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Integrated Policy Strategies and Regional Policy Coordination for Resilient, Green and Transformative Development: Supporting Selected Asian BRI Partner Countries to Achieve 2030 Sustainable Development Agenda

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Coal Sector of Kazakhstan: Challenges and Opportunities for Decarbonizing the Economy

Abstract

Kazakhstan's coal sector remains a critical component of the country's economy, providing 66.7% of electricity generation and 80% of thermal energy production. However, coal combustion is also the primary source of greenhouse gas emissions, accounting for 70% of the nation's total emissions. The transition from coal to cleaner energy sources is an urgent yet complex challenge, requiring a balance between economic stability and environmental sustainability.

To achieve a sustainable energy transition, the paper outlines key policy recommendations, including the gradual reduction of coal reliance through increased renewable energy integration, expansion of the natural gas sector as an interim solution, and the development of coal chemistry industries to diversify economic activities. The study also emphasizes the importance of just transition policies, including financial mechanisms for displaced workers and targeted investments in low-carbon technologies.

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KEYWORDS: Energy Transition, Stranded Assets, Just Transition, Renewable Energy, Coal Chemistry, Economic Diversification, Energy Security, Sustainability

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Introduction

Kazakhstan's coal sector plays a pivotal role in the country's energy and economic landscape. As one of the top 10 countries in terms of proven coal reserves, with 2.4% of global reserves, coal has long been a fundamental driver of energy production, industrial processes, and regional economic stability. Currently, coal accounts for 66.7% of electricity generation and 80% of thermal energy production, making it the dominant energy source in the country. Additionally, major industrial sectors, including metallurgy and manufacturing, rely heavily on coal, reinforcing its strategic importance.

Coal is of significant importance to industry. In particular, the industrial sector accounts for 48.9% of the final consumption of coal and its products. The main consumers are non-ferrous metallurgy (40.2%), ferrous metallurgy (26.9%), production of non-metallic products (14.9%), mining industry (10.6%), chemical industry (4.6%).

However, Kazakhstan's commitment to achieving carbon neutrality by 2060 presents a major challenge for the coal sector. Coal combustion is the primary contributor to the country's greenhouse gas (GHG) emissions, responsible for 70% of total emissions. This underscores the need for a structured transition towards a low-carbon economy while mitigating potential socio-economic disruptions. The phase-out of coal, if not managed properly, could lead to stranded assets, loss of employment, and economic downturns in coal-dependent regions such as Karaganda and Ekibastuz.

This policy paper examines the coal sector's current status, its economic and social implications, and the key challenges associated with decarbonization. It explores international best practices for managing coal dependency, including strategies implemented in Germany, the UK, and Poland, and evaluates their applicability to Kazakhstan. The paper also outlines alternative pathways for a just energy transition, emphasizing the need for policy interventions that balance energy security, economic sustainability, and environmental commitments.

The goal of this study is to provide actionable policy recommendations to facilitate Kazakhstan’s transition from coal dependency while ensuring economic resilience and social stability. Key focus areas include the gradual phase-out of coal, the expansion of renewable energy and natural gas as transitional solutions, the development of coal chemistry as an alternative industrial use, and the introduction of financial mechanisms to support affected communities and workers. By adopting a strategic and inclusive approach, Kazakhstan can navigate the complexities of energy transition while positioning itself as a leader in low-carbon economic transformation.

1. Analysis of the Coal Sector of Kazakhstan

1.1 Overview of the coal sector: economic contributions

The coal sector is the most important sector of the economy, as it provides the necessary energy and heat supplies. Coal is used to produce electrical and thermal energy, which is the basis for the functioning of various industries and economies. Without stable energy and heat supply, it is impossible to ensure the normal operation of enterprises, transport infrastructure, as well as utilities and social services. Thus, the coal industry plays a key role in maintaining the economic stability and development of the country.

Today, Kazakhstan is one of the top 10 countries in terms of proven coal reserves in the amount of 29.4 billion tons (or 2.4% of world reserves), where 2/3 is brown coal, 1/3 is hard coal.

The largest coal basins are located in the central and northern parts of the country: Ekibastuz (10 billion tons), Karaganda (6.9 billion tons) and Turgai (5.9 billion tons) or a total of 77.5% of proven coal reserves (Figure 1). Accordingly, the main regions of coal production are Pavlodar and Karaganda regions - 91.5%.

95.0% of production comes from hard coal, 5.0% from lignite. Hard coal has a high carbon content (about 70-90%), which provides a high calorific value (6000 to 8000 kcal/kg). It is characterized by a low content of moisture and volatile substances. In Kazakhstan it is used mainly in the metallurgical industry (coking), in the production of electricity and heat. It is also an export product. In turn, brown coal contains less carbon (45 to 65%) and more moisture (up to 50%), which reduces its calorific value (3000 to 5000 kcal/kg). It also has a high content of volatile substances. It is used mainly for generating electricity and heat due to the lower cost of production, but has a lower calorific value.

On average, 72.1% is consumed in the domestic market, 27.9% is exported, where the main part (about 75%) is sent to Russia, the rest to Europe and China. At the same time, over the past 3 years (2021-2023), the largest export volumes have been observed over the past 10 years (more than 32 million tons annually).

In the coal industry, unlike the oil and gas industry, there is no "state company" or "national operator", however, about 40% of production comes from the largest coal producer - Bogatyr Komir LLP, owned by the quasi-state Samruk-Energo JSC and the Russian company "RUSAL".

According to the Ministry of Industry and Construction, there are 30 coal mining enterprises in the country, with three quarters of the national production concentrated in four enterprises: Bogatyr Komir LLP, Eurasian Energy Corporation JSC, Shubarkol Komir JSC and ArcelorMittal Temirtau JSC.

Over the past 5 years (2019-2023), coal production according to enterprise data and fuel and energy data averaged 110-113 million tons (Table 1). At the same time, the enterprises have actually reached their designed capacity and further increase in production volumes will be associated with significant investments.

Table 1. Dynamics of coal production for 2019-2023, thousand tons

Company	2019	2020	2021	2022	2023	Plan for 2024	Dynamics 2023/2021
"Bogatyr Komir" LLP	44,848	43 338	44 632	42 473	42,927	46 700	-3.8%
EEC open-pit "Vostochny"	16 172	17 407	17 128	17,422	18,581	19 300	8.5%
JSC "Shubarkol Komir"	11 331	11,464	12,762	12,545	13,813	16 100	8.2%
"Kazakhmys" LLP Coal (youth section)	7 641	7,741	9 211	8 156	9,090	9 600	-1.3%
JSC "Karazhyra"	7,985	7,832	8 428	8,713	7,888	9,000	-6.4%
DM JSC "QARMET"	9,639	9 511	8 309	7,426	6 148	6,006	-26.0%
JSC "Maikuben -West"	4 255	4 148	3,726	4 165	3,867	4 445	3.8%
Angrensor LLP Energy	1,839	1,739	1,006	3 651	3,478	4 400	245.7%
JSC "Shubarkol Premium"	1 230	1 291	1,656	3,002	1,593	4,000	-3.8%
Total	104 940	104 470	106 859	107 552	107 385	119 551	0.5%
Fuel energy balance data (production and extraction of primary energy)	115,000	113 400	107,500	110 165	-	-	-
Office of National Statistics data (+open data)	116 161	113 174	115 693	113 931	112 700	-	-2.6%

Source: Bureau of National Statistics Agency for Strategic Planning and Development data, enterprise data.

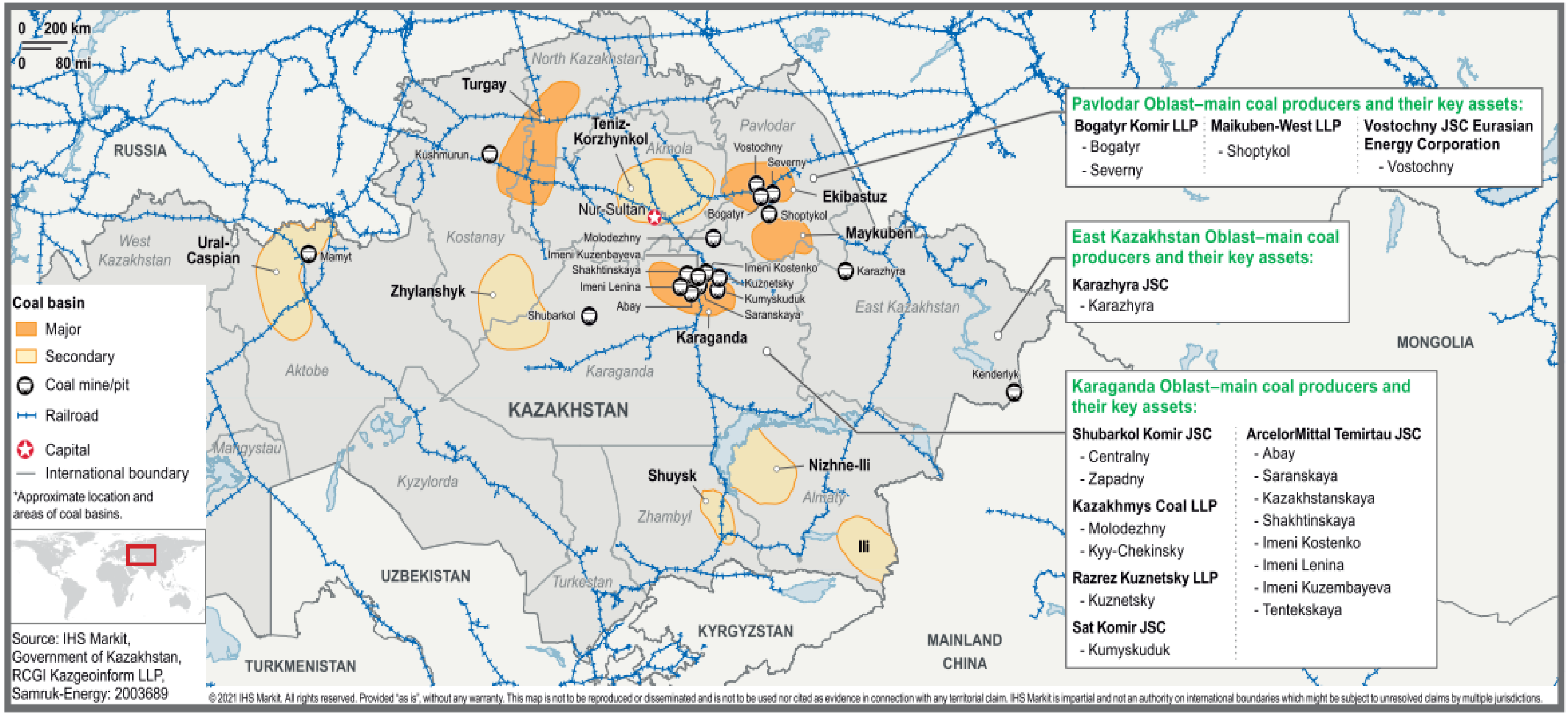
In general, the contribution of the coal industry of Kazakhstan to the republic's GDP varies on average between 0.7 - 1.1% (in 2019 - 1.1%, 2020 - 0.7%, 2021 - 0.7%, 2022 year - 0.8%, 2023 - 0.7%), while the direct share of the coal sector in employment in the country is quite small - 0.7% (about 40 000 people).

Over the past 3 years, investment in fixed assets in the coal mining sector has increased from 86 billion tenge in 2021 to 136.3 billion tenge in 2022 and 156.8 billion tenge in 2023, or by 58.4% and 82.3%, respectively. Investments were 100% provided from the enterprises' own funds.

As of end of 2022, the share of electricity generated by generating sources by fuel type is distributed as follows: coal - 66.7%, gas - 21.5%, hydroelectric power plants (excluding small hydroelectric power plants) - 7.3%, renewable energy sources (solar power plants, wind power plants, small hydroelectric power stations, bioelectric power stations - 4.5%.

In the thermal energy production sector, thermal sources using coal as fuel make up the main share - 80% (natural gas - 15%, fuel oil - 5%).

Figure 1. *Change in trade of goods*



Source: 2021 IHS Markit.

According to the Action Plan for the development of the electric power industry until 2035, which was developed by the Ministry of Energy of the Republic of Kazakhstan, it is planned to introduce 4-5 GW of coal-fired capacity, which will be achieved through the launch of block No. 1 of the Ekibastuz State District Power Plant-1, which will require 2-3 million tons of Ekibastuz coal LLP "Bogatyr Coal", blocks No. 3 and No. 4 of Ekibastuz State District Power Plant-2, construction of thermal power plants in Kokshetau, Semey and Ust-Kamenogorsk, as well as expansion of existing stations in Karaganda, Ust-Kamenogorsk, Stepnogorsk in a small volume.

At the same time, according to this plan, 12 GW of renewable energy will be introduced by 2035.

With the successful implementation of the action plan for the development of the electric power industry, the structure of installed capacity by fuel type by 2035 will look as follows: RES – 24.4%; hydroelectric power station – 10.8%; gas – 25.8%; coal – 34.3%.

Also, the main type of fuel for energy producing organizations is coal and processed products – 66.0% (thermal coal – 65.8%, lignite – 0.2%) (Table 2).

Table 2. Fuel use by energy producing organizations, thousand tons of oil equivalent (fuel and energy balance, transformation sector – input)

Name		Power stations (main activity)	Power stations (secondary activity)	Combined heat and power plants (main activity)	Combined heat and power plants (secondary activity)	Heating boiler houses (main activity)	Heating boiler rooms (secondary activity)	Total	Share
Coal and products of its processing	Energy coal	-	-	18 319.8	2 553.4	1 404.2	-	22 277.4	65.8%
	Lignite (brown coal)	-	-	-	-	61.2	-	61.2	0.2%
	Coke and semi-coke from coal	-	-	-	-	-	-	0.0	0.0%
Gas		1 068.1	1 571.9	4 127.0	186.4	2 305.4	-	9 258.8	27.3%
Oil and petroleum products	Crude oil	-	-	-	-	-	12.6	12.6	0.0%
	Heating and other gas oils	-	49.3	206.7	-	467.5	-	723.6	2.1%
	Petroleum fuel (mazut), with a sulfur content of more than 1%	-	0.0	121.3	115.9	138.4	-	375.7	1.1%
Renewable Energy Sources	Electricity produced by hydroelectric power plants	556.5	234.7	-	-	-	-	791.2	2.3%
	Electricity produced by solar power plants	163.1	0.3	-	-	-	-	163.3	0.5%

	Electricity produced by wind farms	198.5	0.9	-	-	-	-	199.4	0.6%
	Electricity from biogas produced by biogas plants	-	0.1	-	-	-	-	0.1	0.0%
	Waste from the processing of substances containing animal and vegetable fat or wax	-	-	-	-	2.2	-	2.2	0.0%
Total		**1 986.2**	**1 857.1**	**22 774.8**	**2 855.8**	**4 378.9**	**12.6**	**33 865.4**	**-**

Source: Fuel and Energy Balance of the Republic of Kazakhstan (2023)

The next most important fuel for energy producing organizations is gas – 27.3%. Kazakhstan is among the top 20 countries in terms of explored and proven natural gas reserves (0.89%).

More than 75% of gas production in Kazakhstan is provided by the Karachaganak, Kashagan and Tengiz projects (gross production at Karachaganak remained virtually unchanged for four years, and at Tengiz and Kashagan gradually increased over three years)

Kazakhstan's gas import/export infrastructure is supported by 6 different pipelines. The China-Central Asia gas pipeline, with a capacity of 60 billion m3/year, is the largest network transporting gas from Turkmenistan, western Kazakhstan to the Xinjiang region in China.

By its structure, the gas produced in Kazakhstan is mainly associated with petroleum gas. On average, only 48% of gas is processed into commercial gas, 32% is injected back into the reservoir to maintain reservoir pressure, 20% is used for the own needs of subsoil users, electricity generation and disposal.

Of the total volume of processed gas sales, 72% is used for the needs of the domestic market, and 28% for export (China, Switzerland, Ukraine and other countries).

In addition to the population (consumption share 27%), gas is used by industrial enterprises and budgetary organizations (27%), heat and power companies and public utilities (46%).

According to official data, the average annual increase in gas resources over the over the period 2018-2023 is 3.2%, where production is growing only by an average of 2.2%, and imports are already growing by 8.0% annually. Thus, gas resources increase to a greater extent due to its import rather than production.

On the other hand, the use of gas (an increase of 3.2%) is largely due to an increase in its sales on the domestic market by 20.4% annually, while gas supplies for export decrease by an average of 9.7% annually.

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In turn, renewable energy sources, including hydroelectric power plants, solar power plants, wind power plants, and biogas plants, account for about 3.4% of fuel resource use.

The renewable energy sector currently receives significant government support:

– guaranteed access to connection points to electrical and heating networks;
– guaranteed purchase of electricity;
– preferences for facilities producing thermal energy using renewable sources;
– indexation of fixed tariffs and auction prices for renewable energy facilities;
– reserved land plots and connection points for projects participating in auctions;
– priority dispatch of electricity;
– investment preferences within the framework of the Entrepreneurial Code;
– financial support for insolvency risks;
– investment subsidies (reimbursement of up to 30% of the actual costs of construction and installation work and the purchase of equipment excluding VAT and excise taxes), as well as reimbursement of up to 50% of investments for the installation of small-scale renewable energy projects for households and enterprises without access to centralized electricity networks.

As a result, the share of electricity produced by renewable energy facilities excluding large hydroelectric power plants reached 5.9% in 2023 compared to 0.7% in 2015.

As of January 2024, the installed capacity of renewable energy facilities is 2,883.9 MW (46 wind power plants - 1,411.3 MW; 44 solar power plants - 1,196.2 MW; 37 hydroelectric power plants - 275.3 MW; 3 biogas plants – 1.1 MW). On average, 52.7% of renewable electricity is generated by wind, 31.3% by solar, 16.0% by small hydropower plants and 0.01% by biogas plants.

The last place in fuel use is oil and petroleum products – 3.2%.

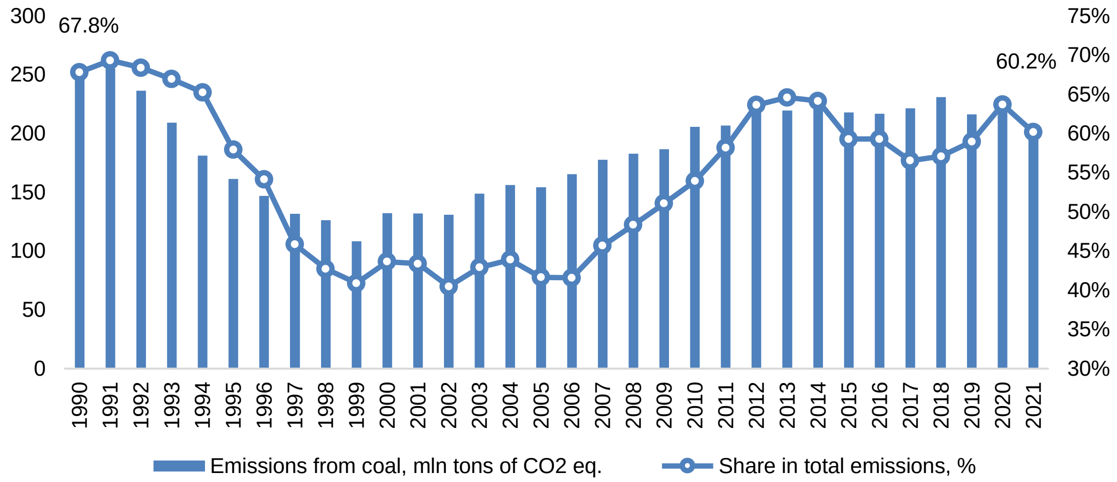
Overall, at current production levels, current reserves could support coal production for up to 300 years.

1.2 Overview of the coal sector: GHG emissions

Over the period 1990-2021, greenhouse gas emissions resulting from coal mining and combustion decreased by 20.5% from 257.9 million tons of CO 2 to 205.1 million tons of

CO_2, with a corresponding decrease in the share of total emissions greenhouse gases from 67.8% to 60.2% (Figure 2).

Figure 2. Dynamics of greenhouse gas emissions arising from the process of coal mining and combustion for 1990-2021



Source: National Inventory Submissions data, 2023, https://unfccc.int/documents/627843

The observed dynamics are explained by changes in solid fuel consumption and coal production from 1990 to 2021.

In turn, on average, more than 63% of greenhouse gas emissions came from coal combustion, the remaining part of emissions, namely 37%, is associated with its production (Table 3).

Table 3. Distribution of emissions from coal mining and combustion for the period 1990-2021

Name	**1990**	**2000**	**2010**	**2015**	**2021**	**Dynamics 2021/1990**
Fuel combustion (solid fuels), mln tons CO_2 eq.	158.3	81.2	132.3	150.1	134.9	-14.8%
solid fuel consumption, petajoule	1847.9	1003, 1	1455.7	1479.4	1501.2	-18.8%
%	*61.4%*	*61.4%*	*64.3%*	*68.8%*	*65.8%*	-
coal mining and handling, mln tons CO_2 eq.	99.7	51.1	73.5	67.9	70.2	-29.6%
coal mining, mln tons	141	75	110	104	108	-23.4 %
%	*38.6%*	*38.6%*	*35.7%*	*31.2%*	*34.2%*	-
Total	**257.9**	**132.3**	**205.8**	**218.1**	**205.1**	**-20.5%**

Source: National Inventory Submissions data, 2023, https://unfccc.int/documents/627843

In the direction of solid fuel combustion, coal is used to a greater extent in "Public electricity and heat production" - 73.4%, followed by the direction "Other sectors" –

14.5% (for commercial and household purposes), "Manufacturing" industries and construction" - 11.7% (to a greater extent in the production of non-ferrous metals, iron and steel).

In terms of coal mining, 52.8% is released in the process of closed mining and 47.2% in the process of open coal mining.

The main type of greenhouse gas released when dealing with coal is carbon dioxide (95.8%). Next comes methane and nitrogen oxide (Table 4).

Table 4. Distribution of greenhouse gas emissions from coal mining and combustion for the period 1990-2021

Name	**1990**	**2000**	**2010**	**2015**	**2021**	**Dynamics 2021/1990**
CO_2	224.6	120.7	195.1	207.6	196.4	-12.6%
%	*87.1%*	*91.2%*	*94.8%*	*95.2%*	*95.8%*	-
CH_4	32.6	11.2	10.0	9.8	8.1	-75.0%
%	*12.6%*	*8.5%*	*4.9%*	*4.5%*	*3.9%*	-
N_2O	0.7	0.4	0.6	0.7	0.6	-14.3%
%	*0.3%*	*0.3%*	*0.3%*	*0.3%*	*0.3%*	-
Total	**257.9**	**132.3**	**205.8**	**218.1**	**205.1**	**-20.5%**

Source: National Inventory Submissions data, 2023, https://unfccc.int/documents/627843

In general, in terms of coal areas and types of greenhouse gases, the following situation has developed (Table 5).

Table 5. Distribution of greenhouse gas emissions from coal mining and combustion for the period 1990-2021

Direction	**PG**	**1990**	**2000**	**2010**	**2015**	**2021**
Fuel combustion (solid fuels)	CO_2	156.3	80.5	131.1	148.4	133.9
%		98.8%	99.2%	99.1%	98.8%	99.3%
	CH_4	1.2	0.3	0.6	1.1	0.4
%		0.8%	0.4%	0.4%	0.7%	0.3%
	N_2O	0.7	0.4	0.6	0.7	0.6
%		0.5%	0.5%	0.5%	0.5%	0.5%
Total		158.3	81.2	132.3	150.1	134.9
Coal mining and handing	CH_4	31.4	10.9	9.5	8.7	7.7
%		31.5%	21.4%	12.9%	12.9%	11.0%
	CO_2	68.3	40.2	64.0	59.2	62.5
%		68.5%	78.6%	87.1%	87.1%	89.0%
Total		**99.7**	**51.1**	**73.5**	**67.9**	**70.2**

Source: National Inventory Submissions data, 2023, https://unfccc.int/documents/627843

Methane emissions from solid fuels in total decreased by 75.4% from 1255.9 kt in 1990 to 308.1 kt at the end of 2021, where 47.1% comes from methane emissions from closed mining (or 6.1% of total methane emissions) and 44.5% for methane emissions from open-pit mining (or 5.7% of total methane emissions), 7.1% for post-mining activities (or 0.9% of total emissions methane), 1.2% - for abandoned underground mines (or 0.2% of total methane emissions).

An interesting situation has developed in the sector of methane emissions from solid fuels. Thus, despite the increase in coal production (since 1999, with some decrease after 2013), there has been a decrease in methane emissions. One of the main reasons for this decrease is the partial abandonment of closed coal mining, as well as the gradual increase in open coal mining, in which significantly less methane emissions occur. In particular, in 1990, almost 50% of all coal mined came from underground mining, as of 2021 - about 8.3%.

At the same time, the preservation of a high share of methane from closed mining is explained by the fact that Kazakhstan’s mines are deep (mining is carried out from 400 meters and deeper), where the most methane-bearing coal is located with a methane content of 25 m3 per ton (in open mining - about 2 m3).

Overall, among fossil energy sources, coal remains by far the most GHG-intensive and currently dominates the Kazakh energy sector, particularly in power and heat generation. Therefore, low-carbon development of Kazakhstan is impossible without a gradual abandonment of coal in the energy balance. Moreover, delaying or abandoning the coal phase-out will undermine overall investor confidence and interest in both the fossil fuel-dominated energy sector and, with untapped lucrative opportunities in that sector, less financially attractive decarbonization investments in other sectors.

2. The Role of Coal in the Manufacturing Sector and the Implications of Phasing Out Coal as an Energy Supply

Coal plays a significant role in Kazakhstan's manufacturing sector. It is used in a variety of processes, including the production of steel, cement and other industrially critical materials.

Moreover, coal provides a stable and relatively inexpensive energy supply, which contributes to the competitiveness of Kazakhstani producers in the global market.

Stopping the use of coal as an energy source have consequences. Thus, the transition to alternative energy sources, such as natural gas, renewables or nuclear energy, will require significant investments in upgrading existing infrastructure and developing new technologies. This may lead to a temporary increase in production costs and, consequently, to a decrease in the competitiveness of products in international markets.

Coal in Kazakhstan's industry is used in various processes, playing a key role in energy supply and production cycles.

First, coal is the main fuel for power plants, which generate more than 66.7% of electricity in Kazakhstan. Coal-fired power plants use coal to burn in boilers, which release heat and convert it into electrical energy. This ensures a stable energy supply for industrial and household consumers.

Secondly, coal is the main fuel for heating and steam supply. Coal is used in boiler houses to produce heat and steam, which are then distributed to heat industrial facilities, buildings and the residential sector. Steam is also used in technological processes in various industrial plants. In particular, in the thermal energy production sector, thermal sources using coal as fuel account for the main share - 80%.

Thirdly, coal is used in the metallurgical industry. In particular, in the production of steel and cast iron:

– coking: Coal, especially coking coal, is used to produce coke, which is needed for blast furnaces in the production of iron and steel. Coke serves as a fuel and a reducing agent for iron ore.

– blast furnaces: In blast furnaces, coke is used to smelt iron ore, where it plays a role in reducing the iron and creating the required temperatures for smelting.

Fourth, in the cement industry, coal is used as fuel for kilns in which raw materials (limestone and clay) are burned to produce clinker, the main component of cement. The high temperatures achieved when burning coal are necessary for chemical reactions to occur.

Fifthly, coal is used in the production of chemical products:

– syngas: Coal is converted into syngas (a mixture of hydrogen and carbon monoxide) through gasification processes. This synthesis gas is used to produce ammonia, methanol and other chemical products.

– fertilizer production: Ammonia produced from synthesis gas is the basis for the production of nitrogen fertilizers needed for agriculture.

In particular, the industrial sector accounts for 48.9% of the final consumption of coal and its products. The main consumers are non-ferrous metallurgy (40.2%), ferrous metallurgy (26.9%), production of non-metallic products (14.9%), mining industry (10.6%), chemical industry (4.6%) (Table 6).

Table 6. Final consumption of coal and its products by sector, thousand tons of oil equivalent, 1000 toe, 2022

	Coal and products of its processing					Share
	Energy coal	Lignite (brown coal)	Coke and semi-coke from coal	Resins obtained by distillation from coal	Blast furnace gas	
Final energy consumption	7 515.4	491.5	838.7	6.5	234.6	
Industry sector	3 326.8	35.0	838.7	6.5	234.6	48.9%
Ferrous metallurgy	566.3	-	395.2	-	234.6	26.9%
Chemical industry (including petrochemical)	12.3	-	191.2	-	-	4.6%
Non-ferrous metallurgy	1 547.9	5.8	226.9	6.5	-	40.2%
Production of non-metallic products	650.7	2.6	7.7	-	-	14.9%
Transport equipment	2.3	-	-	-	-	0.1%
Mechanical engineering	23.3	0.5	0.1	-	-	0.5%
Mining industry	448.6	5.6	17.4	-	-	10.6%
Production of food, beverages and tobacco products	37.1	7.0	-	-	-	1.0%
Pulp and paper production and printing	0.7	-	-	-	-	0.0%
Wood industry	0.7	-	-	-	-	0.0%
Construction	31.6	13.6	-	-	-	1.0%
Textile and leather industry	1.1	-	-	-	-	0.0%
Not elsewhere specified (industry)	4.3	-	-	-	-	0.1%
Transport sector (rail transport)	11.7	7.0	0.0	0.0	0.0	0.2%
Other sectors	4 176.8	449.5	0.0	0.0	0.0	50.9%
Commercial and utilities	674.4	72.3	-	-	-	16.1%
Housing sector (population)	3,402.6	371.0	-	-	-	81.6%
Agriculture/Forestry	97.9	6.2	-	-	-	2.3%
Fishing	2.0	-	-	-	-	0.0%
Statistical discrepancies	0.0	45.5	20.8	0.4	0.0	

Source: Fuel and Energy Balance of the Republic of Kazakhstan (2023)

Thus, coal is important for industrial production processes and providing constant energy to industry.

As previously noted, in the direction of combustion of solid fuels, coal is used to a great extent in "Public electricity and heat production" - 73.4%, followed by the direction "Other sectors" - 14.5% (for commercial and domestic purposes), "Manufacturing industries and construction" - 11.7%. Largely, greenhouse gas emissions come from processes involving non-ferrous metals (43.4%), non-metallic minerals (18.5%), iron and steel (15.8%) (Table 7).

Table 7. Emissions from solid fuel combustion in the direction of "Industrial processes and products", thousand tons CO_2 eq.

Name	1990	2000	2010	2015	2021	Dynamics 2023/2021
Total emissions from burning solid fuels (coal)	158264.0	81222.2	132277.5	150148.6	134933.2	-14.7%
Manufacturing industries and construction	*10660.3*	*15828.0*	*24007.8*	*30906.4*	*15721.2*	*47.5%*
%	*6.7%*	*19.5%*	*18.1%*	*20.6%*	*11.7%*	-
Iron and steel	5556.7	4721.5	7215.5	17681.6	2489.0	-55.2%
%	*52.1%*	*29.8%*	*30.1%*	*57.2%*	*15.8%*	-
Non-ferrous metals	1365.3	7013.0	10393.3	6589.4	6819.6	399.5%
%	*12.8%*	*44.3%*	*43.3%*	*21.3%*	*43.4%*	-
Chemicals	210.0	92.2	24.4	45.5	939.6	347.4%
%	*2.0%*	*0.6%*	*0.1%*	*0.1%*	*6.0%*	-
Pulp, paper and print	20.1	0.7	0.6	0.9	3.0	-85.0%
%	*0.2%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	-
Food processing, beverages and tobacco	219.1	380.6	539.1	196.3	183.9	-16.1%
%	*2.1%*	*2.4%*	*2.2%*	*0.6%*	*1.2%*	-
Non-metallic minerals	2696.6	661.2	2502.2	3335.3	2903.3	7.7%
%	*25.3%*	*4.2%*	*10.4%*	*10.8%*	*18.5%*	-
Other	592.4	2958.8	3332.7	3057.4	2382.9	302.2%
%	*5.6%*	*18.7%*	*13.9%*	*9.9%*	*15.2%*	-

Source: National Inventory Submissions data, 2023, https://unfccc.int/documents/627843

Kazakhstan's manufacturing sector is highly dependent on a stable energy supply to ensure the smooth operation of its processes. Industry uses energy-intensive technologies such as steel smelting, cement production and other materials processing that require a constant and reliable source of electricity.

A stable power supply is critical for several reasons:

– Many manufacturing processes require a continuous supply of energy to maintain the high temperatures, pressures and other conditions required to produce products. Any interruptions in the power supply can lead to production stoppages, damage to materials and significant losses.

– Stable and predictable energy supply allows you to plan production cycles, optimize the use of resources and minimize downtime. This increases the overall efficiency and competitiveness of manufacturing enterprises in both domestic and foreign markets.

– In the production of high-tech and precision products, a stable energy supply directly affects the quality of the product. Power outages can lead to defects, which in turn will reduce confidence in products and potentially damage manufacturers' reputations.

– Reliable energy supply is the basis for the introduction of new technologies and innovations in production. This allows businesses to invest in equipment modernization, automation and digitalization, which contributes to their sustainable development and increased productivity.

For Kazakhstan, where the coal industry plays a key role in energy supply, it is important to consider that the transition to alternative energy sources must be carefully planned and phased. This will avoid negative consequences for the manufacturing sector and ensure stable energy supplies at all stages of the transition period.

Thus, a stable energy supply is the basis for the successful functioning and development of the manufacturing sector in Kazakhstan. It allows us to ensure high quality products, economic efficiency and innovative development, which ultimately contributes to the sustainable economic growth of the country.

Coal remains an important resource for many industries in Kazakhstan, meeting the country's energy and production needs. However, given global trends towards decarbonization and reduction of greenhouse gas emissions, Kazakhstan will have to find a balance between the traditional use of coal and the transition to cleaner and more sustainable energy sources.

In conclusion, the role of coal in Kazakhstan's manufacturing sector is significant and ending its use will require a carefully considered approach. It is necessary to take into account economic, social and environmental aspects in order to ensure the sustainable development of the country and mitigate possible negative consequences for the economy and population.

3. Key Challenges and Opportunities in the Coal Sector: Stranded Assets and Socio-Economic Implications

Decarbonization of the Kazakhstan economy is an important and complex process that carries both significant opportunities and significant threats. The transition to a carbon-neutral economy requires major changes in the energy system, industry, transport and other key sectors.

Opportunities offered by decarbonization include economic development and innovation. Adopting advanced technologies and innovative solutions in renewable energy, energy efficiency and waste management can stimulate the growth of new industries and job creation. Accelerating the transition to a green economy helps develop new markets and attract investment in sustainable development. Improved environmental conditions are also a significant benefit. Reducing greenhouse gas emissions and switching to clean energy sources will improve air, water and soil quality, which will positively impact the health of people and ecosystems. Kazakhstan, actively participating in global initiatives to reduce emissions, will be able to strengthen its position in the international arena by gaining access to international financial and technological resources. Compliance with international environmental standards and requirements will allow Kazakh enterprises to remain competitive in world markets.

However, the process of decarbonization also poses a number of threats and challenges. Economic risks and costs are among the main obstacles. The transition to a low-carbon economy requires significant financial investments and structural changes, which can place a significant burden on budgets and businesses. There may be economic losses and social problems associated with the closure of coal mines and job losses in traditional energy sectors. Technological and infrastructure challenges should also not be underestimated. Lack of modern technology and infrastructure can make it difficult to quickly and effectively transition to renewable energy sources and energy efficient technologies. The need to modernize the energy and transport infrastructure requires significant time and financial resources.

Social and political barriers can also slow down the decarbonization process. Opposition from interest groups associated with the coal and oil and gas industries could create additional difficulties. The lack of public support and understanding of the importance of transitioning to a carbon-neutral economy also poses a significant challenge.

Overall, decarbonization of Kazakhstan's economy is a complex but necessary process that requires careful consideration of both opportunities and threats to achieve a sustainable and green future (Table 8).

Table 8. SWOT analysis of the energy transition

STRENGTHS	POSSIBILITIES
– Availability of resources for the development of renewable energy sources and alternative energy *(especially favorable wind conditions, mild sunny climate, hydroelectric potential, large reserves of uranium, hydrogen, biofuel).* There is progress in the development of elements of climate policies and *(emissions trading system, green finance, ESG principles, monitoring, reporting and verification of greenhouse gases (MRV), taxonomy).*	– Creation of domestic industries and technologies / increasing potential and productivity through the development of breakthrough innovations *(in the field of green energy, alternative energy, construction, industrial processes and others).* – Attracting investments into the economy *(increasing transition investments into low-carbon projects/industries, the opportunity to "earn money" on offset projects).* – Increased export of new products with expansion of export geography *(the global energy transition will lead to increased demand for rare minerals available in Kazakhstan, which is also enhanced by its proximity to major high-capacity markets).* – Increasing the adaptability/resilience of infrastructure to changing conditions *(reducing state budget expenses to eliminate the consequences of climate change).* – Improving the environmental situation due to a significant reduction in emissions of greenhouse gases and pollutants into the air, preserving water resources, biodiversity and more. – Reduce morbidity and premature mortality, and promote food safety, improve diets and increase physical activity levels in the population.
WEAK SIDES	**THREATS**
– Significant depreciation of fixed assets in the energy sector and thermal power	– Decrease in demand for fossil fuels *(decrease in export revenue from the sale of raw*

industry – High energy intensity of economic sectors; – Non-market pricing of tariff costs, which does not allow updating fixed assets *(investments in distribution networks and alternative generation of electricity and heat still remain economically unfeasible, since administratively imposed low consumer tariffs for electricity, heat and fossil fuels impede the modernization of networks and the transition to more sustainable sources of generation).* – Lack of in-house production of "green" equipment *(greater import of low-carbon technologies, lack of established production, high cost of construction of "green" facilities).* – Budget dependence on products with a high carbon footprint *(low complexity of Kazakh exports).* – Low level of environmental education of the population *(disinterest of the population in caring for the environment).* – Lack of human resources for transition *(the education system is not designed to train specialists in the field of ecology and green energy).*	*materials; emergence of bad assets in extractive industries; decline in GDP growth rates; exhaustion of the possibilities of the raw material export model of development).* – Declining competitiveness of domestic production *(declining global demand for goods with a high level of carbon footprint and energy intensity (products of the chemical industry, petrochemicals, metallurgy, agriculture, construction materials industry and other carbon-intensive industries); lag in technological development (including "green technologies").* – Reduced investment attractiveness of the country/companies for large investors *(deterioration of conditions for attracting debt financing; reduction in foreign investment; curtailment of existing projects of large companies in the country).* – Lack of investment in transformation *(declining income from primary industries; maintaining low tariffs in a number of sectors that do not pay off investments in low-carbon technologies; increasing the volume of implementation of low-carbon technologies, requiring large financial and investment resources).* – Insufficient level of technology *(low level of investment in R&D and lack of knowledge about low-carbon technologies and experience with them; the occurrence of direct or indirect losses as a result of the unavailability of IT systems, incorrect settings and operation of algorithms; "transitional technologies" that can delay the introduction of technologies with zero emissions).* – Decrease in the solvency of vulnerable segments of the population *(increasing production costs and, accordingly, prices for manufactured products and services; release of workers who do not have the skills to work in new conditions due to the introduction of new low- and carbon-free technologies at all levels of production and the closure of coal mines).*

If Kazakhstan continues to use coal in the long term and does not take significant action, the following risks may materialize.

Reduced competitiveness of domestic production, namely a decrease in global demand for goods with a high level of carbon footprint and energy intensity (products of the chemical industry, petrochemicals, metallurgy, agriculture, construction materials industry and other carbon-intensive industries).

For example, the implementation of the EU Cross-Border Carbon Management Mechanism (hereinafter referred to as CBAM) can increase the impact on the economy. The goals of introducing this mechanism are to limit carbon leakage, as well as stimulate carbon pricing and promote decarbonization in partner countries.

In the period 2024-2025, the impact on Kazakh exports will be insignificant. However, in the medium-long term, starting from 2026, the impact on Kazakh exports will expand, which may lead to risks such as:

– decrease in exports of Kazakhstani raw materials, the likelihood of loss of the sales market;

– decrease in production of main exported goods from Kazakhstan;

– rise in price of Kazakh goods and a decrease in their competitiveness on the world market / decrease in demand for products produced using traditional energy resources;

– possible losses of the government budget from a decrease in export revenues, including due to a decrease in demand for fossil fuels;

According to various estimates, Kazakhstan's losses may be expressed in a decrease in exports of goods to the EU in the amount of from 157.5 million US dollars (calculations by the Economic Research Institute, 2022) to 352.0 million US dollars (calculations by UNCTAD, 2021).

A decrease in the investment attractiveness of the country/companies for large investors, in particular, there are risks of deterioration in the conditions for attracting debt financing, a decrease in the volume of foreign investment, and the curtailment of existing projects of large companies in the country.

Currently, one of the important sources of investment in the sustainable growth of Kazakhstan is international climate finance, which is provided by developed countries and international organizations for the implementation of sustainable projects (projects for the transition to renewable energy sources, for the introduction of green technologies in industry, projects to combat and adapt to floods and fires, projects for the construction of new sustainable infrastructure, transport projects, etc.).

For example, over the last 5 years (2019-2023), an average of 80 billion US dollars per year has been allocated annually by developed countries and international organizations. At the same time, Kazakhstan attracts less than 1.0% of the total funding (0.6% or 489.5 million US dollars annually, calculations by the Economic Research Institute, 2023).

At the same time, if Kazakhstan gradually begins to abandon coal and implement the energy transition, other risks may arise, particularly in some regions and cities, the local economy is centered around the mining and burning of coal for power generation and industry.

The main risk is the deterioration of the socio-economic situation in coal-mining regions, namely the release of workers who do not have the skills to work in the new conditions. The direct share of the coal sector in employment in the country is quite small - 0.7% (about 40 000 people).

The cessation of coal use could result in job losses in the coal and related industries, causing social and economic problems in coal-producing regions. This is especially true for Kazakhstan, where the coal industry is an important source of employment and income for the local population in at least two regions - Karaganda and Pavlodar regions.

However, it should be noted that according to GIZ calculations, the current costs of coal mining and combustion already exceed the revenues received by the sector. Taking into account these additional costs, as well as the costs borne by the population and the state (subsidies, health care costs), increases the cost of coal several times. While coal production itself also generates some labor income, indirect costs outside the coal sector combined amount to more than US$50 per ton of coal, while coal sector profits are only

US$6.8 per ton of coal. Moreover, this already negative coal balance does not include climate damage from GHG emissions associated with coal mining and combustion, which can be as high as US $15.9 per ton of coal.

In general, a decrease in demand for fossil fuels (a drop in export revenue from the sale of raw materials; the emergence of stranded assets in the extractive industries; a decrease in GDP growth rates, the exhaustion of the possibilities of the raw material export model of development) could sharply reduce future global demand for high-carbon commodities, which in turn increases the risk of stranded assets associated with fossil fuel extraction, refining and use (particularly in the energy, construction and industrial sectors) in brown regions, which would also negatively impact on the socio-economic development of these regions. Climate change may exacerbate existing inequalities between regions in Kazakhstan, leading to worsening economic conditions and rising social tensions.

Although the phase-out of coal will come at the expense of certain parts of the country and the regional economies, causing significant structural changes, the benefits from reduced pollution and reduced climate impacts will be significant and more evenly distributed across Kazakhstan, as, for example, reduced health care costs associated with pollution will be beneficial for all. At the same time, it should be noted that most of the benefits associated with quality of life (for example, clean air and improved health) will be received directly in the transforming regions.

There are also risks of reducing the solvency of vulnerable segments of the population, which is associated with a possible increase in production costs, respectively, prices for manufactured products and services, the release of workers who do not have the skills to work in new conditions, due to the introduction of new low- and carbon-free technologies at all levels production and closure of coal mines.

The situation may be aggravated by the current policy to revise utility tariffs for the population.

The current situation with fixed assets in the energy sector leads to the need to re-equip the economy, and given the significant investment cycles in the energy sectors, these steps must be taken immediately. Given the climate agenda, such steps need to be taken through the introduction of low-carbon technologies. However, there are barriers and associated risks to such modernization. The key barrier is non-market pricing of tariff costs, which prevents the renewal of fixed assets. Investments in distribution networks and technologies for generating electricity and heat still remain economically unfeasible, since administratively imposed low consumer tariffs for electricity, heat and fossil fuels hinder modernization. This leads to the need to work with the tariff mechanism to include investment components for updating fixed assets. At the same time, risks arise that require serious study and the adoption of balanced and correct political decisions.

According to various estimates, changes in tariff policy will lead to an increase in prices compared to the current level, in particular prices for electricity and heat. It should be noted that the share of utility costs in total household expenses, other things being equal, will increase from 6.4% (2021) to 21.7% (2029). Rising tariffs can negatively affect families' budgets and people's living standards. This will put significant pressure on household budgets where the share of spending on food was already as high as 50.8% in 2021.

Needles to say, moving away from coal and implementing green projects will also require significant investment.

According to the Strategy for Achieving Carbon Neutrality of the Republic of Kazakhstan until 2060, net investment in low-carbon technologies that contribute to low-carbon development and achieving carbon neutrality is estimated at $610.0 billion - 19.6% of gross fixed capital formation. Direct government investment in achieving carbon neutrality will represent only a small share of 3.8% of total investment.

More than half of the required investments, or 386.3 billion US dollars, are existing and circulating investments in the economy, which will be reoriented from commodity sectors to greener sectors of the economy, the rest, or 223.7 billion US dollars, are new investment resources.

At the same time, the investment need until 2030 is 10 billion US dollars. The remaining US$600 billion will be invested by the end of 2060.

At the same time, at present, about 2.7 billion US dollars are allocated annually in Kazakhstan from all sources of financing to resolve issues related to mitigation and adaptation to climate change (of which 38.8% is the state budget, 28.8% is internal private investment, 16.6% - international development assistance, 15.7% - foreign direct investment). Thus, a significant deficit of financial resources necessary for full-fledged energy transition.

4. Comparative Analysis of International Best Practices in Managing Coal Dependency and Addressing Stranded Assets

To limit global warming to 1.5°C, coal production must be reduced by 11% annually or 80% of the world's remaining coal reserves must not be used, as it accounts for 40% of global greenhouse gas emissions. However, as the results for 2023 show, global coal production is not declining. 2023 became a historical maximum for coal production – 8.7 billion tons.

Speaking about the changes that await the global coal industry, it is also important to note that in the future, as climate policy intensifies, the fate of the coal industry as a whole will depend on progress in its “greening”: the development and application of carbon capture, the development of coal chemistry, use and storage technologies and “clean" coal technologies that allow minimizing the negative consequences of coal combustion.

In general, we can confidently say that it is too early to talk about the end of the “era of coal”. The coal sector is likely to undergo a rebirth, during which it will transform into a completely new industry that will meet the realities of the time and new, current market demands.

Despite the growth in coal production and combustion in Asian countries, successful international experience in phasing out coal exists in various countries.

Countries/jurisdictions that have made significant progress in achieving coal phase-out goals are generally high-income and tend to have advanced technological and financial capabilities - the UK, Germany, Greece, the Czech Republic, the US and select Canadian states.

In general, countries/jurisdictions can be divided into the following main categories with regard to their coal strategies:

– Historical leaders in coal phase-out strategies (UK and Germany). The UK began phasing out coal in the 90s and aims to complete it by 2024. Since the process began, the UK has seen a 50-fold reduction in coal production. The share of electricity production from coal-fired power plants decreased by 29 percentage points between 2010 and 2020 (less than 1% of total electricity production). Germany is an example of another 30-year strategy to reduce coal production and consumption: the country achieved a fivefold reduction in coal production between 1990 and 2020, and halved the share of electricity generation from coal combustion (or 24% of total electricity production).

– More recent coal phase-out strategies based on natural gas (Greece, Czech Republic, Poland, Israel, South Korea, USA). Between 2010 and 2020, the share of coal generation decreased from 53.7% to 12.9% in Greece, from 57.9% to 40.1% in the Czech Republic, from 87% to 69.3% in Poland, from 58.5% to 28.1% in Israel and from 43.9% to 38.7% in South Korea. These countries are aiming to complete their coal phase-out strategy by 2050.

– Coal phase-out strategies based on energy sources other than natural gas. This category includes the UK and Germany already described above, as well as Bulgaria, Hungary, Nova Scotia and Ontario (Canada). These latter have also recently committed to coal phase-out and carbon neutrality, which, based on the historical and techno-economic context of the country, will largely depend on nuclear and renewable generation. Some of these jurisdictions, such as Hungary, Nova Scotia and Ontario (Canada), are also seeking to reduce their dependence on natural gas.

– Large producers, consumers and exporters of coal with a reduction in national coal consumption. This category includes countries such as Australia, China, Mongolia and South Africa. These countries increased or maintained the same level of coal production as in 2010, but at the same time reduced local coal consumption. The share of coal-fired power generation fell from 71.3% to 55% in Australia, from 77% to 64.1% in China, from 95% to 85.3% in Mongolia and from 93.2% to 87.7% in South Africa between 2010 and 2020. Further commitments to coal generation and phase-out and carbon neutrality are not well established and face various socio-economic and political barriers.

Currently, of the 43 countries with coal phase-out plans in total, 24 have pledged to pay approximately US$209 billion in compensation (Table 9).

This global offset target is US$200 billion, but does not include China and India, the two largest coal consumers, which currently have no such plans. If China and India adopt compensation policies, the estimated compensation amount for both countries will be:

– US$2.4 trillion for 2.0°C target and

– US$3.2 trillion for the 1.5°C target.

Currently, about half of all compensation is financed from international sources such as Just Energy Transition Partnerships (JETP) supporting coal phase-out in Vietnam, Indonesia and South Africa. JETPs are intergovernmental partnerships that coordinate financial resources and technical assistance from countries in the Global North to a recipient country to help it transition away from fossil fuels.

The compensation policy includes the following types of measures:

– regional development and/or development of small and medium-sized businesses (SMEs);

– the closure of coal-fired power plants and mining operations;

– development of the renewable energy sector and development of low-carbon infrastructure;

– unemployment support.

Today's offset policies may also send signals that encourage or discourage coal energy development, depending on whether the governments and companies concerned expect to be donors or recipients of future offsets.

Thus, phasing out coal globally is a necessary step to address climate change, but it comes with serious socio-economic consequences for coal mine workers and local communities dependent on the coal industry. Most coal phase-out plans include monetary compensation for affected parties, highlighting the importance of support and a just transition. Compensation policies, financed largely from international sources, require coordination and support from the global community. Extending compensation policies to new countries may face challenges related to the availability of international funding and the political will of donor countries.

Table 9. Coal phase-out commitments and offset policies

Country	Phase-out year (previous pledge)	Compensation $ billion (uncertainty)	Funding or budgetary source	Support for ...
Germany	2030 (2035−2038)	66 (66−67)	Regional infrastructure fund Just Transition Fund	- coal power plant & mine closure; - unemployment support; - regional development.
Indonesia	2040s	55 (31−79) 9 committed	Just Energy Transition Partnership	- national government for: power plant closure, renewables & low-carbon infrastructure, unemployment support, & regional development.
Vietnam	2040s	43 (25−63) 7 committed	Just Energy Transition Partnership	- national government for: power plant closure, renewables & low-carbon infrastructure; unemployment support, and regional development.
Poland	2049	15	Carbon & electricity revenues, Development fund Just Transition Fund	- coal power plant & mine closure; - regional development .
South Korea	2050	12 (11−13)	Mobilized from treasury	- renewables & low-carbon infrastructure .
South Africa *	-	9	Just Energy Transition Partnership	- national government for: power plant closure and regional development.
Spain	2030	2.1	Funds managed by energy and biodiversity institutes Just Transition Fund, Recovery and Resilience Facility	- renewables & low-carbon infrastructure; - unemployment support - regional development.
Greece	2028 (2023)	1.8 (1.2−2.3)	Carbon pricing revenues Just Transition Fund	- regional development .
Czechia	2033	1.7 (1.2−2.2)	Just Transition Fund, Recovery and Resilience Facility	- renewables & low-carbon infrastructure; - regional development.
Romania	2032	1.6	Just Transition Fund, Recovery and Resilience Facility	- renewables & low-carbon infrastructure; - regional development.
Canada	2030	1.2	Green Infrastructure funding Reinvesting carbon pricing revenues (regional - Alberta)	- renewables & low-carbon infrastructure ; - regional development; - coal power plant closure; - unemployment support .
Italy	2025	1.1 (0.9−1.3)	Just Transition Fund	- regional development .
Bulgaria	2038	1 (0.3−1.7)	Just Transition Fund, Recovery and Resilience Facility	- renewables & low-carbon infrastructure; - regional development.
Slovakia	2025	0.6 (0.5−0.8	N.A.	- coal mine closure;

			Just Transition Fund	- regional development.
Portugal	2021 (2030)	0.3	NA, Just Transition Fund	- regional development .
Hungary	2029	0.3	NA, Just Transition Fund	- regional development .
Finland	mid-2029 (2030)	0.3	Redirected from tendering scheme for renewables	- coal power plant closure; - renewables & low-carbon infrastructure.
Slovenia	2033	0.2 (0.2−0.3)	NA, Just Transition Fund	- regional development .
Netherlands	2029 (2030)	0.2 (0.1−0.3)	Ministry of Economic Affairs and Climate Policy	- coal power plant closure .
Croatia	2033	0.2 (0.1−0.2)	NA, Just Transition Fund	- regional development .
France	2022	0.1	Program 174: Energy, climate and post-mining	- regional development ; - unemployment support .
Chile	2040	N.A.	N.A.	- coal power plant closure; - unemployment support.
North Macedonia	2030	N.A.	N.A.	- renewables & low-carbon infrastructure; - unemployment support; - regional development .
Ukraine **	2040	N.A.	State budget	- coal power plant & mine closure
Total		209 (163−258)	Domestic: 92 (90−95) International: 117 (73−163)	-

Data Nacke , L., Vinichenko , V., Cherp , A. et al. Compensating affected parties necessary for rapid coal phase-out but expensive if extended to major emitters. Nat Commun **15** , 3742 (2024). https://doi.org/10.1038/s41467-024-47667-w

The analysis showed that the coal industry plays a key role in the economy of Kazakhstan. This sector not only provides a significant share of the national energy consumption, but is also an important source of employment and income for 2 regions of the country. At the same time, high dependence on coal poses serious environmental challenges for Kazakhstan, requiring the introduction of modern technologies and approaches to reduce the carbon footprint and transition to more sustainable energy sources.

It is proposed to consider the following measures for the development of the coal industry in Kazakhstan.

It is recommended to be based on a strategy of gradually systematically reducing the share of coal generation with an increase in the share of renewable energy sources and alternative energy, as well as using natural gas as an intermediate fuel.

Strengthen/continue support for renewable energy sources

As previously noted, the renewable energy development sector is currently receiving significant government support. As a result, the share of electricity produced by renewable energy facilities excluding large hydroelectric power plants reached 5.9% in 2023 compared to 0.7% in 2015.

However, despite the development of renewable energy generation, unresolved issues remain that require response.

Firstly, there is no clear understanding of the development of renewable energy generation in terms of mechanisms (direct contracts with foreign partners, auction mechanism for selecting projects, bilateral contracts, small-scale projects), and as a result, “gaps” arise in the development of appropriate government support/policy.

Secondly, the current legislative norms for the development of small-scale generation have not worked “in full force” (targeted assistance in the amount of 50% of the installation cost, sale of excess to the general network, and so on)

At the same time the potential of 5-10% of households is equivalent to the construction of a large thermal power plant with a capacity of 500 - 1000 MW.

It is recommended, based on international practice in the development of small-scale generation, to simplify the procedures and terms for connection, and establish increased “green” tariffs for the sale of excess electrical energy to the network.

Third, the market for bilateral RES contracts remains without due attention (an industrial enterprise, in order to reduce its carbon footprint, enters into a direct contract with a RES generator for the purchase of “green” electricity), which, if properly developed, can be much larger than the RES auction market.

Fourth, there is no sufficient financing for renewable energy projects due to long-term implementation/recoupment, as well as currency risks.

Fifth, insufficient attention is paid to the development of energy storage systems. Renewable generation is unstable, and its further growth in capacity/production can lead to the formation of imbalances in the energy system. In this regard, the introduction of energy storage systems seems especially important. Today, in Kazakhstan there are no successful projects for the implementation of such systems, and there are also no regulations governing the technical requirements for such systems and mechanisms for the implementation of such projects.

Sixth, it is necessary to strengthen support for small-scale renewable energy sources. In general, in the area of state support/policy for distributed generation of renewable energy sources, there is a lack of a systematic approach, which does not contribute to its further development, while according to a UNDP study in Kazakhstan, the potential of 5-10% of households is equivalent to the construction of a large thermal power plant with a capacity of 500 - 1000 MW. This volume of distributed capacity can be integrated into the energy system relatively painlessly.

Supporting the gas industry as an intermediate fuel for the energy transition

If industrial enterprises use gas instead of coal as part of the transition to low-carbon development and reduction of greenhouse gas emissions, the deficit will become even more significant.

Firstly, in this situation it is important to replenish the resource base, where the provision of certain preferences (at all stages: exploration, production and processing) can be a significant impetus for the launch of relevant projects. To provide commercial gas to the domestic market and exports, it is necessary to attract investment in new gas production and processing projects, taking into account the stimulation of investment in gas projects by providing fiscal preferences and favorable purchase prices for commercial gas for subsoil users.

Secondly, the reasons for the unattractiveness of commercial gas production for private investment are the monopoly presence of the state in the market and the price regulation it carries out. Monopolization of the domestic market also containsrisks of monopoly costs. In this regard, the long-term goal of the development of the commercial gas market should be the creation of a competitive model, including gradual deregulation of the market in order to attract private, non-state investments, the development of exchange trading as a tool for market deregulation and ensuring equal, direct access without an intermediary to the resources of subsoil users for independent gas suppliers.

To implement a competitive model of the commercial gas market, it is necessary to increase gas production volumes, reduce losses from its sales to the domestic market and the disparity of prices in the domestic and foreign markets in the context of the formation of a common EAEU gas market by 2025.

It is necessary to revise the pricing and tariff policy in the gas supply system, not only by increasing prices, but also by partially equalizing prices across regions. At the same time, an increase in prices and tariffs in the southern and northern regions may be reflected in a multiple increase in the cost of utilities. The increase may also be affected by the process of harmonizing domestic prices for natural gas with prices in other Eurasian economic union member states in anticipation of the creation of a common gas market. The level of gas prices for end consumers in Kazakhstan is one of the lowest among the Eurasian economic union member states, and therefore their increase should be the most significant.

Thirdly, despite the progress in the development of gasification of the country, there are potential problematic issues regarding the deterioration of the existing gas transportation infrastructure. According to information from the KAZENERGY National Energy Report 2023, the operation of gas transportation infrastructure is negatively affected by a high degree of wear and tear and, as a result, low throughput. The backbone of Kazakhstan's national gas pipeline infrastructure dates back to the Soviet era, and the average level of deterioration is more than 70%. It should be noted that this wear applies to the main gas network. According to various sources, the wear and tear of the existing gas distribution network reaches 45%.

Another key characteristic is comparing the costs and feasibility of expanding the electricity grid with expanding the gas network, which could eventually also supply decarbonized gases (recoverable methane or hydrogen).

The price of natural gas is a major factor to consider when planning the energy transition in Kazakhstan. High prices for natural gas exports from Kazakhstan could provide important support to the energy transition by reducing the overall cost of the energy system to society. However, in reality, high prices may become a barrier to domestic gasification, where producers may have difficulty recovering their costs and may want to export more gas, creating a shortage in the domestic market.

Give impetus to the further development of alternative energy sources

It should be clearly understood that renewable energy sources are not a reliable source of base generation. In order to ensure stable generation in the context of growing energy consumption and the transition to low-carbon development, it is necessary to use alternative energy sources, namely nuclear generation.

World experience shows that the capital costs of nuclear power plant construction, taking into account the indicator "capacity utilization factor" (CUF), are lower in comparison with renewable energy sources (Table 10) (the capacity factor of nuclear power plants is 79%, hydropower - 59%, wind energy - 24%, solar energy – 16%). That is, the energy generation efficiency of a nuclear power plant is significantly higher than that of renewable energy sources.

Thus, taking into account the capacity factor, the cost of constructing renewable energy sources ranges from 4,000 to 5,000 million US dollars, while the cost of constructing a nuclear power plant is only 3,606 million US dollars.

Table 10. Capital costs of construction of nuclear power plants and renewable energy sources, taking into account the capacity factor indicator

View energy	CUF	Generation, GW*year	GW	CAPEX (dollars / kW)	Price, mln dollars
Nuclear energy	79%	6,920	1.0	3 606	3,606.0
Hydropower	59%	6,920	1.3	3 600	4,820.3
Wind energy	24%	6,920	3.4	1 391	4,578.7
Solar energy	16%	6,920	4.9	995	4,912.8

Note : International Energy Agency, expert calculation. CAPEX is indicated as overnight costs, that is, without taking into account the costs of servicing loans.

The construction of a nuclear power plant is a contribution to the long-term environmental safety of the country, to the development of knowledge-intensive related industries (medicine, food industry, materials science and many others) with the creation of jobs.

Kazakhstan has significant advantages:

– experience in operating the world's first pilot industrial fast neutron nuclear reactor (BN-350 in Aktau);

– availability of trained highly qualified personnel working at 3 research reactors (Kurchatov and Almaty). The total number of people employed in the nuclear industry of Kazakhstan is 20 thousand people;

– the largest uranium production in the world - 40% of the world's nuclear energy needs are provided by Kazakhstani uranium;

– experience in the production of uranium powders and pellets at the UMP plant - the fabrication of fuel assemblies, which are the final form of nuclear fuel loaded into the reactor.

It is necessary to develop coal chemistry, taking into account the fact that coal reserves in Kazakhstan are designed for 300 years. This will make it possible to make the most efficient use of available resources, creating new products and technologies based on coal, which will contribute to economic growth and increase the country's competitiveness.

Develop a vision for the development of coal chemistry in Kazakhstan, that is, a gradual reorientation from coal mining to industrial production.

Coal is traditionally used in Kazakhstan to produce energy and heat through combustion. However, coal is also an important raw material for the coal chemical industry. Coal chemistry involves the processing of coal to produce various chemical products such as methanol, ammonia, synthetic gas, liquid fuels, and carbon materials. The development of the coal chemical industry can help Kazakhstan diversify its economy, create new jobs and reduce dependence on imported chemical products.

For the successful development of the coal chemical industry in Kazakhstan, several specific areas and projects that can be implemented in the country can be considered.

– production of methanol and dimethyl ether based on local coal resources as fuel, raw material for the chemical industry and in the production of plastics (using the example of the Chinese Shenhua methanol complex Ningxia Coal Industry Group);

– production of synthetic gas and ammonia, followed by the production of fertilizers (using the example of the Eastman complex Chemical Company in the USA, which uses coal to produce ammonia and other chemicals);

– production of synthetic liquid fuels, such as diesel and kerosene, through the use of direct or indirect coal liquefaction technologies (using the example of the South African company Sasol);

– production of carbon materials such as carbon fibers and graphite for industrial applications (based on the example of manufacturing plants in Japan and the USA);

– production of synthetic chemical products such as olefins, aromatic hydrocarbons and others using thermal decomposition technologies and catalysts (as exemplified by chemical complexes in China and Germany using coal for the synthesis of various chemical products).

According to Kazakh Invest, currently in Kazakhstan the share of coal products is only 3% and, according to preliminary calculations, the unused potential is 25 billion US dollars. Of the three methods of coal processing (pyrolysis, gasification, hydrogenation), the most promising direction for Kazakhstan in obtaining goods of deeper processing is gas synthesis. That is, burning coal, converting it into methanol and ammonia and then into coal chemical products. The resulting products can be widely used in the production of fertilizers, pharmaceuticals, chemical products and other industries. According to Kazakh Invest, by processing coal it is possible to obtain more than 400 different products, the cost of which is 20-25 times higher than the cost of coal itself.

The use of coal for coal chemistry represents significant potential for the economic development of Kazakhstan. Taking into account the successful experience of foreign countries, Kazakhstan can develop the coal chemical industry by investing in technology, creating coal chemical clusters and attracting international cooperation. This will diversify the economy, create new jobs and reduce dependence on imported chemical products.

Decommissioning coal-fired capacity with current operating lives of more than 30 years and introducing carbon capture and storage technology for those units that will continue to operate after 2035.

At the same time, the withdrawn coal facilities must be given priority rights to implement “green” energy projects. One such mechanism could be the Energy Transition Mechanism, implemented by the Asian Development Bank.

According to recent studies, it is expected that in the next 10–15 years, the operation of existing coal plants will be more expensive compared to the average cost of new renewable energy plants. However, in many developing countries, as in Kazakhstan, coal-fired power plants have reliable long-term agreements for the purchase of coal and the sale of electricity, so they aim to continue to operate. The goal of the Energy Transition Mechanism is the gradual and targeted removal of coal capacities from the overall structure of energy and heat generation and their replacement with renewable energy sources over the next 20 years. An Energy Transition Mechanism is developed for a specific country and within a unique political, legal and energy system. The Energy Transition Mechanism is based on two additional financial entities: the Carbon Reduction Fund and the Clean Energy Development Fund.

The Carbon Reduction Fund purchases domestic assets that will continue to operate for an agreed period that is shorter than the current expected life but long enough to return money to Energy Transition Mechanism investors and creditors.

In parallel, income from assets or other investments will be mobilized (Clean Energy Development Fund) for renewable energy sources and the necessary infrastructure, such as networks and storage, to provide clean energy. As the Clean Energy Development Fund expands renewable energy capacity and storage, the Clean Energy Development Fund is retiring its assets and accelerating the country's transition to low-carbon energy.

At the coal mining stage, it is necessary to introduce existing technologies to reduce methane emissions.

As previously noted, the coal sector accounts for the remaining 809 kt (or 21.8% of total methane emissions). Using available technologies, the reduction potential is 32.0% (or 258 kt). At the same time, net costs cannot be avoided (Table 11).

Table 11. Potential for reducing methane emissions in the coal sector of Kazakhstan in the context of the use of currently available technologies

Name of technology	Reduction potential, kt	Share in the overall decline in the sector
CMM utilization	103.04	39.9%
VAM oxidation	49.71	19.2%
Capture and route to abatement system	45.28	17.5%
On-site recovery and use	44.15	17.1%
Flare	10.32	4.0%
Enhance combustion efficiency	5.87	2.3%

By applying "proven policies" to reduce methane emissions in the coal industry, it is possible to reduce methane emissions:

– by 13.9% (by 113 kt) – mine degasification (including the capture of methane from coal deposits, which can then be used to produce heat and electricity or sold to industrial consumers, or flared);

– by 11.6% (94 kt) – abate ventilation air methane (underground coal mines use ventilation systems to bring fresh air into the mine and maintain safe working conditions. On-site recovery and use of methane from ventilation air can provide heat for mine facilities or for coal drying);

– by 6.3% (51 kt) – additional measures, includes efficiency improvements (for example, keeping combustion flares, gas engines and associated equipment as high as possible through process control systems), as well as measures to reduce methane losses by monitoring, capturing and sealing sources (for example, closing unused mine entrances or wells).

Phased abolition of fuel subsidies with reorientation of “freed up” funds to support the population affected by increases in electricity and heat tariffs

Increasing tariffs with targeted support from the population is more effective than universally low tariffs. Poverty levels in Kazakhstan are low by international standards, and the universal provision of low tariffs falsely allocates most social assistance to wealthy households, which consume disproportionately more energy.

The phasing out of fossil fuel subsidies will provide significant savings to the government budget and subsequently offset the adverse effects of price changes on the most vulnerable segments of the population.

According to the International Energy Agency, in the period from 2010 to 2021, on average, direct and hidden fuel subsidies in Kazakhstan annually amounted to 5.7% of GDP. On average, US$5.6 billion is allocated to the energy sector annually, of which US$1.5 billion is allocated to subsidize coal.

According to World Bank calculations, phasing out fossil fuel subsidies by 2030 would lead to significant price increases above the baseline: gasoline prices would rise by 82%, coal by 68%, and diesel by 27%.

According to UNDP with subsidizing the production and consumption of fossil fuels in Kazakhstan for the period from 2016 to 2019 has increased significantly. The total volume of subsidies for fossil fuels increased from about 1.6 trillion tenge in 2016 to 2.9 trillion tenge in 2019. At the same time, the share of budgetary allocations is only about 3-6%, and the remaining subsidies are provided in the form of tax breaks and price support for consumers of oil, coal, gas, heat and electricity through so-called “secondary transfers”. Wherein, Budget funding for fossil fuels exceeds spending on government programs aimed at improving energy efficiency and reducing greenhouse gas emissions directly or indirectly. For example, about 83 billion tenge were allocated from budgets of all levels in 2020 to subsidize the consumption and production of fossil fuels, and only 9.1 billion tenge were allocated for programs promoting low-carbon development.

In general, taking into account past trends, the total “savings” from the abolition of fuel subsidies for the period 2023-2029 could amount to 39.2 billion US dollars or 17.6 trillion tenge At the same time, for the targeted and targeted support of the population with incomes below the subsistence level for the same period, 0.9 trillion is needed tenge *(to maintain the share of utility costs at the same level).*

Therefore, it is possible to use the saved financial resources to offset the impact of higher fuel prices and tariffs on the most vulnerable households. Such compensation can be carried out without additional expenditures from the state budget, but only through the redistribution of savings during the phased out of fuel subsidies.

Reforming ineffective fossil fuel subsidies will increase the capacity to mobilize budgetary funds (the so-called “fiscal space”).

In general, to achieve decarbonization of the economy of Kazakhstan, it is necessary to apply a systematic approach, which includes the creation of an effective carbon regulation system. Such a system should consist of several key elements: monitoring, reporting and verification of emissions; national cap and trade system; carbon taxation for unregulated emissions; climate finance systems, including a carbon fund, project taxonomy, low carbon project bank, green finance and procurement; interaction with best available technologies (BAT); and a unified digital ecosystem for carbon regulation. The central element of this system should be the ETS, the significance of which is reinforced by national commitments to reduce greenhouse gas emissions under the Paris Agreement and the implementation of the EU's cross-border carbon regulation mechanism. Expanding the coverage of carbon pricing instruments and revising specific emission factors are also necessary steps to encourage improvements in economic sectors.

5. Policy Recommendations

To ensure a smooth transition towards a low-carbon economy while maintaining energy security and economic stability, Kazakhstan must implement a comprehensive and phased strategy for coal sector transformation. This strategy should encompass energy diversification, technological innovation, financial mechanisms, and social support measures to facilitate a just transition. The following policy recommendations outline key areas of intervention:

1. Gradual and Systematic Reduction of Coal Dependence

Kazakhstan should implement a long-term strategy to gradually decrease coal reliance while increasing the share of renewable and alternative energy sources. The planned energy transition should align with the national energy security agenda to prevent supply disruptions. The following steps are essential:

- Reduce the share of coal-fired power generation to 34.3% by 2035 while increasing renewable energy to 24.4% and gas-based power generation to 25.8%.
- Expand the use of natural gas as a transitional energy source to ensure stability in power supply while phasing out coal.
- Retire coal-fired power plants that have exceeded a 30-year operational lifespan, prioritizing decommissioning based on economic efficiency and emissions intensity.
- Introduce carbon capture, utilization, and storage (CCUS) technologies for remaining coal-fired capacity, supported by international mechanisms such as the Asian Development Bank's Energy Transition Facility.

2. Development of Coal Chemistry as an Alternative Industrial Pathway

Given Kazakhstan's extensive coal reserves, the country should shift from traditional coal combustion to high-value coal processing industries. Key initiatives should include:

- Promoting coal gasification and liquefaction technologies to produce synthetic fuels, methanol, ammonia, and other chemical products.
- Supporting research and development (R&D) initiatives for coal-based carbon materials, such as graphene and advanced composites.
- Attracting private investment and international partnerships to develop large-scale coal chemical projects, leveraging Kazakhstan's untapped $25 billion potential in this sector.

3. Methane Emission Reduction in Coal Mining

Methane emissions from coal mining must be addressed through technological upgrades and regulatory mechanisms. Key recommendations include:

- Implementing methane capture, recovery, and utilization technologies, such as mine methane recovery and ventilation air oxidation.
- Establishing methane management standards for coal mines, with incentives for operators to invest in emission reduction technologies.
- Strengthening monitoring and reporting systems to ensure accurate measurement of methane emissions and track progress in reduction efforts.

4. Reforming Fossil Fuel Subsidies and Redirecting Savings

Phasing out inefficient fossil fuel subsidies and reallocating financial resources can enhance economic efficiency and support vulnerable populations during the transition. The following measures are recommended:

- Gradually eliminate coal and fossil fuel subsidies, reallocating savings towards renewable energy investments, social protection programs, and energy efficiency measures.
- Utilize fiscal savings from subsidy phase-out (estimated at $39.2 billion for 2023-2029) to support low-income households, ensuring that energy costs remain affordable.
- Develop direct financial assistance programs for affected communities, including retraining initiatives and employment support for workers transitioning from coal-dependent industries.

5. Strengthening Carbon Regulation and Market Mechanisms

Kazakhstan must enhance its carbon pricing policies to incentivize emissions reductions and attract climate finance. Key recommendations include:

- Expanding and strengthening the national emissions trading system (ETS) as a central element of carbon regulation.
- Aligning Kazakhstan's ETS with international carbon markets to improve liquidity and attract foreign investment.
- Implementing additional carbon pricing instruments, such as carbon taxes or performance-based incentives, to encourage industrial decarbonization.

6. Ensuring a Just Transition for Coal-Dependent Regions

To mitigate the socio-economic impacts of coal phase-out, Kazakhstan should implement a comprehensive just transition framework. This should include:
- Providing targeted support for workers and communities in coal-dependent regions such as Karaganda and Ekibastuz through job creation programs, skills development initiatives, and economic diversification strategies.
- Establishing regional transition funds to finance infrastructure development and investment projects in alternative industries.
- Encouraging public-private partnerships to develop new economic opportunities in affected areas, including renewable energy projects and industrial transformation initiatives.

By implementing these policy recommendations, Kazakhstan can achieve a balanced energy transition that minimizes economic disruptions while advancing its decarbonization agenda. A well-planned shift from coal will not only reduce greenhouse gas emissions but also create new economic opportunities and improve long-term energy security.

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