding reductions[25], the emissions caps not being effective, etc. The prices are too low to drive significant investment in low-carbon technologies for the metallurgical sector.
- Absence of a robust carbon pricing mechanism to internalize the environmental costs of emissions. This is a barrier because it reduces the economic incentive for companies to reduce emissions.
- Internal use vehicles' GHG emissions from industrial companies (i.e., vehicles used within the companies' facilities, etc.) are not accounted for in the current ETS system. Internal use vehicles' GHG emissions in industrial and hence in metallurgical companies are not covered by the current ETS system, creating a barrier to decarbonization because these emissions contribute significantly to the overall carbon footprint.

[28] QazaqGreen | Expert opinion | Carbon credits are one of the tools to combat greenhouse gas emissions

More detailed information is presented in the Kazakhstan – Carbon Credits – A Tool To Control Greenhouse Gas Emissions[29].

Integration into regional organizations

- Starting from 2025, the Unified Electric Power Market of the Eurasian Economic Union (EAEU) countries, in which greenhouse gas emissions are not regulated, will be launched. Greenhouse gas emissions not being regulated can cause a blockage of carbon markets in the region, since unregulated greenhouse gas emissions allow metallurgical companies to continue high-emission practices without financial penalties or mandates for cleaner technologies. One possible approach to address this issue could be to implement a CBAM analogue for imports of Russian electricity (which is not subject to GHG emissions pricing controls) into Kazakhstan.

Technology transfer

- Legal barriers related to intellectual property rights can hinder the transfer of low-carbon technologies. This poses a challenge since legal barriers can restrict access to crucial low-carbon technologies, slowing their adoption in metallurgy. Without the ability to share or license these innovations widely, companies face higher costs and longer timelines for implementing sustainable practices.

Fragmented regulatory framework

- Overlapping responsibilities and lack of coordination among different regulatory bodies can create inefficiencies. This can lead to conflicting requirements and inefficiencies in policy implementation. This fragmentation creates confusion and compliance challenges for metallurgical companies, delaying or complicating their efforts to adopt effective decarbonization measures.
- Absence of clear, long-term policy commitments for decarbonization specifically in the metallurgical sector undermines investor confidence. This poses a barrier in terms of attracting financing for decarbonizing metallurgy.

Monitoring and reporting

- Inadequate monitoring and reporting systems hinder the effective implementation of regulations. This is a barrier that makes it difficult to accurately track emissions and verify compliance with regulations. This lack of reliable data undermines enforcement and accountability, preventing metallurgical companies from effectively addressing their carbon footprint and achieving meaningful decarbonization.
- Existing gaps and barriers to climate change adaptation planning, monitoring, and reporting in Kazakhstan comprise insufficient institutional and technical support for

[29] Kazakhstan - Carbon Credits - A Tool To Control Greenhouse Gas Emissions. - Conventus Law

mainstreaming adaptation into sectoral and local development plans, lack of permanent inter-ministerial and cross-regional platform for discussion of adaptation issues, lack of inventories of existing climate information, combined with fragmented and outdated vulnerability assessments, strong need to harmonize techniques for climate-related data collection, analysis and documentation, lack of required trained personnel (numbers and expertise) to meet adaptation objectives.

- A system of annual monitoring and reporting on the implementation of the 2021-2030 Action Plan has been established by the Government of the Republic of Kazakhstan Resolution No 479 of 29 July 2020 on the Action Plan for the implementation of the Concept for the transition of the Republic of Kazakhstan to a "Green Economy" for 2021-2030. A similar mechanism will be established to monitor the implementation of the Roadmap for the NDC implementation when it is adopted. Evaluation of the implementation of the Roadmap for NDC implementation will culminate in a review every five years, enabling corrective planning and implementation of further measures. The success of implementation will be judged against a set of indicators specific to each sector. Apart from reports submitted by public administration bodies on an annual basis, scientific data will be used, where possible

3.1.3 Economic barriers

Contextual conditions

- In Kazakhstan electricity prices are low and there is abundant coal, thus it is difficult to stop coal use for electricity generation and also to raise electricity prices for the integration of renewable energy. Low electricity prices and abundant coal in Kazakhstan make it economically challenging to transition away from coal for electricity generation. This reliance on cheap, carbon-intensive energy limits the financial incentives to invest in renewable energy and cleaner technologies in metallurgy.
- Relative costs of low carbon alternative energy generation sources are high in comparison to conventional generation with fossil fuels. This is also a barrier to decarbonization since companies may look for less costly options.
- Kazakhstan's economy is heavily dependent on the metallurgical sector, making it challenging to implement changes that could disrupt production and employment. This poses a challenge to disruptive or blunt innovations.

Market demand

- Uncertainty in market demand for low-carbon metallurgical products can deter investment. This is an issue because it might increase financial risk for companies and without clear and stable demand, firms may be reluctant to invest in expensive, cleaner technologies.

- Limited market demand for low-carbon metallurgical products (mainly in the EU and applies mainly to aluminum). This is a barrier since limited market demand reduces the economic incentive for companies to invest in cleaner technologies. This lack of demand can lead to higher costs and lower profitability for low-carbon options, discouraging their adoption.

Subsidies to fossil fuels

- The subsidies to coal-fired electricity generation increase the relative price gap between conventional and renewable power generation. This disparity discourages metallurgical companies from investing in renewable energy and cleaner technologies due to higher costs.
- Subsidies to fossil fuel generation do not favor efforts to apply energy efficiency measures. Subsidization stimulates overconsumption of subsidized goods. Subsidized cheap electricity means that metal production plants will have less incentive to try to save energy, to use it efficiently, etc., leading to higher consumption in the end. Long-term downsides of subsidization include financial strain on governments, market distortions, environmental impacts (due to overconsumption), inequitable distribution of benefits, economic inefficiencies, opportunity costs, political challenges, and misleading price signals.

Needed investments are high

- Needed investments amounting to USD 293.5 billion are estimated for the implementation of decarbonization measures (economy-wide, not only in the metallurgical sector) by 2030, including the need to transition to BAT, improving energy efficiency and constructing new renewable energy facilities, according to Kazakhstan's updated NDC (2021).[30] This poses a challenge in the sense that very large amounts of funding will be required, which are complex to find.
- The economy-wide decarbonization until 2060 will require 666.5 billion USD of additional investments. Achieving net zero GHG emissions in the sectors of heat and power generation will require investments of 305 billion USD, almost half of the economy-wide total investment needs.[31] Like mentioned above, the barrier is to attract such large amounts of funds.
- Decarbonization requires the introduction of BAT, energy efficiency improvements and construction of new renewable energy facilities, which are high capital-intensive measures.

[30] Asia Pacific Energy, 2015. Kazakhstan: Intended Nationally Determined Contribution. Accessed via: https://policy.asiapacificenergy.org/node/2409

[31] DIW Econ, 2022. Kazakhstan: Towards Net Zero by 2060

- The economic transition towards low-carbon technologies may involve significant costs related to workforce retraining, plant modifications, and potential short-term production losses.
- Many low carbon energy systems (some renewables, some EE interventions, hydrogen, CCS, etc.) have high-cost profiles that would render metallurgical companies uncompetitive. The high cost of developing new infrastructure for renewable energy and hydrogen is a significant barrier.

Global markets

- Fluctuations in global metal prices can impact the profitability of the metallurgical sector, making it difficult to justify long-term investments in decarbonization. This volatility makes it harder to justify and secure funding for long-term investments in decarbonization.
- Global competition and price sensitivity in the metallurgical sector. Balancing the need for decarbonization with maintaining competitiveness in the global market poses a big challenge.

3.1.4 Financial and funding support barriers

High CAPEX

- High upfront (CAPEX) costs of low carbon energy systems, compared to fossil fuel systems, can complicate the ability to invest in low-carbon technologies.
- The uncertainty associated with the return on investment (RoI) for new technologies can deter companies from making large capital investments. Uncertainty about the RoI for new technologies can make companies wary of committing substantial capital. This financial risk discourages investment in innovative, low-carbon solutions.

Financing

- Lack of access to cheap loans for low-carbon projects and insufficient incentives for renewable energy, while brown assets have access to guarantees and financing with a potentially lower interest rate. This is a barrier that makes financing low-carbon projects more expensive and less attractive.
- Lack of consideration of climate criteria and criteria of Sustainable Development Goals in the budgetary process, which leads to risks of financing and potentially the full range of benefits of RE systems not being accounted for in the economic sense.
- There is limited availability of green bonds, loans, and other financial products specifically designed to support low-carbon projects in the metallurgical sector. This poses a barrier since limited availability of green bonds and financial products for low-carbon projects restricts access to necessary funding for decarbonization in the

metallurgical sector. This shortage increases the cost and difficulty of financing sustainable technologies.

- The complexity of applying for green finance can be a deterrent for companies due to the resource-intensive processes and stringent requirements involved. This is a barrier since the bureaucratic burden may discourage investment in low-carbon technologies.
- Availability of long-term financing is crucial for large-scale infrastructure projects, but it is often scarce. Scarcity of long-term financing limits the ability to fund large-scale infrastructure projects needed for decarbonization. Without access to extended capital, metallurgical companies struggle to invest in substantial, transformative technologies.
- Lack of sufficient funding streams for low carbon energy investments and major scale investments in energy efficiency.
- Financial institutions often perceive investments in new low-carbon technologies as high-risk, leading to reluctance in the provision of financing. The investments of renewable energy or low-carbon technologies for metallurgy come mainly from the private sector, that is, from the project developers themselves. These companies normally receive financing from commercial banks through loans.
- An additional serious barrier to investment in the renewable energy sector is the high volatility of the national currency and the imperfection of the existing indexation mechanism for renewable energy projects. As a result, the investor's currency risks are not fully covered.

High cost of capital and long payback period

- A lack of clear information on the effectiveness and risk profiles of certain low carbon energy solutions results in lenders demanding high risk premiums. This is a barrier that increases the cost of financing for decarbonization projects, making them less attractive to metallurgical companies.
- The long payback periods for investments in low-carbon technologies can be a barrier for companies seeking quick returns. The extended timeline makes these projects less appealing compared to shorter-term gains.

Insufficient government support and incentives

- Insufficient government subsidies and grants for research, development, and deployment of low-carbon technologies. This lack of funding makes it harder for metallurgical companies to invest in and scale up new technologies.
- Lack of robust tax incentives to encourage investment in renewable energy and energy-efficient technologies. Lack of tax incentives reduces the financial attractiveness of investing in renewable energy and energy-efficient technologies. This is a barrier since, without these incentives, metallurgical companies face higher costs and lower returns on such investments.

International support and collaboration

- Accessing international climate finance from sources such as the Green Climate Fund (GCF) and other global initiatives might be difficult. This is a barrier since the GCF is one very relevant provider of funding for low-carbon technologies worldwide.
- Insufficient collaboration between domestic and international stakeholders in financing low-carbon projects. Insufficient collaboration can result in fragmented efforts and missed opportunities for co-financing low-carbon projects. This lack of coordination hinders the pooling of resources and expertise needed for effective decarbonization.

3.1.5 Policy and incentive mechanisms barriers

Decarbonization policies in the metallurgical sector

- Lack of a clear set of policies for decarbonization of the metallurgical sector. Kazakhstan lacks a comprehensive and unified climate policy specifically targeting the metallurgical sector.
- Insufficient sector-specific targets for emission reductions in the metallurgical sector hinder focused and effective action.
- Uncertainty in long-term policy direction about decarbonization obligations in the metallurgical sector and about renewable energy integration in the grid. Uncertainty in these policies creates risk for companies, deterring them from investing in costly low-carbon technologies. This lack of clarity can lead to delays in adopting necessary decarbonization measures.

Incentive mechanisms for decarbonization in the metallurgical sector

- Lack of fiscal / financial incentive mechanisms for decarbonization in the metallurgical sector (e.g. in the current ETS companies can simply request more emissions permits, in the case of increased production, for free from the reserve).
- Insufficient financial incentives, such as tax breaks, subsidies, or grants, for companies adopting low-carbon technologies in the metallurgical sector.
- Existing incentives may be poorly designed or not effectively targeted towards the metallurgical sector. There are no specific incentives for the metallurgical sector.
- Thermal power plants in Kazakhstan have no economic incentive to adjust their schedules to the availability of wind and solar PV electricity. This creates a significant barrier to the development of variable RE in the country, since the economic burden is placed 100% on RE plant operators. Renewable energy developers need to install balancing capacities in addition to their renewable plants in the form of gas-fired electricity generation or battery storage, adding significant costs to their renewable energy project.

Penalties

- No clear financial penalties for not decarbonizing. This represents a barrier because the absence of clear financial penalties for not decarbonizing reduces the immediate financial incentive for companies to invest in cleaner technologies. Without such penalties, there is less pressure to adopt low-carbon solutions.

3.1.6 Availability of raw material barriers

Water

- Water scarcity is one of the main issues, since a significant amount of water is used in metallurgical processes. Water is a primary need, and it needs to be used for sanitation, drinking and agriculture first, as well as for many other industries. Metallurgy could be affected by water scarcity.
- Kazakhstan does not have significant potential for hydropower generation, which would greatly help in the development of dispatchable renewable energy in the country.

Natural gas

- Risk of a shortage of natural gas. An increase in natural gas supply is needed for lowering carbon emissions of coal-fired generation of electrical energy. Kazakhstan is struggling to produce enough natural gas to supply its own domestic requirements. The shortage is not caused by an absence of natural gas, instead, the challenge lies in the structure of the market. Ever since the Soviet period, there have been strict caps on the natural gas price for consumers, and at such prices, natural gas producers cannot make a profit. Natural gas is sold at a loss, largely from oil producers who have no other outlet for associated natural gas, which is produced alongside oil.[32]

Global competition for raw materials

- High global demand for these materials can lead to supply shortages and increased prices, making it challenging to secure a stable supply.

Supply chains

- Geopolitical tensions and trade restrictions can disrupt the supply chains of critical raw materials, affecting their availability.
- Strategic reserves of critical raw materials might be lacking in Kazakhstan. Lack of strategic reserves of critical raw materials in Kazakhstan can create supply shortages and

[32] Natural Gas World, 2022. Kazakhstan's gas dilema. Accessed via: https://www.naturalgasworld.com/kazakhstans-gas-dilemma-gas-in-transition-102539

increase costs for low-carbon technologies. This scarcity makes it challenging to secure the necessary components for decarbonization projects.

- Ensuring the sustainable and ethical sourcing of raw materials is a significant challenge, as mining and extraction can have adverse environmental and social impacts. This poses a barrier in ensuring fairly sourced materials, which will be required more and more in the international context.

Costs

- The high costs of critical raw materials can increase the overall cost of low-carbon technologies, making them less economically viable for the metallurgical sector.

Price volatility

- Price volatility in the global market for critical raw materials can create financial uncertainty and risk for companies investing in decarbonization.

Recycling

- Inadequate infrastructure for the recycling and reuse of critical raw materials can lead to increased dependence on virgin materials. This is a barrier because it increases environmental impact and costs. This dependence undermines efforts to adopt sustainable practices and technologies.

Regulations

- Inconsistent or unclear regulations related to the extraction, import, and use of raw materials can create uncertainty and hinder investment.
- Complying with environmental regulations and obtaining necessary permits for mining and extraction can be time-consuming and costly.

3.1.7 Skills, knowledge and workforce capacities' barriers

Gaps in awareness, expertise or skills

- Shortage of skilled professionals with expertise in low-carbon technologies and processes specific to the metallurgical sector. A lack of skilled workforce trained in low-carbon technologies limits the ability to implement and manage new decarbonization processes effectively. This skills gap slows the adoption of advanced technologies and hampers progress in reducing GHG emissions.
- There may be general lack of awareness and understanding of international best practices in decarbonization among industry stakeholders. This is a barrier because a lack of awareness and understanding of international best practices in decarbonization among industry stakeholders prevents the adoption of effective, proven strategies. This

knowledge gap may lead to suboptimal practices and missed opportunities for improvement.

- Limited collaboration between industry and academia, leading to a gap between the skills taught in educational institutions and those required by industry.

Latest technical advancements and R&D

- A large part of the workforce might need to be updated and trained in the latest technical solutions for metallurgical sector decarbonization. This represents a barrier in terms of the time and resources needed for training needs for the companies.
- Insufficient R&D infrastructure and capacity within the metallurgical sector to innovate and develop low-carbon technologies. Limited funding for R&D activities focused on decarbonization.

There is limited local capacity for research and development in advanced metallurgical technologies. This lack of R&D capabilities might impede the progress of adopting cutting-edge technologies.

Service provision

- There might not be a sufficient number of suitably qualified solutions providers, energy auditors, etc. in the country. Importing service provision from other countries might raise costs.

Just transition

- Job losses in the coal sector – people that have lost their jobs need to be reincorporated in the labor market.
- Concerns about job security due to the adoption of new technologies. This can raise social concerns against new, low-carbon technologies.

Education

- Traditional education and training programs may not provide the holistic knowledge required for effective decarbonization. This is a barrier because the gap in education hinders the implementation of advanced, low-carbon technologies.
- Weak institutional support for workforce development in low-carbon technologies and skills.
- Few opportunities for students and young professionals to gain practical experience through internships and apprenticeships. This is a barrier that limits hands-on learning in low-carbon technologies.
- Lack of comprehensive policies that mandate or incentivize skill development in the context of decarbonization. Without targeted training and incentives, professionals may lack the necessary expertise to implement effective solutions.

3.1.8 Socioeconomic barriers

Societal resistance

- Possible societal resistance to replacing coal fired generation in municipalities where coal plants also supply heat energy (district heating) to local communities.
- Resistance to change among the workforce and management due to a long-standing reliance on traditional metallurgical processes.
- Resistance to change due to lack of understanding of the benefits of decarbonization.

Just transition

- Managing the transition to a low-carbon model in a logical, sensible, acceptable and cost-effective way might be complex.

Awareness and engagement

- Lack of awareness and engagement among stakeholders, including the public, industry, and policymakers. Lack of awareness and engagement among stakeholders leads to insufficient pressure and support for decarbonization initiatives. Without broad buy-in, there is less motivation for industry investments and policy development.

4 DECARBONIZATION POTENTIAL IN THE METALLURGICAL INDUSTRY OF KAZAKHSTAN

Long-term decarbonization goals have been set in climate framework documents in Kazakhstan. This includes reducing the energy intensity of GDP by 50% by the year 2050 and compared with 2008 levels; and increasing the share of alternative (low carbon) power generation sources to 50% by 2050.[33]

The institutional framework for reducing GHG emissions is established in the Environmental Code of the Republic of Kazakhstan,[34] which sets the target of reducing the carbon balance (net carbon emissions) of Kazakhstan by the year 2030 by at least 15% in comparison with the carbon balance level in 1990. Kazakhstan aims to achieve economy-wide carbon neutrality by the year 2060, as defined in its Carbon Neutrality Strategy.[35] Achieving these milestones will require significant investment, policy support, and collaboration between the government, industry players, and international partners.

Regarding Kazakhstan's industrial sector and the metallurgical sector's role specifically, the largest sectors in total output are non-ferrous metallurgy (25%), food industry (22%) and ferrous metallurgy (18%). With a total of 43% of the whole manufacturing in the country, metallurgy is one of the most relevant sectors for Kazakhstan's economy. In terms of greenhouse gases, metallurgy's share in industrial processes and product use emissions amounts to 58%.

Carbon emissions

The German Institute for Economic Research, or Deutsches Institut für Wirtschaftsforschung (DIW) in German, published the document "Kazakhstan: Decarbonization Pathways towards a Net Zero Future by 2060 – The Opportunities and Challenges ahead".[36] This document models the metallurgy sector's emissions in a Business-as-Usual scenario (BAU) and in a Net Zero

[33] Ministry of Ecology and Natural Resources, 2023. Updated Nationally Determined Contribution of the Republic of Kazakhstan to the global response to climate change. Accessed via: https://unfccc.int/sites/default/files/NDC/2023-06/12updated%20NDC%20KAZ_Gov%20Decree313_19042023_en_cover%20page.pdf

[34] Ministry of Justice of the Republic of Kazakhstan, 2021. Environmental code of the Republic of Kazakhstan. Accessed via: https://adilet.zan.kz/eng/docs/K070000212_

[35] Ministry of Justice of the Republic of Kazakhstan, 2023. Approval of the carbon neutrality strategy of Kazakhstan to 2060. Accessed via: https://adilet.zan.kz/rus/docs/U2300000121

[36] DIW, 2023. Kazakhstan: Decarbonization Pathways towards a Net Zero Future by 2060 – The Opportunities and Challenges ahead

Emissions (NZE) scenario in the 2030, 2040, 2050 and 2060 horizons. The calculated emissions from fuel combustion in metallurgy are shown in Table 1.

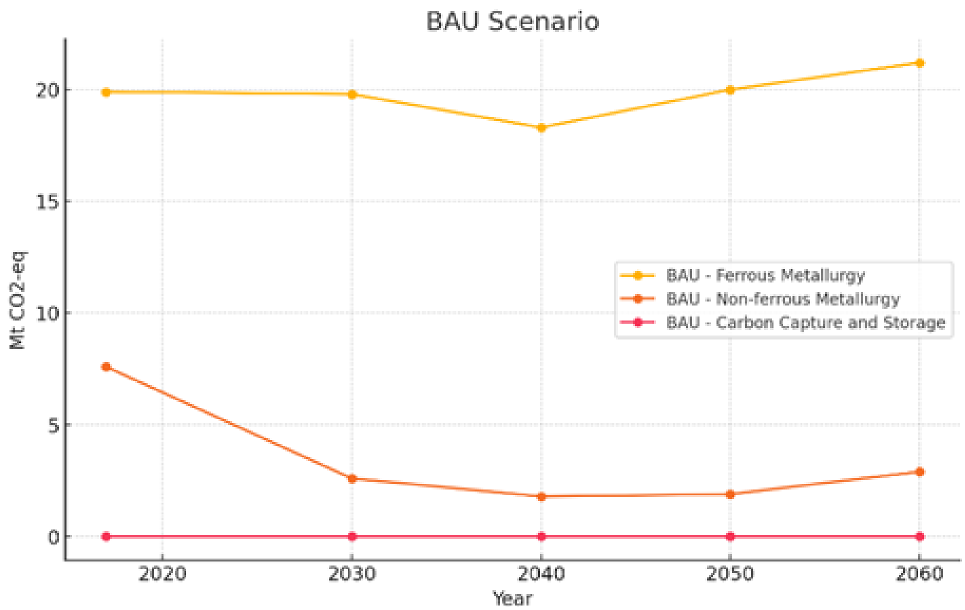
Table 1: Metallurgical sector fuel combustion emissions and CCS, Mt CO2-eq.

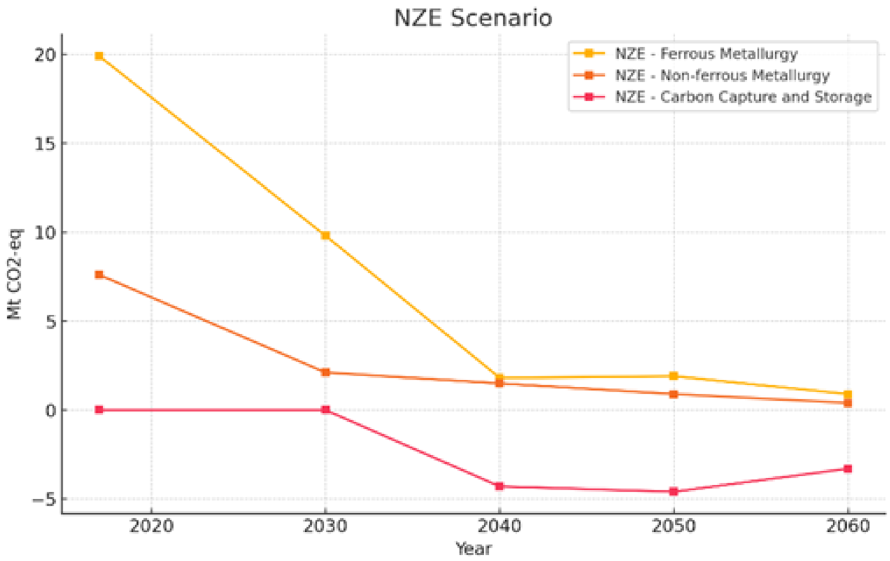
		BAU scenario				NZE scenario			
	2017	2030	2040	2050	2060	2030	2040	2050	2060
Ferrous metallurgy	19.9	19.8	18.3	20.0	21.2	9.8	1.8	1.9	0.9
Non-ferrous metallurgy	7.6	2.6	1.8	1.9	2.9	2.1	1.5	0.9	0.4
Carbon capture and Storage	0.0	0.0	0.0	0.0	0.0	0.0	-4.3	-4.6	-3.3

Source: DIW - "Kazakhstan: Decarbonization Pathways towards a Net Zero Future by 2060 – The Opportunities and Challenges ahead, page-82"

Figure 1 below shows the data included in Table 1 in the form of line graphs, both for the BAU and NZE scenarios.

Figure 1: Metallurgical sector GHG emissions from fuel combustion (BaU and NZE scenarios)





Source: DIW - "Kazakhstan: Decarbonization Pathways towards a Net Zero Future by 2060 – The Opportunities and Challenges ahead"

In the NZE scenario, carbon capture and storage (CCS) technologies will be introduced starting in 2030. This GHG emission reduction that can be observed in Table 1 is achieved by increasing energy efficiency in industry and by changing the energy mix, as coal will be gradually substituted with hydrogen, electricity, and heat in the net zero emissions scenario. Currently, total emissions per USD of output in metallurgy sum up to 2.33 kg CO_2-eq[36] (2017 data - latest available). The World Bank's "Background Note 1 EU CBAM: Modelling the Impacts on Kazakhstan's Economy"[37] states that emissions intensity of Kazakhstan's production of non-ferrous metals (including aluminum) are very high as compared to other countries, amounting to 615 tCO2e/Million USD.

According to the results of a quantitative modelling study of GHG emissions pathways in Kazakhstan, undertaken by GIZ in 2021 (in support of the development of Kazakhstan's 2060 carbon neutrality strategy), the elimination of carbon- and heat-based oxidative reduction of ore (a process that produces CO_2) will play a decisive role in the decarbonization of the metallurgical sector. In aluminum production**,** efficient recycling could reduce demand for primary aluminum and reduce overall emissions by 27% by 2050 compared to today, despite the expected growth in demand for aluminum products. Eliminating carbon in smelting by using inert anodes could reduce direct (energy and process) emissions in the sector by 15% as compared to the baseline emissions scenario outlined in the national carbon neutrality strategy.

In steel production, the use of natural gas-based Direct Reduction of Iron (DRI) already significantly reduces emissions: by 30% compared to legacy blast furnaces and the converter

[37] World Bank, 2023. Kazakhstan Country and Climate Development Report. Background note 1. EU CBAM: Modelling the impacts on Kazakhstan's economy. Accessed via: https://documents1.worldbank.org/curated/en/099420011012227804/pdf/P17736909f4ba20b20a09900704fa0830cb.pdf

process and by 42% compared to coal-based DRI technologies. In fact, Agora Industry report[38] says, "DRI technology can be deployed today and operate with a gradually increasing share of hydrogen; furthermore, it allows the iron and steelmaking stages to be decoupled. Pairing the DRI process with existing basic oxygen furnace (BOF) steelmaking will unlock the use of lower-quality iron ores, as may future iron ore electrolysis technologies. Using scrap steel in combination with electric arc furnaces (EAFs) could reduce the carbon intensity of steel production by up to 83%, allowing emissions to be reduced even as demand grows. This is because recycling scrap metal requires much less energy and bypasses the smelting step of ore, which produces GHG emissions. Further details about scrap use in the steel industry can be found in the world steel association fact sheets.39 The use of (green) hydrogen for DRI in combination with electric arc furnaces using renewable energy sources opens up opportunities for carbon-neutral steel production.

CO2 capture and storage and utilization technologies will play a significant role as well. It is estimated that these technologies could reduce direct emissions by 35% in aluminum production and 60% in steel production.[39] It is worth noting that many options for decarbonizing industrial processes involve upgrading equipment and restructuring production in a way that decouples production processes or allows for easy upgrading of equipment from low-carbon to zero-carbon processes (e.g. switching from natural gas to hydrogen in DRI). Therefore, even if some technologies are still expensive for some producers (e.g. hydrogen-fueled DRI), bridge technologies (e.g. natural gas-fueled DRI) and process improvements pave the way for the complete elimination of process-related greenhouse gas emissions in these industries.

Carbon pricing

Carbon pricing is an economic policy tool used to incentive actions that reduce GHG emissions by assigning a cost to emitting carbon dioxide (CO_2) and other GHGs. The fundamental idea is to internalize the non-monetary costs of carbon emissions, such as health problems, environmental damage, and climate change impacts, thereby reflecting the true cost of carbon emissions in market prices. Carbon pricing is a crucial mechanism for decarbonization because it provides a financial incentive to reduce GHG emissions in the metallurgical industry and other heavy GHG emitting sectors. It is a vital tool for decarbonization as it aligns economic incentives with environmental goals, encouraging widespread adoption of low-carbon technologies and practices. By making the cost of carbon explicit, it drives systemic change across industries and economies.

During 2024 the carbon price in Kazakhstan's Emission Trading System has been about 1 EUR / tCO_2 (1.07 USD / tCO_2). That price is effectively too low to stimulate investments in low carbon energy and renewable systems, for example. The update of Kazakhstan's Nationally

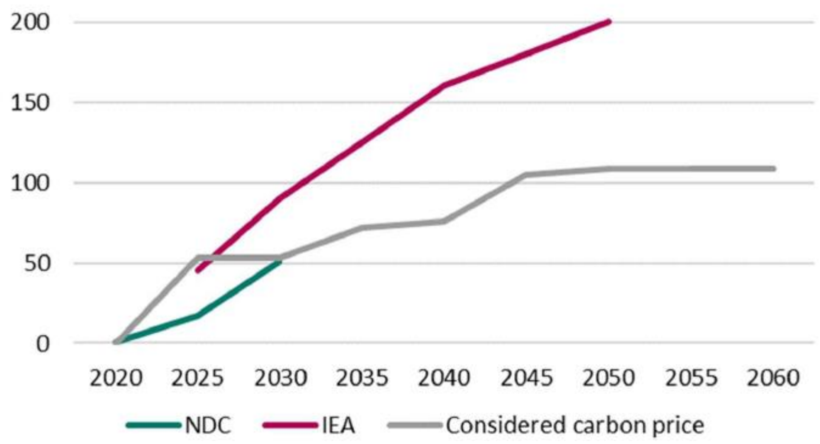
[38] Agora Industry, 2024. Low-carbon technologies for global steel transformation. Accessed via: https://www.agora-industry.org/publications/low-carbon-technologies-for-the-global-steel-transformation

[39] World Steel, 2023. Fact sheets – world steel. Accessed via: https://worldsteel.org/publications/fact-sheets/

Determined Contribution (NDC) proposes an increase of the carbon price in the ETS to 15 EUR / tCO_2 (16.03 USD / tCO_2) in 2023 and 45 EUR / tCO_2 (48.08 USD / tCO_2) in 2026.[40]

Figure 2 below shows three different carbon price estimated trajectories: IEA's projection for emerging market and developing economies, Kazakhstan's NDC plan until 2030, and the lowest carbon price that is necessary for the market to prefer decarbonization over continuing "business as usual" in terms of system costs.[40] As it can be observed, Kazakhstan's NDC plans to reach the "considered carbon price" (that is, the carbon price at which decarbonizing is better than BAU regarding system costs) in the year 2030. This price amounts to around 50 USD/ tCO_2.

Figure 2: Carbon price (NDC and IEA) and the proposed carbon price, USD / t CO_2



Source: "Kazakhstan: Towards Net Zero by 2060 – Financing concept". DIW (2022)

The analysis indicates that after 2025, the NDC carbon price reaches the threshold required to drive decarbonization, at around 50 USD per ton of CO_2. This means that even a carbon price below the IEA projection would be enough to make the net-zero pathway in the power sector more appealing than continuing with business as usual. By 2030, the price aligns closely with the NDC level, then continues to rise gradually, providing realistic long-term carbon pricing targets for Kazakhstan's power sector. By 2050, the price reaches 109 USD per ton of CO_2, which is 50% lower than the IEA projection. It is worth noting that the real situation is far from the above picture. Considering the carbon price impact on the economy, Kazakhstan industry players feel that a carbon price of $10-$15 is more realistic for 2030.

Energy intensity

Concerning energy intensity of the metallurgical sector, gradual retrofitting or replacement of outdated equipment will result in energy efficiency gains. The study "Kazakhstan:

[40] DIW, 2022. Kazakhstan: Towards Net Zero by 2060 – Financing concept

Decarbonization Pathways towards a Net Zero Future by 2060 – The Opportunities and Challenges ahead" showcases the following trends, as summarized in Table 2.

Table 2: Energy intensity (per USD of output) of metallurgy, MJ/USD.

		BAU scenario				NZE scenario			
	2017	2030	2040	2050	2060	2030	2040	2050	2060
Ferrous metallurgy	28.1	21.6	19.0	19.7	19.9	18.8	14.8	15.9	15.4
Non-ferrous metallurgy	5.7	4.7	3.8	3.9	4.2	4.6	3.1	2.7	2.6

Source: DIW - "Kazakhstan: Decarbonization Pathways towards a Net Zero Future by 2060 – The Opportunities and Challenges ahead"

4.1 2030 HORIZON

Carbon Pricing: According to Figure 2 above, in the year 2030 the price of a ton of CO_2 needs to amount to 50 USD/ tCO_2 in the "considered carbon price scenario" so that it is economically better to decarbonize metallurgical production than keeping a BAU trend. This figure is in concordance with Kazakhstan's plan in the NDC. For that to happen, carbon prices would need to rise from current (year 2024) 1.07 USD/ tCO_2 to 50 USD/ tCO_2 in only 6 years, which is a significant, steep rise (almost 50-fold). According to Kazakhstan's plan in the NDC and the current carbon price, the latter (around 1.07 USD/ tCO_2 in the year 2024) is quite lower than planned in the NDC for the year 2024 (15-20 USD/ tCO_2).

Energy Efficiency: Adoption of best available technologies (BAT) and measures to enhance energy efficiency across the board by 2030 should be the focus for the Kazakhstan metallurgy industry. All measures and activities are detailed in section 6 (below).

Renewable Energy: Increasing the use of renewable energy as much as possible for the metallurgy industry. This could involve building/investing in new renewables (solar, wind farms, bioenergy and hydro) dedicated to powering metallurgical plants. The renewable energy sector's growth will lead to increased demand for metals such as copper, lithium, nickel, and neodymium, which are essential for creating solar and storage batteries and wind turbines. This provides additional opportunities for Kazakhstan, a country rich in mineral resources.

Electrification: Main goal of electrification is to decarbonize metallurgical processes by replacing fossil fuels with electricity from renewable sources, e.g., in aluminum production, where electrolysis is the primary process. Kazakhstan can leverage its abundant hydro and renewable energy sources to power the industry.

The renewable energy resource potential in Kazakhstan is summarized in text box 1.

Text box 1. Renewable energy resources in Kazakhstan

The following is an overview of the renewable energy resource and potential in Kazakhstan, for the key renewable energy technologies. The data presented are based on USAID (2022).[41]

Wind Energy

- Wind energy has the greatest potential among all RES in Kazakhstan. Around half of its territory has an average wind speed of about 4 to 5 m/sec at a height of 30m. The greatest wind potentials are in the Atyrau and Mangystau regions in the Caspian Sea area, and northern and southern Kazakhstan. According to the Republic of Kazakhstan 2030 Concept of the Fuel and Energy Complex Development, the country's wind potential is 1,820 billion kWh per year.

Hydro Energy

- Hydropower is the second-largest RES in Kazakhstan. As of 2017, it accounts for about 10.9% of the country's generating capacity. Ranking third among CIS (Commonwealth of Independent States) countries in water resource potential, Kazakhstan has an estimated potential of 170 billion kWh per year, of which about 62 billion kWh are technically feasible. The annual hydropower potential of medium and large rivers is 55 billion kWh, and 7.6 billion kWh from small rivers. About 8 billion kWh from small hydropower plants are estimated to be technically feasible.
- Hydro energy resources are distributed throughout the country, but three areas have particularly large resources: the Irtysh River basin and its main tributaries (Bukhtarma, Uba, Ulba, Kurchum, Kardzhil), the southeast zone with the Ili River basin, and the south zone with the Syrdarya, Talas and Chu river basins. As of 2017, electricity generation from small hydropower plants (HPPs) was 649 million kWh.

Solar Energy

- Solar energy has an enormous potential in Kazakhstan. According to the Concept of the Fuel and Energy Complex Development, solar energy can produce about 2.5 billion kWh per year, with 2,200- 3,000 hours of solar per year (2,500-3,000 hours per year in the southern regions) out of 8760 hours.

Geothermal Energy

- Kazakhstan is also potentially rich in geothermal resources. Its hydrogeothermal resources with temperatures of 40°C to more than 100°C are estimated at 10,275

[41] USAID, 2022. Investor's guide to renewable energy projects in Kazakhstan. USAID Power Central Asia Activity. Accessed via: https://vie.korem.kz/uploads/INVESTORS%20GUIDE%20TO%20RENEWABLE%20ENERGY%20PROJECTS%20IN%20KAZAKHSTAN_2022_USAID_ENG.pdf?ysclid=luqtbvegbo284128785

billion m3 by water rate and 680 billion Gcal by heat rate, which is equivalent to 97 billion toe (ton of oil equivalent) or 2.8 billion TJ, equivalent to the country's estimated fossil fuel reserves. Kazakhstan has estimated hydrocarbon reserves of 12 billion tons of oil and condensate (17.2 billion toe) and about 6-8 trillion cubic meters of gas (7-9.2 billion toe). Its coal reserves are estimated at 150 billion tons (101.0 billion toe). Geothermal sources are located primarily in western Kazakhstan (75.9%), southern Kazakhstan (15.6%) and central Kazakhstan (5.3%). The most promising sources are the Arys, Almaty and Zharkent basins in southern and southeastern Kazakhstan with underground waters with mineralization of up to 3 g/dm3 and tem-re up to 70-100°C.

Process Optimization: All existing metallurgical processes need to be optimized, even if no upgrading is possible, to reduce/minimize GHG emissions.

Carbon Capture, Utilization, and Storage (CCUS): Initial pilot projects for CCUS technologies could be implemented in selected plants to capture CO_2 emissions from the production processes.

Decarbonization R&D Cells: R&D cells play a crucial role in advancing knowledge, driving innovation, and fostering collaboration between academia and industry. These cells serve as the epicentres for scientific inquiry, technological innovation, and applied research, contributing significantly to the development of new technologies, methodologies, and products. The metallurgy industry should create an R&D cell, either individually or collectively, to assess all decarbonization pathways in order to choose the ones that satisfy the sought criteria. This practice should be on an on-going basis.

Kazakhstan Government and Private Sectors Cooperation: Engaging and lobbying with governmental authorities and policymakers to achieve favorable regulations and incentives in decarbonizing the metallurgy industry. Sometimes a joint association of like industries is helpful to extract the best outcome from the government.

Funding: Pursuing all available internal and external funding, like Green/Climate funding to finance decarbonization projects.

International Collaboration: Involving in international collaborations to share knowledge, technologies, and best practices in decarbonizing the metallurgy industry. Engagement with EU CBAM be ascertained by the metal exporting enterprises to EU.

4.2 2050 HORIZON

Carbon Pricing: In the year 2050 a price of 109 USD/ tCO_2 is required, as shown in Figure 2, so that decarbonization of metallurgical processes is better than BAU in terms of system costs according to DIW's "*Kazakhstan: Towards Net Zero by 2060 – Financing concept*". This value is 50% lower than the IEA's projection. Kazakhstan's NDC does not forecast the price of carbon that will exist in the country in 2050, as it only defines the carbon price in the 2020-2030 period. This is not ideal and furthermore the NDC does not explain how, in general terms, the carbon price increase is going to be achieved. The NDC should provide a longer-term view and clear CO_2 emissions price targets up to 2050, in order to provide clarity, drive carbon markets towards a specific direction tailored to the Kazakh context and ensure consistent and predictable policy guidance for businesses and investors. By establishing long-term targets, the NDC can create the necessary investment certainty for the development of low-carbon technologies and infrastructure, enabling industries to plan their transition to a sustainable future effectively. Additionally, clear price signals aligned with global climate goals help to incentivize innovation and reduce emissions cost-effectively, while also demonstrating a firm national commitment to achieving the targets of the Paris Agreement.

New Technologies in Steel and Aluminium: In the Carbon Neutrality scenario considered within a study (GIZ, 2021) of future GHG emissions pathways in Kazakhstan, an active transition to natural gas and hydrogen DRI technologies is projected between 2030 and 2040. This sharply reduces GHG emissions from both Industrial Processes and Product Use (IPPU) and energy use. By 2045, almost all blast furnace sinter production[42] is replaced by DRI technologies, stabilizing emissions from Industrial Processes and Product Use despite production growth.

Establishing Hydrogen as a main Fuel and use of Bioenergy: Investing in addressing challenges such as hydrogen production costs and hydrogen infrastructure with a view to establishing its viable production route and widespread use in metallurgy. Green hydrogen, produced from renewable energy sources, could replace fossil fuels in heating and reduction processes. While the ultimate target should be green hydrogen for metallurgy, transition can start with grey hydrogen.

Utilizing biomass and bioenergy sources, such as wood chips or agricultural residues, can help reduce the carbon footprint of metallurgical processes. The environmental benefits of bioenergy include carbon neutrality and reduced reliance on finite resources.

Circular Economy: Implementing a circular economy approach across the board, focusing on recycling and the efficient use of resources. This includes increasing the recycling rates of metals and using secondary raw materials in production processes.

Processes and Advanced Materials: Developing and adopting new materials and processes of low-emission intensity. This could include innovative smelting and refining technologies that are more energy-efficient and emit less CO_2.

CCUS: By 2040, CCUS technologies should be widely adopted across industry, particularly in steel manufacturing and grey hydrogen production. By the year 2050 and according to a net zero emissions scenario, 4.6 Mt of CO_2 will be captured through CCS technologies.

Decarbonization R&D: Continue with the R&D cell to assess all decarbonization pathways.

[42] Feed material for blast furnace: fine-sized raw materials, including iron ore, coke breeze, limestone, mill scale, and flue dust, into an agglomerated product, sinter, of suitable size for charging into the blast furnace.

Cooperation between the Government of Kazakhstan and Private Sector: Engagement and lobbying with governmental authorities and policymakers, preferably as an association, to achieve favorable regulations and incentives in decarbonizing the metallurgy industry.

Funding: Continue pursuing all available internal and external fundings, like Green/Climate funding to finance decarbonization projects.

Integration with Other Sectors: Continued integration with the decarbonization efforts of other sectors, such as transportation and construction, to create an enthusiastic environment for the overall transition to a low-carbon economy.

International Collaboration: Continued involvement in international collaborations to share knowledge, technologies, and best practices in decarbonizing the metallurgy industry. Engagement with EU CBAM be ascertained by the metal exporting enterprises to EU.

4.3 2060 HORIZON

Zero Emission Technologies

In the year 2060, Kazakhstan aims to reach climate neutrality. To support the achievement of this target, by 2060 steelmaking should shift to hydrogen-based direct reduction of iron (DRI) for iron ore processing or the large-scale use of metal scrap as an alternative input source, with both then processed to steel in electric arc furnaces (EAF). Furthermore, it would be required that all energy used in production activities is sourced from renewable sources, and that any hydrogen used as an energy input (vector) is produced using emissions-free technologies only.

The GHG emissions values and targets referenced here are based on the GHG emissions pathway modelling study undertaken by GIZ in 2021. It is important to underline that, currently, no official document exists that sets potential sector-specific GHG emissions (decarbonization) milestones.

New technologies in steel and aluminum production

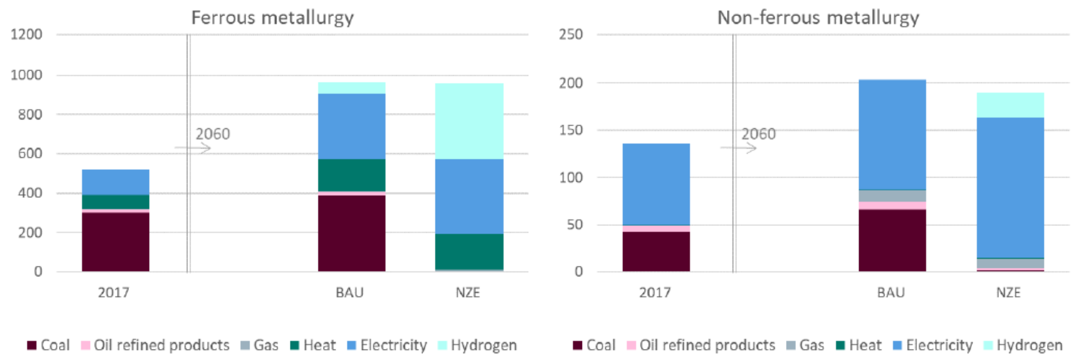
According to the findings of a quantitative modelling study of GHG emissions pathways to 2060, undertaken in 2021 by GIZ (and in support of the development of Kazakhstan's carbon neutrality strategy), by 2060 process GHG emissions from iron and steel production in the baseline scenario will be 33% higher than in 2017 and 29% higher than in 1990. However, in the carbon neutrality scenario, an active transition to natural gas and hydrogen DRI technologies is projected between 2030 and 2040, sharply reducing GHG emissions from Industrial Processes and Product Use (IPPU). In 2060, in the carbon neutrality scenario, process emissions from iron and steel production could be 93% lower than in the baseline scenario.

Regarding aluminum, in the baseline scenario, process emissions from aluminium production in 2060 will be only 1% lower than in 2017, whereas in the carbon neutrality scenario, emissions from aluminium in 2060 are expected to be 40% lower than in 2017.

Fuel type for final energy demand

Final energy demand by fuel type in 2060, both for ferrous and non-ferrous metallurgy, is forecast to have the following components:

Figure 3: Final energy demand in metallurgy by fuel type, ktoe.



Source: DIW - "Kazakhstan: Decarbonization Pathways towards a Net Zero Future by 2060 – The Opportunities and Challenges ahead"

BAU scenario

As Figure 3 above indicates, the BAU scenario continues to make significant use of coal for metallurgy, being the main source of final energy demand.

- In the case of ferrous metallurgy, coal use is forecast to increase from about 300 ktoe in the year 2017 to 400 ktoe (an increase of 33%).
  - The second source of energy is electricity and the third one is heat generated by fossil fuels, followed by hydrogen and oil refined products at a much lower scale.
- Total final energy demand for ferrous metallurgy in the BAU scenario is estimated to be slightly lower than 1000 ktoe.
- Looking at non-ferrous metallurgy, as the processes are different and make use of different energy sources, the BAU scenario forecasts electricity to be the first source of energy (like in the year 2017), with an increase in use of about 90 ktoe in 2017 to around 110 ktoe in 2060.
  - The second source of energy will be coal, with an increase of around 20 ktoe (from 45 ktoe in 2017 to 65 ktoe in 2060). Natural gas, which is currently not used in non-ferrous metallurgy, will start to be utilized and is forecast to amount to around 10 ktoe in 2060. Lastly, oil refined products will also be used, in an amount similar to that used in 2017 - slightly less than 10 ktoe.
- Total final energy demand for non-ferrous metallurgy in the BAU scenario is estimated to be around 200 ktoe.

NZE scenario

The NZE scenario gives quite a different view of final total energy demand as compared to the BAU scenario.

- For ferrous metallurgy, coal will have disappeared from the energy matrix. The first source of energy is foreseen to be electricity, followed by hydrogen in a quite similar amount, both around 400 ktoe. Heat will be the third source of energy, summing up to 200 ktoe. No other sources of final energy demand are foreseen.
  - Like in the BAU scenario, total final energy demand for ferrous metallurgy is estimated to be 1000 ktoe.
- In non-ferrous metallurgy electricity will be by far the main source of energy. An amount of 150 ktoe is expected to be consumed, followed by hydrogen with about 25 ktoe. The demand for natural gas will sum up to about 10 ktoe.
  - In total, a final energy demand of 190 ktoe is estimated for non-ferrous metallurgy in 2060.

CCUS technologies are foreseen to capture up to 4.6 Mt of CO_2 in the net zero emissions scenario, while no capture of emissions is forecast in the BAU scenario.

Carbon Pricing

In the year 2060, like in 2050, a price of 109 USD/ tCO_2 is required, as shown in Figure 2, so that decarbonization of metallurgical processes is better than BAU in terms of system costs. From 2045 on, a plateau is forecast to be reached in terms of the carbon price needed in order for decarbonization to be better in terms of costs than BAU. Kazakhstan's NDC does not forecast the price of carbon that will exist in the country in 2060.

International Collaboration

Continue engaging in international partnerships and collaborations to share knowledge, technologies, and best practices in decarbonizing the metallurgy industry.

5 ECONOMIC EFFICIENCY, COMPETITIVENESS, MARKET FOR DECARBONIZATION

Economic efficiency in the market for decarbonized metallurgical products is crucial for decarbonizing Kazakhstan's metallurgy industry, as it ensures that resources are allocated effectively to reduce emissions at the lowest possible cost. Competitiveness is a key issue that must be addressed, since without maintaining competitive costs, the companies applying low-carbon technologies risk losing market share to companies with less stringent environmental standards. Developing an efficient and functioning market that promotes decarbonization is essential to balance these concerns, providing the right incentives for innovation and investment while safeguarding the industry's economic viability. These points are considered in the following subsections.

5.1 ECONOMIC EFFICIENCY

Cost reduction through energy efficiency

Energy consumption: Operational costs and energy consumption in Kazakhstan's metallurgical industry can be reduced by, on the one hand, implementing energy efficiency measures. These measures entail improved insulation and regular maintenance of equipment for minimizing energy wastage, among others. Additionally, integrating comprehensive **energy management systems** within metallurgical processes helps monitor, control, and optimize energy use across operations, ensuring that all processes run as efficiently as possible. An energy management system needs to include all aspects of metallurgy activities, and it helps the managers and engineers of a company make operational management decisions aimed at minimal consumption of necessary amount of fuel and energy resources and maximum efficiency, based on analytical information. Most companies introducing energy management systems reduce energy intensity by 2–3% yearly, and companies that only start to implement an energy management system can save up to 10–20% during the first two years of implementation.[43]

If a metallurgical company is in the initial process of introducing energy management systems, the mechanism of energy efficiency management lies within implementing best practices in energy supply systems, energy transportation and energy consumption, as well as management methods that do not require significant investments. The result of the introduction of these

[43] Fedorova, S. & Shemetov, Andrey & Chulynin, A. & Shestakova, I., (2016). Implementation of an energy management system in a mining and metallurgical enterprise complex as an effective way of ensuring its sustainable development. 531-539. 10.2495/SDP160441.

measures will be visible in a rather short time. Further development of efficiency increasing is followed by technological changes, such as using new energy sources (i.e., renewable energy) and the introduction of smart grids. These measures usually require large investments. The integration of renewable energy sources into metallurgical operations provides a sustainable way to reduce energy costs. Utilizing solar, wind, and other renewable energy sources decreases reliance on fossil fuels, leading to lower energy expenses. Implementing energy storage systems, such as batteries, ensures a stable energy supply and improves energy management, particularly when using intermittent renewable sources.

Government subsidies, incentives, and green financing options, like green bonds and low-interest loans, can help offset the initial investments required for the upgrades that have been mentioned above. Lastly, training programs to educate employees on energy-efficient practices and fostering a culture of energy conservation can drive behavioral changes that contribute to overall efficiency as well.

Technology upgrades: Decarbonizing the metallurgical industry in Kazakhstan requires substantial technology upgrades, including the adoption of electric arc furnaces (EAFs), which significantly reduce carbon emissions and energy consumption. An electric arc furnace uses electrical energy to heat and melt the raw materials for iron and steel. In the electric arc furnace process, recycled steel scrap or other iron-rich raw materials are charged into the furnace along with slag forming materials (slag is a by-product of smelting ores and recycled metals; mainly a mixture of metal oxides and silicon dioxide). Next, three large graphite electrodes send high-powered electric arcs (electric discharges) through the scrap, generating temperatures up to 1650ºC. At this temperature, the iron-rich, raw materials melt into liquid steel and a protective slag layer is formed. The main task of electric arc furnaces is to convert solid, iron-rich raw materials, such as steel scrap, direct reduced iron (DRI), and/or hot briquetted iron to liquid crude steel as fast as possible, to then be refined further in subsequent secondary steelmaking processes.

Some of the advantages of EAFs in comparison to their counterpart, blast furnaces, are that *i)* they are much smaller and cheaper to build, *ii)* their small size allows them to be built near the point of use, *iii)* they are highly efficient and automated and *iv)* they have much less environmental impact.[44]

Implementing hydrogen-based reduction processes, which use green hydrogen as a reducing agent instead of carbon-intensive coke, can further cut carbon emissions. Direct reduction of iron is the chemical removal (reduction) of oxygen from iron ore in its solid form. The iron used in the steelmaking process is currently chemically reduced from iron ore using fossil resources – natural gas or coal. This process is known as Direct Reduced Ironmaking (DRI). Carbon combines with the oxygen in the iron ore, producing metallic iron and a carbon-rich process gas. It is also possible to reduce iron ore using hydrogen instead of carbon; in this case the waste gas produced is water vapor, resulting in a low-carbon and environmentally friendly process. This

[44] Reibus, 2024. How an electric arc furnace works. Accessed via: https://reibus.com/reibusu/lessons/steelmaking/electric-arc-furnace/

process is more expensive (since fossil fuels, especially in an oil-producing country like Kazakhstan, are much cheaper than hydrogen), and if the hydrogen used in the reduction is green, the output will be a "green" metal, like green steel or green iron, which can be, due to environmental concerns, sold at a higher price than conventional metals.

On the other hand, in natural gas-based DRI production, hydrogen also plays a role in the reduction process, although in combination with carbon. GHG emissions from natural gas-based DRI production are lower than from the blast furnace route, with every tonne of DRI produced leading to the emission of 1.5 tonnes of CO_2.[45]

Additionally, integrating digitalization and smart technologies like AI and IoT for process optimization and energy management are important steps for energy efficiency in metallurgy. Artificial Intelligence can analyze vast amounts of data to identify inefficiencies and recommend improvements, leading to more precise control over production processes and energy usage. IoT devices can provide real-time monitoring and analytics, allowing for proactive maintenance of equipment and reducing downtime. Metallurgical operations can achieve greater precision in energy management through the integration of these technologies, optimize resource allocation, and enhance overall productivity. These advancements are not only able to improve operational efficiency but also contribute to reductions in energy consumption and carbon emissions from the metallurgical industry.

Waste heat recovery: Waste heat recovery in the metallurgical industry involves capturing and reusing the excess heat generated during various high-temperature processes, such as smelting, refining, and casting. Implementing waste heat recovery systems can enhance energy efficiency by converting this otherwise lost energy into useful power, steam, or heat for other processes. Technologies like recuperators, regenerators, and heat exchangers are employed to capture and repurpose this heat. This not only reduces the overall energy consumption and operational costs but also lowers greenhouse gas emissions, contributing to a more sustainable and environmentally friendly metallurgical industry.

The economic efficiency of a functioning carbon market lies in its ability to reduce greenhouse gas emissions at the lowest possible cost. By creating a market-driven mechanism where carbon credits can be traded, it incentivizes companies to innovate and invest in cleaner technologies. Firms that can reduce emissions at lower costs can sell their excess allowances to those facing higher abatement costs, thus ensuring that overall emissions reductions are achieved more cost-effectively. This flexibility allows for the optimal allocation of resources, as the market identifies and exploits the most cost-efficient opportunities for emissions reductions. Furthermore, a well-designed carbon market encourages long-term investment in sustainable practices and technologies, promoting continuous improvement and economic growth within an environmentally sustainable framework.

[45] World Steel, 2024. Fact sheet: Hydrogen (H2)-based ironmaking. Accessed via: https://worldsteel.org/wp-content/uploads/Fact-sheet-Hydrogen-H2-based-ironmaking.pdf

Resource efficiency

Improving the development of low-carbon metallurgy involves focusing on material use, recycling, and process optimization. These strategies not only reduce carbon emissions but also enhance economic efficiency and resource sustainability.

Material use: The selection and utilization of raw materials play a crucial role in reducing the carbon footprint of metallurgical processes. Using high-grade ores and low-carbon raw materials can significantly decrease the emissions generated during metal production. Additionally, incorporating alternative materials such as biomass or hydrogen instead of carbon-based fuels in metallurgical processes can further lower CO_2 emissions. For example, the use of hydrogen in steel production, (hydrogen direct reduction), is a promising technology that can substantially cut down on carbon emissions compared to traditional blast furnace methods.

Recycling: Recycling scrap metals is a highly effective way to reduce the environmental impact of metal production. It requires significantly less energy compared to extracting and processing virgin ores. Establishing efficient collection and sorting systems for scrap metals ensures a steady supply of recyclable materials, thereby minimizing the need for new raw materials and reducing greenhouse gas emissions. The use of electric arc furnaces (EAF), which can utilize scrap steel, is an example of how recycling can be integrated into low-carbon metallurgy practices.

Process optimization: Optimizing metallurgical processes through technological advancements and best practices is essential for reducing carbon emissions. Implementing energy-efficient technologies, such as advanced control systems and heat recovery mechanisms, can significantly cut down on energy consumption and associated emissions. Additionally, process innovations like carbon capture and storage (CCS) can capture emissions from metallurgical processes before they are released into the atmosphere. Continuous improvement in process monitoring and optimization helps in identifying inefficiencies and areas for improvement, leading to more sustainable operations.

Economies of scale

Achieving economies of scale is also an important factor for decarbonizing Kazakhstan's metallurgy sector. Large-scale production facilities can spread the fixed costs of implementing advanced low-carbon technologies, such as electric arc furnaces and hydrogen-based reduction processes, over a higher output, thereby reducing the cost per unit of production. This approach not only makes the adoption of these technologies more financially viable but also enhances overall operational efficiency. Bulk purchasing of renewable energy, raw materials, and other essential inputs can further drive down costs, making sustainable practices more economically attractive. Additionally, larger facilities can justify the investment in sophisticated energy management systems and waste heat recovery technologies, which further improve energy efficiency and reduce carbon emissions.

The benefits of economies of scale extend to R&D and innovation. Larger companies or conglomerates within the metallurgical sector can invest more substantially in R&D, leading to breakthroughs in low-carbon technologies and processes. This investment can result in more effective and efficient decarbonization solutions, which can then be deployed across the industry at a lower cost. Furthermore, large-scale operations are better positioned to form public-private partnerships and attract government incentives and subsidies, further enhancing their capacity to implement decarbonization measures.

5.2 COMPETITIVENESS

Innovation and technological leadership

R&D investment: Investments in research and development are important for decarbonizing Kazakhstan's metallurgy sector. These investments should focus on advancing low-carbon technologies such as electric arc furnaces, hydrogen-based reduction processes, and carbon capture and storage. R&D fosters innovation and can lead to the development of more efficient and cost-effective methods for reducing greenhouse gas emissions. Collaborations between government, industry, and academic institutions can drive these advancements, ensuring that the latest scientific and technological breakthroughs are effectively applied within the sector. Additionally, targeted R&D funding can help overcome technical and economic barriers, making sustainable practices more accessible and scalable.

Patents and intellectual property: Patents and intellectual property can play a role in decarbonizing Kazakhstan's metallurgy sector by protecting and incentivizing innovation in low-carbon technologies. By securing patents for advancements such as electric arc furnaces, hydrogen-based reduction processes, and carbon capture and storage, companies can safeguard their investments and gain a competitive edge. This protection encourages further R&D by ensuring that innovators can benefit from their inventions. Additionally, intellectual property can facilitate technology transfer and collaboration, as companies can license their technologies to others, accelerating the dissemination and adoption of cutting-edge solutions across the industry. Effective intellectual property management ensures that breakthroughs in decarbonization are both rewarded and widely implemented.

Cost Competitiveness

Operational efficiency: Operational improvements offer another effective avenue for reducing costs and energy consumption in metallurgical processes. Streamlining production processes through automation and advanced control systems supports the enhancement of efficiency and lowers resource consumption, and adopting lean manufacturing principles minimizes waste and boosts productivity, directly impacting operational costs. One of the primary goals of lean manufacturing is to eliminate waste by minimizing inventory levels and ensuring efficient raw material sourcing. In the metallurgy industry, raw materials such as alloy, aluminum, steel, and titanium being crucial, optimizing the sourcing and inventory management process can lead to significant cost savings and enhanced production efficiency. For example, a metallurgy company may implement lean manufacturing principles by establishing strategic partnerships with key suppliers. Working closely with suppliers to improve communication and streamline the ordering process can help the company reduce lead times and minimize stockouts.

Supply chain management: Enhancing supply chain efficiency, including the sourcing of raw materials and logistics, can lower production costs and improve competitiveness. Effective supply chain management is essential for enhancing the cost competitiveness of a decarbonized metallurgical industry. The optimization of logistics and transportation routes can greatly reduce emissions and transport costs. Strategic sourcing of raw materials from local or regional suppliers can further lower costs and decrease the carbon footprint associated with long-distance transportation. Implementing just-in-time inventory practices reduces waste and storage costs, while digital supply chain solutions, such as blockchain and IoT, enhance transparency and efficiency.

Process decarbonization while keeping cost competitiveness in final products is not a trivial issue. Decarbonization efforts in the metallurgical sector entail high costs and some companies might be reluctant to introduce these changes, by fear of increasing final product costs and therefore losing market share. Some studies, however, state that it is possible and, moreover, beneficial for companies to enter early in the decarbonization process for keeping and even gaining a competitive edge. Incumbent companies that have created value through decarbonization have focused on the following three key areas of action:[46]

Decarbonize and improve cost competitiveness. Companies that reduce costs and emissions simultaneously can gain market share and finance further decarbonization efforts through the additional cash generated. Combining cost savings with carbon reduction efforts can boost a company's market share. With rising sustainability demands from both public and private sectors, organizations that lead in decarbonization may secure early contracts in emerging markets and generate revenue more quickly than their competitors. However, this early-mover advantage is likely to diminish as others catch up. Leading companies in the international context typically go after the first 20 to 40 % of decarbonization while also reducing costs, leading to an improvement in EBITDA.

- As an example of additional cash that can be generated by being an early mover in decarbonization efforts, Tesla's focus on electric vehicles (EVs) has positioned it as a leader in the decarbonization of transportation. In addition to generating revenue from car sales, Tesla benefits from selling regulatory credits to other automakers who need to meet emissions targets, which has become a significant revenue stream for the company. Governments provide regulatory credits to vehicle manufacturers, who must produce a specified number of zero-emission vehicles to earn these credits. If they don't meet the requirements by year-end, they face substantial fines. Tesla, with its all-electric lineup, accumulates surplus credits. These credits are tradable, so other automakers purchase them from Tesla to avoid hefty fines.

[46] McKinsey, 2023. Decarbonize and create value. Accessed via: https://www.mckinsey.com/capabilities/sustainability/our-insights/decarbonize-and-create-value-how-incumbents-can-tackle-the-steep-challenge

    - Launch net-zero offerings. Companies that are quick to offer zero-carbon offerings can leverage inherent supply–demand gaps in nascent markets and create value through value-based pricing strategies and price premiums.
    - Enter new value pools. Companies that build new businesses along the current value chain and tap adjacent value pools have an opportunity to secure early demand for net-zero offerings and benefit from low-cost financing.
- Companies who embark in decarbonization are already seeing results, with up to 40% reductions in emissions and up to a 15% improvement in financial performance simultaneously.[46] By 2030, incumbents will be able to abate, on average, 20% to 40% of emissions while also reducing production costs. Reductions in production costs could be driven by energy efficiency, sourcing green energy, and variable cost reduction of the manufacturing. Reducing costs and carbon simultaneously can also free up cash to invest in new business opportunities that emerge from the ongoing net-zero transition.

Market differentiation

Market differentiation through green branding and premium pricing can be a useful strategy for decarbonizing Kazakhstan's metallurgy sector. Through the adoption and promotion of sustainable practices, metallurgical companies can distinguish themselves from competitors, appealing to environmentally conscious consumers and businesses. Green branding involves marketing products as eco-friendly and highlighting the company's commitment to reducing carbon emissions and environmental impact. This approach can enhance the company's reputation, attract new customers, and build loyalty among existing ones who prioritize sustainability. Effective green branding can also open new markets and business opportunities, particularly with international clients who adhere to strict environmental standards.

Premium pricing is another key aspect for market differentiation. By offering products that are certified as low-carbon or produced using sustainable methods, companies can justify higher prices due to the added value of environmental responsibility. Customers, especially in developed markets, are often willing to pay more for low-carbon products. This premium can offset the additional costs associated with implementing green technologies and practices, making decarbonization financially viable. Moreover, premium pricing can lead to higher margins, providing additional funds for further investments in sustainable innovations.

5.3 MARKET DEVELOPMENT

Demand for low-carbon products

Growing global demand for low-carbon products, driven by stringent climate policies and increasing consumer preferences for sustainability, creates significant market opportunities. The global market for low-carbon metallurgy products from Kazakhstan is showing promising trends due to the rising demand for sustainable and eco-friendly materials. Internationally, there's a growing emphasis on reducing carbon emissions in the steel and metallurgical industries, driven by stringent environmental regulations and a shift towards greener production practices.

Kazakhstan's metallurgy sector should capitalize on this trend by integrating advanced low-carbon technologies and enhancing its production processes to meet global standards. The adoption of recycling methods, carbon capture and storage, integration of more renewable sources of energy and other decarbonization techniques are crucial for maintaining competitiveness in the international market. As more countries and corporations prioritize sustainability, the demand for low-carbon metallurgical products is expected to increase, presenting Kazakhstan with significant export opportunities.

Industries such as automotive, construction, and electronics are increasingly seeking low-carbon materials to meet their own sustainability goals and regulatory requirements. The automotive industries are seeking for lightweight aluminium, advanced high-strength steel and bio-based plastics which are produced using low-carbon technologies and are part of circular economy (by being recycled).[47] [48] One example is Ford company's use of aluminum in the body of the F-150 pickup truck. The automotive sector is transitioning to electric vehicles (EVs), which require lightweight, low-carbon materials to improve efficiency and reduce overall emissions. Sustainable sourcing of lithium, cobalt and nickel is a growing focus for battery materials for the auto industry.

Furthermore, the construction industry is seeking concrete and cement produced by low-carbon production process and with alternative binders like fly ash and slag. Low carbon steel, glass and asphalt are a few other materials for this industry[49]. One example is the adoption of Kenoteq's K-Briq, which is a carbon-negative brick made from 90% construction waste. Unlike traditional bricks, which require high temperatures to cure, the K-Briq does not need to be fired in a kiln, significantly reducing energy consumption and carbon emissions.

Similarly, the renewable energy sector demands large quantities of low-carbon metals to produce wind turbines and solar panels, essential for building a sustainable energy infrastructure. The electronic industry is increasing its use of recycled and bio-based circuit boards, plastics and battery materials similar to automobile industry[50]. A further example is that of the technology giant, Apple, using recycled aluminum in its product designs.

[47] Novelis, 2021. Construir un automóvil sin emisiones de carbono: cómo los materiales circulares pueden ayudar a la industria automotriz a cumplir sus objetivos climáticos. Accessed via: https://zh-hans.novelis.com/building-the-zero-carbon-car-with-circular-material/

[48] S&P Global Mobility. Autos and Sustainability: From Compliance to Leadership. Accessed via: https://www.spglobal.com/mobility/en/research-analysis/autos-and-sustainability-from-compliance-to-leadership.html

[49] Access, 2024. Low Carbon Building Materials in Construction. Accessed via: https://www.theaccessgroup.com/en-gb/blog/con-low-carbon-building-materials-in-construction/

[50] AB Notebook, 2023. Accessed via: https://www.abnotebook.com/a/9325

In summary, the demand for low-carbon metallurgical materials is growing across several sectors due to increasing environmental awareness and regulatory pressures such as sustainability goals like net-zero emissions.

International demand for low-carbon metallurgy products is expected to develop during coming years and decades; with demand growth being driven by several key factors:

1. Regulatory pressure and policies: Governments worldwide are increasingly implementing stringent environmental regulations to curb carbon emissions. Policies such as the EU's Carbon Border Adjustment Mechanism (CBAM) will compel producers to adopt low-carbon practices to remain competitive in global markets.
2. Technological innovations: Advances in metallurgical technologies, including the development of hydrogen-based steel production and carbon capture and storage (CCS) techniques, are making it more feasible and cost-effective to produce low-carbon metals. These innovations are crucial for meeting the growing demand for sustainable materials.
3. Industry commitments and investments: Major companies in the steel and aluminium industries are committing to carbon neutrality goals and investing heavily in low-carbon technologies. For instance, ArcelorMittal and SSAB are leading initiatives to develop fossil-free steel, which is anticipated to gain substantial market share as these technologies mature.
4. Consumer Demand: There is a rising demand from consumers and businesses for sustainable products. This trend is particularly evident in sectors such as automotive, construction, and electronics, where end-users are increasingly prioritizing sustainability in their purchasing decisions.[51]
5. Economic Incentives: The financial benefits of adopting low-carbon practices, including potential tax breaks, subsidies, and the growing market for carbon credits, are encouraging more companies to transition to greener production methods. This economic shift is expected to further drive the adoption of low-carbon metallurgy products.

Government policies and incentives

To advance low-carbon metallurgy in Kazakhstan, the government needs to implement a comprehensive policy framework that includes both **regulatory measures** (such as public procurement policies favouring green products) **and financial incentives** (such as tax breaks, subsidies, and grants for low-carbon technology investments). First, establishing strict emissions standards for metallurgical processes and mandating the adoption of cleaner technologies is crucial. These regulations should be complemented by a robust monitoring and reporting system to ensure compliance. Additionally, the government should provide tax breaks, subsidies, or

[51] Centre on Global Energy Policy, Colombia University, 2021. Low-Carbon Production of Iron & Steel: Technology Options, Economic Assessment, and Policy. Accessed via: https://www.energypolicy.columbia.edu/publications/low-carbon-production-iron-steel-technology-options-economic-assessment-and-policy/

grants for companies investing in low-carbon technologies and practices, thereby reducing the financial burden of transitioning to greener operations. Such financial incentives can spur innovation and make sustainable practices more economically viable for businesses.

Second, a well-designed carbon pricing strategy within the ETS will incentivize companies to reduce their carbon footprint by making emissions reductions financially attractive. Revenue generated from carbon pricing can be reinvested into research and development for low-carbon technologies and infrastructure improvements. Moreover, establishing a green financing framework, which includes green bonds and climate funds, can attract both domestic and international investments into Kazakhstan's low-carbon metallurgy sector.[52]

Finally, fostering public-private partnerships and international collaborations is essential. The government should work closely with industry stakeholders, research institutions, and international organizations to develop and implement best practices in low-carbon metallurgy. Knowledge transfer and capacity building through such collaborations can enhance the technical expertise required to implement advanced low-carbon technologies. Furthermore, aligning Kazakhstan's policies with global sustainability standards will not only improve the competitiveness of its metallurgy sector but also attract foreign investment. Initiatives such as the "De-risking renewable energy investments"[53] project, supported by the UNDP and the Global Environment Facility, can serve as models for similar programs aimed at promoting low-carbon metallurgical practices.

Renewable energy deployment

Renewable energy (RE) deployment targets in Kazakhstan will play a pivotal role in fostering a market for low-carbon metallurgical solutions and products, ensuring sustained development and investment in this sector. Firstly, by setting clear and ambitious RE targets, such as attaining a 15% share of renewable energy in total electricity production by 2030[54], Kazakhstan signals its commitment to decarbonization, which attracts both domestic and international investors looking for stable and promising markets. This policy certainty reduces investment risks and encourages the private sector to develop and deploy renewable energy technologies.[52]

These targets help in creating a robust demand for low-carbon energy solutions, driving the growth of associated industries and technologies. This stimulates the development of local supply chains and expertise in low-carbon metallurgy and other related fields, contributing to economic diversification and job creation.[5]

[52] UNDP, 2022. Kazakhstan boosts its renewable energy investment system. Accessed via: https://www.undp.org/kazakhstan/stories/kazakhstan-boosts-its-renewable-energy-investment-system

[53] UNDP, 2020. Derisking renewable energy investment. Accessed via: https://www.undp.org/publications/derisking-renewable-energy-investment

[54] Kazakhstan Law Review, 2023. Practical cross-border insights into renewable energy law Renewable Energy 2023. Accessed via: https://kazlawreview.kz/practical-cross-border-insights-into-renewable-energy-law-renewable-energy-2023/

Moreover, RE deployment targets align with global sustainability goals, enhancing Kazakhstan's position in international markets and trade partnerships. As global markets increasingly favor environmentally responsible and low-carbon products, Kazakhstan will benefit from a stronger focus on renewable energy, since this ensures that its metallurgical and industrial products can meet these evolving standards. This not only boosts the competitiveness of Kazakh products but also opens new export opportunities, fostering a continuous market for low-carbon energy solutions.

5.3.1 Impacts of the EU's carbon border adjustment mechanism (CBAM)

In relation to market development of low-carbon metallurgical products to the European Union particularly, the newly created Carbon Border Adjustment Mechanism (CBAM) needs to be carefully assessed. The EU introduced the CBAM officially in May 2023. The transitional phase started on 1 October 2023 and will end on 1 January 2026 after which CBAM will start with financial implications. CBAM is a carbon regulation, a type of carbon pricing, to support lowering carbon emissions in the EU. While the existing EU Emissions Trading System (ETS) covers EU countries, the CBAM applies to goods produced outside the EU by introducing a fee to importers of these goods which might have been produced in countries with less stringent carbon policies. This will have an impact on the metallurgical products that are exported to the EU from Kazakhstan, particularly on aluminum.

The carbon price under the CBAM will, according to CBAM regulations in place, be linked to the price of carbon in the EU Emissions Trading System (EU ETS), which is a cap-and-trade system for greenhouse gas emissions and is the cornerstone of the EU's policy to combat climate change and promote low-carbon investment. It is the world's first and largest carbon trading system, covering around 45% of the EU's greenhouse gas emissions from more than 11,000 heavy energy-using installations (power stations, combustion plants, oil refineries, coke ovens, and factories in energy-intensive industries) and airlines that operate between participating ETS countries.

The price of carbon allowances in the EU ETS fluctuates (currently above 60 Euro per t CO_2) based on supply and demand dynamics, and it is influenced by various factors, including policy decisions, market expectations, and the overall economic environment.

Imported goods from foreign producers will be subject to a carbon tax which would correspond to the hypothetical participation of these producers in the European Emissions Trading System (ETS). Thus, the carbon footprint of products imported into the EU should be subject to the same price as it is for European producers. If the exporting country already has an emissions trading system, the national carbon price will be deducted from the price prevailing at the time the product is imported across the EU border. This mechanism allows Kazakhstan to avoid losses from CBAM if producers-exporters participate in the national ETS with carbon prices comparable to those of the EU. It is important to note that while Kazakh producers will in any case face additional costs from high-carbon production, the advantage of a higher price under the national ETS is to receive revenue from the ETS within the country that could be used for instance to support the decarbonization of the Kazakh industry, whereas in the case of CBAM, these revenues will be received by the European Union to be utilized for (i) supporting Green Development within the EU; (ii) assisting least developed countries for decarbonization and (iii) investing in low-carbon technologies R&D.

The level of CBAM in percentage terms varies depending on the carbon intensity of production but remains significant for Kazakhstan's main export goods. Around 45% of Kazakhstan's total goods exports by value go to the EU. The vast majority is crude oil (41%), although crude oil is not likely to be covered by the CBAM in the near-term.[37] Aluminum production accounts for nearly all of Kazakhstan's covered exports to the EU, and is highly exposed to CBAM impacts, with nearly 30 % of exports going to the EU (exports worth nearly US$200 million a year). The emissions intensity of Kazakhstan's production of non-ferrous metals (including aluminum), at 615 tCO2e/Million USD, is much higher than other major exporters: the EU 122 tCO_2e/million USD and China at 489 tCO2e/Million USD.[37] If the CBAM is broadened, it would impact petroleum products, which constitute 25% of annual exports, totaling over US$1 billion to the EU. Additionally, chemicals and iron and steel products are at risk. While some items from these sectors are currently covered by the proposal, certain exports from Kazakhstan, such as ferro-alloys, are currently exempt but may be included in future expansions.[55]

The World Bank modelling[52] has found the CBAM will hit some industries particularly hard, so targeted support may be needed to transition these sectors to lower-emissions production, different products or alternative markets. It also concluded, "Kazakhstan's exports to the EU of covered products could be impacted by nearly US$1.8 billion if the CBAM is expanded, compared with a baseline with no CBAM. The impact is much greater for some sectors than others. Under the 'Current proposal', exports of iron and steel ('ferrous metals') could be 38% lower by 2035, and more than 65 per cent lower, a loss of nearly $650 million in value, under an 'Expanded CBAM'. Under the current proposal exports to the EU of aluminium could be 4 per cent lower, representing a loss of nearly $60 million. This impact is much higher – 16 per cent and over $250 million – under an 'Expanded CBAM'. Petroleum products and chemicals also face declines of nearly 30 per cent where they are covered ('Expanded CBAM')."

Text Box 2: CBAM operation from 2026 onwards

Starting in 2026, the CBAM will operate as follows:

- Goods will be imported into the Customs Territory of the Union (TAU) only by an authorized declarant for CBAM purposes. EU importers of CBAM-covered goods register with national authorities, where they can also purchase CBAM certificates at a price based on weekly emissions allowances - ETS (expressed in €/tonne of CO2 issued). The CBAM will ensure that the carbon price of imports is equivalent to the

[55] State regulation of greenhouse gases in the Republic of Kazakhstan, ECOJER, 2024

carbon price of domestic production, and that the EU's climate targets are not undermined. The CBAM is designed to be compatible with WTO rules.

- The EU importer must declare by May 31 of each year the quantity of products imported into the EU in the previous year and the emissions embodied in those products. Simultaneously, the importer will present the number of CBAM certificates that corresponds to the amount of GHG emissions incorporated into the products. The phasing out of the free allocation under the ETS will take place in parallel with the phasing in of the CBAM in the period 2026-2034. If importers can demonstrate that a carbon price has already been paid during the production of the imported goods, the corresponding amount can be deducted from their final invoice.

Source: Spanish Tax Agency, 2024 [56]

Projections for the future of the EU ETS are subject to various factors, including policy decisions, technological advancements, and global economic conditions. However, some general trends and projections can be outlined:

- Carbon Price Increase: The carbon price is expected to rise over time due to the decreasing cap and the increasing scarcity of allowances. This is intended to drive investment in low-carbon technologies and energy efficiency. It is estimated that the carbon price will continue to rise in the European Union ETS until 2035, reaching US$ 142.3 per ton, after which it will stabilize This is one possible scenario and that rising CO_2 prices are generally expected. It is believed that the 142.3 Euro here suggests more precise knowledge of the future than we have.
- CBAM Integration: The introduction of the Carbon Border Adjustment Mechanism (CBAM) is expected to work in tandem with the EU ETS to ensure that imported goods are subject to similar carbon costs as domestically produced goods, thereby preventing carbon leakage.
- International Alignment: The EU may seek to align its carbon pricing with international efforts, potentially linking with other carbon markets or influencing the design of carbon pricing mechanisms in other jurisdictions.
- Technological Innovation: The EU ETS is likely to continue driving technological innovation as companies seek to reduce their carbon footprint and comply with the system's requirements.

It is important to note that these projections are based on the current state of policy and market conditions. Any changes in legislation, international agreements, or unforeseen economic events could significantly impact on the future trajectory of the EU ETS. For the most current projections and developments, it is advisable to consult the latest reports from the European

[56] Spanish Tax Agency, 202. CBAM. Accessed via: https://sede.agenciatributaria.gob.es/Sede/en_gb/aduanas/prohibiciones-restricciones-operaciones-comercio-exterior-carbono/mecanismo-ajuste-frontera-carbono/funcionamiento-cbam.html

Commission, environmental agencies, and financial institutions that specialize in climate policy and carbon markets.

5.3.1.1 Requirements to apply to CBAM

As of January 1, 2026, only authorized declarants can import CBAM goods into the EU. Companies importing CBAM-covered goods can apply for the status of authorized CBAM declarants from December 31, 2024.[57]

The national competent authority in the Member State in which the applicant is established shall grant the status of authorized CBAM declarant. To be approved by the competent authority, an applicant company must meet the following criteria:

- The applicant has not been involved in a serious infringement of customs legislation, taxation rules and/or market abuse rules.
- It demonstrates the financial and operational capacity to fulfill CBAM obligations.
- It is established in the Member State where the application is submitted.
- It has been assigned an (Economic Operators Registration and Identification) EORI number.
- To prove "operational capability" to fulfill CBAM obligations, it will be important that companies have necessary operational and legal measures in place before then. For the transition phase up to December 31, 2025, an Indirect Customs Representative can be used as substitute for a CBAM Declarant.

The EU Commission has published all details about CBAM in their website.[58] They have also a program to assist developing countries, like Kazakhstan, for CBAM guidance and technical support for green transition.[59]

For countries in the EU's neighbourhood, there exist numerous specific initiatives and projects with CBAM relevance. Examples of regional/bilateral programs in the EU neighbourhood, which could be accessible to Kazakhstan:

[57] Dentons, 2024. The EU Carbon Border Adjustment Mechanism (CBAM) applies now. Access via: https://www.dentons.com/en/insights/articles/2024/february/21/the-eu-carbon-border-adjustment-mechanism-cbam-applies-now

[58] European Comission,2024. Carbon Border Adjustment Mechanism. Accessed via: https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism_en

[59] European Commission, 2024. CBAM and developing countries/LDCs. Accessed via: https://taxation-customs.ec.europa.eu/document/download/7abe56cc-4af0-490d-90e1-0a0825aabe37_en?filename=CBAM%20and%20developing%20countries.pdf

- EU4Energy:[60] Promoting the clean energy transition and empowering consumers through better regulation in Eastern Partnership countries.
- EU4Climate:[61] Aiding governments in the six EU Eastern Partner countries (Armenia, Azerbaijan, Belarus, Georgia, the Republic of Moldova and Ukraine) to take action against climate change and towards a low-emissions and climate-resilient economy.
- Energy Community:[62] Supporting member countries of the Energy Community to adapt to CBAM.

[60] EU Neighbours East, 2024. EU4Energy-Promoting the Clean Energy Transition-Empowering Consumers through Better Regulation. Accessed via: https://euneighbourseast.eu/projects/eu-project-page/?id=1508

[61] European Union, 2024. EU4 Climate webpage. Accessed via: https://eu4climate.eu/

[62] Energy Community, 2024. CBAM readiness. Accessed via: https://www.energy-community.org/implementation/package/CBAM.html

6 APPLICABILITY OF BEST AVAILABLE TECHNOLOGIES AND ENERGY EFFICIENCY MEASURES

Decarbonizing the metallurgy industry poses several challenges due to the carbon-intensive nature of their processes. Their reliance on fossil fuels for energy and the use of carbon as a reducing agent in smelting contribute to high carbon emissions. Additionally, the environmental impact of metallurgical activities, such as air and water pollution, further underscores the need for decarbonization. Regulatory pressure from governments and increasing consumer demand for sustainable products also drive the industry towards adopting cleaner technologies.

The World Economic Forum[63] acknowledges that "efforts are underway worldwide towards Net-zero commitments. Decarbonization strategies, technology partnerships, low-carbon pilot projects, and discussions around green products and premiums have emerged. However, most transformative technologies are either yet to be proven at full commercial scale or too costly compared to existing alternatives. They are only expected to reach commercial readiness after 2025".

A considerable degree of progress has been made in adopting decarbonization technologies by the world metallurgy sector. As for example, green steel has a great leap forward according to Wood Mackenzie[64], "The ESF (Electric Smelting Furnace) technology has emerged as a possible solution to bridge the technological gap in the use of low- and medium-grade ores for green direct reduced iron (DRI). The ESF converts DRI into liquid hot metal and integrates low-carbon DRI plants seamlessly with existing basic oxygen furnace (BOF) steelmaking facilities, potentially reducing capex, operational complexity, and project execution time. Watch for results as Voestalpine starts their first industrial pilot plant in 2024 and Thyssenkrupp firms up plans for their industrial 2.5 Mtpa ESF facility. We expect another dozen ESF project announcements in 2024, unlocking the green steel projects pipeline and potentially changing the narrative on steel's ultimate decarbonization pathway".

The objective of this section is to provide an overview of the technological decarbonization options in the metals sector, specifically in the iron and steel sector and in the aluminum industries. To this end, the individual technology options will be identified, described and specific

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[63] WEF, 2022. Netzero industry tracker. Accessed via: https://www3.weforum.org/docs/WEF_NetZero_Industry_Tracker_2022_Edition.pdf

[64] Wood Mackenzie, 2024. Metals outlook. Accessed via: Wood Mackenzie Metals and mining - Things to look for in 2024.pdf

performance indicators will be given. In addition, opportunities and barriers to the implementation of these new technologies are discussed.

The best available technologies/techniques are discussed here with their possible applicability in Kazakhstan metallurgical industries and their status worldwide. The benefits of these technologies are huge. Quantifying them in the metallurgy industry can be complex, as it involves various factors such as the specific context, scale of operations, regional energy costs, technological advancements, and so on and often requires a case-by-case analysis. To get accurate quantitative benefits, a detailed analysis of the current operations, energy use, and potential improvements would be necessary. However, some general examples of how these measures can lead to quantitative benefits are provided below for each measure. BAT's international status for steel and aluminum industries are illustrated at the end of this section.

A. Electrification of processes using renewable energy

Electrification offers pathway to decarbonize metallurgical processes by replacing fossil fuels with electricity ideally generated from renewable or low-carbon sources. Here are several aspects of how electrification can be implemented in the metallurgy industry as part of decarbonization efforts. As technology advances and costs decrease, the electrification of metallurgical processes will become increasingly viable and essential for decarbonizing the industry.:

(i) Steel: Steel production involves producing iron from ore and then converting iron into steel, which can be accomplished via various routes (a) BF-BOF (Blast Furnace – Basic Oxygen Furnace) route, which is a traditional route; (b) DRI-EAF (Direct Reduced Iron – Electric Arc Furnace) route; (c) Scrap-EAF (Scrap-Electric Arc Furnace); (d) DRI+ESF-BOF (Electric Smelting Furnace – Basic Oxygen Furnace) route; (e) Direct reduced iron (DRI) using hydrogen or natural gas; (f) Electrolysis processes: Electrowinning and molten oxide electrolysis (MOE). Electric arc furnaces (EAF) in steel production use electricity to melt scrap steel, eliminating the need for coal or coke. By switching to an EAF for steel production, a mill might reduce its CO_2 emissions by 50% compared to a basic BF-BOF route. If the mill previously emitted 1 million tons of CO_2 annually, it could now emit only 500,000 tons, potentially saving on carbon taxes or credits. Since EAF is a matured technology, Kazakhstan may consider this as soon as possible, if they have not done yet.

(ii) Aluminum: The aluminum industry is exploring more efficient electrolysis technologies, such as inert anode technology, to reduce the carbon footprint of aluminum production. This is done by replacing carbon anodes, which are consumed in the traditional Hall-Héroult process, with non-consumable anodes made from various ceramics, titanium boride (TiB_2), and other refractory metals or compounds. Traditional Hall-Héroult process involves electrolytic reduction of alumina (Al_2O_3) to aluminum in a molten bath of cryolite (Na_3AlF_6) using carbon anodes. The carbon anodes are consumed during the reaction, leading to the production of carbon dioxide (CO_2) and carbon monoxide (CO), contributing to the industry's substantial carbon footprint, while the inert anodes are resistant to oxygen and hence no production of greenhouse gases. The inert anodes method has lower energy consumption[65] and produces better quality aluminum. However, high cost of developing and implementing new materials, ensuring the long-term stability and durability of inert anodes under smelting conditions, and addressing potential technical and operational issues that may arise in full-scale production are preventing its widespread acceptance. The status of this anode technology is still in infancy. Alcoa Corporation has been exploring a new smelting process that uses an inert anode to eliminate the production of greenhouse gases during the aluminum smelting process. So, Kazakhstan may collaborate with those companies who are testing this technology or set up its own R&D cell to test it.

(iii) Copper and other non-ferrous metals: Electrowinning and electrorefining are two electrochemical processes widely used in the metallurgy industry for the extraction and purification of metals, respectively. Both processes rely on the principle of electrolysis. Both electrowinning and electrorefining can be powered by renewable electricity, significantly reducing their carbon footprint.

(iv) Changing fossil fuel powered machineries and heavy transport vehicles to renewable electric powered is also a part of decarbonization process. This shift involves not only the development of electric vehicles (EVs) and machinery but also the expansion of renewable energy sources to power them. This change may not be accomplished overnight, so gradual change would be applicable for Kazakhstani companies as more and more renewables are added to the mix of energy.

Overall, the benefits of electrification include lower emissions, higher energy efficiency, and flexibility in sourcing renewable electricity.

B. Energy efficiency

Enhancing the energy efficiency of furnaces and other equipment can significantly reduce energy consumption and emissions. This includes using advanced process controls, heat recovery systems, and more efficient combustion technologies. It requires a comprehensive approach of:

I. Energy audits:

   a. Identify areas of energy waste and inefficiency, allowing them to prioritize energy-saving measures;

   b. Implement ISO 50001 energy management systems to establish energy performance indicators and set improvement targets.

II. Energy-efficient equipment:

   a. Equip furnaces with efficient control system to reduce energy consumption. Furnaces are critical components used for melting, refining, and alloying metals. An efficient control system for these furnaces is essential to ensure optimal performance, energy efficiency, and safety. It is assumed Kazakhstan metallurgical industries' furnaces are equipped with control system that include

[65] https://www1.eere.energy.gov/manufacturing/resources/aluminum/pdfs/dyninertmetanodes.pdf

PLC (Programmable Logic Controllers), process parameters controls, HMI (Human Machine Interface) and standard communication protocols. Here are some key elements and technologies that can be integrated into a control system for furnaces in the metallurgy industry for advanced control system:

- Advanced Process Control (APC) systems optimize furnace operations in the metallurgy industry by using sophisticated algorithms and real-time data to make precise adjustments to the process variables.
- Energy Management Systems: These systems optimize energy consumption by controlling the furnace's heating elements and ensuring that energy is used efficiently. They can also help in complying with environmental regulations. The cost can range from a few thousand to tens of thousands of dollars, depending on the complexity and coverage of the system.
- Automation, Robotics and AI: Automation can reduce the need for manual intervention, increasing efficiency and safety. Robotics can be used for tasks such as loading and unloading materials from the furnace. AI can help in identifying patterns and making data-driven decisions to improve furnace performance.
- Environmental Controls: To reduce emissions and comply with environmental regulations, control systems can include features to manage the combustion process and treat exhaust gases.

b. Upgrade to high-efficiency motors, pumps, and fans to reduce electricity consumption;

c. Use energy-efficient lighting and HVAC systems in facilities.

The scale of investment is not that high for process control ranging from few thousands to hundreds of thousands dollars. However, if existing furnace is to be replaced then the cost will be up to millions. A steel plant might reduce its energy consumption by 10% through the installation of a new, more efficient furnace control system. If the plant's annual energy bill was $10 million, this could translate into savings of $1 million per year.

III. Waste heat recovery systems capture and reuse excess heat generated during production processes, further reducing energy consumption and costs and minimising waste. It is done by:

a. Installing heat recovery systems to capture waste heat from furnaces and use it for other processes or to generate electricity;

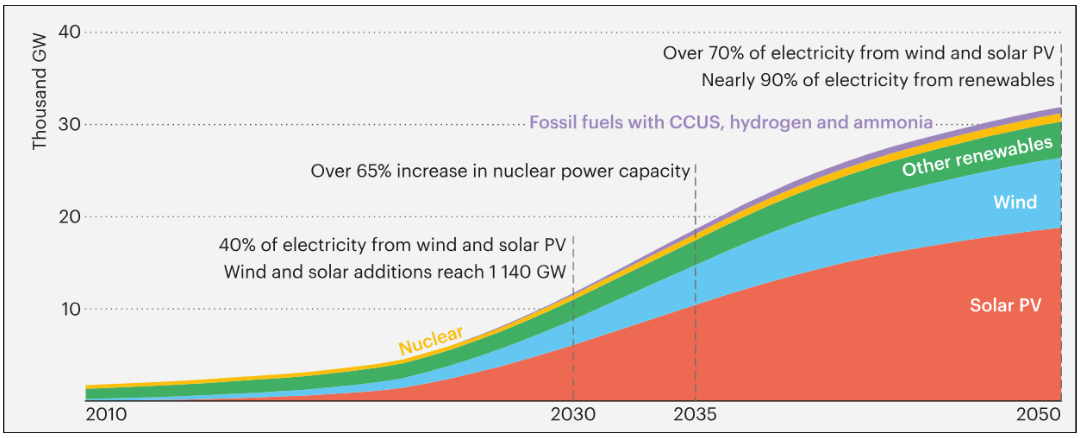
b. Implementing cogeneration or combined heat and power (CHP) systems to improve energy efficiency.

The cost for such systems can range from $100,000 to several million dollars, depending on the scale and complexity.

IV. Renewable energy:

The IEA has analyzed the scenario of low-emission energy future as shown in Figure 4 and in Table 3.

Figure 4: Low emission electricity capacity (Global) by source



Source: IEA 2023, Net Zero Roadmap

According to IEA, renewables capacity triples by 2030 led by solar PV and wind, complemented by growth in nuclear and other sources, raising the share of low-emissions sources in electricity generation from 39% in 2022 to 71% in 2030 and 100% in 2050.

Table 3: Low emission electricity capacity (Global) by source

Milestones	2022	2030	2035	2050
Total electricity generation from low-emissions sources (TWh)	**11 281**	**27 061**	**43 117**	**76 603**
Solar PV and wind	3 416	15 247	27 362	54 679
Other renewables	5 183	7 284	9 377	13 752
Nuclear	2 682	3 936	4 952	6 015
Share of low-emissions source in total generation	**39%**	**71%**	**91%**	**99.7%**
Share of solar PV and wind in total generation	12%	40%	58%	71%
Share of renewables in total generation	30%	59%	77%	89%
Annual capacity additions of low-emissions sources (GW)	**344**	**1 301**	**1 382**	**1 268**
Solar PV	220	823	878	815
Wind	75	318	350	352
Nuclear	8	35	37	21
Average annual investment (USD billion 2022, MER)	**2017-22**	**2023-30**	**2031-35**	**2036-50**
Low-emissions	**507**	**1 202**	**1 321**	**973**
Renewables	466	1 080	1 185	875
Nuclear	41	114	121	93

Source: IEA 2023, Net Zero Roadmap

The IEA's low-emission energy future scenario will equally be applied to developing countries, such as Kazakhstan. Hence, it would be wise to:

a) Utilize renewable energy such as solar or wind or hydro power (although current focus is on wind which is found to be cheaper in Kazakhstan), helping companies to reduce their reliance on fossil fuels and lower their carbon footprint.

b) Purchase green power or renewable energy certificates to offset energy use.

c) Invest in renewable energy. Kazakhstan plans to invest 50 billion tenge ($110.7 million) in renewable energy sources in 2024. This allocation includes nine billion tenge ($19.9 million) for wind power stations, 13 billion tenge ($28.7 million) for solar power stations, and 28 billion tenge ($62 million) for hydroelectric power stations.[66]

The cost can range from tens of thousands to millions of dollars, depending on the capacity and technology. Capital costs for renewables-based projects in emerging market and developing economies remain at least double those in advanced economies (IEA 2023 update of Net Zero Roadmap). Detailed information on RE integration for Kazakhstan metallurgy industry is given in section 7. The impact of energy efficiency measures on decarbonizing the metallurgical sector is further discussed in section 8 of this White Paper.

Despite the benefits of improving efficiency, metallurgical companies may face barriers such as:

d) High initial investment costs: Investing in energy-efficient technologies and equipment can require a significant upfront investment, which may deter some companies from pursuing efficiency improvements.

e) Resistance to change: Reluctance to adopt new procedures, technologies or practices from employees or management can impede progress.

f) A lack of expertise: A lack of technical knowledge or resources to implement efficiency measures effectively can block progress.

C. Operational efficiency

Improving operational efficiency can be accomplished by streamlining processes, reducing waste, and optimizing resource utilization as explained below,

I. Process optimization:

As mentioned above under energy efficient equipment, it involves:

a. Implementing advanced process control systems to optimize furnace operations, reducing energy consumption and improving product quality;

b. Automation and Robotics are increasingly being used to streamline production processes, enhance safety, and reduce labor costs;

[66] Kazakhstan to Allocate Over $110 Million Investment in Renewable Energy in 2024 - The Astana Times

c. Use of real-time data analytics helps to monitor and adjust processes for maximum efficiency.

Process optimization may allow a smelter to increase its production throughput by 20%. If the smelter previously produced 500,000 tons of aluminum per year, it could now produce 600,000 tons, potentially increasing revenue by the same percentage if the market can absorb the additional output. Advanced process control might lead to a 10% reduction in defects, which could save $2 million annually for a plant with a $20 million product rejection cost.

II. Best maintenance practice:

a. Adopting predictive maintenance strategies using sensors and IoT (Internet of Things) devices to identify equipment issues before they lead to downtime or inefficiency. Advanced monitoring systems allow companies to track energy usage, identify inefficiencies, and make data-driven decisions to optimize their operations;

b. Regular maintenance of equipment to ensure it operates at peak performance.

Implementing predictive maintenance could reduce unscheduled downtime by 30%. If a plant experienced 100 hours of downtime per year, costing $10,000 per hour, the savings could be $300,000 annually. Predictive maintenance might extend the lifespan of a critical piece of equipment by 20%. If the equipment would cost $20 million to replace, this could defer $4 million of capital expenditure.

III. Material handling:

a. Using conveyor belts instead of trucks for internal transport to reduce fuel consumption;

b. Optimizing material handling systems to reduce energy use in transporting raw materials and finished products. Moving towards renewable energy based handling systems;

c. Decarbonization in the transport of ore from mine to plant is difficult because there is not yet a technologically and economically profitable substitute, but everything points to the fact that this should materialize in the coming years as the technological costs decrease and there is more infrastructure for implementation. The technologies that are in the pilot stage correspond to high tonnage mining trucks using electric powertrain systems powered by batteries and/or hydrogen, as well as alternative trolley-type trucks.

d. Sustainable supply chain management is a critical component of decarbonization efforts, as it addresses the environmental impact of products and services from raw material extraction to end-of-life disposal. It involves integrating environmental, social, and economic considerations into the supply chain to ensure that it operates in a sustainable manner. It will also play a key role in ensuring ethical sourcing, and meeting consumer demands for transparency and accountability.

IV. Lean manufacturing principles focussing on eliminating waste, improving process flow, and maximizing value for customers:

   a. Reducing scrap generation through better process control and quality management;

   b. Implementing recycling programs to recover and reuse materials such as slag, dust, and other by-products.

   Recycling and reducing scrap could lead to a 15% reduction in raw material costs. For a plant with annual raw material expenses of $50 million, this could result in savings of $7.5 million. Efficient waste management practices could decrease waste disposal costs by 40%. If the annual waste disposal bill was $2 million, the savings could be $800,000.

   c. Implementing water-saving technologies across the facility. Water-saving technologies might reduce water usage by 25%. If the plant was spending $500,000 annually on water, the savings could be $125,000 per year.

V. Employee training and engagement:

   a. Training on energy-efficient practices and

   b. Engaging employees in the improvement process which can lead to innovative ideas, increased motivation, and a culture of energy conservation and continuous learning & development.

   Increased productivity resulting from improved operational efficiency can also help companies meet customer demands more effectively and gain a competitive edge in the market.

D. Hydrogen

One of the promising technologies for decarbonizing metallurgy is the use of hydrogen as a reducing agent to substantially reduce the industry's environmental footprint. Hydrogen has the potential to replace carbon in the reduction of metal ores, leading to water vapor as the only byproduct with no greenhouse gases. Hydrogen is being considered and used in the metallurgy industry in the following ways:

- Direct Reduction of Iron Ore: Hydrogen can be used to directly reduce iron ore to iron without the need for coke (a carbon-based material). This hydrogen-based direct reduction produces iron with a much lower carbon footprint.
- Electric Arc Furnaces (EAFs): In the electric arc furnace steelmaking process, scrap steel is melted and refined. Hydrogen can be used in EAFs in replacement of natural gas to further reduce emissions.
- Blast Furnace Injection: Hydrogen can be injected into blast furnaces as a supplement to coke. This can reduce the carbon intensity of the blast furnace process, although it is a more incremental step compared to full decarbonization.

- Hydrogen in emerging aluminium production process: Green hydrogen could potentially be used as a clean fuel to offset the use of fossil fuels in the production of the thermal energy needed for various processes in the aluminium smelter. In some aluminium recycling processes, hydrogen can be used as a reducing agent or as a protective atmosphere to prevent oxidation of the aluminum during melting.[67]
- Fuel cell electric vehicles (FCEVs) powered by hydrogen could replace diesel trucks for hauling metals and ores such as alumina and aluminum, further reducing the carbon footprint.

Hydrogen can be:

a) Green if produced by electrolysis of water using renewable electricity,

b) Grey, produced from fossil fuels, mainly from natural gas, using steam methane reforming (SMR) process which is currently the widely practised route, or

c) Brown, produced from coal gasification, or

d) Blue, produced by either b or c option accompanied by CCS (Carbon Capture and Storage).

Green Hydrogen is preferred, followed by Blue Hydrogen, for the metallurgy application, mainly due to their potential of reducing carbon footprints. Green Hydrogen is completely emission free and the cleanest option for climate change measures. However, challenges such as hydrogen production costs and infrastructure requirements need to be addressed for widespread adoption. Despite these challenges, the potential of hydrogen to decarbonize the metallurgy industry is significant, and there is growing interest and investment in hydrogen technologies as part of the global effort to combat climate change as shown in Table 4. According to IEA, low-emissions hydrogen production projects as shown in Table 4, if realized, represent 55% of the level in the NZE (Net Zero Emission) Scenario in 2030. It is evident that green hydrogen will be dominated from 2030 onwards with over two-thirds of hydrogen production. The demand is low (430 Mt H_2) due to lack of widespread use. Bold policy action is needed to create demand for low-emissions hydrogen to stimulate investment in production projects.

As part of their decarbonization policy, Germany's Thyssenkrupp AG will replace the blast furnaces by direct reduction and melter (ESF – electric smelting furnace) or electric arc furnaces (EAF). The German government has given 2 billion Euro to ThyssenKrupp towards their green hydrogen project. This will be added by another billion Euro by TK themselves. Currently, they have no running plant on green steel, but they said to have tested the concept in their blast furnace by injecting H_2 through 1 of 28 existing nozzles.

[67] Hydro, 2024. World's first batch of recycled aluminium using hydrogen fueled production. Accessed via: https://www.hydro.com/en/global/media/news/2023/worlds-first-batch-of-recycled-aluminium-using-hydrogen-fueled-production/

Another German company, HyIron, has established a DRI demonstration plant of producing iron using hydrogen in Lingen. HyIron has the goal of establishing this new technology concept to produce green iron worldwide.

- HyIron technology can recycle H_2O produced in DRI thus minimizing the required water quantity for electrolysis process.
- Currently they are in the process of constructing a large-scale plant in Namibia where there is plenty of sun and iron ores. The Namibian project, if successful, would revolutionize the use of hydrogen in iron and steel making process.

Kazakhstan may think to enter early into the hydrogen and iron market with its own iron ore, vast land mass and plenty of sun during the summer.

Table 4: Hydrogen production scenario

Milestones	2022	2030	2035	2050
Total hydrogen demand	**95**	**150**	**215**	**430**
Refining (Mt H_2)	42	35	26	10
Industry (Mt H_2)	53	71	92	139
Transport (Mt H_2-eq, including hydrogen-based fuels)	0	16	40	193
Power generation (Mt H_2-eq, including hydrogen-based fuels)	0	22	48	74
Other (Mt H_2)	0	6	10	14
Share of total electricity generation	**0%**	**1%**	**1%**	**1%**
Low-emissions hydrogen production (Mt H_2)	**1**	**70**	**150**	**420**
From low-emissions electricity	0	51	116	327
From fossil fuels with CCUS	1	18	34	89
Cumulative installed electrolysis capacity (GW electric input)	**1**	**590**	**1 340**	**3 300**
Cumulative CO_2 storage for hydrogen production (Mt CO_2)	**11**	**215**	**410**	**1 050**
Hydrogen pipelines (km)	**5 000**	**19 000**	**44 000**	**209 000**
Underground hydrogen storage capacity (TWh)	**0.5**	**70**	**240**	**1 200**

Source: IEA 2023, Net Zero Roadmap

E. Bioenergy and biomass

Utilizing biomass and bioenergy sources can help reduce the carbon footprint of metallurgical processes and dependence on fossil fuels. Here is how bioenergy and biomass can be utilized in the metallurgy industry.

- Biomass as a Fuel Source: Biomass, such as wood chips, pellets, agricultural residues, and energy crops, can be used as a direct replacement for coal and other fossil fuels in some industrial furnaces and boilers. This can reduce the emissions of greenhouse gases like carbon dioxide (CO_2) because the carbon released during combustion is part of the natural carbon cycle.

- Bioenergy for Heat and Power: Bioenergy can be used to generate heat and electricity needed for metallurgical processes. For example, biogas produced from organic waste can be used to fuel combined heat and power (CHP) systems, providing both electricity and thermal energy for industrial operations.
- Waste-to-Energy: Metallurgical processes often generate organic waste. By using this waste as a feedstock for bioenergy production, the industry can close the loop on its resource consumption, turning waste into a valuable energy source.
- Sustainable Supply Chains: The metallurgy industry can contribute to sustainable land use and rural development by sourcing biomass from sustainably managed forests and agricultural lands. This ensures that bioenergy production does not compete with food production or lead to deforestation.

Total global bioenergy supply is projected to increase by 48% in 2050 from 2022 level as shown in Table 5.

Table 5: Total Bioenergy supply (Global)

Milestones	2022	2030	2035	2050
Total bioenergy supply (EJ)	67	74	89	99

Source: IEA 2023, Net Zero Roadmap

The industry must also consider the economic and technical challenges associated with the adoption of these renewable resources. Globally, there is a growing interest in developing bioenergy solutions for the metallurgy industry, particularly in regions with abundant biomass resources and strong commitments to reducing greenhouse gas emissions. Europe, for example, has been at the forefront, and countries in North and South America, as well as Asia, are investigating how bioenergy can contribute to the decarbonization of their industrial processes.

F. Circular economy

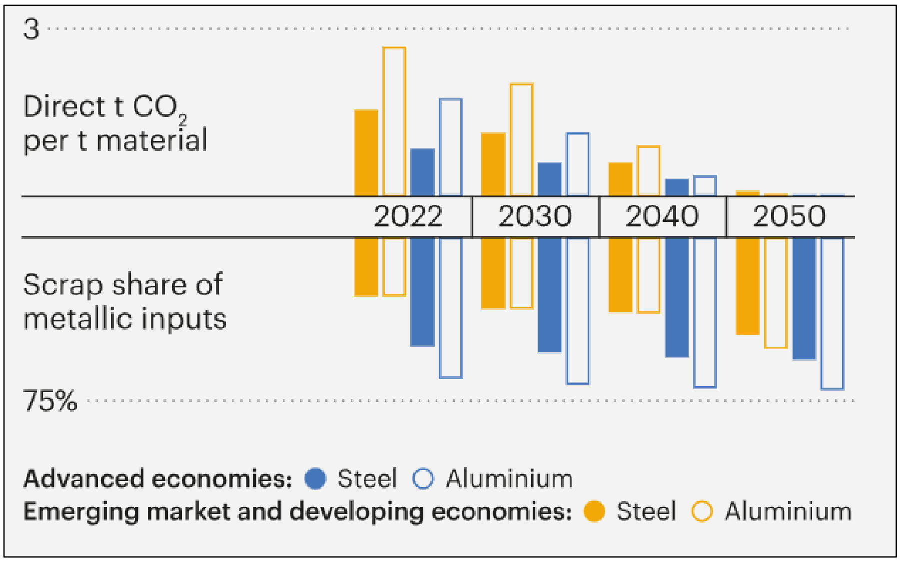
Circular economy principles advocate for recycling and reusing materials to minimize waste and resource consumption. In the metallurgy industry, adopting circular economy approaches involves recovering and reprocessing metal scraps, implementing closed-loop systems, and designing products for recyclability. By closing the material loop, companies can reduce their environmental impact, conserve resources, and create a more sustainable production cycle. Here are several ways in which the circular economy can be implemented in the metallurgy industry:

- Resource Efficiency: Optimizing processes to reduce the amount of raw materials needed for production. This can include improving yield rates, using scrap metal as a raw material, and designing products for material efficiency.
- Recycling and Recovery: Establishing effective systems for collecting and recycling metal products at their end-of-life. This ensures that valuable materials are recovered and reintroduced into the production cycle, reducing the need for virgin raw materials.

- Collaboration and Partnerships: Working with suppliers, customers, and other stakeholders to create collaborative networks that facilitate the sharing of materials and the optimization of material flows.
- Sustainable Mining Practices: For primary production, adopting sustainable mining practices that minimize environmental disturbance, rehabilitate land, and conserve biodiversity.
- Life Cycle Assessment (LCA): Adopting LCA approaches helps in understanding and minimizing the environmental impact of metallurgical products throughout their life cycles, guiding more sustainable practices.

As for example, successful implementation of circular economy principles in steel and aluminum industries has been materialising. The steel industry's increased use of high–grade scrap through recycling is one of the main drivers of decarbonization efforts. Reuse of scrap metals are projected to increase both in advanced and developing countries as shown in IEA graph below (Figure 5), although at a higher rate in advanced countries. Scrap share in aluminum is much higher than that in steel. At the same time, the intensity (t CO_2/t material) of emission decreases to be almost zero in 2050.

Figure 5: Emission intensity and scrap metal use for steel and aluminum industries



Source: IEA 2023, Net Zero Roadmap

Implementing a circular economy in the metallurgy industry requires a systemic change in how we think about production and consumption. It involves not only technological innovation but also changes in business models, consumer behavior, and policy frameworks. The international status of this technology is as follows:

1. Europe: The EU has set targets for recycling in metallurgy and has funded research and innovation projects that focus on sustainable materials management and recycling technologies.

2. Scandinavia: Countries like Sweden and Norway with a long history of efficient waste management and recycling, which extends to the metallurgy industry have implemented advanced recycling systems and are investing in research to further develop circular economy solutions.
3. China: China has implemented a number of policies to promote a circular economy, particularly in its steel industry. This includes measures to increase scrap steel recycling and to improve the energy efficiency of steel production processes.
4. United States: In the U.S., the steel industry has been working on improving recycling rates and developing technologies for more efficient use of materials. The American Iron and Steel Institute (AISI) has set sustainability goals that align with circular economy principles.
5. India: The Indian government has launched initiatives to promote a circular economy in the metals sector, focusing on increasing the use of scrap in steel production and improving the recycling infrastructure.
6. Australia: The Australian steel industry has been exploring ways to implement circular economy practices, such as through the use of recycled materials and the development of new technologies that reduce waste and emissions.

These examples illustrate that while the full implementation of a circular economy in the metallurgy industry is a complex and ongoing process, many regions and companies are taking steps in this direction. It often involves a combination of government policies, industry collaboration, technological innovation, and changes in consumer behavior to create a more sustainable and resource-efficient system. It is true and applicable for Kazakhstan metallurgy industry too.

G. Carbon capture, utilization and/or storage (CCUS)

CCUS technology involves capturing carbon dioxide emissions from industrial processes and either utilizing them to produce valuable products or storing them underground permanently (see Figure 6). In the metallurgy industry, CCUS can be applied to capture emissions from steel plants and metal smelting facilities using various technologies, including pre-combustion, oxy-fuel combustion, and post-combustion capture. The CO_2 can be captured from the exhaust streams produced by blast furnaces, which are a major source of emissions in steel production or DRI plants, where natural gas or other hydrocarbons are used to reduce iron ore. These technologies can be retrofitted to existing plants or integrated into new facilities.

Pre-combustion capture refers to removing CO_2 from fossil fuels before combustion is completed. This technology is particularly suitable to be applied to integrated gasification combined cycle (IGCC) power plants.

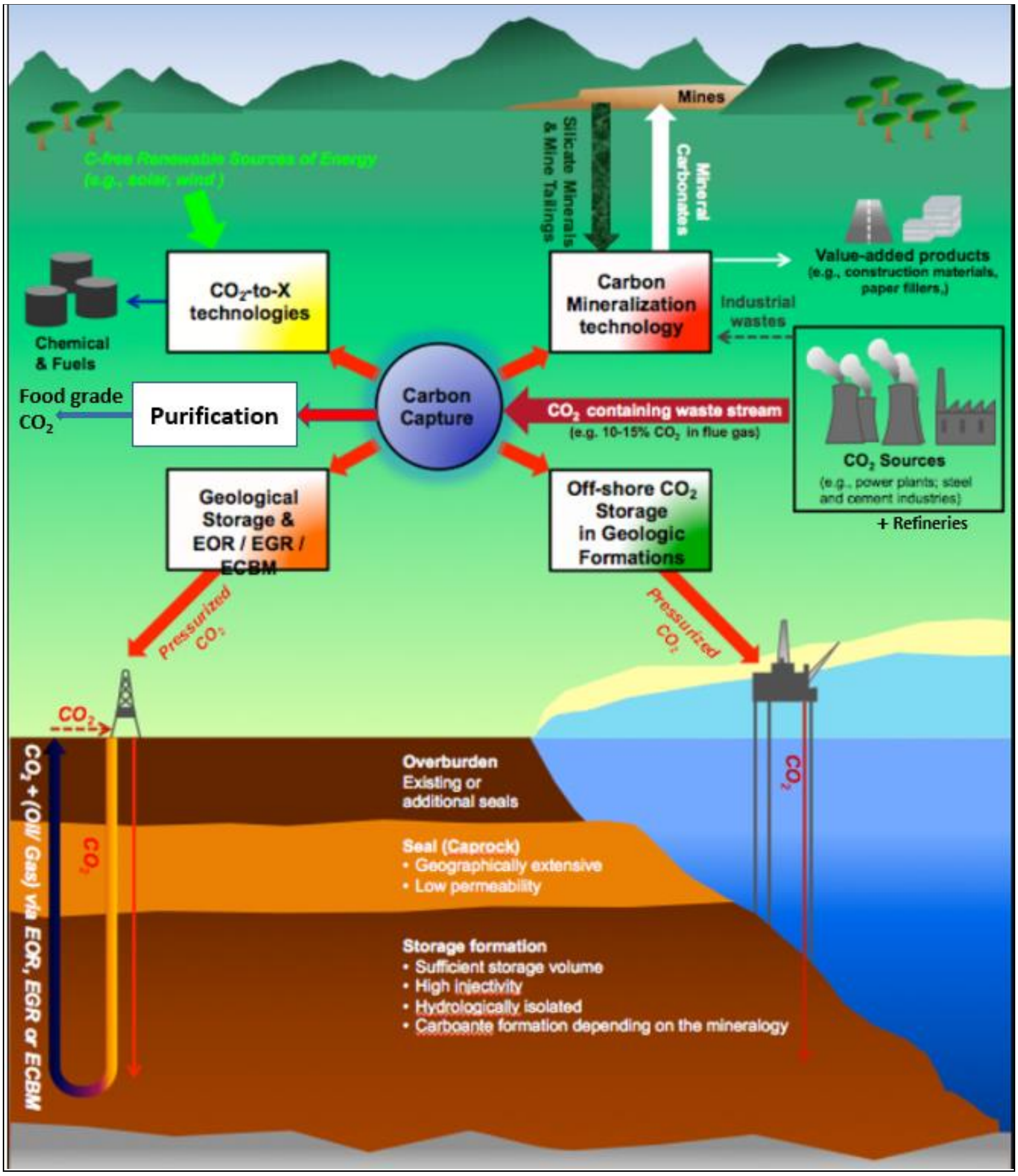
In post combustion capture, CO_2 is removed from the flue gas resulting from the combustion of a fossil fuel. Typical applications for this technology include pulverized coal (PC) plants, and natural gas combined cycle plants (NGCC) and CO_2 containing industrial flue gases, making it most appropriate for metallurgy industry too. Post-combustion separation involves the use of a solvent, membrane or adsorbents or combination of these for example, a hybrid of solvent and membrane or alternative processes such as cryogenic, electrochemical membranes, catalysed solvent materials to capture the CO_2.

The oxy-fuel combustion process involves combusting a carbon bearing fuel in either pure oxygen or a mixture of pure oxygen and a CO_2 -rich recycled flue gas. Oxyfuel combustion involves an ASU (air separation unit) to allow coal to be burned in an oxygen-enriched environment, which leads to having pure CO_2 in the flue gas stream. The flue gas stream in an oxyfuel combustion process includes primarily CO_2 and water vapor, which can be condensed out easily.

The captured CO_2 can be utilized in different applications, such as enhanced oil recovery (EOR), where CO_2 is injected into oil reservoirs to increase oil production. The captured carbon can be stored permanently in geological formations, such as depleted oil and natural gas reservoirs, saline aquifers, or coal seams. Additionally, CO_2 can be converted into chemicals, fuels, or other materials through processes like mineralization or conversion into synthetic fuels. Some of the examples are given below:

- LanzaTech piloted a plant looking at converting steel plant waste gases to ethanol at New Zealand Steel in 2008. The process has subsequently been commercialised, with the first plant beginning operation in 2018 in China at Shougang Steel. The plant produced 30 million litres of ethanol for sale in the first year of operation. A large scale plant at ArcelorMittal in Ghent, Belgium began operation in 2022. Once production reaches full capacity, the Steelanol plant will produce 80 million litres of advanced ethanol, almost half of the total current advanced ethanol demand for fuel mixing in Belgium. Ethanol can be used in a wide range of applications, including the production of synthetic fuels.
- Thyssenkrupp's Carbon2Chem project is looking to produce ammonia and methanol from steel off-gases and reached a pilot phase in 2018. The company is aiming to develop an industrial scale plant.
- The Carbon4PUR, project by a consortium of 11 partners across Europe, including ArcelorMittal, is piloting converting steel off-gases to polyurethane foams and coatings (20 t/yr).
- The FReSMe project, a consortium of European partners including Tata Steel and SSAB, is piloting steel off-gas conversion to methanol (1 t/day).

Figure 6: CCUS in picture

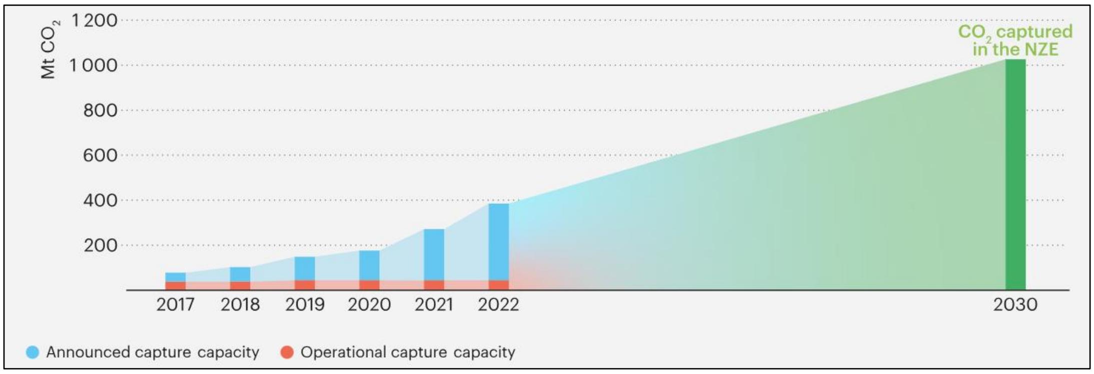


Source: Own elaboration (Global Factor), 2024

Successful implementation of CCUS requires suitable storage sites, efficient capture technologies, and supportive policies to incentivize investment in this technology. The main challenge of implementing CCUS is its high cost which makes it economically not attractive under the current carbon price environment. However, depending on the capture cost and proximity of storage location, a CCUS project may be an option for a hard-to-abate industry, like metal and steel industries. Hence, it requires a case-by-case study before coming to a final decision for the Kazakh metallurgy industry.

IEA has projected world outlook of CCUS as shown in Figure 7. It is clear that there is a gap between announced and operational capture capacities till now. It is estimated that we will need to capture and store over 1 Gt CO_2 by 2030 and over 6 Gt CO_2 by 2050 (seeTable 6). If all announced CO_2 capture capacity is realised and the current growth trend continues, global capacity could reach NZE levels by 2030. Reducing project lead times, particularly related to the development of CO_2 storage, will be critical to achieve those levels.

Figure 7: CO_2 capture capacity (Global)



Source: IEA 2023[68]

The following table shows the global CCUS capacity, which is estimated to be needed, according to the IEA:

Table 6: CCUS capacity

Milestones	2022	2030	2035	2050
Total CO_2 captured (Mt CO_2)	**45**	**1 024**	**2 421**	**6 040**
CO_2 capture from fossil fuels and industrial processes	**44**	**759**	**1 712**	**3 736**
Power	1	188	568	811
Industry	4	247	769	2 152
Merchant hydrogen	0	161	285	756
Other fuel transformation	38	163	90	17
CO_2 capture from bioenergy	**1**	**185**	**506**	**1 263**
Power	0	44	204	438
Industry	0	23	77	232
Biofuels production	1	114	213	474
Other fuel transformation	0	5	13	121
Direct air capture	**0**	**80**	**203**	**1 041**
Total CO_2 removed (Mt CO_2)	**1**	**234**	**632**	**1 710**

Source: IEA 2023[68]

[68] IEA 2023 Net Zero Roadmap. Accessed via: https://www.iea.org/reports/CCUS#dashboard

According to Jarad Daniels, CEO of Global CCSI, "The climate math is clear: carbon capture and storage (CCS) and carbon dioxide removal (CDR) must scale up to gigatonnes per annum to mitigate climate change and reach net-zero emissions. The Global CCS Institute is now tracking 41 projects in operation and 351 in development globally (see Figure 8). The growing interest from CCS project developers is now palpable in many regions, across industries and in diverse applications. According to Wood Mackenzie, "To date, most CCUS projects have focused on emissions reduction in power generation or natural gas processing. But going forward, we expect CCUS to expand into other industries (this is a driving force behind the hub and cluster concept, whereby a central CCUS 'hub' will process emissions from a range of industrial plants clustered nearby). Cement and steel production — which have limited commercial alternatives to fossil fuel use — will probably lead the way, while the CCS component in the production of blue hydrogen could also be important."

Although development of CCS for iron/steel/metallurgy is still in infancy, some developments are visible. One project is in operation since 2026 in UAE for ADNOC Al-Reyadah, which is using its captured CO_2 for enhanced oil recovery (0.8 Mtpa CO_2). The other project is in evaluation stage for China's Baotou Steel to capture 0.5 Mtpa CO_2 for underground storage. So, the momentum is increasing for CCUS deployment. Kazakhstan may start feasibility study for its facilities.

Figure 8: CCS project pipeline by industry and year of operational commencement

Source: Global CCSI, 2023[69]

[69] Global CCSI, 2023. Global Status of CCS 2023 scaling up through 2030

BAT Summary information:

All of headings of possible BATs are shown in Table 7 along with international status and their applicability to Kazakhstan.

Table 7: BAT international status and applicability to Kazakhstan

BAT		International Status	Applicability to KZ
A. Electrification:			
1.	EAF for Steel	Matured TRL 11	Applicable
2.	Inert Anode for Aluminum	Small prototype	Needs R&D?
3.	Renewable Energy powered Electrowining/Electrorefining	Unknown	Can be applicable
4.	Change machineries & heavy vehicles to electric	Gradual start	Applicable
B. Energy Efficiency			
5.	ISO 50001 energy management systems	Matured	Applicable
6.	Efficient Furnace Control System	Matured	Applicable
7.	Waste heat recovery	Matured	Appliable
8.	Renewable Energy	Unknown	Applicable
C. Operational Efficiency			
9.	9. Process Optimization	Matured	
10.	Best Maintenance Practice		
11.	Material Handling		
12.	Lean Manuf Principles		
13.	Employee training		
D. Hydrogen			
14.	Production (Green)	Small prototype	Pre-feasibility reqd
15.	Use as a reducing agent	Small prototype	Pre-feasibility reqd
E. Bioenergy and Biomass			
16.	As fuel	Large prototype	Feasibility reqd
17.	As heat and power	Small prototype	Feasibility

F. Circular Economy			
18.	Resource efficiency	Partially applied	
19.	Recycling and recovery	Matured	
20.	Collaboration / partnership	Developing	
21.	Sustainable mining	In practice	
G. CCUS			
22.	Feasibility study	Performed by many	Pre-feasibility reqd
23.	Pilot testing		Parallel pilot testing

Source: Own elaboration (Global Factor), World Economic Forum[70] and Global CCSI, 2023[69]

BAT international Status for Steel and Aluminum according to World Economic Forum Report

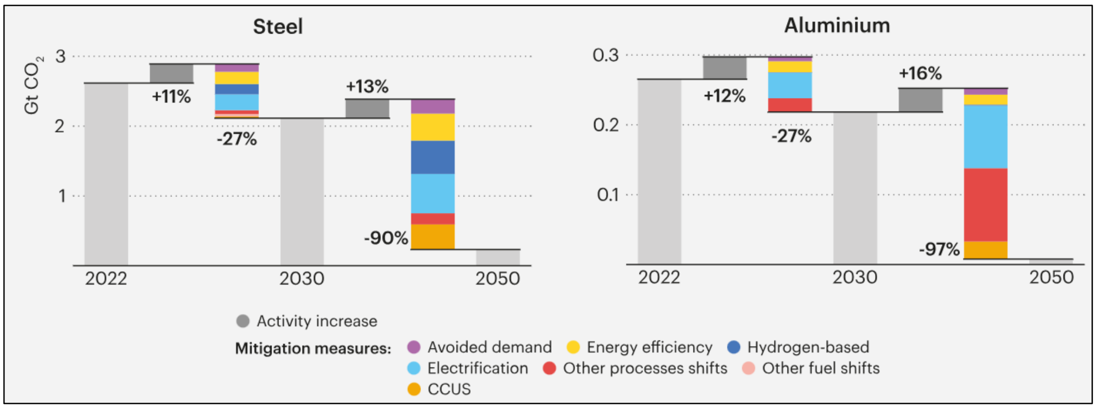
Steel: Three pathways exist to decarbonize primary steelmaking: carbon capture, hydrogen and electrochemistry.[70]

Today, steelmaking using green hydrogen is seeing the most substantial momentum, with multiple projects under development worldwide. Technology costs for carbon capture and hydrogen use in the steel industry are expected to decrease over the decade but should remain at least 25-50% higher than traditional routes by 2030. Steelmaking via electrochemical processes is yet to be proven at scale and is not expected to become commercially available before 2035.

IEA has assessed emission reduction scenario for steel industry as shown in Figure 9. As we can see various mitigation measures need to be applied to reach net zero by 2050. Among all the measures, electrification, hydrogen, energy efficiency and CCUS will have prominent roles for decarbonizing steel industry.

[70] World Economic Forum, 2023. Net Zero Industry Tracker 2022

Figure 10: GHG emission reduction in steel and aluminium industry



Source: IEA, 2023[68]

The low-emission production technologies are largely prototyped at scale and the necessary infrastructure required by the low-emission industry needs to be developed almost entirely. Figure 11 shows the technology readiness level (TRL) of decarbonization technologies in steel industry. Apart from scrap based EAF (TRL 11), all their technologies are either at small prototye (TRL 4-6) or at demonstration phase (TRL 7-8). However, as mentioned earlier, Germany's Thyssenkrupp AG and HyIron are advancing faster than this report indicates.

According to the World Economic Forum Report,[63] the "Good news is, most of the market can pay the required green premium". Given the high costs of clean technologies, low-emission steel is expected to come with a green premium of 25-50% for steel buyers. More than $2 trillion will need to be invested in low-carbon power, clean hydrogen and CO_2 handling infrastructure to enable clean technologies in steel production.

Five priorities for the global steel sector have been emphasised:

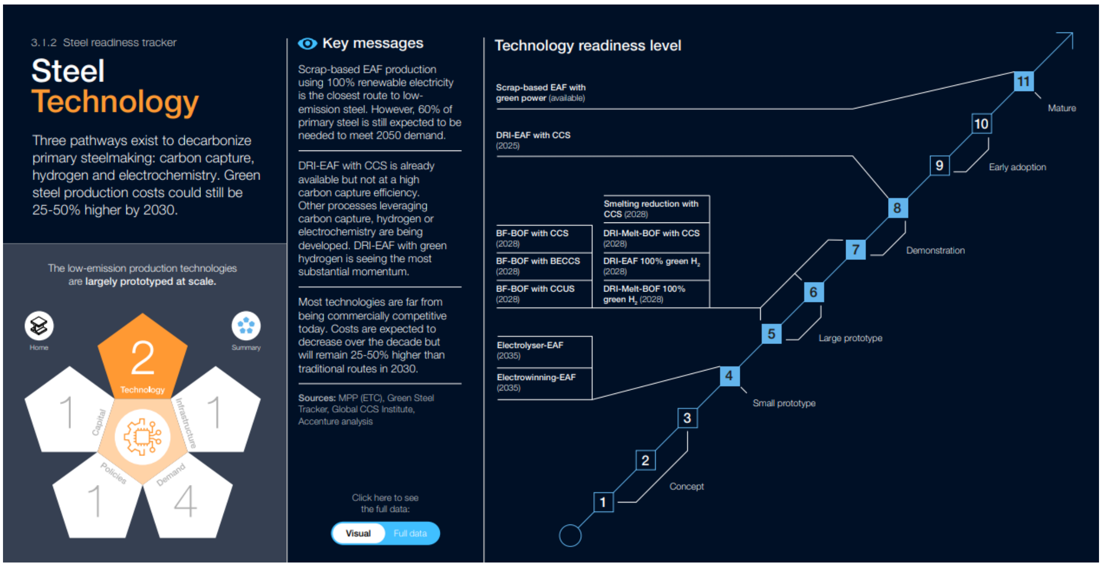
1. Implement efficiency levers to maximize emission reduction in existing processes.
2. Boost the number of low-emission projects to accelerate the learning curve, drive costs down and bring forward the commercial readiness of clean steel technologies.
3. Develop the renewable power capacity, green hydrogen production and CO_2 transport and storage infrastructure required to enable low-emission steel production.
4. Multiply demand signals for green steel to incentivize producers and investors to direct capital towards low-emission production assets.
5. Develop policies to support the four priorities above and strengthen the business case for low-emission steel production.

In addition to the above priorities, the technological approach of each BAT for iron and steel should include the followings, particularly for a country like Kazakhstan:

1. Specific material and energy demand in addition to CO_2 emissions (Scope 1, 2 & 3);

2. Critical issues for the uptake of respective technological options, including technical and practical constraints on their installation and operation and enabling factors that need to be in place for their successful use. This covers but not necessarily limited to special requirements of particular processes such as the availability of high-grade iron ore or influences of the process on steel quality; and
3. An overview of the cost profiles based on regional energy prices and resources.

Figure 12: Steel technology readiness level



Source: World Economic Forum, 2022[63]

Aluminum: The main pathway to decarbonize aluminium production is a combination of electrification using decarnonized electricity, transition to hydrogen and inert anodes – however, carbon capture is also being explored.[63]

IEA's assessment on emission reduction scenario for aluminum industry as shown in Figure 13. Here also we can see various mitigation measures need to be applied to reach net zero by 2050. Among all the measures, electrification and process shift (use of inert anode) will be dominating. Energy efficiency and CCUS will have some role for decarbonizing aluminum industry.

The challenge for primary aluminium is twofold: decarbonize energy for refining and smelting and prevent CO_2 release to the atmosphere during the smelting process. The decarbonization pathway combines two building blocks: electrification with low-carbon power for refining and smelting, and hydrogen use for high heat. Carbon capture is also being explored but faces significant challenges (e.g. low CO_2 concentration). Today, decarbonizing power can already cut emissions by 60%, and up to 85% could be achieved with future electric boilers and inert anodes. Cost estimates for aluminium low-emission technologies are largely unknown due to their early stage of maturity, except for the use of CCUS for thermal energy and process emissions, which is estimated to raise production costs by 40%.

The low-emission production technologies are largely prototyped at scale and the necessary infrastructure required by the low-emission industry is partially in place. Expected year of commercial readiness of first low-emission production is 2030. Figure 13 shows the technology readiness level (TRL) of decarbonization technologies in aluminum industry. Apart from decarbonised electricity (TRL 9-11), all ther technologies (Hydrogen, CCUS, Inert anode, Mechanical vapour recompression) are at TRL 2-5. So, as mentioned earlier, Kazakhstan may try to collaborate with companies who are testing this technology unless they have a set up for R&D.

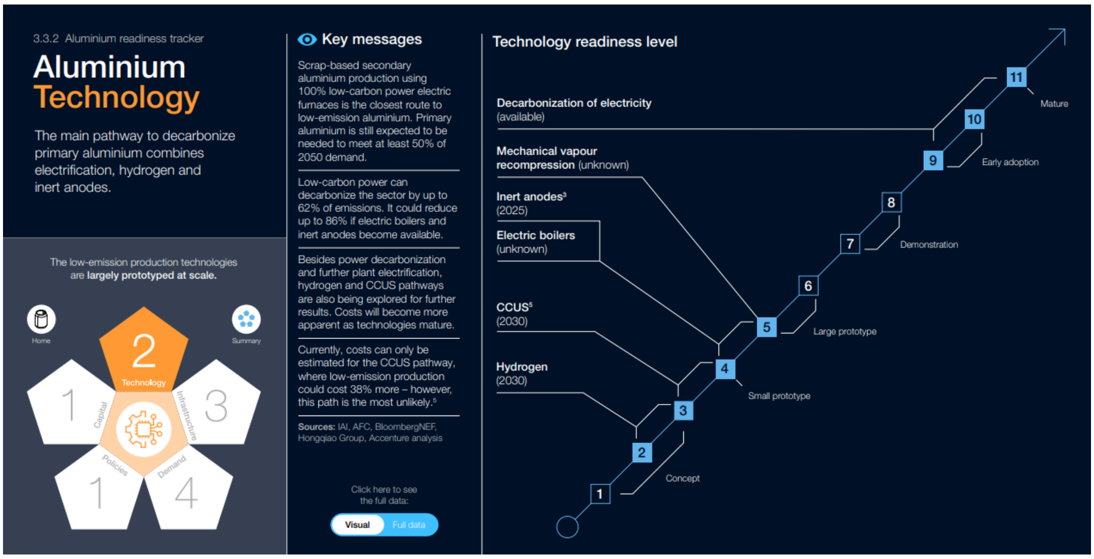
Again, five priorities for the aluminum sector have also been emphasised:

1. Promote and further expand aluminium recycling networks.
2. Boost the number of low-emission projects to accelerate the learning curve, drive costs down and bring forward the commercial readiness of clean technologies.
3. Develop the low-emission power capacity, clean hydrogen production and CO_2 transport and storage infrastructure required to enable lowemission aluminium production.
4. Multiply demand signals for green aluminium to incentivize producers and investors to direct capital towards low-emission production assets.
5. Develop policies to suport the four priorities above and strengthen the business case for low-emission aluminium production.

In addition to the above priorities, the technological approach of each BAT for aluminium should include the following points, particularly for a country like Kazakhstan:

1. Specific material and energy demand in addition to CO_2 emissions (Scope 1, 2 & 3).
2. Critical issues for the uptake of respective technological options, including technical and practical constraints on their installation and operation and enabling factors that need to be in place for their successful use. This covers but not necessarily limited to special requirements of particular processes such as the availability of high-grade iron ore or influences of the process on steel quality.
3. An overview of the cost profiles based on regional energy prices and resources.

Figure 13: Aluminum technology readiness level



Source: World Economic Forum, 2022[63]

7 RENEWABLE ENERGY INTEGRATION IN THE METALLURGICAL INDUSTRY

Kazakhstan is rich in natural resources including coal, oil, natural gas and uranium and has significant renewable potential from wind, solar, hydro and biomass. Despite this, the country is currently dependent upon fossil fuels for power generation. Coal-fired plants account for 75% of total power generation leading to concerns over greenhouse gas emissions and impacts on human health and the environment.

Kazakhstan ranks 108th out of 139 countries in terms of energy intensity of GDP, with its most energy-intensive sector being the mining industry. As the demand for solid minerals grows worldwide, an equivalent increase in the overall demand for energy is expected to facilitate mineral production and processing activities. This presents an opportunity for the country to capitalize on renewable energy sources (RES), as the mining industry turns to greener energy solutions. Kazakhstan has a large natural and climatic potential of renewable energy. For example, wind energy - 920 billion kWh/year, technically possible hydro potential is estimated at 62 billion kWh, solar energy in the southern regions of the country reaches 2500 - 3000 hours of sunshine per year. The use of wind, solar, and biomass energy is on the rise, along with emerging green hydrogen projects. The mining industry, being one of the most energy-intensive sectors, can greatly benefit from adopting renewable energy sources.

The development of bilateral renewable energy contracts in the Republic of Kazakhstan is central to the increase of renewable energy integration. First, it is necessary to provide a flexible approach to the development of renewable energy sources in the country, taking into account the interests of consumers and investors, in order to achieve strategic goals for carbon neutrality. The opportunity to implement renewable energy projects for their own needs and take advantage of the existing package of support measures for renewable energy sources should be provided to all enterprises, regardless of their form of ownership. Thus, the development of renewable energy sources as a direct tool for decarbonizing the economy should become a national task.

One of the tools for developing the renewable energy market is the segment of bilateral RRA contracts on renewable energy sources, when an industrial enterprise, in order to reduce its carbon footprint, enters into a direct contract with a renewable energy generator for the purchase of "green" electricity. According to experts, this segment has great prospects due to the fact that most companies in the real sector of the economy have adopted strategies at the corporate level aimed at decarbonizing production processes. In general, the market for bilateral contracts can be much larger than the auction market for renewable energy sources and become a driver for further development of the sector and will not have an impact on the growth of tariffs for the population and business of the country.

Bilateral renewable energy contracts are an agreement governing the sale and purchase of electricity between a renewable energy producer and a consumer at a pre-agreed price and for a specified period. In this case, the long-term buyer of electricity from renewable energy sources is the consumer.

The main goal of developing bilateral RE contracts is to create the opportunity for buyers to independently choose the source of production of consumed electrical energy, while the RE electricity producer gets the opportunity to plan the financing of its activities. Also, it should be noted that bilateral renewable energy contracts allow solving the following problems:

- No dependence on a single electricity purchaser.
- Determination of the fair value of electricity.
- The ability to hedge risks from changes in legislation to support renewable energy sources and international requirements for reducing the carbon environment.
- Fulfillment of environmental obligations by the buyer of electricity.
- Organization of long-term planning for the purchase and sale of electricity for the buyer and seller, respectively.
- One of the solutions to reduce the level of negative impact of renewable energy sources on the energy system.

The segment of bilateral renewable energy contracts faces however several barriers that significantly limit the development of the market:

- Uncertainty of the prospects for bilateral renewable energy contracts in the light of the introduction of the "Single Buyer" model.
- The lack of a regulatory framework governing the development of the market for bilateral contracts.
- There is a problem of additional requirements of the system operator for the availability of regulatory capacities to connect such operators, despite the fact that renewable energy facilities are not directly connected to the network.
- Issues of balancing, transportation and priority dispatching remain open.
- There is no understanding of how financial institutions can lend to such projects, given the lack of any mechanisms to mitigate risks, in the event of termination of the purchase of electricity from renewable energy facilities by an industrial enterprise.
- The possibility of selling surplus electricity under bilateral contracts to the Single Buyer.
- In case of termination of a bilateral contract by the electricity consumer, there is no mechanism for the transition of such projects to a contract with the Single Buyer.

In accordance with the legislation of the Republic of Kazakhstan, the following norms are established:

1. "On support for the use of renewable energy sources" Law of the Republic of Kazakhstan dated July 4, 2009, No. 165-IV (subparagraph 2 of Article 9 of the Law) - "

1. An energy-producing organization using renewable energy sources has the right, at its discretion, to sell the produced electrical energy using one of the following options:

> 1) to a single purchaser of electrical energy at a fixed tariff in force on the date of conclusion of the purchase and sale agreement between it and the financial settlement centre, or at the auction price determined based on the results of the auction, taking into account the indexation provided for in paragraph 2 of Article 8-1 of this Law ;
>
> 2) to consumers at negotiated prices in accordance with concluded bilateral agreements in accordance with the requirements of the legislation of the Republic of Kazakhstan on the electric power industry."

2. "On Electric Power Industry" Law of the Republic of Kazakhstan dated July 9, 2004 No. 588 (subparagraph 2 of Article 17)

2. Electricity purchase and sale agreements must contain:

> 1) daily power consumption schedule;
>
> 2) the procedure for reserving electric power by energy producing organizations.

However, despite the fact that there are legislative norms, strategic programs and one of the main goals of the RE Law is to create favourable conditions for the production of electricity by both existing and newly introduced RE facilities, today there are a number of significant barriers that affect the further development of the bilateral market RE contracts.

Despite the fact that legislation regulating the development of renewable energy sources does not exclude the development of the bilateral contracts market, the key barriers to the development of this segment are:

- uncertainty about the rules of operation of bilateral renewable energy contracts in light of the introduction of the "Single Purchaser" model;
- lack of "rules of the game" for market participants as a whole;
- strict requirements of the system operator for connecting such facilities, despite the fact that renewable energy facilities are not directly connected to the network;
- the issues of balancing, free transportation and priority dispatch for such projects remain controversial;
- the possibility of selling surplus electricity under bilateral contracts to a single buyer;

- there is no understanding of how financial institutions can lend to such projects, given the absence of any mechanisms to reduce risks, in the event of an industrial enterprise ceasing to purchase electricity from a renewable energy facility;
- For the state and quasi-public sector that would like to implement renewable energy projects, access to a package of government support measures (investment, customs, tax preferences) is limited. The Business Code limits the shares and duration of participation of such organizations in investment priority projects and for them the implementation of renewable energy projects becomes problematic;
- allocation of land plots for bilateral renewable energy projects.

Requirements of the system operator for the availability of balancing capacities as part of the implementation of bilateral contracts

In accordance with the power grid rules (clause 4, chapter 2), the power supply scheme of the power plant is agreed upon with the relevant organization (energy transmission or energy producing) to whose electrical networks it is planned to connect, the system operator.

At the same time, the system operator agrees on the power supply scheme only subject to the availability of control capacities. Thus, if the intention is to implement the project within the framework of bilateral agreements, without support through RFC LLP, a necessary condition for the implementation of this project (taking into account the shortage of regulatory capacity in the UES of Kazakhstan, as a result of which an increase in the share of unstable RE facilities poses a threat to reduce the reliability of the operation of the UES of Kazakhstan) is the provision from the applicant of a project for regulating power with connection to the AFC and the conclusion of a corresponding agreement with KEGOC JSC for the provision of services for regulating electric power in the Unified Power System of Kazakhstan (draft agreement is attached). At the same time, maneuverable generating capacities that are currently not involved in the power balance of the UES of Kazakhstan should be presented as regulating capacity. As an alternative option, it is possible to consider equipping the SES with an energy storage device with a capacity of 50% of the installed power of the SES and a capacity sufficient to deliver the installed power of the storage device for four hours.

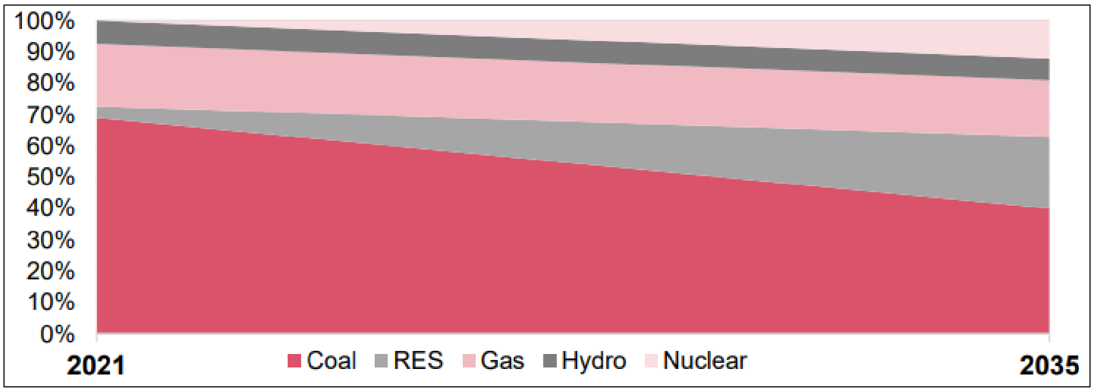
For example, the Solidcore Resources company is implementing a project involving the construction of 2 solar power plants with a total installed capacity of 39.6 MW in the Abay and Kostanay regions within five years. As a regulating power, it is planned to build one gas-piston manoeuvring station with an installed capacity of 40 MW to cover the unstable generation of solar stations. The total investment volume will be around $75 million. That is, such actual requirements entail an increase in the cost of the RE project by more than 2 times.

7.1 THE IMPACT OF RENEWABLE ENERGY FOR MINING COMPANIES AND THE NATIONAL GRID

The metallurgical industry, in the context of the global energy crisis and the new European green deal, needs urgent investments on energy and resource efficiency. The 2021-2022 energy crisis was caused by many factors including the global campaign to reduce carbon emission, the shortage in fossil fuel reserves due to divestment from fossil fuels, the halt in oil production due to the COVID-19 pandemic and the Ukraine and Russia conflict. The metallurgical sector, which includes the production of different metals is an energy-intensive industry that requires large amounts of energy for various processes such as smelting, refining, and casting.

In recent years, there has been a growing trend towards the use of renewable energy sources and energy efficiency measures in the metallurgical sector to reduce greenhouse gas emissions and mitigate climate change.

Figure 14: Breakdown of power generation in 2021 and forecast by 2035.



Source: PWC, 2022[71]

By 2035, it is required to ensure commissioning of new generation capacities, of which 11 GW are low-carbon generation sources, including 6.5 GW of RE facilities (solar and wind).

The metallurgical sector, which includes the production of iron, steel, aluminum, copper, and other metals, is an energy-intensive industry that requires large amounts of energy for various processes such as smelting, refining, and casting. The energy systems in the metallurgical sector can be categorized into two types: primary energy systems and secondary energy systems. Secondary energy systems involve the use of by-products from primary energy systems or renewable energy sources such as hydropower, solar and wind energy.

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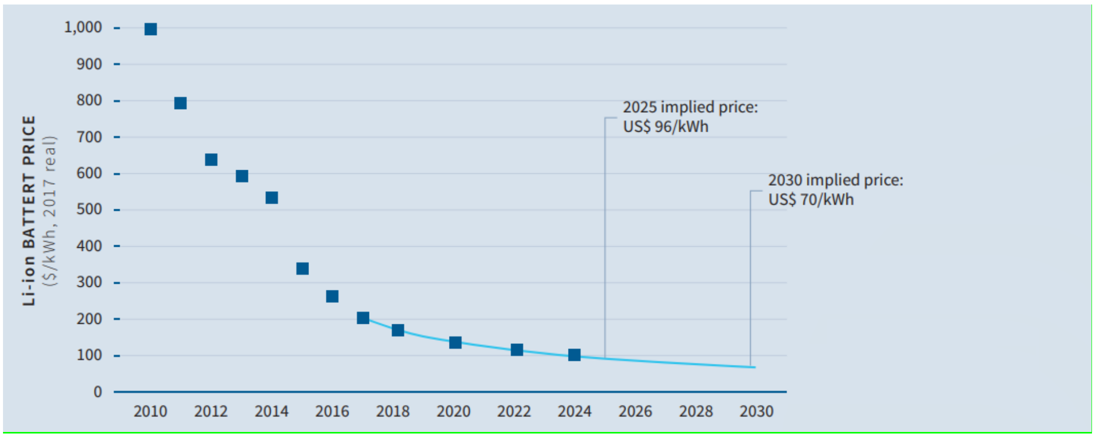
[71] PWC, 2022. Energy Transition in Kazakhstan – Back to the Sustainable Future. Accessed via: https://www.pwc.com/kz/en/assets/energy-report/energy-report-eng-final-1.pdf

Choosing appropriate renewable energy technologies based on energy demand and resource availability

There are several aspects in the development of RE projects to serve the metallurgical industry.

- First, the amount of electricity generated by RE facilities depends on weather conditions: solar power plants (SPP) - on the intensity of solar radiation, wind power plants (WPP) - on the presence of wind speed. Therefore, in order to include new RE facilities in the energy system, it must be adapted. How? By introducing changes to the regulatory mechanisms for priority dispatch of RE facilities, so that the system operator can regulate - by reducing - the supply of electricity to the grid from RE facilities during a decrease in demand from consumers.
- The second is the instability of electricity generation by renewable energy sources. This problem can be solved by the development and implementation of energy storage systems that could store excess electricity and release it into the network during peak demand hours from consumers.
- The cost of the batteries have reduced significantly in recent years. This information is presented below. Additionally, each company should consider the following measures:
    - Dispatching processes development,
    - improving RE planning accuracy,
    - enhancing the maneurability of the conventional coal plants,
    - possible gas peaking plants like balancing capacities,
    - grid construction and respective interconnections.
- At the moment, this industry of energy accumulation and storage is actively developing and it is necessary to introduce appropriate regulatory mechanisms that would establish the obligation to use energy storage systems for new renewable energy facilities. All this will allow balancing the energy system during peak load hours and reducing energy consumption, reducing imbalances in the electricity market from renewable energy sources and increasing the reliability of the energy system in Kazakhstan.

Figure 15: Lithium-Ion Battery Pack Price



Source: Integrating Clean Energy in Mining Operations: Opportunities, Challenges, and Enabling Approaches[72]

- Third, the main problem of Kazakhstan's metallurgical sector is that a large percentage of the installed generation capacity consists of morally and physically obsolete coal power plants dating back to the Soviet era. For the production of electricity from renewable energy sources, the country has "raw materials": wind and solar radiation as natural energy carriers. But there is no mass production of means of generating electricity from them. In order for wind energy and renewable energy sources to become a competitively dominant sector of the economy, not only conditions are needed in the form of raw materials and sales markets, but also industries related to the generation, transport and sale of electricity, many enterprises united in clusters and creating an added value chain from design to final product and even environmentally friendly processing of exhausted RE elements. With this approach, the price of components for renewable energy facilities can be reduced due to the effect of scaling production. Insufficient development of the mechanical engineering and electrical engineering industries related to renewable energy sources may become an obstacle to the effective development of the RE industry.

Given that the amount of electricity sent from RE sources to the power grid over a period of time depends on weather conditions, it is necessary to provide for the presence of additional traditional generating capacities. They operate on traditional fuels, which can be stored and used in the required volume to generate the required amount of electricity. These are the so-called shunting capacities that can balance the country's energy system.

Taking into account the unresolved technical problems for energy storage systems that could balance the energy received from renewable energy sources over time, there will be a need for traditional generating capacities as shunting facilities.

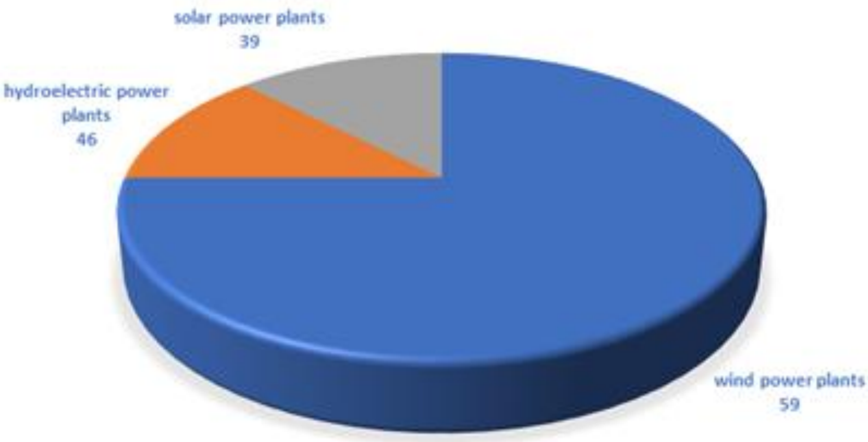
[72] Integrating Clean Energy in Mining Operations: Opportunities, Challenges, and Enabling Approaches

Currently, 147 renewable energy facilities (with a capacity of over 100 kW) with a total installed capacity of 2,903.54 MW are operating in the Republic of Kazakhstan:

- 59 wind power plants with a total capacity of 1,409.55 MW.
- 46 solar power plants with a total capacity of 1,222.61 MW.
- 39 hydroelectric power plants with a total capacity of 269,605 MW.
- 3 biogas power plants with a total capacity of 1.77 MW.

In 2023, 16 RE facilities with the total installed capacity of 495.57 MW were put into operation:

Figure 16: Renewable energy facilities put into operation in Kazakhstan in 2023



- 12 wind power plants with a total capacity of 437.1 MW in the Akmola region and the Zhetisu region,
- 2 hydroelectric power plants with a total capacity of 3.7 MW in the Almaty and Turkestan regions and
- 2 solar power plants with a total capacity of 54.77 MW in the Turkestan region.

The most popular RE technologies in the Kazakhstan metallurgical industry are:

- PV plants and Natural Gas Cogeneration Units (like shunting capacities) installation with the partial usage of the generated hot water.
- Wind Power Plants. By 2027, it is planned to commission 25 renewable energy projects with a capacity of 599.85 MW.

Challenges, barriers and solutions to integrating RE in the metallurgical industry

There are many areas that need to be improved to increase the potential of renewable energy sources, including the following:

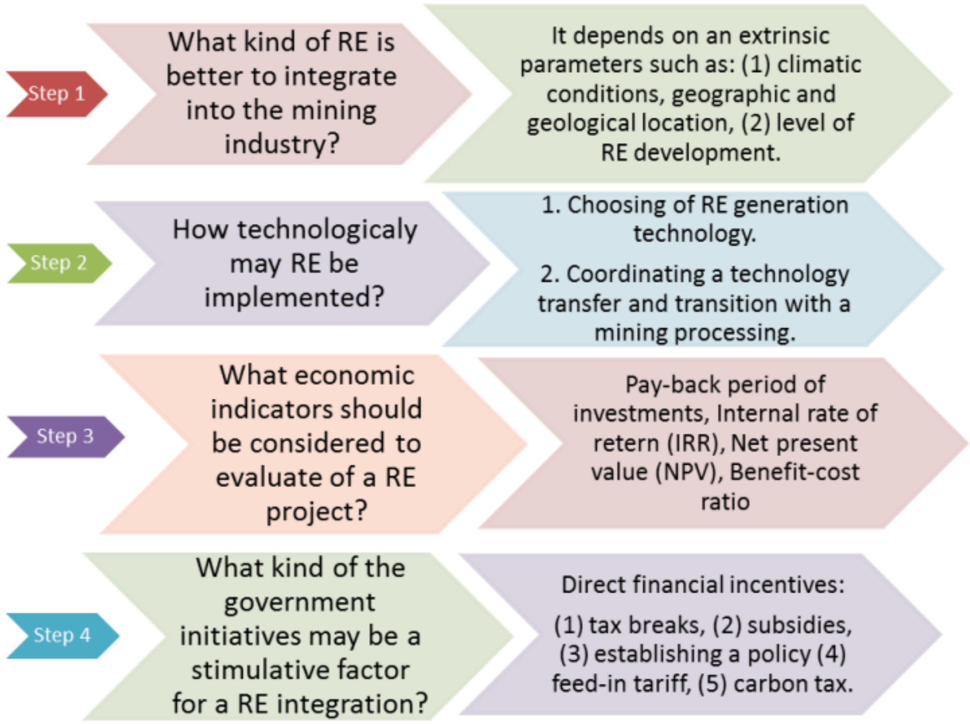
- One of the main problems of the sector is the instability of production, the lack of sun and wind immediately lead to a decrease in electricity generation.

    - This problem can be solved by creating a balancing power market and an electricity storage system.
- It is necessary to develop flexible capacities, increase flexible sources which include natural gas power plants and hydroelectric power stations or build electricity storage facilities.
    - Implementation of RE projects with energy storage through the auction mechanism. The lack of such capacity limits the growth of renewable energy sources. The higher the share of renewable energy sources in the energy balance, the more reserve capacity is needed to cover demand when generation from renewable sources decreases.
    - The problem of lack of reserve capacity can also be solved by stimulating conscious consumption. It implies that large consumers limit their electricity consumption for a certain number of hours a day in exchange for economic incentives (monetary rewards). This is a widely used mechanism around the world and it will cost much less than building stations.
    - Formation of attractive conditions for investment in the renewable energy sector in Kazakhstan (increase auction capacities, improving the conditions for tariff indexation, development of the practice of project auctions, etc.)
- Many companies are actively implementing ESG principles into their corporate policies.
    - Lack of a regulatory framework, excessive requirements of the system operator for the implementation of such projects
- The system operator requires renewable energy facilities to find balancing capacities themselves, that is, to build storage facilities.
    - KEGOC explains this by the shortage of balancing capacities in the energy system of Kazakhstan. The installation of storage devices significantly increases the cost of projects.
- The prices which will be after the contracts for the guaranteed purchase of electricity expire.
    - By the beginning of the 2030s this issue will need to be resolved. Without increasing electricity tariffs, it will be difficult to solve this problem.

Recommendations for the implementation of RE into the metallurgical industry

The metallurgical processes are complex systems and completed within the technological requirements. The metallurgical industry needs a reliable and affordable source of energy round-the-clock. In order to grasp into detail of understanding how RE can be integrated into the metallurgical industry the following scheme has been developed:

Figure 17: How renewable energy can be integrated into the metallurgical industry



Source: USAID, 2022[41]

The main idea for using the 4 steps scheme is to answer on each question together with an economic evaluation (from step 1 to step 4) in order to prepare of a business plan. The proposed 4 steps scheme will lead the metallurgical companies to better forecasting:

- At first, what kind of RE sources should be integrated, what a technology for RE generation and delivery, what amount of RE can be generated in the following weather conditions.
- Secondly, the economic evaluation of a RE integration may be done by using of the characteristics such as pay-back period of investments, internal rate of return (IRR), net present value (NPV), and benefit cost ratio.
- Thirdly, the government can support of RE implementation by different support measures.

State support measures

- Kazakhstan provides investors with several preferences and government support measures for the construction of renewable energy facilities. The state company "Financial Center" signs off-take contracts with investors with the liability to purchase the electricity for 15-20 years at a price fixed.
- The KEGOC company (which manages the unified energy system) undertakes to connect renewable energy facilities to networks, carry out maintenance and give priority when dispatching electricity from renewable energy sources.
- In addition, auction prices are indexed annually to consider inflation and changes in the exchange rate. Investors in renewable energy projects are exempt from customs duties, VAT on imports, property, land, and corporate income taxes, and they are also provided with state grants. The reduction in the cost of construction of renewable energy sources led tariffs to decline from year to year.
- From 2014 to 2017, fixed tariffs for electricity from renewable energy sources in local currency were in effect. With investors who implemented or began implementing projects during this period the state entered contracts at fixed tariffs.
- With the introduction of an auction model in 2017 the price is set through bidding. The average tariff for contracts concluded based on the results of bidding last years: for solar power plants – 16.95 tenge/kWh, for wind farms – 15.76 tenge/kWh. The cost of electricity has dropped significantly.
- Another significant measure to support the industry is the obligation of the so-called "conditional consumers" to purchase from the Financial Center all electricity produced using renewable energy sources. Such consumers include energy companies using coal, natural gas, petroleum products and nuclear fuel as well as hydroelectric power plants.

8 THE IMPACT OF ENERGY EFFICIENCY MEASURES ON DECARBONIZING THE METALLURGICAL SECTOR

The metallurgical industry faces several challenges, including high energy consumption, environmental concerns, and operational inefficiencies. The energy-intensive nature of metallurgical processes contributes to high operational costs and carbon emissions, making it imperative for companies to find ways to reduce their energy usage and environmental footprint. Additionally, operational inefficiencies can lead to production delays, quality issues, and increased costs, affecting the overall competitiveness of companies in the industry. In this section, we will explore the importance of improving operational efficiency and energy efficiency in the metallurgical industry and discuss strategies to achieve these goals. Advancements in technology have paved the way for innovative solutions to improve operational and energy efficiency in the metallurgical industry.

Kazakhstan government's 2024 Handbook on BAT[73] has highlighted the importance of operational and energy efficiencies. According to the handbook, the existing metallurgical enterprises will be modernized with a reduction in resource and energy intensity, labor productivity will be increased, work will continue the development of innovations in technologies for the extraction and integrated processing of raw materials, as well as the expansion and reproduction of the mineral resource base. The main guidelines for the development of the mining and metallurgical industry are to increase operational efficiency, deepen processing as much as possible, and be included in global supply chains.

The benefits of both operational and energy efficiencies are huge. Quantifying them in the metallurgy industry can be complex, as it involves various factors such as the specific context, scale of operations, regional energy costs, technological advancements, and so on and often requires a case-by-case analysis. To get accurate quantitative benefits, a detailed analysis of the current operations, energy use, and potential improvements would be necessary. However, some general examples of how these measures can lead to quantitative benefits are provided below for each measure.

Improving energy efficiency

Improving energy efficiency is achieved by investing in energy-efficient technologies and practices, which not only helps companies comply with regulations and industry standards but

[73] Ministry of Justice, Government of Kazakhstan. Energy efficiency in economic and other activities. Accessed via: https://adilet.zan.kz/rus/docs/P2400000024

also demonstrates their commitment to sustainability and corporate social responsibility. It requires a comprehensive approach of:

i. Energy audits:
   a. Identify areas of energy waste and inefficiency, allowing them to prioritize energy-saving measures.
   b. Implement ISO 50001 energy management systems to establish energy performance indicators and set improvement targets.

ii. Energy-efficient equipment:
   a. High-efficiency furnaces to reduce energy consumption.
   b. Upgrade to high-efficiency motors, pumps, and fans to reduce electricity consumption.
   c. Use energy-efficient lighting and HVAC systems in facilities.

   A steel plant might reduce its energy consumption by 10% through the installation of a new, more efficient furnace control system. If the plant's annual energy bill was $10 million, this could translate into savings of $1 million per year.

iii. Waste heat recovery systems capture and reuse excess heat generated during production processes, further reducing energy consumption and costs and minimizing waste.
   a. Installing heat recovery systems to capture waste heat from furnaces and use it for other processes or to generate electricity.
   b. Implementing cogeneration or combined heat and power (CHP) systems to improve energy efficiency.

iv. Electrification of processes:
   a. Convert some processes from fossil fuel-based to electric, such as using electric arc furnaces (EAF) instead of basic oxygen furnaces (BOF) for steelmaking.
   b. Electrify transportation within the plant where possible.

Barriers to improving efficiency

Despite the benefits of improving efficiency, metallurgical companies may face barriers such as:

a) High initial investment costs: Investing in energy-efficient technologies and equipment can require a significant upfront investment, which may deter some companies from pursuing efficiency improvements.

b) Resistance to change: Resistance to change from employees or management can also impede progress.

c) A lack of expertise: A lack of technical knowledge or resources to implement efficient measures effectively can block progress.

In conclusion, improving operational efficiency and energy efficiency is essential for the long-term success and sustainability of the metallurgical industry in terms of reducing costs, enhancing productivity, and minimizing environmental footprint. It is imperative for industry stakeholders to prioritize efficiency measures, collaborate with government agencies, and embrace future trends to drive positive change and secure a competitive advantage in the evolving metallurgical landscape.

9 GOVERNANCE FOR SECTORAL IMPLEMENTATION

The governance of the decarbonization of Kazakhstan's metallurgical industry should be considered on several levels. These include the international scale, the national level, regional level (oblast) and company level. Each is considered here below.

9.1 GOVERNANCE AT INTERNATIONAL AND REGIONAL SCALE

International treaties such as the UN Paris agreement with its Nationally Determined Contributions (NDCs) push for the mitigation of climate change at the global scale and set up long-term goals for international collaboration against climate change. The NDCs are at the heart of the Paris Agreement and the achievement of these long-term goals. NDCs embody each country's efforts to reduce national emissions and adapt to the effects of climate change. The Paris Agreement (Article 4, paragraph 2) requires each Party to prepare, communicate and maintain the successive nationally determined contributions it intends to achieve.

The UNFCCC Technology Mechanism is pivotal in recommending strategies for establishing linkages between global industry players, technology providers, initiatives, and funding bodies to enhance global cooperation in technology development and deployment. To address the variability in green hydrogen and electricity production feasibility, countries with net-zero goals in hard-to-abate industries are advised to explore sourcing resources from other countries, facilitated by international development organizations. Expediting the development of standardized Life Cycle Assessments (LCAs) and promoting knowledge exchange among countries on decarbonization technologies are recommended to accelerate global transformation efforts. International development organizations are urged to play a role in facilitating financial, technical, and capacity-building support from developed to developing countries to ensure equitable participation in climate action efforts, aligning with UNFCCC and Paris Agreement obligations.

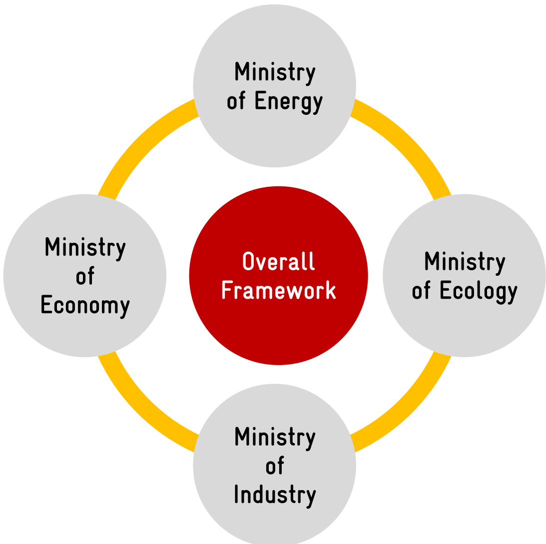
The Technology Executive Committee (TEC), the policy arm of UNFCCC's Technology Mechanism, has been very active in decarbonization efforts. Based on the results of the mapping exercise, the TEC, in partnership with the United Nations Industrial Development Organization, agreed to develop a policy brief and organize a Technology Day focusing on the integration of industrial decarbonization in updated NDCs that countries around the world are preparing. The policy brief will provide concrete policy and technology options to reduce emissions from the steel, cement, chemicals and petrochemicals industries and ways to implement them, including through international cooperation, research, development and demonstration (RD&D) and the use of blended finance to de-risk private sector investment. At COP29 in Baku, Azerbaijan, later this year the TEC will host the Technology Day, dedicated to advance the inclusion of hard-to-abate industries in updated NDCs and supporting the implementation of countries' identified climate actions in this area. UN Climate Change also supports the decarbonization of heavy-emitting industries through the recently launched Industrial Transition Accelerator.[74]

On another note, and regarding regional cooperation and governance for metallurgic sector decarbonization, the countries of Kazakhstan, Kyrgyzstan, Uzbekistan, Tajikistan and Turkmenistan share economic interest, cultural heritage, environmental challenges, and face common external threats. Joint efforts among these central Asian countries can be a vehicle of shared decarbonisation policies for the metallurgical sector.

9.2 GOVERNANCE AT NATIONAL LEVEL

Regulatory framework and compliance / enforcement mechanisms

To improve governance for decarbonizing Kazakhstan's metallurgy sector, a robust regulatory framework is essential. This framework should include clear emission reduction targets aligned with national climate goals, comprehensive legislation mandating GHG reduction and clean technology adoption, and incentives for companies to invest in green technologies. Additionally, fostering public-private partnerships can facilitate knowledge-sharing and innovation, aiding in the sector's transition to sustainable practices. Ministries that will be mainly involved in the further development of this regulatory framework are the Ministry of Energy, Ministry of Ecology and Natural Resources, Ministry of Industry and Construction, and the Ministry of Economy. It needs to be ensured that each of these Ministries has clear mandates and responsibilities in the drafting of the Regulatory Framework and enforcement mechanisms for the decarbonisation of the metallurgical sector, and there are no overlaps in their functions and jurisdiction.



The regulations, emission targets, legislation, incentives, compliance mechanisms, etc. issued by these bodies need to be developed in cooperation to ensure alignment in all official documents. Gaps or inconsistencies need to be avoided under all circumstances.

[74] Mission Possible Partnership, 2024. Accessed via: https://www.missionpossiblepartnership.org/

Effective compliance and enforcement mechanisms are crucial for the successful implementation of this regulatory framework. Advanced monitoring systems, regular inspections, and audits will ensure adherence to environmental standards. Strict penalties for non-compliance, capacity building for regulatory authorities, and stakeholder engagement are vital components of enforcement. Encouraging a collaborative approach to compliance, coupled with judicial and administrative review processes, will enhance fairness and accountability. Performance-based incentives can further motivate companies to exceed regulatory requirements and demonstrate leadership in decarbonization.

Emission reduction targets

Kazakhstan has a net zero by 2060 target, which was enshrined in law in February 2023. The targets regarding carbon emissions are shown in Table 8 below:

Table 8: Carbon emission targets in Kazakhstan

2030 unconditional NDC target	
Formulation of target in NDC[75]	Reduction of GHG emissions by 15% by the end of 2030 relative to 1990 base year.
Absolute emissions level in 2030 excl. LULUCF	Level of emissions to be achieved at home (domestic target) 318 $MtCO_2e$ [18% below 1990] [1% above 2010]
Status	Submitted on 27 June 2023
2030 conditional NDC target	
Formulation of target in NDC	Reduction of GHG emissions by 25% by the end of 2030 relative to 1990 base year.
Absolute emissions level in 2030 excl. LULUCF	280 $MtCO_2e$ [27% below 1990] [11% below 2010]
Status	Submitted on 27 June 2023
Net zero & other long-term targets	
Formulation of target	Kazakhstan will reach carbon neutrality by 2060.
Absolute emissions level in 2050 excl. LULUCF	45 MtCO2e
Status	Enshrined in law on 02 February 2023, not yet submitted in LTS to UNFCCC.

Source: Climate Action Tracker, 2024[76]

[75] NDC Partnership, 2024. Kazakhstan. Accessed via: https://ndcpartnership.org/country/kaz

[76] Climate Action Tracker, 2024. Updated Nationally Determined Contribution of the Republic of Kazakhstan to the global response to climate change. Accessed via: https://climateactiontracker.org/countries/kazakhstan/targets/

Monitoring, reporting, and verification (MRV) systems

There are two levels of MRV for GHG emissions and removals: national level and source and sink level.

National level

Kazakhstan, as a Party to Annex I of the UNFCCC for the purposes of the Kyoto Protocol, regularly prepares a National Report on the inventory of anthropogenic emissions from sources and removals by sinks of all greenhouse gases not regulated by the Montreal Protocol, using IPCC methodologies (hereinafter referred to as the national GHG inventory).

The Tier 2 method (enhanced data and gross energy input approach) is used to estimate emissions from cattle and sheep. The simplified Tier 1 method using default emission factors is used for the remaining animal species. In the LULUCF sector, a combination of Tier 2 and Tier 1 methods is used to estimate emissions (using national data on humus content in soil, volume of wood and forest area, etc.) to estimate removals from Pastures, forests and emissions from cropland.

Level of sources and sinks (within Kazakhstan ETS).

In 2013, Kazakhstan launched a national carbon cap and trade system (Kazakhstan ETS), which is constantly being improved. Currently it regulates only CO2 emissions. Only large sources whose emissions exceed 20 thousand tons of CO2 per year are subject to quotas in six industries: production of electrical and thermal energy, oil and natural gas industry, mining industry, metallurgical industry, chemical industry and manufacturing industry in terms of production of cement, lime, gypsum and bricks

For the purposes of the Kazakhstan ETS, there is a mandatory MRV system for quota-based and administered installations.[77] The relevant regulation is regulated by the Environmental Code of the Republic of Kazakhstan and the Rules.

Emissions from agriculture, small energy installations and transport are not regulated under the Kazakhstan ETS. A carbon taxation system has not yet been introduced in Kazakhstan but is expected according to the Strategy for Achieving Carbon Neutrality of the Republic of Kazakhstan until 2060. Accordingly, there is no mandatory MRV for AFOLU sources and sinks in Kazakhstan.

It is important to note that in Kazakhstan it is possible to register carbon units in the State Register and implement offset projects in any sector of the economy that can reduce emissions from any quota-free sources or increase absorption. The sale of registered offset units in Kazakhstan ETS is not currently limited. Initiators of offset projects have the right to independently choose any relevant international methodology for calculating offsets. To credit

[77] Administered installations include sources in regulated industries whose emissions exceed 10 thousand tons of CO2, but less than 20 thousand tons of CO2 per year. Operators of managed installations report emissions from managed installations but are not required to verify the reports.

the offset project initiator's account with the appropriate number of carbon units achieved in the reduction, the project initiator (owner) must prepare an inventory report, adhering to the previously chosen methodology. Accredited bodies for validation and verification of greenhouse gases are required to adhere to the methodology chosen by the initiator for calculating GHG emissions and removals.[78]

It is necessary to strengthen the quality control of reporting on GHG emission inventories of quota subjects, as well as strengthen the requirements for the integrity of validation and verification bodies.

Level of sources and sinks (within voluntary carbon credit markets)

Despite the great interest of Kazakh and foreign investors in low-cost offset projects in Kazakhstan, the legislation of the Republic of Kazakhstan does not regulate the functioning of voluntary markets for carbon units in Kazakhstan. A voluntary carbon market is typically governed by independent private programs (standards) that guarantee the quality of carbon offsets provided, ensure equal market access, and aim to encourage participation in trade. In Kazakhstan, international voluntary carbon offset standards are applied. The most famous international programs in Kazakhstan also include Verra and Golden Standard. In 2023, the first voluntary offset transactions outside the national emissions trading system were completed.

The first national voluntary standard for the certification of carbon offsets has been developed in Kazakhstan, however, due to the uncertain position of the Regulator, all work on promoting the national standard has been suspended. The Government body responsible for preparing the national inventory is the Ministry of Ecology and Natural Resources of the Republic of Kazakhstan[79], which provides a webpage to free access to national inventory data.[80]

Institutions that usually prepare national inventories in Central Asian countries are Zhassyl Damu and JSC.[81] [82] The frequency of quality control of national inventory data provided to the UNFCCC Secretariat takes place once every two years, last check being realized in 2023. Quality control before submission to the UNFCCC Secretariat is done by the Interagency Working Group on functioning of the State GHG inventory system under the chairmanship of the

[78] Since 2017, accreditation of greenhouse gas validation and verification bodies in Kazakhstan has been carried out by the National Accreditation Center of the Committee for Technical Regulation and Metrology of the Ministry of Trade and Integration of the Republic of Kazakhstan https://www.nca.kz/info/articles/media/ob-akkreditatsii-organov-po-validatsii-i-verifikatsii-parnikovykh-gazov/

[79] Government of Kazakhstan, 2024. Accessed via: https://www.gov.kz/memleket/entities/ecogeo?lang=en

[80] UNFCCC, 2023. National Inventory Submissions 2023. Accessed via: https://unfccc.int/ghg-inventories-annex-i-parties/2023

[81] JSC "Zhassyl Damu" is responsible for: (1) the organization and meetings of the Interagency Working Group; (2) distribution of funds initial data between representatives of the Interagency Working Group; (3) collection of information containing initial data for quantitative assessment emissions and absorption of GHG from enterprises, organizations, government organs; (4) analysis and processing of received data, calculations and preparation National GHG cadaster; (5) quality control and quality assurance of the National GHG cadaster; Coordination of the GHG report with government agencies.

[82] Recycle KZ, 2024. Promoting the development of the processing industry. Accessed via: https://recycle.kz/en

Ministry of Ecology and Natural Resources. After submission to the UNFCCC Secretariat the International IPCC experts make the quality check.

Capacity Building

Capacity building of governments, businesses, and communities to implement decarbonisation strategies is a critical aspect of governance. This can involve training, education, and the sharing of best practices. To effectively decarbonize Kazakhstan's metallurgical industry, enhancing the capacity of regulatory authorities and industry stakeholders is essential. This includes comprehensive training programs for regulatory staff on environmental standards and monitoring technologies, ensuring regulatory bodies are well-funded and equipped, and fostering international collaborations for technical assistance. Industry stakeholders should benefit from training in clean technology implementation and sustainable practices, supported by grants for R&D and partnerships with research institutions. Strengthening institutional frameworks through clear policies, robust data management systems, and regular performance evaluations is also crucial.

Public awareness and education

Improving governance for decarbonizing Kazakhstan's metallurgical industry can benefit from public awareness and education initiatives. These initiatives should aim to inform and engage the public about the importance of reducing emissions and adopting sustainable practices within the industry. Educational campaigns can highlight the environmental and economic benefits of decarbonization, using media, workshops, and community programs to reach diverse audiences. Collaborating with schools and universities to integrate climate and environmental education into curricula will cultivate a well-informed future workforce. Additionally, fostering transparent communication between the government, industry, and the public can build trust and support for decarbonization policies.

Financial incentives, (e.g., subsidies, tax breaks, and grants)

To enable the decarbonization of Kazakhstan's metallurgical industry, implementing financial incentives such as subsidies, tax breaks, and grants is essential. Subsidies can reduce the upfront costs of adopting clean technologies and energy-efficient processes, making it easier for companies to transition. Tax breaks for investments in renewable energy, emissions reduction technologies, and R&D can further motivate businesses to prioritize decarbonization. Additionally, grants can support pilot projects, innovation, and the development of low-carbon solutions, particularly for smaller enterprises that may lack the necessary capital. In terms of governance, it is very important that the organizations in Kazakhstan dealing with the provision of subsidies, tax breaks and grants (i.e., Ministry of Economy, Ministry of Finance, Damu Fund and others) design their strategies and programs in a coordinated way. Cohesion, certainty and clarity when looking for financial incentives is essential for companies who would like to decarbonize their metallurgical processes. It would be a good idea to create a website which depicts all possible tax breaks, grants, subsidies or other kinds of financial support in Kazakhstan in a simple and clear manner, all in the same place. That way the process of looking for funding is simplified for the companies.

Institutional arrangements for overseeing decarbonization efforts

Overseeing decarbonization efforts of Kazakhstan's metallurgical industry needs the establishment of a robust and well-coordinated institutional framework. The foundation of this framework could be a National Decarbonization Council, serving as the central coordinating authority for all decarbonization initiatives across various sectors, including metallurgy. The Council would be responsible for developing and implementing national policies, setting emission reduction targets, monitoring progress, and ensuring alignment with international climate commitments. Its composition should include representatives from key government ministries, industry stakeholders, academic institutions, and civil society organizations, fostering a collaborative approach to policy-making and implementation.

Specialized regulatory oversight is critical for decarbonizing the metallurgical sector. The establishment of a Metallurgical Decarbonization Authority would focus specifically on regulating and promoting decarbonization within this industry. The functions of this institution would include enforcing regulations, conducting inspections, providing technical assistance, and promoting best practices. By working closely with the National Decarbonization Council and other regulatory bodies, this authority can ensure cohesive oversight and enforcement, driving the industry's compliance with decarbonization standards. Additionally, forming expert advisory committees comprising technical, industry, and community representatives would provide valuable insights and guidance, ensuring that decarbonization strategies are technically sound, practically feasible, and socially responsible.

Financial oversight and support mechanisms could be managed by a Decarbonization Finance Office, which would manage financial incentives, grants, and subsidies, ensuring transparent and accountable allocation of resources. Furthermore, the creation of a Decarbonization Research Institute would drive innovation through research on low-carbon technologies and processes tailored to the metallurgical sector. A comprehensive Monitoring and Reporting System would track progress on emission reductions, regularly publishing reports and maintaining a transparent database to ensure data accuracy and accessibility for all stakeholders.

Voluntary systems for decarbonization

On top of mandatory decarbonization targets in the metallurgy industry, voluntary systems for decarbonization could be applied in Kazakhstan. These voluntary systems can complement regulatory frameworks by encouraging industry stakeholders to adopt sustainable practices proactively. Establishing an industry-led initiative, such as a green metallurgy alliance, would bring together major metallurgical companies committed to reducing their carbon footprint. This alliance could share best practices, set voluntary targets for emission reductions, and collaborate on joint sustainability projects, fostering a culture of sustainability within the industry and leveraging collective resources for a larger impact.

Certification programs like a voluntary carbon certification can recognize metallurgic companies that achieve specific decarbonization milestones. By certifying and publicly acknowledging businesses that implement low-carbon technologies, energy efficiency measures, and sustainable practices, these programs provide market differentiation, enhance brand reputation, and potentially open access to new markets focused on sustainability. Public-private partnerships, such as clean technology projects, can further support this by establishing collaborations between the government, industry and research institutions to pilot and scale innovative clean technologies.

Voluntary reporting and transparency initiatives, such as sustainability reporting standards, encourage companies to report their greenhouse gas emissions and sustainability efforts using standardized frameworks like the Global Reporting Initiative83 or the Carbon Disclosure Project.84 These initiatives enhance stakeholder trust, improve investor relations, and drive accountability within the industry.

Carbon offset partnerships and voluntary carbon offset programs allow companies to offset their emissions by investing in renewable energy, reforestation, or other carbon sequestration projects. These partnerships can compensate for unavoidable emissions, support global carbon reduction efforts, and enhance corporate social responsibility.

Improving the rules and efficiency of public investments (minimum standards)

Improving the rules and efficiency of public investments for decarbonizing Kazakhstan's metallurgical sector involves establishing clear, transparent criteria for funding allocation, prioritizing projects that demonstrate significant potential for emissions reduction and sustainability. Simplifying bureaucratic processes and ensuring rigorous project evaluation and monitoring can enhance accountability and effectiveness. Leveraging international financial and technical assistance can also boost the impact of investments.

Promoting participatory planning, formalization of community and stakeholder consultation systems

The promotion of participatory planning and community and stakeholder consultation systems for decarbonizing Kazakhstan's metallurgical sector involves creating structured and inclusive platforms for dialogue between government, industry, local communities, and environmental organizations. Establishing regular consultation forums and public hearings ensures that diverse perspectives are considered in decision-making processes and integrating feedback mechanisms allows stakeholders to contribute to policy development, project planning, and implementation strategies. Transparency in sharing information about decarbonization goals, progress, and impacts fosters trust and collaboration.

Eco-labelling and certification

Implementing eco-labelling and certification for the decarbonization of Kazakhstan's metallurgical sector involves developing standards that recognize and reward companies for adopting sustainable practices and reducing their carbon footprint. The implementation of a certification system that assesses and verifies the environmental performance of metallurgical

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[83] Global Reporting Initiative, 2024. Accessed via: https://www.globalreporting.org/

[84] Carbon Disclosure Project, 2024. Accessed via: https://www.cdp.net/en

processes may incentivize companies to improve their operations. Eco-labels can be displayed on products, signaling to consumers and investors the company's commitment to decarbonization. This not only enhances market competitiveness but also drives demand for greener products. Additionally, collaborating with international certification bodies can ensure that Kazakhstan's eco-labels meet global standards, further promoting the country's metallurgical products in the international market.

9.3 GOVERNANCE AT LOCAL LEVEL (OBLASTS)

To support regional and local implementation of national policies, establishing Regional Decarbonization Offices is recommended. These offices would monitor local industry compliance, facilitate regional projects, and engage with stakeholders to adapt strategies to local contexts. They would report to the National Decarbonization Council, and would also have regional delegates for the Metallurgical Decarbonization Authority and the Decarbonization Finance Office (as defined above in "institutional arrangements at national level"). The Regional offices should also closely collaborate with the Decarbonization Research Institute so that innovation in decarbonization processes for metallurgy is well spread across the country.

Roles and responsibilities of local governments

Local governments in Kazakhstan can support the decarbonization of the metallurgical industry by enforcing national and regional environmental regulations, developing local policies and incentives, and ensuring regulatory compliance. They are responsible for environmental monitoring, data collection, and reporting on emissions to national authorities.

Local authorities can also promote green jobs and innovation through training programs and partnerships with local institutions as well as secure and manage funding for decarbonization projects, ensuring transparent financial practices to support sustainable development aligned with national climate goals.

Supporting improved financial self-sufficiency of cities and towns

To support financial self-sufficiency of cities and towns in Kazakhstan for decarbonizing the metallurgical sector, it is essential to empower local governments with enhanced revenue-generation capabilities. This can be achieved by, for instance, enabling them to retain a higher share of local taxes, particularly from environmentally sustainable businesses and green initiatives. Introducing local green bonds and establishing municipal sustainability funds can attract private investment for decarbonization projects. Additionally, capacity-building programs for local officials on financial management and sustainable development planning are also helpful. Facilitating access to national and international grants specifically aimed at supporting local decarbonization efforts can further enhance financial self-sufficiency.

9.4 GOVERNANCE AT COMPANY LEVEL

Capacity building

To drive decarbonization in Kazakhstan's metallurgical sector, companies must establish robust governance frameworks that integrate comprehensive capacity-building efforts. This involves creating clear decarbonization policies and goals, setting up dedicated teams to oversee sustainability initiatives, and investing in employee training to build expertise in green technologies and practices.

A dedicated team within the companies should be responsible for designing an internal training needs assessment, apply it and then design the capacity building program. Experts in the topics that each company would like to explore should be hired for the capacity building activities. Typically, capacity building within companies will focus on i) technical skills and expertise, ii) research and development capabilities, iii) digitalization and automation, iv) financial and economic analysis, v) environmental management and vi) understanding of climate policy and regulatory requirements.

Internal carbon pricing mechanisms

Internal carbon pricing is a tool that allows companies to assign a monetary value to their GHG emissions, promoting positive changes within their operations. By establishing an internal carbon price, companies can attribute a cost to each ton of carbon emitted, integrating this cost into their business and investment decisions. This approach encourages greater efficiency and drives innovation in low-carbon technologies.

Currently, there are no international standards that businesses can follow when setting an internal price on carbon, but there are some helpful guides and initiatives that businesses can look to, such as the Caring for Climate[85] initiative from the UN Global Compact. The UN Global Compact calls on companies to set an internal price for carbon at a minimum of $100 per metric ton over time.

Integrating carbon considerations into core business operations is essential for mitigating future risks associated with carbon pricing and understanding the impact of carbon and related risks on the business. This approach not only helps in future-proofing business strategies but also facilitates the generation of finance for sustainability initiatives. By raising awareness both internally and externally, companies can effectively address investor and consumer concerns regarding the climate crisis. Additionally, such efforts contribute to reducing carbon emissions, aligning the business with broader environmental goals.

[85] UN Global Compact, 2024. Carbon pricing. Accessed via: https://unglobalcompact.org/take-action/action/carbon

Uptake of environmental and emissions standards

Effective governance for the uptake of environmental and emissions standards in metallurgical companies requires the establishment of a comprehensive framework that integrates sustainability into the core of corporate decision-making. This begins with the board of directors and executive leadership committing to environmental goals and embedding them into the company's mission and strategy. Key components of this governance structure include the formation of specialized committees or roles focused on sustainability, such as a Chief Sustainability Officer or an Environmental Oversight Committee, tasked with driving the adoption of emissions standards and ensuring compliance with national and international regulations. These governance bodies should be empowered to set ambitious decarbonization targets, monitor progress, and adjust strategies as needed to meet evolving standards and market demands.

Additionally, the governance framework must promote transparency, accountability, and continuous improvement. This involves implementing robust reporting mechanisms to track emissions and environmental performance, which are then communicated regularly to stakeholders, including shareholders, employees, and regulators. The governance structure should also encourage innovation by supporting investments in low-carbon technologies and fostering a corporate culture that prioritizes sustainability. By aligning incentives with environmental goals, such as linking executive compensation to the achievement of emissions reduction targets, companies can ensure that the uptake of environmental standards becomes a strategic priority.

Monitoring and reporting of emissions

To effectively monitor and report emissions for metallurgical companies aiming to decarbonize, a robust governance structure is essential. This begins with the establishment of clear policies and procedures that mandate the accurate tracking of GHG emissions across all operations. The board of directors and senior management must prioritize emissions monitoring as a key component of the company's strategic goals, ensuring that resources and attention are dedicated to this area. Specialized roles, such as a Chief Sustainability Officer or an Environmental Compliance Manager, should be created to oversee the implementation of GHG emissions monitoring systems, ensuring data accuracy, consistency, and alignment with national and international reporting standards.

Furthermore, governance structures must include rigorous internal and external reporting mechanisms. Internally, regular reports should be generated to inform leadership and relevant departments about emissions levels, trends, and areas requiring improvement. Externally, companies should establish transparent communication channels to disclose emissions data to stakeholders, including regulators, investors, and the public. This could involve publishing annual sustainability reports or adhering to frameworks such as the Global Reporting Initiative86 or the

[86] Global Reporting Initiative, 2024. Accessed via: https://www.globalreporting.org/

IFRS.[87] Accountability is crucial, so the governance framework should also include periodic audits and third-party verification of emissions data to maintain credibility and trust.

Operating standards (e.g., ISO) and best practice transparency and disclosure

Company governance must also prioritize the adoption of recognized operating standards, such as ISO certifications, and ensure best practices in transparency and disclosure. The board of directors and executive leadership should first commit to integrating these standards into the company's strategic framework, recognizing that adherence to international standards like ISO 14001[88] (Environmental Management Systems) not only enhances environmental performance but also strengthens market competitiveness. To operationalize this, governance structures should establish dedicated teams or departments responsible for ensuring compliance with these standards, including regular audits and continuous improvement processes. These teams must also stay informed about evolving standards and industry best practices to ensure that the company remains at the forefront of environmental performance.

In addition to adopting operating standards, governance must ensure that transparency and disclosure are central to the company's approach to decarbonization. This includes setting up comprehensive reporting systems that track compliance with standards and openly communicate performance to stakeholders. These reports should detail not only the company's adherence to ISO standards but also its progress toward decarbonization goals, challenges faced, and future plans.

Technological innovation, R&D and innovative technology demonstration projects

Effective governance for promoting technological innovation, research and development (R&D), and the implementation of innovative technology demonstration projects is another important point to consider. The board of directors and senior management should prioritize innovation as a key driver of the company's decarbonization strategy, embedding it within the corporate mission and long-term goals. This commitment requires the establishment of governance structures that specifically focus on innovation, such as an Innovation Committee or a Chief Technology Officer role, tasked with overseeing R&D initiatives. These governance bodies should be responsible for allocating sufficient resources to R&D efforts, setting clear objectives for technological advancements, and fostering a culture of innovation throughout the organization.

Additionally, governance must ensure that there are mechanisms in place to support the development and scaling of innovative technology demonstration projects. This involves creating partnerships with academic institutions, research organizations, and technology providers to accelerate the adoption of cutting-edge solutions. The governance framework should also include

[87] IFRS, 2024. ISSB and TCFD. Accessed via: https://www.ifrs.org/sustainability/tcfd/

[88] ISO, 2015. Environmental management systems — Requirements with guidance for use. Accessed via: https://www.iso.org/standard/60857.html

evaluation and feedback loops, where the success of demonstration projects is regularly assessed, and lessons learned are integrated into future projects.

International collaboration (company to company)

To facilitate international collaboration for decarbonization, metallurgical companies need governance structures that actively support and manage partnerships with other companies across borders. The board of directors and executive leadership should recognize the strategic importance of international cooperation in achieving decarbonization goals and incorporate it into the company's overarching strategy. Establishing a dedicated unit or appointing a senior executive, such as a Chief Partnerships Officer, to oversee international partnerships can ensure focused attention on these initiatives. This governance body would be responsible for identifying potential partners, negotiating agreements, and ensuring that collaborative projects align with the company's sustainability objectives and compliance with international regulations.

Moreover, the governance framework should promote transparency, accountability, and the sharing of best practices within these partnerships. Regular communication channels and joint reporting mechanisms should be established to monitor the progress of collaborative projects and to ensure that all parties are meeting their commitments. Additionally, the governance structure should encourage knowledge transfer and the co-development of technologies that can be mutually beneficial in reducing emissions.

10 PILOT CASES AND APPROACHES FOR THE DECARBONIZATION OF THE METALLURGICAL SECTOR

Study of pilot cases and approaches for the decarbonization of the metallurgical sector (including the steel sector) in other countries and assessment of its applicable potential to Kazakh context, here at least 3 countries must be analyzed with a significant share of the steel industry or the metal sector in gross domestic product)

10.1 GERMANY

10.1.1 Context

As a basic sector, the production of pig iron, steel and ferroalloys is of particular importance in the value chains of German industrial companies. Steel is a versatile material that is processed in various stages and used to manufacture products in a wide range of industries. The numerous innovations in this sector and its close links with other industrial sectors contribute to the success of the automotive industry and mechanical engineering, for example. Since 2019, industry turnover has risen by an average of 3.8% per year to €50.6 billion, which is due in particular to the sharp rise in the price of steel over the last five years.

The metallurgical industry has faced various challenges over the last five years. These included the volatility of the steel price and the negative economic impact of the coronavirus pandemic, as well as the increase in trade tensions, which made export trade more difficult. In addition, the outbreak of the war in Ukraine in February 2022 led to a sharp rise in electricity and natural gas prices, which had a negative impact on this energy-intensive industry. This prompted steel producers to take cost-cutting measures and pass on cost increases to customers, while some industry players cut back on production. Industry turnover is expected to fall by 5.7% in 2024. This is primarily due to the European Central Bank's high key interest rate, which is damping demand for steel products in the construction industry. The price of steel is expected to fall in 2024, which should also have a negative impact on industry turnover.

Germany is one of the top 10 steel producers in the world and the largest steel producer in the EU. Most of the steel in Germany is produced by the state of North Rhine-Westphalia - 40%. According to the Economic Association of Steel Producers in Germany, more than 40 million tons of crude steel were produced in Germany in 2021. Germany has become the 8th largest steel producer in the world. The steel sector accounts for about one-fifth of purchases of machinery products and 12% of purchases of automotive products. Other important consumer sectors are electrical engineering, construction, steel and metal processing. The steel industries, which employ around 4 million people, account for two out of three industrial jobs in Germany. More than 80,000 employees are engaged in the steel industry. German union IG Metall and Germany's largest steelmaker Thyssenkrupp Steel Europe AG have agreed to cut 3,000 jobs by 2026. According to WV Stahl, in November 2022, crude steel production in Germany decreased by 18% compared to November 2021 and amounted approx. 2.8 mil. tons.

Germany is the world record holder for aluminum consumption. Per capita is 40 kilograms. The information portal Planet Wissen explains this by the fact that Germany produces cars, and each car contains an average of 150 kilograms of aluminum. Currently, the industry is in a critical situation due to rising energy prices: about 15 MWh of electricity is required to produce one ton of aluminum. There are four primary aluminum plants in Germany, three of which are owned by Trimet Aluminum. For reference: Trimet's aluminum smelter in Essen consumes as much electricity per year as the city of Essen, with a population of 600,000. In March 2022, the company announced that it was cutting its production at the Essen plant in half. Trimet began cutting production at three of the five domestic plants back in the fall of 2021. By the end of 2022, raw aluminum production in Germany fell by a quarter. In January-March 2024, Germany increased steel production by 6% y/y – to 9.7 million tons, including 4.6% y/y, to 6.77 million tons, – in converters and 9.4% y/y, to 2.93, – million tons.

In the next five years, industry turnover is expected to fall by an average of 2.3% and reach €45.1 billion in 2029. The trend towards lightweight construction in industries such as automotive and aerospace means that metals such as aluminum and other materials are increasingly being used in products instead of steel. This trend is likely to continue in the future and have a negative impact on the development of the industry. In addition, increasingly stringent environmental regulations are forcing industry players to invest heavily in modernizing their machinery and equipment to reduce their CO2 emissions. Many companies in the sector cannot afford this financially, which is why market exits and consolidations are to be expected in the next five years. Germany national greenhouse gas reduction targets:

- At least 65 percent by 2030, compared to 1990.
- At least 88 percent by 2040.
- Net greenhouse gas neutrality by 2045.
- Negative greenhouse gas emissions after 2050.

10.1.2 Actions and measures taken

Germany Launches €50 Billion Industrial Decarbonization Subsidy Program

Germany has launched a massive EUR 50 billion funding program to support energy-intensive industries such as steel, chemical, and cement to become climate-neutral. The program offers considerable financial support for companies that would like to invest in innovative and climate-friendly technologies. To make green technologies more attractive, the German government relies on the Carbon Contracts for Difference ("CCfD") concept, which has adopted an innovative new format.

These hedging contracts compensate companies for the additional costs they incur through the construction (CAPEX) and the operation (OPEX) of more climate-friendly plants (or retrofitting of existing plants). One example of such climate-friendly alternatives is the use of green hydrogen. The CCfD approach has the advantage of investment risks being cushioned, but without placing an excessive burden on taxpayers. If climate-friendly production becomes cheaper than conventional production, the payment will be reversed: The subsidized companies must then repay the subsidies.

Overall, there are different funding programs available, and several funding decisions have already been made by the government for pilot green steelmaking projects.

The award procedure follows an auction model. Companies wishing to participate must demonstrate the amount of government funding they require per avoided ton of CO2. The Government's objective is to incentivize only those companies that convert their production in a particularly efficient way by awarding a climate protection contract. Selected companies receive a variable subsidy in the amount of excess costs incurred by employing climate-friendly technology over conventional technology.

Companies applying for the scheme must submit a fictional CO2 price that would allow them to develop clean production while remaining competitive against rival companies running on fossil fuels. A steelmaker switching to green hydrogen, for instance, may require a CO2 price of €300 per ton to be competitive, meaning €200 of state subsidy would be needed for each ton of CO2 avoided. Green hydrogen, produced using renewable electricity, will receive higher subsidies. The scheme is expected to save 350 million tons of CO_2 over its lifetime – a third of German industry's path towards climate neutrality.

On March 2023 Germany launched its first tender for climate contracts for difference (CFD) offering up to Eur 4 billion of support to industrial decarbonization projects. Companies submitted a required carbon price supplement for projects to proceed. Those with the lowest supplement to compliance carbon prices in the EU ETS will proceed. The first tender focuses on mid-sized companies in the paper, glass, chemical, steel and metals sectors. Support has been capped at Eur1 billion per project, with a typical 15-year support contract more likely to sum in the triple digit hundred million euros range.

Companies can use funds to switch to greener processes using renewable power or clean hydrogen, or to add carbon capture equipment to existing processes. A second tender focused on larger projects is to open in the summer and two more tenders are planned for 2025.

In total, the instrument is estimated to support some 350 million mt of CO2 savings by 2045 amounting to around 20 million mt/year, which is a third of the 2030 emissions reduction target for German industry. The German industry, which saw annual CO2 emissions plunge 12% on year in 2023 to around 144 million mt, needs to hit a 2030 sector target of 118 million mt under Germany's climate law.

Spelling out the coal exit – Germany's phase-out plan

The German parliament adopted the country's coal exit law in July 2020. The coal exit law sets out the roadmap for shutting down the country's remaining coal power capacity, clearly distinguishing between the pathways for lignite and hard coal. A lignite phase-out has greater effect on mining regions and workers than a hard coal phase-out. Germany's last hard coal mine closed in 2018.

The coal exit law serves to spell out in detail the step-by-step reduction and end of electricity production using coal in Germany. It follows the coal exit commission's recommendations from 2019 and states how much coal power generation capacity will remain in the German power market at future dates. The exit will happen in three stages:

- 15 gigawatt (GW) hard coal and 15 GW lignite capacity are left by the end of 2022 (from 22.8 GW hard coal and 21.1 GW lignite in 2019)
- 8 GW hard coal and about 9 GW lignite are to remain by 2030
- By the end of 2038 at the latest, there will be no coal power capacities left as the phase-out is completed
- Three reviews in 2026, 2029 and 2032 are scheduled to decide whether the phase-out can already be completed by 2035

The government approved draft law from 30 June 2020 states that the hard coal capacity reductions will be implemented using auctions organized by the Federal Network Agency (BNetzA) until 2027. In these auctions, coal plant operators can tender capacity volumes to be taken offline, and how much money they demand for the closure. The coal plant operators receive a "hard coal premium" for the capacity they take offline.

The auctions:

- first auction in September 2020 to take 4 GW offline - maximum remuneration 165,000 euros/MW
- auction for 2021 to take 1.5 GW offline - maximum remuneration 155,000 euros/MW
- an auction in early 2021 with the volume necessary to reach the target of having 15 GW left at the end of 2022 - maximum remuneration 155,000 euros/MW
- another auction in summer 2021 for capacity to be taken offline by 2023 -- maximum remuneration 116,000 euros/MW
- more auctions in 2022-24 for capacity to be taken offline by 2024-2027 -- maximum remuneration 107,000/98,000/89,000 and 89,000 euros/MW

In addition, the government introduced adaptation payments for older workers in lignite mines and hard coal and lignite power plants who lose their jobs due to the coal exit plans. This amounts to a maximum total of 5 billion euros by 2048.

Introduction of the LESS Steel Label in Germany – an Important Step for Steel and Metallurgical Industry Decarbonization

The uniform LESS label for green steel is a prerequisite for establishing green lead markets and green public procurement. The steel label is being developed by the steel association, and they aim to introduce it at EU level. It will be a private label, not a national or government-managed label.

The Low Emission Steel Standard (LESS), which is aiming to be adopted internationally, categorizes steel products based on their greenhouse gas intensity and the proportion of scrap used in a six-stage scaling system.

Such a label is essential for establishing green lead markets and public procurement. By uniformly defining which products can be classified—and thus marketed—as green, the previously fragmented market dominated by various certificates is unified.

- Especially for steel traded on the global market, the international perspective is decisive. The fact that LESS is designed to be internationally compatible is correct and important.
- Transparency must be considered an integral part of the process. If successful, this could spur the decarbonization of the international steel industry. It is planned to introduce the certification system within this year.
- While it is to be permitted only within a narrow and defined framework, this will determine to what extent the label promotes transformation efforts. Mass balancing that equates partially transformed products with fully transformed products risks delaying profound transformations – especially as long as there is no widespread demand for green steel.
- At the same time, there is significant time pressure to initiate profound transformations now to meet approved climate goals and keep pace with international developments.

10.1.3 Impacts and results

Germany's BMWK's grant for steel processing decarbonization

The Federal Ministry of Germany for Economic Affairs and Climate Action, or BMWK granted Eur 880,000 ($914,000) to steelmaker Georgsmarienhütte's decarbonization project, which would cut carbon emissions and natural gas imports. This was the first time BMWK was funding a project aimed at decarbonizing steel processing. Using this fund, Georgsmarienhütte - a German supplier of bars made of high-grade structural and stainless steel, has built a quenching and tempering plant for the thermal treatment of steel bars and put it into operation in mid-2023.

In the traditional energy-intensive tempering process, the reheating furnaces are fired with natural gas and generate greenhouse gas emissions, but in this project, they are powered instead by green electricity. The project has replaced a major source of CO2 emissions at the Georgsmarienhütte site in Lower Saxony, and at the same time contribute to reducing Germany's dependence on natural gas imports. At this mill alone, around 2,800 mt/year of CO2 emissions are avoided, according to BMWK's statement.

Green electricity from Amrumbank wind farm to power trains of Deutsche Bahn

In 2019, RWE closed a PPA with Deutsche Bahn to supply electricity from its Nordsee Ost offshore wind farm, also close to Heligoland. Starting with 2024, Deutsche Bahn (German Rail) is powered by electricity from RWE Renewable's Amrumbank West offshore wind farm. The relevant power purchase agreement (PPA) has been signed by Deutsche Bahn and RWE Supply & Trading, RWE's trading subsidiary. The PPA will begin in 2024 and run until 2039.

Deutsche Bahn is already the largest consumer of green electricity in Germany. By 2038, all the electricity powering Deutsche Bahn's trains is to come from 100% renewables; the rate is currently 61%. Green electricity from RWE will make a key contribution here. The company's hydropower stations have been providing around 880 megawatt hours (MWh) of green electricity a year to Deutsche Bahn since 2014.

Amrumbank West is located around 30 km off the coast of Heligoland and has a total of 80 wind turbines with an installed capacity of 288 megawatts. It has been in operation since 2015. The supply volume to Deutsche Bahn requires the capacity of 18 wind turbines, or around one quarter of the annual generation capacity of the offshore wind farm. That's a total of around 260 MWh. This is enough to supply around 300,000 households with clean energy every year.

Offshore Wind Energy Development in Germany

In total, 1,501 offshore wind turbines with a capacity of 7,770 MW are feeding electricity into the German grid from the North Sea and Baltic Sea. Germany currently has 7,770 MW of installed offshore wind capacity and is currently the third in the world behind the UK and China. In 2020, the country added 219 MW of offshore wind capacity.

In terms of installed capacity, Germany is in second place worldwide behind the United Kingdom, with, in 2019, 7.5 GW installed, representing 12.3% of the country's total installed wind power capacity, for 1,500 offshore wind turbines in operation. In 2019, offshore wind turbine installations exceeded onshore installations for the first time, with 1.1 MW installed at sea this year. As a result, Germany's offshore wind turbine production amounted to 24,700 GWh that same year, accounting for 19.6% of the country's wind power production.

According to industry group Fachagentur Windenergie an Land, the gross capacity expansion of onshore turbines reached about 0.9 GW with 276 turbines in 2019. Thousands of planned onshore wind projects in Germany are currently put on hold, mainly due to regulatory conflicts with aviation authorities but also due to protest groups challenging new installations in court.

The German wind farm accounts for 27.6% of the world's offshore wind installations and has overtaken Denmark and China in recent years. Germany has recently accelerated the development of offshore wind turbine installations, with an increase in 2019 of 17% compared to 2018. In 2020, energy from wind turbines accounted for 30% of the amount of electricity fed into the German grid. Offshore wind energy thus accounts for about 6% of all the electricity produced by the country in 2020.

10.1.4 Lessons learned for Kazakhstan

The in-depth case studies shed light on the pivotal strategies for decarbonization:

1. Energizing Energy Efficiency

German experience encompasses an array of techniques to optimize energy utilization within manufacturing processes. It is very important that these measures have proven to be not just effective but also cost-efficient. For example, in several cases, the implementation of energy efficiency measures stabilized energy demand at a constant level, which is a significant achievement in itself.

2. Embracing Renewable Energy

Companies that invested in expanding their renewable energy capacity or that entered into long-term renewable energy supply offtake agreements to cover their energy needs emerged as leaders in the journey to decarbonization. The German country and respective companies experience explicitly highlights the value of transitioning to cleaner, self-generated energy sources. This is particularly pertinent in the context of the changing dynamics of electricity generation and the substantial abatement potential it offers.

3. The Hydrogen Transition

Transitioning from natural gas to hydrogen emerges as another powerful strategy with substantial greenhouse gas abatement potential. This transition affects not only Scope 1 but also Scope 2 emissions. It provides a clear path toward a sustainable and lower-carbon future.

4. Decarbonization Roadmap: The Guiding Light

One pivotal aspect is the development of a decarbonization roadmap aligned with GHG emissions mitigation targets, offering companies a detailed plan for achieving emission reduction targets. This roadmap is replete with a well-defined timeline, specific targets, and identified measures to realize the desired reduction in GHG emissions.

5. Bridging the Gap: Transition Challenges and Successes

The German country experience acknowledges certain limitations, such as the need for more extensive data and better cross-border comparability. It is important because it shows how important it is to look at upstream emissions in the value chain, which supports a complete approach to reducing carbon emissions.

It should be mentioned that the German country met serious technical problems with the transmission line and respective transmission capacities. Existing transmission lines have been used, outdated and German State invested additional considerable amounts in infrastructure renovation: new higher voltage transmission and distributions electrical lines, new interconnections, automation and delimitation equipment, new transformer station and respective connections and interconnections, etc.

6. The option to enter long-term offshore PPAs is an advantage for metallurgical industry

The power prices paid by industry are one of the most contentious aspects of Germany's energy transition and its economic impacts. But it should be mentioned that there is no single power price for industrial consumers, but instead an exceptionally broad range of prices. Due to a complex system of taxes and levies, they depend on how much electricity companies need, when they need it, how they source it, whether they compete with rivals abroad, and many other factors.

Many companies keep a keen eye on green power purchase agreements (PPA) to get a better handle on power prices. These contracts between a power generator and a consumer – for example, between a wind park and a factory – specify the terms for the sale of electricity and guarantee long-term price security.

7. Policy Implications: Driving Corporate Climate Action

German State experience accentuates the need for policy incentives to encourage corporate GHG emissions reduction. It suggests that a long-term, defined carbon price could play a significant role in motivating businesses to adopt decarbonization strategies. Furthermore, the need for state-level support for renewable energy systems and green hydrogen infrastructure, via targeted investment support, is paramount. The findings underline the essential role that policy and regulatory frameworks play in fostering climate action.

In summary, analysis of the decarbonization strategies for German manufacturing companies from metallurgical industry represents a significant step toward understanding the diverse industries' role in mitigating climate change. It shows that there is no one-size-fits-all approach to decarbonization. Companies need to consider their unique circumstances, strategic shifts, and the adoption of renewable energy sources, all of which are vital for achieving climate action goals.

10.2 AUSTRALIA

10.2.1 Context

BlueScope is Australia's largest steel manufacturer with ~$2billion shareholding value, and has facilities in other countries of Pacific Ocean, China, India and North America. Its Australian business, Australian Steel Products (ASP) employs around 7,000 employees at approximately 100 sites across Australia. ASP segment manufactures and distributes flat steel products – with leading brands such as COLORBOND® steel and TRUECORE® steel. It's steel making facility is located at Port Kembla, NSW, Australia and known as Port Kembla Steek Works (PKSW). PKSW is a traditional integrated steelmaking facility using the blast furnace ironmaking (BF)-basic oxygen furnace (BOF) route. This pilot case study is for PKSW.

BlueScope is following World's largest steel makers (ArcelorMittal, ThyssenKrupp, Voestalpine SSAB/LKAB/Vattenfal, Nippon Steel and POSCO) in committing to net zero emission by 2050 targets. BlueScope's decarbonization pathway is as shown in Figure 18, which is equally applied for PKSW. It is based on two mid-term 2030 greenhouse gas (GHG) emissions intensity targets and a longer-term 2050 net zero goal (see Figure 19). Their 2030 targets of 12% carbon intensity reduction in steel-making and 30% in non-steel-making are based on realistic conditions of the plant.[89]

PKSW's decarbonization activities will be undertaken across two parallel streams of work. Firstly, in this next decade, activities will involve optimizing existing blast furnace assets via exploring a range of initiatives to improve emissions intensity. Secondly, and in parallel, activities will involve building a pathway to meet BlueScope's goal of net zero emissions by 2050. This second future-orientated workstream includes a comprehensive technical investigation program.[90]

They also acknowledge that achieving the 2050 net zero goal is highly dependent on several enablers, including the commerciality of emerging and breakthrough technologies, the availability of affordable and reliable renewable energy and hydrogen, the availability of quality raw materials, and appropriate policy settings. Breakthrough technologies will take time to be at a commercial stage, so are viable green hydrogen, CCUS and electrolytic reduction. At this stage their concentration is over optimization, emerging technologies, BF replacement and EAF. Optimizing current operating assets involves improving efficiency of assets and processes and upgrading technology where it is possible.

10.2.2 Actions and measures taken

Recognizing that 'green steel' is not yet commercially available at scale, PKSW are working on optimizing existing assets and processes and working in partnership with industry and research bodies to progress the technical and commercial viability of future technology options[1]. In the near to mid-term, the focus will be on

- Optimizing raw material mixes.
- Capturing and reusing a greater proportion of waste heat and gases.
- Potentially replacing a portion of the coal currently used in the blast furnace process with alternative reductants such as hydrogen.
- Establishing markets for co-products via carbon capture, utilisation and storage (CCUS).

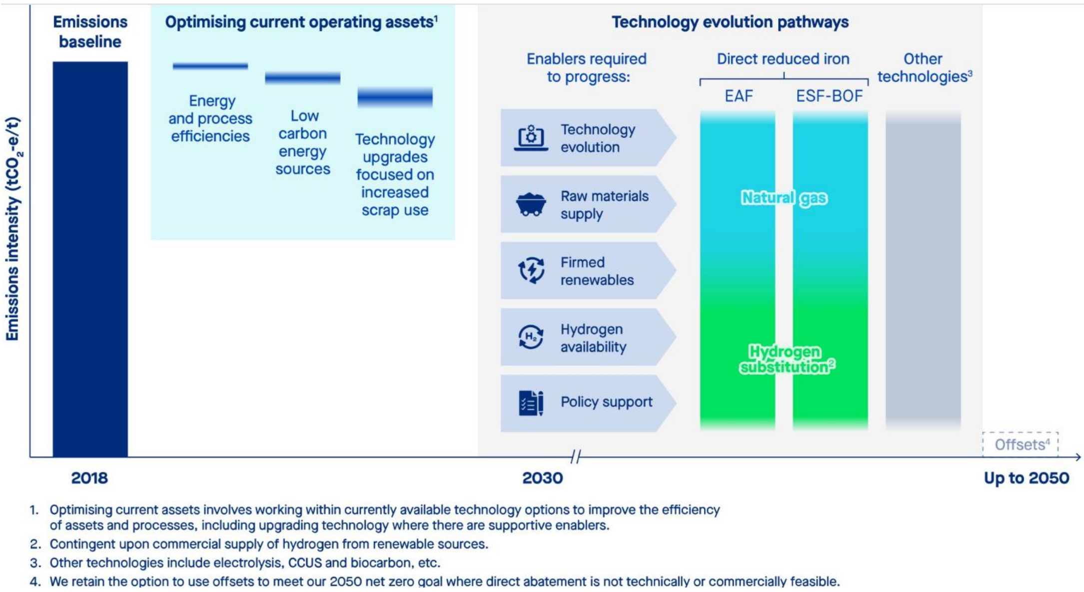
[89] BlueScope, 2024. Climate Action Report. Accessed via: https://www.bluescope.com/sustainability/climate-action

[90] Paul Zulli, 2023. Phase 3 report Port Kembla Steelworks renewables and emissions reduction study - Assessment of prioritized options and potential decarbonization pathways for the Port Kembla Steelworks.

- Increased rates of scrap use and renewable energy to reduce or eliminate Scope 2 GHG emissions are also key focus areas.

BlueScope have allocated $150 million over five years starting FY22 to fund their climate-related technology plan.

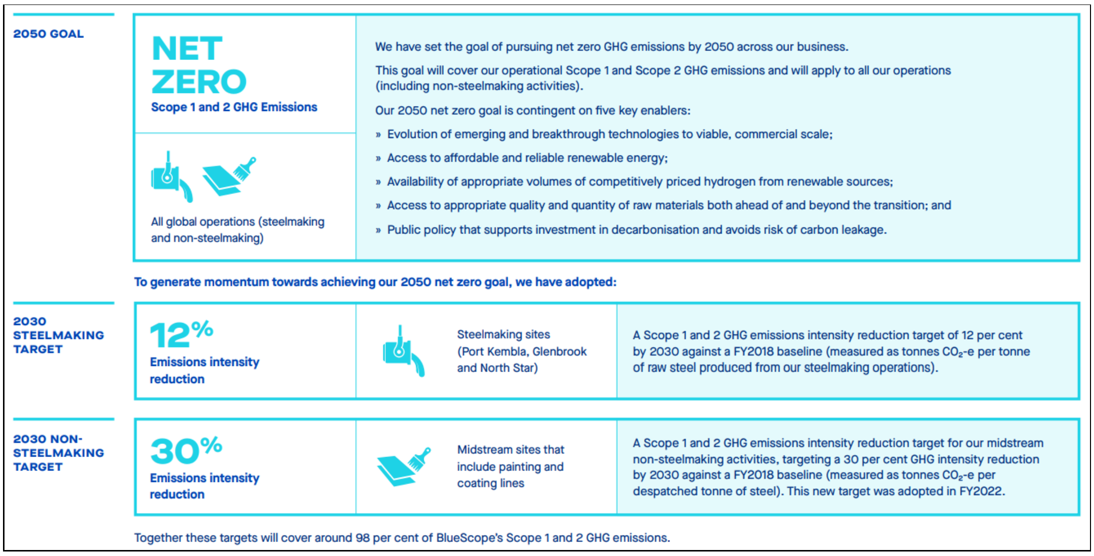
Figure 18: Bluescope's indicative iron- and steelmaking decarbonization pathway.



Source: BlueScope Climate Action[91]

[91] BlueScope Climate Action, 2024. Accessed via: https://www.bluescope.com/sustainability/climate-action

Figure 19: BlueScope's 2030 targets and 2050 Net Zero Goal



Source: BlueScope Climate Action[91]

Actions between now and 2030

A. PKSW has already performed the following investigation plan in 3 phases:[92]

Phase 1: Investigated potential GHG emissions reduction opportunities at PKSW and identified a set of Prioritized Options[93] [3]. In this phase Qualitative Options Analysis (QOA) was applied for an evaluation of 17 current and future emerging carbon avoidance technological areas for Blast Furnace Ironmaking / Cokemaking / Sintering; Alternate Ironmaking; Steelmaking; and Carbon Capture, Utilization and Storage (CCUS). Approximately 100 different processes and materials options across these areas were reviewed in the process using the following methodology.

Four Technical Decision Criteria, with specificity and application to PKSW, were applied for evaluation of each area:

(1) Technology Readiness Level.

(2) Anticipated timeline and availability.

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[92] Paul Zulli, Xue Feng Dong, Chris McMahon, Andrew McClure and Peter Austin, "Phase 3 report Port Kembla Steelworks renewables and emissions reduction study - Assessment of prioritised options and potential decarbonisation pathways for the Port Kembla Steelworks", Sept, 2023. Accessed via: https://arena.gov.au/assets/2024/03/Bluescope-Steel-Port-Kembla-Steelworks-Renewables-Emissions-Reduction-Study-Phase-3-Report.pdf

[93] Phase 1 report - Port Kembla Steelworks Identification of Prioritised Options Port Kembla Steelworks Identification of Prioritised Options - Australian Renewable Energy Agency (ARENA)

(3) Abatement potential (Scope 1 and Scope 2).

(4) Potential production and key performance indicators impact, including operational risks.

A "Fatal Flaws" approach was applied to identify/screen non-viable technologies for PKSW, based on an inability to achieve at least one of three key objectives: BlueScope's high-level business plans (e.g. major capital investments, including the planned No. 6 Blast Furnace reline and upgrade), the energy sector's plans (e.g. renewable energy) and government policy changes.

A project team-based evaluation.

- Both short-term and long-term objectives were identified in this phase.

Phase 2: Investigated potential biomass and biochar supply options, pyrolysis equipment options to produce biochar from biomass, and pilot and plant trials of biochar.[94]

Phase 3: Final assessments of the Prioritized Options identified in Phase 1 including:

- Qualitative assessment of operational, engineering, environmental and safety aspects for PKSW.
- Process integration (PI)-based flowsheet modelling of some Prioritized Options relative to a baseline PKSW operation.
- Final assessment process.
- PKSW's decarbonization roadmap, including planning for further investigations.

B. To meet 2030 reduction targets, they are continuing to optimize current operating assets.

i. They first focussed on biochar and the potential for it to replace some of the coal injected into the blast furnace. Pilot testing at University of Wollongong [supported by ARENA (Australian Renewable Energy Agency)] and plant trials at PKSW's No. 5 Blast Furnace showed that biochar/coal blends of up to approximately 20% biochar could be successfully used to replace pulverised coal in BF operations for at least short periods of time, without detriment to the stability, productivity of the process or the quality of the hot metal. They are currently working with several sustainable biochar supply projects within Australia, given there is no industrial scale biochar supply chain in Australia.

ii. A simulation model was used to assess potential emissions (CO_2) reduction with the use of four alternative reductants in No. 5 Blast Furnace (5BF): biochar, torrefied biomass (TB), coke ovens gas (COG) and hydrogen. The outcomes from the modelling were used in the assessment of these Prioritised Options. The Prioritised Options were categorised based on short-to-medium term and long-term, with the knowledge that No. 6 Blast Furnace would be relined and operated through the short-to-medium term, and

[94] Phase 2 report – Port Kembla Steelworks Renewables and emissions Reduction Study – Biochar Investigation Bluescope Generic Report Template_v5. Accessed via: www.arena.gov.au

that a step change would be required for the long-term to achieve a net zero goal by 2050.

C. Maximising the use of scrap steel at PKSW remains a key focus for thr period till 2030. Steel is one of the most highly recycled materials in use today, and is a key enabler in lower emissions steelmaking. IEA predicts that 45% of global steel demand can be satisfied by scrap steel by 2050. There are wide regional variations in the availability of scrap steel of a quality suitable for producing secondary steel. The shortfall in suitable quality scrap in Australia makes the EAF production method difficult for producing flat products (e.g. COLORBOND® steel).

- However, PKSW have increased scrap content in the steelmaking process from approx. 21.5% to 25% from 2019 to 2022. Given its cooling effect, current levels of scrap in the steelmaking process are approaching their technical maximum limit. Their aim is to increase scrap content to 30% by 2030 by investigating ways to pre-melt scrap, along with a number of asset modifications, which has the potential to reduce emissions intensity by ~6%.

D. They are also working to optimise water monitoring, reduce the consumption of fresh water drawn from community water sources, for example through water recycling and rainwater capture, and improve water discharge quality.

Actions from 2030 and beyond

BlueScope is focused on developing a clear pathway to low emissions 'primary' steelmaking in Australia. Direct Reduced Iron (DRI) is the most prospective technology to decarbonize BluScope's Australian business. They are investigating accelerated technological developments in natural gas DRI as a transitional pathway to using green hydrogen to produce lower emissions steel.

In February 2024, BlueScope announced a new framework agreement with Rio Tinto and BHP to accelerate the decarbonization of steelmaking by jointly investigating the development of the country's first ironmaking electric smelting furnace (ESF) pilot plant. ESF is the type of furnace that processes DRI feed and separates impurities to produce a liquid pig iron product suitable for a BOF that can produce a wider range of steel products.

"We believe the development of ESF technology is key to unlocking Australia's unique advantages in this decarbonization journey – and, more importantly, has the potential for wider adaptation across the global steel industry. We believe that this collaboration where we can contribute BlueScope's unique experience in operating an ESF will be key to cracking the code for Pilbara ores in low emission-intensity ironmaking." Tania Archibald, Chief Executive Australian Steel Products.

In the longer-term, PKSW will continue to explore multiple process routes and understand how they might fit into their operations depending on how the technologies, energy and raw materials availability, and regional policies evolve.

10.2.3 Impacts and results

Prioritized Options proposed for further action, for both short-to-medium term and long-term, are shown in Figure 17 below. Further actions were recommended for Prioritized Options with the greatest potential to be economically viable and contribute to emissions reduction at PKSW.

Short-to-medium Term:

Pre-Reduced Agglomerates (PRA): Novel charging materials to the blast furnace include Carbon Containing Agglomerates (CCA), PRA and Ferro-coke. PRA in the form of Hot Briquetted Iron (HBI) produced using a DR process, is, to a limited extent, a globally traded commodity, though most production is captive to downstream users. Kobe Steel reports a potential 12% reduction in overall ironmaking GHG emissions is possible, taking Scope 3 emissions into account. The ongoing cost/benefit of HBI will need to be monitored and included in PKSW's material selection processes. Further investigations would be required to conduct a HBI trial.

Biomass: As indicated before, following successful trials of up to 30% biochar mixed with Pulverized Coal Injection (PCI) coal for 24 hours at PKSW it is proposed, to enable longer duration trails to be conducted, to further investigate those potential suppliers planning to produce biochar in Australia.

Scrap Use in BOF: As mentioned earlier, with the success of increasing scrap to 25% from 2019 to 2022, PKSW is working to maximize scrap content to 30% by 2030 and beyond hereafter.

Figure 20: Prioritised Options for PKSW

PRIORITISED OPTION	FURTHER INVESTIGATION	RECOMMENDATION
SHORT-TO-MEDIUM TERM		
Blast Furnace Ironmaking		
Novel charging materials to BF		
• Pre-reduced agglomerates (PRA)	YES	Further investigate what would be required to conduct a HBI trial.
Biomass application in ironmaking	YES	To enable longer duration trials to be conducted, further investigate those planning to produce biochar in Australia.
Steelmaking		
DRI and scrap utilisation in Basic Oxygen Furnace		
• Scrap utilisation in Basic Oxygen Furnace, including scrap preheating	YES	Continue with current trials and investigations to increasing scrap utilisation in the BOF.
LONG TERM		
Alternate Ironmaking		
Fluidised bed direct reduction	YES	Complete Options Study.
Shaft furnace direct reduction	YES	Complete Options Study.
Steelmaking		
DRI utilisation in ESF-BOF	YES	Complete Options Study. Continue existing collaborations on the development of a DRI-ESF pathway.
DRI utilisation in an EAF	YES	Complete Options Study

Source: PKSW, 2023[95]

[95] Port Kembla Steelworks, 2023. Phase 3 report Port Kembla Steelworks renewables and emissions reduction study - Assessment of prioritised options and potential decarbonisation pathways for the Port Kembla Steelworks". Accessed via: https://arena.gov.au/assets/2024/03/Bluescope-Steel-Port-Kembla-Steelworks-Renewables-Emissions-Reduction-Study-Phase-3-Report.pdf

Long Term:

Fluidized Bed Direct Reduction: Fluidized bed direct reduction processes utilize iron ore fines, with no significant agglomeration treatment required. In this process, iron ore fines move through a series of fluidized bed reactors and are efficiently heated and reduced by natural gas (typically, reformed natural gas and syngas present-day; and, potentially, in the future, renewable hydrogen). It has been recommended to perform complete Options study for considering DRI for long-term steelmaking.

Shaft Furnace Direct Reduction: Most direct reduction plants utilize shaft furnace reactors based on either MIDREX or HYL-ENERGIRON technologies. Shaft furnaces are moving bed, counter-current reactors with upwards flowing reducing natural gas and downwards flowing iron-bearing materials. Also, recommended for complete options study for this process for PKSW.

DRI-ESF-BOF Route: In the long term, steelmaking operations will be dependent on the selected ironmaking technology. DRI-ESF (Direct Reduced Iron – Electric Smelting Furnace) route, using hematite would align with continuing BOF steelmaking, whereas DRI using magnetite would not and an EAF would be required. PKSW will utilize experience of BlueScope's New Zealand Steel plant that has extensive experience of ESFs. A complete Options Study is recommended.

DRI-EAF Route: DRI utilization in the EAF (Electric Arc Furnace) is a mature technology with approximately 8% of global steel now being produced via this route. The main limit in applying this technology is the requirement to use high quality iron ore. BlueScope will include the DRI-EAF process in future ironmaking considerations.

Barriers

PKSW have similar barriers and opportunities as most of the hard-to-abate industries, like steel, are facing when decarbonization with Net Zero goal is to achieve. However, the most noticeable barriers are:

- Availability of affordable and reliable renewable energy and hydrogen
- Proper supply chain for novel charging materials and scrap metals
- Supply of biomass/biochar
- New technologies' knowledge gaps
- Complete understanding of BF hydrogen metallurgy
- Complexity in retrofitting new technology
- High cost
- Unfavourable Governmental regulations

The most significant opportunities are:

- Favourable Governmental regulations

- Access to all technoloy players through collaboration
- Determination to follow decarbonization pathway with a goal to achieve Net Zero by 2050.

Favorable Government Regulations

Australian Government's Safeguard mechanism has started from July 1, 2024[96]. Under the mechanism, the nation's heaviest-polluting companies will be forced to cut their carbon footprint by up to about 5 per cent a year from July 1 until the end of the decade. However, manufacturers of products including steel, cement and aluminum – whose processes depend on fossil fuels but do not yet have commercially viable electric alternatives – will have to cut their carbon footprints by only 1 per cent a year. They will also have access to $400 million in grants to help them transition to cleaner operations.

Potential adverse impacts on BlueScope from the Federal Government's safeguard mechanism to reduce emissions, which comes into effect on July 1, have been materially alleviated, according to the company.

10.2.4 Lessons learned for Kazakhstan

Kazakhstan's position on resource-based economy is similar to Australia with similar iron ore reserves and hence the raw material for iron and steel making. One would expect BlueScope's decarbonization strategies should be similar for Kazakhstan's iron and steel industry. Hence the main learning from this pilot case for Kazakhstan would be to:

- Optimize all available assets and processes as mentioned for PKSW.
- Concentrate for near to medium term on emerging technologies, BF replacement by DRI-melter and EAF. Scrap metal use, use of biochar in BOF, testing DRI-ESF-BOF route are a few examples.
- Investigate all options available for short-to-medium term as well as for long term and cost them; Hydrogen use for green steel should be an option.
- Prioritise options as per company set criteria.
- Collaborate with technology players around the world, which is necessary to enable to adopt new low-to-zero carbon technologies.
- Lobby for favourable government policies and regulations.

[96] Australian Government, 2024. Safeguard mechanism. Accessed via: https://www.dcceew.gov.au/climate-change/emissions-reporting/national-greenhouse-energy-reporting-scheme/safeguard-mechanism#toc_2

10.3 CANADA

10.3.1 Context

Canada is the second-largest country in the world by land area and has a population of about 39 million. In 2023, Canada produced nearly 60 million metric tons of iron ore and was by far the leading metallic mineral produced by the country based on volume. Copper accounted for the second-largest metallic mineral produced in Canada that year, with a distant 5.1 million metric tons produced[97]. Canada is also a key global producer of nickel (6th in the world), aluminum (global 4th) and cobalt (5th in the world) and hosts advanced mineral projects for rare earth elements, lithium, graphite and vanadium. Canada counts more than 30 smelters, refineries, and pelletizers which process feedstock that contains nickel, aluminum, copper, gold, silver, cobalt, iron ore, lead, bismuth, and platinum group metals.

Concerning steel, Canada is the world's 19th largest steelmaker with about 21,700 kt yearly[98]. Since 1990, the Canadian steel industry has made significant investments to cut energy consumption and emissions, resulting in a 31.5% reduction in absolute GHG emissions by 2016, and an improvement in emissions intensity by roughly 27.6%[99]. Thanks to these efforts, Canada's steel sector boasts the lowest GHG intensity worldwide for integrated steelmaking plants that produce steel from iron ore, and the second lowest GHG intensity globally for Electric Arc Furnace plants that manufacture steel from scrap, according to an assessment of the largest steel-producing nations[100].

Regarding aluminum production, Canada is the 4th largest producer in the world with 3 million MT (metric tonnes)[101]. According to the Pan-Canadian Framework on Clean Growth and Climate Change, Quebec's aluminum smelters have reduced their emissions by 30 % since 1990 and Canada's aluminum industry is now the most carbon-efficient producer in the world.

10.3.1.1 NDC and carbon emission reduction targets

Canada announced its Intended Nationally Determined Contribution (INDC) in May 2015, pledging a 30% reduction from 2005 levels by 2030, which translates into 524 Mt in 2030 off a

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[97] Statista, 2023. Metallic mineral production volume in Canada in 2023, by mineral. Accessed via: https://www.statista.com/statistics/434815/estimate-of-metallic-mineral-production-in-canada-by-mineral/#:~:text=In%202023%2C%20Canada%20produced%20nearly%2060%20million%20metric,with%20a%20distant%205.1%20million%20metric%20tons%20produced.

[98] Wise voter, 2024. Steel production by country. Accessed via: https://wisevoter.com/country-rankings/steel-production-by-country/

[99] Canadian Steel Producers Union, 2021. Canadian Steel Industry Energy & Greenhouse Gas Emissions Intensity, Technology and Carbon Reduction Roadmap. Accessed via: https://canadiansteel.ca/files/resources/Golder-Report-CSPA-NRCan.pdf

[100] All Hasanbeigi & Cecillia Springer. Global Efficiency Intelligence. November 2019. How Clean is the U.S. Steel Industry? An International Benchmarking of Energy and CO2 Intensities.

[101] INN, 2024. Top 10 aluminum-producing countries. Accessed via: https://investingnews.com/daily/resource-investing/industrial-metals-investing/aluminum-investing/aluminum-producing-countries/

forecast of 798 Mt (including land-use GHGs)102. To put these targets into action, Canada has two main clean growth and climate action plans, which are the Pan-Canadian Framework on Clean Growth and Climate Change103 and the 2030 Emissions Reduction Plan - Canada's Next Steps for Clean Air and a Strong Economy104. In both documents metallurgy is not treated as a separate sector, instead it is embedded within "industry". The Pan-Canadian Framework does not have emission reduction targets specifically for the metallurgical sector, neither the 2030 Emissions Reduction Plan does.

10.3.2 Actions and measures taken

The federal budget released in April 2021 introduced some commitments to support pan-Canadian initiatives for developing critical minerals and battery value chains[105], such as:

- $47.7 million over three years for research and development focused on upstream critical minerals processing, battery precursors, and materials engineered from both primary and secondary sources.
- $9.6 million over three years to establish a Critical Minerals Centre of Excellence.
- $5 billion for the Net Zero Accelerator (NZA), adding to the previously announced $3 billion. This funding aims to expedite decarbonization projects with major emitters, scale up clean technology, and accelerate Canada's industrial transformation across all sectors, with a particular emphasis on developing a battery innovation ecosystem.
- A 50% reduction in the general corporate tax rate for businesses manufacturing zero-emission technologies.

Here below several actions and measures taken in the country are listed and briefly depicted.

10.3.2.1 The Low Carbon Economy Fund

The Government of Canada created in 2017 the Low Carbon Economy Fund106 (LCEF), which supports projects that help reduce Canada's greenhouse gas (GHG) emissions, generate clean growth, build resilient communities, and create quality jobs. The LCEF supports the Government

[102] Low carbon pathways group, 2015. Pathways to deep decarbonization in Canada. Accessed via: https://cmcghg.com/wp-content/uploads/2015/07/Final-Canada-DDPP-Country-Report-July-14.pdf

[103] Government of Canada, 2016. Clean growth and climate change. Accessed via: https://publications.gc.ca/collections/collection_2017/eccc/En4-294-2016-eng.pdf

[104] Government of Canada, 2022. 2030 emissions reduction plan. Accessed via: https://publications.gc.ca/collections/collection_2022/eccc/En4-460-2022-eng.pdf

[105] CMMP, 2021. The Canadian minerals and metals plan. Accessed via: https://www.minescanada.ca/sites/minescanada/files/CMMP-ActionPlan2021_May27-ACC.pdf

[106] Government of Canada, 2022. Low carbon economy fund. Accessed via: https://www.canada.ca/en/environment-climate-change/services/climate-change/low-carbon-economy-fund/what-is-lcef.html

of Canada's plans to achieve GHG emissions reductions in 2030 and goals for net-zero emissions by 2050. The fund is a significant part of Canada's clean growth and climate action plans.

10.3.2.2 Canadian Minerals and Metals Plan and Action Plan

The Canadian Minerals and Metals Plan[107], published in 2019, includes a vision, principles and strategic directions that governments, industry and stakeholders can pursue to drive industry competitiveness and long-term success. This plan was developed by federal, provincial and territorial governments in collaboration with partners and stakeholders involved in the minerals and metals industry.

There is also the Minerals and Metals Action Plan, published in 2021,[107] which focuses on implementing the vision. It provides an update on the pan-Canadian initiatives introduced in Action Plan 2020, areas of collaboration, and highlights the actions that federal, provincial and territorial governments, Indigenous organizations, and stakeholders have taken. It also introduces an approach so that Canada's mineral and metals sector can continue to prosper across all regions of the country.

10.3.2.3 Strategic Innovation Fund – Net Zero Accelerator (SIF-NZA)

The Government of Canada introduced the $8 billion Net Zero Accelerator to facilitate the decarbonization and sustainable growth of the country's largest industrial emitters. This program invests in the adoption of clean technologies and processes aimed at significantly reducing greenhouse gas emissions by 2030, paving the way for industries to achieve net zero emissions by 2050.

10.3.2.4 Clean Growth Program

The $155 million Clean Growth Program ended on March 31, 2022. This program was fully allocated, funding 43 clean technology research and development and demonstration projects in energy, mining and forestry over 4 years. The program advanced emerging clean technologies toward commercial readiness so that natural resource operations can better reduce their impacts on air, land, and water.

10.3.2.5 The 2030 Emissions Reduction Plan

The 2030 Emissions Reduction Plan mentions that to meet Canada's 2030 target and lay the groundwork for net-zero emissions by 2050, the Government of Canada commits to "develop a comprehensive CCUS Strategy to guide the development and deployment of CCUS technologies to

[107] The Canadian minerals and metals plan, 2019. Accessed via: https://www.minescanada.ca/en/what-canadian-minerals-and-metals-plan

mitigate GHG emissions from a range of industrial sectors in Canada, such as steel, cement, chemicals, and the oil and natural gas sector". The Plan does not include metallurgy-sector specific emissions reduction targets.

10.3.3 Impacts and results

10.3.3.1 The Low Carbon Economy Fund

The Canadian government awarded C$18.1 million (US$13.4 million) from the Low Carbon Economy Fund to lower carbon dioxide emissions from Rio Tinto's iron ore operations in the province of Newfoundland and Labrador. This represents approximately 25% of the total cost of the CO2 reduction project, with the remaining amount being funded by Rio Tinto's Iron Ore Company of Canada.

This grant awarded to Rio Tinto's Iron Ore Company of Canada (IOC) will decrease the consumption of heavy fuel oil in the production of iron ore pellets and concentrate. To achieve this, IOC will install an electric boiler to replace the heavy fuel oil boilers, significantly cutting CO2 emissions from iron ore processing in Rio Tinto's Labrador plant. Additionally, new instrumentation and fuel-efficient burners will be implemented to further reduce heavy fuel oil usage in the induration machines used for pellet production. These enhancements are projected to lower greenhouse gas emissions from the facility by 2.2 million metric tons over the project's duration.

10.3.3.2 Canadian Minerals and Metals Plan and Action Plan

As stated in the Canadian Minerals and Metals Plan, Alcoa Corp. and Rio Tinto Group are collaborating to develop a new aluminum-making process that eliminates greenhouse gases. This technology will be available to retrofit existing smelters or build new facilities. Canada and Quebec are each investing $60 million for this project, Rio Tinto and Alcoa will invest $55 million, and Apple is providing $13 million and technical expertise.

On the other hand, the Action Plan 2021 states that the Saskatchewan Research Council announced construction of a rare earth elements processing plant, which will improve North America's supply chains and contribute to the production of EVs and permanent magnets outside of China.

10.3.3.3 Strategic Innovation Fund – Net Zero Accelerator (SIF-NZA)

Through the Strategic Innovation Fund, the Government of Canada is committing $400 million to support a $1.8-billion initiative aimed at decarbonizing steel production at ArcelorMittal Dofasco's Hamilton, Ontario facility. This funding will facilitate the transition of the facility to a hydrogen-ready direct reduced iron-fed electric arc furnace. The project is expected to significantly advance Canada's climate goals by reducing GHG emissions by up to 3 million metric tons annually by 2030.

On the other hand, and through the (SIF-NZA), the Government is allocating $60 million towards a $558-million large-scale demonstration project spearheaded by Alcoa Corporation and Rio Tinto Aluminium in Quebec. This project aims to pilot an innovative production process that could nearly eliminate the carbon footprint of Canada's aluminium industry. If fully adopted across the industry, the technology could cut annual greenhouse gas emissions by about 6.5 million metric tons - equivalent to removing over 1.8 million passenger vehicles from the road.

10.3.4 Lessons learned for Kazakhstan

This section describes lessons that can be drawn from the Canadian case into Kazakhstan. Both countries have similarities such as being very vast, having a low population density and large reservoirs of several metallic minerals. This and the fact that Canada has an advanced metallurgy sector makes Canada a good country to draw lessons from for Kazakhstan.

Strategic investments in decarbonization

Canada's commitment to significant financial investments in decarbonizing its metallurgical sector demonstrates the importance of robust funding to achieve substantial emissions reductions. Kazakhstan could benefit from establishing similar financial mechanisms to support clean technology adoption and industrial transformation.

Research and development funding

Canada allocated substantial funds to research and development for critical minerals processing and battery technology. Kazakhstan should consider investing in R&D to innovate and improve the efficiency and environmental footprint of its own mineral processing technologies.

Establishing centers of excellence

The creation of a Critical Minerals Centre of Excellence in Canada emphasizes the value of specialized institutions dedicated to advancing knowledge and practices in the sector. Kazakhstan could establish similar centers to focus on its unique mineral resources and promote best practices.

Tax incentives for clean technology

The 50% reduction in the corporate tax rate for businesses manufacturing zero-emission technologies in Canada highlights the role of tax incentives in promoting green technology. Implementing similar tax incentives could stimulate Kazakhstan's clean technology sector.

Comprehensive climate action plans

Canada's use of comprehensive plans like the Pan-Canadian Framework and the 2030 Emissions Reduction Plan provides a structured approach to achieving climate targets. Kazakhstan could develop detailed action plans that include specific targets and measures for the metallurgical sector.

Public-private partnerships

Collaborations between the public sector and private companies, such as the partnership between Alcoa Corp. and Rio Tinto Group with the government, show the effectiveness of public-private partnerships in advancing technological innovations and large-scale industrial projects. Kazakhstan should encourage such partnerships to leverage private sector expertise and investment.

Circular economy and recycling initiatives

Canada's focus on reducing waste and enhancing recycling as stated in the Canadian Minerals and Metals Plan underscores the benefits of a circular economy. Kazakhstan can implement policies to increase recycling and waste reduction in its metallurgical industry.

Adapting to climate change

The Canadian approach to integrating climate adaptation measures within the metallurgy industry illustrates the importance of preparing for climate impacts. Kazakhstan should adopt similar strategies to ensure its metallurgical sector remains resilient to climate change.

Greenhouse gas emission targets

Setting clear GHG emission reduction targets provide direction and accountability. Kazakhstan could establish specific, measurable targets for reducing emissions in its metallurgical sector.

Global competitiveness through environmental leadership

Canada's efforts to position its metallurgical sector as a global leader in low-GHG intensity production highlight the competitive advantage of environmental leadership. Kazakhstan can enhance its global market position by adopting and promoting sustainable practices in its metallurgical industry.

10.4 COMPANY PILOT CASES

Apart from these individual country cases, there are some other successful examples of alternative energy development in the global mining industry:

- Centamin's Egyptian Sukari mine reduced its direct emissions by commissioning a 26-megawatt solar power plant with a battery system in 2022, saving 70,000 litres of diesel fuel per day.
- Similarly, Polyus Gold International managed to reduce its energy emissions by almost 100% by switching to hydroelectric power supplied by Russian companies.

- On 1 May 2019, Anglo-Australian mining multinational Rio Tinto announced that it would reduce the annual carbon footprint associated with its Kennecott Utah copper mine by as much as 65%, by purchasing renewable energy certificates and permanently shutting its coal power plant. The mine's electricity needs will now be supplied with 1.5 million megawatt hours (MWh) of renewable energy certificates supplied by energy company Rocky Mountain Power, primarily sourced from its renewables portfolio in Utah and including wind power from Wyoming.
- In June 2019, South African mining company Gold Fields announced its plans to predominantly operate its Agnew gold mine in Western Australia (WA) using renewable energy. This move to renewable energy is in partnership with global energy group EDL and involves an AUD112m ($77.59m) investment in an energy microgrid combining wind, solar, natural gas and battery storage. The project has also received support from the Australian Government with the, Australian Renewable Energy Agency (ARENA) contributing a recoupable AUD13.5m to the construction of the microgrid. Construction has already started for the development of the microgrid, which is owned and operated by EDL. The microgrid is comprised of five wind turbines capable of delivering 18 megawatts (MW) of power, a 10,000-panel solar farm contributing 4MW and a 13 MW / 4 MWh battery energy storage system. The grid is also supported by a 16 MW natural gas engine power station, and is expected to initially provide between 55% and 60% of the mine's energy requirements.
- In June 2018, Chilean copper mining company Antofagasta signed an agreement with utility company Colbún to make the Zaldívar mine the first Chilean mine to operate with 100% renewable energy. From 2020 the mine is powered by a mix of hydro, solar and wind power producing 550 gigawatt hours per year, which remove emissions equivalent to 350,000 tons of greenhouse gases per year.
- In September 2018, UK-based solar company Cambridge Energy Partners (CEP) announced that American mining corporation Newmont had deployed CEP's Nomad mobile solar power array at the Akyem gold mine in Ghana.
- The Nomad solar photovoltaic tracker is a redeployable and prefabricated solar generator, designed to be quickly deployed in scalable 30 kW segments and is suitable for both small and large-scale projects. The energy generated by Nomad is also fully integrated into existing electrical networks, creating a 'reliable and sustainable' hybrid power system. The Akyem mine is located in the Birim North District of Eastern Ghana, and produces around 450,000 ounces of gold annually. Newmont's decision to deploy Nomad at the Akyem mine was to offset the energy demand from the mining operations and demonstrate lower-cost renewable electricity production.
- In May 2017, UK-based power generation company Aggreko announced that it had signed a ten year deal to provide solar-diesel hybrid power to the Bisha mine in Eritrea owned by Chinese mining group Zijin. Aggreko provides 22MW of diesel and 7.5MW of solar-generated power for the Bisha mine's copper and zinc operations. The hybrid power system deployed by Aggreko was developed at the company's technology centre in Dumbarton and uses diesel generators considered to be the most efficient in the

world. These generators are monitored using Aggreko's Remote Monitoring telemetry to ensure optimum operational and fuel efficiencies.

- Aggreko has also provided hybrid power systems to a number of mining operations around the world, including the Gold Fields-owned Granny Smith gold mine in WA. In February 2019, Aggreko was contracted to create a hybrid solar-battery generation system to power the Granny Smith mine, following a partnership to explore the possibilities of renewables at the mine in June 2018. This hybrid system is one of the world's largest renewable energy microgrids, powered by more than 20,000 solar panels and backed up by a battery system with a capacity of 2MW. The microgrid reduce the mine's fuel consumption by up to 13%, the equivalent of removing 2,000 cars from the road, and produce about 18 GWh of clean energy annually.

- Atlas Renewable Energy has signed an BRL 881 million (US$190 million), 15-year solar power purchase agreement (PPA) with the Brazilian arm of mining giant Anglo American. The deal will support the development of a 330MW PV plant in Pirapora Municipality in the southeastern state of Minas Gerais (estimated annual generation is 613 GWh-per-year). Construction of the Casablanca solar plant was started in the second half of 2020.

- Global mining giant BHP has signed a five year contract that will see it source wind and solar to deliver up to half of the power needs for its coal mining operations in Queensland. Karara is a facility being built by CleanCo within the larger Macintyre wind project owned by Acciona. Both Western Downs and MacIntyre have signed long term PPAs with CleanCo, forming the bulk of its targeted 1,000 MW of wind and solar additions by 2025. BHP says its Queensland coal mines, operating in ventures with Mitsubishi and Mitsui, have an average load of around 150MW. BHP says the "firm renewable power purchasing agreement will meet half of its electricity needs across its Queensland coal mines, reduce the company's Australian "Scope 2 emissions" by 20 per cent from FY2020 levels, and displace an estimated 1.7 million tonnes of CO2e between 2021 and 2025 – which it says it equivalent to the annual emissions of around 400,000 combustion engine cars.

- Canadian gold-mining company B2Gold is to install one of the world's largest off grid solar battery hybrid systems at the Fekola gold mine in Mali, West Africa. B2Gold Corp. approved the $US38 million ($A56.2 million) project. The Fekola Solar Project will consist of a 30MW solar plant with 13.5MWh battery storage and will be integrated with the existing power plant which powers the gold mine, in an effort to provide safe and reliable operation of the hybrid project and avoid 13.1 million litres heavy fuel oil per year.

In the Kazakh mining industry, there are only isolated cases of projects implemented by large companies:

- Thus, in 2019, a subsidiary of Kazakhmys put into operation the Kengir solar station (Ulytau region) with a capacity of 10 MW, and
- in 2023 - the Balkhash station with a capacity of 50 MW, which is planned to be expanded to 100 MW by the end of 2025.

- The remaining projects are still at the design or construction stage - the Khromtau-1 wind power plant (155 MW) in the Donskoy OMPP (ERG) area,
- the expansion of existing cascades of small hydroelectric power plants to 106 MW with the participation of KAZ Minerals.

11 CAPACITY DEVELOPMENT NEEDS

Decarbonizing the metallurgy industry is a complex challenge that requires a multifaceted approach, involving technological innovation, policy reform, financial investment, and capacity development. The capacity development needs for decarbonizing the metallurgy industry can be broadly categorized into the following areas.

1. Technical skills and expertise

a) Process engineering: Training in advanced metallurgical processes that reduce carbon emissions, such as direct reduction of iron ore with hydrogen instead of coke.

b) Energy efficiency: Skills in optimizing energy use and implementing energy-efficient technologies.

c) Renewable energy integration: Knowledge of integrating renewable energy sources into metallurgical processes including hydrogen and biomass.

d) Carbon capture, utilization and storage (CCUS): Expertise in CCUS technologies and their application in metallurgical processes.

2. Research and Development (R&D) Capabilities

a) Innovation in materials: Development of new materials and alloys that require less energy to produce or have lower carbon content.

b) Process innovation: R&D to create new, low-carbon metallurgical processes.

c) Circular economy: Research into recycling and reuse of metals to reduce the need for primary production.

3. Digitalization and automation

a) Data analytics: Ability to use data analytics for process optimization and emissions reduction.

b) Industry 4.0: Skills in implementing digital technologies and automation to improve efficiency and reduce emissions.

Industry 4.0, also known as the fourth industrial revolution, refers to the current trend of automation and data exchange in manufacturing technologies, including cyber-physical systems, the Internet of Things (IoT), industrial internet, cloud computing, cognitive computing, and artificial intelligence.

4. **Financial and economic analysis**

   a) Cost-benefit analysis: Skills in assessing the economic implications of decarbonization strategies.

   b) Investment in green technologies: Understanding of financial mechanisms and instruments for funding low-carbon technologies.

5. **Environmental management**

   a) Sustainability practices: Training in sustainable practices that reduce the environmental footprint of metallurgical operations.

   b) Emission monitoring and reporting: Skills in monitoring and reporting greenhouse gas emissions.

   c) Life-cycle assessment (LCA): Ability to perform LCA to understand the environmental impact of metallurgical processes.

   d) Environmental impact assessment: Capacity to assess and mitigate the environmental impacts of metallurgical activities.

6. **Policy and regulatory framework**

   a) Understanding of climate policy: Knowledge of international and national climate policies and how they impact the metallurgy industry.

   b) Regulatory compliance: Skills in navigating and complying with environmental regulations and standards.

   c) Policy development: Capacity to contribute to the development of policies that support decarbonization.

7. **Cross-sectoral collaboration**

   a) Stakeholder engagement: Skills in engaging with a wide range of stakeholders, including governments, NGOs, industry associations, and communities.

   b) Supply chain management: Understanding of how to decarbonize the supply chain and work with suppliers to reduce emissions.

   c) Public-private partnerships: Capacity to establish and manage partnerships that support decarbonization efforts.

8. **Workforce development and training**

   a) Continuous learning: Establishing programs for ongoing education and training to keep the workforce updated on the latest decarbonization technologies and practices.

   b) Change management: Training in managing the transition to new technologies and processes.

To address these capacity development needs, a combination of formal education, vocational training, professional development, and knowledge exchange platforms is required. Additionally, governments, industry associations, and international organizations can play a crucial role in facilitating capacity development through funding, policy support, and the creation of collaborative networks.

11.1 CAPACITY DEVELOPMENT NEEDS ASSESSMENT BASED ON IDENTIFIED BARRIERS AND GAPS

11.1.1 In renewable energy

Integration of the RE in the metallurgy industry, similar to decarbonization process, is a complex and serious challenge that requires a multifaceted approach, involving technological innovation, policy reform, financial investment, legislation adaptation and capacity development.

The capacity development needs for RE application in the metallurgy industry can be categorized into the following areas:

1. **Technical skills and expertise**

    a) Process engineering: Trainings on RE integration in the metallurgical/technological processes that reduce energy consumption from fossil fuels, lead to carbon emissions decreasing, partial independence from external electrical grid and green image of the company.

    b) Energy efficiency: Skills in proper analysis and RE selection, calculations and modelling on optimizing energy use by implementing REP and technologies, REP financial efficiency, proper pay-back periods calculation and respective OPEX evaluation.

    c) Renewable energy integration: Knowledge of integrating renewable energy sources into metallurgical/technological processes including photovoltaic technologies, wind power generators, hydro powers units, hydrogen, heat recovery systems, accumulation capacities and biomass. Special attention should be dedicated to the balancing capacities and RE project synchronization with the external electrical grid.

2. **Research and Development (R&D) Capabilities**

    a) Innovation in technologies: Development of different technical or technological schemes of RE technologies combination in parallel (PV / Hydropower / Wind Crafts, etc) with the aim to consume less electrical energy from the external grid, to improve company feasibility and to have lower carbon content.

    b) Process innovation: R&D to reduce the dependence from fossil fuels and possible disconnection on electrical energy supply from external electrical grid, to improve or reduce electrical energy consumption from external grid, to install heat recovery systems and to transform losses into incomes and to transform the already existing technological process into a new low-carbon metallurgical activity.

c) Circular economy: Renewable energy plays a more and more significant role now and in the future. Circular economy aims to close the technical and technological loops to let the resources cycle in the system with minimum losses. In this way the RE will provide energy that is clean and renewable to power the comprehensive and restorative circular economy.

3. Digitalization and automation

a) Data analytics: Ability to perform data analytics from different sources with the aim of proper calculation on RE efficiency and further integration in the ongoing technological process for desired energy consumption reduction from external electrical grid, company feasibility improvement, existing process optimization and planned emissions reduction.

b) Industry 4.0: Professional skills in application of different RE technologies, technological process digitalization and data storage and proper analysis, optimization and automation to improve selected RE technology and technological process efficiency and CO_2 emissions reduction.

4. Financial and economic analysis

a) Cost-benefit analysis: Proper financial analysis and comparison analysis of the selected RE technology, payback calculation, IRR, OPEX estimation and deep understanding of the related risks. Skills in assessing the economic implications of decarbonization strategies.

b) Investment in green technologies: Understanding of different financial sources and proper correlation between them, access to finance and correct preparation of a complete package of documents to obtain the necessary financing (possibly with grants), application of different financial mechanisms and instruments for funding RE Projects and technologies.

5. Environmental management

a) Sustainability practices: Analysis of the already existing information and implemented projects, achieved results on CO_2 emissions reduction, respective benefits and obstacles. Training and sustainable practices on RE Projects integration and implementation that reduce the environmental footprint of metallurgical operations and create a green image of the company.

b) Emission monitoring and reporting: Skills in RE Project digitalization, information collection, reports creation, data analysis and further process improvements. RE Projects monitoring and reporting on equipment efficiency, green electrical energy generation and greenhouse gas emissions reduction.

c) Life-cycle assessment (LCA): Ability to perform proper data collection and analysis, regular to perform LCA with the aim to understand the environmental impact of RE Project integration in the ongoing metallurgical processes.

d) Environmental impact assessment: Capacity to assess, collect, storage and analyze the information regarding RE project, at maximum to mitigate the environmental impacts of metallurgical activities by the optimization of the RE Project operation.

6. Policy and regulatory framework

a) Understanding of climate policy: Knowledge of international and national climate policies by the main players (Government, State Institutions, Private companies, NGOs, Industry Associations, Verification Bodies, etc.) and how they impact the RE Projects in frames of the metallurgy industry.

b) Regulatory compliance: Professional skills on Governmental level, State Institutions, Verification Bodies, Private companies, Associations, etc. in navigating, complying and possible adjustments with environmental regulations and standards.

c) Policy development: Professional knowledge, regular training and capacity to contribute to the development of policies, legislative documents, norm, standards and other legislative documents that support integration of the RE Projects in metallurgical industry.

7. Cross-sectoral collaboration

a) Stakeholder engagement: Skills in engaging with a wide range of professional stakeholders, including governments, NGOs, industry associations, and communities.

b) Supply chain management: Understanding of how to communicate, clear understanding of the basic/main principals of the robust supply chain, to ensure professional dialog and information exchange between all members, to realize the RE Project and cooperate with suppliers to reduce emissions, to create a green image of the company.

c) Public-private partnerships: Information collection and analysis, PPA adjustment and improvement in line with the actual legislation and requirements, capacity to establish and manage partnerships that support in RE Project implementation and common emissions reductions efforts.

8. Workforce development and training

a) Continuous learning: Establishing programs for ongoing education and training to keep the workforce updated on the latest results on RE Projects implementation and integration, BAT and practices.

b) Change management: Training in managing the transition to new technologies and processes.

To address these capacity development needs, a combination of different forms of education, vocational training, professional development, site visits, document and knowledge exchange platforms is required. Additionally, governments, industry associations, and international organizations can play a crucial role in facilitating capacity development through funding, policy support, and the creation of collaborative networks.

12 REGULATORY NEEDS AND FINANCING INSTRUMENTS

12.1 REGULATORY NEEDS

A comprehensive and supportive regulatory framework is critical to promoting and facilitating the decarbonization of the metallurgical sector; and specifically, to creating an operating and investment environment for the adoption of low or zero GHG emission technologies and processes and clean (sustainable) production standards.

In general, it is important to establish a stable regulatory framework for sectoral decarbonization, as amongst other things this will provide certainty for investors, thereby increasing the probability of investments being made in transition technologies. Frequent changes in regulations should be avoided, as such changes can disrupt industry planning and investment, leading to loss of confidence by the private sector.

The key regulatory needs for Kazakhstan's metallurgical sector include the following.

1. Carbon emission standards and regulations
    a) Setting and applying relevant carbon emission standards for metallurgical processes.
    b) Demanding regular reporting and transparent monitoring of greenhouse gas emissions.
    c) Setting targets for gradual reductions in emissions over time.
2. Carbon pricing mechanisms
    a) Introducing carbon taxes or cap-and-trade systems to put a price on carbon emissions.
    b) Ensuring that the price signal is strong enough to drive investment in low-carbon technologies.
3. Financial incentives
    a) Providing tax credits, rebates, or grants for the adoption of cleaner technologies.
    b) Supporting research and development in low-carbon metallurgical processes.
    c) Offering financial incentives for the deployment of carbon capture, utilization and storage (CCUS) technologies.
4. Permitting and environmental compliance
    a) Streamlining the permitting process for new low-carbon technologies while maintaining environmental standards.
    b) Ensuring that environmental compliance does not create unnecessary barriers to innovation.

5. International cooperation and standards
   a) Standardizing regulations across countries to facilitate trade in low-carbon metals.
   b) Participating in international agreements and initiatives that support decarbonization efforts.
6. Infrastructure development
   a) Investing in infrastructure needed for low-carbon technologies, such as hydrogen production facilities or renewable energy sources.
   b) Ensuring that the grid can support the increased demand for electricity from low-carbon processes.
7. Regulation of waste and by-products
   a) Implementing regulations to manage and reduce waste products from metallurgical processes.
   b) Fostering recycling and reuse of materials to reduce the need for primary production.
8. Innovation and technology dissemination
   a) Creating regulatory frameworks that encourage the sharing of technology and best practices among industry players.
   b) Supporting pilot projects and demonstrations of new technologies to accelerate learning and adoption.
9. Worker and community protection
   a) Ensuring that decarbonization efforts consider the health and safety of workers and local communities.
   b) Providing support for workforce transition and retraining as the industry evolves.
10. RE improvements
   a) One of the main problems of the sector is the instability of production, the lack of sun and wind immediately lead to a decrease in electricity generation.

This problem can be solved by creating a balancing power market and an electricity storage system.

   b) It is necessary to develop flexible capacities, increase flexible sources which include natural gas power plants and hydroelectric power stations or build electricity storage facilities.

Implementation of RE projects with energy storage through the auction mechanism. The lack of such capacity limits the growth of renewable energy sources. The higher the share of renewable energy sources in the energy balance, the more reserve capacity is needed to cover demand when generation from renewable sources decreases.

c) Formation of attractive conditions for investment in the renewable energy sector in Kazakhstan (increase auction capacities, improving the conditions for tariff indexation, development of the practice of project auctions, etc.).

d) Many companies are actively implementing ESG principles into their corporate policies.

Lack of a regulatory framework, excessive requirements of the system operator for the implementation of such projects.

e) System operators require renewable energy facilities to find balancing capacities themselves, that is, to build storage facilities.

KEGOC explains this by the shortage of balancing capacities in the energy system of Kazakhstan. The installation of storage devices significantly increases the cost of projects.

f) The prices which will be after the contracts for the guaranteed purchase of electricity expire. By the beginning of the 2030s this issue will need to be resolved. Without increasing electricity tariffs, it will be difficult to solve this problem.

g) The problem of lack of reserve capacity can also be solved by stimulating conscious consumption. It implies that large consumers limit their electricity consumption for a certain number of hours a day in exchange for economic incentives (monetary rewards). This is a widely used mechanism around the world and it will cost much less than building stations.

To ensure their effectiveness and acceptance among industry, key regulatory measures should be designed following consultation with industry stakeholders, environmental groups, and other relevant parties. Such an approach can help ensure that regulations are practical, achievable, and address the legitimate concerns and needs of sectoral market players and the investment community in Kazakhstan.

12.2 FINANCING INSTRUMENTS

The current structure of the Kazakh electricity system is driven by regulated tariffs and subsidization of fossil fuels, which are directed to coal and natural gas-fired electricity generation. Consumer tariffs in Kazakhstan are low, and averaged 4.3 US cent / kWh in 2021.[31] This low cost of the tariff covers only operation and maintenance costs as well as fuel costs, and it does not allow to make enough revenues to use for the modernization of the grid or the introduction of more renewable energy sources. To be viable and economically sustainable, electricity prices should cover all system costs, comprising: *i)* capital costs, *ii)* variable and fixed operation and maintenance costs, *iii)* fuel costs and *iv)* carbon prices.

The development of low-carbon technologies for low-carbon metallurgy and a transformation of the Kazakh electricity system towards net zero emissions by 2060 require significant investments in renewable electricity generation capacities, expansion of the power transmission and distribution grid as well as energy storage, hydrogen capacities and CCUS technologies.

To boost investment in the abovementioned sectors, the revenues in the electricity system or in low-carbon technologies for metallurgy must cover capital costs as well, which is not currently the case in Kazakhstan. In case capital costs are not covered by the end user tariffs, it is very likely that private investments in new capacities, in retrofitting of existing generation capacities and in low-carbon technologies for metallurgy will not take place. To provide enough funding for the maintenance, expansion and modernization of the electricity system, and for low-carbon technologies for metallurgy, the State would have to step in with either public funds to finance new generation capacities or cover the difference between tariffs and actual costs, to attract investors. Both options are economically inefficient and would burden public budgets, while diverting government expenditure from other policies.

Some more contextual aspects that are needed to attract investments for the modernization and greening of the grid are the following:

- Using carbon pricing as a tool to send clear market signals, providing certainty over the decarbonization ambition for the metallurgical sector. Currently the carbon price in Kazakhstan's Emission Trading System is about 1 EUR / tCO_2 (1.07 USD / tCO_2)[108], which is too low to stimulate investments in renewables.
- Putting in place funding mechanisms to support CCUS deployment and low carbon hydrogen infrastructure.
- Establishing an adequate policy framework to ensure an uptake of fuel switching.
- As a longer-term goal, creation of a market for negative emissions technologies.
- Establishing a targeted approach to mitigating carbon leakage.
- Understanding how the EU Carbon Border Adjustment Mechanism will affect Kazakhstan's metallurgy sector exports.
- Phasing out of fossil fuel subsidies and reframing the tariff system.

Once an adequate contextual background for financing has been created, there are various options when funding decarbonization projects, falling mainly under three broad categories: *i)* using internal funds, *ii)* debt and *iii)* service agreements.

12.2.1 Internal funds

These are typically existing CAPEX budgets or funds dedicated to decarbonization projects. Internal funds may be invested in any technology, but designing and self-implementing carbon

[108] XE Currency converter, 21 June 2024. Accessed via: https://www.xe.com/es/currencyconverter/convert/?Amount=1&From=EUR&To=USD

reduction mechanisms requires a significant amount of time, resources and technical capabilities. Outsourcing this work is also an option.

The most important issue when using internal funds for decarbonization is whether the opportunity cost of shifting fund allocation from the core business to decarbonization solutions is the best option, with the aim of obtaining a competitive advantage. In some cases, it could be more advantageous to invest capital in the core business, and finance through other ways the decarbonization solutions where the providers are the experts.

Choosing the self-funding route will have a significant impact on the company's equity and EBIT (Earnings Before Interest and Taxes), and depreciation of the assets will also increase the cost of capital over time. There will be lower total cost of ownership (TCO - i.e., purchase price of an asset plus the costs of operation) due to not incurring financing costs when using internal funds, but limitations in technical know-how and in available funds might hinder the possibility of getting the best scope of decarbonization solutions.

12.2.2 Debt

External financing options are available through debt financing. Debt financing for decarbonization projects includes *i)* general corporate loans or bonds, *ii)* asset-specific loan products (leases), and *iii)* sustainable debt products (green loans, bonds, sustainability-linked loans).

- General corporate loans offer funding through a credit line, typically provided by a bank (the lender). The loan is given against the security of repayment, interest, and additional costs. The duration of repayments is discussed between the business and the lender and depends on the loan amount. These loans function either as secured or as unsecured. Secured loans have the benefit of a collateral, which is reposed in case of failure to repay. Collateral is not needed if the loan is not secured.
- Asset-specific loan products loan money in an agreement secured by collateral. An asset-based loan or line of credit may be secured by inventory, accounts receivable, equipment, or other property owned by the borrower.
- Green loans are loans provided only for sustainable, environmentally friendly purposes, such as reducing CO_2 emissions, or developing new environmentally friendly technology. A green loan is based on a loan typically smaller than a bond and done in a private operation.
- Green bonds are fixed-income financial instruments which are used to fund projects that have positive environmental and/or climate benefits. These usually have a bigger volume than green loans, may have higher transaction costs, and could be listed on an exchange or privately placed.
- Sustainability-linked loans encourage borrowers to achieve ambitious sustainability performance targets. This type of loan measures the degree of improvement in

sustainability by presetting appropriate sustainability performance targets and ensures transparency through post-loan reporting on them.

External funds will not solve operational, technical complexity issues, but they enable companies to implement larger-scale solutions by lowering impact on internal funds. Designing a decarbonization mechanism such that the energy cost savings offset the loan payments effectively neutralizes the net financial impact of the loan. However, this will increase the company's debt load and could negatively impact on the company's attractiveness to investors.

It is to be noted that debt funding adds financing costs, increasing the total cost of ownership compared to internal funding. Ownership of the equipment comes with depreciation expenses as well, eventually increasing the cost of financing. External funding can expand the scope of a project, but financial viability concerns should be well evaluated.

12.2.3 Service agreements

Service agreements are another type of financing instrument for decarbonization options. The service agreements have the potential to remove some complexities to the carbon transition process, such as the disbursement of CAPEX. Within this model, both asset ownership and responsibility for its performance remain with the service provider. The main types of service agreements are energy savings as-a-service (ESaaS) contracts, power purchase agreements (PPAs), and utilities as a service (UaaS).

The service agreements outsource to a service provider the upfront capital outlay for the assets (e.g., solar panels, heat pumps, energy saving measures, etc.) as well as the responsibility for asset performance, maintenance, and ownership. In this model, companies pay for the outcome (e.g., demand reduction) and not for the ownership of machinery, but they come at the cost of some operational flexibility due to the long-term nature of the service contracts.

Service contracts are usually longer than loans, resulting in lower annual financial expenditures. At the end of the contract, the equipment can either be transferred or sold to the client, or the service provider may remove the assets from the client's site.

13 RECOMMENDATIONS ON KEY MILESTONES FOR DECARBONIZING THE METALLURGICAL INDUSTRY IN KAZAKHSTAN

Decarbonizing the metallurgical industry in Kazakhstan requires a strategic and phased approach. The following key milestones are proposed.

Baseline assessment (short-term, 0-2 years)

a) Conduct a comprehensive assessment of the current carbon footprint of the metallurgical industry in Kazakhstan.

b) Identify the major sources of emissions and the most carbon-intensive processes.

c) Evaluate the technical and economic feasibility of various decarbonization options.

Regulatory framework and policy development (short-term, 0-2 years)

a) Establish a strong collaboration between government, industry stakeholders, environmental groups, and other relevant parties to develop a national strategy for the decarbonization of Kazakhstan metallurgy industry.

b) Develop a national strategy for decarbonizing the metallurgical industry, aligned with Kazakhstan's overall climate goals.

c) Introduce regulations and standards for emissions reduction, including energy efficiency standards.

d) Establish a supportive policy environment with incentives for low-carbon technologies and penalties for high-emission practices.

Research, development, and demonstration (RD&D) projects (medium-term, 2-5 years)

a) Initiate RD&D projects for the most promising low-carbon technologies, such as electric arc furnaces, direct reduced iron (DRI) using hydrogen, and carbon capture, utilization and storage (CCUS). One of the projects can be initiated for green iron based on the HyIron technology (Kazakhstani delegate has visited the facility in Germany in April 2024).

b) Support pilot projects to demonstrate the viability of these technologies in Kazakhstan's specific industrial context.

Financial mechanisms and incentives (medium-term, 2-5 years)

a) Create financial mechanisms to support the transition, such as green bonds, subsidies, and tax incentives for low-carbon investments.

b) Attract international funding and investment for decarbonization projects.

Infrastructure development (medium to long-term, 2-10 years)

a) Invest in the necessary infrastructure to support low-carbon technologies, such as renewable energy sources and hydrogen production facilities.

b) Upgrade the electricity grid to handle the increased demand from electrified processes.

Scale-up and Industry-Wide Adoption (Long-term, 5-15 years)

a) Scale up successful pilot projects to full industrial deployment.

b) Initiate the widespread adoption of proven low-carbon technologies across the metallurgical industry.

Monitoring, reporting, and compliance (ongoing)

a) Implement a robust system for transparent monitoring and reporting greenhouse gas emissions.

b) Ensure compliance with national and international regulations and standards.

Workforce training and capacity building (ongoing)

a) Develop training programs to build the skills needed for operating new low-carbon technologies.

b) Foster a culture of continuous improvement and innovation within the industry.

Review and adjustment (continuous process)

a) Regularly review the progress of decarbonization efforts and adjust strategies as needed.

b) Stay informed about technological advancements and incorporate new developments into the decarbonization roadmap.

International collaboration and knowledge sharing (ongoing)

a) Participate in global initiatives and agreements that support decarbonization efforts.

b) Engage in international partnerships to share knowledge, technologies, and best practices.

Retrofit blast furnaces and implement carbon capture and storage (CCS)

a) Existing blast furnaces can be retrofitted to reduce emissions.

b) Additionally, implementing CCS technology captures CO_2 emissions and prevents them from entering the atmosphere.

Scale up hydrogen-based direct reduced iron (DRI)

a) Hydrogen-based DRI processes can replace traditional blast furnaces. By using green hydrogen, emissions can be significantly reduced.

Targets for steel recycling

a) Encouraging steel recycling reduces the need for primary steel production from iron ore.

b) Policies that promote recycling and circular economy practices are essential.

Efficient steel use and demand reduction

a) Slowing down the growth in steel demand through efficient use and design can help reduce emissions. This includes lightweight materials, better construction practices, and improved product lifecycles.

Targets for clean electricity use and green hydrogen supply

a) Policymakers should prioritize clean electricity and green hydrogen production to support low-carbon steelmaking.

Create lead markets for green steel

a) Encourage industries and consumers to adopt green steel by creating demand and incentivizing its use.

Support research and innovation

a) Investment in research and development of new technologies is crucial for achieving decarbonization goals.

Climate policies and regulation

a) Implement policies, standards, and regulations that guide the sector toward decarbonization.

International cooperation

a) Collaborate globally to ensure consistent efforts and prevent slow adopters from undermining progress.

These milestones should be adapted to the specific conditions and capabilities of Kazakhstan's metallurgical industry, considering the country's natural resources, existing industrial infrastructure, and economic priorities. Collaboration with international organizations, such as the United Nations Industrial Development Organization (UNIDO) or the International Energy Agency (IEA), can provide valuable support and expertise in this process.

14 SECTORAL NEXUS REFERENCES

Kazakhstan is already experiencing the effects of climate change, such as air temperature increase, extreme weather events (heavy rain and snowfall, storm and hail), droughts and glaciers melting. The average annual temperature in the country increased by 0.32°C every 10 years, growing faster than the global average.[76] The growing shortage of water (most of the water intake goes to agriculture) and the degradation of aquatic ecosystems are among the most pressing problems for Kazakhstan. Due to the challenges posed by a changing climate now and in the future, and in line with international efforts, the Republic of Kazakhstan aims to achieve carbon neutrality by 2060, objective which is depicted in the country's national long-term Carbon Neutrality Strategy (CNS).

14.1 ENVIRONMENTAL IMPACTS

Regarding climate change adaptation efforts, mainly in these key sectors, the general objective of the adaptation chapter of the Environmental Code is to promote the reduction of climate risks in Kazakhstan by building climate resilience while addressing the impacts of climate change. This comprises the minimization of climate risks, implementation of measures enabling adaptation of natural ecosystems, economic activities, and infrastructure, safeguarding public health, ensuring food security and access to water and gender equality.

Key sectors impacted by climate change in Kazakhstan are:

14.1.1 Agriculture and Forestry

Interactions with industry processes

The metallurgical industry carries out processes that include the extraction of raw materials, the emission of greenhouse gases that contribute to the formation of acid rain, and the generation of toxic waste such as slag and furnace dust. Consequently, the agriculture and forestry sectors are exposed to disturbances due to the absorption of water contaminated with high concentrations of heavy metals[109]. The soil, acting as a reservoir for these metals, can become toxic to soil organisms and plants, compromising their viability and that of the surrounding ecosystems.

[109] MDPI, 2023. Challenges and side effects of heavy metals in agriculture. Accessed via: https://www.mdpi.com/journal/agriculture/special_issues/heavy_metals_agriculture

General information about Kazakhstan

The contamination of agriculture and forestry in Kazakhstan is a critical issue that carries importance at both national and global levels. Extensive regions of the country's soil and plant life are contaminated with dangerous substances like heavy metals, petroleum products, and intricate organic compounds. This pollution is linked to the discharge from factories and vehicles.

Table 9: Agriculture and forestry impacts in Kazakhstan.

Sources of Pollution	Solid and liquid waste from mining and metallurgical companies.
Causes	• Transboundary transport of heavy metals, sulfur oxides and nitrogen. • Toxic waste is still stored in various storage facilities, often without observing relevant environmental standards and requirements.
Locations affected	• Small area along roads. • Near industrial enterprises. • Airfields.
Quantity of waste	• 4 billion tons of mining. • billion tons of enrichment. • 105 million tons of metallurgical processing.

Source: Obtained from activities of mining and metallurgical industry enterprises of the Republic of Kazakhstan

In every industrial area, there exist zones that pose environmental risks, including mounds, landfills, pits, and drilling sites, as well as mining debris spread over an expanse exceeding 60,000 hectares, leading to ongoing soil pollution. In the East Kazakhstan region, the soil is tainted with elements such as copper, zinc, cadmium, lead, and arsenic. Hazardous waste is often discarded in dumps that fail to comply with health and ecological standards. The districts of Shemonaikhinsky, Glubokovsky, and Zyryanovsky are notably affected by lead contamination.

The agriculture and forestry sectors in Kazakhstan are under threat due to contamination from heavy metals. This contamination is a result of water absorption from polluted sources, leading to toxic soil conditions that can harm organisms and plants, and disrupt ecosystems.

Extensive regions of Kazakhstan's soil and plant life are contaminated with dangerous substances like heavy metals, petroleum products, and complex organic compounds. This pollution is primarily linked to waste discharge from factories and vehicles, including transboundary transport of heavy metals and sulfur oxides.

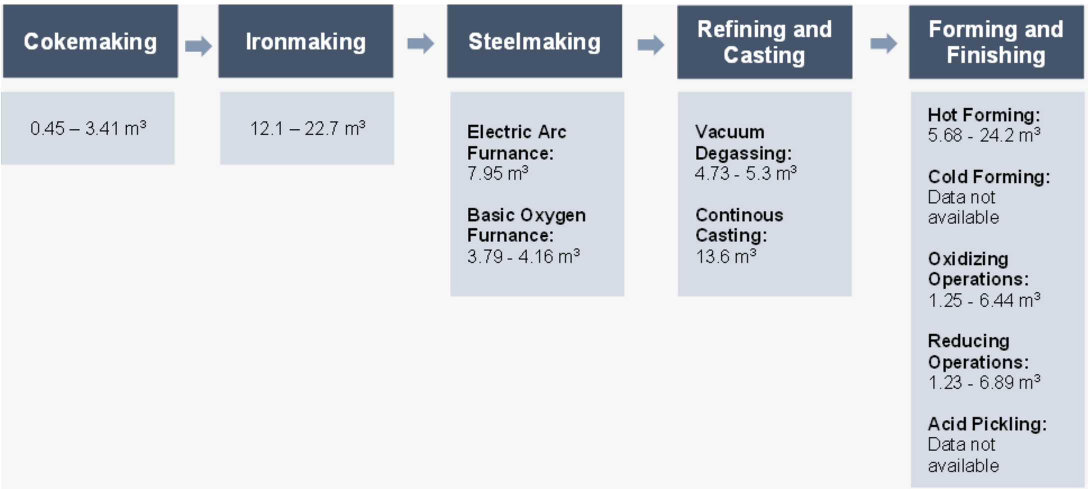
There is a significant issue with the management of hazardous waste in Kazakhstan. Waste is often stored in facilities that do not meet environmental standards and requirements. Furthermore, specific regions, such as the East Kazakhstan region and the districts of Shemonaikhinsky, Glubokovsky, and Zyryanovsky, are notably affected by contamination from elements like copper, zinc, cadmium, lead, and arsenic.

14.1.2 Water resources management

Interactions with industry process

Water is an essential and crucial resource for most production processes, it needs to be managed correctly, which implies reducing its consumption and emissions. The steel industry uses large volumes of water, although a minimal portion is consumed as most of it is reused or returned to its source. Water is not only used for cooling, but also for other processes such as lime removal and dust purification. All types of water are used in the steel industry. Fresh water is mainly used for process, direct and indirect cooling, while seawater is generally used for single-use cooling after pre-treatment to prevent scaling.

Figure 21. Steelmaking water use.



Source: Own elaboration (Global Factor, 2024) based on Industrial Water Use and its Energy Implications

The steel industry, one of the divisions of metallurgy, consumes on average 28.6 m^3 of water for every ton of steel produced, and discharges an average of 25.3 m^3 per ton of steel in an integrated plant. Most of the water used evaporates, and about 90% of the water is released after cleaning and/or cooling, often being reused by other utilities.

Freshwater is a major concern due to its availability and quality. Therefore, water resource management is a significant challenge to improve the sustainability of the production process. As previously indicated, water can be reused and recycled during manufacturing processes. However, it is necessary to cool and desalinate the water, as salt concentration in the systems due to evaporation is an environmental problem and has a negative impact on the plant equipment.

General situation in Kazakhstan

The main sources of groundwater pollution in Kazakhstan are industrial enterprises, solid and liquid waste deposits, waste storage areas of industrial and agricultural facilities, oil fields and refineries[110]. The most polluted areas and territories are located in Almaty, East Kazakhstan and Karaganda provinces. These areas are distinguished by high water salinity, water hardness and concentrations of sulphates and chlorides exceeding the maximum permissible values. Meanwhile, anthropogenic groundwater contamination is noted in the western and north-western regions of Kazakhstan, i.e. in the areas of oil extraction and mining, where water contamination by iron, manganese and hexavalent chromium is detected.

In Kazakhstan, the Republican State Enterprise on the Right of Economic Management "Kazhydromet" conducted water quality assessments across thirteen water bodies. These included the Kara Ertis, Yertis, Breksa, Tikhaya, Ulbi, Glubochanka, Krasnoyarka, Oba, Buktyrma, Emel, Ayagoz, Markakol, and the Ust-Kamenogorsk Reservoirs. The observations yielded the following results for water quality:

Table 10. Water pollution in Kazakhstan.

<table>
<tr><th>Water Pollution level</th><th>Water bodies affected</th><th>Causes</th></tr>
<tr><td>Moderate</td><td>Kara Yertis, Yertis, Buktyrma, Oba, Ayagoz, Emel rivers, Markakol lake, Buktyrma and Ust-Kamenogorsk reservoirs.</td><td rowspan="3">• Mining enterprises.
• Historical pollution.
• Chemical
• Raw Materials: zinc, manganese, copper, cadmium and iron.
• Spoil heaps</td></tr>
<tr><td>High</td><td>Breksa, Tikhaya, Ulbi, and Glubochanka rivers.</td></tr>
<tr><td>Extremely high</td><td>Krasnoyarsk river.</td></tr>
</table>

Source: Obtained from Activities of mining and metallurgical industry enterprises of the Republic of Kazakhstan

Reducing pollution of drinking water sources is a critical issue in water management. There are several outstanding issues related to the quality of industrial wastewater. A considerable volume of industrial wastewater flows directly to municipal wastewater treatment plants, which are not designed to treat industrial wastewater. Approximately 50% of the wastewater discharged by large industries does not meet the required standards. Most industries do not have wastewater treatment plants (WWTPs), or pre-treatment is carried out inadequately.[110] There are no laws obliging companies to sign contracts with water utilities for additional wastewater treatment. In addition, several cities in Kazakhstan lack a rainwater drainage system.

[110] UNECE, 2019. Kazakhstan environmental performance reviews. Accessed via: https://unece.org/sites/default/files/2021-08/ECE_CEP_185_Eng_0.pdf

Conclusions

The key conclusions regarding water resource management include:

- Water is a vital resource in many industrial processes, particularly in the steel industry. Despite the large volumes of water used, a significant portion is reused or returned to its source, highlighting the importance of effective water management in reducing consumption and emissions.
- The steel industry uses water for various processes, including cooling, lime removal, and dust purification. On average, 28.6 m3 of water is consumed for every ton of steel produced, with most of it being released after cleaning and/or cooling.
- Freshwater availability and quality are major concerns in industrial processes. The need to cool and desalinate water due to salt concentration from evaporation presents environmental challenges and can negatively impact plant equipment.
- Industrial enterprises, waste deposits, and oil fields are the main sources of groundwater pollution in Kazakhstan. A significant volume of industrial wastewater does not meet required standards, and many industries lack adequate wastewater treatment plants. This highlights the need for improved water management and pollution reduction strategies.

14.1.3 Disaster risk reduction

Interactions with industry process

Decarbonization in the metallurgy industry can significantly reduce disaster risks linked to climate change and environmental degradation. The main effects of decarbonization include a significant decrease in greenhouse gas emissions, improved energy efficiency and increased economic competitiveness. However, there are several problems related to industrial processes that generate disaster risks, such as industrial pollution due to metallurgy waste, equipment malfunctions that cause accidents, and ageing infrastructures that put at risk the integrity of equipment.

Global production of metallurgical waste is estimated at 400 million tons per year.[111] These wastes originate from electric arc furnace steelmaking and are linked to steel production. Solid metallurgical waste from electric arc furnace steelmaking is stored in slag dumps close to the production plants, causing environmental pollution in water, soil and air.[112] Globally, there is a considerable effort to find solutions for the recovery of these metallurgical wastes. Their use is motivated by economic and environmental reasons, to eliminate metallurgical slag dumps. It is crucial to develop a sustainable system that can transform all the valuable resources that are landfilled as waste into useful products. Given the large quantities of metallurgical waste and

[111] World Steel, 2024. Accessed via: www.worldsteel.org

[112] Ilutiu D et al., 2022. Metallurgical Wastes as Resources for Sustainability of the Steel Industry. Accessed via: https://www.mdpi.com/2071-1050/14/9/5488

increasingly stringent environmental regulations, recycling and utilization of this waste presents itself as an attractive option to minimize and ultimately eliminate the cost of disposal, as well as to reduce pollution of natural resources.

The metalworking industry is a high-risk industry. Statistical risk analyses have been carried out in other hazardous sectors, such as coal mining, the transport industry and the chemical industry.[113] Despite the serious consequences of fatal accidents in the metalworking industry, not many statistical analyses of fatal accidents in this sector are available. A clear example is the ILVA steel plant in Italy, which has an annual production capacity of 10 million tons of steel and accounts for 40% of Italian production. This plant is located near the residential areas of Taranto, which in 2019 had a population of 200,000 inhabitants. An epidemiological study conducted in the vicinity of the factory revealed that exposure to industrial emissions had caused a high level of illness and mortality in the area due to respiratory diseases.[114]

General situation in Kazakhstan

In 2023, Kazakhstan ranked 40th out of 134 countries in the urban pollution index.[115] In 2013, the national government presented a plan for the transition to a green economy. Key sectors of this plan include waste management, water supply management, sustainable energy and transport. Currently, there is a notable lack of facilities and technologies to treat toxic emissions from industries, which means that air pollution is not fully controlled. In addition, transport is fueled by low-cost, inferior fuels, and water sources throughout the country are susceptible to damage.

The considerable expansion of industries has led to an increase in demand for raw materials, which has driven the rapid development of both underground and surface minerals. In eastern Kazakhstan, non-ferrous metallurgy, tungsten, lead, zinc and other industries are causing harm to local communities and city residents. Currently, Ust-Kamenogorsk is one of the largest cities in terms of ecology in the world. The concentration of PM2.5, which refers to suspended solid microparticles and the smallest liquid droplets present in the air, in Ust-Kamenogorsk these days (2024) is 1.1 times higher than the annual average value of the air quality standard recommended by the World Health Organization.[116]

As an example, Lakshmi Mittal, owner of the company "ArcelorMittal Temirtau", operates several steel production plants globally. However, waste emissions in the city of Temirtau are significantly higher compared to other plants around the world. This is attributed to the lack of stringent regulations, controls and requirements for environmental standards by the country's government.

[113] Xu et al, 2022. Statistical Analysis and Prediction of Fatal Accidents in the Metallurgical Industry in China. Accessed via: https://pmc.ncbi.nlm.nih.gov/articles/PMC7312879/

[114] Righi et al, 2021. Disaster risk reduction and interdisciplinary education and training. Accessed via: https://www.sciencedirect.com/science/article/pii/S2590061721000259

[115] IQAir, 2024. Kazakhstan air quality index. Accessed via: https://www.iqair.com/es/kazakhstan

[116] IQAir, 2024. Ust-Kamenogorsk Air quality index. Accessed via: https://www.iqair.com/es/kazakhstan/east-kazakhstan/ust-kamenogorsk

It is important to mention that Balkhash, a city known for its lake, is also one of the main centers of non-ferrous metallurgy in Kazakhstan. Air pollution in this city is critical due to the proximity between residential and industrial areas. The waste produced by the Balkhash metallurgical facilities has increased the levels of heavy metals and Sulphur oxides in Balkhash Lake. In 2014, the city suffered an incident that resulted in the death of hundreds of birds, the cause of this mass mortality was a large release of gases into the atmosphere. Various amounts of greenhouse gases are released into the air from the Balkhash basin, and this mixes with moisture evaporating from the surface of the lake, producing acid rain that reaches the ground.

Conclusions

The conclusions of the Disaster Risk Reduction are:

- Industrial processes can generate disaster risks, such as pollution due to metallurgy waste, equipment malfunctions, and ageing infrastructures.
- The global production of metallurgical waste is estimated at 400 million tons per year, causing environmental pollution in water, soil, and air. There is a global effort to recover these wastes for economic and environmental reasons. Recycling and utilization of this waste can minimize disposal costs and reduce pollution.
- The metalworking industry is a high-risk industry with serious consequences of fatal accidents. For example, the ILVA steel plant in Italy, located near residential areas, has caused a high level of illness and mortality due to exposure to industrial emissions.
- In 2023, Kazakhstan ranked 40th out of 134 countries in the urban pollution index. The expansion of industries has led to an increase in demand for raw materials, causing harm to local communities and city residents. Air pollution in cities like Ust-Kamenogorsk and Balkhash is critical, with the latter experiencing incidents of mass bird mortality due to large releases of gases into the atmosphere.

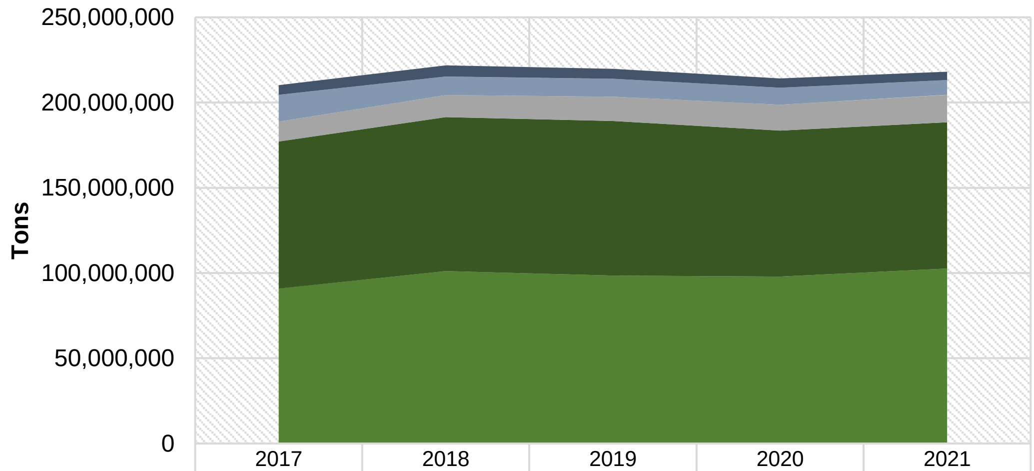
14.2 AVAILABILITY OF RAW RESOURCES

Scarcity of water is one of the main challenges in Kazakhstan, and as such, limited water resources require intersectoral and interregional cooperation. In the Central Asia region, abundant hydropower resources of upstream countries (Tajikistan, Kyrgyz Republic) are critical for decarbonization, while the fossil fuel rich and downstream countries such as Kazakhstan need water for agriculture, drinking, sanitation and many other basic uses. The Central Asia Water & Energy Program (CAWEP) works to improve regional cooperation on water and energy security in Central Asia. CAWEP is a partnership between the World Bank, the European Union, Switzerland and the United Kingdom.[117]

[117] World Bank, 2024. Central Asia water and energy programme. Accessed via: https://www.worldbank.org/en/region/eca/brief/cawep

In 2021, Kazakhstan recorded significant production of mineral raw materials as shown in Figure 22. The largest share of this production was attributed to thermal coal, with a total of 102 million tons. This was followed by oil and iron ore, with 85 and 15 million tons respectively.[118]

Figure 22: Production of mineral raw materials in Kazakhstan



	2017	2018	2019	2020	2021
Lignite	5,739,000	6,560,700	5,929,100	5,422,100	4,828,700
Coking Coal	15,749,700	10,836,000	10,478,500	10,052,900	8,751,800
Iron	11,705,660	12,968,800	14,278,750	15,105,100	15,966,300
Petroleum	86,194,400	90,359,500	90,555,500	85,656,100	85,877,800
Steam coal	90,910,400	101,085,800	98,593,000	97,924,100	102,638,200

Source: World Mining Data, 2023[118]

By 2024, in terms of underground resources, Kazakhstan is among the top 20 nations in proven reserves of various minerals, including chromium, zinc, lead, copper, gold, titanium, iron, manganese, cadmium and bauxite.[119] In addition, the country is estimated to hold significant potential reserves of other minerals, such as lithium. According to World Bank estimates, there are more than 5,000 undiscovered deposits in the country with an estimated value of more than US$46 trillion.[120]

RE potential in Kazakhstan

As part of the project of Ministry of Energy of the Republic of Kazakhstan, the United Nations Development Program (UNDP), and Global Environment Fund "Kazakhstan Wind Energy

[118] World Mining Data, 2023. Accessed via: https://www.world-mining-data.info/wmd/downloads/PDF/WMD2023.pdf

[119] EIAS, 2022. Assessing the impact of the EU Kazakhstan MOU on critical raw materials. Accessed via: https://eias.org/publications/assessing-the-impact-of-the-eu-kazakhstan-memorandum-of-understand-on-critical-raw-materials/

[120] The Astana Times, 2024. Kazakh-Italian roundtable concludes with $1.5 billion in signed deals. Accessed via: https://astanatimes.com/2024/01/kazakh-italian-roundtable-concludes-with-1-5-billion-in-signed-deals/

Market Development Initiative", the wind potential at various sites across the country was studied in accordance with the methodology for estimation of wind potential, in particular annual dynamics of wind characteristics was determined for 15 sites. Based on this work, a Wind Atlas of Kazakhstan and pre-investment studies for these sites were developed.

Wind Energy

Wind energy has the greatest potential among all RE sources in Kazakhstan. Around half of its territory has an average wind speed of about 4 to 5 m/sec at a height of 30 m. The greatest wind potentials are in the Atyrau and Mangystau regions in the Caspian Sea area, and northern and southern Kazakhstan. According to the Republic of Kazakhstan 2030 Concept of the Fuel and Energy Complex Development, the country's wind potential is 1,820 billion kWh per year.

Hydro Energy

Hydropower is the second largest RE source in Kazakhstan. As of 2017, it accounts for about 10.9% of the country's generating capacity. Ranking third among CIS (Commonwealth of Independent States) countries in water resource potential, Kazakhstan has an estimated potential of 170 billion kWh per year, of which about 62 billion kWh are technically feasible. The annual hydropower potential of medium and large rivers is 55 billion kWh, and 7.6 billion kWh from small rivers. About 8 billion kWh from small hydropower plants are estimated to be technically feasible.
Hydro energy resources are distributed throughout the country, but three areas have particularly large resources: the Irtysh River basin and its main tributaries (Bukhtarma, Uba, Ulba, Kurchum, Kardzhil), the southeast zone with the Ili River basin, and the south zone with the Syrdarya, Talas and Chu River basins. As of 2017, electricity generation from small hydropower plants (HPPs) was 649 million kWh.

Solar Energy

Solar energy has an enormous potential in Kazakhstan. According to the Concept of the Fuel and Energy Complex Development, solar energy can produce about 2.5 billion kWh per year, with 2,200- 3,000 hours of solar per year (2,500-3,000 hours per year in the southern regions) out of 8760 hours.

Geothermal Energy

Kazakhstan is also potentially rich in geothermal resources. Its hydrogeothermal resources with temperatures of 40°C to more than 100°C are estimated at 10,275 billion m3 by water rate and 680 billion Gcal by heat rate, which is equivalent to 97 billion toe (ton of oil equivalent) or 2.8 billion TJ, equivalent to the country's estimated fossil fuel reserves. Kazakhstan has estimated hydrocarbon reserves of 12 billion tons of oil and condensate (17.2 billion toe) and about 6-8 trillion cubic meters of natural gas (7-9.2 billion toe). Its coal reserves are estimated at 150 billion tons (101.0 billion toe).

Geothermal sources are located primarily in western Kazakhstan (75.9%), southern Kazakhstan (15.6%) and central Kazakhstan (5.3%). The most promising sources are the Arys, Almaty and

Zharkent basins in southern and southeastern Kazakhstan with underground waters with mineralization of up to 3 g/dm3 and temperature up to 70-100°C

Biogas Energy

Kazakhstan is a major producer of grain and other agricultural products, which produce a significant amount of waste from crops and manure. The largest volumes of mixed agricultural wastes are available in the Almaty, East Kazakhstan, Zhambyl, Kostanay, Akmola and Karaganda regions. Livestock waste is a stable source of biomass for energy production. Household solid waste is another source. No data is yet available on total and available volumes of waste and their geographic locations. Waste and residues are rarely used efficiently, for example, as raw materials for bioenergy projects. Currently, the European Bank for Reconstruction and Development is implementing a project to assess the potential for biofuel production in Kazakhstan.