

Kazakhstan's Mining Sector's Response to Carbon Neutrality Strategy: A Comparative Analysis with South Africa

by
Zarina Kyssykova,
Zaid Mohammad,
Zhanbolat Galymov

Supervisor
Professor Peter Howie

Policy Analysis Project

Paper submitted in partial fulfillment of the
Degree of Master of Public Policy

Graduate School of Public Policy
Nazarbayev University

Astana, Kazakhstan
April 17, 2026

ABSTRACT

The mining sector in Kazakhstan plays an important role in national development and the well-being of urban residents. However, because it is heavily reliant on coal, the sector contributes to greenhouse gas emissions. Kazakhstan has committed to becoming carbon neutral by 2060. The study aims to identify the drivers that accelerate and hinder the decarbonization process in Kazakhstan's mining sector, and to develop effective policies for achieving carbon neutrality in this sector, through a comparative analysis with South Africa. The study employs a comparative case study design to examine the mining sectors of South Africa and Kazakhstan and a qualitative approach to gather information on Kazakhstan's mining sector through semi-structured interviews. The study finds that the most consistent drivers of acceleration are trade and market requirements, pressure from buyers and supply chains, international financing, and investor expectations. At the same time, the current barriers are the high capital intensity of projects, long payback periods, weak internal incentives, and low public pressure. Effective policies include increasing the price per carbon unit in the emission trading system, introducing a carbon tax, while simultaneously implementing "green" subsidies and preferential financing, and implementing a just energy transition partnership. This research is important for policymakers, scholars, and others interested in this field, as it informs and enhances understanding of the current drivers, barriers, and effective policies important to Kazakhstan's mining sector's decarbonization transition.

ACKNOWLEDGEMENTS

We want to acknowledge the use of Grammarly to assist us in the revision and editing of this policy analysis exercise project, with all intellectual content remaining the original work of our group.

TABLE OF CONTENTS

ABSTRACT.....	2
ACKNOWLEDGEMENTS.....	3
LIST OF TABLES	6
LIST OF FIGURES	7
LIST OF ACRONYMS	8
CHAPTER 1. INTRODUCTION	9
1.1 Background	9
1.2 Problem statement	10
1.3 Purpose of the study	11
1.4 Research questions	11
1.5 Significance of the study	11
1.6 Scope of the study	12
1.7 Overview of the PAE study.....	12
CHAPTER 2. LITERATURE REVIEW	13
2.1 Introduction	13
2.2 Mining sector and carbon neutrality.....	13
2.3 Mining sector and RE.....	14
2.4 Mining sector and energy efficiency	14
2.5 Different approaches of countries to carbon neutrality	15
2.6 External factors driving carbon neutrality	16
2.7 Government policies and initiatives in achieving carbon neutrality	16
2.8 Research gap	18
CHAPTER 3. METHODOLOGY	19
3.1 Introduction	19
3.2 Conceptual framework	19
3.3 Description of research design and approach.....	20
3.4 Participants and sampling.....	20
3.5 Data collection methods	21

3.6 Data analysis procedures	21
3.7 Ethical considerations	21
CHAPTER 4. RESEARCH FINDINGS.....	22
4.1 Introduction	22
4.2 Case study on South Africa	22
4.3 Case Study on Kazakhstan	26
4.4 Findings from semi-structured interviews.....	29
4.4.1 Drivers of achieving carbon neutrality.	30
4.4.2 Barriers to achieving carbon neutrality.	30
4.4.3 Domestic mechanisms	31
CHAPTER 5. DISCUSSION AND ANALYSIS	33
5.1 Introduction	33
5.2 Matrix	33
5.3 Alternatives	34
5.4 Projected outcomes and trade-offs	35
5.5 Comparative analysis of South Africa and Kazakhstan.	36
5.6 Lessons from South Africa.....	37
CHAPTER 6. CONCLUSIONS	39
6.1 Research summary	39
6.2 Limitations of the study.....	39
6.3 Policy recommendation.....	40
REFERENCES	42
APPENDICES	52

LIST OF TABLES

Table 1. Research findings of interviews supported by secondary sources.....	31
Table 2. Matrix.....	34
Table 3. Comparative table between South Africa and Kazakhstan.....	36

LIST OF FIGURES

Figure 1. Total GHG emissions, including LULUCF, from 2000 to 2023 in Kazakhstan.	10
Figure 2. South Africa's CO ₂ emissions from fuel combustion from 2000 to 2023.	22
Figure 3. Kazakhstan's CO ₂ emissions from fuel combustion from 2000 to 2023.	26

LIST OF ACRONYMS

AIFC	Astana International Financial Centre
BAT	Best Available Techniques
CAPEX	Capital Expenditure
CBAM	Carbon Border Adjustment Mechanism
CO ₂	Carbon Dioxide
EU	European Union
ESG	Environmental, Social, and Governance
ETS	Emissions Trading System
GDP	Gross Domestic Product
GHG	Greenhouse Gas
IEA	International Energy Agency
IGF	Intergovernmental Forum on Mining, Minerals, Metals, and Sustainable Development
JET	Just Energy Transition
JETP	Just Energy Transition Partnership
KZ	Kazakhstan
NDC	Nationally Determined Contributions
NGOs	Non-governmental Organizations
RE	Renewable Energy
RES	Renewable Energy Sources
ROI	Return on Investment
RQ	Research Question
R&D	Research & Development
SA	South Africa
SBTi	Science Based Targets initiative
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
US	United States
USD	United States Dollars

CHAPTER 1. INTRODUCTION

1.1 Background

One of the major environmental issues worldwide is climate change, caused mainly by greenhouse gas (GHG) emissions (Filonchyk et al., 2024). In 2023, total aggregated GHG emissions, including LULUCF in Kazakhstan, reached 349,21 million tons (Bureau of National Statistics of the Republic of Kazakhstan, n.d.). Figure 1 shows a volatile trend in the country's GHG emissions from 2000 to 2023. In addressing climate change, the Paris Agreement plays a crucial role by guiding the global community to reduce GHG emissions, to hold the increase in global average temperature to 2°C, and to pursue efforts to limit the increase to 1.5°C (United Nations, 2015). Kazakhstan, a country that has previously ratified this agreement, has approved the strategy for achieving carbon neutrality by 2060. The strategy's medium-term unconditional goal is to reduce GHG emissions by 15% by 2030 relative to 1990 emission levels, whereas its conditional goal is to achieve a 25% reduction, with the help of international support for the economy's decarbonization (Adilet, 2023). Also, the government aims to increase the share of renewable energy resources (RES) to 15% by 2030 (Guliyev, 2023).

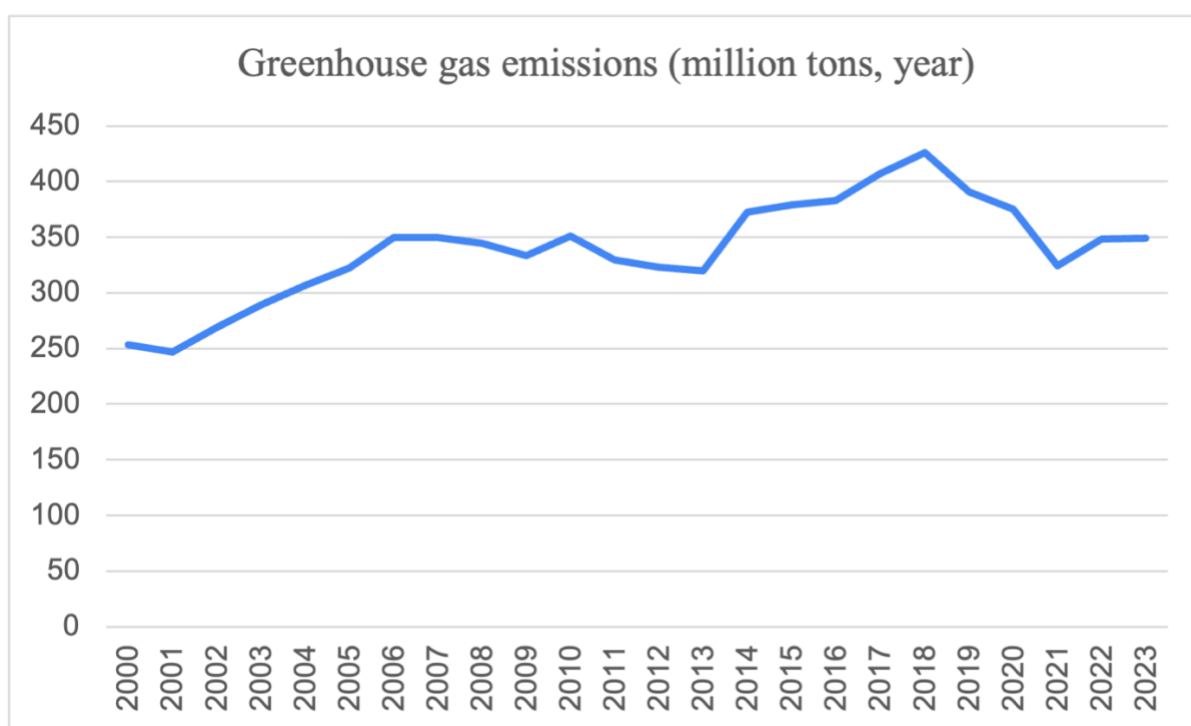
The mining sector in Kazakhstan plays a vital role in the country's economic development, contributing to social well-being by providing employment opportunities. This sector accounts for 7.35% of gross domestic product (GDP) excluding oil and gas, while production volume exceeds 10 trillion tenge (Bureau of National Statistics of the Republic of Kazakhstan, 2025). The industry employs more than 119,373 people (Bureau of National Statistics of the Republic of Kazakhstan, 2026). The mining industry is a critical contributor to residents' well-being and prosperity (World Bank Group, 2023). Most single-industry towns in Kazakhstan rely heavily on the mining sector for employment and income (Akhmetkali, 2023).

Despite its significant contribution to the country's economy and employment, Kazakhstan's mining sector has a negative environmental impact due to its heavy reliance on coal. Kazakhstan, with significant coal reserves, has traditionally relied on fossil fuels and has emitted high levels of GHG (United Nations Development Programme [UNDP], 2024). While coal is important in major sectors of the country, the coal-fired mining sector contributes to carbon emissions in Kazakhstan, complicating the transition to a carbon-neutral strategy.

However, the decarbonization process in Kazakhstan's mining sector is capital-intensive and faces challenges in attracting financing, which negatively affects enterprise sustainability (Aubakirova et al., 2023). The delay in developing green energy is explained by access to affordable fossil-fuel electricity (Aubakirova et al., 2023). Outdated infrastructure and limited experience in localization also constrain decarbonization through renewable energy (RE) (Zhakiyev et al., 2025).

Kazakhstan's mining sector, which contributes to GHG emissions, needs to transition to clean energy sources to meet its climate commitments and stay competitive in national exports in global markets.

Figure 1. Total GHG emissions, including LULUCF, from 2000 to 2023 in Kazakhstan.



Note. Created by authors based on data from the Bureau of National Statistics of the Republic of Kazakhstan (n.d.).

1.2 Problem statement

The mining sector in Kazakhstan is vital for national economic stability, employment, and public revenues. However, the sector is at a crossroads as the global shift towards low-carbon economies accelerates. While the sector underpins Kazakhstan's resource-dependent GDP, it is a

principal contributor to the country's national carbon emissions, driven predominantly by fossil-fuel-based power and process heat. International climate policies, including the Carbon Border Adjustment Mechanism (CBAM) introduced by the European Union (EU) and tightening Environmental, Social, and Governance (ESG) criteria in international finance and trade, are rapidly reshaping global trade and finance. These risk the competitiveness of Kazakhstan's mining exports. Despite notable policy commitments to carbon neutrality by 2060 and to increasing the share of renewables in the energy mix to 15% by 2030, key barriers remain: outdated energy infrastructure, high capital costs, and limited green financing. Without a coordinated transition to RES in mining, Kazakhstan faces the threat of economic decline. Addressing these challenges calls for a holistic policy framework that advances decarbonization, secures economic competitiveness, and fosters technological and financial innovation.

1.3 Purpose of the study

In this research, we aim to find factors that accelerate and hinder the decarbonization process in Kazakhstan's mining sector, and effective practices that would help to overcome these barriers through comparative analysis with South Africa.

1.4 Research questions

The following research questions (RQs) will be attempted to be answered:

RQ1: What factors accelerate and hinder the decarbonization process of the mining sector of Kazakhstan?

RQ2: What policy solutions are most effective in achieving carbon neutrality of Kazakhstan's mining sector, considering lessons from international (e.g., South Africa) initiatives?

1.5 Significance of the study

The research improves knowledge of the drivers, barriers, and effective policies for a better Kazakhstan's approach to mining-sector decarbonization. The comparative analysis with South Africa sheds light on effective and ineffective practices and provides lessons for policymakers aiming at achieving decarbonization in this sector.

1.6 Scope of the study

The study examines the mining sectors of Kazakhstan and South Africa to learn from the latter's experience. After comparing the two mining sectors of these economies, recommendations for achieving carbon neutrality in the mining sector of Kazakhstan are offered. However, these recommendations preclude detailed implementation, monitoring, and evaluation.

1.7 Overview of the PAE study

The research study continues as follows: Chapter 2 provides a literature review on the mining sector on the way to its decarbonization, considering different themes; Chapter 3 explains the research methodology; Chapter 4 delivers research findings of case studies on Kazakhstan and South Africa and findings of semi-structured interviews for Kazakhstan; Chapter 5 discusses the results and presents analysis; Chapter 6 provides conclusions and recommendations.

CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

In this chapter, we provide literature on carbon neutrality in the mining industry. We covered aspects such as the mining sector and carbon neutrality, the use of RES and energy efficiency in the mining sector, the reasons for different approaches of countries, and external factors on the ways mining companies reduce their emissions. The map created from the literature review allows us to identify the main areas and mechanisms to achieve decarbonization of the mining industry.

2.2 Mining sector and carbon neutrality

The mining sector negatively contributes to climate change as it is one of the most energy-intensive industries in the world. It has always been considered the backbone of global economic development, accounting for around 10–20 percent of GDP in some countries (Ericsson & Löf, 2018). It contributes around 4–7% of GHG emissions worldwide (Aguilar, 2022), mainly through energy-intensive activities such as extraction, comminution, and transportation. Companies are now increasingly adopting strategies including carbon capture and storage, equipment electrification, and the transition to low-carbon energy sources (International Energy Agency, 2021). Carbon neutrality in mining is a goal to achieve net-zero GHG emissions while pursuing mining activities (Sharma et al., 2023).

The United Nations Environment Programme (UNEP) identifies the integration of carbon neutrality within corporate strategies and suggests that mining companies need to balance economic growth with environmental stewardship (UNEP, 2024). The World Bank Group (2019) states that peer-reviewed studies also propose that carbon pricing mechanisms and regulatory frameworks are an important factor in incentivizing firms to reduce their emissions.

However, challenges including high upfront costs, technological limitations, and the lack of standardized metrics for measuring carbon neutrality remain significant barriers (Azapagic, 2004). Also, with the implementation of ESG standards to facilitate responsible governance in the mining sector, companies that adopt these policies stand to gain the most in investment, suffer less regulatory scrutiny, and be known for having a better reputation (Jenkins & Yakovleva, 2006). On the other hand, the culture and organizational structure of the industry, especially those that are

overly reliant on conventional mining techniques, will be difficult to modify to accommodate more sustainable mining practices (Dashwood, 2014).

2.3 Mining sector and RE

The transition to RE is crucial to mitigating the climate impact of the mining industry. RE can be used in different stages of mining operations, such as the extraction, processing, and refining, also in activities such as transportation, drilling, excavation, loading, and power generation for remote mining sites and for process heat (Igogo et al., 2021). Mining companies currently use solar, wind, and hydropower as an alternative to using transmission lines to supply electricity and to increase the energy capacity of their mining sites. For example, mining companies in Chile and Australia have been equipped with solar power plants that are large enough to generate the electricity to continue running their businesses (Norton Rose Fulbright, 2017).

However, there are still obstacles in implementing RES. The main challenges are that they are interruptible, have a lack of storage options, and high installation costs (Franks et al., 2018). For example, in Canadian mines, barriers to the adoption of RE include insufficient expertise and management, complex logistics of implementation, weak economic viability, and many other barriers (Issa et al., 2023). Despite the interest in RE adoption, the degree of its use is low due to the numerous barriers mining companies face.

2.4 Mining sector and energy efficiency

To achieve carbon neutrality, it is important to improve the energy efficiency of the mining sector as it reduces operating costs and negative impact on the environment. Oluokun et al. (2024) found that policy and technological innovations, such as smart sensors, real-time monitoring systems, automation, robotics, and machine learning, play an important role in energy efficiency in the mining industry. Mining companies are increasingly attracted to new digital technologies such as automation, the Internet of Things, digital platforms, and robotics, among others, as solutions for energy delivery and processing (Hodgkinson & Smith, 2018). Artificial intelligence-based predictive maintenance technology can reduce energy waste by ensuring that plant equipment operates at the highest possible efficiency (Liang et al., 2024).

However, although digital technologies are transforming how the mining sector operates, mining companies tend to prioritize areas such as cost, safety, and productivity, rather than considering energy consumption and GHG emissions reduction (Asa'd & Levesque, 2024).

2.5 Different approaches of countries to carbon neutrality

The Paris Agreement of 2015 united almost all countries of the world. However, it is not a legally binding document, and the specific goals of the countries remain voluntary (Savaresi, 2016). Consequently, each country tries to achieve carbon neutrality in its own way. That is why the question: why do some countries try to achieve carbon neutrality, while others do not? It is especially important.

One of the most common reasons in the literature is the benefits related to economic dependence. Countries that are not strongly committed to achieving carbon neutrality are mainly those that have not reached their peak production and have a high dependence on carbon-intensive products. For example, Martus (2019) conducted a study on the reaction of Russian mining companies and found that economic dependence and active lobbying of coal companies were the main reasons for remaining carbon-intensive. Also in Guizhou, the factor of social injustice of the transition left local miners without sufficient compensation (Zhang et al., 2024). Meanwhile, countries like Canada, Australia, and Chile are making great strides in achieving carbon neutrality by adopting RE (Abbaspour et al., 2022). This is thanks to their regulatory frameworks and access to renewable potential facilitation (Igogo et al., 2021). As a result, Canada has installed a photovoltaic system at Snowline Gold's Forks camp that powers a gold mine (Issa et al., 2023) or Gold Fields in Australia, which reduced GHG emissions by 10% by replacing a gas-fired power plant with an 8-megawatt solar power plant, which can be a good example (Mahlangu, 2021).

Another reason is public pressure and social responsibility. Cormier et al. (2004) paid attention to 150 of the largest companies in Germany and found that media attention and pressure from non-governmental organizations (NGOs) have a positive relationship with the quality of reporting. Also, the work of Kassinis and Vafeas (2006), where they studied 5033 United States (US) industrial enterprises and confirmed the hypothesis that an increase in the number of people participating in environmental organizations has a positive effect on reducing emissions. Even in

more authoritarian countries like China, public pressure plays a big role (Li, 2022). However, there is another side to the coin. The people can also negatively influence the progress of this issue. For example, in Poland and Germany, trade unions block political decisions to close coal facilities (Rentier et al., 2019). Thus, they slow down this process.

2.6 External factors driving carbon neutrality

There is a growing talk that the decarbonization process involving carbon-intensive industries is increasingly based not on internal reforms, but on external regulatory and financial pressure. One of which is the investors' requirements. There is a lot of literature that has examined the impact of this principle on achieving carbon neutrality. For example, Shen et al. (2025), who analyzed Chinese companies from 2013 to 2023, found that the ESG principles played a huge role for companies to get financing, and the environmental component, rather than the social or governance components, was more influential (Shen et al., 2025). This means that mining companies to receive financing are trying to meet the standards of ESG and pay attention to environmental issues. Pressure on the mining industry also comes in the form of tariffs. One such tariff is the EU's CBAM. According to Zhong and Pei (2022), it would positively affect the reduction of emissions and lead to a decrease in production in other countries. Zhang and Sovacool (2024) also wrote that CBAM is a very effective trade policy tool that stimulates green modernization and gives investors a reason to change their investment decisions. Ramsook et al. (2025), who conducted a case study on how CBAM could impact the ammonia industry in Trinidad and Tobago, found that, under current CBAM tariff rates, 1/3 of EU revenue could go toward CBAM payments. Moreover, the authors state that market diversification is not a panacea (Ramsook et al., 2025). They admit that alternative markets may have their own problems or that other countries may also introduce similar measures (Ramsook et al., 2025). Therefore, they state that reducing carbon intensity is the only tool that can help in the long term (Ramsook et al., 2025).

2.7 Government policies and initiatives in achieving carbon neutrality

Many scholars, such as Zaporozhets et al. (2026), note that early decarbonization creates an advantage over other competitors, and delays can lead to market loss. That is why the state is trying to stimulate mining companies in every possible way through various measures.

Jin (2023) emphasized that a green transition is impossible without expansion of the mining sector, as green technologies require critical minerals, and that countries should stimulate the development of cleaner production as much as possible. One of these methods is the carbon tax. Nkwor (2025) wrote that states with strict regulations exert strong pressure on companies. However, much of the literature on the carbon tax concluded that this method is effective only with an appropriate economic structure and its interactions with other environmental instruments (Hájek, 2019). In this case, Mardones (2023) believes that the missing component in achieving carbon neutrality is subsidies for RES. This position is held by Li and Peng (2020), arguing that the tax will push companies to reduce emissions, while subsidies will mitigate economic losses. Issa et al. (2023) support this position by emphasizing that carbon neutrality requires not only the introduction of RES or the use of economic incentives, but also a comprehensive transformation of the entire system. The specific mechanism of this idea was clearly demonstrated in the work of Macaluso et al. (2018), where if the government properly uses revenues from taxes and redistributes them to finance green technologies, it can avoid economic costs and positively impact sustainable development. Also, Wang et al. (2024) analyze the redistribution of carbon price revenues.

Another important mechanism is the Just Energy Transition (JET) framework. Its implementation plan for 2023-2027 is a roadmap that allows South Africa to take steps towards achieving decarbonization by delivering outcomes for energy transition-affected people (The World Bank et al., 2023). Basically, the JET framework was initiated by the Presidential Climate Commission to introduce a chance to begin addressing practical concerns connected to employment, skill development, social assistance, and governance (*Just Transition Framework*, n.d.). It was an initiative towards achieving decarbonization with a just transition. Also, in the 2021 UN Climate Change Conference, an agreement between South Africa and the International Partners Group was signed for the Just Energy Transition Partnership (JETP), which marks a novel initiative of global climate finance and assistance (Csanadi & Helmecci, 2025). Thus, South Africa has found a good financing tool, i.e., JETP, an innovative financing agreement to encourage fair transition for the promotion of renewables, and incentivize coal phase-out (Karg et al., 2025).

Emission Trading Systems (ETS) also have a very positive impact in many regions of the world. Shen et al. (2023) showed that ETS in China reduced pollution in mining cities by 22%.

Narassimhan et al. (2018) found that ETS reduces emissions, but a lot depends not on the system's existence itself, but on its stringency and carbon pricing. That is, if the price is low, the incentive is weak, but if the price is stable and rising, investment in green technologies increases (Narassimhan et al., 2018). Dechezleprêtre et al. (2023), examining the effect of ETS on profitability, employment, revenue, and closure, found no significant negative effect on the probability of closure, profitability, or employment, while they increased revenue (Dechezleprêtre et al., 2023). Sweden is also noted for its ability to reduce emissions without negatively impacting economic growth by setting a high rate of \$137 per tonne, thanks to its "green tax shift" tax reform (Nurhayati et al., 2024). This allowed for a redistribution of the tax burden among companies by reducing taxes on labor and income while simultaneously raising taxes on carbon dioxide (CO₂) emissions (Nurhayati et al., 2024).

2.8 Research gap

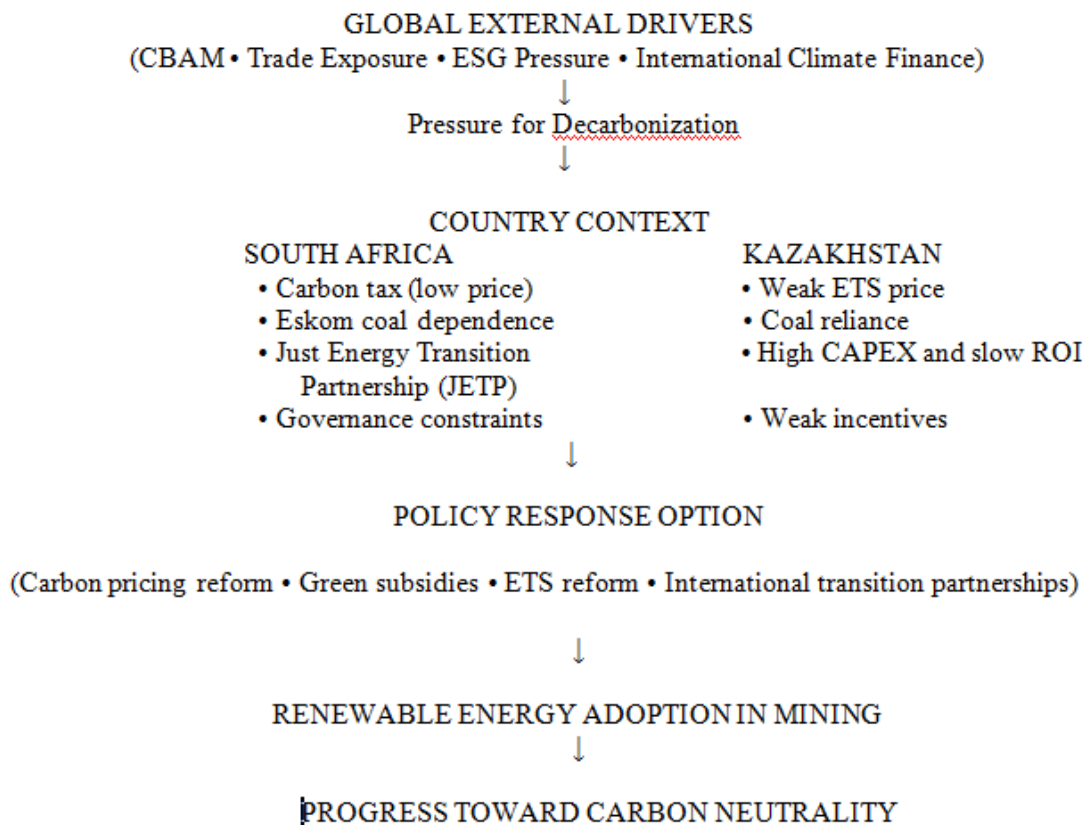
There are still gaps in existing studies on the decarbonization of the mining sector of Kazakhstan. Less progress has been made in analyzing government regulations of Kazakhstan that create incentives for companies to transition to carbon neutrality. Thus, a more in-depth investigation is needed into other factors driving the transition to carbon neutrality in the mining sector, using resource-based countries such as Kazakhstan.

CHAPTER 3. METHODOLOGY

3.1 Introduction

In this chapter, we describe the methodology of our research for examining the drivers, barriers, and effective policies for Kazakhstan's mining sector decarbonization transition. The chapter describes the comparative case study design with a qualitative research approach, purposeful sampling method, data collection through semi-structured interviews, primary data analysis, document analysis of secondary sources, and discusses the ethical conduct of our interviews.

3.2 Conceptual framework



This study critically examines how outside pressures, internal problems, and specific rules affect the adoption of decarbonization strategies and how the mining industry uses RE. Mining companies do not just operate on their own, but they react to things happening both domestically and internationally. Policies like the CBAM, being open to trade, ESG rules, and money from other

countries are all pushing many economies to cut down on carbon and use cleaner energy. But at the same time, several factors within the company are causing this process to be stagnant. These can be investing huge capital, inadequate carbon pricing, technological constraints, heavy reliance on coal, and no public demand. These problems mean that switching to RE usually takes time and resources. Strategies such as imposing carbon taxes, designing the emissions trading framework, providing green subsidies, and setting up JETP may help in addressing these challenges. The transition to RE and their progress toward carbon neutrality also depend on the interaction of various factors. These can be motivations and incentives driving them, the obstacles these mining and energy-generating firms face, and the existing domestic policies and roadmap towards decarbonization.

3.3 Description of research design and approach

To compare the mining sectors of South Africa and Kazakhstan, we used a comparative case study research design. South Africa was selected as a comparative case because it shares key structural characteristics with Kazakhstan, such as strong coal dependence and a mining-driven economy, while also having more advanced policy experience with decarbonization initiatives, allowing the study to draw practical lessons for Kazakhstan's transition. The comparative design helped us to investigate the differences and similarities in the decarbonization approaches through conducting two case studies, one for the mining sector of South Africa and the other for the mining sector of Kazakhstan, based on secondary sources. To have more information on the mining sector of Kazakhstan, the research employed a qualitative approach incorporating semi-structured interviews. The qualitative approach allowed us to receive insights and have a deep understanding of the mining sector of Kazakhstan, namely, current drivers, barriers, and effective policies on its way to decarbonization.

3.4 Participants and sampling

We used a purposeful sampling method. Research participants were selected based on their experience and knowledge of the field of research. We conducted semi-structured interviews with 10 participants. Our participants included representatives of mining companies operating in Kazakhstan, a representative of the mining industry association, a government environmental

official, a representative of the private sector, and academics. As no new themes, ideas, or patterns emerged in interview responses, data collection was paused at 10 participants.

3.5 Data collection methods

For the case studies, we used secondary sources such as international and local reports, policy documents, government websites, research papers, and news. The primary data was collected through semi-structured interviews. During the interviews, participants were asked a list of questions in Appendix A.

3.6 Data analysis procedures

After collecting the interviews, coding was first conducted to identify recurring themes, followed by thematic analysis to categorize the key topics of discussion and explore frequencies among participants.

3.7 Ethical considerations

Interviews with participants were conducted after obtaining permission from the Nazarbayev University Institutional Research Ethics Committee. Participation in this study was strictly voluntary, with the ability to withdraw at any time and not to answer any questions. All the personal information about research participants and their answers obtained during the interviews was kept confidential and stored, with access to data limited to the research team. The interviews had no sensitive or distressing topics. Also, all secondary sources were properly cited.

CHAPTER 4. RESEARCH FINDINGS

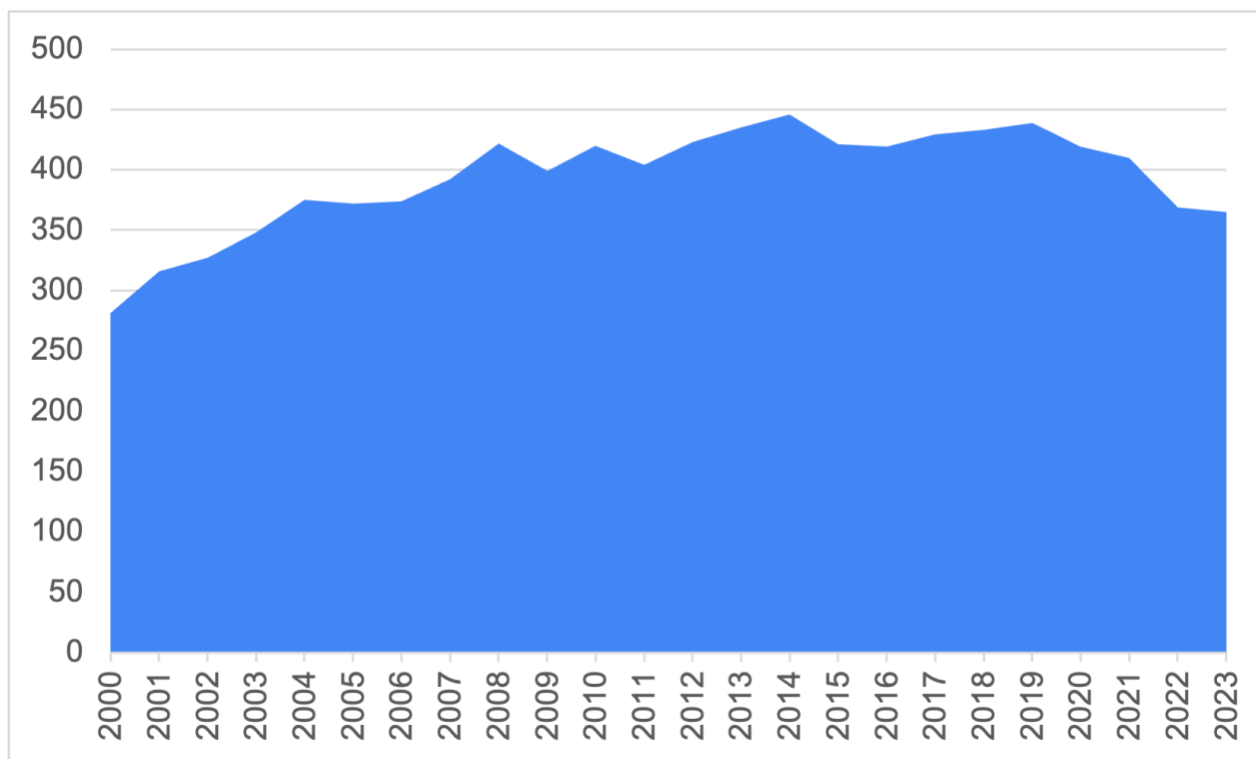
4.1 Introduction

In this chapter, we present the results of a study based on interviews with experts and industry representatives, as well as content analysis using cases of Kazakhstan and South Africa. The research findings demonstrate both the internal characteristics of the mechanisms and the industry as a whole, and the influence of external economic, regulatory, and institutional factors on companies' decarbonization strategies.

4.2 Case study on South Africa

The mining sector of South Africa has a paradoxical position in the global energy transition. A carbon-intensive industry embedded in a coal-dependent energy system. Based on the International Energy Agency (IEA) (n.d.), Figure 3 illustrates an increasing trend of South Africa's energy sector's CO₂ emissions from fuel combustion from 2000 to 2023. The mining sector contributed R356bn (21.7~ bn USD) or 7.3% to South Africa's GDP and accounted for 25% of the country's total export earnings (Invest SA, 2026). The data about South Africa from the World Bank states that South Africa has undergone numerous policy reforms to align their energy sector with global decarbonization goals. The International Bank for Reconstruction and Development (IBRD) is helping by providing one billion United States dollars (USD) as a loan (The World Bank et al., 2023). The objective of this one billion USD proposed Development Policy Loan is to fix the power sector to promote low-carbon energy transition (The World Bank et al., 2023). Additionally, South Africa received \$497 million from the World Bank Group to decommission and transform the Komati coal-fired power plant using renewables and batteries (World Bank Group, 2023). Further, we have six key findings on South Africa.

Figure 2. South Africa's CO₂ emissions from fuel combustion from 2000 to 2023.



Note. Created by authors based on data from the International Energy Agency (n.d.).

SA-1: Weak Carbon Pricing as a Limited Decarbonization Incentive

South Africa has updated its Nationally Determined Contribution (NDC), which shows how it is using GHG mitigation targets of 2025 and 2030 through implementing policies such as carbon tax, carbon budget, emissions targets, etc. (World Bank, 2023). As defined in national policy, South Africa's NDC target emissions by 2025-2030 will be between 350 and 420 Mt CO₂~ or between 15 and 30 percent reduction from the current level ("South Africa First Nationally Determined Contribution Under the Paris Agreement," 2021). But the current trajectory shows 475-492 Mt CO₂ –eq. in 2026-2030, which is above the NDC pathway, implying a need for tighter pricing (Intergovernmental Forum on Mining, Minerals, Metals, and Sustainable Development [IGF], 2024). Also, in 2025, the current rate of carbon tax is R236 (15 USD) per metric ton of CO₂ (Carbon Knowledge Hub | South Africa's Carbon Tax, 2025), which is much lower than the USD50–100/tCO₂ by 2030 (United Nations Climate Change, 2017). In short, the carbon tax is very low in South Africa as compared to the expected rate of carbon pricing.

SA-2: Structural Electricity Dependence and Eskom's Monopoly

Additionally, understanding emission structure is essential, including Scope 1 and Scope 2. In South Africa, approximately 77% of the mining's Scope 1 and Scope 2 emissions derive from

electricity, more than six times higher than the Scope 2 of global peers (Bour et al., 2022). The reason being, Eskom generates roughly 85-90% of electricity from coal, thus mining emissions are structurally embedded in national dependency.

In one of the studies done by the Gordon Institute of Business Science, they found that there are barriers to adopting green energy in the mining sector (Mabalane, 2023). This study says that carbon tax legislation is perceived as punitive rather than incentivizing decarbonization, and Eskom's (South Africa's state-owned utility, which produces nearly 40 %–45 % of Africa's electricity) energy supply holds a monopoly on electricity supply in South African industry (Ukoba et al., 2025). Eskom is involved in coal-based electricity generation, and approximately 90% of electricity is generated using coal-based power plants (Ukoba et al., 2025). This coal-based energy generation and its monopoly in the South African energy market hampers the widespread adoption of RE, and 'just transition' is seen as difficult to act upon.

SA-3: Trade Exposure and the CBAM Constraint

The EU's CBAM is in a transitional phase, and South Africa's long-term energy security and decarbonization should benefit and contribute to its energy transition through a World Bank loan (World Bank Group, 2023). The EU CBAM introduces a trade-linked decarbonization constraint for carbon-intensive exporters (Agyei et al., 2025; IGF, 2024). It seeks to ensure that goods imported into the EU bear a similar carbon price to those produced within its borders, thereby protecting EU industries from "carbon leakage" and encouraging global decarbonization. Based on 2022 data, a total of 2.8 US billion dollars (R52.5 billion ~) of SA exports were at risk, and this number is expected to increase (Maimele, 2024). Given South Africa's high export carbon content relative to competitors, failure to decarbonize may reduce trade competitiveness. In effect, CBAM functions as an external compliance mechanism that compensates for weak domestic carbon pricing (Bour et al., 2024).

SA-4: Coal Employment and Just Transition Risks

Coal is an inexpensive input for electricity generation. It is also a source of export revenue and jobs in the mining industry (Bhorat et al., 2024). In 2018, a total of approximately 120 000 coal value chain jobs were quantified (Patel et al. 2020). Research indicates that 43% of South Africa's coal workforce are contract workers with limited job protections, and over half are unskilled or semi-skilled. These are critical factors for energy transition planning (Cole et al., 2025).

South Africa's mining sector has been in structural decline in recent years. Real production output declined by 10% between the year 2010 and 2018, with a total direct employment decrease of 50,000. Meanwhile, in 2019, South Africa employed more than 50,000 mining sector employees directly, and almost 60% of those jobs were related to thermal coal and Platinum Group Metals mining in various parts of the country (Just Transition and Climate Pathways Study for South Africa, 2021).

SA-5: Governance and Institutional Capacity Constraints

In February 2022, South Africa's government introduced a Bill in the parliament on climate change. This shows the government's interest and alignment towards decarbonizing its overall industry. Later, this became the law, and commencement began after a proclamation notice was published in the Government Gazette on 17 March 2025 (Minister George Announces Proclamation and Implementation of the Climate Change Act, 2024 (Act No. 22 of 2024), 2025). Additionally, in March 2022, South Africa's treasury came up with the Sustainable Finance Taxonomy, a policy for investment towards low GHG emissions, which includes mining. This policy outlines projects, activities, and sectors that can be classified as "green," and matches with international best practices for decarbonization (IGF, 2024).

In short, despite expanding policy frameworks and international financing commitments, implementation remains uneven. Further issues include corruption, clientelism, selection bias (only consulting some stakeholders or certain leaders), and lack of access to information to the public due to language or technology barriers (Strambo et al., 2024). Institutional coordination constraints, regulatory bottlenecks, and political resistance linked to coal-sector interests have further slowed reform (Doesburgh & Winkler, 2025).

SA-6: Technological and Regulatory Limitations

Continuing the studies done by the Gordon Institute of Business Science, they found that there are barriers to adopting green energy in the mining sector (Mabalane, 2023). First, they relied on the findings in South Africa's mining industry, that the adoption and limitation of green hydrogen in operation have hurdles, such as it can be used in an open pit only, and its technology to produce, store, and transport needs massive research and time to develop infrastructure (Mabalane, 2023). Also, this study finds that Carbon Capture and Storage is also at an initial stage of development and needs more investment and technical expertise for implementation at a larger level. Additionally, regulatory and governance frameworks also influence the decarbonization

process. A global governance framework, named Science Based Targets Initiative (SBTi), exists, encouraging companies to embark on a journey to a low-carbon economy based on climate science and the goals of the Paris Agreement (World Wide Fund for Nature, 2018). However, SBTi in South Africa has not been implemented on a large scale due to technological incapacity and no long-term investment planning.

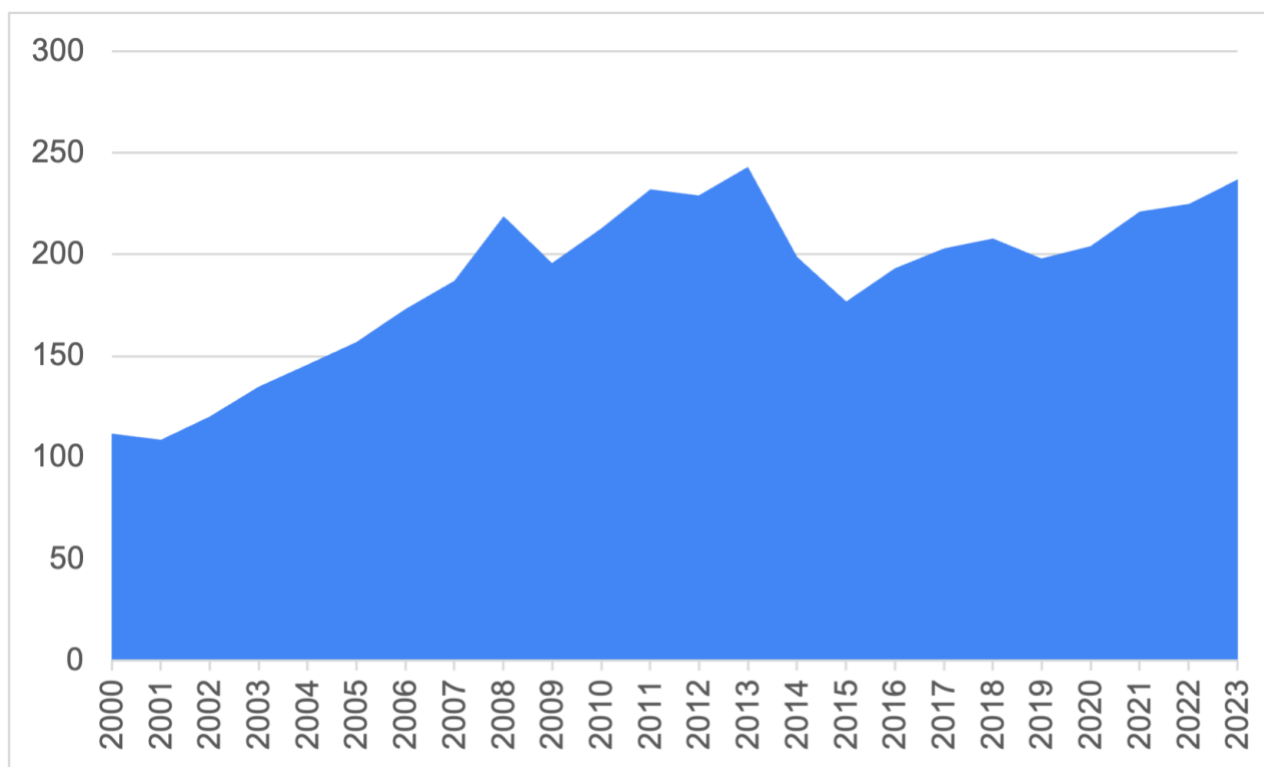
4.3 Case Study on Kazakhstan

KZ-1: Coal dependence requires a gradual transition to RE

Coal provides 66.7% of electricity generation and 80% of thermal energy production (Beisengazin, 2025). Coal plays an important role in major sectors of the country. But despite this, it accounts for 70% of the country's emissions (Beisengazin, 2025). In Figure 3, we also see an increasing trend of Kazakhstan's energy sector's CO₂ emissions from fuel combustion from 2000 to 2023, based on the IEA (n.d.).

A forced transition to RE, as well as a phase-out of coal, could worsen Kazakhstan's energy security problems (Aubakirova et al., 2023). Despite the growth in RE generation, its share of total electricity generation remains low (Aubakirova et al., 2023). Carbon neutrality goals can only be achieved in the long term, as decarbonization is complicated by technological and economic factors (Aubakirova et al., 2023). The decline of the coal industry could also lead to economic and social problems for communities dependent on coal mining, requiring the government to develop a plan for a coal phase-down (Lanshina et al., 2024).

Figure 3. Kazakhstan's CO₂ emissions from fuel combustion from 2000 to 2023.



Note. Created by authors based on data from the International Energy Agency (n.d.).

KZ-2: The CBAM is a driving factor in reducing emissions

The EU's CBAM could cost Kazakhstan over \$250 million in export revenues per year (World Bank Group, 2022). The EU's CBAM poses challenges for Kazakhstan's exports (The Agency of the Republic of Kazakhstan for Regulation and Development of Financial Market, 2025). Kazakhstan and the EU are significant trading partners, with Kazakhstan's exports accounting for 37% in 2024, with 95% of exports primarily consisting of fuels and mining products (European Commission, n.d.). The introduction of a carbon tax increases the cost of exported goods, thereby affecting the competitiveness of products, and pushes enterprises to switch to alternative technologies (Qazaq Green, 2024).

KZ-3: Adherence to ESG principles is a driving factor in the transition

One of the driving factors behind decarbonization in the mining industry is adherence to ESG principles. Adopting ESG principles plays a significant role in ensuring the competitiveness of enterprises and prioritizing internal sustainable development goals (Aubakirova, 2023). For example, the EBRD prioritizes "green" projects and does not finance coal or uranium projects (Aubakirova et al., 2023). Adherence to ESG principles is crucial for the attractiveness and long-term success of investments (Kovalenko & Samambayeva, 2022).

KZ-4: National decarbonization policies have a limited impact

To achieve GHG emissions reduction by 15% by 2030, the government of Kazakhstan launched the Kaz ETS 2013. The system covers 47% of emissions from 135 companies and 212 installations (Astana International Financial Centre [AIFC], 2025). Kazakhstan's carbon budget for each calendar year is planned to be reduced by 2.25% to 5.1% in the period from 2026 to 2030 (Adilet, 2023). But low carbon prices limit the impact of the Kaz ETS (Lanshina & Asikritov, 2025). The price of a carbon unit is about 1 US dollar (AIFC, 2025). Low prices incentivize companies to purchase carbon credits rather than reduce emissions (Perzadayeva & Yskakova, 2022). Countries should set a strong carbon price, aiming to reach \$50-100 per tonne of CO₂ by 2030 (High-Level Commission on Carbon Prices, 2017).

The Environmental Code of Kazakhstan, adopted in 2021, requires the implementation of best available techniques (BAT) to minimize negative anthropogenic impact on the environment (Adilet, 2021). Coal-fired power plants must receive a comprehensive environmental permit and implement BAT (Lanshina & Asikritov, 2025). Companies that implement BAT are exempt from emissions charges, while those that do not switch face increases in emissions charges every three years (Lanshina & Asikritov, 2025). However, the policy's limitation lies in low emissions charges and delays in implementation (Lanshina & Asikritov, 2025).

Kazakhstan also has a green finance market, run by the AIFC. Here, economic incentives such as subsidized interest rates on loans, subsidized coupon rates on green bonds, and guarantees on green bonds are implemented at the legislative level (AIFC, 2023). But Kazakhstan's banking sector has a low impact on developing a low-carbon economy (AIFC, 2023).

KZ-5: The mining sector of Kazakhstan faces challenges in its decarbonization

Decarbonizing the economy by 2060 nationwide requires significant additional investment for Kazakhstan (Menzies et al., 2024). The transition is complicated by capital-intensive processes for implementing BAT, improving energy efficiency, and constructing RE facilities (Menzies et al., 2024).

When implementing RE, the mining sector faces high tariffs, unstable energy supply, and a high debt burden (Vassilyev, 2024). Investing in low-carbon technologies is complicated by the high initial expenditures (CAPEX) of low-carbon energy systems compared to those operating on fossil fuels (Menzies et al., 2024). Uncertainty regarding the return on investment (ROI) of new technologies also hinders large-scale capital investments (Menzies et al., 2024). Demand for low-

carbon metallurgical products, mainly in the EU, limits market demand for such products, reducing incentives to invest in cleaner technologies for companies (Menzies et al., 2024). Furthermore, the lack of legally binding targets, clear decarbonization mandates, and lax emission standards creates weak regulatory pressure, slowing the implementation of low-carbon technologies (Menzies et al., 2024).

KZ-6: Carbon taxation, paid carbon allowances, and the creation of the Carbon Fund are possible solutions

Carbon taxation can provide a stable revenue source, improve economic efficiency, and support Kazakhstan's international competitiveness (World Bank Group, 2025). Although a carbon tax was considered, the government of Kazakhstan did not introduce it because it requires an analysis assessing the possible economic consequences, impact on industries, and comparison with current climate policy measures (Kazakhstan Newslines, 2025).

Possible changes to the ETS system include the introduction of paid carbon allocation and the creation of a fund accumulating revenues from carbon auctions (AIFC, 2025). Carbon Fund can create revenues from auctioning carbon allowances that could be further allocated for financing priority decarbonization initiatives (AIFC, 2025). Funding for priority areas is implemented through "green transition financing" mechanisms, which include subsidies, guarantees for green projects, green capital, and concessional lending (AIFC, 2025).

KZ-7: Low public engagement and awareness in influencing climate governance is another obstacle

Out of 3,500 respondents nationwide in Kazakhstan, only 10.6 percent cite environmental issues as the country's main challenges. Most respondents cited inflation, increasing prices, small wages, and pensions as top challenges (UNDP, 2025). Also, the majority is unable to clearly explain the nature of climate processes, international agreements, and national climate strategies, showing low awareness of climate change (UNDP, 2025). The understanding of carbon footprint, GHG, and territorial vulnerability is fragmented or nonexistent (UNDP, 2025).

4.4 Findings from semi-structured interviews

In this section, we present the semi-structured interview findings (IF) supported by the findings from the case study on Kazakhstan. We grouped our key findings from 10 interviews to 3 groups, with three findings for each of them.

4.4.1 Drivers of achieving carbon neutrality.

IF 1: CBAM is an important driver of renewable energy technology integration (7/10). According to interviews, we found that incentives for RE integration emerge primarily when companies face various external demands. 7 out of 10 of our respondents believe that the CBAM is a practical and highly effective example of external pressure. However, 3 out of 10 respondents declared that CBAM pushes the mining sector to reorient to China and Turkey and that CBAM does not have a huge impact on decarbonization.

IF 2: Trade exposure is one of the key drivers (10/10). All the respondents agreed that companies focusing on specific markets with strict tariffs accelerate the pace of renewable energy integration. But they also don't exclude the possibility of reorienting to markets with more lenient regulations.

IF 3: External financing pushes to decarbonization (10/10). All the respondents stated that international banks and investors are important for companies because they open or close the capital window. They explained that accelerating the adoption of RE in the mining sector occurs primarily when external financing provides a clear signal to producers. In other words, decarbonization leads to international competitiveness and the ability to trade and secure financing.

4.4.2 Barriers to achieving carbon neutrality.

IF 4: Financial problems/ High CAPEX and slow ROI as an obstacle (8/10). Financial barriers, such as CAPEX and the slow ROI of these projects, were repeatedly mentioned. They believe that the transition is expensive, and the payback is slow, especially given competition for budgets, and access to financing is even more difficult for small and private companies. Thus, even with external pressure, companies may postpone projects and reorient to other markets if they are perceived as risky.

IF 5: Weak internal incentive mechanisms in Kazakhstan (6/10). Particularly through low-carbon policy signals, such as low prices in the ETS. This often appears in the data as a slowing factor because it does not create domestic economic pressure to accelerate. This is reinforced by weak state support for decarbonization and a lack of research and development (R&D) in the KZ mining sector, mentioned twice.

IF 6: Public pressure is limited in Kazakhstan (10/10). Social pressure was also noted by 10 out of 10 respondents as an equally important framework, having a significant impact in

different countries. However, 8 out of 10 respondents noted the very limited influence of public pressure and NGOs in Kazakhstan. Only two respondents noted a positive development, citing visible growth over the past 10 years, but they also acknowledged weaknesses in public engagement with this issue. All respondents agreed that this area is important in theory, but still weak in practice in Kazakhstan.

4.4.3 Domestic mechanisms

IF 7: The mechanism of ETS should be remade (8/10). 8 out of 10 of our respondents noted that revising this mechanism, which implies increasing quota prices, is very important. Only two respondents referred to the limited capacity of mining companies, which could pose problems if carbon pricing were to increase in Kazakhstan.

IF 8: A combination of carbon tax and green subsidies is an effective instrument (10/10). All respondents agreed that the most realistic mechanism for incentivizing the mining sector is a combination of a carbon tax and green subsidies. Respondents who emphasized the importance of a carbon tax always considered the importance of equitable subsidies for companies, and vice versa. They also emphasized that, when creating a price signal, it is necessary to lower the barrier to entry for modernization through various instruments, thereby making this transition economically feasible for companies with varying financial capacities.

IF 9: Gradual transition is needed (10/10). All our respondents agreed that a gradual transition is necessary. However, their opinions differed regarding the cause of this policy. 2 out of 10 respondents considered that economic dependence is not the most critical factor. In contrast, the majority indicated that it is one of the most important challenges facing Kazakhstan. The problems of single-industry towns, job losses, the potential for significant social discontent, and the need for mass retraining through a gradual transition program without causing a massive shock were mentioned.

The interview findings are supported by secondary sources, which are shown in Table 1.
Table 1. Research findings of interviews supported by secondary sources.

Theme	Frequency	Supportive secondary sources
-------	-----------	------------------------------

CBAM is an important driver of RE technology integration	7/10	KZ-2
Trade exposure is one of the key drivers	10/10	KZ-2, KZ-5
External financing pushes to decarbonization	10/10	KZ-3
Financial problems/ High CAPEX and slow ROI as an obstacle	8/10	KZ-5
Weak internal incentive mechanisms in Kazakhstan	6/10	KZ-4
Public pressure is limited in Kazakhstan	10/10	KZ-7
Mechanism of ETS should be remade	8/10	KZ-4
A combination of carbon tax and green subsidies is an effective instrument	10/10	KZ-6
Gradual transition is needed	10/10	KZ-1

Our key findings highlight several key factors influencing the mining sector's transition to carbon neutrality. The results demonstrate that this process is shaped by both the industry's internal characteristics and external economic and institutional incentives. Particularly prominent are international regulatory frameworks, sustainable financing requirements, and pressure from global markets.

CHAPTER 5. DISCUSSION AND ANALYSIS

5.1 Introduction

Findings for Kazakhstan shows that RE integration into the mining sector is advancing faster under external pressure, driven by factors such as the CBAM (IF-1), trade exposure (IF-2) and external financing (IF-3), but is hindered by internal barriers due to CAPEX and slow ROI (IF-4), weak domestic incentives (IF-5), including the low ETS price (IF-7), limited public pressure (IF-6), and the need for a phased transition (IF-9) by considering effectiveness of mixture of carbon tax and green subsidies (IF-8) also play a role.

5.2 Matrix

Therefore, in this section, we evaluate 4 policy alternatives using common criteria (Table 2). All our evaluation criteria, policy alternatives, and their estimates (++/+0/-/--) are based on our key findings.

Evaluation criteria:

At first, we used five criteria based on our findings that best reflect the identified mechanisms and constraints:

1. Effectiveness. To what extent does the alternative accelerate the integration of renewable energy sources or energy efficiency into the mining sector? (IF-5)
2. Cost-efficiency. To what extent does the alternative reduce the CAPEX barrier and the slow ROI issue identified in IF-4, thereby creating conditions under which companies can realistically invest?
3. Political feasibility. To what extent can the policy overcome persistent resistance from interest groups, such as coal regions and the industry, given the need for a phased transition (IF-9) and limited public pressure (IF-6)?
4. Administrative feasibility. To what extent is it feasible to implement the policy, considering administrative capacity? Findings from South Africa (SA-5) indicate that, even with funding, reforms can stall due to governance and capacity constraints.

5. Equity and Just Transition. To what extent does policy distribute the costs of transition and support at-risk groups, such as workers, single-industry towns, and regions with high dependence on the coal economy (IF-9 and SA-4)?

5.3 Alternatives

Also, we provide 4 different policy alternatives that we evaluate with our five evaluation criteria

A-1: Status quo. The current ETS remains in place, with a weak price signal and no significant tightening. Support for RE and energy efficiency remains limited. This means there will be no support for avoiding high installation costs. The sector will rely on external pressures, including CBAM, market forces, and banks.

A-2: Enhanced ETS. Reform of the ETS as the main domestic pricing mechanism. Increase quotas and focus on domestic pressure through emissions pricing, without large global subsidy packages or with only minimal compensation—a response to IF-7 and IF-5.

A-3: Carbon tax + green subsidies. Strengthen the carbon price through a tax and channel part of the revenues to targeted measures through subsidies, guarantees, and preferential financing of CAPEX for RE and energy efficiency in mining (IF-4), including just-transition components (IF-9).

A-4: CBAM alignment package. Accelerated alignment of practices with external market requirements—maximum focus on IF-1 and IF-3 programs, with external funding.

Table 2. Matrix.

Criteria	A-1: Status quo	A-2: Enhanced ETS	A-3: Carbon tax + green subsidies	A-4: CBAM alignment package
Effectiveness	–	++	+	++
Cost-efficiency	0	+	++	+
Political feasibility	++	+	+	--

Administrative feasibility	++	+	--	-
Equity and Just transition	0	-	++	+

5.4 Projected outcomes and trade-offs

The matrix shows that neither option is stronger across all parameters. A-1 guarantees the highest political and administrative feasibility (++) (SA-5,6) while declining in effectiveness (--) (IF-4,5,6,7). This contradicts findings about the need to accelerate the transition and the weakness of internal incentives. Here, the tradeoff is stability and low conflict for modest progress. The status quo would imply that RE integration would be faster for export-oriented companies and slower for others (IF-1,2,3). Because of weak Internal incentives (ETS) (IF-5), major investments in RE will be postponed. The risk of CBAM will only partially decrease for individual companies. The overall pace of decarbonization will remain insufficient.

A-2 shows very high effectiveness (++) (IF-5,7) and shows good administrative and political feasibility since this instrument is already in use (KZ-4), and a price increase is required, but weak equity (-) (IF-9). That is, strengthening the ETS would create a robust internal price signal, incentivizing companies to adopt low-carbon solutions. Emissions reduction efficiency will increase, but the CAPEX barrier will remain (IF-5). Without parallel support, this scenario increases the risk of socio-political resistance and of problems related to the just transition (IF-9).

A-3 is the most balanced. It has the highest cost-effectiveness ratio (++) (IF-8), very high equity (++) (IF-8,9), and positive political feasibility and effectiveness (+) (SA-5,6). Here, a price signal is generated, while the barrier to entry for modernization is lowered through the subsidy system, thereby making the transition economically feasible for companies with varying financial strengths. This option is the most viable solution to the current situation, as it simultaneously increases the price signal and lowers the barrier to entry for modernization through subsidies (IF-8). The weak point is administrative feasibility (--) (SA-5,6). Here, it is necessary to manage taxation competently, distribute subsidies, and monitor outcomes. Otherwise, there is a risk of non-compliance (SA-5,6).

A-4 appears to be one of the strongest in terms of efficiency (++) (IF-1) and good in cost-efficiency (+) (IF-1), but it has the lowest scores for political (--) and administrative (--) feasibility

(SA-5,6). This policy will enhance competitiveness by aligning with external market requirements and by strengthening standards and reporting (IF-1,2,3). It can accelerate the adoption of RE through requirements, financial mechanisms, and technological standards (IF-1,2,3). However, implementation is complex. High levels of coordination and institutional capacity are needed. Otherwise, risks include resistance (SA-5,6). In terms of equity, it appears moderately positive (+), but given the complexity of implementation and potential industry pressures, it is a highly ambitious yet risky strategy (IF-9).

5.5 Comparative analysis of South Africa and Kazakhstan.

By comparing the findings from the South African case study and Kazakhstan, we identified four dimensions that can be compared (Table 3).

Carbon Pricing: Carbon pricing in South Africa (SA-1) is much higher than in Kazakhstan (KZ-4). Also, 8 out of 10 respondents agreed that the price should be increased (F-7). However, both are much lower than those suggested by the High-Level Commission on Carbon Prices (SA-1, KZ-4).

Just Transition: In both countries, there is dependence on coal (SA-4, KZ-1). Additionally, all respondents agreed that a gradual transition is necessary, and 8 out of 10 agreed that this is due to structural dependence on electricity (IF-9). Therefore, our findings in both countries suggest a gradual and just transition (IF-9, SA-4).

Impact of external drivers: In both cases, external drivers stand out (SA-3). SA-3 and KZ-2 show that CBAM can lead to huge losses. Also, 7 out of 10 of our respondents declared that. In addition to this, we have two more findings (IF-2,3) related to the impact of external drivers for Kazakhstan, where all our respondents defined them as a key driver.

Key internal barriers: In South Africa, the primary barriers are implementation challenges, as outlined in SA-5 and SA-6. In Kazakhstan, barriers include financial constraints (IF-4, KZ-5), weak internal incentive mechanisms (IF-5, KZ-4), and limited public pressure (IF-6, KZ-7).

Table 3. Comparative table between South Africa and Kazakhstan.

Dimensions	South Africa	Kazakhstan
------------	--------------	------------

Carbon pricing	SA-1: Weak Carbon Pricing as a Limited Decarbonization Incentive	IF-7: Mechanism of ETS should be remade IF-8: A combination of carbon tax and green subsidies is an effective instrument
Just transition	SA-2: Structural Electricity Dependence and Eskom's Monopoly SA-4: Coal Employment and Just Transition Risks	F-9: Gradual transition is needed
Impact of external drivers	SA-3: Trade Exposure and the CBAM Constraint	IF-1: CBAM is an important driver of renewable energy technology integration IF-2: Trade exposure is one of the key drivers IF-3: External financing pushes to decarbonization
Key internal barriers	SA-5: Governance and Institutional Capacity Constraints SA-6: Technological and Regulatory Limitations	IF-4: Financial problems/ High Capex and slow ROI as an obstacle IF-5: Weak internal incentive mechanisms in Kazakhstan IF-6: Public pressure is limited in Kazakhstan

5.6 Lessons from South Africa

In this section, based on our findings on South Africa, we identified lessons that should be considered in policy design and implementation in Kazakhstan. However, as Coletti (2013) wrote, lessons don't mean emphasizing only successful moments. Here, we also learn from mistakes for future reference.

SA-1: Weak Carbon Pricing as a Limited Decarbonization Incentive. The lesson here is simple. Policy instruments alone will not achieve miracles, especially if enforcement is weak. It is necessary to implement stronger carbon pricing, even if, in the short term, industries may have little incentive to shift their production systems toward low-carbon technologies.

SA-2: Structural Electricity Dependence and Eskom's Monopoly. The lesson is that even if mining companies wish to decarbonize, their dependence on the national grid limits their ability to do so. In such cases, sectoral transition becomes inseparable from a single national electricity producer.

SA-3: Trade Exposure and the CBAM Constraint. The lesson is that international trade rules and carbon border measures can shape a nation's decarbonization pathways.

SA-4: Coal Employment and Just Transition Risks. This means that energy transition is not purely a domestic or international environmental issue. We also need labor and social policies to address JETP challenges. Without careful planning, rapid decarbonization could lead to unemployment and economic disruptions in the country concerned.

SA-5: Governance and Institutional Capacity Constraints. In South Africa, state capacity is weak in implementing reform. The lesson is that policy design alone does not guarantee outcomes unless implementation capacity is strong.

SA-6: Technological and Regulatory Limitations. The lesson is that technological advancement requires time and financial resources to develop new approaches to decarbonization. Additionally, strict and supportive regulation is necessary to integrate decarbonization frameworks in practice. Without these enabling conditions, the shift toward low-carbon mining practices is likely to be very slow.

CHAPTER 6. CONCLUSIONS

6.1 Research summary

In this paper, we examined how Kazakhstan's mining sector aligns with the carbon neutrality strategy. Specifically, we examined how and under what circumstances the sector can accelerate the integration of RES while maintaining international competitiveness, and which policies and mechanisms can mitigate key barriers to the transition. The paper's empirical basis is interviews conducted in Kazakhstan, which we sequentially coded, as well as comparisons with South Africa.

The main conclusion is that decarbonization of the mining sector in Kazakhstan is currently internally constrained. In terms of RQ1, the most consistent drivers of acceleration are external incentives, such as trade and market requirements, pressure from supply chains, and the roles of international financing and investor expectations. A second set of RQ1 addresses barriers to achieving carbon neutrality. In interviews, which were supported by our case study, these barriers are most often attributed to the high capital intensity of projects, long payback periods, and weak internal incentives through pricing mechanisms with low public pressure. For RQ2, the most viable architecture appears to be a policy mix in which the carbon price signal is amplified by increasing the ETS and carbon tax, accompanied by "green" subsidies, along with realistic step-by-step transition planning.

6.2 Limitations of the study

These findings are empirically grounded in content analysis and semi-structured interviews, meaning they reveal the mechanisms and logic of respondents but do not provide a statistically representative picture of the entire sector. Our comparison with South Africa may be based on content analysis rather than on interviews with South African stakeholders using the same methodology. Therefore, for us, South Africa is not primarily a fully symmetrical empirical comparison, but rather a context for identifying lessons. Third, qualitative coding, by its nature, can involve an element of researcher interpretation, although we sought to minimize this through the specific (step-by-step) coding and grouping. But subjectivity cannot be eliminated.

6.3 Policy recommendation

We used the 6W framework to formulate our recommendations based on our findings. However, we exclude the questions “When” and “How” because they relate to administrative matters, which are beyond the scope of our master’s thesis.

Recommendation 1: Reforming ETS. It is proposed to establish a minimum price in the ETS, with subsequent gradual increases to eliminate the weak signal and make emissions economically tangible, by the Ministry of Ecology and Natural Resources of the Republic of Kazakhstan, together with the Ministry of Finance of the Republic of Kazakhstan. This would establish a price floor of at least \$15 per tonne of CO_{2e} with a subsequent increase of \$5. A three-year price schedule would be published annually to ensure predictability of CAPEX budgeting. This measure applies to all companies covered by Kazakhstan's ETS, with a focus on the mining sector. The measure follows from our findings IF-5 and IF-7, since with a low internal signal, companies operate mainly under external drivers (IF-1, IF-2, IF-3), and lessons from South Africa show that low pricing provides a limited incentive to decarbonize (SA-1). This recommendation is politically feasible. Given that the mechanism already exists, it can be assumed that the political costs will be low. We propose avoiding potential resistance from the mining industry through a gradual and predictable increase in carbon pricing, as mentioned frequently by our respondents (IF-7).

Recommendation 2: Establishing a Carbon Fund. The Ministry of Finance of the Republic of Kazakhstan, together with the Ministry of Ecology and Natural Resources of the Republic of Kazakhstan, should implement a carbon tax or an equivalent carbon levy and simultaneously create a targeted Green Fund to allocate a predetermined share of revenues. This fund would finance grants and co-financing of CAPEX for RE and energy-efficient projects, as well as financing for risk mitigation with subsidies tied to measurable reductions in emissions and energy consumption. This measure applies to the mining sector. This recommendation is due to CAPEX and slow payback being persistent barriers (IF-4), while a combined carbon tax and green subsidies received support in our data (IF-8). It also recognizes that public pressure is weak (IF-6), meaning that the primary incentive mechanism should be economic and institutionally anchored, rather than reputational. According to our findings, this recommendation is also considered politically feasible (IF-8). Although introducing a carbon tax could theoretically provoke resentment among mining companies, green subsidies could mitigate this by reducing resistance.

Recommendation 3: Establishing JETP. The initiative could be coordinated by the Ministry of Energy of the Republic of Kazakhstan in cooperation with the Ministry of Ecology and Natural Resources. They should collaborate with the World Bank, the IBRD, and other climate finance institutions to attract international finance and facilitate the transition. Additionally, several practical actions can be undertaken through this partnership, ranging from supporting the development of RE projects to training and retraining the existing workers.

In South Africa, JETP attracted substantial financial support from international partners for the energy transition, a lesson to learn (SA-4). Chile also closed coal plants gradually while promoting the development of RE projects. These countries integrated solar and wind energy projects into mining activities to reduce emissions. Additionally, the partnership can be useful for mining companies to access international green finance and facilitate a gradual transition without adversely affecting the workers. This recommendation is based on the Kazakhstani economy's reliance on coal, which means the country cannot afford to rush the transition, given the potential impacts on the economy and employment (IF-9).

The political feasibility of this recommendation is moderate. On the one hand, there is a need for such a program, and international funding relieves the government of its burden and is generally an effective tool (IF-3). However, it would create demands for transparency and a commitment to decarbonization. Taken together, these recommendations create conditions under which external incentives and internal structures will support one another, and the integration of RE will become a systemic transformation rather than a set of ad hoc responses to external pressure.

REFERENCES

- Abbaspour, H., & Abbaspour, F. (2022). Renewable energy systems in the mining industry: a literature review and research agenda. *International Journal of Renewable Energy Research (IJRER)*, 12(1), 569-580.
- Adilet. (2023). *Об утверждении Стратегии достижения углеродной нейтральности Республики Казахстан до 2060 года*. <https://adilet.zan.kz/rus/docs/U2300000121>
- Aguilar, J. (2022). Decarbonization of Mining in Peru: A Background Note. <https://documents1.worldbank.org/curated/en/099220112062230081/pdf/P177137096c6550f70866108814dc2907b4.pdf>
- Agyei, K., Shah, K., & Prieto, A. P. (2025). Reframing risk as opportunity: Africa's Strategic Response to the EU Carbon Border Adjustment Mechanism. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.5549818>
- Akhmetkali, A. (2023, August 10). *Karagandy – Heartland of Kazakhstan's Coal Mining Industry*. The Astana Times. <https://astanatimes.com/2023/08/karagandy-heartland-of-kazakhstans-coal-mining-industry/>
- Akhmetov, D., & Howie, P. (2024). Coal-based generators' corporate response to an emissions trading scheme in Kazakhstan. *Utilities Policy*, 90, 101797. <https://doi.org/10.1016/j.jup.2024.101797>
- Asa'd, O., & Levesque, M. (2024). Digital technologies for energy efficiency and decarbonization in mining. *CIM Journal*, 15(1), 1-20.
- Astana International Financial Center. (2023, November). *Green finance market in Kazakhstan*. <https://aifc.kz/wp-content/uploads/2024/07/3.3-green-finance-market-of-kazakhstan.pdf>
- Astana International Financial Center. (2025, February). *Системы торговли выбросами и добровольный углеродный рынок: глобальный обзор и перспективы для Казахстана*. <https://aifc.kz/wp-content/uploads/2025/02/cistemy-torgovli-vybrosami-i-dobrovolnyj-uglerodnyj-rynok-globalnyj-obzor-i-perspektivy-dlya-kazahstana.pdf>
- Aubakirova, G. M., Isataeva, F. M., Mazhitova, S. K., & Togaibaeva, L. I. (2023). Decarbonization of the mining and metallurgical sector: the experience of Kazakhstan. *Bulletin of the University "Turan"*, (4), 54-69.

- Azapagic, A. (2004). Developing a framework for sustainable development indicators for the mining and minerals industry.**Journal of Cleaner Production*, 12*(6), 639–662. [https://doi.org/10.1016/S0959-6526\(03\)00075-1](https://doi.org/10.1016/S0959-6526(03)00075-1)
- Beisengazin, K. (2025). Coal Sector of Kazakhstan: Challenges and Opportunities for Decarbonizing the Economy. United Nations Conference on Trade and Development (UNCTAD). https://unctad.org/system/files/information-document/unda2030d26-kazakhstan-coal_en.pdf
- Bhorat, H., Kupeta, T., Martin, L., Steenkamp, F., & Development Policy Research Unit. (2024). Just transition and the labour market in South Africa: Measuring individual and household coal economy dependence. In *DPRU Working Paper* (Vol. 202402) [Report]. https://commerce.uct.ac.za/sites/default/files/media/documents/commerce_uct_ac_za/1093/dpru-wp202402.pdf
- Bour, A., Chaumontet, L., Clearkin, P., Kuipers, H., Möncks, T., Scholtz, D., & BOSTON CONSULTING GROUP. (2022). *HOW SOUTH AFRICAN MINING CAN ADDRESS CLIMATE CHANGE CHALLENGES*. <https://www.bcg.com/publications/2022/how-south-african-mining-can-address-climate-change-challenges>
- Braams, R. B., Wesseling, J. H., Meijer, A. J., & Hekkert, M. P. (2022). Understanding why civil servants are reluctant to carry out transition tasks. *Science and Public Policy*, 49(6), 905–914.
- Bureau of National Statistics of the Republic of Kazakhstan. (n.d.). Ecological indicators of environmental monitoring and assessment. *Greenhouse gas emissions*. https://stat.gov.kz/en/ecologic-indicators/28427/greenhouse_gas_emissions/
- Bureau of National Statistics of the Republic of Kazakhstan. (2025). *Statistical yearbook of Kazakhstan (2024)*. <https://stat.gov.kz/en/publication/collections/>
- Bureau of National Statistics of the Republic of Kazakhstan. (2026). *Number and wages of employees in the Republic of Kazakhstan (IV quarter of 2025)*. Page 9 <https://stat.gov.kz/en/industries/labor-and-income/stat-wags/spreadsheets/>
- Carbon Knowledge Hub | South Africa's carbon tax. (2025). <https://www.carbonknowledgehub.com/factsheets/south-africa-carbon-tax>
- Coletti, P. (2013). Evidence for public policy design: How to learn from best practice. Springer.

- Cole, M., Canpolat, E., & Sijapati, B. (2025). Profiling risk in South Africa's just transition: Who is left behind? *Energy Research & Social Science*, 11. <https://doi.org/10.1016/j.erss.2025.104351>
- Cormier, D., Magnan, M., & Van Velthoven, B. (2005). Environmental disclosure quality in large German companies: economic incentives, public pressures or institutional conditions?. *European accounting review*, 14(1), 3-39.
- Csanadi, A., & Helmeçi, D. (2025, October 20). *The Just Energy Transition Partnership Crossroads*. <https://carnegieendowment.org>. Retrieved November 28, 2025, from <https://carnegieendowment.org/research/2025/10/the-just-energy-transition-partnership-crossroads?lang=en>
- Dashwood, H. S. (2014). Sustainable development and industry self-regulation: Developments in the global mining sector. *Business & Society*, 53(4), 551–582. <https://doi.org/10.1177/000765031347599>
- Dechezleprêtre, A., Nachtigall, D., & Venmans, F. (2023). The joint impact of the European Union emissions trading system on carbon emissions and economic performance. *Journal of Environmental Economics and Management*, 118, 102758.
- Ericsson, M., & Löf, O. (2018). Mining's contribution to low- and middle-income economies. In Oxford University Press eBooks (pp. 51–70). <https://doi.org/10.1093/oso/9780198817369.003.0003>
- European Commission. (n.d.). *Kazakhstan - EU trade relations with Kazakhstan*. https://policy.trade.ec.europa.eu/eu-trade-relationships-country-and-region/countries-and-regions/kazakhstan_en
- Filonchyk, M., Peterson, M. P., Zhang, L., Hurynovich, V., & He, Y. (2024). Greenhouse gases emissions and global climate change: Examining the influence of CO₂, CH₄, and N₂O. *The Science of the Total Environment*, 935, 173359. <https://doi.org/10.1016/j.scitotenv.2024.17335>
- Frank, M., Deja, R., Peters, R., Blum, L., & Stolten, D. (2018). Bypassing renewable variability with a reversible solid oxide cell plant. *Applied energy*, 217, 101-112.
- Guliyev, F. (2023). Renewable Energy Targets and Policies in Traditional Oil-Producing Countries: A Comparison of Azerbaijan and Kazakhstan. *Journal of Eurasian Studies*, 15(1), 110–124. <https://doi.org/10.1177/18793665231177720>

- Hájek, M., Zimmermannová, J., Helman, K., & Rozenský, L. (2019). Analysis of carbon tax efficiency in energy industries of selected EU countries. *Energy Policy*, 134, 110955.
- High-Level Commission on Carbon Prices. (2017). *Report of the High-Level Commission on Carbon Prices*. https://www.uncclearn.org/wp-content/uploads/library/carbonpricing_fullreport.pdf
- Hodgkinson, J. H., & Smith, M. H. (2018). Climate change and sustainability as drivers for the next mining and metals boom: The need for climate-smart mining and recycling. *Resources Policy*, 74, 101205. <https://doi.org/10.1016/j.resourpol.2018.05.016>
- Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development. (2024). Decarbonization of the Mining Sector: Case studies on the role of mining in nationally determined contributions in Chile, Indonesia, and South Africa. <https://www.iisd.org/system/files/2024-10/igf-decarbonization-mining-sector-case-study.pdf>
- Igogo, T., Awuah-Offei, K., Newman, A., Lowder, T., & Engel-Cox, J. (2021). Integrating renewable energy into mining operations: Opportunities, challenges, and enabling approaches. *Applied Energy*, 300, 117375.
- International Energy Agency. (n.d). South Africa - Total CO2 emissions from energy. <https://www.iea.org/countries/south-africa/emissions>
- International Energy Agency. (n.d). Kazakhstan - Total CO2 emissions from energy. <https://www.iea.org/countries/Kazakhstan/emissions>
- Invest SA. (2026, March 20). *Mining & Mineral Processing - INVEStSA*. InvestSA. <https://www.investsa.gov.za/key-sectors/mining-mineral-processing/#:~:text=The%20mining%20sector%20contributed%20R356bn,the%20three%20largest%20mining%20exports>
- Issa, M., Ilinca, A., Rouse, D. R., Boulon, L., & Groleau, P. (2023). Renewable energy and decarbonization in the Canadian mining industry: Opportunities and challenges. *Energies*, 16(19), 6967.
- Jenkins, H., & Yakovleva, N. (2006). Corporate social responsibility in the mining industry: Exploring trends in social and environmental disclosure. *Journal of Cleaner Production*, 14(3–4), 271–284. <https://doi.org/10.1016/j.jclepro.2004.10.004>

- Jin, H. (2023). Analyzing factors and resource policymaking options for sustainable resource management and carbon neutrality in mining industry: Empirical study in China. *Resources Policy*, 86, 104185.
- Just Transition Framework*. (n.d.). climatecommission.org.za. Retrieved November 28, 2025, from <https://www.climatecommission.org.za/just-transition-framework>
- Just Transition and Climate Pathways Study for South Africa: Decarbonising The South African Mining Sector*. (2021). National Business Initiative, (pp. 22, 24 26, 28, 29, 30). <https://www.nbi.org.za/wp-content/uploads/2021/10/NBI-Chapter-4-Decarbonising-the-South-African-Mining-Sector.pdf>
- Karg, A., Gupta, J., Chen, Y., Amsterdam Institute for Social Science Research, & IHE-Delft Institute for Water Education. (2025). Just Energy Transition Partnerships: An inclusive climate finance approach? *Energy Research & Social Science*, 104103. <https://doi.org/10.1016/j.erss.2025.104103>
- Kassinis, G., & Vafeas, N. (2006). Stakeholder pressures and environmental performance. *Academy of management journal*, 49(1), 145-159.
- Kazakhstan Newline. (2025, September, 26). *Kazakhstan government abandons plan to introduce carbon tax*. <https://newline.kz/article/1214880/>
- Kovalenko, V., & Samambayeva, A. (2022, September 29). *On the way to decarbonization: the agenda of the mining and metallurgical industry of Kazakhstan*. Qazaq Green. <https://qazaqgreen.com/en/journal-qazaqgreen/analitics/597/>
- Lanshina, T., & Asikritov, V. (2025, February 2). *How to phase down coal in Kazakhstan in a just way?* Qazaq Green. <https://qazaqgreen.com/en/journal-qazaqgreen/industry-news/2476/>
- Lanshina, T., Ngo Thuy, N., Redl, C., Asikritov, N. (2024). *Enabling a just coal transition in Kazakhstan*. Agora Energiewende. https://www.agora-energiewende.org/fileadmin/Projects/2024/2024-13_INT_Central_Asia_and_Caucasus/2024-13_335_Enabling_coal_transition_Kazakhstan_WEB.pdf
- Li, H., & Peng, W. (2020). Carbon tax, subsidy, and emission reduction: Analysis based on DSGE model. *Complexity*, 2020(1), 6683482.

- Li, Z., Hou, Y., Cao, J., Ding, Y., & Yuan, X. (2022). What drives green development in China: public pressure or the willingness of local government?. *Environmental Science and Pollution Research*, 1-15.
- Liang, G., Liang, Y., Niu, D., & Shaheen, M. (2024). Balancing sustainability and innovation: The role of artificial intelligence in shaping mining practices for sustainable mining development. *Resources Policy*, 90, 104793. <https://doi.org/10.1016/j.resourpol.2024.104793>
- Mabalane, O. (2024). *Decarbonisation in the South African mining industry: A study on strategies, drivers and barriers for Climate Change mitigation*. (Master's thesis, University of Pretoria). <http://hdl.handle.net/2263/96136>
- Macaluso, N., Tuladhar, S., Woollacott, J., Mcfarland, J. R., Creason, J., & Cole, J. (2018). The impact of carbon taxation and revenue recycling on US industries. *Climate Change Economics*, 9(01), 1840005.
- Mahlangu, M. A. (2021). *The Mining Sector's Response to the National Climate Change Response Policy (NCCRP)(2011-2020)*. University of Johannesburg (South Africa).
- Mardones, C. (2023). Economic and environmental effects of financing subsidies for non-conventional renewable energies with a carbon tax—A comparison of intersectoral models. *Renewable Energy*, 217, 119205.
- Martus, E. (2019). Russian industry responses to climate change: the case of the metals and mining sector. *Climate Policy*, 19(1), 17–29.
- Menzies, C., Qader, A., & Bologa, A. (2024). *Decarbonization of the metallurgical sector of Kazakhstan*. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). <https://www.giz.de/en/downloads/giz2024-en-white-paper-on-decarbonization-of-the-metallurgical-sector-of-kazakhstan.pdf>
- Minister George announces proclamation and implementation of the Climate Change Act, 2024 (Act No. 22 of 2024). (2025, March 17). [Press release]. Retrieved February 11, 2026, from https://www.dffe.gov.za/mediarelease/george_climatechangeact
- Narassimhan, E., Gallagher, K. S., Koester, S., & Alejo, J. R. (2018). Carbon pricing in practice: A review of existing emissions trading systems. *Climate Policy*, 18(8), 967-991.

- Nkwor, N., Ezeoha, A., Uche, C., Akinyoade, A., & Ujunwa, A. (2025). Multinational companies and climate change and sustainable development debate: evidence from cement production in Nigeria. *Climate and Development*, 17(2), 173-189.
- Norton Rose Fulbright. (2017). *Renewable energy in Latin America: Chile*. <https://www.nortonrosefulbright.com/en-au/knowledge/publications/a130d46e/renewable-energy-in-latin-america-chile>
- Nurhayati, Y., Ifrani, Said, M. Y., & Yanova, M. H. (2024). Carbon pricing policy to support net zero emission: a comparative study of Indonesia, Finland and Sweden. *Environmental Policy and Law*, 54(1), 53-63.
- Oluokun, O. A., Akinsooto, O., Ogundipe, O. B., & Ikemba, S. (2024). Energy Efficiency in Mining Operations: Policy and Technological Innovations.
- Patel, M., Makgetla, N., Maseko, N. and Montmasson-Claire, G. 2020. Sector jobs resilience plan: Coal value chain. TIPS Report. TIPS: Pretoria (South Africa). https://www.tips.org.za/images/TIPS_for_DEFF-dtic_-_SJRP_for_the_coal_value_chain_final_May_2020.pdf
- Perzadayeva, S., & Yskakova, D. (2022, May 7). *Carbon credits are one of the tools to combat greenhouse gas emissions*. Qazaq Green. <https://qazaqgreen.com/en/journal-qazaqgreen/expert-opinion/183/>
- Qazaq Green. (2024, March 18). *What impact will the EU's CBAM have on industrial sector of Kazakhstan*. <https://qazaqgreen.com/en/news/kazakhstan/1846/>
- Ramsook, D. A., Boodlal, D., & Maharaj, R. (2025). Navigating Carbon Border Adjustments: A Case Study Analyzing the Impacts and Strategies for Trinidad and Tobago's Ammonia Exports. *European Journal of Energy Research*, 5(6), 1-11.
- Rentier, G., Lelieveldt, H., & Kramer, G. J. (2019). Varieties of coal-fired power phase-out across Europe. *Energy Policy*, 132, 620-632.
- Savaresi, A. (2016). The Paris Agreement: a new beginning?. *Journal of Energy & Natural Resources Law*, 34(1), 16-26.
- Shen, J., Tang, P., Zeng, H., Cheng, J., & Liu, X. (2023). Does emission trading system reduce mining cities' pollution emissions? A quasi-natural experiment based on Chinese prefecture-level cities. *Resources Policy*, 81, 103293.

- Shen, L., Zhang, W., & Ma, D. (2025). ESG practices and financing constraints of Chinese high-carbon enterprises under carbon reduction pressure: The role of credit financing and corporate reputation. *Economic Modelling*, 107252.
- Sharma, S., Singh, R. K., Mishra, R., & Subramanian, N. (2024). Developing climate neutrality among supply chain members in metal and mining industry: natural resource-based view perspective. *The International Journal of Logistics Management*, 35(3), 804-832.
- Strambo, C., Patel, M., & Maimele, S. (2024). *Taking stock of the just transition from coal in South Africa*. Stockholm Environment Institute. <https://www.sei.org/wp-content/uploads/2024/09/just-transition-coal-south-africa.pdf>
- Strazzabosco, A., Gruenhagen, J. H., & Cox, S. (2022). A review of renewable energy practices in the Australian mining industry. *Renewable Energy*, 187, 135-143.
- The Agency of the Republic of Kazakhstan for Regulation and Development of Financial Market. (2025). Climate Stress-Testing of Kazakhstan's Banking Sector. <https://www.gov.kz/memleket/entities/ardfm/documents/details/900913?lang=en>
- The World Bank. (2023). South Africa Sustainable and Low-Carbon Energy Transition Development Policy Loan (P179077). In K. Carey, J. Pryor, & A. Balabanyan (Eds.), *The World Bank*.
- The World Bank. (2017). The Growing Role of Minerals and Metals for a Low Carbon Future. World Bank Report. <https://documents1.worldbank.org/curated/en/207371500386458722/pdf/117581-WP-P159838-PUBLIC-ClimateSmartMiningJuly.pdf>
- Vassilyev, S. (2024, May 28). *Overcoming obstacles: why are the leaders of the mining industry in no hurry to switch to renewable energy?* Qazaq Green. <https://qazaqgreen.com/en/journal-qazaqgreen/industry-news/2036/>
- Ukoba, K., Jen, T., & Yusuf, A. A. (2025). Transformation of South Africa's energy landscape: Policy implications, opportunities, and technological innovations in the Fourth Industrial Revolution. *Energy Strategy Reviews*, 59, 101752. <https://doi.org/10.1016/j.esr.2025.101752>
- United Nations Climate Change. (2017, May 19). *A Strong Carbon Price Needed to Drive Large-Scale Climate Action* [Press release]. Retrieved February 12, 2026, from <https://unfccc.int/news/a-strong-carbon-price-needed-to-drive-large-scale-climate-action>

- United Nations Development Programme. (2024, May 14). *On the road to carbon neutrality*.
<https://www.undp.org/kazakhstan/stories/road-carbon-neutrality>
- United Nations Development Programme. (2025, October 17). *Ecology in the minds of people in Kazakhstan: navigating concern, awareness, and action*.
<https://www.undp.org/kazakhstan/news/ecology-minds-people-kazakhstan-navigating-concern-awareness-and-action>
- United Nations Environment Programme. (2024). UNEP and IGF strengthen collaboration on environmental sustainability of minerals and metals. UNEP - UN Environment Programme. <https://www.unep.org/technical-highlight/unep-and-igf-strengthen-collaboration-environmental-sustainability-minerals-and>
- United Nations. (2015). Paris Agreement. https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf
- Van Doesburgh, N., & Winkler, H. (2025). Challenges and pathways to inclusive low-carbon development in South Africa: a political settlements analysis. *New Political Economy*, 30(4), 590–606. <https://doi.org/10.1080/13563467.2025.2473079>
- Wang, X., & Lo, K. (2022). Political economy of just transition: Disparate impact of coal mine closure on state-owned and private coal workers in Inner Mongolia, China. *Energy Research & Social Science*, 90, 102585.
- Wang, Y., Zhou, K., Wang, X., Yang, T., & Chen, H. (2024). Can carbon tax revenue recycling coordinate climate mitigation and energy poverty alleviation?. *Energy*, 308, 132363.
- World Bank Group. (2022). *EU CBAM: Modelling the Impacts on Kazakhstan's Economy*. World Bank.
<https://documents1.worldbank.org/curated/en/099420011012227804/pdf/P17736909f4ba20b20a09900704fa0830cb.pdf>
- World Bank Group. (2023). *Mining Sector Diagnostic Report - Kazakhstan*. World Bank.
<https://documents.worldbank.org/en/publication/documents-reports/documentdetail/099081823001539573/p17674501063760b08b290a4ae6547845d>
- World Bank Group. (2023, June 5). World Bank Approves \$497 Million in Financing to Lower South Africa's Greenhouse Gas Emissions and Support a Just Transition. *World Bank*.
<https://www.worldbank.org/en/news/press-release/2022/11/04/world-bank-approves-497->

[million-in-financing-to-lower-south-africa-s-greenhouse-gas-emissions-and-support-a-just-transit](#)

World Bank Group. (2023, October 23). Climate action can help Kazakhstan diversify its economy away from oil and create new drivers of Growth. World Bank. <https://www.worldbank.org/en/news/press-release/2022/11/03/climate-action-can-help-kazakhstan-diversify-its-economy-away-from-oil-and-create-new-drivers-of-growth-world-bank>

World Bank Group. (2025). Options for carbon pricing in Kazakhstan. World Bank. <https://documents.worldbank.org/en/publication/documents-reports>

World Wide Fund for Nature (2018). *First African company announces ambitious science-based target*. <https://www.wwf.mg/?331316/wwf-science-based-target-Africa>

Zhakiyev, N., Burkhanova, D., Nurkanat, A., Zhussipkaliyeva, S., Sospanova, A., & Khamzina, A. (2025). Green energy in grey areas: The financial and policy challenges of Kazakhstan's energy transition. *Energy Research & Social Science*, 124, 104046.

Zhang, G., & Zhang, B. (2024). Hidden dimensions of injustice in the green transition of China's coal mining industry. *Social Inclusion*, 12.

Zhang, W., & Sovacool, B. K. (2024). The Geopolitics of Net-Zero Transitions: Exploring the Political Economy of Carbon Border Adjustment Mechanism Implementation in the Global South. *Available at SSRN* 4853573.

Zaporozhets, A., Khaustova, V., Kyzym, M., & Trushkina, N. (2026). Sustainable Financing Mechanism for Energy System Development Toward a Decarbonized Economy: Conceptual Model and Management Framework. *Energies*, 19(2), 422.

Zhong, J., & Pei, J. (2022). Beggar thy neighbor? On the competitiveness and welfare impacts of the EU's proposed carbon border adjustment mechanism. *Energy Policy*, 162, 112802.

APPENDICES

Appendix A. Semi-structured interview questions

Block 1. Implementation of new technologies and energy efficiency

1. What do you think about the impact of the implementation of energy efficiency practices? (WH2 and WH2a)
2. How do you evaluate the level of readiness in Kazakhstan's mining sector to implement energy-efficient technologies? (WH3a)
3. What financial barriers may Kazakhstan face in implementing energy-efficient practices? (WH3)
4. Are there any other issues that you consider significant? (WH3)

Block 2. Government policies and initiatives in achieving carbon neutrality

2.1 Economic dependence

5. To what extent do you think economic dependence on the mining sector is an obstacle to achieving carbon neutrality? (WH4)
6. Could mining companies face financial difficulties if they move from traditional technologies to clean ones? If yes, then what kind? (WH4a)
7. Could the transition to green technologies lead to job losses? Why? (WH4b)

2.2 Public pressure and social responsibility

8. What do you think about the impact of public pressure, such as public criticism or public participation in environmental organizations, on the environmental policies of mining companies in terms of carbon neutrality? (WH5)
9. To what extent does public opinion influence the decisions of mining companies related to environmental policy in the context of Kazakhstan? (WH5)
10. How does public opinion influence mining companies' reporting on emissions and sustainability? (WH5a)
11. Can active environmental activities encourage companies to achieve carbon neutrality goals faster? (WH5b)

2.3 External pressure

12. What do you think about the importance of international investors, such as the World Bank or other non- Kazakhstani banks' requirements in affecting the adoption of cleaner technologies? (WH6)

13. What do you think about the impact of regulations such as CBAM (Carbon Border Adjustment Mechanism) on the adoption of cleaner technologies? (WH6)

14. Can you consider these factors, such as international investors' requirements or tariffs like CBAM, as a key driver in the implementation of clean technologies for mining companies (WH6a and WH6b)

2.4 Financial and administrative instruments

15. What do you think about the current financial measures in Kazakhstan? How does it affect the activities of mining companies? (WH7)

16. What do you think about the current administrative measures in Kazakhstan? How does it affect the activities of mining companies? (WH7)

17. Which measures do you think are more effective in stimulating emissions reduction: carbon taxes or subsidies for green technologies? Why? (WH7a)

Block 3. Barriers and obstacles to achieving carbon neutrality

3.1 Consequences of postponing carbon neutrality

18. What do you think about the impact of postponing carbon neutrality implementation stages on achieving this goal? Can you give examples or describe possible consequences? (WH8)

19. How do you assess the costs for mining companies in early adoption of green technologies? Are there risks that costs will be higher? (WH8a)

3.2 International climate treaties

20. In your opinion, to what extent can international climate agreements stimulate Kazakhstan's mining sector to achieve carbon neutrality? Do you think these mechanisms are sufficient, or are additional measures required? (WH9)

21. What do you think about the idea of stronger sanctions for countries that fail to implement climate commitments? (WH9a)