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CLEAN AIR AND COOL PLANET

Cost-Effective Air Quality Management in Kazakhstan and Its Impact on Greenhouse Gas Emissions

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ACRONYMS AND ABBREVIATIONS

Abbreviation	**Meaning**
AAQMS	Automatic Air Quality Monitoring Station
AEI	Average Exposure Indicator
API_5	Air Pollution Index
AQM	Air Quality Management
BAT	Best Available Technique
BC	Black Carbon
BREF	EU Best Available Techniques Reference Document
CAPP	Clean Air Priority Program
CBAM	Carbon Border Adjustment Mechanism
CEIP	Centre on Emission Inventories and Projections
CHP	Combined Heat and Power
CLRTAP	Convention on Long-Range Transboundary Air Pollution
COP	Coefficient of Performance
COPD	Chronic Obstructive Pulmonary Disease
DPF	Diesel Particulate Filter
EEA	European Environmental Agency
EIA	Environmental Impact Assessment
EIP	Environmental Impact Permit
ELV	Emission Limit Value
EMEP	European Monitoring and Evaluation Programme
ETS	Emissions Trading Scheme
EU	European Union
GAINS	Greenhouse Gas and Air Pollution Interactions and Synergies
GBPP	Green Bridge Partnership Programme
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GWP	Global Warming Potential
HF	Highest Frequency
IAQCC	Integrated Air Quality and Climate Change
IEA	International Energy Agency
IEP	Integrated Environmental Permit
IIASA	International Institute for Applied Systems Analysis
IIR	Informative Inventory Report
KazETS	Kazakhstan Emission Trading Scheme
Kazhydromet	National Hydrometeorological Service of the Republic of Kazakhstan
KOREM	Kazakhstan Electricity and Power Market Operator
LEZ	Low Emission Zone
LPG	Liquified Petroleum Gas
LULUCF	Land Use, Land-Use Change, and Forestry
LV	Limit Value

MAC	Maximum Allowed Concentration
MCI	Monthly Calculation Index
MEGNR	Ministry of Ecology, Geology and Natural Resources of the Republic of Kazakhstan
MET	Mineral Extraction Tax
MFB	Multi-Family Building
NAP	National Allocation Plan
NCD	Noncommunicable Disease
NDC	Nationally Determined Contribution
NEI	Negative Environmental Impact
NFR	Nomenclature for Reporting
NMVOC	Non-Methane Volatile Organic Compounds
OC	Organic Carbon
OECD	Organization for Economic Co-operation and Development
PM	Particulate Matter
PM_1	Particulate Matter with Diameter Less than or Equal to 1 µm
PM_{10}	Particulate Matter with Diameter Less than or Equal to 10 µm
$PM_{2.5}$	Particulate Matter with Diameter Less than or Equal to 2.5 µm
QA/QC	Quality Assurance and Quality Control
RES	Renewable Energy Source
SCR	Selective Catalytic Reduction
SDGs	Sustainable Development Goals
SFB	Single-Family Building
SI	Standard Index
SLCP	Short-Lived Climate Pollutant
SNCR	Selective Non-Catalytic Reduction
STEPS	Stated Policies Scenario
TPP	Thermal Power Plant
TSP	Total Suspended Particles
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
VOC	Volatile Organic Compound
WHO	World Health Organization
WTO	World Trade Organization

SIGNS AND UNITS

Sign/Unit	Meaning
kt	kiloton
kWh	kilowatt-hour
KZT	Kazakhstani tenge
m^3	Cubic meter
mg/m^3	milligram per cubic meter
Mt	megaton
Mtoe	Million tons of oil equivalent
PJ	petajoule
PLN	Polish zloty
toe	tons of oil equivalent
$\mu g/m^3$	microgram per cubic meter

Note: All dollar amounts are US dollars.

EXECUTIVE SUMMARY

Background

Kazakhstan has committed to decarbonization over the next few decades and is also stepping up efforts to reduce air pollution that imposes high health costs on its citizens. Every year, 6,000–9,360 people in Kazakhstan are dying prematurely due to poor air quality**.** Kazakhstan's Concept for Transition to Green Economy estimates that air pollution causes up to 6,000 premature deaths per year. Moreover, a 2020 study prepared by the World Bank estimates that annually, particulate matter (PM) pollution alone causes 9,360 premature deaths and costs the economy more than $7.1 billion.[1]

International experience shows that the least-cost decarbonization and air pollution reduction strategies often differ in prioritizing pollutants, emission sources, and interventions. Pursued in isolation, climate policies may actually lead to a temporary increase in air pollution while air pollution policies alone can lock in carbon-intensive assets. Therefore, an integrated approach is needed to achieve the two objectives and to better understand interlinks—both synergies and trade-offs—between priority actions to rapidly improve air quality and to facilitate long-term decarbonization, particularly for the most polluted cities.

This report provides the first national-level approximation of priority sources and actions to address air pollution while maximizing synergies with climate mitigation and managing trade-off challenges. The study uses mean population exposure as the best approximation of air quality impact currently available. It is a scoping exercise to determine the least-cost priority measures to improve air quality and identify potential key synergies or trade-offs with climate change mitigation that can be managed through coherent application of air and climate protection policies.

According to the latest Informational Bulletin 'On the State of the Environment in the Republic of Kazakhstan for 2019', 10 cities had high air pollution levels. These are Aktobe, Almaty, Atyrau, Balkhash, Karaganda, Nur-Sultan, Shymkent, Temirtau, Ust-Kamenogorsk, and Zhezkazgan. The air quality monitoring data provided for these cities showed that concentrations of key air pollutants in the ambient air consistently exceeded the limit values (LVs) of both Kazakhstan and the European Union (EU), especially in the winter. In some cases, the average annual concentrations were two or three times higher than the EU annual concentration LVs. Thus, this scoping study focuses on the key air pollutants that cause winter smog, namely fine particulate matter (PM_{10} and $PM_{2.5}$),[2] and other chemicals that contribute to the secondary formation of particulate matter through reactions in the atmosphere, such as sulfur dioxide (SO_2), and nitrogen dioxide (NO_2).[3] The World Health Organization (WHO) considers all of these pollutants dangerous to human health.

Kazakhstan has a legal and regulatory framework for air quality management (AQM). Basic ambient air quality standards have been established and are mandatory, although their levels and definitions need to be aligned with international best practices and enforced. Institutions at different levels of the government are responsible for air quality, yet allocation of responsibilities and institutional capacities require improvement. There is also a growing body of research and scientific capacity at Kazakhstan's universities to support policy makers in their actions on the ground. Notwithstanding the needed modernization,

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[1] World Bank. 2020. *The Global Cost of Ambient $PM_{2.5}$ Air Pollution*. Report No: AUS0001948. Washington, DC: World Bank. http://documents1.worldbank.org/curated/en/202401605153894060/pdf/World-The-Global-Cost-of-Ambient-PM2-5-Air-Pollution.pdf.

[2] PM_{10} refers to particulate matter (PM) with diameter less than or equal to 10 µm and $PM_{2.5}$ refers to PM with diameter less than or equal to 2.5 µm.

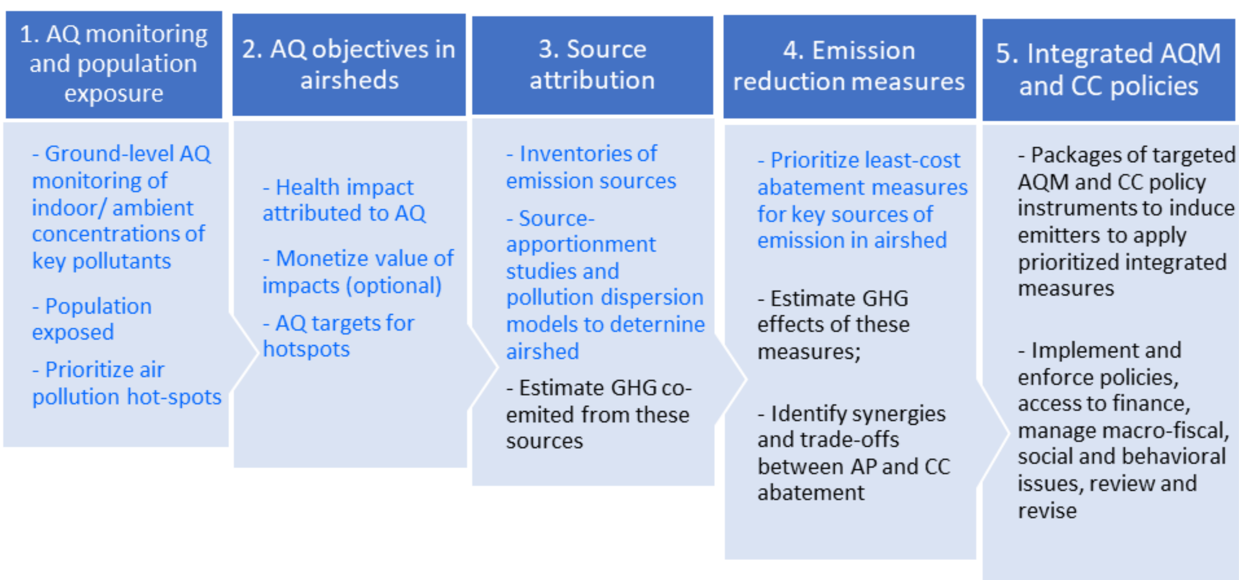
[3] Ground-level ozone (O_3) is briefly considered in the analysis of air quality data, but its formation increases in summer; hence, it is less responsible for winter smog that causes most of the health impacts of air pollution in Kazakhstan's cities.

monitoring of ground-level ambient air quality is implemented in most cities which aids the identification of major hot spots where large populations are exposed to air pollution health hazards.

In parallel to improving air quality, Kazakhstan has committed under the Paris Agreement to reduce greenhouse gas (GHG) emissions by 15 percent (unconditional target) and up to 25 percent (conditional target) by 2030 as compared to the base year of 1990. In 2019, GHG emissions, including for land use, land-use change, and forestry (LULUCF), were 2 percent lower than the base year of 1990. In fact, in the last decade, the GHG emissions have steadily grown, with the exception of 2019, posing a significant challenge for Kazakhstan in meeting its Nationally Determined Contribution (NDC) targets and attaining its strategic goal of carbon neutrality in the longer term.

This report uses the best available data and a state-of-the-art modeling to make an initial assessment of the cost-effective technical pathways to reduce mean population exposure to $PM_{2.5}$ in Kazakhstan while also assessing such pathways' interactions with GHG emissions. It applies the Integrated Approach to Air Quality and Climate Change (IAQCC) Policy (Figure 1) framework.[4] This approach facilitates policy integration by which institutions align their mandates, policies, and sectoral objectives considering the interactions (synergies and trade-offs) among different policy areas to address multiple dimensions of sustainable development challenges in a more balanced manner.[5] An IAQCC approach dynamically focuses on the near-term health impacts of air pollution in the most polluted areas while paving the way for the long-term phaseout of fossil fuels.

Figure 1: Five steps of the IAQCC policy process



Source: World Bank.

Note: AP = Air pollution; AQ = Air quality; CC = Climate change.

Blue text denotes actions driven primarily by air pollution health considerations. Black text refers to actions driven primarily by climate mitigation.

Kazakhstan has made significant strides in AQM as part of Steps #1 (Air quality monitoring) and #2 (Air quality objectives) of the IAQCC process, but further efforts are needed to deliver effective

[4] Peszko, G. Forthcoming. *Air Pollution and Climate Change: From Co-Benefits to Coherence*. Washington, DC: World Bank.
[5] OECD (Organisation for Economic Co-operation and Development). 2019. *Recommendation of the Council on Policy Coherence for Sustainable Development*. OECD/LEGAL/0381. https://www.oecd.org/gov/pcsd/recommendation-on-policy-coherence-for-sustainable-development-eng.pdf.

solutions. The country's preparedness for air pollution management is less advanced than for climate mitigation. Air quality monitoring data and existing emissions source inventories have significant gaps providing a strong rationale for knowledge advancement and action toward Kazakhstan's progress in Steps #3 (Source attribution) and #4 (Emission reduction measures) of the IAQCC process. The support for Steps #4 and #5 (Integrated policies) of IAQCC could be prioritized for Almaty and Nur-Sultan. These cities, Kazakhstan's largest, are experiencing very different local conditions for AQM but are equally interested in support from the World Bank.

Emission Sources and Measures to Reduce Population Exposure to $PM_{2.5}$

Most air quality-related diseases and premature deaths are linked to the winter smog and fine particles. Concentrations of nitrogen dioxide (NO_2) and particles (PM_{10}, and $PM_{2.5}$) peak in winter months to high levels in almost all analyzed cities in Kazakhstan and are a major source of health effects especially when exacerbated by local meteorological conditions such as temperature inversions, which prevent air pollutant dispersion, leading to poor air quality, for example, in Almaty. Epidemiological studies attribute premature air pollution deaths mainly to fine dust particles, or $PM_{2.5}$, which are emitted directly by multiple sources and are also formed in the atmosphere from primary emissions of other air pollutants, such as sulfur dioxide (SO_2) and nitrogen oxides (NOx). Therefore, this study's focus is the assessment of cost-effective technical pathways to improve air quality by reducing the mean population exposure to $PM_{2.5}$.

The study suggests that the greatest human exposure to $PM_{2.5}$ in Kazakhstan results from a relatively small mass of pollution emitted by dispersed small residential heating stoves and boilers. The latest household survey conducted in 2018 shows that only one-third of households in Kazakhstan use district heating, or gas or electricity for heating, and the remaining two-thirds burn solid fuels in their stoves and boilers integrated into the buildings—a mixture of fossil fuels (coal) and renewable energy (biomass, mainly wood).[6] The household survey suggests roughly equal proportions between coal and wood used for individual residential heating, but the design of the survey leaves significant uncertainty about the exact shares of coal and biomass, especially used by urban and peri-urban households. These small stoves and boilers pose a major health hazard because their emissions are coming from low stacks and tend to condense in or close to densely populated urban centers, sometimes trapping smog near the ground by winter atmospheric inversion events during which pollutant dispersion is limited. The combustion processes in these installations are inefficient and extremely polluting per unit of useful energy. Building-integrated heating installations are too small to be equipped with filters or other post-combustion emission reduction equipment.

Availability of options to replace/improve household heating sources using solid fuels differs from city to city. For instance, access to a centralized gas distribution network or district heating is one important technical and financial constraint for households. Increase in the cost of electricity resulting from potential electricity market reforms may also be an important affordability constraint to reduce emissions from residential heating such as in the case of switching to electric heating. Depending on the local situation, different emission sources and abatement measures may be cost-effective in preventing premature deaths in the exposed population. Techniques used to remove already formed pollutants such as installation of scrubbers and filters and flue gas desulfurization, i.e., the so-called end-of-pipe emission controls, in power and industrial installations are more likely to play an important role in AQM in cities surrounded by heavy industry and having no access to a gas network (for example, Karaganda and Temirtau) or in cities with frequent events of atmospheric inversions (for example, Almaty). Analysis of costs, feasibility, and affordability of pollution abatement measures or infrastructure investment specifically for individual cities was beyond the scope of this national scoping study and is proposed as a next step. Likewise, policy

[6] The extent to which biomass (mainly wood) is sustainably sourced and used is uncertain and is beyond the scope of this study.

incentives to make households and firms willing to implement and operate technical air pollution reduction measures will be considered in subsequent studies in cities.

Cost-Effective Air Quality Measures and Climate Mitigation: Modeling Results

Will decarbonization by itself solve the health hazards of air pollution and will air quality improvement always lead to reduction of GHGs? These two environmental issues have different timelines, geographical scales, and distinct causes rooted in different market failures. Priority sources and measures for air quality do not always overlap with priority measures to meet climate mitigation pledges. In Kazakhstan, like in many other countries, the priority measures to improve air quality in cities involve small residential stoves and boilers using coal and biomass for heating, while priority measures for climate mitigation, including the country's NDC commitments, involve large point combustion sources burning coal in the power sector and industry. Although, in some regions power and industry can play a major role, residential heating using solid fuels is one of the main culprits of health effects associated with winter smog in Kazakhstan's cities. This study identifies the cost-effective technical measures to reduce mean population exposure to $PM_{2.5}$ in Kazakhstan and calculates their co-impact on GHG emissions.

The quantitative modeling conducted for this study suggests that there is a large potential for cost-effective reduction of population exposure to $PM_{2.5}$ through the measures that also reduce GHG emissions. The Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) model was applied to help prioritize the technical measures to improve air quality by ranking them according to their cost per unit of reduction of mean population exposure to $PM_{2.5}$ across Kazakhstan. The results (Figure 2) suggest that the most significant and low-cost progress toward better air quality can be achieved by replacing individual coal stoves and boilers with connections to improved district heating and conversion to natural gas or liquified petroleum gas (LPG), briquettes, or heat pumps. Improving building energy efficiency integrated with such measures reduces investment costs and fuel use by new heating sources. Waste management, especially elimination of burning of agricultural waste and increasing of recycling rates, also shows potential for synergies between air pollution and climate mitigation at a relatively low cost. Therefore, even though priority sources and measures to improve air quality are often different from those that are critical for climate mitigation, opportunities for synergies between air quality and climate change mitigation exist as most measures considered in the analysis improve air quality and reduce GHG emissions at the same time.

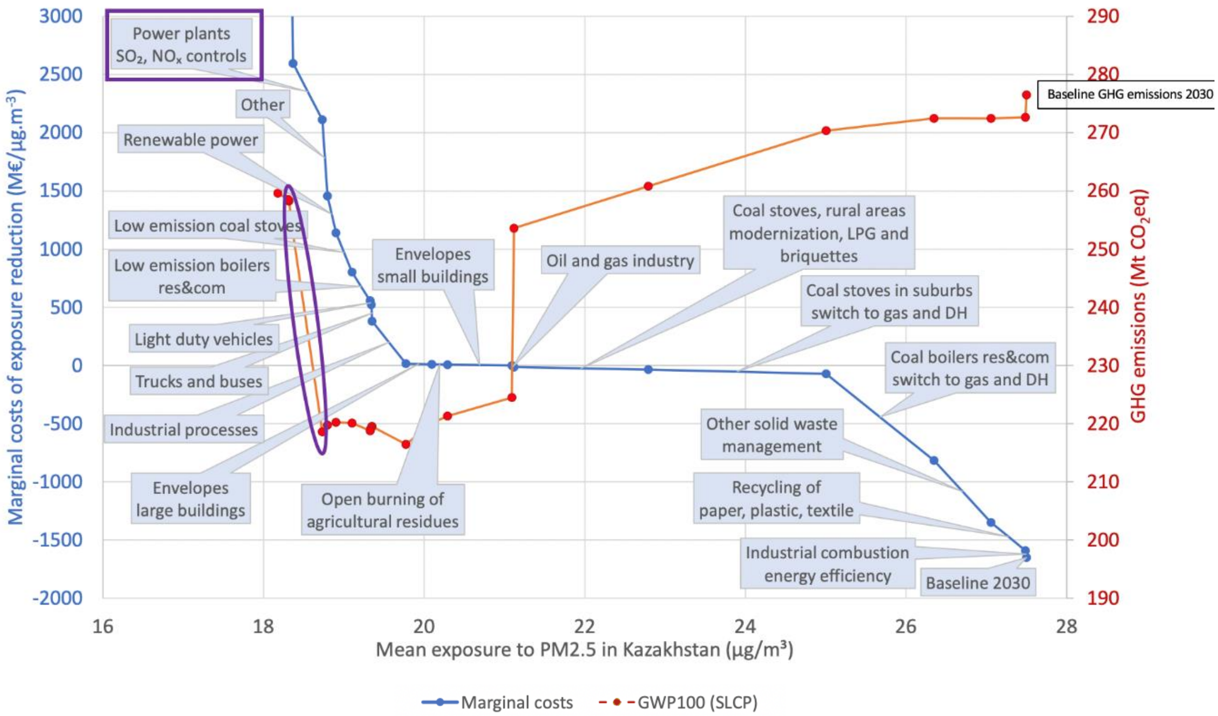
However, some air pollution abatement measures may warm climate. Air pollutant filters installed in the power, industrial, and district heating plants can reduce over 99 percent of air pollution from individual sources but contribute to climate warming, because of increased internal use of energy by the plant to run the filters and reduced emissions of sulfates and nitrates, which have a cooling effect on climate. Sulfites and nitrates reflect nearly all radiation they encounter and thus are potent climate coolants. The climate disbenefits of these measures are small compared to Kazakhstan NDC commitments but may cancel out most of the climate mitigation co-benefits of other air pollution reduction measures (Figure 2). The air pollution abatement measures through end-of-pipe technologies have higher marginal costs of air quality improvement on average in Kazakhstan (although they can be cost-effective in specific areas), so their contribution is important at the 'last miles' of the AQM programs. Because of their relatively high costs, installation of end-of-pipe air pollution abatement equipment is usually integrated with deep retrofitting of the existing coal plants. Such retrofits would lock in coal power plants in the electricity system for decades. Therefore, effective climate policies (for example, carbon pricing) are needed for the plant operators to recognize both local and global environmental costs of their installations when they make investment decisions whether to retrofit existing coal assets and make them locally clean or retire them and switch to new, low-carbon assets.

Another potentially important air pollution abatement measure with climate disbenefits is switching from biomass burned by a part of the population for heating in winter to natural gas, electricity, district heating, or briquettes. Fuel switch from biomass to cleaner fossil fuels was not simulated in these GAINS model runs because of the uncertain data about biomass use by urban and peri-urban households. The switch from biomass to natural gas can quickly improve air quality where it is most needed but with some small negative impact on climate as it represents conversion from renewable energy to fossil fuels. Such tensions do not justify inaction on any of these environmental crises but require integrated application of coherent air quality and climate policy instruments to ensure that one environmental problem is not solved by aggravating another.

Electricity and heat generation, industry, and transport contribute relatively little to mean air pollution exposure in the country, with possible exceptions in select cities, but are key to national NDC pledges. This is also an area where trade-offs between air pollution and climate mitigation measures can be significant and need to be managed by coherent policies. Large coal-fired combustion plants are the largest emitters, on a mass basis, especially for SO_2, NOx, and PM but are much less important than small heating boilers and stoves to winter smog in the majority of Kazakhstan's cities. In some places/cities,[7] however, these large emission sources may disproportionally contribute to both background pollution throughout the year and peak pollution during winter smog, especially when industrial emissions are trapped by the temperature inversion events that are more common in colder seasons. Conversion of large coal-fired installations to natural gas—and in the longer term to renewable electricity—would have clear synergies for both environmental problems. It can be integrated into the long-term decarbonization strategy of Kazakhstan. But the near-term role of natural gas in improving air quality is limited because gas is not available in the industrialized northern parts of the country, and reliable solar or wind electricity would require massive grid infrastructure. Strategic choices related to developing large-scale infrastructure, whether for natural gas or for a power grid to integrate solar and wind power, can be tough for the vast and sparsely populated country and is beyond the scope of this analysis.

[7] City-level dispersion modeling was not conducted as part of this scoping study.

Figure 2: Marginal cost curve for reducing population exposure to $PM_{2.5}$ in Kazakhstan in 2030 and the impacts of the air pollution abatement measures on GHG emissions



Source: GAINS model.

Figure 2 Note:

GHG emissions are expressed as Mt of CO_2 equivalent using the Global Warming Potential over 100 years (GWP_{100}) metric that accounts for short-lived climate pollutants (SLCPs) impacts over a 100-year time horizon. The blue schedule represents a marginal air pollution abatement cost curve for Kazakhstan with a potential to reduce mean exposure to $PM_{2.5}$ on the horizontal axis and a cost of reducing exposure by one unit on the vertical left (blue) axis. The red schedule represents the impact of air pollution technical abatement measures on national GHG emissions (right red) axis. The curves should be read from right to left. The first dot to the right on the blue schedule represents projected baseline $PM_{2.5}$ mean exposure in Kazakhstan in 2030, whereas the first dot to the right on the red schedule represents projected baseline GHG emissions in Kazakhstan in 2030.

Each dot moving from right to left on both schedules represents a modeled measure to improve air quality (blue curve) and its respective impact on GHG emissions (red curve). The down-sloping red curve means an air pollution measure also reduces GHG emissions (synergy), while the upward-sloping red schedule implies a trade-off.

The figure shows that reducing mean national exposure from 28 µg/m³ to 18.5 µg/m³ can have a number of climate co-benefits. The measures showing the largest potential for cost-effective reduction of both mean $PM_{2.5}$ population exposure and GHG emissions are: i) replacing individual coal stoves and boilers with connections to improved district heating and conversion to natural gas or liquified petroleum gas (LPG), briquettes, or heat pumps, ii) improving building energy efficiency, and iii) improving waste management. The air quality measure showing the main GHG emission trade-off is installation of emission control equipment at power plants (highlighted in purple). The switch from biomass to gas/LPG was not included among available abatement measures in this model run and would increase trade-offs.

Toward Integrated Air Pollution and Climate Mitigation Policies

AQM programs need to be designed at the subnational level, focusing on the most polluted and densely populated areas. The 10 most polluted cities in Kazakhstan have unique weather conditions, topography, and pollution sources contributing to winter smog. Available abatement measures also differ depending on such factors like availability of gas, for instance. This analysis provides the first high-level evidence to help scope the solutions, but it was conducted for mean population exposure to $PM_{2.5}$ across all of Kazakhstan without modeling air pollution and prioritizing air pollution abatement measures for individual cities. The city-specific analysis of priorities for AQM and their GHG impacts will be the focus of follow-up analytical work and policy dialogue.

Future analysis needs to go beyond technical measures and consider policies and institutions. Achieving significant air quality improvements and paving the way for a long-term decarbonization requires a comprehensive mix of policy instruments that encourage economic agents to choose abatement measures and consider both the short-term health impacts of air pollution and the long-term pathways to a low-carbon economy. Putting a price on carbon without a strong AQM system could encourage measures that increase population exposure to air pollution, just like stringent air pollution policies can lock in coal combustion installations in the absence of the carbon pricing and thus increase contingent fiscal liabilities associated with stranded assets.

State-of-the-art AQM programs rely on a mix of direct regulations (such as emission performance standards, best available technique (BAT) requirements, or urban zoning requirements) with economic and fiscal instruments. Kazakhstan's new Environmental Code effective since July 1, 2021, was an important step toward bringing environmental management in line with global best practice. It introduced mandatory integrated environmental permits (IEPs) based on BAT for the most polluting enterprises. The design of follow-up regulations and technical reference books for BAT should align immediate measures to save lives from air pollution and long-term phase-out of fossil fuels. However, proper institutional functioning will require capacity building. Air quality and climate change are multisectoral and thus require efficient horizontal and vertical coordination among different agencies and government levels to harness synergies and manage trade-offs. The Council on Transition to Green Economy under the President could potentially play this role.

Coherent and integrated policy instruments for AQM and climate change mitigation can save costs by building on synergies and managing trade-offs. There is a need to include both air pollution and climate change into the major national infrastructure programs and strategic documents. In particular, the benefits of health and lives saved from air pollution in major urban centers need to be factored into the national investment strategies in natural gas pipelines and electric power transmission infrastructure. Air pollution in cities due to oil and gas extraction provides a strong local rationale for addressing gas leakage and flaring problems. Moreover, incorporating air quality considerations in Kazakhstan's NDC implementation would provide a major impetus for integrating AQM and climate change mitigation.

The Environmental Code's commitment to the 'polluter pays' principle offers an opportunity for better alignment with the Tax Code. For instance, the system of industrial pollution taxes and charges could be converted from a plethora of small fees serving mainly the role of revenue raisers to fewer fees or taxes on key pollutants designed to incentivize the use of cleaner and more efficient fuels and technologies when and where they are the most needed to protect people's health. Strengthening the Emissions Trading Scheme (ETS) and gradually introducing carbon taxes may also play an important role in maintaining the competitiveness of Kazakhstan's carbon-intensive exports, as the EU and other future export markets may implement the Carbon Border Adjustment Mechanism (CBAM). Fossil fuel subsidy reforms and carbon pricing should be applied jointly with new air pollution taxes to prevent solving one problem by aggravating the other. A detailed policy analysis was beyond the scope of this report but can be conducted as a next step.

1. AIR QUALITY REVIEW

1.1. Air Quality Management

Air quality management (AQM) in Kazakhstan is regulated through the Environmental Code. There is no specific legislation that describes AQM in further detail than what is provided in the Environmental Code. Nevertheless, there are a number of ministerial orders that relate to AQM. For instance, the 2015 Order of the Minister of National Economy No. 168 defines Maximum Allowed Concentrations (MACs) for 683 air quality pollutants. There are two types of MACs—a short-term maximum and a daily average (Table 1). The short-term maximum is compared to the concentrations measured at 20-minute intervals at automatic monitoring stations with continuous monitoring. Every pollutant has a defined hazardous classification from class 1 to class 4, with class 1 being the most hazardous. The order does not prescribe actions if any of the MACs are exceeded as is the case in the European Union (EU), where exceedance of the air quality limit values (LVs) requires the development of local air quality action plans.

Table 1: MACs in Kazakhstan and LVs in the EU of key air quality pollutants

Pollutant	MACs in Kazakhstan[a]		LVs in EU[b]		
	One-time (μg/m³)	24-hour (μg/m³)	Concentration (μg/m³)	Averaging period	Number of permitted exceedances per year
$PM_{2.5}$	160	35	25	1 year	n.a.
PM_{10}	300	60	50	24 hours	35
			40	1 year	n.a.
NO_2	200	40	200	1 hour	18
			40	1 year	n.a.
SO_2	500	50	350	1 hour	24
			125	24 hours	3

Note: PM_{10} refers to particulate matter (PM) with diameter less than or equal to 10 μm and $PM_{2.5}$ refers to PM with diameter less than or equal to 2.5 μm.

a. MACs are given in milligram per cubic meter (mg/m³) in the 2015 Order of the Minister of National Economy No. 168. For easier comparison with EU air quality standards, MACs are converted to μg/m³.

b. EU LVs of key air pollutants are as under Directive 2008/50/EU.

Source: 2015 Order of the Minister of National Economy No. 168 and Directive 2008/50/EU.

Table 1 shows that the daily MAC in Kazakhstan for SO_2 is lower compared to the EU's 24-hour LV. In addition, MACs in Kazakhstan and LVs in the EU for NO_2 define the same concentrations but over different averaging periods—MACs for NO_2 in Kazakhstan are averaged over shorter periods. When it comes to PM concentrations ($PM_{2.5}$ and PM_{10}), Kazakhstan's MACs are higher than the EU's LVs. $PM_{2.5}$ and PM_{10} have come to the fore of attention globally as their negative impacts on human health are better understood. As new research on the detrimental health impacts of $PM_{2.5}$ and PM_{10} has emerged, the EU introduced additional $PM_{2.5}$ objectives that are based on the average exposure indicator (AEI). The AEI is a three-year running annual mean $PM_{2.5}$ concentration averaged over the selected urban background monitoring stations in a given location. EU member states were obliged to undertake measures needed to achieve a $PM_{2.5}$ AEI of 18 μg/m³ by 2020.

The National Hydrometeorological Service of the Republic of Kazakhstan (Kazhydromet) publishes monthly, quarterly, semiannual, and annual reports on the state of the environment, including air quality. In addition, Kazhydromet supports an online platform on its website on which near real-time concentrations of different pollutants in each of the monitoring stations across the country are displayed. The concentration values are color coded to provide an indication of whether or not the concentration is within the acceptable range.

Urban air quality in Kazakhstan is assessed using three indexes: the Standard Index (SI), Highest Frequency (HF), and Air Pollution Index (API_5). The most important and commonly used index is the API_5, which represents the sum of the average daily means of the five most important pollutants divided by the respective MAC values of the different pollutants and benchmarked by a factor related to the MAC value of SO_2.

The SI is defined as the highest measured one-time concentration of a pollutant divided by the one-time MAC of the respective pollutant. The HF represents the share of concentrations that exceeded the MAC from the total number of concentrations.

The final assessment of air quality considers different ranges in the values of the API_5, SI, and HF and groups them into four classes of air pollution, ranging from low to very high as described in Table 2. When there is a contradiction in the values among different indexes, the API_5 is the leading index used for air quality assessment.

Table 2: Air quality assessment in Kazakhstan based on different indexes

Class	Air pollution level	Air quality index	Annual assessment
I	Low	SI	0–1
		HF, %	0
		API_5	0–4
II	Increased	SI	2–4
		HF, %	1–19
		API_5	5–6
III	High	SI	5–10
		HF, %	20–49
		API_5	7–13
IV	Very high	SI	>10
		HF, %	>50
		API_5	≥14

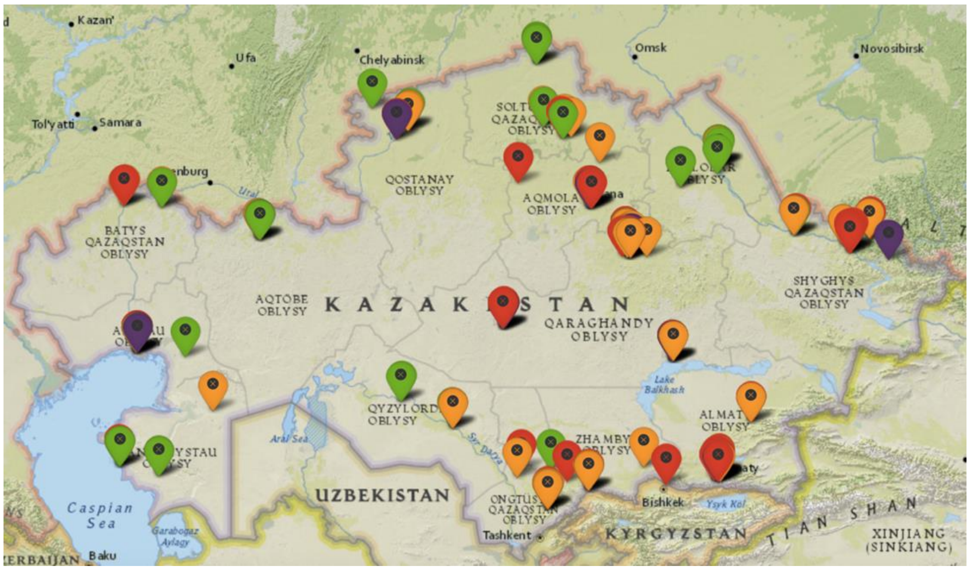
Source: Annex 2, Informational Bulletin 'On the State of the Environment in the Republic of Kazakhstan for 2019'.

The use of three different indexes individually and in combination complicates air quality assessment. The use of indexes also means that the actual measured values are rarely reported. Air quality information presented in such a way can be difficult to understand not just for the average citizen but also for air quality practitioners.

1.2. Air Quality Monitoring

Kazakhstan's air quality monitoring network includes both manual and automatic stations with continuous monitoring. Manual air quality stations measure the level of the different air pollutants by taking samples only three or four times a day (at 7 a.m., 1 p.m., 7 p.m., and 1 a.m.). Automatic air quality monitoring stations (AAQMSs) monitor air pollutants continuously, at 20-minute intervals. In 2019, the network consisted of 84 automatic monitoring stations and 56 manual monitoring stations—a total of 140 monitoring stations, encompassing 45 settlements. There is one background air quality station—Borovoe. In addition, there were 14 mobile air quality monitoring stations. Air quality stations monitored a total of about 35 pollutants, including the key air quality pollutants defined by the World Health Organization (WHO)—PM (PM_{10} and $PM_{2.5}$), nitrogen oxides (NOx), sulfur dioxide (SO_2), and ground-level ozone (O_3).

Figure 3: Kazakhstan's air quality monitoring network in 2019



Source: Kazhydromet.

Since 2013, Kazakhstan's air quality monitoring network has undergone significant expansion and modernization with 63 AAQMSs added to the network. Yet, potential for further expansion remains as some major cities and pollution hot spots still have only one or two AAQMSs. For instance, in 2019, there were only two AAQMSs in Kazakhstan's third largest city and an industrial center—Shymkent with population of more than 1 million at the end of 2019. Compared to the EU criteria for the minimum number of air quality stations at settlements where air quality norms are exceeded, a city the size of Shymkent should have four AAQMSs for pollutants other than PM and six AAQMSs, when monitoring includes PM_{10} and $PM_{2.5}$.[8] In 2019, Almaty had the most air quality stations, 16 (11 automatic and 5 manual), followed by Nur-Sultan, 10 (6 automatic and 4 manual).

1.3. Air Quality Assessment

According to the latest annual Informational Bulletin 'On the State of the Environment in the Republic of Kazakhstan for 2019', there were 10 cities with high air pollution levels in 2019 (Table 3).

Table 3: Air pollution levels in cities in Kazakhstan, 2019

Air pollution class	Cities
I - Low	Kokshetau, Stepnogorsk, Taldykorgan, Kostanay, Rudny, Zhanaozen, Petropavlovsk, Zhanatas, Uralsk, Aksay, Kyzylorda, Ekibastuz, Altay, Aksu, Pavlodar, Saran, Ridder, Glubokoe, Borovoe, Shchuchinskaya-Borovskaya resort, Akay, Toretam, Karabalyk, Beyneu, and Yanvartsevo
II - Increased	Atbasar, Aktau, Kulsary, Semey, Taraz, Karatau, Shu, Turkestan, Kentau, and Korday
III - High	Nur-Sultan, Almaty, Karaganda, Shymkent, Atyrau, Aktobe, Temirtau, Balkhash, Ust-Kamenogordsk, and Zhezkazgan

[8] Directive 2008/50/EC of the European Parliament and of the European Council of May 21, 2008, on ambient air quality and cleaner air for Europe.

Air pollution class	Cities
IV - Very high	—
Source: Annex 2, Informational Bulletin 'On the State of the Environment in the Republic of Kazakhstan for 2019'.	

For this report, air quality data for the 10 cities categorized in Table 3 as cities with high air pollution levels in 2019[9] were requested. The requested data consisted of daily averages in 2017–19.[10] Only data from AAQMSs were analyzed. In addition, the analysis included only data for pollutants and stations for the given year that covered the minimum data coverage standards according to Annex I of EU Directive 2008/50/EU, which stipulates that the minimum data capture for air quality assessment should be at least 90 percent of monitoring data coverage for a given pollutant, that is, monitoring data should be available for at least 328 days per year.

The air quality assessment compared pollutant concentrations at the selected monitoring stations against the air quality standards in both Kazakhstan and the EU. To analyze the air quality data against the EU LVs, annual average concentrations were calculated for some of the pollutants from the provided daily averages. In addition, the analysis focused on the key air quality pollutants highlighted by the WHO: $PM_{2.5}$, PM_{10}, NO_2, and SO_2.

Table 4: Monitored pollutants at selected AAQMSs

City	Number of AAQMS	Received pollutant data from at least one AAQMS
Aktobe	3	$PM_{2.5}$, PM_{10}, SO_2, NO_2, NO, CO, H_2S, and O_3
Almaty[a]	10	SO_2, NO_2, NO, and CO
Atyrau	3	$PM_{2.5}$, PM_{10}, total suspended particles (TSP), SO_2, NO_2, NO, NOx, CO, H_2S, O_3, and NH_3
Balkhash	1	$PM_{2.5}$, PM_{10}, SO_2, NO_2, NO, CO, H_2S, O_3, and NH_3
Karaganda	3	$PM_{2.5}$, PM_{10}, SO_2, NO_2, NO, CO, H_2S, O_3, and NH_3
Nur-Sultan	6	$PM_{2.5}$, PM_{10}, TSP, SO_2, NO_2, NO, CO, and H_2S
Shymkent	2	$PM_{2.5}$, PM_{10}, SO_2, NO_2, NO, CO, H_2S, NH_3, and O_3
Temirtau	1	$PM_{2.5}$, PM_{10}, SO_2, NO_2, CO, and HCOH
Ust-Kamenogorsk[b]	2	TSP, PM_{10}, NO_2, NO, CO, O_3, and NH_3
Zhezkazgan	1	$PM_{2.5}$, PM_{10}, SO_2, NO_2, NO, CO, H_2S, NH_3, and O_3

Note: a. Received data from the AAQMSs in Almaty did not contain data on PM_{10} and $PM_{2.5}$, and hence, those pollutants were not included in the current analysis. However, PM_{10} and $PM_{2.5}$ concentrations for AAQMSs in Almaty are reported on the air quality data portal developed by Kazhydromet (http://apps.kazhydromet.kz:3838/app_dem_visual/).

b. Received data from the AAQMSs in Ust-Kamenogorsk did not contain data on $PM_{2.5}$ and SO_2, and hence, those pollutants were not included in the current analysis. However, $PM_{2.5}$ and SO_2 concentrations for AAQMSs in Ust-Kamenogorsk are reported on the air quality data portal developed by Kazhydromet (http://apps.kazhydromet.kz:3838/app_dem_visual/).
Source: World Bank based on Kazhydromet data.

Kazakhstan's air quality monitoring network has incorporated over 60 AAQMSs since 2013. Some of the AAQMSs started operating in the period covered by the current analysis (2017–19). AAQMSs need proper maintenance and calibration of the monitoring equipment to function optimally. Table 5 summarizes the main issues encountered in the process of analyzing data from AAQMSs.

[9] Usually, the statistic offices in countries report data with a two-year lag.
[10] 2019 was the last full calendar year at the time of writing of this report. The air quality data analysis includes only full years in order to avoid misrepresentation of conclusions and air quality trends.

Table 5: Air quality monitoring data issues

City	Monitoring data coverage and technical issues
Aktobe	• Monitoring data for 2017 from all AAQMSs did not meet the minimum data coverage standards. • PM_{10} and $PM_{2.5}$ are monitored at only one of the 3 AAQMSs. • $PM_{2.5}$ data did not meet the minimum data coverage standards.
Almaty	• The received data did not contain PM_{10} and $PM_{2.5}$ monitoring data. • SO_2 monitoring data did not meet the minimum data coverage requirements at two AAQMSs for 2017 and 2018, whereas SO_2 data coverage was not sufficient for 2017–19 at one AAQMS. • NO_2 monitoring data did not meet the minimum data coverage requirements at one AAQMS for 2017 and 2018. • The first reported monitoring data at two AAQMSs was from the last quarter of 2017.
Atyrau	• Monitoring data for 2017 from all AAQMSs included a number of improbable values and hence were not analyzed. • PM_{10} and $PM_{2.5}$ monitoring data coverage from all AAQMSs was not sufficient in 2019.
Balkhash	• The first reported monitoring data at the AAQMS in Balkhash was from November 2017. • PM_{10} and $PM_{2.5}$ monitoring data coverage was not sufficient in 2018.
Karaganda	• PM_{10} and $PM_{2.5}$ monitoring data for 2017 did not meet the minimum data coverage standards. • Only one of the three AAQMSs had sufficient PM_{10} and $PM_{2.5}$ data coverage for 2019. However, a number of improbable PM_{10} and $PM_{2.5}$ values were reported at this AAQMS, and hence, PM_{10} and $PM_{2.5}$ data for 2019 were not analyzed.
Nur-Sultan	• PM_{10} and $PM_{2.5}$ monitoring data for 2017 and 2018 from all AAQMSs did not meet the minimum data coverage standards. • Three AAQMSs started reporting data in July 2018.
Shymkent	• PM_{10} and $PM_{2.5}$ monitoring data for the entire analyzed period 2017–19 from all AAQMSs did not meet the minimum data coverage standards. • Monitoring data for 2017 from all AAQMSs did not meet the minimum data coverage standards. • SO_2 monitoring data did not meet the minimum data coverage requirements for the entire analyzed period 2017–19.
Temirtau	• PM_{10} and $PM_{2.5}$ monitoring data for 2017 and 2018 from the only AAQMS did not meet the minimum data coverage standards. • SO_2 monitoring data did not meet the minimum data coverage requirements for 2017.
Ust-Kamenogorsk	• The received data did not contain $PM_{2.5}$ and SO_2 monitoring data. • PM_{10} monitoring data for 2017 from all AAQMSs did not meet the minimum data coverage standards.
Zhezkazgan	• Monitoring data for 2017 did not meet the minimum data coverage standards. • PM_{10} and $PM_{2.5}$ monitoring data for the entire analyzed period 2017–19 from the only AAQMS did not meet the minimum data coverage standards. • SO_2 monitoring data did not meet the minimum data coverage requirements for 2018 and 2019.
Source: World Bank.	

The main issue encountered during the analysis of data from the selected AAQMSs was data coverage (Table 5). The analysis of air quality monitoring data revealed that the EU minimum data coverage standards were not met for some pollutants and, in some years, even for all pollutants at all AAQMSs from which data was received. In terms of pollutant coverage, PM_{10} and $PM_{2.5}$ monitoring data had the most associated issues, followed by SO_2 monitoring data. At some AAQMSs, monitoring data reported improbable values and were excluded from the current analysis to ensure credibility. Because of these issues with the air quality monitoring data from AAQMSs, analysis from the Informational Bulletin 'On the State of the Environment in the Republic of Kazakhstan for 2019', which reported aggregated data that also includes manual air quality stations, was additionally utilized.

1.3.1. PM_{10} and $PM_{2.5}$

From a health perspective, particulate matter is one of the key air quality pollutants. Recent research has shown that the smaller fractions of particulate matter—PM_{10}, but especially $PM_{2.5}$ and even PM_1[11] are the most dangerous to human health. The smaller fractions of particulate matter have been shown to be able to pass even into the bloodstream, thus causing problems beyond the respiratory system. As PM_{10} and $PM_{2.5}$ are different-sized fractions of the same pollutant/particulate matter, and since $PM_{2.5}$ is included in PM_{10}, the two pollutants are discussed together.

Considering that not all AAQMSs in the selected cities monitored PM_{10} and $PM_{2.5}$, as well as that the data coverage at some AAQMSs did not meet the minimum requirements of the 90 percent data coverage (Table 5), high levels of PM_{10} and/or $PM_{2.5}$ in 2017–19 were found in the following cities with sufficient PM_{10} and $PM_{2.5}$ data coverage: Aktobe, Balkhash, Karaganda, Nur-Sultan, Temirtau, and Ust-Kamenogorsk.

Table 6: Highest calculated PM_{10} and $PM_{2.5}$ annual average concentrations at AAQMSs in the sample cities, 2017–19

City	Calculated PM_{10} annual average		Calculated $PM_{2.5}$ annual average	
	Highest annual average (μg/m³)	Year	Highest annual average (μg/m³)	Year
Aktobe	**53.2**	2019	n.a.	n.a.
Almaty	n.a.	n.a.	n.a.	n.a.
Atyrau	33.3	2018	18.8	2018
Balkhash	**50.5**	2019	**48.6**	2019
Karaganda	**75.7**	2018	**73.3**	2018
Nur-Sultan	**50.3**	2019	**39.8**	2019
Shymkent	n.a.	n.a.	n.a.	n.a.
Temirtau	**44.6**	2019	**44.2**	2019
Ust-Kamenogorsk	**178.5**	2018	n.a.	n.a.
Zhezkazgan	n.a.	n.a.	n.a.	n.a.

Note: Bolded values exceed the EU LV.
Source: Original calculations for this publication.

The available monitoring data from AAQMSs in the selected cities shows that $PM_{2.5}$ and PM_{10} pollution is an issue for most of the cities in the sample. In addition, the Informational Bulletin 'On the State of the Environment in the Republic of Kazakhstan for 2019' summarizes data from all air quality stations, including manual stations, in Kazakhstan and highlights that $PM_{2.5}$ and PM_{10} pollution occurs in all other cities, for which a sample PM_{10} and $PM_{2.5}$ monitoring from AAQMSs was not available or the data coverage was not sufficient. Therefore, it can be concluded that $PM_{2.5}$ and PM_{10} pollution is problematic for all of the selected cities in the current analysis.

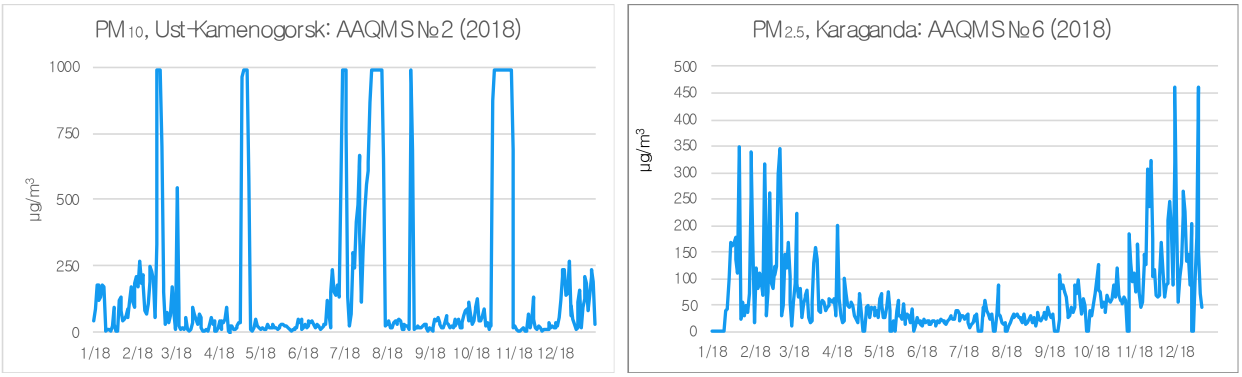
In 2018, the highest annual average PM_{10} concentration was calculated for Ust-Kamenogorsk, while the highest annual average $PM_{2.5}$ concentration was calculated for Karaganda (Figure 4). It is likely that in Ust-Kamenogorsk in 2019, the annual $PM_{2.5}$ concentration would also have been high had that pollutant been monitored at the AAQMSs.

On the other hand, the highest number—160—of days with exceedance of both the Kazakhstan and EU 24-hour LVs was recorded in Balkhash in 2019. Overall, more than the allowed 35 exceedances of the 24-

[11] PM_1 refers to PM with diameter less than or equal to 1 μm.

hour EU LV were also reported at AAQMSs with sufficient data coverage in Aktobe, Atyrau, Karaganda, Nur-Sultan, Temirtau, and Ust-Kamenogorsk.

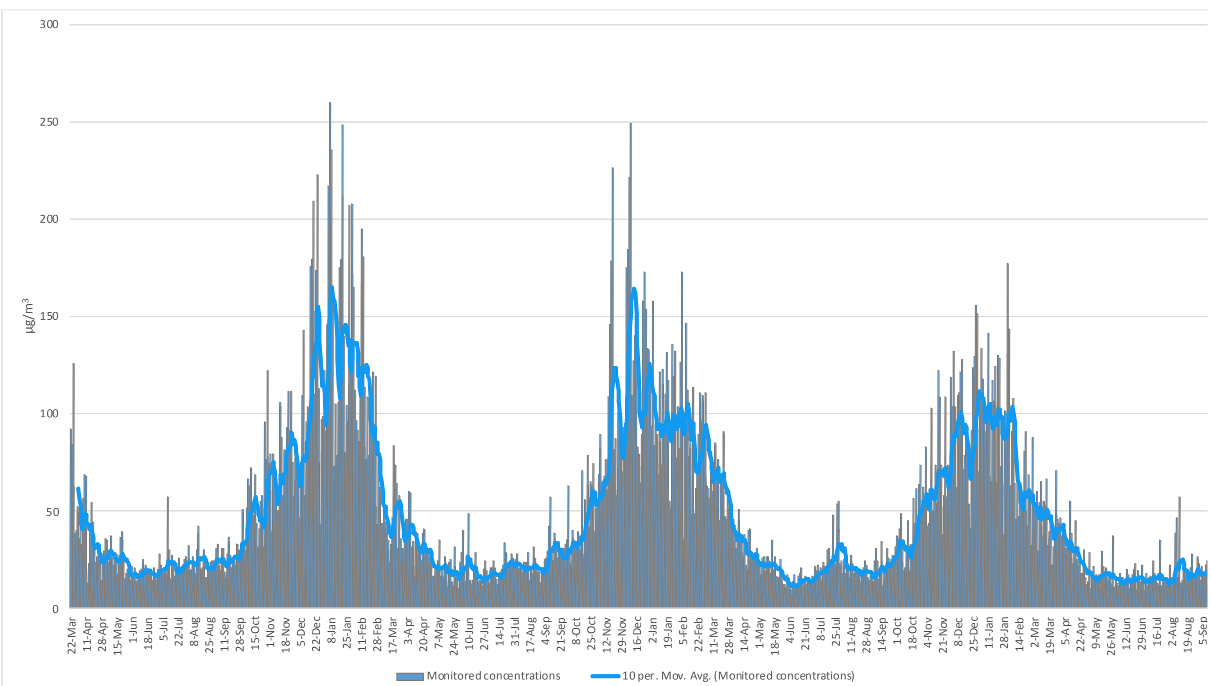
Figure 4: Daily average concentrations of PM_{10} in Ust-Kamenogorsk (left) and $PM_{2.5}$ in Karaganda (right), 2018



Source: Original figures for this publication.

It is important to consider PM exposure in Almaty—Kazakhstan's largest city. Table 4 shows that the received air quality data for Almaty did not include PM_{10} and $PM_{2.5}$ monitored at AAQMSs. Nevertheless, there are about 40 air quality sensors that monitor $PM_{2.5}$ installed throughout Almaty as part of the citizen initiative AirKaz. Figure 5 shows the $PM_{2.5}$ daily average concentrations from those sensors.

Figure 5: $PM_{2.5}$ concentrations from 40 sensors in Almaty, March 2017–September 2020



Source: AirKaz.

Table 7: Maximum 24-hour average PM_{10} concentrations reported at AAQMSs in selected cities, 2018 and 2019

City	Date of highest recorded PM_{10} 24-hour average concentration	
	2018	2019
Aktobe	November 11	March 23
Almaty	n.a.	n.a.
Atyrau	May 8	March 17
Balkhash	n.a.	July 27
Karaganda	December 16	December 16
Nur-Sultan	March 18	January 6
Shymkent	n.a.	n.a.
Temirtau	n.a.	December 12
Ust-Kamenogorsk	Daily average of 985 µg/m^3 in February, April, July, August, and October	Daily average of 985 µg/m^3 in March, July, November, and December
Zhezkazgan	n.a.	n.a.

Source: Kazhydromet.

In Karaganda, $PM_{2.5}$ concentrations exhibit a clear seasonal pattern with higher concentrations in the winter months when residential heating on solid fuels has an additional impact on air quality (Figure 4). On the other hand, monitoring data from Ust-Kamenogorsk show some seasonality in PM_{10} concentrations but also have clear peaks in daily concentrations even outside of the heating season. The validity of some of the data for Ust-Kamenogorsk should be verified as there are over 30 concentrations throughout 2018 of exactly 985 µg/m^3, which might represent an error or indicate that the equipment's maximum detection limit may have been reached. Ust-Kamenogorsk is located in a major mining and smelting area, and thus, particulate matter emissions from industry are also a likely contributor to peaks in PM_{10} concentrations.

Other cities that are near heavy industry enterprises also record peaks in PM_{10} and $PM_{2.5}$ outside of the winter season. Table 7 shows the maximum 24-hour average concentrations at AAQMSs in selected cities. The majority of the concentrations occurred in winter. Similarly, data from 40 air quality sensors in Almaty show marked winter peaks in $PM_{2.5}$ concentrations, thus, highlighting that building-level residential heating on solid fuels is a likely major source that contributes to high $PM_{2.5}$ concentrations (Figure 5).

1.3.2. NO_2

Exposure to nitrogen dioxide (NO_2) has been associated with reduced lung functioning and symptoms of bronchitis in asthmatic children. In addition, NO_2 is a significant source of $PM_{2.5}$ aerosol and ozone (in the presence of ultraviolet light).

Data from the AAQMSs in the selected cities (Table 5) subject to data coverage limitations show that Almaty, Shymkent, and Temirtau had the highest NO_2 concentrations, which also exceeded the average annual NO_2 LV in the EU in 2017–19. Average annual concentrations at 7 out of 10 AAQMSs in Almaty were higher than the EU LV in at least one year in 2017–19. However, the highest annual average NO_2 concentration in 2017–19 was recorded in Temirtau (Table 8).

Table 8: Highest calculated annual average concentrations of NO_2 in selected cities, in 2017–19

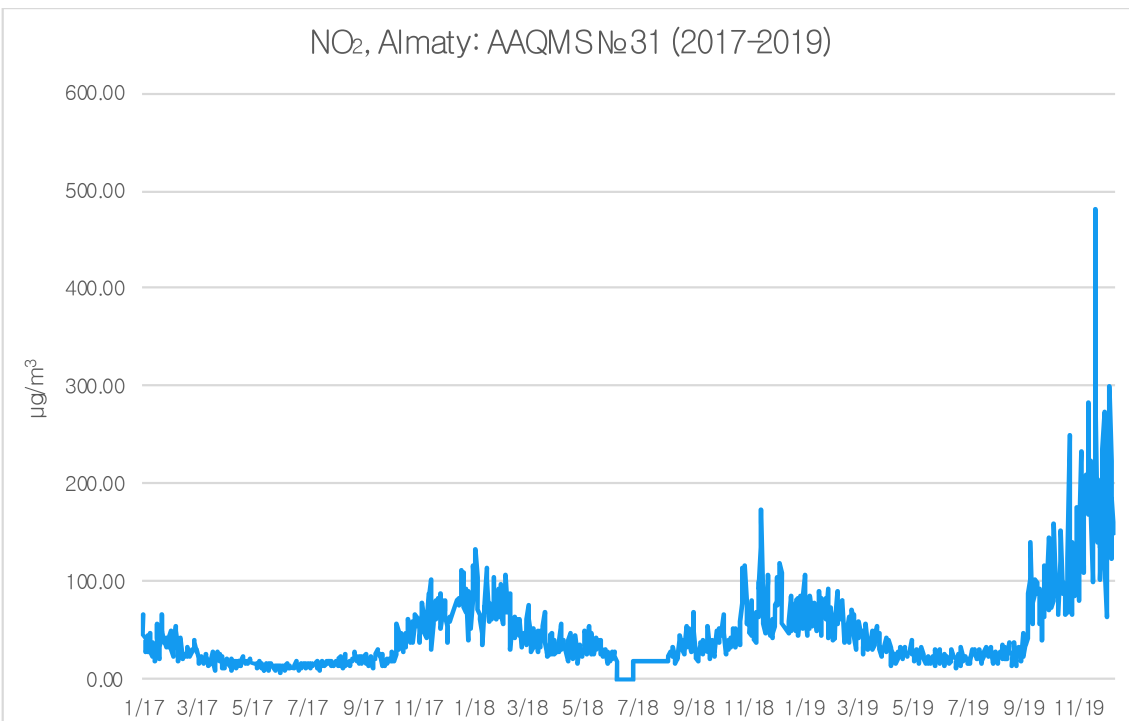
City	Highest calculated annual average (μg/m³)	Year	Maximum 24-hour average concentration (μg/m³)	Date of maximum 24-hour average concentration
Almaty	63.5	2019	480.8	December 10, 2019
Shymkent	63.4	2018	311.8	December 8, 2019
Temirtau	131.0	2019	1,355.2	March 13, 2019

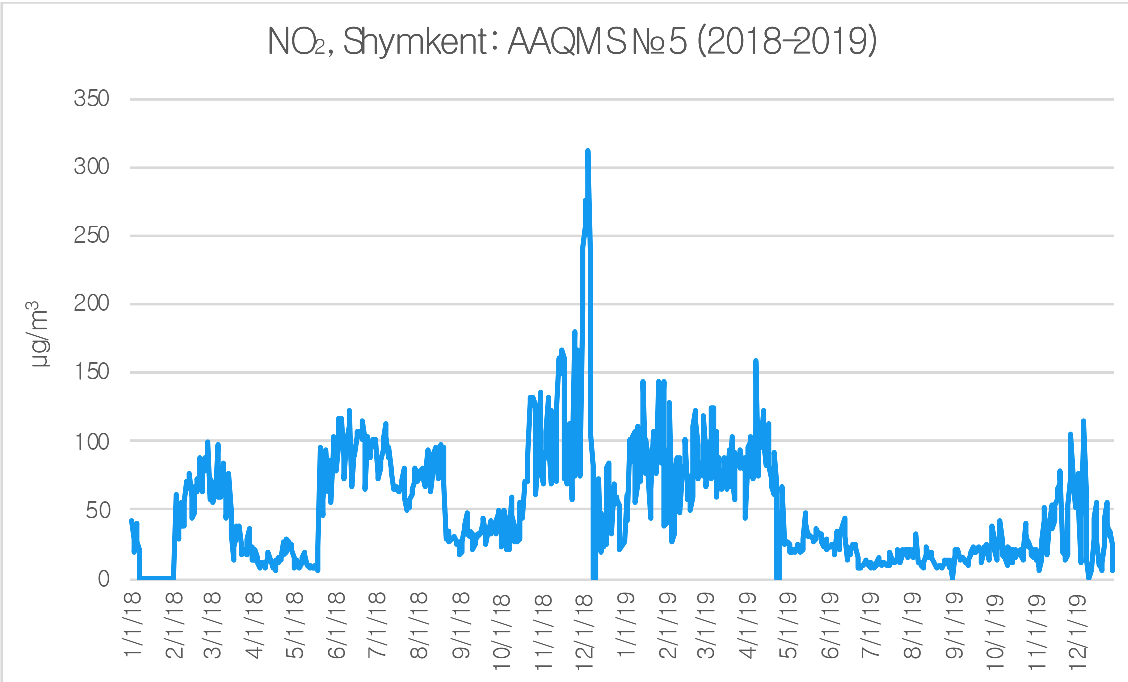
Source: Original calculations for this publication.

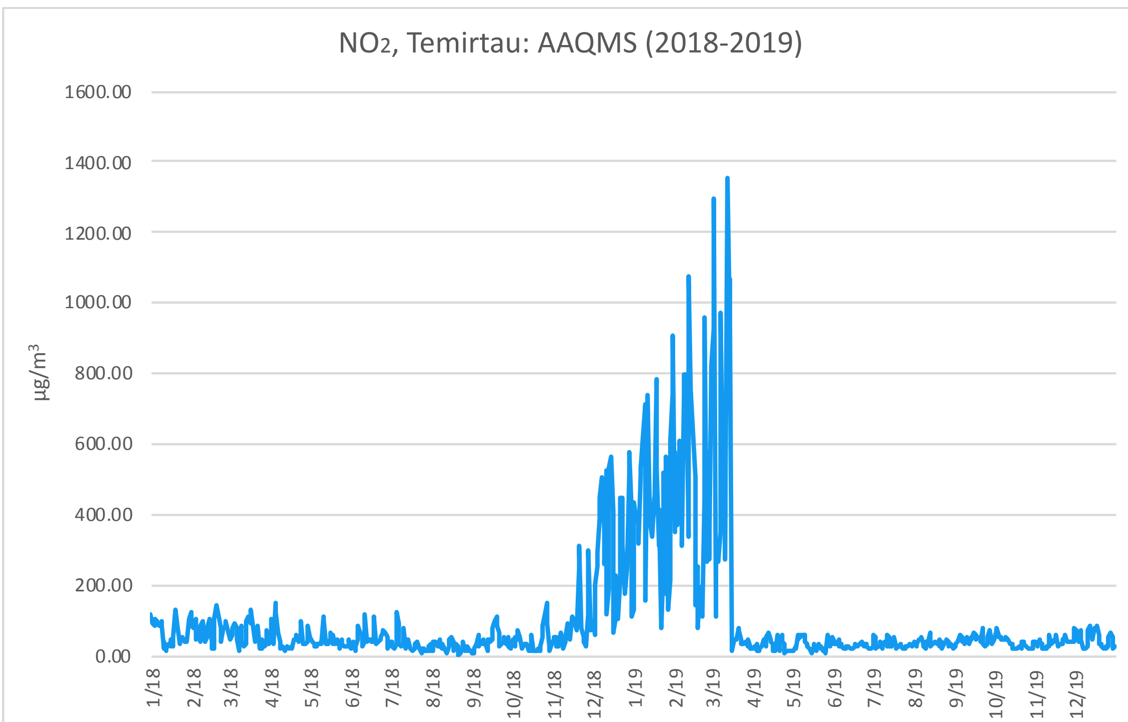
Almaty and Shymkent are the largest and third largest, respectively, cities in Kazakhstan. At the end of 2019, Almaty's population was nearly 2 million, whereas Shymkent's population was just over 1 million. Almaty is the city with the most registered passenger vehicles in Kazakhstan—nearly 470,000 at the end of 2019. Given the level of pollution control technology currently in place, transport is a likely source of NO_2 emissions. Other important sources of NO_2 emissions are industrial processes, which are a probable cause for the high NO_2 concentrations in Temirtau—a center for heavy industry.

Small-scale combustion for residential heating also has an impact on NO_2 concentrations. NO_2 concentrations at the AAQMSs with the highest annual average concentration in Almaty show a seasonal pattern with higher concentrations in the winter (Figure 6). The maximum 24-hour average NO_2 concentrations in Almaty, Shymkent, and Temirtau were all reported in the winter months in 2017–19 (Table 8).

Figure 6: 24-hour average concentrations of NO_2 at select AAQMSs in Almaty (top), Shymkent (middle), and Temirtau (bottom)







Source: Original figures for this publication.

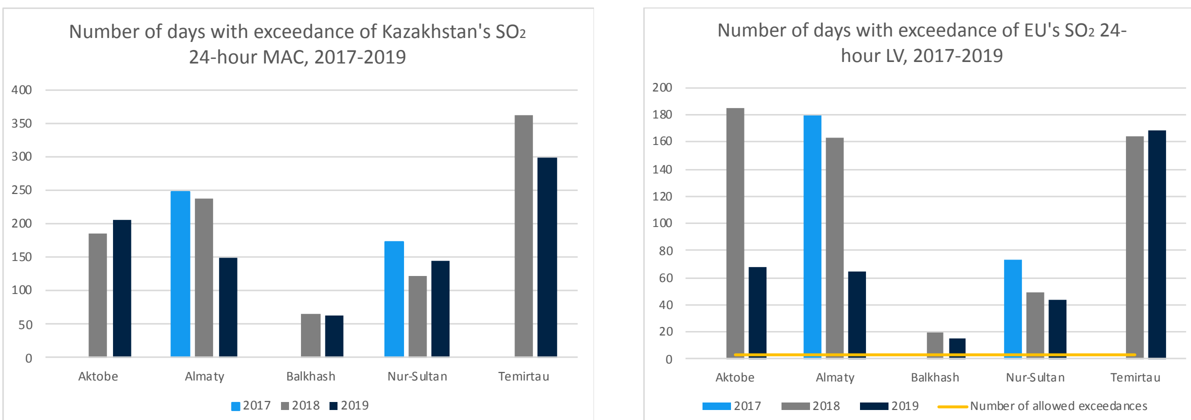
Data from the Informational Bulletin 'On the State of the Environment in the Republic of Kazakhstan for 2019', which also includes monitoring data from manual stations, reports high levels of NO_2 in Ust-Kamenogorsk and elevated levels of NO_2 in Nur-Sultan and Karaganda in 2019.

1.3.3. SO_2

Exposure to sulfur dioxide (SO_2) is harmful to the respiratory system, damages lung function, and can cause eye irritation. Formed by SO_2 combined with water, sulfuric acid is the major component in acid rain, which is a cause of deforestation and negative impacts to aquatic and wildlife ecosystems. In addition, SO_2 is an important precursor of $PM_{2.5}$.

Air quality data obtained from the selected AAQMSs were analyzed against Kazakhstan's 24-hour MAC and the EU's 24-hour LV. In 2017–19, both Kazakhstan's and the EU's 24-hour LV for SO_2 were exceeded in: Aktobe, Almaty, Balkhash, Nur-Sultan, and Temirtau (Figure 7). The EU's 24-hour LV is lower than Kazakhstan's 24-hour MAC (Table 1). However, the EU legislation allows the 24-hour LV to be exceeded up to three times per year.

Figure 7: Highest number of days with exceedance of Kazakhstan's 24-hour MAC (left) and EU's 24-hour LV (right) for SO_2, 2017–19



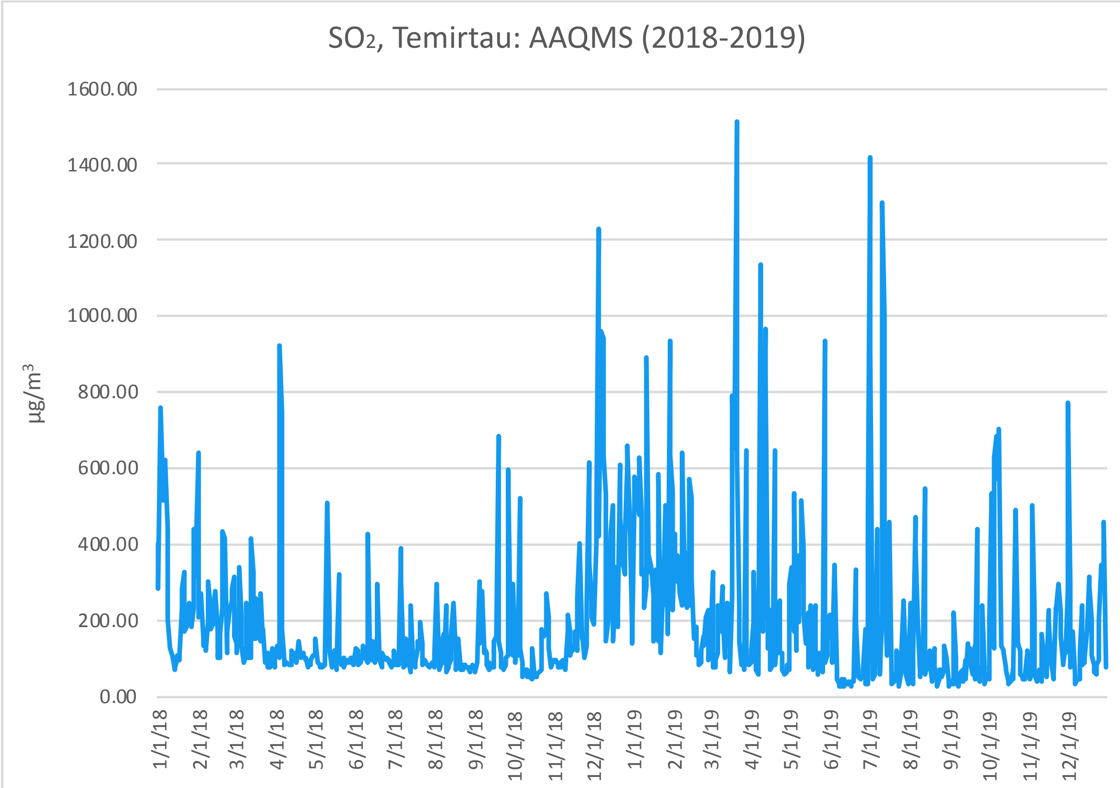
Source: Original figures for this publication.

The main source of anthropogenic SO_2 globally is the burning of sulfur-containing fossil fuels for power generation, industrial processes, or residential heating. The city with the greatest number of days with exceedance of Kazakhstan's 24-hour MAC was Temirtau, which is a center of heavy industry (Figure 7). Source*: Original figure for this publication.*

Table 9 shows that the maximum SO_2 daily concentration for 2017–19 was measured in Aktobe—another important industrial region in Kazakhstan. In addition, Source: *Original figure for this publication.*

Table 9 demonstrates that the majority of maximum SO_2 daily concentrations was measured in winter, a likely consequence of the burning of coal for residential heating.

Figure 8: 24-hour SO_2 concentrations in Temirtau, 2018–19



Source: Original figure for this publication.

Table 9: Maximum 24-hour average SO_2 concentrations reported at AAQMSs in select cities, 2017–19

City	Maximum recorded 24-hour SO_2 concentration (µg/m^3)	Date
Aktobe	2,213.0	September 21, 2018
Almaty	1,160.5	April 23, 2018
Balkhash	675.0	November 10, 2018
Nur-Sultan	1,011.8	December 22, 2019
Temirtau	1,509.7	March 21, 2019
Source: Kazhydromet.		

In addition to the cities discussed above, the Informational Bulletin ‘On the State of the Environment in the Republic of Kazakhstan for 2019’ reports high levels of SO_2 in Ust-Kamenogorsk in 2019 based on monitoring data from manual stations.

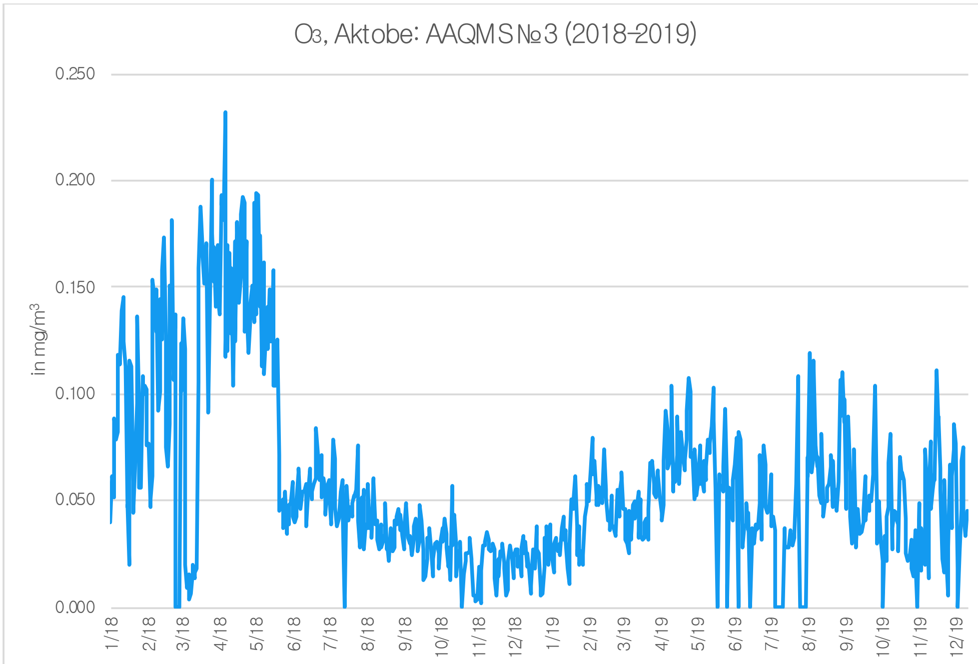
1.3.4. Other Pollutants

Kazakhstan’s air quality network monitors about 35 different pollutants. According to the Informational Bulletin ‘On the State of the Environment in the Republic of Kazakhstan for 2019’, extremely high levels of hydrogen sulfide (H_2S) have been recorded in Atyrau in 2019. High H_2S concentrations were also recorded in Aktobe, Temirtau, and Ust-Kamenogorsk—areas with heavy industry and/or oil refining activities.

Concentrations above Kazakhstan's 24-hour MAC for carbon monoxide (CO) were recorded in Aktobe, Almaty, Balkhash, Karaganda, Nur-Sultan, Shymkent, and Ust-Kamenogorsk. CO is a general marker of combustion which can be related to residential heating, transport, and industry.

In 2019, the levels of ground-level ozone (O_3) were high in Aktobe, Balkhash, Karaganda, and Zhezkazgan (Figure 9). O_3 concentrations were also elevated in Shymkent and Ust-Kamenogorsk.

Figure 9: 24-hour O_3 concentrations in Aktobe, 2018–19



Source: Original figure for this publication.

Figure 9 shows the seasonality in the daily O_3 concentrations in Aktobe in 2018–19 with higher concentrations registered in spring and early summer.

1.4. Air Quality and Health

Protection of human health is the primary driver of ambient air quality standards and expanded air quality monitoring. The WHO has declared air pollution as the largest single environmental health risk.[12] The importance of air quality to human health was emphasized even further at the Third United Nations (UN) High-Level Meeting on Noncommunicable Diseases (NCD) in September 2018 when air quality was introduced as one of the risk factors for NCDs.[13] NCDs such as cardiovascular diseases, cancer, and respiratory diseases were the leading causes of death in Kazakhstan in 2016.[14]

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[12] WHO. 2014. "Media Center News Release." https://www.euro.who.int/__data/assets/pdf_file/0019/341137/Fact-Sheet-10-Better-air-for-better-health.pdf.

[13] UN. 2018. "Third United Nations High-level Meeting on NCDs." https://www.unscn.org/en/news-events/recent-news?idnews=1835.

[14] UNECE (United Nations Economic Commission for Europe). 2019. *Kazakhstan: Environmental Performance Reviews - Third Review.* https://www.unece.org/environmental-policy/environmental-performance-reviews/enveprpublications/environmental-performance-reviews/2019/3rd-environmental-performance-review-of-kazakhstan/docs.html.

A 2020 World Bank study estimated that $PM_{2.5}$ pollution alone caused 9,360 premature deaths in 2016 and costs the economy more than $7.1 billion annually.[15] The latest State of Global Air data on mortality related to ambient air quality shows that in 2019 in Kazakhstan,[16] ambient $PM_{2.5}$ pollution accounted on average for 67 deaths per 100,000 whereas estimates in Kazakhstan's Concept for Transition to Green Economy suggest that air pollution causes up to 6,000 premature deaths per year.

Various studies have highlighted the impacts of air pollution on health in different cities in Kazakhstan. One study[17] illustrates the high prevalence of chronic obstructive pulmonary disease (COPD) in Nur-Sultan (in 67 people per 1,000), while another[18] links COPD with high concentrations of NO_2 in Temirtau, Ust-Kamenogorsk, and Aktau. A 2019 study[19] found high hazard indexes for both chronic and acute exposure of the respiratory organs to different air pollutants in all 26 cities in Kazakhstan that were analyzed. A 2013 study[20] concludes that the highest impact on premature mortality attributable to $PM_{2.5}$ pollution is in Almaty. In addition, this study also estimated the mean mortality risk attributable to air pollution to be around 16,000 cases per year.

A 2013 World Bank report estimated that reducing PM concentrations by as little as 1 μg/m^3 can bring annual health cost savings of around $57 million.[21] The health cost savings are due to the reduction in premature mortality and in the number of days of absence from work. Table 10 provides the breakdown of health cost savings estimated in the study.

Table 10: Potential health cost savings from reducing PM_{10} and $PM_{2.5}$ concentrations

Ambient PM concentration reduction (μg/m^3)	Potential annual health cost savings ($, millions)
1	57
5	275
10	514
15	762
20	1,011
Source: World Bank.	

[15] World Bank. 2020. *The Global Cost of Ambient PM2.5 Air Pollution*. Report No: AUS0001948. Washington, DC: World Bank. http://documents1.worldbank.org/curated/en/202401605153894060/pdf/World-The-Global-Cost-of-Ambient-PM2-5-Air-Pollution.pdf.
[16] https://www.stateofglobalair.org/data/#/health/plot.
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2. MAIN EMISSION SOURCES

This chapter reviews the main emission sources responsible for air pollution which, in many cases, are also significant sources of greenhouse gases (GHGs). There are important overlaps between significant sources that contribute to both air pollution and GHG emissions. Therefore, in some cases, the issues of air quality and climate change mitigation can successfully be tackled simultaneously using holistic approaches.

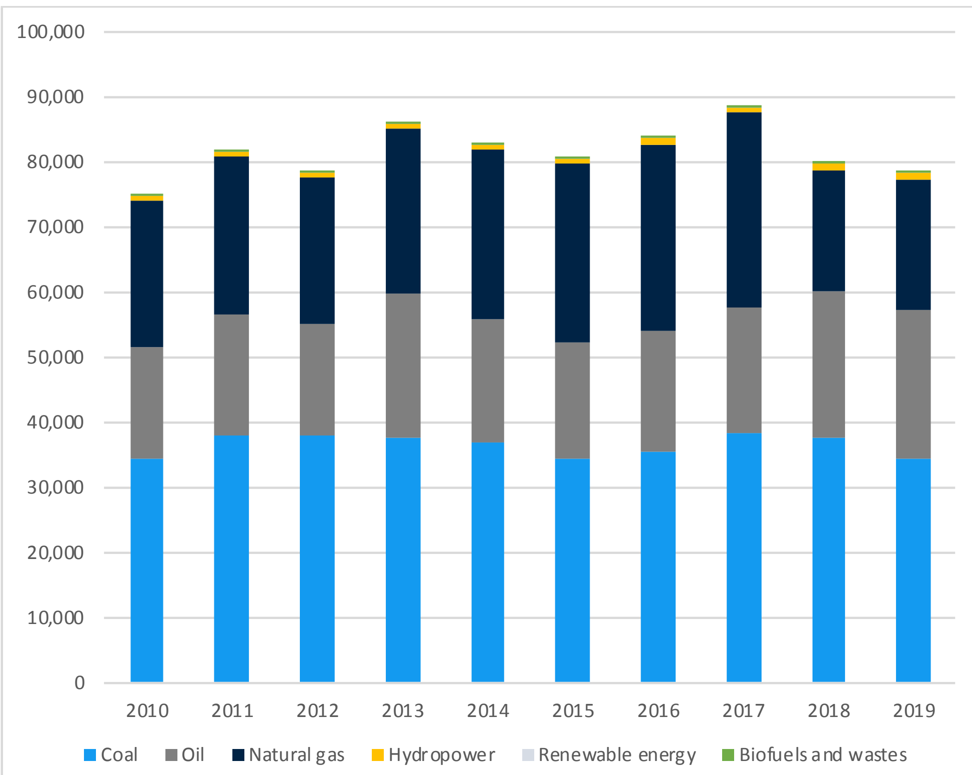
Kazakhstan is a major producer of solid fuels. According to the United Nations Economic Commission for Europe (UNECE), Kazakhstan is the world's tenth and twelfth largest producer of coal and oil, respectively.[22] Considering such availability of fossil fuels in Kazakhstan, this chapter provides an overview of the energy production context in the country before considering the main emissions sources.

2.1. Energy Profile

2.1.1. Energy Supply

Kazakhstan's total energy production in 2019 was nearly 167 million tons of oil equivalent (Mtoe), out of which about 73 Mtoe was consumed domestically. Over 95 percent of primary energy was supplied by fossil fuels: coal, oil, and natural gas (Figure 10).

Figure 10: Total primary energy supply, 2010–19, in thousand tons of oil equivalent (toe)



Source: Bureau of National Statistics Kazakhstan.

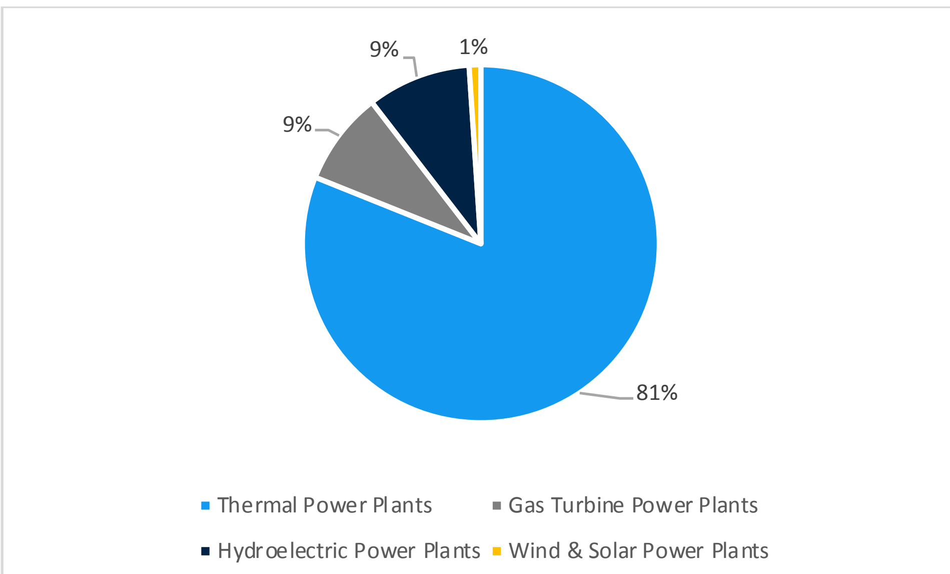
[22] UNECE. 2019. "Kazakhstan: Environmental Performance Reviews - Third Review." https://www.unece.org/environmental-policy/environmental-performance-reviews/enveprpublications/environmental-performance-reviews/2019/3rd-environmental-performance-review-of-kazakhstan/docs.html.

The main consumer of primary energy in Kazakhstan is power plants, producing electricity and heat to serve end users. In 2019, around 106 million kilowatt hours (kWh) of electricity and 105 million kWh of heat were generated. Nearly 30 percent of the generated electricity was produced in combined heat and power (CHP) plants. In addition, district heating plants, including CHPs, were responsible for nearly 60 percent of total heat production.

In 2019, 80 percent of the electricity was produced in thermal power plants burning coal, while 9 percent of the electricity was produced in gas-fired power plants. Thus, fossil fuel combustion was responsible for nearly 90 percent of all electricity produced in Kazakhstan.

Renewable energy sources (RESs) accounted for 10.4 percent of the total electricity production in 2019 with a 9.4 percent share of hydropower and 1 percent share of solar and wind combined. In terms of heat production, the share of RESs in total heat production was 0.13 percent. More than 35 percent of the heat is generated in CHP plants, the majority of which are over 35 years old.

Figure 11: Share of fuels in electricity generation, 2019, in %

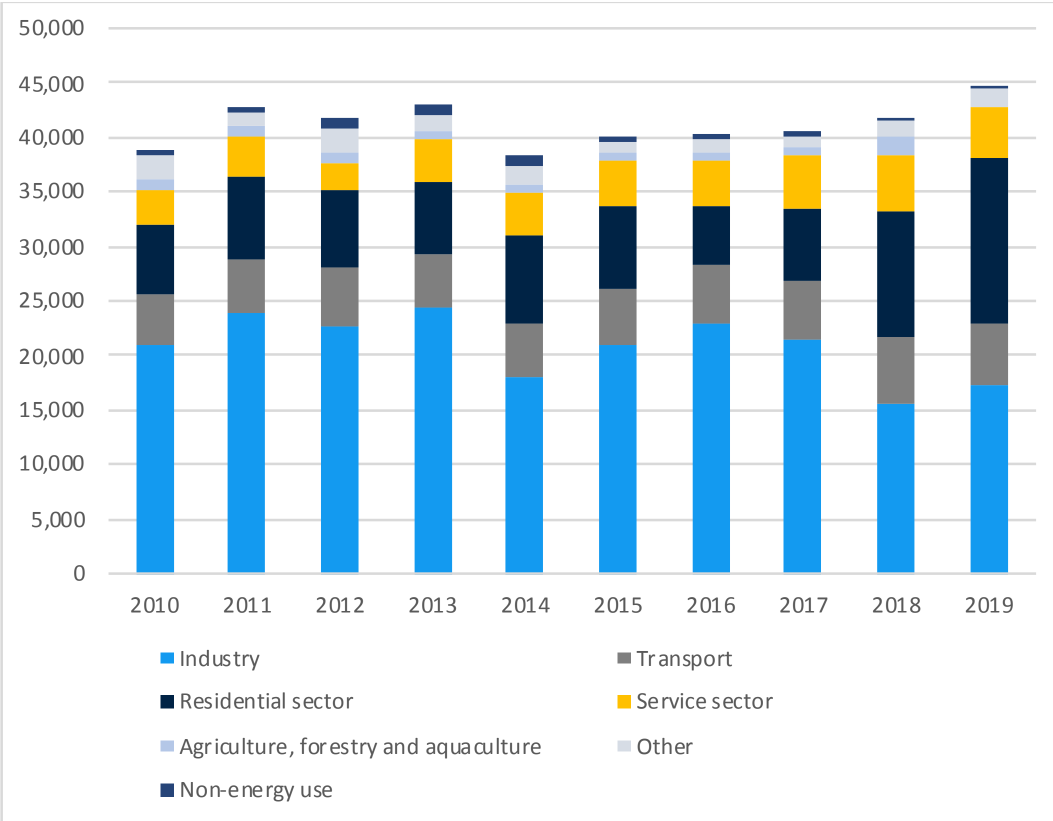


Source: Kazakhstan Electricity and Power Market Operator (KOREM).

2.1.2. Energy Consumption

Industry is the largest consumer of energy in Kazakhstan, followed by the residential and transport sectors (Figure 12). The industrial, residential, and transport sectors accounted for 38 percent, 33 percent, and 13 percent, respectively, of the total final energy consumption in 2019.

Figure 12: Final energy consumption, 2010–19, in thousand toe



Source: Bureau of National Statistics Kazakhstan.

Figure 12 shows that the share of industry in the final energy consumption has been decreasing in 2010–19. The industrial sector accounted for nearly 54 percent of the final energy consumption in 2010, compared to 38 percent in 2019. On the other hand, the share of the residential sector in the final energy consumption has increased in 2010–18—from 16 percent in 2010 to 33 percent in 2019. The share of the transport sector in the final energy consumption has grown slightly from 12 percent in 2010 to 13 percent in 2019.

2.1.3. Fossil Fuels

Kazakhstan is rich in reserves of fossil fuels, which play an important role in the country's economy and the energy sector (Table 11).

Table 11: Proven fossil fuel reserves, production, and international trade in Kazakhstan, 2019

Fossil fuel	Proven reserves	Resources (at year-end)	Production	Export	Import
Coal, tons, millions	25,605	128.20	115.00	25.30	0.29
Oil, tons, millions	3,900	89.80	78.60	69.70	0.04
Natural gas, m^3, millions	2,700	34.00	12.10	18.50	15.80

Sources: BP Statistical Review of World Energy 2020; Energy Balance of Kazakhstan 2019.

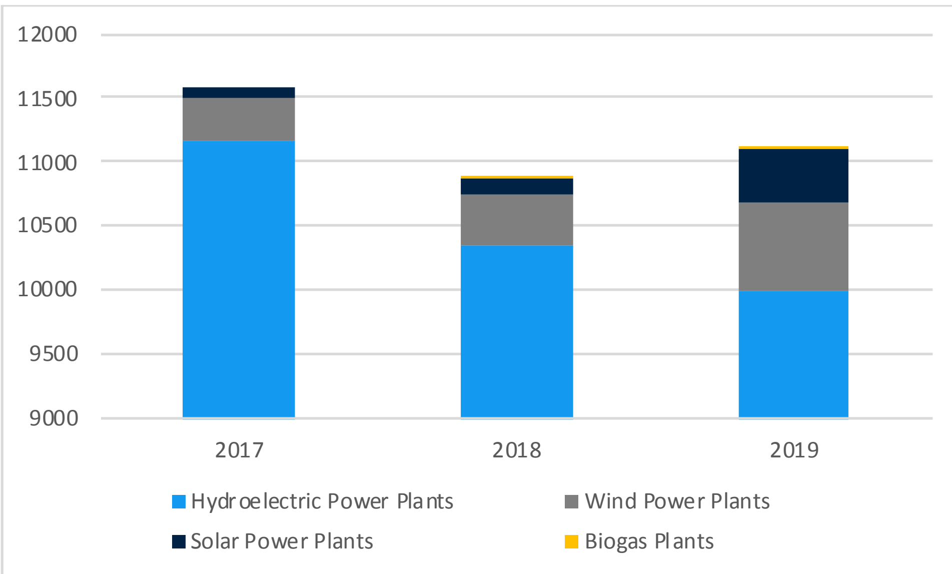
In 2019, thermal coal accounted for the bulk (74 percent) of the produced coal. However, 84 percent of the produced thermal coal is classified as having high ash content. More than half of the produced coal (52 percent) was used for electricity and heat generation, of which 79 percent had a high ash content. Around 8 percent of the produced coal was used by the general population.

Domestic oil consumption accounted for 20 percent of the total oil resources in 2019. On the other hand, domestic consumption of natural gas was 38 percent of the total natural gas resources. More than half (51 percent) of the natural gas used domestically was for electricity and heat generation, while 22 percent was used by households.

2.1.4. Renewable Energy

Renewable energy represented just over 1 percent of the total primary energy in 2019, as well as for 10.4 percent of the electricity production in 2019. Hydropower is the most important RES and was responsible for 90 percent of the electricity produced from renewable energy in 2019. Wind energy is the second largest RES in Kazakhstan after hydropower. Electricity produced from wind energy and solar energy doubled and quadrupled, respectively, in 2019, compared to 2017, but combined, they still contribute just 1 percent to the total electricity production.

Figure 13: Electricity generated from RESs, 2017–19, in kWh, millions



Source: KOREM.

There are large regional differences in the utilization of RESs for electricity production in Kazakhstan. In 2019, in three regions (Turkistan, East Kazakhstan, and Almaty), RESs accounted for more than 50 percent of electricity production, and in two regions (Akmola and Zhambyl), the RES share in electricity production was around 20 percent, while for all the other regions, the RES share was below 5 percent and in most cases under 1 percent. Table 12 lists the regions with the highest electricity production by type of RESs in 2019.

Table 12: Highest electricity production from renewable energy by type and by region, 2019

Source	Region with the highest electricity production from source in 2019	Electricity production	
		kWh, millions	Share in total electricity production for region (%)
Hydropower, including large hydropower	East Kazakhstan	6,841.3	71.00%
Small hydropower	Almaty region	345.6	9.00%

Source	Region with the highest electricity production from source in 2019	Electricity production	
		kWh, millions	Share in total electricity production for region (%)
Wind power	Akmola	230.8	21.00
Solar power	Karaganda	170.3	1.00
Biogas	Karaganda	2.9	0.02

Source: Energy Balance 2019.

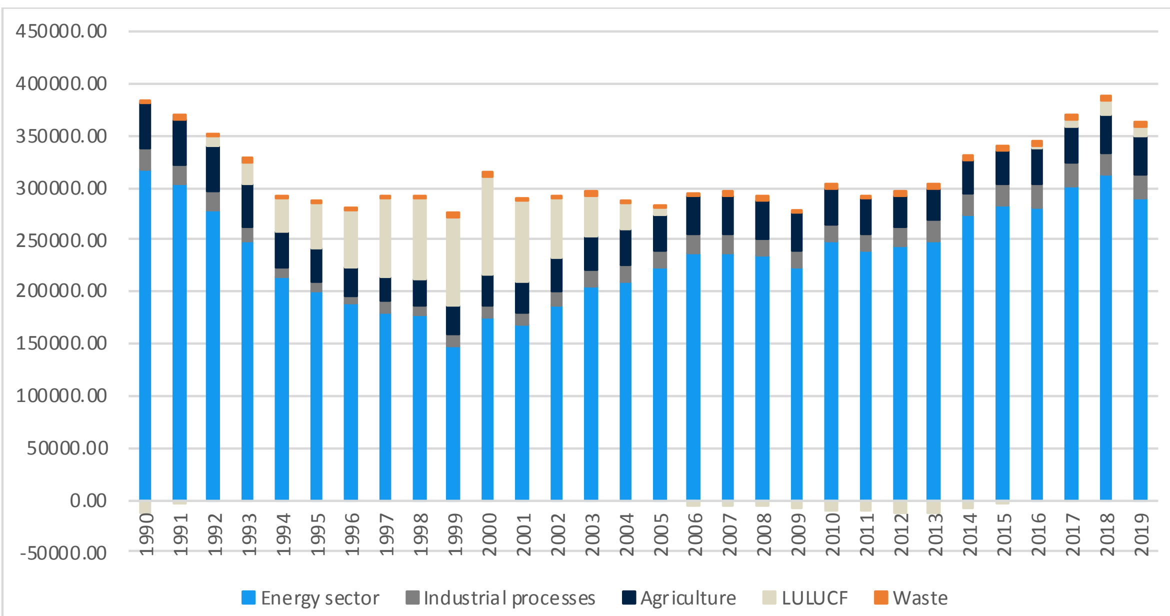
If the results of the renewable energy auctions that the government published in 2018 and 2019 (discussed in Chapter 4) are considered, then wind and solar generation capacities seem to be the priority areas for the development of renewable energy projects.

2.2. Greenhouse Gas and Black Carbon Emissions

2.2.1. Greenhouse Gas Emissions

As a party to the United Nations Framework Convention on Climate Change (UNFCCC), Kazakhstan annually submits a national report on GHG emissions. The latest submission was in May 2021, reporting up to 2019 GHG emissions.[23] Figure 14 summarizes the dynamics in the reported GHG emissions, including the land use, land-use change, and forestry (LULUCF) sector for 1990–2019. GHG emissions with LULUCF were 2.4 percent lower than the base year of 1990 and 6 percent lower than in 2018.

Figure 14: GHG emissions, 1990–2019, thousand tons of CO_2-equivalent



Source: Kazakhstan's National Inventory Report 2021.

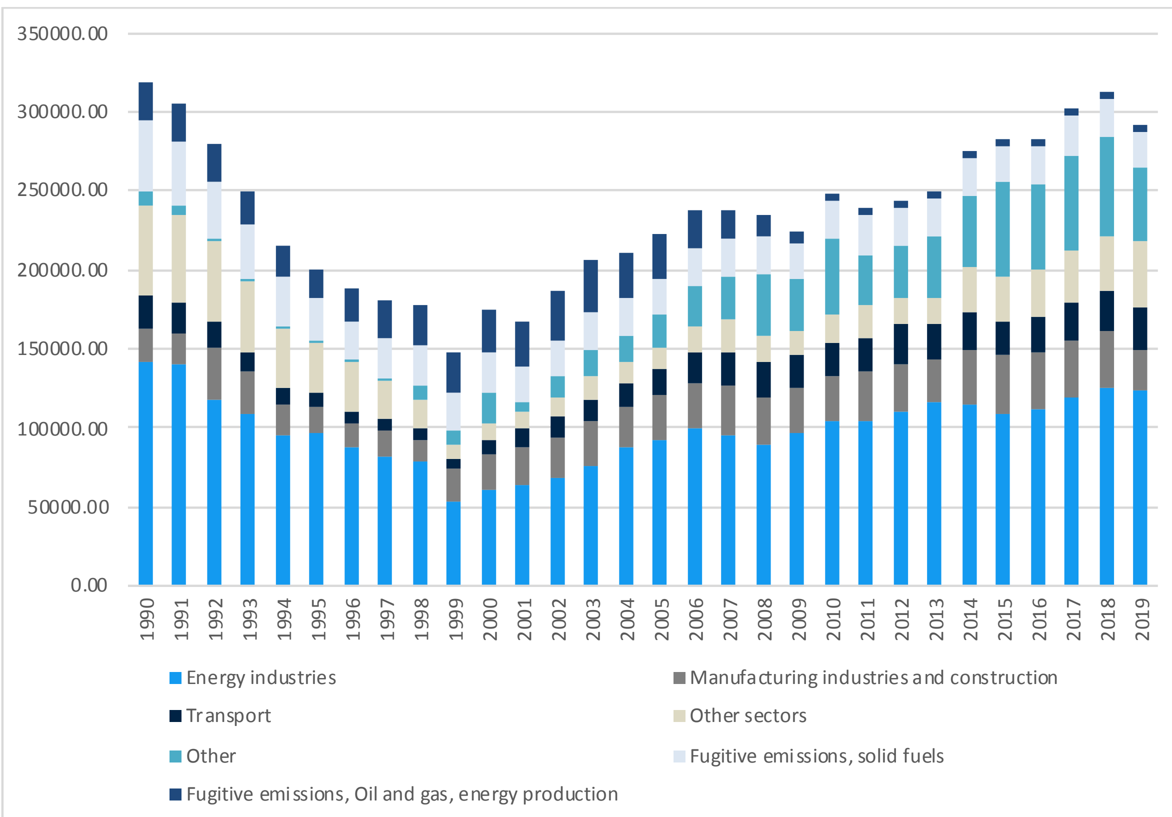
Kazakhstan's energy sector accounts for the largest share of GHG emissions and has been consistently responsible for over 80 percent of all GHG emissions in 1990–2019. The other source categories have had

[23] In accordance with the Conference of the Parties (COP) conclusion (FCCC/CP/2001/13/Add.4, section V.C.) and following ratification by Kazakhstan of the Kyoto Protocol on 19 June 2009 and its entry into force on 17 September 2009, Kazakhstan is considered an Annex I Party for the purposes of the Protocol but remains to be a non-Annex I Party for the purposes of the Convention. Therefore, Kazakhstan submitted biennial GHG inventory update report in 2021 for data up to 2019.

more or less stable contributions to GHG emissions with the exception of the LULUCF sector, which became a net GHG emitter in 1992–2005 and then again in 2016–2019. The second highest contribution to GHG emissions is agriculture, which was responsible for 10 percent of the total GHG emissions in 2019. The contribution of the waste sector to the total GHG emissions has increased slightly in 2019 compared to 1990 and was 1 percent of the total GHG emissions in 1990 compared to 1.4 percent in 2019.

The biggest sources of GHG emissions within the energy sector are the energy industries (Figure 15), namely public electricity and heat generation. The Public electricity and heat generation sector is consistently responsible for about 40 percent of all GHG emissions in Kazakhstan. The main source of GHG emissions from public electricity and heat generation was the use of solid fuels, which accounted for 81 percent of the total energy consumption in the sector in 2019. Nevertheless, GHG emissions from the energy industries sector were 13 percent lower in 2019, compared to 1990.

Figure 15: GHG emissions in the energy sector, 1990–2019, thousand tons of CO_2-equivalent

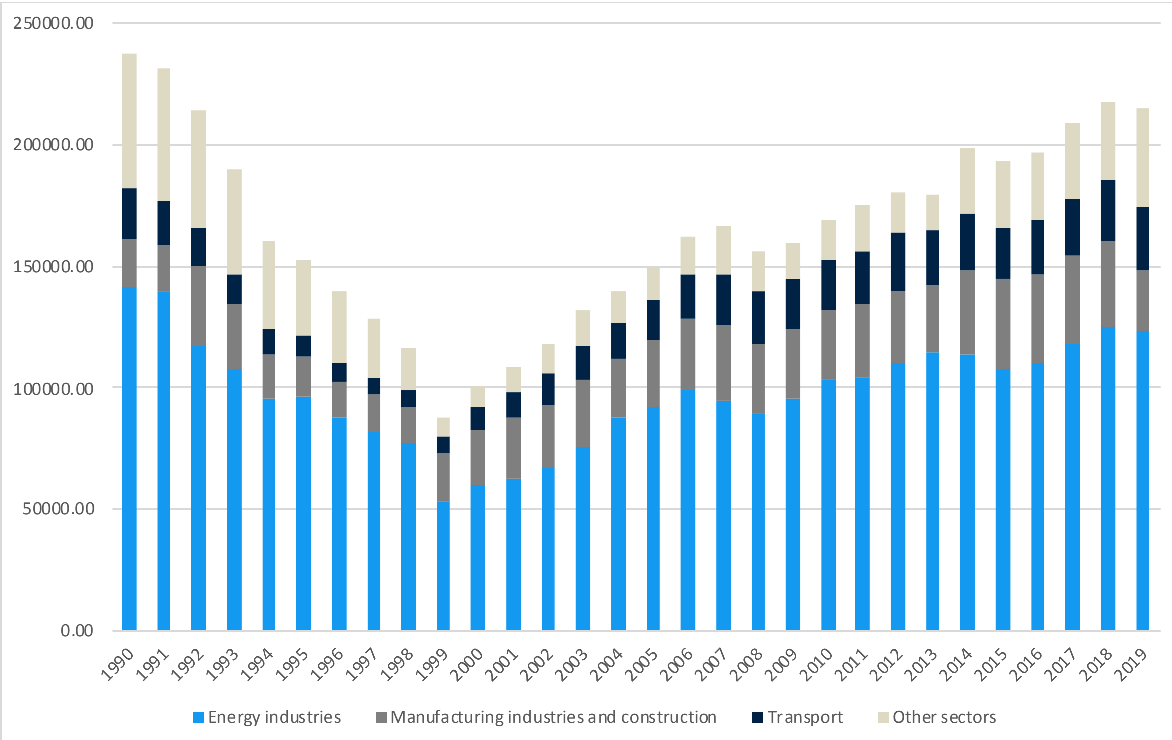


Source: Kazakhstan's National Inventory Report 2021.

Fuel combustion is responsible for over 90 percent of all CO_2 emissions in Kazakhstan. Energy industries accounted for 40 percent of all CO_2 emissions in 2019. Manufacturing industries and construction, as well as transport, were each responsible for 8 percent of the total CO_2 emissions in 2019. In 2019, combustion in other sectors, including the residential, commercial, agriculture, fishing, and forestry sectors, accounted for 13 percent of total CO_2 emissions (Figure 16).

Among the larger sector categories, the major CO_2 emissions contributors were public electricity and heat generation, which alone accounted for 36 percent of all CO_2 emissions in Kazakhstan in 2019, while the residential and transport sectors were far behind.

Figure 16: CO_2 emissions from fuel combustion in Kazakhstan, 1990–2019, in kt



Source: Kazakhstan's National Inventory Report 2021.

Table 13: Main sources of CO_2 emissions in Kazakhstan, 2019

Sector category	Sector	CO_2 emissions (million tons)	Share in total CO_2 emissions (%)
Energy industries	**Public electricity and heat generation**	109.9	36
Other sectors	**Residential**	32.9	11
Transport	**Road transport**	21.8	7
Manufacturing and construction	**Iron and steel manufacturing**	10.6	3

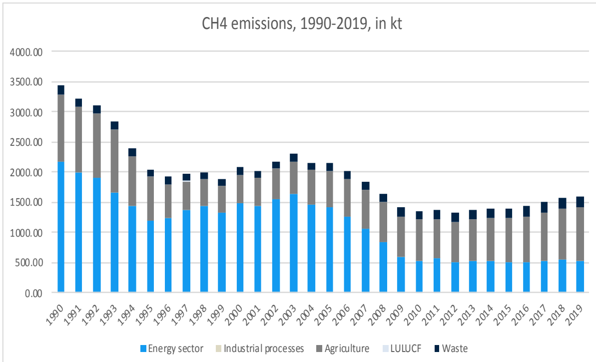
Source: Kazakhstan's National Inventory Report 2020.

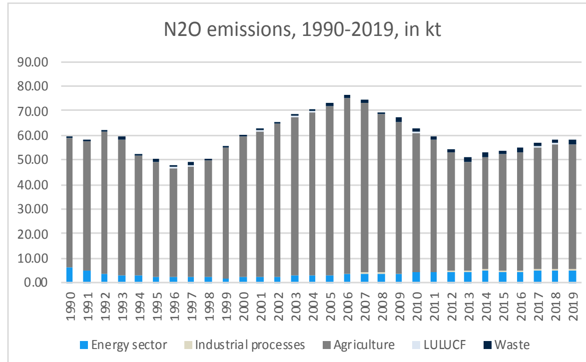
Overall, in 2019, the use of solid fuels across sectors was responsible for just over half of all CO_2 emissions in Kazakhstan. The use of solid fuels in public electricity and heat generation alone was responsible for 31 percent of the country's CO_2 emissions. At the same time, in the residential and the iron and steel manufacturing sectors, solid fuels contributed to 50 percent and 83 percent of CO_2 emissions in the sectors, respectively. The use of gaseous fuels contributed to 12 percent and 42 percent of all CO_2 emissions from the public electricity and heat generation and the residential sectors, respectively.

With regard to CO_2 emissions from road transport, cars were responsible for 64 percent of all emissions in 2019. Moreover, gasoline cars contributed to 78 percent of CO_2 emissions from all cars. Heavy-duty and light-duty trucks were responsible for 24 percent and 12 percent, respectively, of all road transport CO_2 emissions in 2019.

Figure 17 shows the emission trends, including emissions from the LULUCF sector, for the other important GHGs, methane (CH_4) and nitrous oxide (N_2O). Compared to the base year of 1990 and including LULUCF emissions, CH_4 emissions were down 53 percent, whereas N_2O emissions decreased by 3 percent in 2019.

Figure 17: CH_4 (left) and N_2O (right) emissions, including for LULUCF, 1990–2019, in kt





Source: Kazakhstan's National Inventory Report 2021.

The agriculture sector accounted for 55 percent of all CH_4 emissions in Kazakhstan in 2019. Within the agriculture sector, enteric fermentation accounted for 94 percent of all CH_4 emissions from the sector. The energy sector was the second most important sector in terms of CH_4 emissions in Kazakhstan in 2019 with a share in total emissions of 34 percent. Fugitive emissions from fuels were responsible for 86 percent of all the CH_4 emissions from the sector (Table 14).

Table 14: Main activities responsible for CH_4 emissions in Kazakhstan, 2019

Activity	CH_4 emissions (kt)	Share in total CH_4 emissions (%)
Enteric fermentation	821.85	51
Fugitive emissions from coal mining and handling	280.78	18
Fugitive emissions from oil and natural gas	185.18	12
Source: Kazakhstan's National Inventory Report 2021.		

The main source of N_2O emission in Kazakhstan in 2019 was agriculture (88 percent of the total N_2O emissions) with soil management responsible for 83 percent of N_2O emissions from the agricultural sector.

2.2.2. Black Carbon Emissions

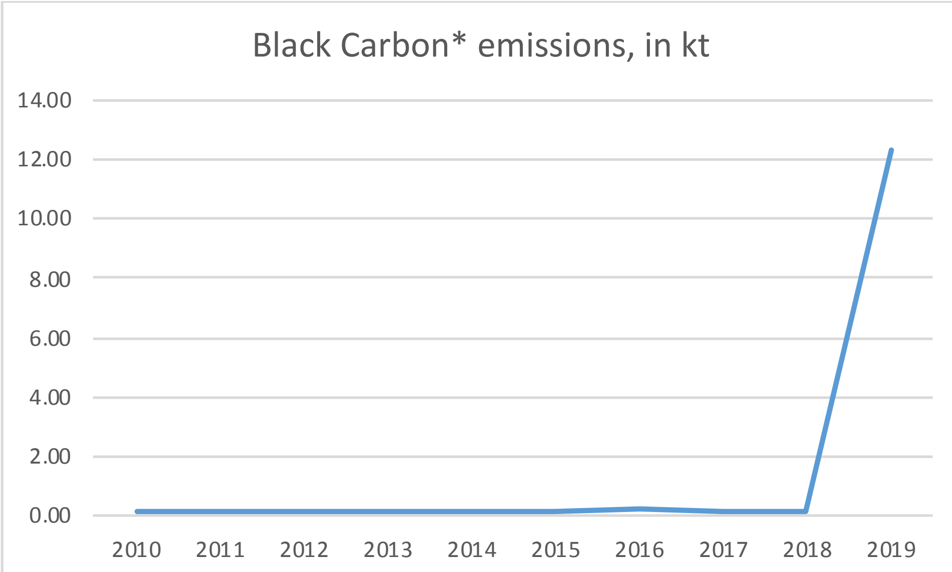
Black carbon (BC) particles are a major constituent of soot and strongly absorb solar radiation, which subsequently heats the atmosphere. BC has been estimated to be the second most important source of anthropogenic climate change after CO_2.[24] BC emissions have received increased attention lately because reducing them can slow down the warming of the atmosphere relatively quickly due to their short lifetime compared to GHG.

Kazakhstan reports BC emissions in the country's inventory submission under the Convention on Long-Range Transboundary Air Pollution (CLRTAP). However, estimation of BC emissions from major sources

[24] European Commission. "Mitigation of Arctic Warming by Controlling European Black Carbon Emissions." https://ec.europa.eu/environment/life/project/Projects/index.cfm?fuseaction=home.showFile&rep=file&fil=LIFE09_ENV_FI_000572_LAYMAN.pdf.

such as public electricity and heat generation or the residential sector was missing until the latest submission under CLRTAP. Figure 18 shows the estimated emissions of BC in 2010–19.

Figure 18: BC emissions in Kazakhstan, 2009–18, in kt



Source: Center on Emission Inventories and Projections (CEIP).

*Note: *. BC emissions from important sectors such as public electricity and heat generation (CLRTAP Nomenclature for Reporting [NFR] code 1A1a), industry (NFR codes 1A1b, 1A1c, 1A2a, 1A2b, 1A2c, 1A2d, 1A2e, and 1A2f), residential: stationary (NFR code 1A4bi), and all of the road transport categories were not estimated until 2019.*

The large increase in BC emissions in 2019, compared to 2018, can be attributed to the fact that important BC emission sources were not included in the emissions estimates up to 2019. Some of those sources were estimated to be among the largest BC emitters in 2019. The residential sector was the largest emitter of BC, responsible for one third of total BC emissions in 2019. Iron and steel manufacturing was the sector with the second highest BC emissions, accounting for 26% of total BC emissions in 2019.

2.3. Emissions of Key Air Pollutants

Kazakhstan has been a party to the CLRTAP since 2011, yet, it has not ratified any of the protocols to the convention. Nevertheless, Kazakhstan submits emissions data and reports to CEIP annually, including a filled-in Annex I template with emissions per sector according to the CLRTAP NFR. However, in 2016-2020, Kazakhstan has not submitted the structured Informative Inventory Report (IIR) that explains the methodologies and activity data used in emissions reporting, as well as the associated uncertainties and quality assurance and quality control (QA/QC) procedures implemented. The IIR was submitted as part of the latest reporting in 2021.

In 2017, under the coordination of CEIP, a review of Kazakhstan's emission inventory submissions under the CLRTAP was carried out. The main conclusions from the review were as follows:

- Kazakhstan's inventory was partly in line with the European Monitoring and Evaluation Programme (EMEP)/European Environmental Agency (EEA) inventory guidebook.
- Improvement in the transparency, completeness, consistency, and accuracy of the inventory is needed.

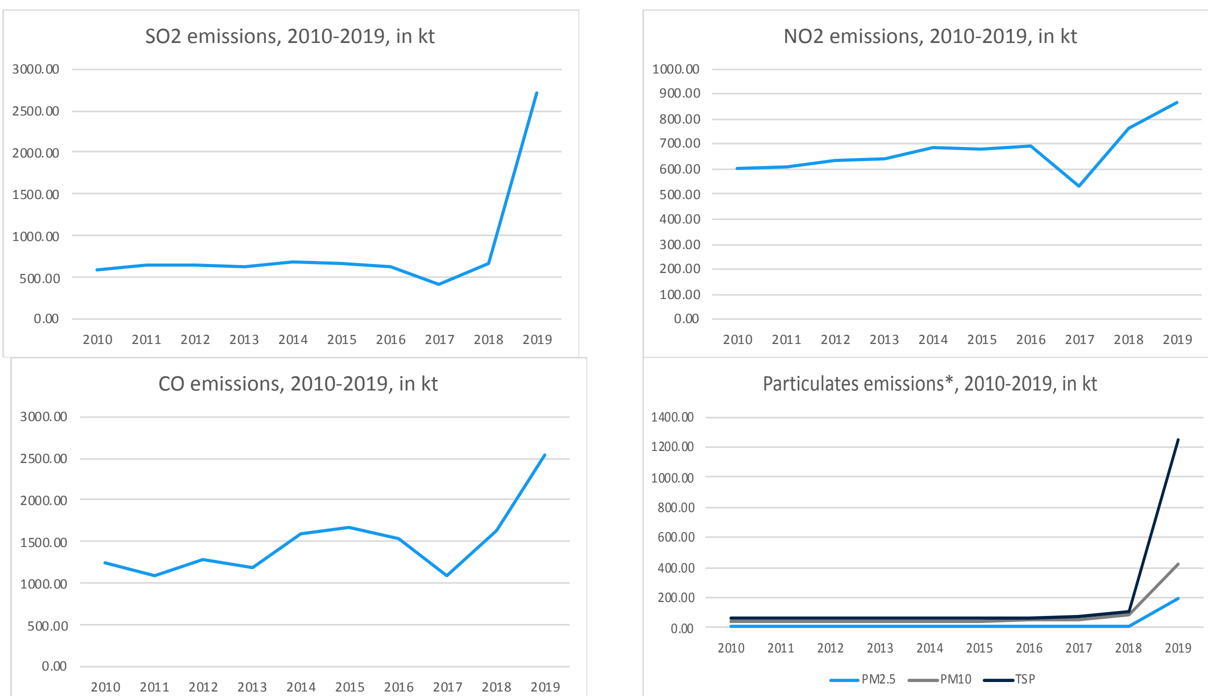
- Kazakhstan has not implemented key category analysis and, therefore, has not prioritized data collection for key categories to facilitate the use of a Tier 2 or higher methodology for emission estimations.
- It is difficult to explain why data are missing for certain emission categories, including important ones in the energy sector.
- Kazakhstan has not implemented sector-specific QA/QC procedures.

The latest emission data submission for Kazakhstan under the CLRTAP was in February 2021, reporting up to 2019 emissions.[25] In the absence of source apportionment studies from within Kazakhstan to draw conclusions about the contribution to air pollution of different emission sources, the CLRTAP emission reporting provides an indication of the main emission sources in Kazakhstan, as well as the emission trends over the years.

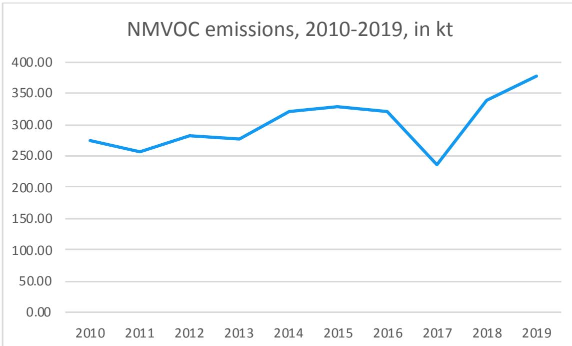
In 2010–19, the emissions of all major pollutants have increased. Sulfur dioxide (SO_2) emissions have grown by 4.5 times and carbon oxide (CO) emissions have doubled in 2019, compared to 2010. Nitrogen dioxide (NO_2) and non-methane volatile organic compounds (NMVOC) emissions have grown by 44 percent and 38 percent, respectively, during the same period (Figure 19).

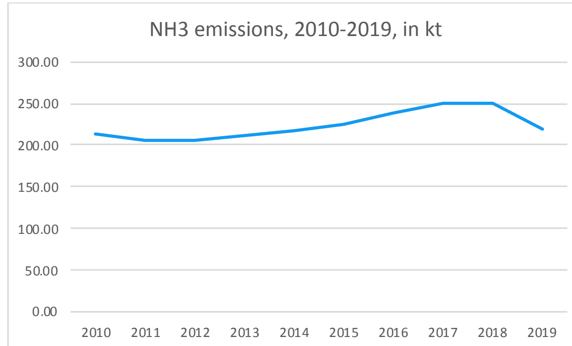
Figure 19 shows a marked increase in particulate emissions in 2019. Until 2019, the emissions reporting of particulates did not include emissions from generally important sources such as residential heating and public electricity and heat generation. The reported emissions for 2019 include those important sectors, which mostly explains the increase in particulate emissions levels in 2019. Particulate emissions were not recalculated for 2010-2018 to include the previously omitted sectors.

Figure 19: Trends in emission levels of main air pollutants, 2008–19, in kt



[25] Submissions under CLRTAP for a given year report emissions for the year that is two years before the given submission by default. Therefore, this should not be considered a gap in emissions reporting.



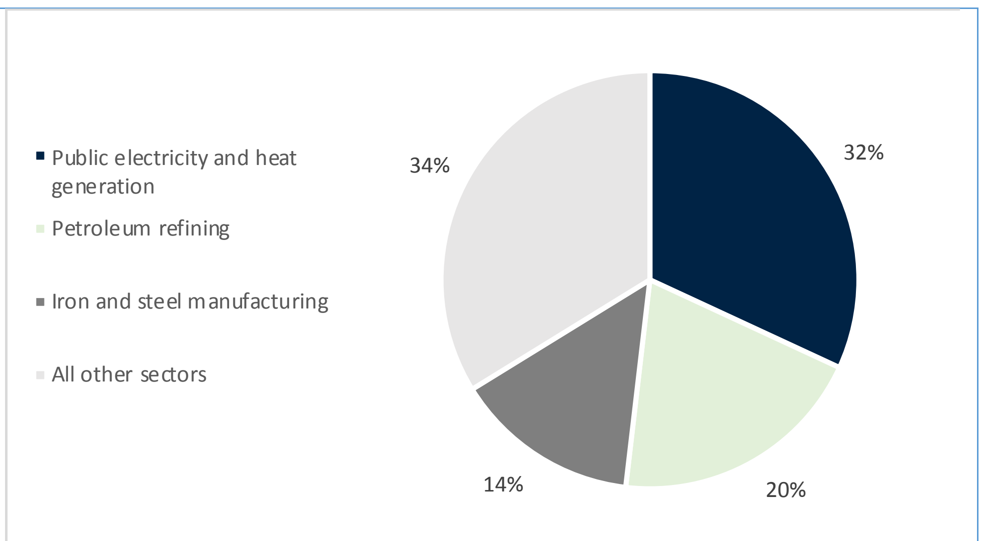


Source: CEIP.

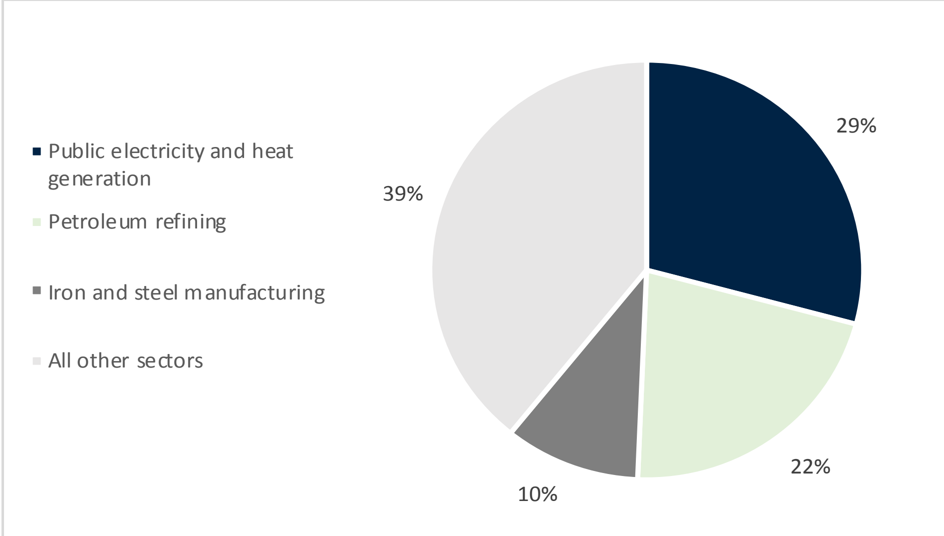
*Note: *. Data from important sectors such as public electricity and heat generation (NFR code 1A1a), industry (NFR codes 1A1b, 1A1c, 1A2a, 1A2b, 1A2d, 1A2e, and 1A2f), residential: stationary (NFR code 1A4bi), and all of the road transport categories in the case of PM_{10} and TSP are missing in 2010-2018.*

Table 15 highlights the most important sectors contributing to emissions of key air pollutants in 2019 according to Kazakhstan's emission inventory submission under the CLRTAP. While the total mass of emissions is an important indicator for analyzing the carbon intensity and conventional emission intensity of a given sector, for instance, the emission rate is less relevant for establishing the health impacts of air pollution. The concentrations of pollutants and population exposure to pollutants are the key variables in estimating the health impact of air pollution. In addition, there is no linear relationship between emissions and pollutant concentrations. Thus, an enterprise or a sector might emit a large mass of emissions, but, depending on the source specifics (such as height of the emission source, temperature of gases, and so on) and the dispersion conditions, such large mass of emissions might not result in high pollutant concentrations or contribute significantly to increased population exposure to air pollutants.

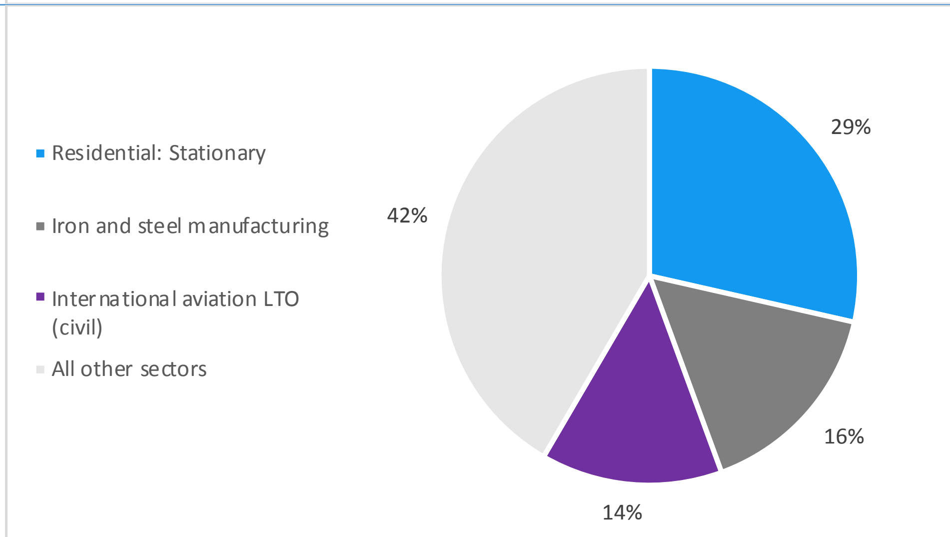
Table 15: Main emission sectors for selected pollutants according to the 2021 emission inventory submission under the CLRTAP, reporting 2019 emissions

SO_2	

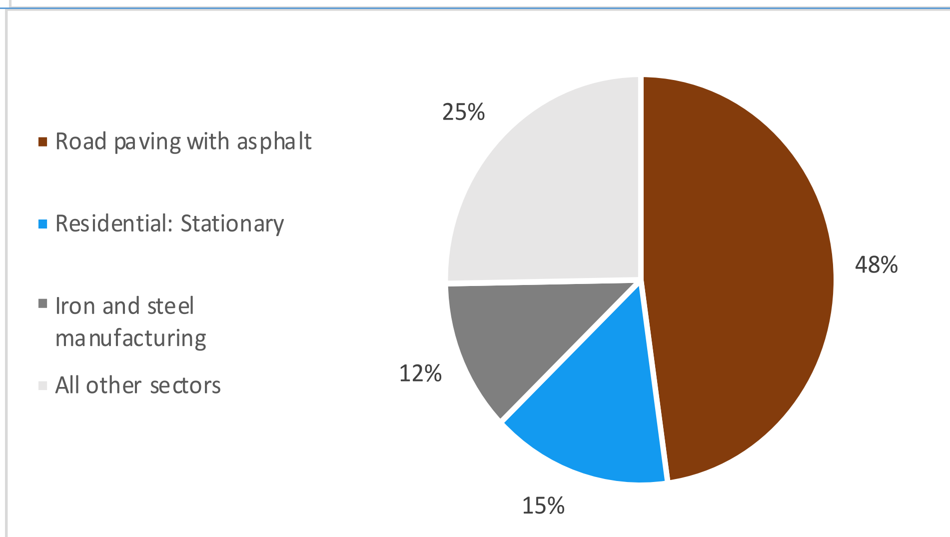
NO_2

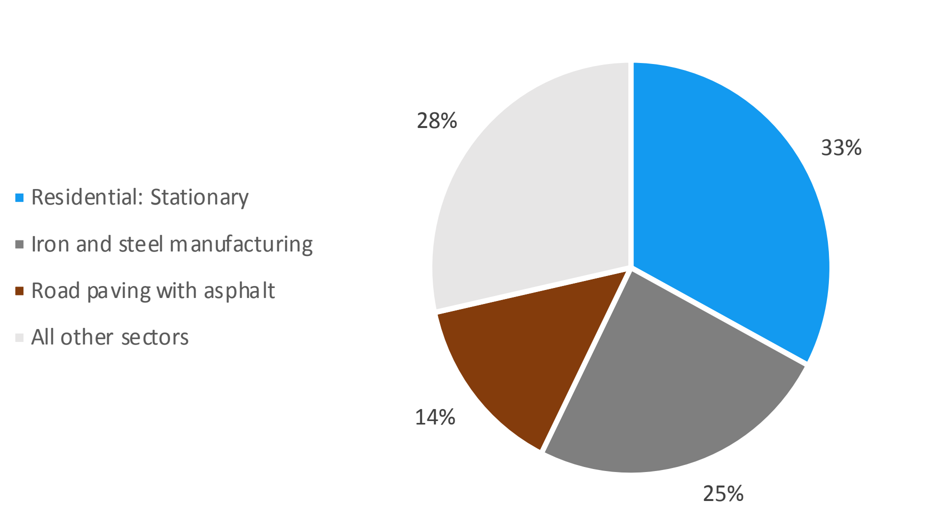
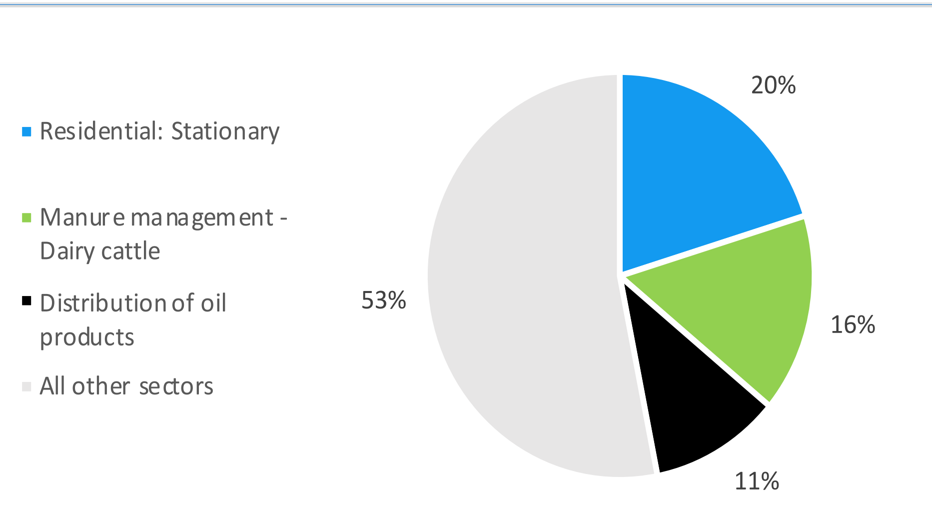
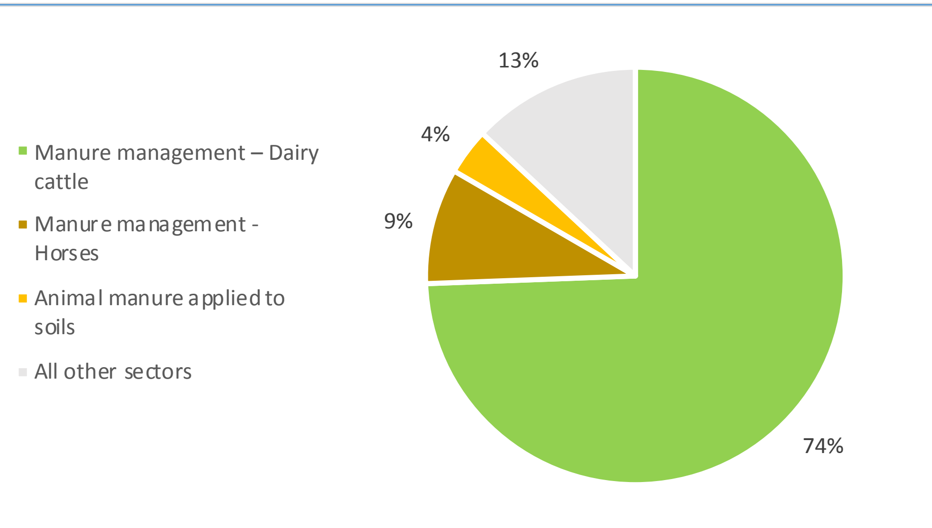

Public electricity and heat generation
Petroleum refining
Iron and steel manufacturing
All other sectors
29%
22%
10%
39%

CO


Residential: Stationary
Iron and steel manufacturing
International aviation LTO (civil)
All other sectors
29%
16%
14%
42%

PM_{10}


Road paving with asphalt
Residential: Stationary
Iron and steel manufacturing
All other sectors
48%
15%
12%
25%

$PM_{2.5}$	
NMVOC	
NH_3	

Source: CEIP.

Table 15 shows that depending on the pollutant, the main emission sources vary, but overall, industry, residential heating, and agriculture (in the case of NMVOC and NH_3) are important contributors to air emissions. In 2019, public electricity and heat generation accounted for 32 percent and 29 percent of all emissions of SO_2 and NO_2, respectively. Iron and steel production appears to be the most polluting activity from the manufacturing sector. In 2019, iron and steel production was responsible for 14 percent, 10 percent and 25 percent of total SO_2, NO_2 and $PM_{2.5}$ emissions, respectively. In addition, combustion in the residential sector accounted for 29 percent of CO emissions, 15 percent of PM_{10} emissions, 33 percent of $PM_{2.5}$ emissions, and 20 percent of NMVOC emissions. Agricultural practices, mainly manure management, are the main sources of NH_3 emissions and contribute significantly to NMVOC emissions.

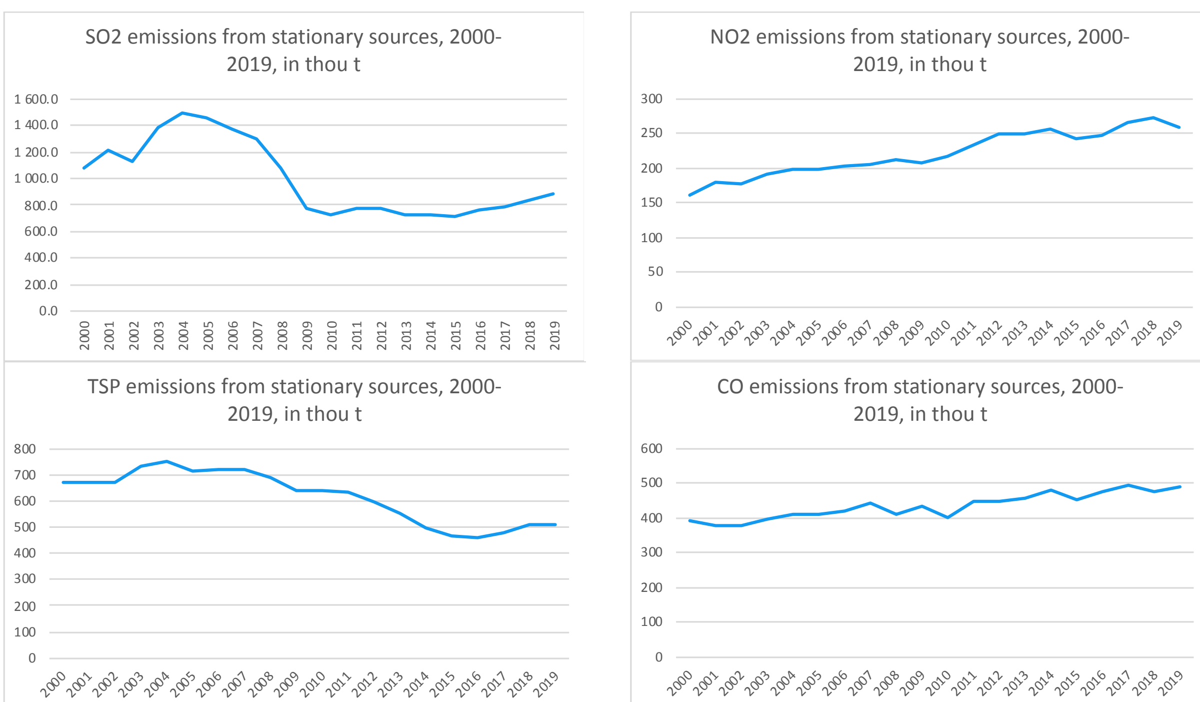
2.3.1. Emissions from Stationary Sources

Kazakhstan's Bureau of National Statistics publishes extensive data sets on emissions from stationary sources and activities in the sector. However, most of the data sets present aggregated information about the total emissions of all pollutants, instead of information about the separate pollutants.

In 2019, there were 144,481 point emission sources in Kazakhstan. For 56,094 (39 percent) of those, the total emissions in 2019 increased compared to 2018.

Figure 20 shows the dynamics of key pollutants' emissions from stationary sources in 2000–19. In 2019, emissions of SO_2 and TSP decreased by 18 percent and 24 percent, respectively, compared to 2000. Nevertheless, SO_2 and TSP emissions have been growing since 2015. On the other hand, emissions of NO_2 and CO increased in 2019 compared to 2000, by 60% and 25%, respectively. When comparing the emissions from stationary sources reported by the Bureau of National Statistics to Kazakhstan's emission inventory submission under the CLRTAP, it is evident SO_2 emissions from stationary sources are higher than SO_2 emissions reported for all sectors in Kazakhstan. The difference in the emission levels may be because emissions are not estimated for a number of industrial sectors in the emission inventory submitted under the CLRTAP.

Figure 20: Emissions of key pollutants from stationary sources, 2000–19, in thousand tons



Source: Bureau of National Statistics.

In 2019, the industrial sector accounted for 86 percent of the total emissions of all pollutants from stationary sources in Kazakhstan. Within the industrial sector, energy accounted for 45 percent of the total emissions of all pollutants, followed by the processing industry representing 37 percent of the total emissions.

Pursuant to Kazakhstan's legislation, every year, permissible limits on total emissions from stationary sources are set. Nearly all point emission sources were subject to compliance with permissible emission limits in 2019. Usually, the permissible emission limits significantly exceed the actual total emission levels indicating that the emission limits are set too high. For instance, the actual total emissions from stationary sources in 2019 were 60 percent of the permissible emission levels. Moreover, actual emissions from the industrial sector in 2019 were 66 percent of the sector's permissible emission limits. In 2019, the total actual emissions in the industrial sector with the highest emissions, namely the energy sector, were 73 percent of the permissible emission levels.

In 2019, more than half of the total emissions from stationary sources in Kazakhstan originated in two regions—Pavlodar (29 percent) and Karaganda (26 percent). Together, these regions accounted for 70 percent, 56 percent, 55 percent, and 52 percent of the total SO_2, NO_2, TSP, and CO emissions from stationary sources, respectively. Kazakhstan's Karaganda region is the largest manufacturing region with rich reserves of minerals and raw materials. Mining and heavy industry such as steel production are well developed in the region. Pavlodar is the second largest industrial region in Kazakhstan. Aluminum, coal, and ferroalloys production as well as electricity generation account for about 90 percent of the region's industrial output.

Table 16: Regions with the highest emissions from stationary sources of selected pollutants, 2019

Pollutant	Regions with the highest emissions from stationary sources	Emissions, kt	Share of the total emissions for pollutant, %
SO_2	Pavlodar	330.6	37
	Karaganda	287.1	33
	Atyrau	47.9	5
NO_2	Pavlodar	101.9	39
	Karaganda	44.0	17
	Atyrau	18.1	7
TSP	Pavlodar	157.1	31
	Karaganda	122.1	24
	Kostanay	55.5	11
CO	Karaganda	158.3	33
	Pavlodar	93.4	19
	Atyrau	44.0	9
Source: Bureau of National Statistics.			

Despite large emissions from industry, often the contribution of industry to city or settlement-level air quality is overstated compared to the other sectors if the assessment is based only on emission discharges. There is no linear relationship between emissions and air pollutant concentrations. A number of factors determine the concentrations of air pollutants from an emission source and its impact on population exposure. Those factors include, among others, the location of the source (often industrial sites are located outside of settlements), the source's specifics (height, temperature, velocity of gases, and so on), the meteorology (such as wind speed and direction and the atmosphere stability class), the topography, the settlement's density, and chemical reactions in the atmosphere.

The Bureau of National Statistics reports that in 2019, 93.2 percent of the total volume of emissions at stationary sources was captured and treated. Moreover, on the national level, the share of emission volumes treated by some type of abatement technology at point sources was as follows: 98.4 percent for TSP, 72.1 percent for CO, 57.2 percent for SO_2, and 4.3 percent for NO_2. There are significant regional differences in terms of the share of the captured and treated emissions at point emission sources. Table 17 shows the shares of treated emission volumes in Pavlodar and Karaganda—the regions with the highest emissions from point sources.

Table 17: Share of treated emissions (by volume) using abatement technologies in Pavlodar and Karaganda regions

Region	Share of treated emissions (by volume) using abatement technologies			
	SO_2	NO_2	CO	TSP
Pavlodar	6.2	9.2	92.1	99.1
Karaganda	67.6	0.3	51.9	98.1
Source: Bureau of National Statistics.				

2.3.2. Emissions from Transport

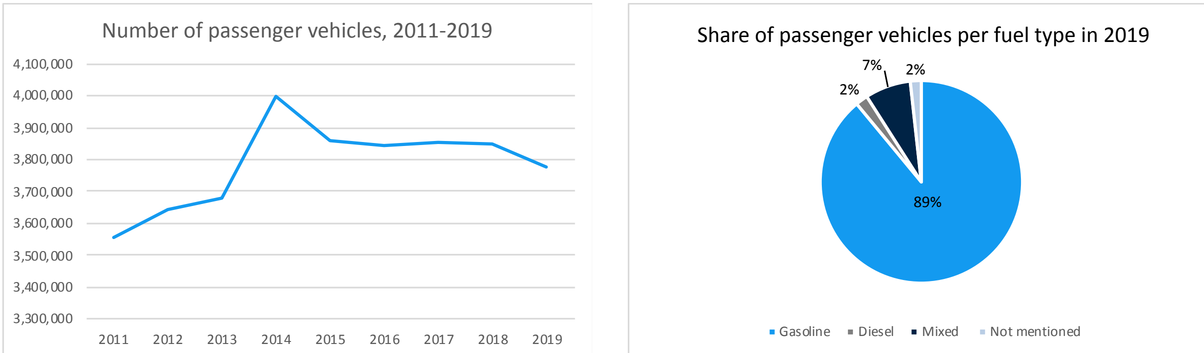
According to Kazakhstan's emission inventory submission under the CLRTAP, in 2019, the road transport sector accounted for

- 17 percent of the total CO emissions,
- 14 percent of the total NMVOC emissions,
- 10 percent of the total NO_2 emissions, and
- 2 percent of the total $PM_{2.5}$ emissions.

The main parameters affecting transport emissions are the number of vehicles on the road, the fuel used, the technical condition of the vehicles, and the mileage driven. At the end of 2019, there were 3,776,893 registered passenger vehicles in the country, 89 percent of which were gasoline vehicles and 2 percent were diesel vehicles.

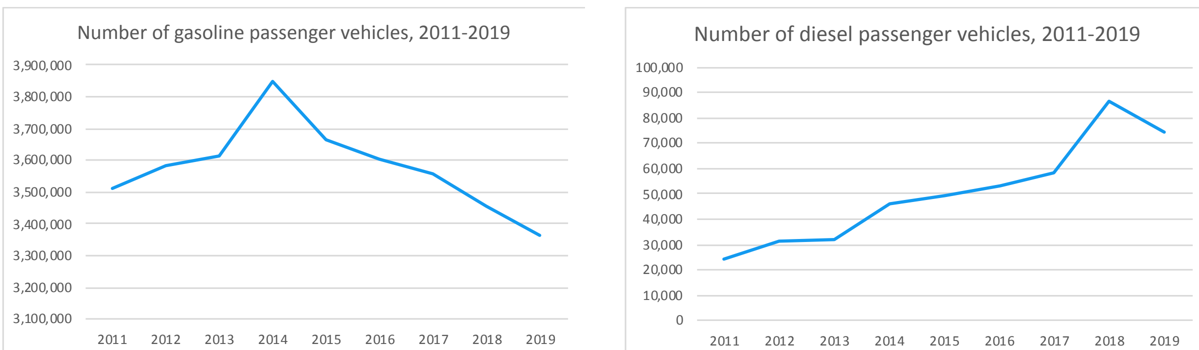
Figure 22 shows that in 2011–19, the number of gasoline passenger vehicles has been decreasing, while the number of diesel vehicles has been growing.

Figure 21: Number of passenger vehicles, 2011–19, (left) and share of passenger vehicles by fuel type, 2019 (right)



Source: Bureau of National Statistics.

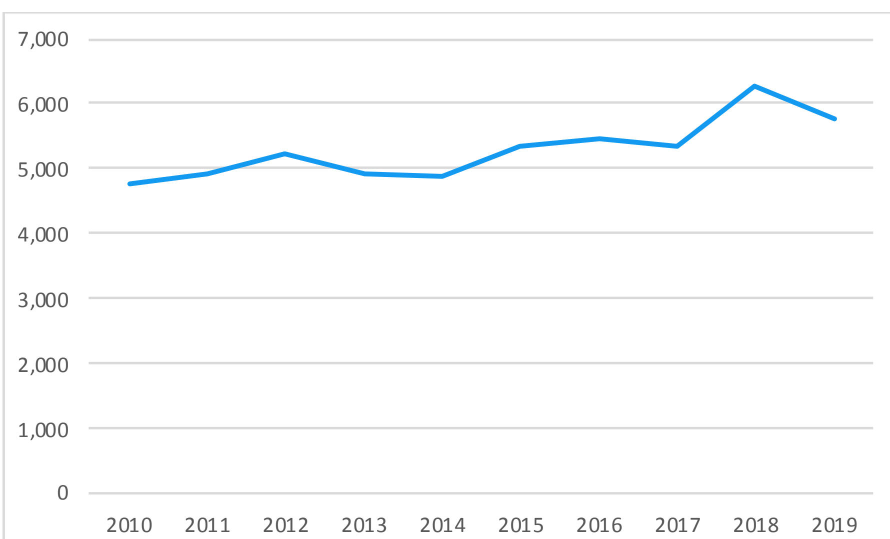
Figure 22: Number of gasoline (left) and diesel (right) vehicles, 2011–19



Source: Bureau of National Statistics.

The transport sector accounted for 13 percent of final energy consumption in Kazakhstan in 2019, down from 15 percent in 2018 (Figure 23).

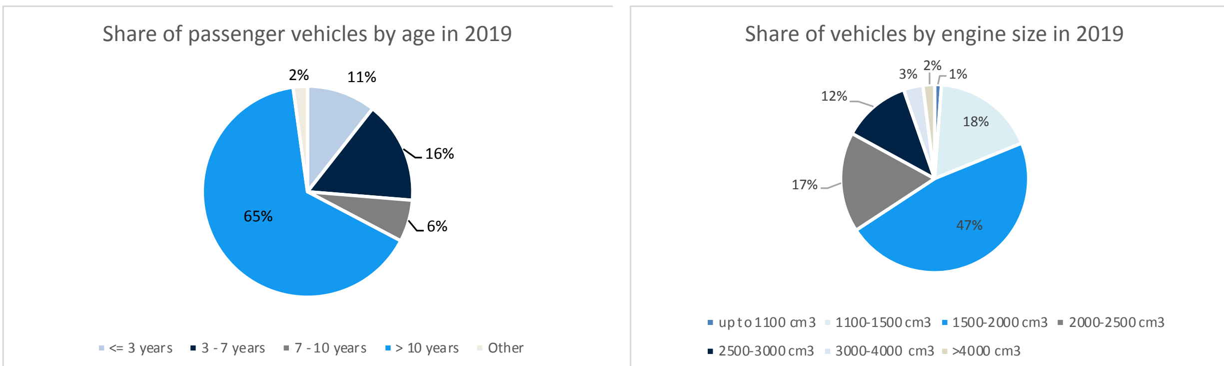
Figure 23: Final energy consumption of the transport sector, 2010–19, in thousand toe



Source: Bureau of National Statistics.

The passenger vehicle fleet consists mainly of vehicles older than 10 years—65 percent of all passenger vehicles in 2019 (Figure 24). Older vehicles emit more pollutants and might not have adequate equipment such as catalytic converters and diesel particulate filter (DPF) installed. Nevertheless, the share of passenger vehicles over 10 years of age has declined by 12 percent in 2019, compared to 2011. On the other hand, the number of passenger vehicles under 3 years old tripled in 2019, compared to 2011. Overall, even though passenger vehicles older than 10 years represented the dominant share of Kazakhstan's passenger vehicle fleet in 2019, a trend is observed toward a decreasing age of the passenger vehicles (Table 18). This trend is aided by the ban introduced in 2018 on the import of vehicles older than 5 years or below Euro 4 emission standards.

Figure 24: 2019 passenger vehicle fleet: share of vehicles by age (left) and engine size (right)



Source: Bureau of National Statistics.

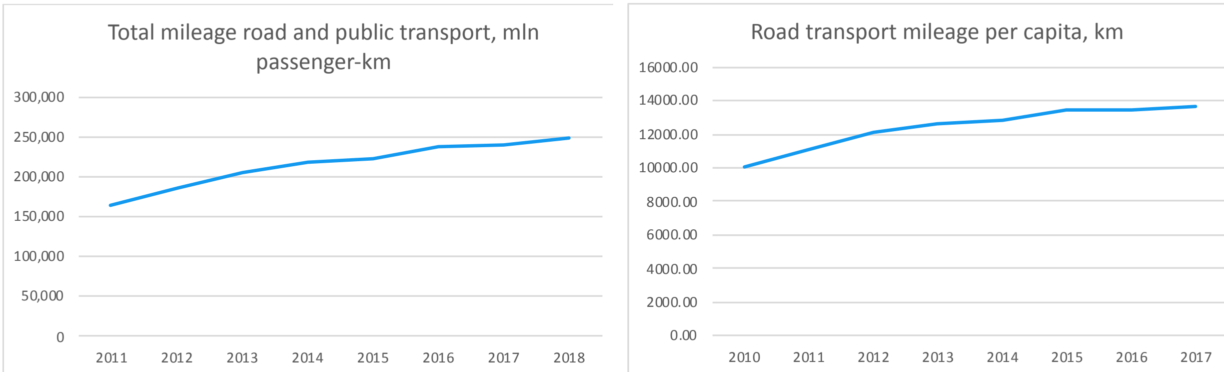
Table 18: Kazakhstan passenger vehicle fleet age dynamics

Passenger vehicle's age	Number of vehicles in 2019	Change in number of vehicles, compared to 2011 (%)	Change in number of vehicles, compared to 2018 (%)
Under 3 years	401,148	249	−4
3–7 years	593,038	61	3
7–10 years	240,156	−5	−11
Over 10 years	2,459,007	−12	−1

Source: Bureau of National Statistics.

Robust vehicle mileage data are usually more difficult to obtain. Kazakhstan's Bureau of National Statistics publishes data on passenger mileage that combine both road and public transport. Figure 25 shows a steady increase in passenger-kilometers travelled by road. In 2018, travelled kilometers by road were 50 percent higher, compared to their level in 2011.

Figure 25: Total mileage (left) and per capita mileage (right) of road transport and public transport combined, 2011–18



Source: Bureau of National Statistics.

2.3.3. Emissions from the Residential Sector

According to Kazakhstan's 2021 emission inventory submission under the CLRTAP reporting 2019 emissions, the residential sector was responsible for

- 33 percent of the total $PM_{2.5}$ emissions,
- 20 percent of the total CO emissions,
- 20 percent of the total NMVOC emissions,
- 15 percent of the total PM_{10} emissions, and
- 5 percent of the total SO_2 emissions.

Air pollutants from the residential sector originate from the combustion of fuels (especially solid fuels such as coal and wood) to meet households' needs mainly for heating and cooking. Estimating emissions from the residential sector is difficult due to the large spatial distribution and multitude of emission sources (individual households) and the variety of fuels and combustion equipment used.

In 2018, the Bureau of National Statistics of Kazakhstan conducted a comprehensive, nationwide household survey with the objective to collect data on households' fuel and energy consumption—21,000 households participated in the survey. This survey represents the latest and the most detailed available data on households' fuel and energy consumption. Some of the key results from the survey are summarized in the following paragraphs.

There were about 5 million households in Kazakhstan in 2018. Nearly 30 percent of the residential building stock was built before 1970 while merely 1.1 percent was built after 2016. According to a survey conducted, 58 percent of households lived in apartments in multi-family buildings (MFBs) and 41 percent lived in single-family buildings (SFBs) in 2018. There are marked differences between urban and rural regions. For example, 78 percent of households in urban regions lived in apartments, compared to 22 percent of households in rural regions. This difference is important because it influences the available heating options that households living in SFBs have, compared to households living in apartments in MFBs. In general, MFBs are more likely than SFBs to be connected to a centralized heating network.

At the household level, the survey distinguished between three main types of residential heating options:

- Centralized heating networks—usually supplied by district heating plants

- Autonomous building-level heating systems—a heating system that uses a building-level boiler to supply heat to all dwellings in the building
- Individual stove—a heating appliance that provides heating for a single dwelling/space within the dwelling.

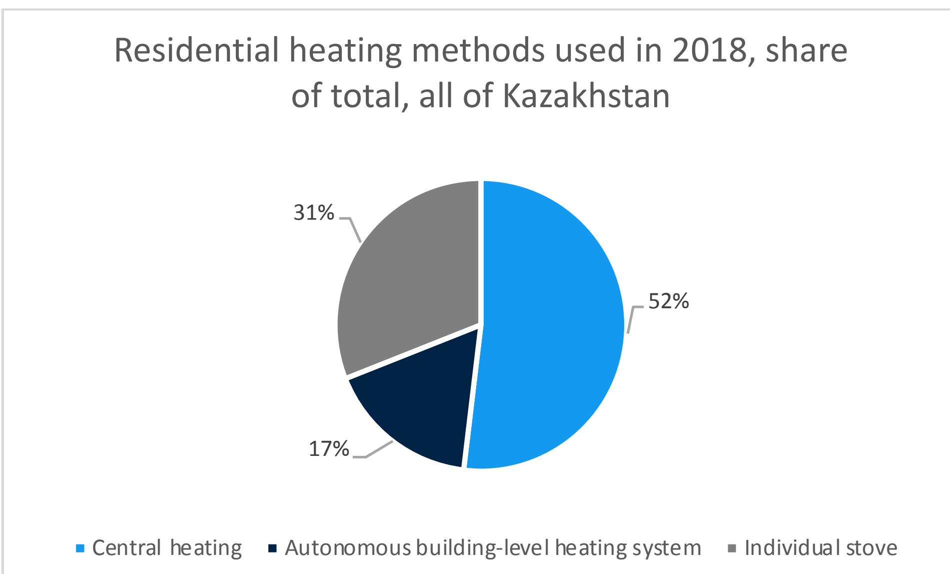
Residential heating supplied through centralized heating networks was available to the largest share of households in Kazakhstan (52 percent), followed by individual stoves (31 percent) and autonomous building-level heating systems (17 percent) (Figure 26). A large share of households in urban areas used centralized heating networks, 76 percent, compared to just 3 percent in rural areas. Inherited from the Soviet times, the central heating networks in Kazakhstan are over 25 years old, in some cases over 50 years old. Some of the CHP and district heating plants are reaching the end of their life cycle and need replacement.[26] Coal accounts for nearly 70 percent of the central heat produced in Kazakhstan.[27]

Table 19 shows that out of the three largest cities in Kazakhstan, Almaty has the largest district heating network, yet 57 percent of it needs to be repaired or replaced.

Table 19: Length of district heating networks in Kazakhstan's three largest cities

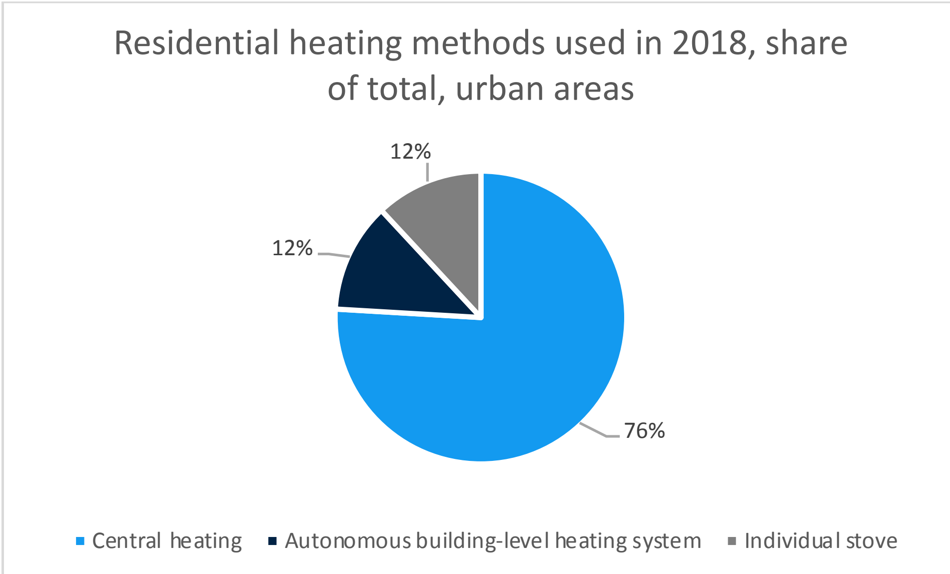
City	Total length of district heating network, km	Share of district heating network in need of repair/replacement, %
Almaty	1,368.6	56.8
Nur-Sultan	831.4	25.2
Shymkent	208.1	19.9
Source: Bureau of National Statistics.		

Figure 26: Residential heating methods used in all of Kazakhstan (top) and in urban areas only (bottom), 2018



[26] World Bank. 2017. *Kazakhstan: Energy Efficiency Transformation in Astana and Almaty.* Washington, DC: World Bank.http://documents1.worldbank.org/curated/en/362411510931587832/pdf/121462-ESM-P130013-PUBLIC-KEEPAstanaEEPlanNovengfinal.pdf.

[27] Kerimray, A., Rocco, M., Rojas-Solórzano and Gallachóir, B. 2016. "Incidence of District Heating and Natural Gas Networks on Energy Poverty across Kazakhstan." Conference Paper, 1st IAEE Eurasian Conference. https://www.researchgate.net/publication/305702961_Incidence_of_District_Heating_and_Natural_Gas_Networks_on_Energy_Poverty_Across_Kazakhstan.

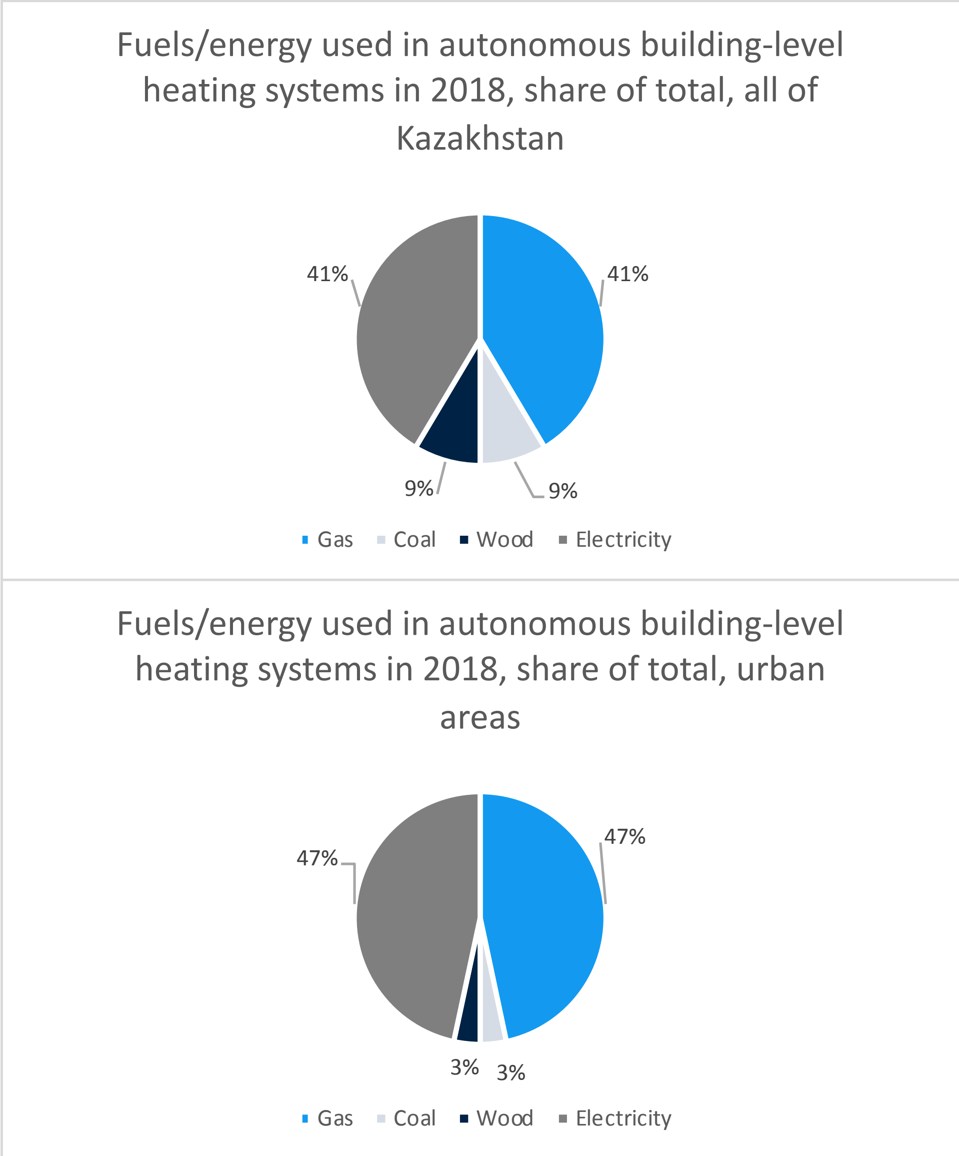


Source: Bureau of National Statistics.

In Kazakhstan, solid fuel-based (coal and wood) autonomous building-level systems accounted for 18 percent (9 percent coal and 9 percent wood) of all residential heating. In urban areas, the use of solid fuels in such systems was 6 percent (3 percent coal and 3 percent wood), while in rural areas, the share of solid fuels used in autonomous systems reached 27 percent. The equal share of coal and wood used in autonomous building-level systems raises potential questions about the way data were collected or might be an indication that coal and wood are often used together in such heating systems. In general, most autonomous building-level heating systems used natural gas or electricity.

The use of natural gas is uneven across the country due to limitations in natural gas availability. Households in Akmola, Karaganda, North Kazakhstan, Nur-Sultan (city), and Pavlodar report no natural gas use for heating. Since natural gas is not available, virtually all autonomous building-level residential heating systems in these regions/cities are reported to use coal and/or wood.

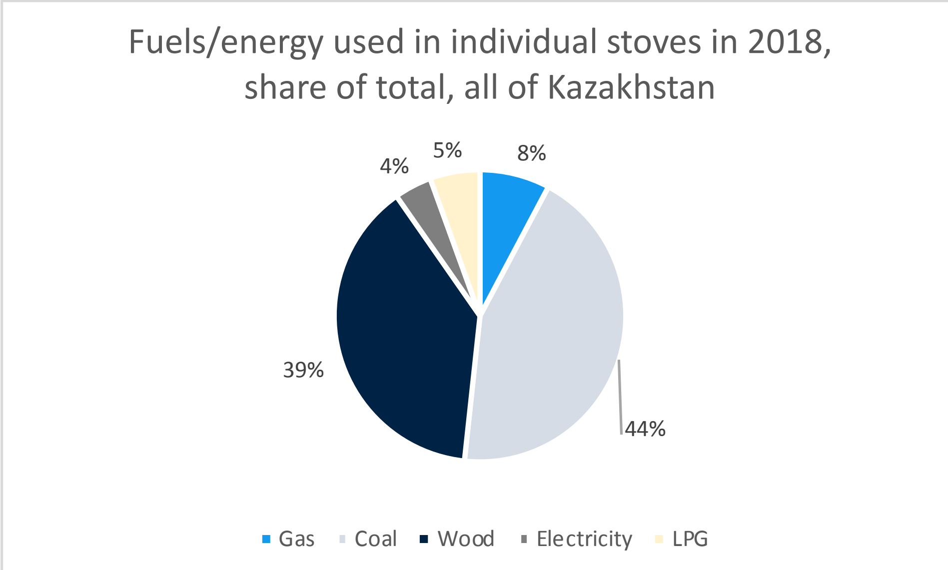
Figure 27: Fuels/energy used in autonomous building-level heating systems in all of Kazakhstan (top) and in urban areas only (bottom), 2018

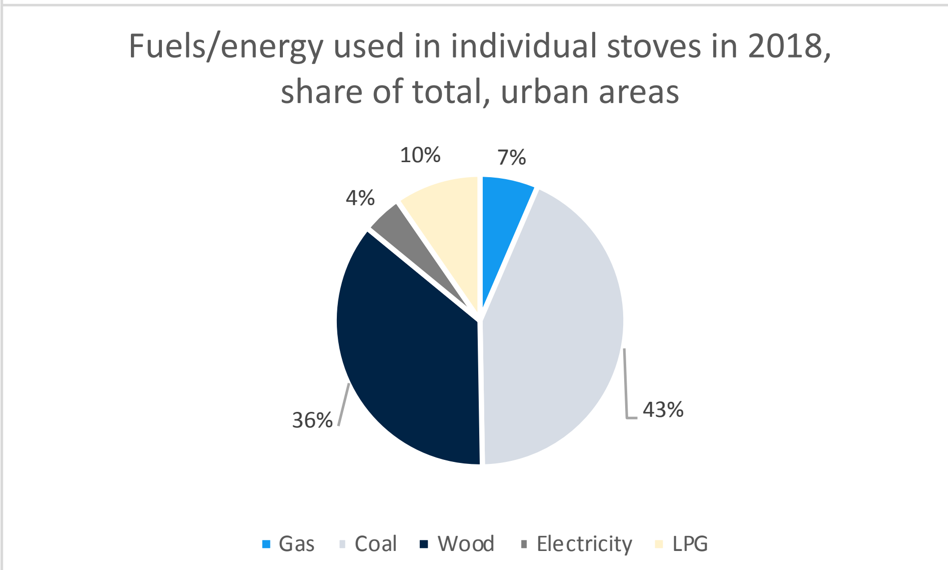


Source: Bureau of National Statistics.

In 2018, regardless of the location, solid fuels were the main fuels used in individual stoves and accounted for 79 percent and 84 percent in urban and rural areas, respectively. Coal was the preferred solid fuel used in individual stoves for residential heating (44 percent at the national level and 43 percent for urban households), followed closely by wood (39 percent and 36 percent, respectively). It is uncertain whether the close shares for coal and wood used for heating indicate co-firing of the two or point to an exclusive use of one of the fuels for heating in households.

Figure 28: Fuels/energy used in individual stoves in all of Kazakhstan (top) and in urban areas only (bottom), 2018





Source: Bureau of National Statistics.

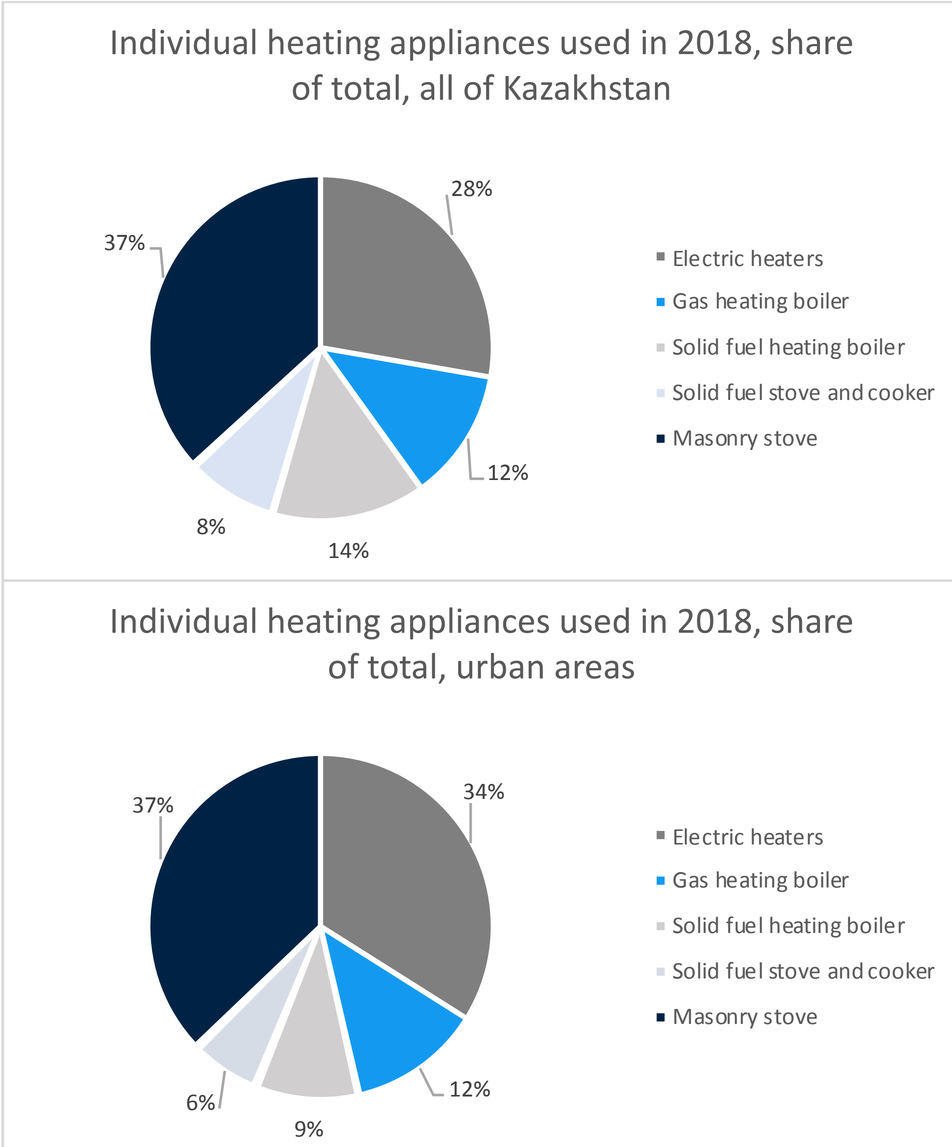
Across Kazakhstan, masonry stoves (Figure 29) were the predominant individual heating appliances and represented 37 percent of all individual stoves in 2018. The heating efficiency of masonry stoves usually ranges between 60 percent and 75 percent. The emission factors of masonry stoves for different pollutants such as CO, PM_{10}, and $PM_{2.5}$ are among the highest among the various heating fuels and technologies included in the EMEP/EEA Inventory Guidebook.

Figure 29: Typical solid fuel masonry stove used for heating and cooking in Kazakhstan

Source: Kerimray et al. 2016.

Electric heaters were also widely used in urban areas (34 percent of all individual heating appliances) and rural areas (26 percent of all individual heating appliances). Solid fuel appliances, outside of masonry stoves, were more popular in rural areas (25 percent of all individual heating appliances), compared to urban areas (16 percent of all individual heating appliances). Heat pumps were not widely used and accounted for 0.4 percent of individual heating appliances in the country in 2018.

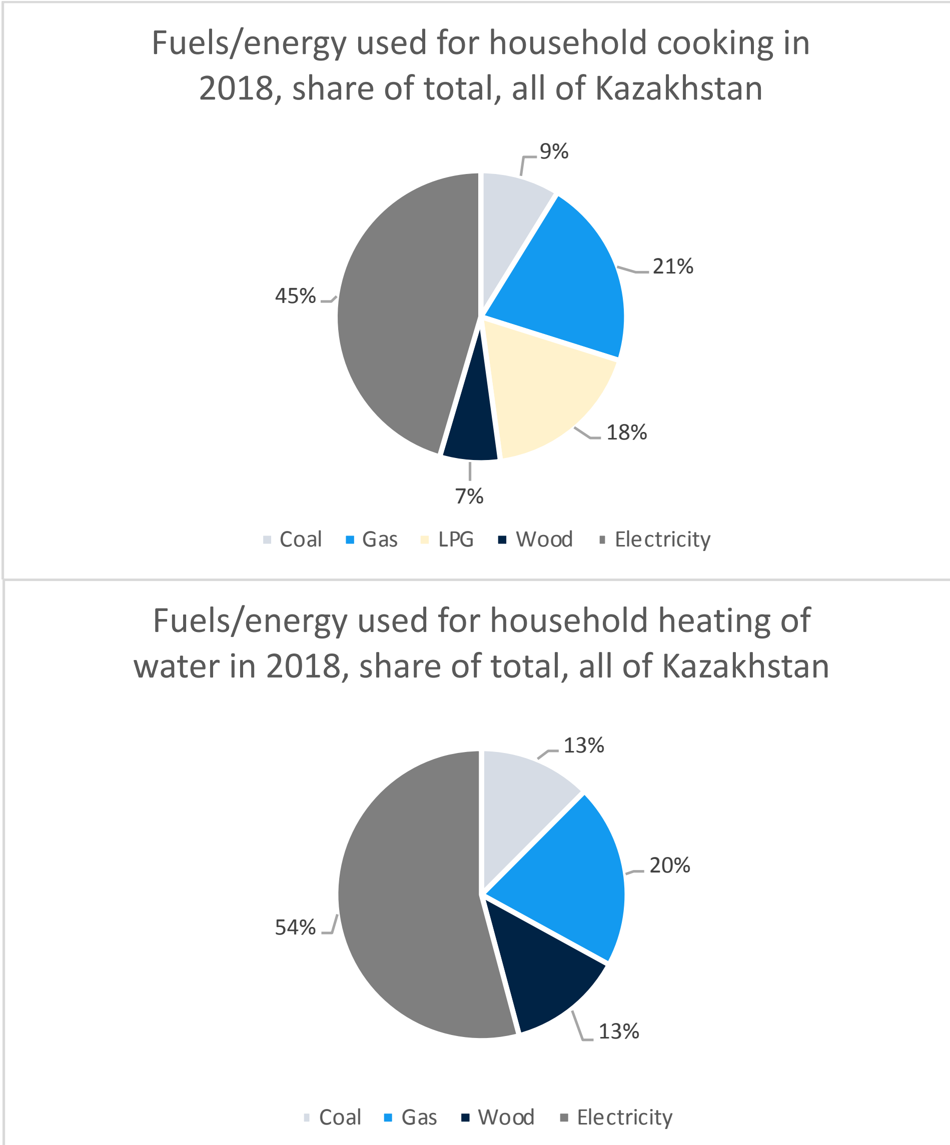
Figure 30: Individual heating appliances used in all of Kazakhstan (top) and in urban areas only (bottom), 2018



Source: Bureau of National Statistics.

In Kazakhstan, in 2018, electricity and gas were the main fuel/energy used for both household cooking and water heating, while solid fuels were also used for household cooking and water heating and accounted for 16 percent and 26 percent of all fuels used, respectively.

Figure 31: Fuels/energy used for household cooking (top) and water heating (bottom) in Kazakhstan, 2018, share of total



Source: Bureau of National Statistics.

The 2018 household survey demonstrates that large differences exist in fuels and energy consumption between urban and rural areas. With regard to solid fuels, 74 percent of all coal and 85 percent of all wood was consumed in rural areas. On the other hand, 72 percent of all natural gas and 78 percent of all liquified petroleum gas (LPG) was consumed in urban areas. In addition, the Concept for Transition of the Republic of Kazakhstan to Green Economy states that buildings in Kazakhstan consume 1.5–2 times more heat than buildings in the European countries with similar climates indicating that large energy efficiency gains can be achieved in the residential sector.

2.3.4. Hypothesis about Key Sources of Population Exposure to $PM_{2.5}$

Based on international experience and data on air quality presented in Chapter 1 and on fuels used in Kazakhstan's residential sector presented in Chapter 2, this report proposes a hypothesis that the residential sector is the country's key source of direct $PM_{2.5}$ and PM_{10} emissions of population exposure to $PM_{2.5}$. The analysis of air quality data, presented in Chapter 1, shows clear seasonality trends in $PM_{2.5}$ and PM_{10} concentrations with the highest concentrations reported in winter, which is likely related to the combustion of solid fuels for residential heating.

A more detailed airshed-level analysis planned for the second phase of this study will aim to validate this hypothesis. Collection of accurate data for parameters that influence emissions from the residential sector (especially the heating sources) is fundamental for designing cost-effective measures to reduce the health impacts of air pollution in Kazakhstan's cities.

3. EXPLORING AIR QUALITY - CLIMATE CHANGE INTERACTIONS: GAINS MODELING

A Greenhouse Gas Air Pollution Interactions and Synergies (GAINS) model was used to identify cost-effective measures to reduce mean population exposure to $PM_{2.5}$ and to analyze the effect of those measures on GHG emissions. The GAINS model was launched in 2006 by the International Institute for Applied Systems Analysis (IIASA). It is used as part of a standard modeling framework, in policy analyses under the CLRTAP and by the European Commission for strategic air quality planning.

The GAINS model assesses the cost-effectiveness of the strategies that aim to reduce multiple air pollutants and GHG emissions. The GAINS modeling of cost-effectiveness simulates technological and structural measures only and does not examine fiscal/tax options (for example, pollution/emission taxes or fuel subsidy removals), place-based options (such as low emission zones [LEZs] or relocation of industries and power plants), or behavioral aspects (for example, residents switching to less emitting behaviors). In addition, the abatement costs included in the modeling represent the pure 'project cost' to install and operate a low-emission technology, seen from the point of view of a social planner rather than individual economic agents. Therefore, the modeling takes a social planner's perspective with the goal to minimize societal resources while improving air quality and reducing GHG emissions.

For this report, two scenarios were modeled in GAINS. The main input parameter in GAINS is energy consumption of different fuels in key sectors. A 'Baseline' scenario models emissions of air pollutants and GHG under expected energy consumption if no additional measures beyond compliance with current legislation and emission controls are implemented. An 'Efficiency' scenario models the effects of a set of structural measures implemented across different sectors in Kazakhstan. The descriptions and results from the two scenarios are presented in this chapter.

The scenarios aim to identify the most cost-effective measures to reduce population exposure to $PM_{2.5}$ and simulate their impact on GHG emissions across Kazakhstan. The results can inform the first stage of discussion on priority sources and measures to address air pollution at the national level. However, these results should not be interpolated to the level of the most polluted regions. When considering individual cities, the prioritization of sources and measures will differ from city to city depending on costs and availability of various technology options, technical or economic feasibility of implementation, and city-specific (as opposed to national averages) input parameters in the modeling. Therefore, such analysis should also be conducted in combination with airshed-specific pollution dispersion models for the most polluted airsheds in Kazakhstan.

3.1. GAINS Modeling Methodology

3.1.1. The GAINS Model

The GAINS model explores cost-effective multi-pollutant emission control strategies that meet environmental objectives with respect to air quality impacts (on human health and ecosystems) and GHG. For this, GAINS brings together data on economic development; the structure, control potential, and costs of emission sources; the formation and dispersion of pollutants in the atmosphere; and the assessment of health, ecosystems, and climate impacts of the emissions.

In addition to GHG emission mitigation, the GAINS cost-effectiveness analysis of air quality and GHG management options considers the impacts on human health from air pollution with fine particulate matter and ground-level ozone, vegetation damage caused by ground-level ozone, the acidification of terrestrial and aquatic ecosystems, and excess nitrogen deposition to soils. GAINS describes the interrelations among these multiple effects and the pollutants that contribute to these effects at a defined scale.

The assessment starts from a detailed emission inventory of key air pollutants (SO_2, NOx, $PM_{2.5}$, PM_{10}, BC, organic carbon [OC], NMVOC, NH_3, and CO) and the Kyoto basket of GHG (CO_2, CH_4, N_2O, and fluorinated gases [F-gases]), so that the full set of precursor emissions of ambient $PM_{2.5}$ and ground-level ozone, long-lived GHG, and short-lived climate pollutants (SLCPs) is covered. Emission estimates are based on detailed statistical information about emission-generating human activities (energy, transport, industrial production, agricultural activities, waste volumes, and so on), plausible emission factors that reflect local conditions, fuel quality, technological status, and the effectiveness of applied emission control measures. Natural emissions are derived from estimates employed by the EMEP atmospheric chemistry and transport model.[28]

In terms of emission projections, GAINS combines changes in emission-generating economic activities as derived from exogenous studies and policy reports with the envisaged penetration of predefined control measures. It estimates the potential for additional emission reductions that is offered by several control measures, for which it assesses pollution control costs (up-front investments and operating costs) based on international and local cost data.

The resulting emission fields of all precursor emissions then feed into reduced-form source-receptor relationships that have been derived from the EMEP atmospheric chemistry-transport model. Annual mean concentrations of $PM_{2.5}$ in ambient air are computed for primary emissions of $PM_{2.5}$ at a 10 km × 10 km spatial resolution using local meteorological information for entire years and distinguishing the release heights of different emission sources. The chemical formation and atmospheric transport of secondary $PM_{2.5}$ in ambient air from the emissions of the relevant precursor emissions (that is, SO_2, NOx, NH_3, and volatile organic compounds [VOCs]) are modeled with a 0.5º × 0.5º longitude–latitude resolution. The resulting concentration fields are then compared with air quality standards, and the corresponding population exposure is computed for the population distribution assumed in the socioeconomic projection.

3.1.2. Emission Control Measures Considered in the Analysis

There are three types of measures to reduce emissions: behavioral, structural, and technical. The conducted GAINS assessment does not consider behavioral measures to reduce emissions and focuses on structural and technical measures. Structural measures supply the same level of (energy) services to the end consumer in cleaner and less-polluting ways. Examples of structural measures are fuel substitution (for example, switch from coal to natural gas) and energy conservation/energy efficiency improvements. Technical measures capture emissions before they are released into the atmosphere at the source, that is, end-of-pipe measures. Emission reductions achieved through these options neither modify the driving forces of emissions nor change the structural composition of energy systems or agricultural activities. The analysis considers pollutant-specific end-of-pipe measures, mainly for reducing SO_2, NOx, VOC, NH_3, and PM emissions, and assesses their application potentials and costs.

Structural Measures Considered in the Analysis

The current analysis considers the most prominent GHG mitigation options for which application potentials and costs are derived from external studies and model analyses.[29] The measures for the reduction of air

[28] For details see Simpson, D., Benedictow, A., Berge, H., Bergström, R., Emberson, L.D., Fagerli, H., Flechard, C.R., Hayman, G.D., Gauss, M., Jonson, J.E., Jenkin. M.E., Nyíri, A., Richter, C., Semeena, V.S., Tsyro, S., Tuovinen, J.P., Valdebenito, Á,, and Wind, P. "The EMEP MSC-W Chemical Transport Model – Technical Description.", *Atmospheric Chemistry and Physics* 12: 7825-7865. https://acp.copernicus.org/articles/12/7825/2012/.
[29] This is a subset of the measures that are conceivable for reducing GHG emissions.

pollutant and GHG emissions considered in the analysis for Kazakhstan are summarized in Table 20. Note that many measures are only applicable at specific source categories, and their technical and economic features differ greatly across source categories.

Table 20: Structural measures for the reduction of air pollutant and GHG emissions considered in the GAINS analysis

Sector	Summary of structural measures and their assumed maximum penetration in 2030
Power sector	• Scrappage of all small coal plants and replacement with new large ones • Modernization of 50% of the existing large coal plants commissioned before 2000 and replacement with large new ones to increase generation efficiency • Scrappage of 50% existing gas-fired boilers and switch to gas combined cycle power plants, increasing the share of power generation from gas
Renewable energy generation	• Doubling of electricity production from solar photovoltaics in all sub-sectors compared with the Baseline scenario
Fuel production and conversion other than power sector	• Reduction of fuel use and losses by 10% compared to the Baseline scenario through the refurbishment of the district heating network, among other measures
Manufacturing industry	• Fuel efficiency improvement of 1.0% per year (per unit of value added), on top of the improvement in the Baseline scenario
Transport	• Increased electrification of cars and buses (50% more electric vehicles compared to the Baseline scenario) • Implementation of Euro VI/6 standards after 2025 • Faster scrappage of old vehicles, with the scrapped vehicles replaced with new ones with better fuel efficiency • Vehicle turnover calculated with conservative assumptions of vehicle lifetime (20–25 years)
Residential - new residential buildings in urban areas	• More efficient building envelopes: 2% more new buildings per year compared to the Baseline scenario • New buildings using 50% less energy • 20% of additional new buildings supplied with natural gas, 50% by district heating system and the remaining 30% using heat pumps with coefficient of performance (COP = 3)
Residential - old residential buildings in urban areas	• More efficient building envelopes: 2% more refurbished buildings per year compared to the Baseline scenario, with the refurbished buildings using 30% less energy • 10% of additionally refurbished buildings switch from conventional old coal boilers* to natural gas, 30% to the district heating system, and the remaining 60% using modern coal boilers or stoves
Residential - new residential buildings in rural areas	• More efficient building envelopes: 2% more new buildings per year compared to the Baseline scenario • New buildings using 50% less energy • 20% of additional new buildings supplied with natural gas or LPG, 30% by district heating systems, and the remaining 50% using heat pumps.
Residential - old residential buildings in rural areas	• More efficient building envelopes: 1.5% more refurbished buildings per year compared to the Baseline scenario, with the refurbished buildings using 30% less energy • Larger buildings with boilers: 10% of refurbished buildings switch from conventional old coal boilers[a] to natural gas and 30% to district heating, while the others install new modern coal boilers or stoves, with the new coal boilers meeting the energy efficiency and emission requirements of the EU Ecodesign directive • Smaller residential buildings with stoves: Refurbished buildings in the suburbs connected to natural gas or district heating, while in rural areas, refurbished buildings switch from conventional old coal boilers[a] to LPG or heat pumps others install new modern coal briquette stoves, which meet the energy efficiency and emission requirements of the EU Ecodesign directive[30]

[30] In general, the GAINS approach allows to include as a measure a switch from biomass to natural gas in residential heating. However, such transition was not included in the current assessment. The use of biomass in the applied energy scenario for this report is small—likely due to the lacking statistics on noncommercial biomass in Kazakhstan. Thus, potential air quality improvements from such transition are minor and were not assessed. Evidence on noncommercial biomass use would change this approach.

Sector	Summary of structural measures and their assumed maximum penetration in 2030
Commercial - new commercial buildings	• 2% more new buildings per year compared to the Baseline scenario • New buildings use 50% less energy • 20% of additional new buildings supplied with natural gas, 50% by district heating system, and the remaining 30% of new commercial buildings using modern coal boilers meeting the energy efficiency and emission requirements of the EU Ecodesign directive.
Commercial - old commercial buildings	• 2% more refurbished buildings per year compared to the Baseline scenario, with the refurbished buildings using 30% less energy • 10% of additionally refurbished buildings supplied with natural gas, 30% by district heating system, while the remaining 60% using modern coal boilers or stoves with briquettes meeting the energy efficiency and emission requirements of the EU Ecodesign directive
Agriculture and other sectors	• Reduction of consumption of liquid fuels and district heat by 10% compared to the Baseline scenario
Note: a. The official statistics used as a starting point in the analysis report insignificant consumption of biomass for heating at the national level; thus, it does not appear in the analysis. The share of biomass use for heating in specific cities should, nevertheless, be considered when conducting city-level analyses. *Source: World Bank.*	

Technical Measures Considered in the Analysis

In addition to and separately from the structural measures, and to explore further cost-effective air quality improvements, the GAINS model is able to also consider multiple end-of-pipe emission reduction measures. These measures are defined for various source categories with their specific emission reduction efficiencies for all air pollutants and GHG, investments and operating costs, and application potentials. The key technical measures considered in the current analysis are summarized in Table 21.

Table 21: Summary of the end-of-pipe and other technical emission control measures considered in the analysis for Kazakhstan

Sector	Technical measures considered in the analysis
Power sector	• Gradual implementation of best available technique (BAT) on new plants after 2025 **Power plants - utilization of:** • Flue gas desulfurization • Low-NOx burners • NOx removal through selective catalytic reduction (SCR) or selective non-catalytic reduction (SNCR) • High-efficiency particulate removal and electrostatic precipitators • Low-sulfur fuels **Diesel generators:** • Enhanced supply security of electricity • Emission standards
Mobile sources	**Light-duty diesel and gasoline road vehicles:** • Enhanced inspection and maintenance of vehicles and enforcement of emission standards • Up to Euro 6 emission standards for new vehicles, accompanied by improved fuel quality **Heavy-duty diesel road vehicles:** • Enhanced inspection and maintenance of vehicles and enforcement of emission standards • Up to Euro 6 emission standards for new vehicles, accompanied by improved fuel quality **Non-road mobile machinery (construction, agriculture, inland ships, trains, machinery, and so on):** • Enhanced emission standards, including DPFs **2- and 3-wheelers:** • Improved emission standards • Switch to electric vehicles

Sector	Technical measures considered in the analysis
Industry	**Industrial boilers - utilization of the following:** • Flue gas desulfurization • DeNOx with SCR or SNCR • High-efficiency dedusters and electrostatic precipitators • Low-NOx burners • Low-sulfur fuels **Emissions from industrial processes (cement, steel, glass, and so on) - utilization of the following:** • Flue gas desulfurization • DeNOx with SCR or SNCR • High-efficiency PM filters • Good practices to capture fugitive emissions • Implementation of standards equivalent to the EU BAT requirements for major process emission sources from 2025 onward **Nonferrous metal smelters:** • Capture of SO_2 from flue gases to produce sulfuric acid or elemental sulfur • Implementation of standards equivalent to the EU BAT requirements for major process emission sources from 2025 onward **Brick kilns:** • Replacement of brick tunnel kilns by vertical shaft brick kilns or zig-zag kilns **Oil and gas industry:** • Recovery of fugitive losses • Good practices, regular inspection, and maintenance • Reduced flaring and venting
Residential and commercial	• Replacement of biomass cook stoves with electric, LPG, or natural gas cook stoves • New cook stoves • Low-solvents household products • Low-sulfur coal and fuel oil • Use of oil and gas boilers with lower emissions of NOx • Coal and biomass stoves and boilers[a] meeting the requirements of the EU Ecodesign Directive • Switch from coal to coal briquettes or coke • Enhanced energy efficiency of air conditioners, freezers, washing machines, and light bulbs, supported by eco-labels for new appliances, assumed in the baseline. However, because the savings will be counteracted by higher ownership and use of appliances, the net effect on total electricity consumption is considered small.
Municipal waste	**Collection:** • Separation of waste at source into biodegradables, dry waste, and other type of waste **Waste management:** • Closing/upgrade of dumpsites • Avoiding of open burning of waste • Incineration **Organic waste:** • Diverting of organic waste from dumpsites/landfills • Incineration • Composting • Biogas digesters **Plastic, paper, glass, metal, and textile waste:** • Increased recycling rates **Other waste:** • Diversion of waste from dumpsites/landfills • Incineration

Sector	Technical measures considered in the analysis
Agriculture	**Fertilizer application:** • Efficient use of urea • Nitrification inhibitors • Replacement of urea **Manure management:** • Covered manure storage • Enhanced open grassing • Low-emission application of manure **Open burning of agricultural residues:** • (Enforcement of) ban on open burning of agricultural residues • Co-firing of agricultural residues pellets with coal power plants and biofuel blending with diesel/gasoline

Note: a. It is assumed that biomass stoves and boilers are mainly used in rural areas that do not have access to centralized natural gas systems, while coal is used in both rural and urban areas. The share of biomass use for heating in specific cities should, nevertheless, be considered when conducting city-level analyses.
Source: World Bank.

3.1.3. Cost Estimates

The cost evaluation in GAINS attempts to quantify the values to society when resources are diverted to reduce emissions. In practice, these values are approximated by estimating costs at the production level rather than at the level of consumer prices. Therefore, any mark-ups charged over production costs by manufacturers or dealers do not represent actual resource use and are ignored. Any taxes added to production costs are similarly ignored as subsidies since they are transfers and not resource costs.

A central assumption in the cost calculation is the existence of a free international market for (abatement) equipment that is accessible to all countries at the same conditions. Thus, net expenditures for emission controls are differentiated into capital investments, operating and maintenance costs, and cost savings.

From these three components, annual costs per unit of activity level are calculated. Investments include fixed capital costs associated with the control option, discounted at a 4 percent annual rate. Operating and maintenance costs include all variable costs associated with a given measure. These are usually made up of material, energy, and labor costs for operation of the abatement equipment, as well as waste separation and collection costs. Cost savings emerge primarily from the sale of by-products (for example, gypsum), reduced energy demand (for example, for more efficient appliances), reduced losses (for example, from leakages), and other productivity increases. Avoided costs for waste disposal when waste is recycled or composted are also included as cost savings.

Data for Kazakhstan have been derived from the GAINS database.[31] All costs are expressed in euros (€) in 2015 prices.

In addition, GHG mitigation measures can have important (positive or negative) side effects on air pollutant emissions and, consequently, on air quality (and vice versa). This offers the potential for economic gains from integrated approaches in which AQM and GHG mitigation are considered simultaneously and where existing trade-offs between these two aspects are avoided.

To this end, the current analysis does not embark on a full assessment of the costs of GHG mitigation measures in Kazakhstan, as any simplistic approach could deliver misleading messages. Instead, costs of the relevant GHG mitigation options are approximated by available cost estimates in the literature. The

[31] http://gains.iiasa.ac.at.

analysis presented in this report employs the marginal carbon mitigation costs as presented in McKinsey's Global GHG Abatement Cost Curve V2.1 for 2030.[32]

3.2. GAINS Scenarios

3.2.1. Baseline and Efficiency Scenarios

The 'Baseline' projection starts from 2018 and uses the national energy statistics and, in the case of road transport, the data reported by Kazakhstan to the UNFCCC, and extrapolates the data up to 2030 along the sectoral trends of the Stated Policies Scenario (STEPS) of the World Energy Outlook 2020 of the International Energy Agency (IEA).[33] The STEPS scenario generated a forecast for Caspian Sea countries, which also includes Kazakhstan. The forecasts for the Caspian Sea countries were downscaled to define a Kazakhstan-specific scenario. The 'Baseline' scenario established 2020 as the base year for the modeling calculations. The energy consumption for the year 2030 in the 'Baseline' scenario outlines a 'business as usual' development of emissions based on plausible projections of socioeconomic activities and assuming full compliance with the current emission control legislation in Kazakhstan.

Currently, Kazakhstan has no emission limit values (ELVs) for stationary sources similar to the LVs in force in several countries (for example, China, the EU, and the US). For large point sources, Kazakhstan has not yet established generally applicable ELVs, but rather a maximum annual emission limit is specified for each large combustion plant. Given the lack of specific prescriptive regulations, the current extent of applied emission control measures for SO_2 and NOx has been estimated from the sectoral emissions in the emission inventory reported under CLRTAP, so that bottom-up estimates based on statistical information on activity data and plausible emission factors derived from other countries with similar conditions have been developed instead.

For transport, emission characteristics were developed based on information about the age structure of vehicles as presented in Section 2.3.2. Thus, for new cars, it has been assumed that vehicles will meet the Euro 5 emission standards. Similar type of legislation has been assumed for heavy-duty vehicles. The penetration of tighter emission standards considers the age distribution of vehicles as provided by the Statistical Office of Kazakhstan.

The 'Efficiency' scenario forecasts the energy consumption of different fuels in key sectors for 2030 based on the assumptions related to improved energy efficiency and fuel switch toward cleaner fuels. The 'Efficiency' scenario includes all the structural measures described in Table 20.

3.2.2. Scenario Comparison

Table 22 and Table 23 provide a comparison of the forecasted energy consumption in the 'Baseline' and 'Efficiency' scenarios. Total energy consumption in 2030 in the 'Efficiency' scenario is 11 percent less, compared to the 'Baseline' scenario. The biggest differences between the 'Baseline' and the 'Efficiency' scenarios are

- 20 percent reduction in coal consumption in the 'Efficiency' scenario, compared with the 'Baseline' scenario;
- 31 percent increase in the consumption of renewable energy (excluding biomass) in the 'Efficiency' scenario, compared with the 'Baseline' scenario;

[32] https://sallan.org/pdf-docs/2009_mckinsey.pdf.
[33] IEA. World Energy Outlook 2020. https://www.iea.org/reports/world-energy-outlook-2020/overview-and-key-findings.

- 19 percent reduction in residential energy consumption in the 'Efficiency' scenario, compared with the 'Baseline' scenario;
- 12 percent reduction in energy consumption in power and heating plants in the 'Efficiency scenario, compared with the 'Baseline' scenario; and
- 50 percent increase in electric road vehicles in the 'Efficiency' scenario, compared with the 'Baseline' scenario.

Table 22: Energy consumption by fuel used in the 'baseline' and 'efficiency' scenarios, petajoules (PJ) per year

Fuel	Base year (2020)	Baseline scenario (2030)	Efficiency scenario (2030)	% change in efficiency/baseline scenario (2030)
Coal	1,455.2	1,543.9	1,233.6	−20
Liquid fuels	802.8	902.7	860.2	−5
Gaseous fuels	792.9	830.4	786.2	−5
Biomass	4.2	5.7	5.7	0
Renewable energy (excluding biomass)	45.4	66.8	87.5	31
Nuclear	0.0	23.4	23.4	0
Electricity	−15.2	−11.4	0.0	−100
Heat (steam, hot water)	−0.3	0.0	0.0	0
Total	**3,085.1**	**3,361.5**	**2,996.6**	**−11**

Note: Negative numbers in the table represent energy production or net exports. Positive numbers represent energy consumption.
Source: Original calculations for this publication.

Table 23: Energy demand by key sectors used in the 'baseline' and 'efficiency' scenarios, PJ per year

Sector	Base year (2020)	Baseline scenario (2030)	Efficiency scenario (2030)	% change in efficiency/baseline scenario (2030)
Power and heating plants	530.7	593.0	523.2	−12
Fuel conversion	708.9	664.7	629.2	−5
Residential combustion and other	836.0	913.3	735.9	−19
Industrial combustion	578.9	656.7	592.4	−10
Light-duty vehicles	212.3	276.2	261.8	−5
Heavy-duty vehicles	91.5	103.6	100.0	−4
Electric road vehicles	0.0	0.6	0.9	50
Non-road machinery	113.4	139.9	139.9	0
Non-energy use of fuels	13.4	13.4	13.4	0
Total	**3,085.1**	**3,361.5**	**2,996.6**	**−11**

Source: Original calculations for this publication.

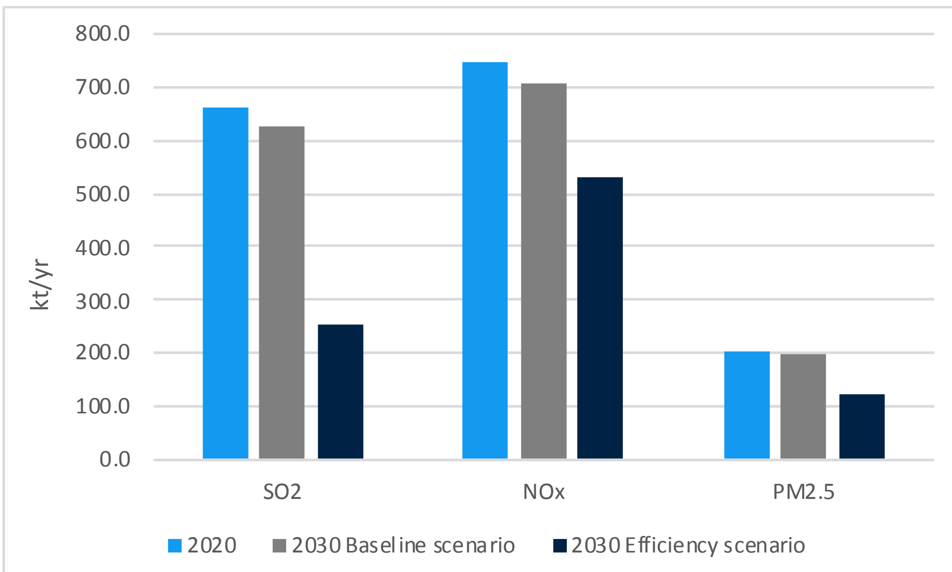
3.3. GAINS Modeling Results: Emissions

The scenarios described in Section 3.2 were modeled using GAINS with emissions of air pollutants and GHG estimated. Such modeling allows to assess the level of change in emissions of both air pollutants and

GHG following the adoption of the measures under the 'Efficiency' scenario. Figure 32 provides the results for the two modeled scenarios in the base year of 2020 and in 2030 for key air pollutants while Figure 33 shows the change in CO_2 emissions in the two scenarios.

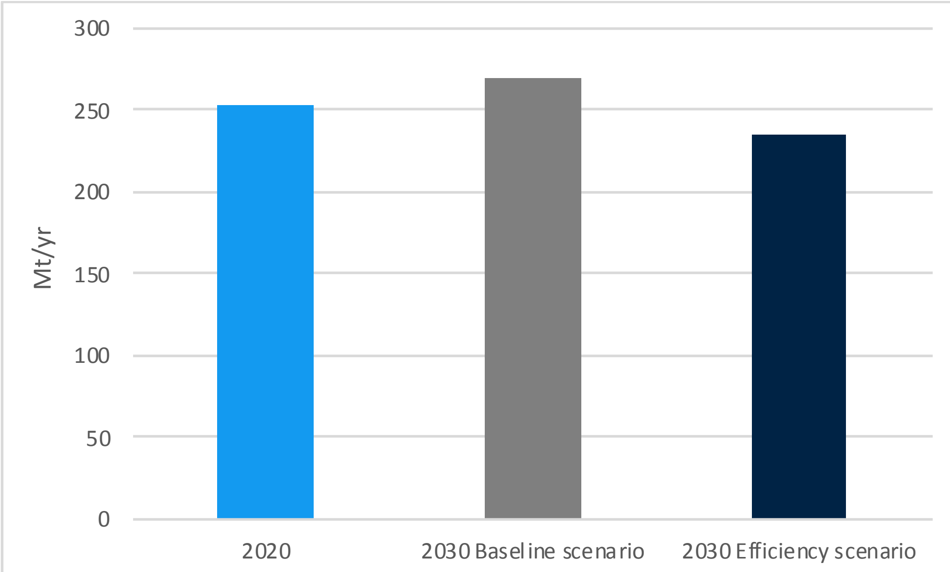
Air pollutant emissions in the base year of 2020 were compared to the emissions reported by Kazakhstan in its latest emission inventory submission under the CLRTAP (Table 15). The modeled SO_2 and NOx emissions using GAINS were 1 percent and 2 percent lower, respectively, than those reported by Kazakhstan. There was a significant difference in modeled $PM_{2.5}$ emissions, compared to those reported. The modeled $PM_{2.5}$ emissions were 93 percent higher than the emissions reported by Kazakhstan in its emission inventory submission under the CLRTAP. This is because Kazakhstan's emission inventory under the CLRTAP does not report $PM_{2.5}$ emissions from significant sources such as public electricity and heat generation, residential heating, and some industrial sectors.

Figure 32: Modeled emissions of key air pollutants in 2020 (base year) and under the 2030 'Baseline' and 2030 'Efficiency' scenarios, in kt per year



Source: Source: Original figure for this publication.

Figure 33: Modeled CO_2 emissions in 2020 (base year) and under the 2030 'Baseline' and 2030 'Efficiency' scenarios, in megatons (Mt) per year



Source: Original figure for this publication.

The modeling results estimate a decrease in all emissions under the 'Efficiency' scenario, compared to the 'Baseline' scenario in 2030. Emissions of SO_2 show the largest reduction, compared with the 'Baseline' scenario—nearly 60 percent—whereas CO_2 emission are forecasted to decrease by 13 percent under the 'Efficiency' scenario, compared with the 'Baseline' scenario (Table 24).

Table 24: Emission reductions under the 'Efficiency' scenario, compared with the 'Baseline' scenario in 2030, in %

Pollutant	Change in emissions under the 'Efficiency' scenario, compared with the 'Baseline' scenario in 2030 (%)
SO_2	−59
NOx	−25
$PM_{2.5}$	−39
CO_2	−13
Source: Original calculations for this publication.	

The power and residential sectors are primarily responsible for emission reductions for both air pollutants and CO_2 emissions. Table 25 shows the emission reductions forecasted for those sectors under the 'Efficiency' scenario, compared with the 'Baseline' scenario.

Table 25: Modeled emission reductions from the power and residential sectors under the 'Efficiency' scenario, compared to the 'Baseline' scenario in 2030, in %

Pollutant	Change in emissions under 'Efficiency' scenario, compared with the 'Baseline' scenario in 2030	
	Power sector	Residential sector
SO_2	−72	−76
NOx	−43	−39
$PM_{2.5}$	−52	−80
CO_2	−10	−40

Source: Original calculations for this publication.

As shown in Table 25, the same package of measures achieves different levels of emission reductions for the different pollutants. This illustrates the value of modeling the effect of measures under different scenarios using GAINS. Depending on the policy goal, GAINS can inform the composition of the most cost-effective package of measures. By modeling the effects of different packages of measures and comparing the expected results, decision makers can make an informed choice of the package of measures that delivers the largest co-benefits between air quality improvement and climate change mitigation.

3.4. GAINS Modeling Results: Cost-Effectiveness

The completed GAINS modeling provides a clear representation of the measures' effects and determines, for each of these measures, the overall impact of 'co-control' of multiple pollutants on selected air quality and climate indicators. Thereby, the modeling takes full account of the simultaneous impacts of a measure on all types of air pollutant and GHG emissions, which could be positive or negative, as well as of the combined impacts of all these emission changes on ambient $PM_{2.5}$ concentrations, health,[34] and climate impact indicators[35].

The modeling not only incorporates the costs of the measures and their reduction efficiencies for the various pollutants but also considers atmospheric chemistry, the transport of pollutants in the atmosphere, impact on population considering spatial differences in population densities, and the relative climate impacts of different long- and short-lived emissions.

Exploration of cost-effective pollution control strategies requires reliable statistics on emission-generating activities and utilizes some macro-level data such as gross domestic product (GDP), population, and projections of future macroeconomic development. In addition, numerous technical control measures are predefined into GAINS. A summary of the specific technical control measures used in the current national-level study for Kazakhstan is presented in Table 21.

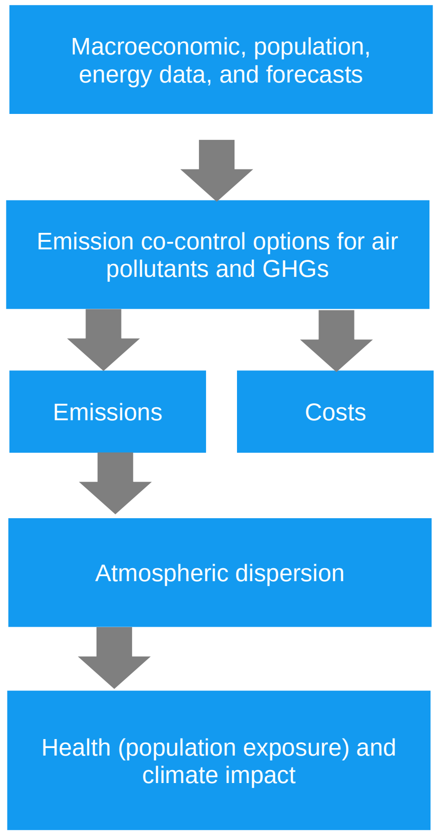
The assessment relies on a detailed emission inventory of key air pollutants (SO_2, NOx, $PM_{2.5}$, PM_{10}, BC, OC, NMVOC, NH_3, and CO) and the Kyoto basket of GHGs (CO_2, CH_4, N_2O, and F-gases), so that a full set of precursor emissions of ambient $PM_{2.5}$, long-lived GHGs and SLCPs is covered. The resulting emission fields of all precursor emissions have been derived from the EMEP atmospheric chemistry-transport model. Annual mean concentrations of $PM_{2.5}$ in ambient air are computed for primary emissions of $PM_{2.5}$ using local meteorological information and distinguishing the release heights of different emission sources. The chemical formation and atmospheric transport of secondary $PM_{2.5}$ in ambient air from the

[34] Health impacts are inferred from changes in population exposure to $PM_{2.5}$.
[35] The analysis uses the Global Warming Potential (GWP) for 100 years (GWP_{100}) metric.

emissions of the relevant precursor emissions (that is, SO_2, NOx, NH_3, and VOC) are also modeled. Concentration fields and the corresponding population exposure are then computed for the population distribution assumed in the socioeconomic projection.

The steps implemented in the cost-effectiveness analysis of the individual measures for the improvement of air quality and/or the mitigation of GHG are illustrated in Figure 34.

Figure 34: Steps in the conducted cost-effectiveness analysis for least-cost measures to reduce mean $PM_{2.5}$ population exposure



Source: Original figure for this publication.

With a focus on cost-effectiveness, the remainder of this section introduces cost curves that rank for 2030 the available emission control measures beyond the current legislation according to their marginal costs for reducing population exposure to $PM_{2.5}$ and GHG emissions in Kazakhstan.

3.4.1. Least-Cost Measures to Reduce $PM_{2.5}$ Exposure in Kazakhstan

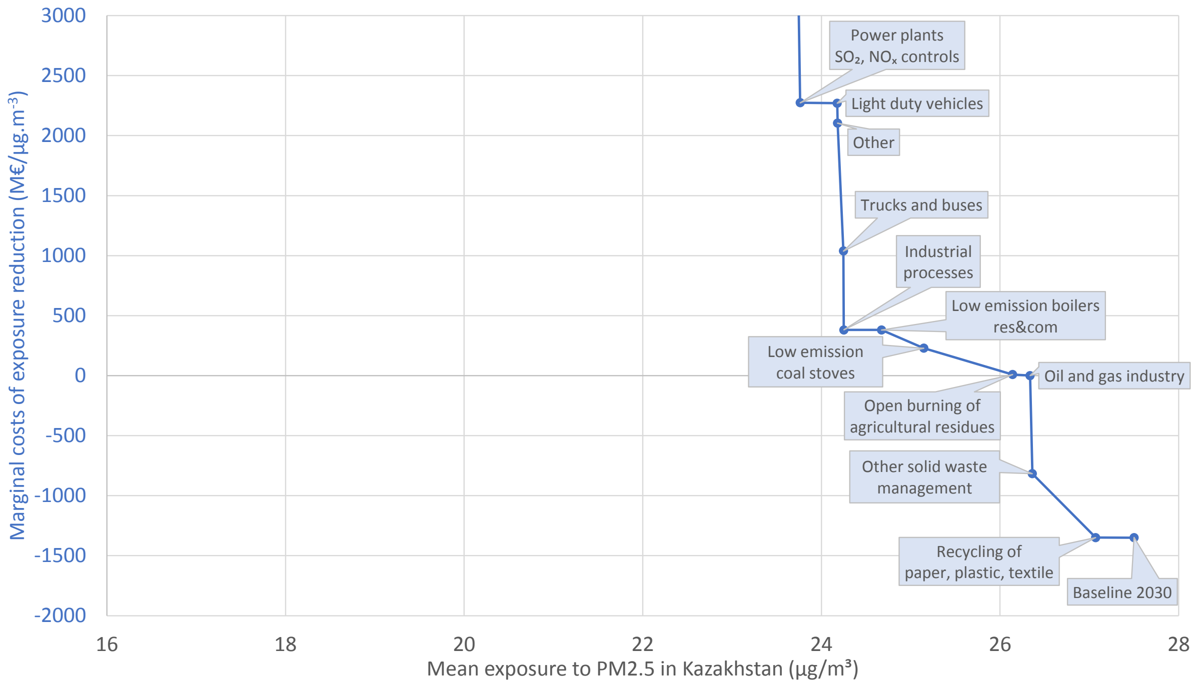
The $PM_{2.5}$ exposure level[36] in Kazakhstan resulting from the 'Baseline' GAINS scenario was estimated at 27.5 microgram per cubic meter (µg/m³), of which about 15 µg/m³ is caused by natural sources (wind-blown soil dust) and inflow from neighboring countries.[37] This leaves a contribution of about 12 µg/m³ from sources in Kazakhstan, whose emissions could be controlled through further economic or environmental policies.

[36] The analysis focused on $PM_{2.5}$ due to its significant health impact. In addition, as demonstrated in Chapter 1, most cities in Kazakhstan report high $PM_{2.5}$ concentrations, especially in winter, which indicates that residential heating on solid fuels is an important source of $PM_{2.5}$ pollution.
[37] As estimated by the EMEP modeling framework based on global emissions inventories.

The modeling estimated that adding a full application of all conventional air pollution technical control measures such as cleaner combustion devices to the ‘Baseline’ scenario, improved fuel quality, and the other end-of-pipe emission controls, presented in Table 21 in Kazakhstan could reduce exposure to about 22.5 µg/m³ (

Figure 35) which is below EU’s annual $PM_{2.5}$ LV of 25 µg/m³ (Table 1). Limits to the technical efficiencies of the available control measures as well as to their application potentials result in considerable residual emissions and exposure.

Figure 35: Marginal cost curve for population exposure to $PM_{2.5}$ with conventional air pollution control measures for Kazakhstan, 2030



Source: Original figure for this publication.

Figure 35 demonstrates that the net cost savings are identified for some waste management options (for example, recycling) where the market value of the collected waste (for example, paper) exceeds collection costs. Such a finding might be surprising, but it indicates that if improved waste management is implemented and recycling rates are increased, then less waste will be available to be burned in household stoves which can be a significant source of air pollution. Furthermore, it is notable that some measures in the residential sector, especially those which reduce heating demand, emerge among the lower-cost options, while some end-of-pipe controls at large point sources appear as less cost-effective for reducing population exposure to $PM_{2.5}$ at the national level, given the large size and low population density of the country. However, those end-of-pipe controls might offer cost-effective reductions at highly polluted places in industrial areas. Therefore, implementation of end-of-pipe controls at large point sources would be beneficial for air quality in some of the cities in Kazakhstan located close to heavy industries such as Karaganda and Temirtau.

The scope of the modeled measures presented in

Figure 35 was broadened with GHG mitigation measures that aim at lower consumption of fossil fuels, which very often also result in lower air pollution emissions, especially at sources where only limited technical potential for end-of-pipe measures exists and at sources which use coal. Therefore, a marginal cost curve that includes the structural GHG mitigation measures (described in Table 20) in the developed 'Efficiency' scenario, some of which are not traditionally in the focus of air quality managers, is presented in Figure 36. The figure highlights the significant additional exposure reduction potential that emerges from such an enlarged portfolio of measures.

The modeling shows that the structural measures (Table 20) from the 'Efficiency' scenario together with the technical end-of-pipe measures (Table 21) reduce $PM_{2.5}$ exposure in Kazakhstan to about 18.5 µg/m³, that is, by about 30 percent below the baseline and 17 percent below the level in the case when only technical end-of-pipe measures are implemented (

Figure 35).

Most prominently, measures to enhance the thermal insulation of the building stock offer a large potential for air quality improvements, both at large multi-family apartment buildings and smaller single-family houses. The lower heat demand from enhanced insulation would then also enable the installation of cleaner and more efficient heating devices, such as boilers, stoves, and heat pumps, which together allow a significant reduction of the use of polluting fuels.

GHG mitigation measures not only enhance the potential for air quality improvements but also, by their nature, reduce emissions of GHGs. The change in total GHG emissions in Kazakhstan that occurs as a side effect of the cost-effective measures to reduce exposure to $PM_{2.5}$ is also shown in Figure 36. In general, all modeled cost-effective measures for PM exposure also reduce GHG emissions; a minor exception emerges for the installation of SO_2 and NOx controls at power plants, which leads to a slight increase in GHG emissions due to additional energy consumption for operating the devices.[38] Lower coal use for heating purposes through enhanced insulation of building envelopes and a switch to cleaner fuels and higher combustion efficiencies bring benefits both for air pollution exposure and GHGs. Abolition of methane flaring from oil and gas extraction brings some benefits to air quality in Kazakhstan (minor due to the location of these sources) and major benefits for GHG emissions. It is also noteworthy that the additional energy demand for operating end-of-pipe emission control devices, which is considered in this analysis, is rather small compared to the reductions of CO_2 and CH_4 emissions that occur from other measures.

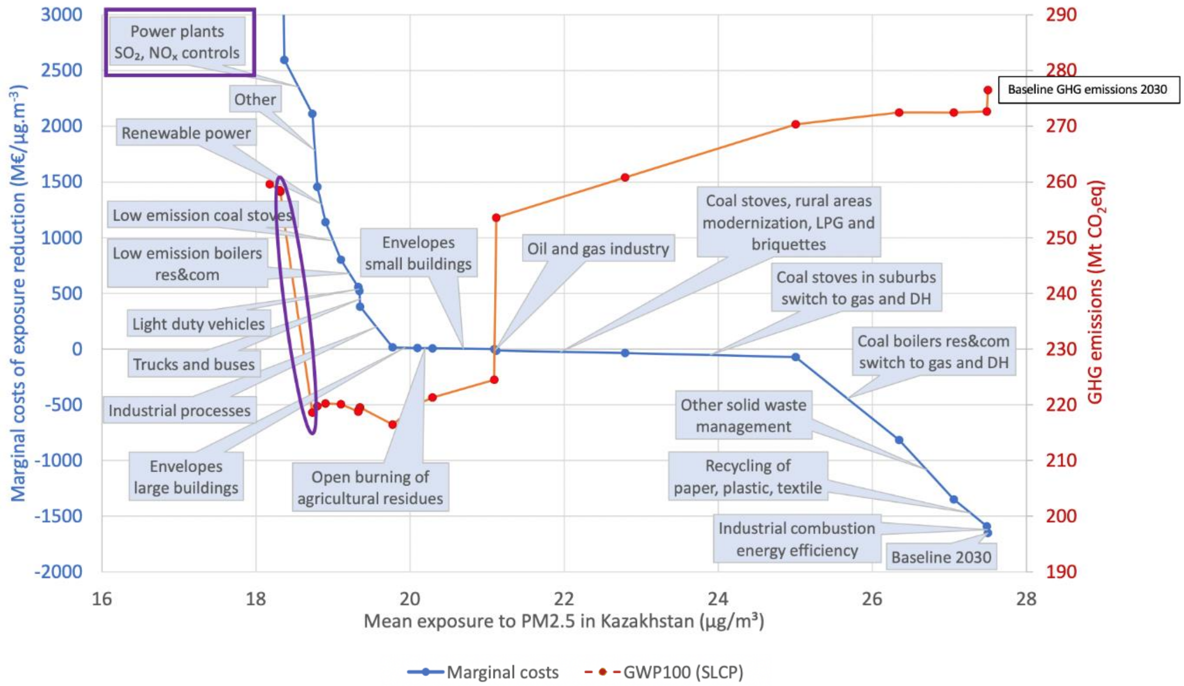
However, the quantification of climate benefits is challenging due to the complexity of the relevant spatial and temporal scales, and the general scientific uncertainties in the quantification of the climate effects. In the last decade, the climate impacts of short-lived air pollutants, the so-called SLCPs, gained global attention due to the near-term temperature impacts of air pollutants. By no means does this diminish the vital importance of long-lived GHG such as CO_2 and CH_4. Nevertheless, it has been established that CH_4, BC, and CO contribute to warming in addition to CO_2, while SO_2, NOx, NH_3, and OC emissions exert cooling to the atmosphere. Thus, the net balance of the temperature impacts of specific measures depends on the relative changes that the measure has on the emissions of all the different pollutants (co-controls). Most relevant for AQM, SO_2 and NOx reductions as such enhance temperature increase, while BC and CH_4 reductions counteract warming.

To analyze the fuller climate impacts of the measures that can be taken to reduce $PM_{2.5}$ exposure in Kazakhstan, the impacts of the most powerful SLCPs, that is, CH_4, BC, SO_2, NOx, and NH_3, in addition to

[38] If a switch from biomass burning for heating in households to natural gas was included as a measure, then this measure would also lead to an increase in GHG emissions. Such a measure can be included in future work at the city level.

CO_2 changes are explored. The metric used in this analysis is GWP_{100} using SLCPs coefficients. The result of this analysis is the red line in Figure 36.

Figure 36: Marginal cost curve for population exposure to $PM_{2.5}$ in Kazakhstan in 2030, along with the impacts of the measures on GHG emissions, using the GWP_{100} metric that accounts for SLCP's impact on climate over a 100-year time horizon



Source: Original figure for this publication.

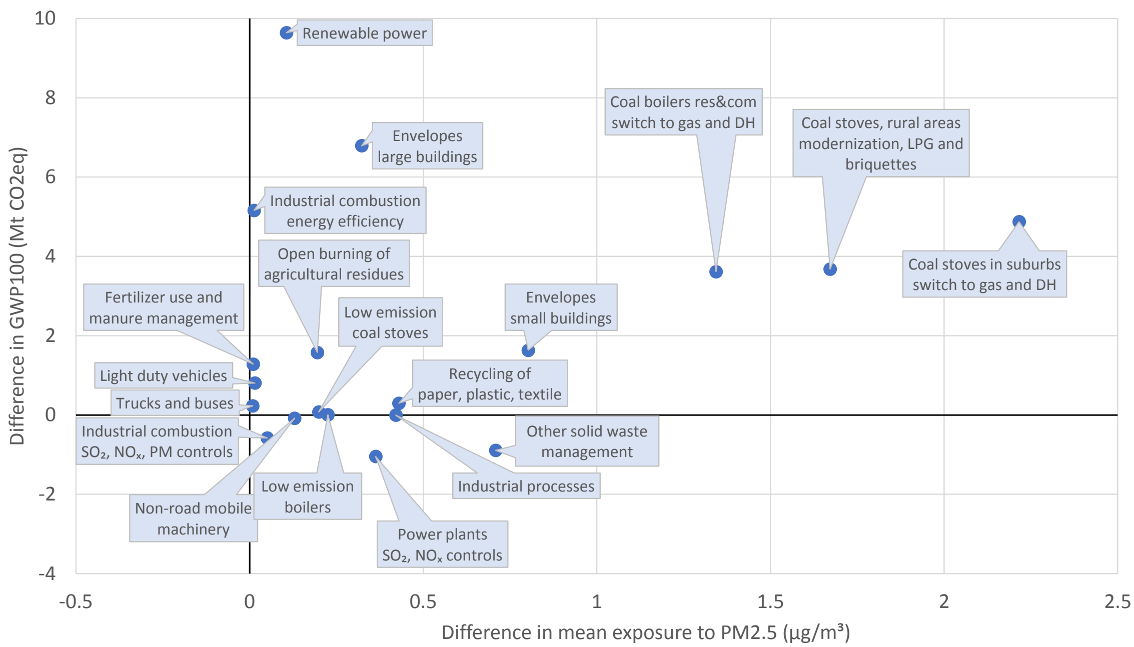
Note: The blue schedule represents marginal air pollution abatement cost curve for Kazakhstan with the potential to reduce mean exposure to $PM_{2.5}$ on the horizontal axis and a cost of reducing exposure by one unit on the vertical, left (blue) axis. The red schedule represents the impact of air pollution technical abatement measures on national GHG emissions (right (red) axis). The curves should be read from right to left. The first dot to the right on the blue schedule represents projected baseline $PM_{2.5}$ mean exposure in Kazakhstan in 2030, whereas the first dot to the right on the red schedule represents projected baseline GHG emissions in Kazakhstan in 2030. Each dot moving from right to left on both schedules represents a modeled measure to improve air quality (blue curve) and its respective impact on GHG emissions (red curve). A down-sloping red curve means an air pollution measure also reduces GHG emissions (synergy), while an upward-sloping red schedule implies a trade-off. The figure shows that reducing mean national exposure from 28 µg/m³ to 18.5 µg/m³ can have a number of climate co-benefits. The air quality measure showing the main GHG emission trade-off is highlighted in purple. The switch from biomass to gas/LPG was not included among available abatement measures in this model run and would increase trade-offs.

The inclusion of the climate impacts of air pollutants using the GWP_{100} metric has profound impacts on the analysis as there are clear climate disbenefits of measures that involve significant SO_2 reductions without accompanying cuts in BC or CO_2 emissions. While most air pollution control measures, which have been found to be most cost-effective in Kazakhstan, deliver simultaneous climate benefits, some of the most prominent conventional air pollution control measures, such as end-of-pipe controls for SO_2 and NOx, lead to additional warming and could nullify the positive impacts of the other controls. Despite being at the high end of the exposure reduction cost curves, such end-of-pipe controls at large sources might be needed to reduce population exposure if other more cost-effective measures do not bring the necessary air quality improvement, especially in cities with heavy industry, large CHP and power plants, and unfortunate meteorological and topographic conditions causing atmospheric inversions.

3.4.2. Simultaneous Reductions of $PM_{2.5}$ Exposure and GHGs

A comparison of the $PM_{2.5}$ exposure and GHG impacts of the emission control measures in various economic sectors clearly reveals the options that yield simultaneous benefits on both end points (the measures that are above the x-axis and simultaneously to the right of the y-axis as shown in Figure 37). Because the modeled measures were selected, in this case, focusing on air quality improvements, most if not all measures analyzed[39] here show positive impacts on exposure (appearing on the right side of the y-axis), although some much stronger than others. For climate impacts, however, several measures result in climate disbenefits (below the x-axis) or are neutral with respect to climate mitigation effect (are sitting on or close to x-axis).

Figure 37: Impacts of the sectoral emission controls on $PM_{2.5}$ exposure (x-axis) and on GHG emissions using the GWP_{100} metric that accounts for SLCP's impact on climate over a 100-year time horizon (y-axis)



Source: Original figure for this publication.

Note: Measures to the right of the y-axis have positive impact on air quality. Measures above the x-axis have a positive effect on climate change mitigation. As illustrated on the figure, multiple abatement measures are on one of the axes, meaning that they help one environmental problem without contributing positively or negatively to the other. There are a few measures (in the lower right quadrant) that improve air quality but result in some climate warming. The figure also confirms that measures in the residential heating sector have the largest impact on reducing mean exposure to $PM_{2.5}$—by nearly 2.5 µg/m³. Measures in the residential heating sector also have a positive impact on climate change mitigation, reducing GHG emissions (CO_2eq as estimated based on the GWP_{100}) by about 4 Mt CO_2eq. However, from a climate change mitigation perspective, the measure with the highest reduction potential for GHG emissions is the higher share of renewable energy generation—estimated here to reduce GHG emissions by nearly 10 $MtCO_2eq$.

This insight provides useful information for the design of integrated strategies that aim to quickly improve human health due to better air quality and support the gradual transition to a low-carbon economy. A truly holistic analysis needs to consider not only the mitigation costs of different abatement measures but also

[39] As mentioned above, a switch from biomass burning for household heating to the use of natural gas was not included as a measure since it was assumed that biomass for heating is burned in rural areas with no access to natural gas. Nevertheless, such a measure would lead to an increase in GHG emissions as it is replacing a renewable energy source (biomass) with a fossil fuel (natural gas).

the relative magnitude of their potential benefits and disbenefits to human health and climate in the context of an overall package of measures. In addition, a holistic approach would also consider the potential lock-in risks of carbon-intensive technology. Energy infrastructure, for instance, is an expensive and long-lived investment where the risks of carbon-intensive technology lock-ins are especially potent. Therefore, such lock-in risks should be weighed against the potential benefits to improving air quality, and respectively improving human health, as well as against the possible introduction of barriers to long-term decarbonization.

As discussed above, at the mean national level, numerous options with win-win opportunities prove to be more cost-effective than some of the options that result in trade-offs, and thus, a cost-effective staged approach could attribute lower priority to the latter measures. This priority setting will look different, however, from city to city, and in some cities, end-of-pipe pollution control equipment on large stationary emission sources may be an essential part of the overall package of measures. Implementation of relatively costly air quality control measures with climate disbenefits may be well justified by the lives saved and diseases prevented from air pollution. The climate disbenefits of such measures could also be outweighed in a comprehensive package by other measures that deliver more climate benefits than air quality benefits.

3.5. Conclusions from the Cost-Effectiveness Analysis

The GAINS modeling described in this chapter presents an innovative analysis of the potential for GHG mitigation and air quality improvements in Kazakhstan. Based on a comprehensive data set of economic activities, resulting emissions, atmospheric dispersion, and climate impact metrics, the analysis offers a ranking of cost-effective measures that improve air quality and, at the same time, contribute to the mitigation of GHG emissions.

Most salient, the analysis reveals a large low-cost potential for measures in sectors, which in the past received less attention in Kazakhstan regarding AQM. It highlights the importance of effective action to reduce emissions from the management of solid waste as well as from space heating in the residential and commercial sectors, both in the country's urban and rural areas. These include measures to refurbish thermal efficiency of buildings, switch from coal to gas and district heating, and modernize the remaining solid fuel boilers and stoves with more efficient and less polluting ones. Due to their direct impact on population exposure, these measures appear to be much more cost-effective in reducing the health hazard of air pollution than some of the conventional emission control measures on visible point sources, such as end-of-pipe emission controls at large power stations and industrial installations.

Reducing the use of solid fuels in the residential sector has a larger potential to reduce population exposure to $PM_{2.5}$ than replacing the use of solid fuels in public electricity and heat generation, as well as in manufacturing industries. Although, in some regions, the power and industrial sources of emissions can play a major role, residential heating on solid fuels, especially stoves and boilers used in individual buildings, is one of the main sources of winter smog events in settlements across Kazakhstan.

The analysis demonstrates the potential synergies between GHG mitigation and air quality improvements, as well as the potential trade-offs, where air pollution reduction measures are well justified by the lives saved from air pollution despite having a neutral or small warming effect on climate. In addition to end-of-pipe pollution control equipment, another example of an important trade-off between GHG mitigation and air quality measures is the use of biomass in residential heating. Survey data suggests that almost one-third of households in Kazakhstan use wood or other biomass for heating and cooking in individual stoves—roughly the same number as those who use coal which raises some concerns whether the survey design influenced such an outcome. Biomass is considered a carbon-neutral fuel in official GHG reporting as renewable energy. However, burning of biomass in individual buildings for heating might be a major source of population exposure to $PM_{2.5}$ pollution in Kazakhstan. Therefore, switching from biomass heating in households to less polluting fossil fuels, such as natural gas or coal-fired district heating plants meeting BAT standards might be a key measure to improve air quality in some urban and suburban areas notwithstanding a climate warming effect.[40] Small and temporary climate penalty can be offset by intensifying other climate mitigation efforts with or without air pollution co-benefits. The use of biomass for household heating at the city level can be analyzed in more detail in future work.

Nevertheless, air quality is largely managed at the local level, and local specifics should be considered when adopting measures for implementation. However, given the long-range transport of elevated emission sources, local authorities in areas with heavy industry should still consider end-of-pipe emission controls at large sources even if those measures do not appear as the most cost-effective ones in the modeling presented in this chapter. Similarly, the mix of residential heating measures to be implemented is largely dependent on the local availability of infrastructure and fuel distribution options. For instance, centralized use of natural gas for heating is a more relevant measure in cities with adequate gas infrastructure in the west and south of the country, whereas switching to more efficient stoves, boilers, or electricity might be prioritized in cities lacking gas infrastructure.

Despite useful statistics being available, it seems urgent to develop better emission inventories that include not only emissions from large point sources in the power sector and industry but also emissions from the residential sector and waste management. In addition, these emission inventories should have sufficiently fine spatial resolution, going down to the regional and city levels. In this way, the priority sources and their specific locations can be clearly identified and potential trade-offs between AQM and climate change mitigation better managed. For a cost-effectiveness analysis, to assess the potential for further reductions at these sources, emission inventories should also provide information on the state of the already implemented emission control measures.

3.6. Limitations

As in any modeling, the GAINS results are dependent on data availability and data quality. In addition, when it comes to modeling the effect of current or upcoming legislation in GAINS, there is some uncertainty brought by the level to which the legislation is efficiently enforced. Some of the key limitations are as follows:

- There were some discrepancies between the officially reported energy balance by Kazakhstan's Bureau of National Statistics and the activity data presented in the country's inventory reporting under the UNFCCC. The differences were especially notable in the transport sector.
- There are no ELVs for individual types of combustion devices that are specific to Kazakhstan.
- There are missing data and emission estimates for some sources in Kazakhstan in the emission inventory under the CLRTAP.
- For some sectors included in the emission inventory under the CLRTAP, sources are included in the wrong source sectors.
- The analysis presented through the GAINS modeling was developed for entire Kazakhstan. Air quality is the most pressing in some of the urban areas in Kazakhstan. It should be noted that the overall results obtained for the whole country might not be fully applicable for the different urban areas. City-level analyses, informed by source apportionment studies and local pollution dispersion models, are needed to tailor cost-effective measures and policy instruments to individual airshed conditions.

[40] Since the use of biomass in the energy scenario analyzed in this report is small, its potential for air quality improvement is minor. This might change with more evidence about larger use of noncommercial biomass in particular cities.

- The analysis does not provide a full assessment of the GHG mitigation measures' cost in Kazakhstan. Instead, some costs of the relevant GHG mitigation options (mainly for CO_2) are approximated by available cost estimates in the literature.
- The abatement costs included in the modeling represent the pure 'project cost' to install and operate the low-emission technology, seen from the point of view of a social planner rather than individual economic agents. Capital availability is not considered a constraint. The full cost of a CO_2eq-efficient alternative incorporates investment costs (calculated as annual repayment of a loan over the lifetime of the asset with the social interest rate), operating costs (including personnel and materials costs), and possible cost savings generated by use of the alternative (especially energy savings). The full cost does not include transaction costs, communication/information costs, subsidies or explicit CO_2 costs, taxes, or the consequential impact on the economy. Moreover, the modeling represents a social planner's perspective which aims at minimizing societal resources while improving air quality and reducing GHG emissions. As such, many of the measures appear as very cost-effective if net costs are accounted for over the full technical lifetime, where up-front investments can be (partially) compensated by subsequent savings in operating costs. However, investment decisions by private profit-oriented actors are following different rationales, with much shorter pay-back periods. For instance, from a social planner's perspective, up-front investments in energy efficiency renovations are compensated by savings from reduced energy costs in the subsequent years during the lifetime. However, it is noted that up-front investments can establish serious barriers for adoption, especially for private consumers who operate with very short pay-back periods or face capital availability constraints. As the social planner's optimization perspective does not allow to simulate real market conditions as seen by firms, public agencies, and households, it cannot be concluded without further analysis that the measures that emerge in this study as cost-effective from a societal perspective would be autonomously implemented by the market. Therefore, further analysis is needed to identify what packages of specific *policy instruments* could encourage economic agents to undertake and invest in these *abatement measures*.
- The analysis does not capture fiscal policy, tax/subsidy instruments, or behavior change.
- The analysis does not capture the role of infrastructure investments in altering the estimated cost structures.

4. POLICY CONTEXT

This chapter reviews critically relevant policies that affect air quality improvement and climate change mitigation efforts. As a general guidance, air pollution and climate change are different environmental challenges caused by different market failures. Therefore, each problem should be addressed with a different set of policy instruments targeted at the specific root cause of the problem. Nonetheless, because of some overlap and complex interactions between air and climate pollutants, sources, and abatement measures discussed in this report, an integrated approach requires that these different sets of policy instruments be applied together in a coherent policy package to mitigate the risk of solving one problem while aggravating another.

This chapter will focus on the description and analysis of existing regulations and policy instruments. Wherever appropriate, it also identifies opportunities for policy reforms. However, a detailed policy impact analysis is beyond the scope of this report.

4.1. Strategic Documents and International Commitments

4.1.1. Strategic Documents

The strategy 'Kazakhstan 2050: A New Political Course of the Established State' adopted in 2012 sets ambitious goals for sustainable development and the country's transition to a low-carbon economy. The Kazakhstan 2050 strategy provides that

- By 2050, alternative and RES should account for at least 50 percent of the total energy consumption;
- By 2050, Kazakhstan should fully upgrade its production facilities and assets in line with the latest technological standards. In addition, all mining companies should practice environmentally responsible production; and
- By 2025, the local market should provide transport fuels according to the latest environmental standards.

In 2013, the Concept for Transition of the Republic of Kazakhstan to Green Economy (hereinafter referred to as the Concept) was adopted. The Concept builds on the 'Kazakhstan 2050' strategy and sets specific sector targets. A summary of air quality and climate change-related targets included in the Concept is given in Table 26. In the absence of a specific environmental program or a strategy, the Concept is the main driver for the implementation of environmental measures in key sectors of the economy.

Table 26: Air quality and climate change-related targets included in the Concept

Sector	Target description	2020	2030	2050
Energy efficiency	Reduction of energy intensity of GDP from 2008 levels	25%	30%	50%
Power sector	Share of alternative sources (solar, wind, hydropower, and nuclear) in electricity production	Solar and wind not less than 3%	30%	50%
	Share of gas power plants in electricity production, including switching of coal to gas in large cities provided that gas supply is secured at a reasonable price level	20%	25%	30%

Sector	Target description	2020	2030	2050
	Gasification of regions	Akmola and Karaganda	Northern and eastern regions	
	Reduction of CO_2 emissions in electricity production	2012 levels	−15%	−40%
Air pollution	Reduction of SOx and NOx emissions		European levels of emissions	
Source: Concept for Transition of the Republic of Kazakhstan to Green Economy.				

To achieve the targets highlighted in Table 26, the Concept outlined areas of interventions, such as energy efficiency, cleaning of industrial processes, and so on. It estimates that the largest improvement in energy efficiency can be achieved in the residential sector through insulation of homes, among other things. The second important sector for energy efficiency improvements and emission reduction is replacing old boilers in thermal power plants (TPPs) and CHP plants with new, more efficient ones.

In terms of increasing the share of RESs in energy generation, the Concept projects commissioning of 4.6 GW of wind and 0.5 GW of solar capacity by 2030 so that solar and wind account for 10 percent of the electricity generation in Kazakhstan in 2030.

A key measure to reduce air pollution is the installation of dedusting and desulfurization equipment at coal power plants, as well as converting CHPs in large cities from coal to gas. In general, the Concept envisions developing and implementing emission standards and control mechanisms similar to the ones in the EU.

The latest strategic document is the 2018 'Strategic Plan for Development until 2025'. It features green economy and environmental protection as specific policies. It also lists the achievement of Kazakhstan's commitments under the Paris Agreement, continuing work on decarbonizing the economy and promoting investment in green technologies and RES development, among specific tasks. Despite the outlined specific tasks, the plan includes only two indicators related to the environment—GDP energy intensity and share of RESs.

4.1.2. International Commitments

Kazakhstan ratified the UNFCCC in 1995, the Kyoto Protocol in 2009, and the Paris Agreement in 2016. Kazakhstan is considered an Annex I Party for the purposes of the Kyoto Protocol but remains a non-Annex I Party for the purposes of the UNFCCC. Under the Paris Agreement, Kazakhstan submitted its Nationally Determined Contributions (NDCs) and committed to reduce GHG emissions by 15–25 percent by 2030, compared to the base year of 1990. The goal of the 15 percent reduction is unconditional, whereas the 25 percent goal is conditional on international support for further GHG emission cuts. Since 2010, Kazakhstan has been submitting annually a National Inventory Report, which is an obligation under the UNFCCC and the Kyoto Protocol.

Kazakhstan has been a party to the CLRTAP since 2001 but has not ratified any of the protocols of the convention. Nevertheless, the country submits an annual emission inventory according to the requirements of the CLRTAP.

Kazakhstan adopted the UN's Sustainable Development Goals (SDGs) in 2015. The SDGs' main objectives are to end poverty, protect the environment, and achieve sustainable development by 2030. The Bureau of National Statistics of Kazakhstan reports on the progress toward achieving the SDGs.

In 2011, Kazakhstan claimed its leadership role in promoting green growth in Central Asia by establishing the Green Bridge Partnership Programme (GBPP). The goal of the GBPP is to promote green growth through international cooperation, transfer of knowledge and technology, and financial support. Among the countries which have joined the GBPP Charter are, in addition to Kazakhstan's neighbors, some Eastern European and Scandinavian countries—a total of 15 countries as of October 2019.[41]

4.2. Environmental Code

The Environmental Code is the primary environmental legislation in Kazakhstan. The code has been revised a number of times through the years. However, in 2018 a major redesign of the Environmental Code based on experiences in the Organisation for Economic Co-operation and Development (OECD) countries was initiated. A new Environmental Code was adopted in January 2021 and has been effective since July 1, 2021 (hereinafter the 2021 Environmental Code). The 2021 Environmental Code provides a legal framework for strengthening efforts in a number of areas of environmental management, including air quality and climate change.

One of the key changes in the 2021 Environmental Code is the implementation of integrated environmental permits (IEPs) based on BATs. The largest sources of industrial pollution in Kazakhstan, namely Category I enterprises, will be required to obtain an IEP based on BAT starting in 2025. Moreover, Category I enterprises will be required to conduct automatic emission monitoring, which improves transparency of emissions reporting.

The procedures related to Environmental Impact Assessment (EIA) have also been drastically amended. The 2021 Environmental Code stipulates mandatory EIA for a list of industrial sectors that are among the most polluting. In addition, it lists activities, outside of the scope of a mandatory EIA, which have to be screened to determine the need for an EIA. The 2021 Environmental Code also improves the scoping of EIA and strengthens public participation in the process.

Other important amendments concern the use of revenues from pollution fees and charges. Instead of simply going to the state budget as is currently the case, the 2021 Environmental Code provides for revenues from such payments to go to the local executive bodies and to be used in full specifically for environmental protection measures.

The provisions on AQM are also strengthened in a number of key areas in the 2021 Environmental Code. First, it includes the setting of average annual concentrations to be used as LVs for certain pollutants. A number of countries, namely in the EU, as well as New Zealand, the US, and others, use average annual concentrations for some key pollutants as indicators of overall exposure to pollutants. Second, the 2021 Environmental Code strengthens the process of emission inventories. For instance, emission inventories of industrial sources would be required for all settlements with more than 10,000 inhabitants, which will provide much more granular data than the current reporting of emissions on a regional level. The 2021 Environmental Code also considers emission inventories of mobile sources and requires that these sources be included in the emission assessments for settlements with high air pollution. Moreover, it mandates that emission inventories for such settlements should be updated at least once every five years. Third, it includes provisions for local authorities to restrict certain activities that lead to emissions, including traffic, in case of high pollution levels or unfavorable meteorological conditions. Thus, it puts in place a legal framework for establishing LEZs, which, if implemented properly, have proven to be an efficient measure to reduce air pollution in a number of EU countries.

As far as GHG emissions are concerned, the 2021 Environmental Code stipulates that the benchmarking approach will be used for the setting of tradable GHG quotas, instead of using the historical levels of

[41] The Astana Times. https://astanatimes.com/2019/10/fifteen-countries-join-green-bridge-initiative-sharing-ideas-and-learning-with-kazakhstan/.

pollution method of allocating GHG quotas (Section 3.6.3). In addition to GHG quotas, the 2021 Environmental Code allows for the setting of emission quotas that can be traded or distributed for free.

Overall, the 2021 Environmental Code has the potential to facilitate improved environmental management and strengthen efforts to reduce air pollution and GHG emissions. Nevertheless, such major changes of the existing system will undoubtedly require capacity building in institutions for the new provisions to be implemented efficiently and bring the desired results.

4.3. Relevant Policies in the Industrial Sector

As seen in Chapter 2, Kazakhstan's industry is responsible for a significant share of SO_2, NO_2, and GHG emissions. The main ways to reduce emissions from the industrial sector are by using cleaner fuels, utilizing abatement technologies, and/or strengthening the policy framework. Environmental permits are the main policy instruments that aim to control the level of emissions.

The environmental impact of each stationary source is defined in one of four categories that relate to hazard classes according to the hygienic and sanitary classes described in Kazakhstan's legislation.[42] Table 27 describes the four categories of environmental impact, with Category I having the greatest impact on the environment and Category IV having the least.

Table 27: Categories of environmental impact

Category of environmental impact	Description	Corresponding hygienic and sanitary class
I	>1,000 t emissions to air per year (>50 t for oil and gas industry) >2,000 t of wastewater discharge per year >10,000 t of industrial waste generated per year	Class I of sanitary impact; sanitary protection zone of 1,000 m or more Class II of sanitary impact; sanitary protection zone between 500 m and 999 m
II		Class III of sanitary impact; sanitary protection zone between 300 m and 499 m
III		Class IV of sanitary impact; sanitary protection zone between 100 m and 299 m
IV		Class V of sanitary impact; sanitary protection zone between 0 m and 99 m
Source: Environmental Code, Government Order No. 237, March 20, 2015.		

Category I enterprises are subject to mandatory EIA, whereas Category II enterprises are screened to determine whether an EIA is needed. Category III enterprises are required to submit environmental impact declarations. These are, for example, warehouses, furniture workshops, concrete mortar units, or others whose activities are localized and might be sources of insignificant environmental pollution. Category IV enterprises are exempt from EIA regulation or environmental impact declarations as their environmental impact is deemed to be minimal. Category IV enterprises might include car washes, service stations, public catering facilities, or micro and small business facilities with low-power boiler installations for meeting their own energy needs.

The 2021 Environmental Code defines two types of environmental permits:

- Environmental impact permits (EIP)

[42] Sanitary and Epidemiological Requirements for Establishing Sanitary Protection Zones of Production Facilities, Order No. 237, March 20, 2015.

- IEPs.

Construction and operation of Categories I and II installations without the appropriate environmental permit are prohibited. An environmental permit is not required for the construction and operation of Category III and IV installations unless they are located within the industrial site of a Category I or II installation and are technologically connected to it. Moreover, GHG emissions are not included in environmental permits.

IEPs are mandatory for Category I enterprises from 2025 onward. In addition, obtaining an IEP is mandatory for newly commissioned enterprises. All other enterprises may obtain an IEP on a voluntary basis if such is recommended pursuant to the BATs. IEPs are issued by an authorized environmental protection agency and are valid indefinitely or until a change in the specified BAT and/or facility's conditions occurs.

Transition to the implementation of BAT principles involves development by July 1, 2023, of BAT Reference Books for the 50 most polluting enterprises in Category I. The Reference Books provide the competent authorities with a technical basis for establishing permit conditions for industrial facilities considering such facilities' technical characteristics, geographical location, and local environmental conditions.

At the time of writing of this report, five Reference Books are being developed and discussed. They cover the following sectors:

- Fuel combustion at large energy-producing installations
- Oil and gas processing
- Production of inorganic chemicals
- Cement and lime production
- Energy efficiency.

To oversee the transition to BAT principles, the National Bureau on BAT has been established as part of the International Green Technologies and Investment Projects Center.

The amendments adopted in the 2021 Environmental Code that mandate IEPs for Category I enterprises will undoubtedly facilitate emission reductions in those enterprises. Nevertheless, an important consideration should be given to the reconciliation between the IEP and the previous emission permitting system. ELVs under the previous emission permitting system were based on historical emission levels and did not require implementation of cleaner technologies, whereas the IEP system is based on sector-specific BATs. Therefore, the coordination between the two systems should be carefully considered, along with the institutional capacities that need to be established to monitor compliance with the newly introduced IEP system.

The air quality monitoring data analyzed in Chapter 1 suggest that there might be cities in Kazakhstan where industrial emissions play a larger role in air pollution than in other settlements. Additional analyses and dispersion modeling are needed to determine the significance of the industry's contribution to air pollution at those locations. Nevertheless, the IEP system and the corresponding sectoral EU Best Available Techniques Reference Documents (BREFs) could be considered for setting stricter emission standards for enterprises in such locations. The EU encourages its member states to introduce stricter ELVs and higher energy taxes than the minimum values prescribed in EU legislation. Most polluted Chinese provinces, such as Beijing, have also introduced stricter ELVs than in the rest of China (or even elsewhere in the world), encouraging coal power plant operators to retire their plants early and switch to natural gas rather than modernizing them and installing expensive air pollution control equipment.

On the other hand, a key source of population exposure to PM pollution in cities in Kazakhstan is residential heating on solid fuels in individual dwellings. District heating plants operate in a number of cities in Kazakhstan. Those plants are generally old and use coal for generating heat. At the same time, district heating is an important alternative to using solid fuels for heating at households. Therefore, the implications of IEP implementation based on BAT could be considered for such plants in light of improving their efficiency, reducing the impact on local air quality, and, potentially, improving the attractiveness of district heating among households.

Nevertheless, the GAINS modeling described in Chapter 3 highlights the complex nature of interactions between key air pollutants and GHGs. The modeling showed that significant SO_2 and NOx reductions without accompanying cuts in BC and CO_2 emissions represent an important trade-off between AQM and climate change mitigation as end-of-pipe SO_2 and NOx controls lead to additional warming. Therefore, proper design of emission reduction regulations and incentives in the industrial sector is an important consideration for national authorities that have to act simultaneously on climate change commitments, measures to improve air quality, and actions to protect the environment.

4.4. Relevant Policies in the Transport Sector

Chapter 2 illustrated that passenger vehicles are responsible for 64 percent of all CO_2 emissions in the transport sector. The key issues in the transport sector with an impact on emissions are the old vehicle fleet (65 percent of passenger vehicles over 10 years old), the use of low-quality fuel, and the low attractiveness of public transport use.

In Kazakhstan, vehicle emissions requirements are defined in technical regulations. Since 2018, all new vehicles produced locally or imported must comply with an ecological vehicle standard of at least K4 (comparable to Euro 4 vehicle standards in the EU). The highest ecological class of vehicles currently implemented in Kazakhstan is K5 (comparable to Euro 5 in the EU). In addition, since 2018, import of vehicles older than five years and with engine volumes exceeding 3,000 cm^3 has been prohibited. An important drawback to the minimum requirements of vehicles is that the rules introduced in 2018 apply only to new and not to used vehicles.

Another major issue with renewing the vehicle fleet has been the availability of domestically produced fuel of adequate quality. It was not until 2018 when the upgrade of the domestic oil refineries allowed them to produce K4 and K5 fuel. Until then, fuel of such quality was imported and hence more expensive than the locally produced fuels available on the market. The use of lower-grade fuels in new vehicles could cause technical issues with the vehicle's proper operation. The upgrade in the fuel quality means that K4 and K5 fuels now have up to 35 times lower sulfur content than fuels of lower standards as seen from Table 28.

Table 28: Evolution of transport fuel standards in Kazakhstan

Fuel standard	Year of introduction	Sulfur content, mg/kg	
		Gasoline	Diesel
K3	2011	150	350
K4	2018	50	50
K5	2018	10	10
Source: UNECE.			

Periodic technical inspections are an important instrument to monitor the proper operation of vehicles, including the emission discharges from vehicles. In June 2015, technical inspection of cars was made mandatory only when the car reaches seven years of age. Cars older than seven years must pass the technical inspection check annually. As emission standards of vehicles evolve and as emissions are also influenced by the vehicle's technical condition, it is suggested that the periodic technical inspections are conducted more regularly for cars of up to seven years of age.

In April 2017, a road map for the development of electric cars' production and the necessary infrastructure was approved in Kazakhstan. The main pillars of the road map are development of local production of electric cars, development of charging infrastructure, and raising awareness to encourage purchase of electric vehicles by the population.

The transport sector is a good example of different approaches that can be implemented depending on the policy goal—to improve air quality or to reduce GHG emissions. If the goal is to reduce GHG emissions, then diesel vehicles might be promoted, whereas, generally, gasoline vehicles have lower emissions of air pollutants. Therefore, if an integrated approach that can provide co-benefits for air quality and climate change is to be pursued, then the focus should be placed on limiting the use of passenger vehicles altogether. This can be achieved through improving the attractiveness of public transport, providing incentives to use public transport, developing car sharing schemes (ideally, based on electric vehicles), promoting walking and cycling in cities, and shifting from individual passenger vehicles-dominated modal splits to shared mobility. Some of those measures can be promoted by mechanisms such as LEZ or congestion charges that are implemented to discourage the most polluting vehicles to enter into designated areas.

4.5. Relevant Policies in the Residential Sector

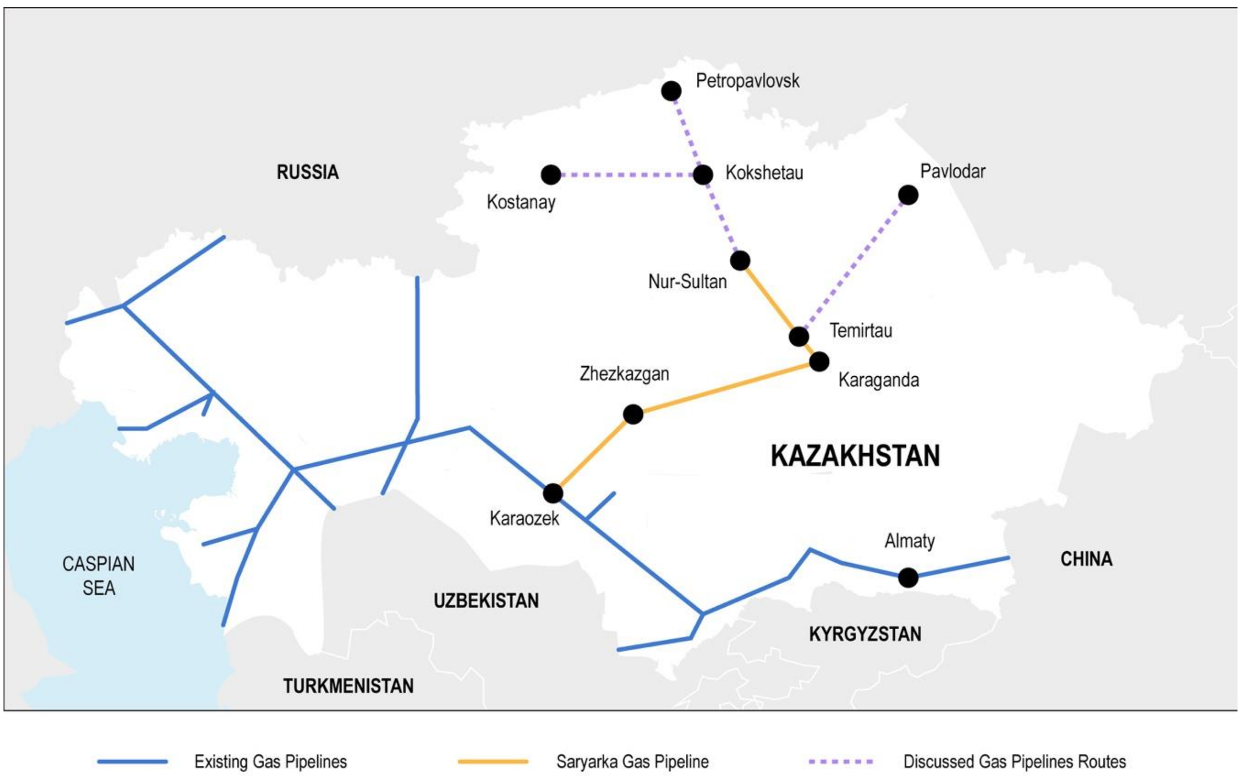
The residential sector is a major contributor to PM pollution across Kazakhstan. In addition, the GAINS modeling shows that the residential sector provides opportunities for cost-effective measures to tackle air pollution. The sector was also responsible for 11 percent of CO_2 emissions in Kazakhstan in 2019. Its key issues are burning of solid fuels (coal and biomass) in households, as well as inefficiencies in residential energy use. The Concept estimates that the largest improvement in energy efficiency can be achieved in the residential sector through insulation of homes.

The main legal instrument that addresses energy issues in the residential sector is the 2012 Law on Energy Saving and Energy Efficiency Improvements. The law provides for mandatory energy efficiency assessments for new buildings and, in the case of expansion, existing buildings. As for existing buildings, the law provides for support to dwelling owners to implement energy efficiency measures in their homes. Moreover, the law introduces heat meters so that payments for heat energy can be based on actual consumption. Payment per use is an important step toward incentives to save energy and invest in thermal rehabilitation of buildings and more efficient appliances. Nevertheless, implementation of energy efficiency measures in practice also requires behavioral incentives through adequate price levels that reflect the full costs of using fuels, including the cost of damages imposed on victims of pollution. When access to finance or affordability impede behavioral response to price signals, additional financial support for targeted homeowners may be needed to maintain energy comfort and invest in energy efficiency.

In addition to energy efficiency measures targeted at the building envelope, improved efficiency of heating systems should also be considered as a way to reduce emissions. Reduction of losses in the energy and heat networks is one of the objectives of the program 'Energy Saving 2020'. The 2014 Concept for Development of the Energy and Heat Sector until 2030 envisions the modernization of energy-generating capacities. Moreover, the Concept for Transition of the Republic of Kazakhstan to Green Economy places a high importance on switching from coal to gas in urban TPPs and CHPs. Efficiency of district heating systems was not included in the national-level GAINS modeling presented in Chapter 3 but is an important consideration when analyzing individual cities with such systems.

In addition to improving energy efficiency of buildings and district heating generation using coal and/or switching generation to natural gas, measures to reduce emissions from individual boilers and stoves on solid fuels (coal and biomass) are critical to tackling air pollution in Kazakhstan as shown by the GAINS model. According to the IEA, residential coal consumption per capita in Kazakhstan is one of the highest in the world.[43] There are important reasons why this is the case, such as coal availability, affordability of adequate heating in a harsh climate, and a lack of alternatives. There is uneven accessibility of natural gas for residential use, as seen in Figure 38. A natural gas network is developed in the west and the south of the country thus limiting the heating options for households in the other regions. The highest share of coal used for heating was reported in the Karaganda region (without access to natural gas) and the lowest share of coal used for heating was in Almaty (with access to natural gas and district heating network). Thus, wider development of the natural gas network or consideration of renewable development coupled with grid enhancement and combined with appropriate incentives might encourage a switch away from coal for residential heating.

Figure 38: Existing (blue), future (yellow), and planned (purple) gas networks in Kazakhstan



Source: IEA.

Experience from other countries shows that to reduce emissions from residential heating, a set of policies should be put in place. First and foremost, perverse incentives in energy pricing, taxation, and subsidies that encourage the use of polluting fuels should be reviewed, identified, and phased out. Second, quality standards for solid fuels and/or heating appliances used in households could be set and effectively enforced. Third, the use of solid fuels for heating in areas with high air pollution could be restricted or banned altogether. Fourth, subsidies, public investments, and behavioral nudges could be applied to encourage the use of cleaner fuels for heating. Public support can take the form of public investments in

[43] IEA. https://www.iea.org/data-and-statistics?country=WORLD&fuel=Energy%20consumption&indicator=CoalConsBySector.

infrastructure that provide clean heating to households that currently do not have access to it or financial support to households, firms, and public entities to invest in cleaner heating fuel/technology through subsidized/blended loans, heating equipment leasing/rebate programs, and tax credits, to name a few.

4.6. Taxes, Subsidies, and Market-Based Instruments

Kazakhstan employs some taxes, subsidies, and market-based instruments that directly or indirectly influence emissions of air pollutants and GHGs. The main fiscal tools and market-based instruments utilized in Kazakhstan in relation to AQM and climate change mitigation are discussed in this section.

4.6.1. Taxes and Fees

In the adopted 2021 Environmental Code, the term 'emission fee' was replaced by 'payment for negative environmental impact (NEI)'. The 2021 Environmental Code stipulates a gradual increase in the payment for NEI every three years starting in 2025 for the top 50 large enterprises and in 2028, for all other enterprises. Payments for NEI are waived if BAT is introduced. This exemption is expected to accelerate the transition to IEP in industry.

For air pollutants, payments of NEI are based on the actual mass of emissions. Payments for NEI for stationary sources with emissions within the permit limits are set as coefficients or multipliers of the monthly calculation index (MCI). The MCI is established annually by the Law on National Budget and, in general, is used to determine taxes, penalties, and other fees. Thus, the base pollution tax that a stationary source has to pay is determined by multiplying the applicable pollutant coefficient (Table 29) by the MCI. The MCI for 2020 was KZT 2,778 (about $6.60),[44] a 10 percent increase from 2019. On average, the MCI increased annually by 7 percent in 2015–20.

The tax defined in the way described above represents the base tax rate for emissions from stationary sources. Local authorities can additionally set higher tax rates that can be up to two times the base tax rate. There are no taxes on CO_2 emissions. The ETS establishing a carbon price for large emitters is described in Section 4.6.3.

Table 29: Pollutant coefficients for determining emission tax rates in Kazakhstan

Pollutant	Tax coefficient per ton of pollutant to be multiplied by MCI
SO_2	10
NOx	10
Dust and ash	5
Carbon oxides	0.16
CH_4	0.01
Source: Tax Code.	

Administrative penalties apply for emissions from stationary sources above the approved ELVs. Those penalties are also based on the MCI, and the largest businesses can be a subject of an additional tax multiplier. In addition to administrative penalties, stationary sources with emissions above the approved ELVs can be subject to environmental damage payments. The economic value of environmental damage represents the cost of environmental remediation, which can be assessed directly or indirectly. The direct assessment of environmental damage costs involves the determination of the expenditure to restore the damaged natural resource. The indirect method uses a predefined formula based on the level of pollution

[44] https://egov.kz/cms/ru/articles/article_mci_2012.

tax and the damage incurred. In either way, environmental damage payments do not guarantee the remediation of the environmental damage done and represent another fiscally inefficient revenue raiser rather than incentive for firms to innovate and improve environmental performance and efficiency.

The 2021 Environmental Code mandates that revenues from payments for NEI are paid to the local budget in the area where the stationary source is located. This is an important amendment compared to the previous Environmental Code where revenues from pollution taxes and other environmental payments were not necessarily earmarked to be spent on environmental protection measures. It is reported that under the previous code, 30 percent of revenues collected from pollution taxes and environmental charges were spent on such measures.[45] In addition, revenues from taxes and administrative and damage penalties are collected at the regional (oblast) level and allocated to the regional and state budgets. Revenues from pollution taxes and administrative penalties, except for those in the oil and gas sector, are allocated to the regions where the enterprise is located. Revenues from damage payments, except for those in the oil and gas sector, are allocated to the state budget. Revenues from taxes and other penalties from the oil and gas sector are allocated to a national fund.

In Kazakhstan, the total value of environmental and pollution taxes was estimated to be around 2 percent of GDP in 2013–17.[46] Taxes on energy resources accounted for the largest share of revenues from environmental taxes—85 percent of the total environmental tax revenue in 2017. The second largest revenue from environmental taxes came from pollution taxes—7 percent of total environmental tax revenue in 2017[47] or 0.86 percent of GDP in 2018.[48]

When it comes to mobile sources of emissions, vehicle taxation in Kazakhstan is based on the engine size rather than on emission levels (Table 30). Tax coefficients are set for different engine sizes which are then multiplied by the MCI. In theory, vehicle taxation based on engine size might incentivize the purchase of smaller vehicles, which can be less polluting. However, taxation based on the engine size does not directly tax one of the main externalities of vehicle use—emissions of air pollutants and GHGs.

Table 30: Tax rates for passenger vehicles in Kazakhstan

Engine size, cm^3	Tax coefficient to be multiplied by the MCI
Up to 1,100 cm^3	1
1,101–1,500 cm^3	2
1,501–2,000 cm^3	3
2,001–2,500 cm^3	6
2,501–3,000 cm^3	9
3,001–4,000 cm^3	15
Over 4,000 cm^3	117
Source: Tax Code.	

In addition to vehicle taxes, there are emission and excise taxes on fuels. Emission fuel taxes are based on a tax coefficient per fuel multiplied by the MCI (Table 31).

[45] UNECE. 2019. *Kazakhstan: Environmental Performance Reviews - Third Review*. https://www.unece.org/environmental-policy/environmental-performance-reviews/enveprpublications/environmental-performance-reviews/2019/3rd-environmental-performance-review-of-kazakhstan/docs.html.
[46] Bureau of National Statistics. https://stat.gov.kz/api/getFile/?docId=ESTAT271106.
[47] OECD. 2018. *Introduction of Green Growth Indicators in the Republic of Kazakhstan*. https://www.oecd.org/countries/kazakhstan/Green-Growth-Indicators-Kazakhstan-English.pdf.
[48] https://stats.oecd.org/Index.aspx?DataSetCode=ERTR.

Table 31: Emission fuel use taxes for mobile sources in Kazakhstan

Type of fuel	Tax coefficient per ton of used fuel to be multiplied by the MCI
Unleaded gasoline	0.33
Diesel fuel	0.45
Liquid, compressed gas and kerosene	0.24
Source: Tax Code.	

Excise fuel taxes in Kazakhstan have two different rates for the summer (June–October) and for the winter (November–May). Excise fuel taxes were reformed in 2017. Following the amendments, excise taxes on both wholesale and retail sale of gasoline more than doubled to KZT 10,500 (around $25) per ton. On the other hand, excise taxes on wholesale and retail sale of diesel in the summer jumped by around 17 times to KZT 9,300 (around $22) per ton for wholesale and KZT 9,360 (around $22.30) per ton for retail. Excise taxes on wholesale and retail sale of diesel in the winter remained unchanged at KZT 540 (around $1.30) per ton for wholesale and KZT 600 (around $1.40) per ton for retail. The excise tax on the sale of diesel in the winter is significantly lower than in the summer. If diesel is used for heating in the winter, this could worsen air pollution during the heating season. Therefore, the potential impact of the seasonal excise rate for diesel on air pollution in the winter could be analyzed in future work.

The Tax Code sets a Mineral Extraction Tax (MET) for a number of minerals and mining products. The MET for coal is set at 0 percent. In addition, provisions in the Code on Subsoil and Subsoil Use allow for deductions of exploration costs from taxable incomes for fossil fuel operations. There is also a coal export rent tax of 4.7 percent, which implies a subsidy on domestic coal consumption. The impact of such taxation policies, especially on the incentives to use coal by households and firms, could be analyzed in future work as an important factor in the use of coal for residential heating—a decision that might be predominantly driven by the price of coal relative to other heating options.

Tree bark as a source of firewood is subject to a tax rate ranging between 0.11 MCI and 0.35 MCI depending on the tree species. In addition, the fee rate for residues after the sale of timber is 20 percent from the rate of the given tree species. As a comparison, the tax rate for larger diameters of tree trunks ranges between 0.18–1.15 MCI (3–12 cm trunk), 0.37–1.91 MCI (13–24 cm trunk), and 0.52–3.24 MCI (25 cm or more trunk).

As far as taxation in the residential sector is concerned, the type of heating used by households is one of the multiple coefficients in determining the property tax level. Property tax is calculated using a formula with multiplication of a number of variables. One of the variables is the coefficient of functional depreciation. The type of heating used in a dwelling, in turn, is one of the variables in the coefficient of functional depreciation formula. Table 32 shows the coefficients used for different types of heating that influence the calculation of the functional depreciation coefficient.

Table 32: Coefficients for the type of heating used in a dwelling for the calculation of the coefficient of functional depreciation

Type of heating used in a dwelling	Heating coefficient
Central heating	1.00
Local heating systems on gas or fuel oil	0.98
Heating with stoves	0.90
Water heating using solid fuels	0.95
Source: Tax Code.	

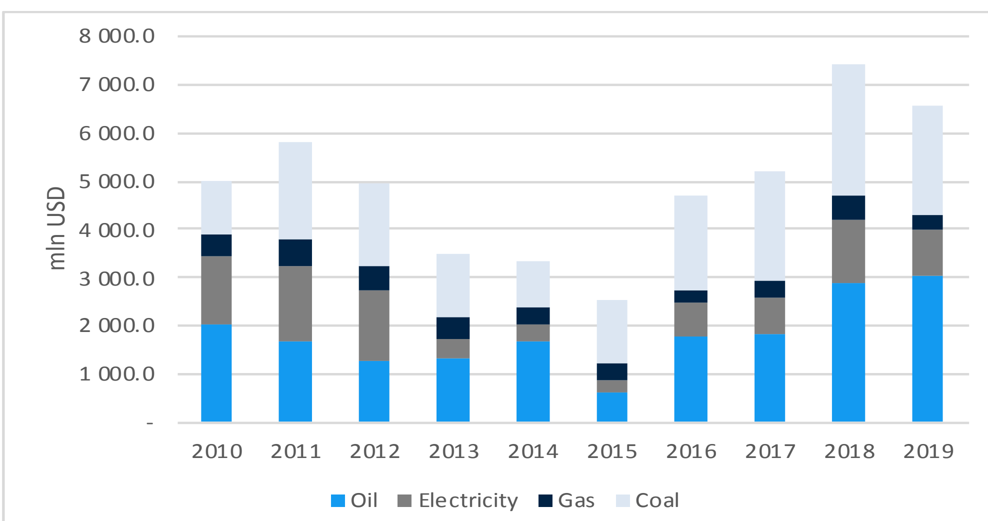
As seen from Table 32, the coefficients for heating with solid fuels are the lowest and thus have a downward impact on the functional depreciation coefficient and hence the overall property tax rate. Given that the final property tax rate is influenced by multiple variables and that the difference between the individual heating coefficients is small (the range is 0.9–1), the heating coefficient does not have a major impact on the property tax rate. Nevertheless, the values of the heating coefficients demonstrate that the property tax rate disregards the environmental implications that the choice of household heating might have.

4.6.2. Subsidies

Kazakhstan subsidizes the use and production of fossil fuels that are consumed directly by end users or used for the generation of electricity. Electricity is also subsidized, even though direct subsidies of electricity and heat consumption have been eliminated. Nevertheless, the Government indirectly supports electricity and heat consumption by keeping rates below the market cost for supplying the services.

According to the IEA,[49] the value of fossil fuel and electricity subsidies in Kazakhstan equaled 3.9 percent of GDP in 2019. On average, 45 percent of the costs associated with fossil fuels and electricity were subsidized in 2019. The largest share of subsidies was allocated to oil (46 percent), followed by coal (34 percent). The impact of subsidies, especially of coal subsidies, on air pollution and GHG emissions could be analyzed in future work that considers the incentives that coal subsidies provide for coal use in building-level residential heating, district heating plants, and industry as a whole. There are legitimate questions about the applicability of IEA price-gap methodology (difference between domestic price and export price) to estimate fossil fuel subsidy for some fuel commodities in Kazakhstan, such as coal. Most of the coal used in the country is relatively low-quality black lignite, which has very low export value. Nonetheless, it represents the vast majority of the country's coal exports destined to power plants in the Urals in Russia. Even Kazakhstan's better-quality coal is hardly tradable, because of the long distance to premium markets and high transport costs due to the lack of access to oceans. Yet some fiscal subsidies for coal can be identified beyond doubt. These are zero rates on MET on coal and taxing rents only from exported coal (roughly a quarter of the coal produced), which by World Trade Organization (WTO) standards implies a subsidy for domestic consumers.

Figure 39: Fossil fuel and electricity subsidies in Kazakhstan, in 2019 $, millions, 2010–19



Source: IEA.

[49] IEA. Energy Subsidies. https://www.iea.org/topics/energy-subsidies.

Some limited subsidies for renewable energy are also available, but they are miniscule compared to subsidies for fossil fuels. Off-grid renewable energy projects are eligible to receive subsidies from the Ministry of Energy. In addition, imported equipment for renewable energy are exempt from excise tax.

4.6.3. Market-Based Instruments

The 2021 Environmental Code prohibits the operation of an installation without a quota for GHG emissions if the emissions exceed the equivalent of 20,000 tons of CO_2 per year in a number of sectors, including those responsible for the largest share of GHG emissions such as the power sector, mining, metallurgy, and the oil and gas sector. Therefore, Kazakhstan's Emission Trading Scheme (KazETS) was first launched in 2013. Under the KazETS, emissions from the highest-emitting sectors were capped and tradable emission quotas were allocated to enterprises.

Quotas are allocated according to National Allocation Plan (NAP) approved by the Government. The first NAP allocated quotas only for 2013, whereas the second NAP allocated quotas for 2014–15. In 2016, however, with falling oil prices in the backdrop, the KazETS was suspended because of encountered technical and legal challenges. The KazETS was relaunched in 2018 under the third NAP for 2018–20, and trade on the KazETS restarted in 2019.

Some improvements were made to the KazETS during the period it was suspended. Under the first and second NAPs, quotas were allocated based on historical emissions in the base year of 2010—the so-called 'grandfathering' approach. Under the third NAP, enterprises could choose quota allocation using the grandfathering or the benchmarking approach. The benchmarking method is considered to incentivize greater efficiencies and cleaner production at industries. When allocating quota under subsequent NAPs after 2020, the Government plans to use only the benchmarking approach.

Table 33: Overview of KazETS, 2013–19

	Unit	NAP 2013	NAP 2014–15	NAP 2018–20 (data for 2019)
Number of deals	Number	35	40	3
Volume of deals	Thousand t of CO_2	1,271.3	1,983.9	1,202.2
Value of deals	KZT, millions	182.2	754.6	519.1
Average price for a ton of CO_2	KZT	301	830	363
Source: JSC Zhasyl Damu.				

In 2018, Kazakhstan introduced a market-based instrument to promote the development of renewable energy. The country switched from a feed-in tariff for RESs to an auctioning system in an effort to reduce costs and improve transparency.

Kazakhstan's Ministry of Energy approves a schedule for auctioning renewable energy projects. The announced auctions for 2019 amounted to 255 MW of installed capacity. The bids received at the auction attracted offers from 32 companies from eight countries with the total offered installed capacity three times higher than the announced target. During the 2019 renewable energy auction, 13 projects were selected for implementation; the outcome of the auction is summarized in Table 34.

Table 34: Overview of renewable energy projects' auction in 2019

Renewable energy source	Announced auction target (MW)	Offered by participants (MW)	Installed capacity of selected projects (MW)	Number of selected projects	Starting auction price (KZT/kWh)	Minimum auction price (KZT/kWh)
Wind	100	278.99	108.99	5	22.66	19.27
Solar	80	522.60	86.50	3	29.00	9.90
Hydropower	65	7.00	7.00	2	15.48	15.43
Biogas	10	10.40	10.40	3	32.15	32.13
Total	**255**	**818.99**	**212.89**	**13**		

Source: KOREM.

As demonstrated in Table 34, solar projects attracted the most interest by participants while achieving the lowest auction price. Installed capacity of selected projects for both wind and solar exceeded the announced target before the auction. On the other hand, interest in hydropower projects was low, and only two projects were selected. Both were for small hydropower plants with installed capacity of 2.5 MW and 4.5 MW.

4.6.4. Fiscal Considerations

Often, perverse fiscal incentives encourage the emissions of pollutants. To reform fiscal policies, the sources of the perverse incentives should be discovered and investigated. Detailed analysis of options, impacts, and road maps toward environmental fiscal reforms was beyond the scope of this study. This report only highlights a few initially identified opportunities that deserve further attention. It is important to note that the new Environmental Code and the proposed bylaws indicate that Kazakhstan strives to optimize its fiscal policies to promote environmental protection.

The review of emission sources in Chapter 2 and the subsequent GAINS modeling, the results of which were presented in Chapter 3, highlight the importance of the use of coal and biomass for residential heating in individual boilers and stoves as well as the use of coal in district heating, power, and industrial sectors. Therefore, further analysis could look into the existing fiscal policies that encourage the use of coal and biomass and discourage the use of natural gas and cleaner and more efficient district heating, and other cleaner heating options.

A detailed policy review might identify policies that impede the development of RESs and propose actions, including fiscal reforms, to remove such barriers. A review of coal subsidies and tax incentives that encourage the use of coal in Kazakhstan can identify options for fiscal reforms that can improve fiscal efficiency; incentives for industry to innovate; and incentives to use cleaner fuels in power plants, district heating, and residential heating. The impact of those subsidies on coal prices for households and the incentives the taxes and subsidies might provide for the use of coal for residential heating could be analyzed. Similarly, subsidies or other perverse incentives for the use of biomass for residential heating could also be investigated. The impact of the seasonal diesel excise rates could also be analyzed as the diesel excise rate is low in the winter, which may encourage some households to use polluting diesel engines and generators during the winter or even use diesel for heating.

In general, the current system of environmental taxes in Kazakhstan does not incentivize investment in cleaner and more efficient industrial processes and is a very inefficient fiscal instrument to collect government revenue. Design of taxes such as excise, vehicle, and property taxes paid by the population does not appear to consider environmental externalities. For instance, the vehicle tax is based on engine size. To integrate more features that directly influence emissions from vehicles, the tax rate should consider the age of the vehicle and the emissions in addition to the engine size. Similarly, property taxes currently do not provide incentives to use cleaner fuels in households as heating sources. As a variable used to establish the property tax rate, coal used for heating has the lowest tax coefficient. In addition, MET rate is set at zero and no rent is collected by the Government from domestic consumption of coal.

The main concerns with environmental fiscal instruments that Ministries of Finance across the world usually express are the negative effect that such instruments can have on competitiveness, the social dimension of potentially increased energy prices, and the possible decrease in state revenues in the longer term. However, experience and research among EU member states on the potential of environmental fiscal reforms shows such concerns can be managed by adequate design with joint benefits for environmental outcomes, industrial innovation, and fiscal policy. [50] Usually the most challenging aspect of an environmental fiscal reform is generating an initial political support rather than the long-term economic impact of the reform. But, there is also a body of international experience on how to do that. The design options for environmental fiscal reforms were beyond the scope of this study, however.

[50] European Commission. 2016. *Study on Assessing the Environmental Fiscal Reform Potential for the EU28*. https://ec.europa.eu/environment/integration/green_semester/pdf/Eunomia%20EFR%20Final%20Report%20MAIN%20REPORT.pdf.

5. TOWARD INTEGRATED AIR QUALITY MANAGEMENT AND CLIMATE CHANGE MITIGATION

Until 2019, the Ministry of Energy was responsible for most of the environmental management in Kazakhstan. In 2019, recognizing the need for a central entity that can manage the entire environmental sector, the Ministry of Ecology, Geology, and Natural Resources (MEGNR) was created. The establishment of MEGNR was a positive sign that increased attention was being given to the environmental issues that Kazakhstan faces. This chapter discusses some key areas that need to be strengthened to achieve improved integration of AQM and climate change mitigation policies in Kazakhstan. Policy integration is the process by which institutions align their mandates, policies, and sectoral objectives considering the interactions (synergies and trade-offs) among different policy areas with a view to addressing the multiple dimensions of sustainable development challenges in a more balanced manner.

5.1. Improving Air Quality Management and Integration with Climate Change Mitigation

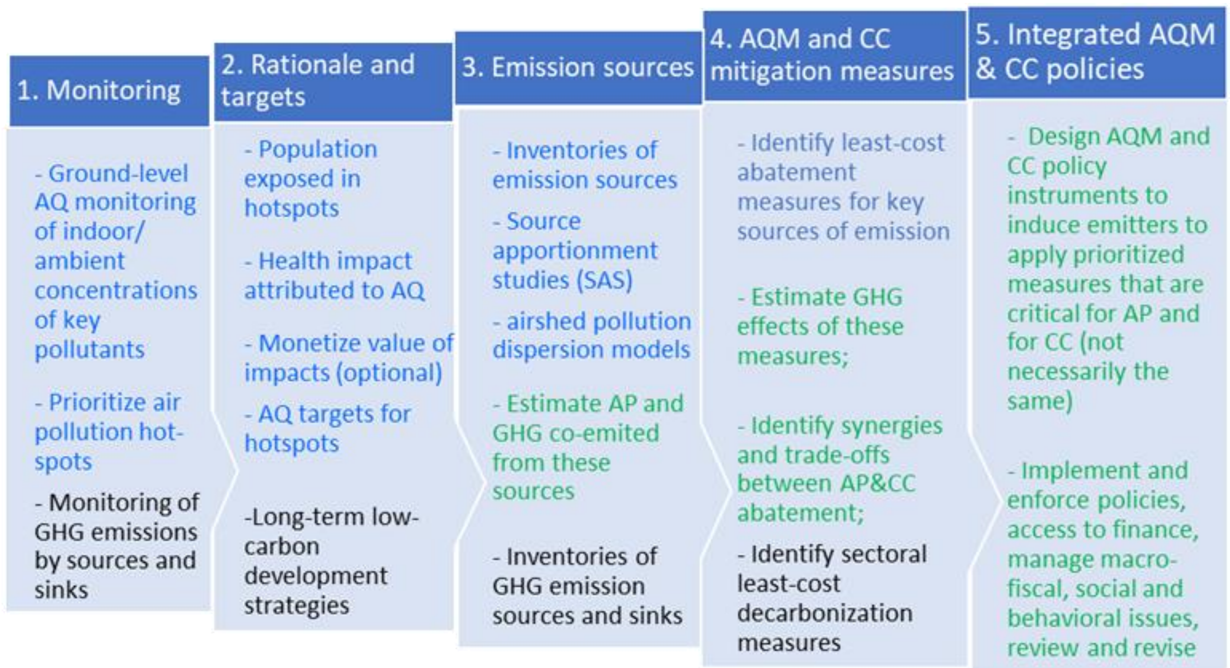
Kazakhstan has no specific air quality legislation or a strategy. AQM is included in and follows the provisions of the 2021 Environmental Code and a number of government orders. In general, air quality assessment is focused on reporting monitoring data without an in-depth analysis of the causes of high air pollution episodes and/or trends. In addition, air quality data reporting can be somewhat confusing for the average citizen as a number of different air quality indexes are used for air quality assessment (Section 1.1). Actual measured values are rarely reported, and even when they are, they do not provide much information about the causes for poor air quality. For instance, maximum measured concentrations of pollutants are reported, but presented in isolation, such reporting does not add much value to the overall assessment of air quality.

Kazakhstan's legislation sets MACs for 683 air quality pollutants. Instead, Kazakhstan could focus on a set of air quality pollutants with the highest impact on human health and influence on ecosystems. According to the WHO, key pollutants for human health are $PM_{2.5}$, PM_{10}, SO_2, NO_2, and ground-level O_3. Kazakhstan could focus on these and other pollutants that are locally important (such as CO, H_2S, or selected toxic substances) and set LVs based on the experience of the OECD countries, with a longer-term view of convergence with the WHO guidelines.

Protecting human health is the underlying driver of air quality legislation. The objective of air quality standards is to establish the concentration levels, above which air pollution becomes a real public health issue. Therefore, exceedance of MACs and pollution levels that are deemed dangerous for human health could trigger actions to reduce pollutants' concentrations. A good example of air quality LVs can be found in the EU legislation. The EU sets daily, hourly, and annual average LVs for the key air quality pollutants. Some daily and hourly LVs have a maximum allowed number of exceedances per year. If the LVs and the maximum allowed number of exceedances per year are breached, the EU legislation requires that an air quality plan for the noncompliant area and pollutants be prepared outlining actions to bring pollutant concentrations in line with the LVs in the shortest possible period. Furthermore, in 2008, the EU legislation introduced additional health-based $PM_{2.5}$ objectives targeting the exposure of population to fine particles. These objectives are set at the national level and are based on the AEI. This indicator represented an objective function in the GAINS modeling for Kazakhstan discussed in Chapter 3.

In general, AQM should focus on reducing air pollution by targeting action on improving air quality in regions where exceedances of air quality standards affect the health of large vulnerable populations. Achieving significant air quality improvements while paving the way for a long-term low-carbon development would require strengthening of both air quality and climate mitigation policies and institutions. Integrated policy making is required to consider the long-term impacts of policies and actions to avoid introducing barriers to long-term decarbonization while trying to solve air quality problems in the short term. Adequate targeting and design of policies and institutions to harness synergies and manage trade-offs between these two important social objectives require sequential policy processes illustrated in Figure 40.

Figure 40: Five steps of the Integrated Air Quality and Climate Change (IAQCC) policy process



Source: World Bank.

Note: AP = Air pollution; AQ = Air quality; CC = Climate change.

Blue text denotes actions driven primarily by air pollution health considerations. Black text refers to actions driven primarily by climate mitigation. Green text indicates gradual introduction of an integrated approach to mitigating air pollution and climate change.

Step #1 in AQM begins from a ground-level system for monitoring air quality to identify areas where the concentration of air pollutants poses a significant health risk to a large, exposed population. Step #2 develops a rationale and focus for action and targets for air quality in the pollution hot spots. Step #3 identifies the key sources of emissions that contribute the most to the exposure of population in the polluted regions. Step #4 of the IAQCC policy process pictured in Figure 40 includes identifying the least-cost technical, structural, and behavioral measures to improve air quality in the polluted hot spots and the least-cost pathways to decarbonize the economy. Step #5 is to design, implement, and enforce an integrated package of policy incentives for firms and households to implement the abatement measures prioritized earlier. Integration means that the mix of policy instruments needs to encourage economic agents to optimize investment and behavioral decisions considering both the short-term health impacts of air pollution and the long-term impacts of climate change. Integration also means a creative design of comprehensive mixes of direct regulations (such as emission performance standards setting emission benchmarks, BAT requirements, or urban zoning requirements) along with economic and fiscal instruments.

The design, implementation, and enforcement of the policy package should consider at least the following:

- **How** will the identified policy package be implemented?
- **Who** is responsible for implementation?

- **Where** will implementation resources come from?
- **What** is the expected result from the implementation of the policy package?
- **Who** monitors and controls whether the policy package has been implemented and the expected result has been achieved (and if it has not been achieved - **Why** was the policy package ineffective)?

The foundation of any quality management system is data. Data are fundamental to understanding the nature, extent, and causes of the problem. Reliable monitoring data and robust emission inventories (discussed in more detail in Section 4.2) provide the basis for a well-functioning AQM system. Kazakhstan has made major strides in expanding and modernizing its air quality monitoring network. Nevertheless, there may be some technical and/or calibration issues at a number of AAQMSs that take some time to correct. In addition, data validation from AAQMSs can be improved as even official sources report some improbable values from air quality monitoring. In general, clear QA/QC procedures should be implemented when working with data, whether or not monitoring or emission data.

The assessment carried out in this report suggests that Kazakhstan's preparedness to manage air pollution is less advanced than its preparedness to manage climate mitigation. The national and subnational policy makers seem to have made uneven progress toward the first three steps in the IAQCC process illustrated in Figure 40. This report makes progress to Step #4 by assessing the least-cost measures to address both air pollution and climate mitigation at the national level. Despite shortcomings, the available air quality monitoring data and existing information on emissions sources provide a strong rationale for action and allowed for this study to conduct the first, high-level approximation of priority measures to address both air pollution and climate mitigation challenges. In the next step, such analysis will need to be tailored to the most polluted cities and will need to identify the package of policies that would be the most effective in saving people's lives from air pollution while facilitating a long-term transition toward a low-carbon economy. The implementation of these next steps as part of an AQM program could be prioritized in Kazakhstan's biggest cities: Almaty and Nur-Sultan.

Box 1. Air quality management in Almaty

Almaty, Kazakhstan's largest city, has been making efforts to incorporate air quality issues into strategic documents. For example, in 2017, two strategic documents at the local level were drafted that identify air quality issues and outline measures to improve air quality in Almaty. These were the Municipal Energy Efficiency Plan for the City of Almaty' and the 'Almaty 2020 Development Program'. The Almaty 2020 Development Program, in particular, identifies improvement of air quality in the city as a specific development goal and a number of actions to achieve this goal. The actions range from improvement of air quality monitoring to a fuel switch in different sectors and installation of abatement technologies in industry.

Including air quality actions in a strategic development program helps emphasize the importance of improved air quality. Nevertheless, considering air quality issues in such wide-focused programs does not follow the more systematic, targeted, and integrated AQM approach presented in Figure 40. The foundation for following the IAQCC process should be the monitoring and emissions data. Compiling a robust emissions inventory is a fundamental task in Step #3 of the IAQCC process because the analysis of emission sources will inform the prioritization of sources and aid the process of identifying the policy packages that will contribute the most to the improvement of air quality in Almaty.

In addition to identifying policy packages, a well-formulated action plan would also define each measure in the policy package, the timeline, institutions/people responsible for the implementation of the measure, the financial resources needed, the potential sources of finance, and the monitoring indicators to assess the success of the measure's implementation.

Therefore, if Almaty wishes to maximize its efforts in efficient AQM and climate change mitigation policies, the local authorities must consider implementing the IAQCC policy process illustrated in Figure 40. The process could begin by collecting source emission data, compiling an emission inventory, conducting source apportionment studies, and employing best international practices in analyzing the available air quality data. After the relevant data are collected, the least-cost measures to improve air quality in the context of least-cost pathways to decarbonization could be identified, based on which the integrated policy package of AQM and climate change mitigation can be established.

5.2. Improving Emission Inventories

Data are fundamental to understanding key emission sources. Thus, reliable emission data can provide an indication of the priority sources where co-benefits for air quality improvement and climate change mitigation can be achieved. Nevertheless, actions aimed at the same source can have divergent outcomes depending on whether the policy focus is placed on air quality improvement or on climate change mitigation. Therefore, detailed emission data can facilitate the identification of areas where synergies between air quality improvement and climate change mitigation can be achieved, as well as areas where trade-offs should be managed.

The main principles in emission inventories are transparency, consistency, comparability, completeness, and accuracy. Kazakhstan's Bureau of National Statistics publishes a wide range of data. In addition, Kazakhstan submits emission inventories as part of the reporting obligations under the CLRTAP and UNFCCC. Nevertheless, the adherence to the main principles of emission inventories cannot be fully assessed. Kazakhstan's inventory submissions were recently reviewed by expert review teams under the CLRTAP (in 2017) and under UNFCCC (in 2019). In both cases, the expert review teams concluded that adherence to the principles of emission inventories could not be fully evaluated due to a lack of information or evidence of robust QA/QC procedures for data verification.

Data collection for emission inventories is a huge task in itself, but equally important is the QA/QC validation of the data and calculations. Therefore, it is recommended that Kazakhstan establishes dedicated QA/QC procedures for the validation of emission inventories. Moreover, submission of the full package of documents, including those that provide more information on the approaches used in calculating the emission inventories will also improve the process.

It appears Kazakhstan uses Tier 1 methods for a number of sectors that play an important role in both air pollution and GHG emissions. International guidance recommends that at least Tier 2 approach be used for the calculation of emissions from key sources. Moreover, there are several important emission sources for which emissions were not calculated until recently in Kazakhstan. For example, PM_{10} and $PM_{2.5}$ emissions from the residential sector were not calculated in Kazakhstan's emission inventory submissions under the CLRTAP until those calculations were included in the 2021 submission.

Thus, for improved AQM, it will be essential to develop robust emission inventories that include not only emissions from large point sources in the power sector and industry but also emissions from the residential sector and waste management. Ideally, these emission inventories would be developed not only for the entire country but also with a sufficiently fine spatial resolution for subregions and urban areas so that priority sources at specific locations can be clearly identified. For a cost-effectiveness analysis, emission inventories should also provide information on the state of the already implemented emission control measures to assess the potential for further reductions at these sources.

Overall, it can be concluded that the main weaknesses in the emission inventory process in Kazakhstan are due to the insufficient capacity of institutions and difficulties with data collection for certain sectors. Therefore, a more detailed analysis on the institutional arrangements and resources in the emission inventory system in Kazakhstan should be conducted so that appropriate actions to optimize the process can be then taken.

5.3. Use of Cleaner Fuels and Technologies

Analysis of cost-effective measures to reduce the average population exposure to $PM_{2.5}$ in Kazakhstan using the GAINS models (described in Chapter 3) suggests that the most progress toward better air quality can be achieved cost-effectively by switching away from burning coal and biomass in small stoves and boilers to district heating and natural gas and utilizing improved combustion technologies. Replacing individual stoves on biomass with connection to natural gas networks was not included as a measure in the GAINS modeling but is an important measure that will be included in future city-level analyses. Improving building energy efficiency and efficiency of the remaining solid fuel heating appliances can also play a major role. These AQM measures also improve peoples' comfort and convenience while contributing, albeit in small amounts, to Kazakhstan's climate mitigation commitments.

Switching to natural gas, for example, would solve the problem of exposure to $PM_{2.5}$ and can be integrated into Kazakhstan's long-term decarbonization strategy as a bridge fuel during the transition to fossil fuel-free future. However, the near-term role of natural gas in improving air quality is limited because this fuel is not available in the central and northern parts of the country. Analysis of strategic choices related to developing large-scale infrastructure, whether for natural gas, for a power grid to integrate solar and wind power, or for efficient district heating systems based on locally clean use of coal is beyond the scope of this analysis. Nonetheless, the analysis in this report suggests that the short-term objectives of saving people's lives from air pollution and the long-term goal of the transition to a low-carbon economy should inform priorities for short-term reforms of policies and incentives, as well as for long-term infrastructure planning.

From the climate perspective, the key to meeting Kazakhstan's climate commitments is in switching large power stations and industrial installations from coal to gas and, subsequently, to renewable energy and improving their energy efficiency. These measures to reduce the carbon intensity of Kazakhstan's economy would have an insignificant impact on air quality on average in the country, although it could be important in specific locations. City-specific analyses and priorities for integrated air quality and climate change management programs were beyond the focus of this report. These issues and more informed policy recommendations can be the scope of the follow-up analytical work and policy dialogue.

In general, encouraging the use of cleaner fuels and technologies requires both strengthened regulations (local and/or national) and incentives to make adopting cleaner fuels and technologies more attractive. There are different potential approaches to strengthening regulation: from emission standards to banning/restricting the use of certain fuels. In addition, incentivizing the use of cleaner fuels could take different forms, including fiscal measures and implementation of financial instruments. Follow-up analytical work and policy dialogue at the city level might consider the most appropriate mix of regulations and incentives to promote the use of cleaner fuels and technologies, especially in the residential heating sector.

Box 2. Residential heating measures in Poland

Some of the highest levels of air pollution in Europe are registered in Poland–36 of 50 cities with the most polluted air in Europe are in Poland.[51] Residential space and water heating on solid fuels (mainly coal) in low-quality appliances has been found to be the main source of air pollution in Polish cities. In addition, the residential sector is the second largest energy consumer in Poland. Approximately half of Polish households live in SFBs, which are key contributors to GHG emissions and emissions of particulate matter.

In 2018, the Government of Poland launched the Clean Air Priority Program (CAPP)—a dedicated 10-year initiative that focuses on low-stack emissions with an allocation of PLN 103 billion (€24 billion). The objectives of the CAPP are to improve air quality and reduce GHG emissions by replacing low-quality solid fuel heating appliances and improving energy efficiency in SFBs. The CAPP strives to help around 3 million households living in SFBs to replace their solid fuel boilers and conduct energy efficiency retrofits through a system of subsidies, tax incentives, and targeted loans in cooperation with commercial banks.

In addition to the financial incentives to improve household heating and increase energy efficiency under the CAPP, in 2015, the Government of Poland made an important amendment to the Act on Environmental Protection allowing regional authorities (voivodeships) to enact regional anti-smog regulations. The anti-smog regulations can ban or restrict the use of certain fuels and heating systems in households. By the end of 2020, almost all 16 voivodeships in Poland adopted anti-smog regulations that mandate the replacement of noncompliant solid-fuel heating appliances and/or a ban on the use of solid fuels for heating by a certain date in the near future.

The launch of the CAPP was preceded by long-standing efforts to tackle air quality in settlements in Poland, including energy pricing, increased competitiveness of utilities, permitting of pollution charges, and zoning, among others. A number of initiatives were accelerated after widespread public response to air pollution in Poland in the last five years, resulting in the adoption of the anti-smog regulations. Moreover, to inform the design of the CAPP, key improvements to the quality of data on buildings, fuel use, households (including social aspects), air quality monitoring, dispersion modeling, and so on were undertaken.

The example from Poland demonstrates a holistic approach to tackling the complex issue of low-stack emissions. Unlike industrial stack emissions that have a well-known location and are easier to monitor and regulate, there could be millions of sources of low-stack emissions that are irregularly distributed in a given territory. Moreover, the reason why a certain household has high low-stack emissions might originate from economic reasons in the attempt to secure an adequate level of heating. Therefore, such a multi-faceted problem needs to be addressed with a combination of legal tools and financial instruments. On the one hand, regulations (for example, the anti-smog regulations) clearly define the policy objective, restricting or banning the use of certain fuels and/or heating appliances by a given date, while on the other hand, targeted financial instruments (for example, through the CAPP) are put in place to assist vulnerable households with the necessary heating and energy efficiency improvements at an affordable cost.

5.4. Institutional Capacity Building

As with any system change, changing the paradigm of environmental management in Kazakhstan will require capacity building at institutions to further the understanding and acceptance of the new system requirements. Capacity building would be necessary at all institutional levels—from the regulatory level to the executive levels responsible for monitoring and control.

At the regulatory level, coordination between different legal acts and policies should be ensured so that there are no contradicting provisions. Where applicable, the use of parallel systems or a switch from one system to another (for example, from historical ELV permits to IEPs) should be reconciled. The mere fact that the 2021 Environmental Code includes a number of major amendments requires adequate capacity building at the regulatory level.

[51] World Bank. 2019. *In the Spotlight: Air Quality in Poland, What are the Issues and What Can be Done*. Washington, DC: World Bank. https://documents1.worldbank.org/curated/en/426051575639438457/pdf/Air-Quality-in-Poland-What-are-the-Issues-and-What-can-be-Done.pdf.

At the executive level, capacity building should be a priority in the areas of data management. Data are the foundation of any analysis that facilitates decision-making. Therefore, data should be of the highest quality possible. Adequate QA/QC systems have to be set up for air quality monitoring and for emission inventories. Generally, there appears to be good data availability, and therefore, solid foundations for reliable data reporting systems have to be built based on robust data validation and verification protocols. Otherwise, data will continue to be used for simple reporting and its value in decision-making will be uncertain. An important issue is the declining number of staff at key institutions such as JSC Zhasyl Damu (responsible for GHG emission reporting) whose staff strength declined from 106 in 2012–16 to 70 in 2017–18.[52] Such trends in staff numbers at key institutions make capacity building an ever more pressing issue.

A major component in the system of environmental management is the control of emissions and discharges. The context of institutional control needs to change from one based on conformity to one based on actual promotion of environmental protection. Additional control mechanisms should be set up, as well. For instance, AQM should move toward the five steps of IAQCC policy process, presented in Figure 40. This requires the placement of additional control functions as part of the responsibilities of local administrations. Such changes will require capacity building in institutions to achieve the desired results of air quality improvement and reduction of GHG emissions.

Finally, environmental issues such as air quality and climate change are multi-sectoral. Therefore, a central, high-level mechanism is required to provide horizontal and vertical coordination of efforts in those areas. The Council on Transition to Green Economy under the President seems to be an adequate platform for such coordination. International experience has shown that air quality and climate change issues are most likely to be efficiently addressed if there is high-level coordination that cuts across sectors.

[52] UNECE. 2019. Kazakhstan: Environmental Performance Reviews – Third Review. https://www.unece.org/environmental-policy/environmental-performance-reviews/enveprpublications/environmental-performance-reviews/2019/3rd-environmental-performance-review-of-kazakhstan/docs.html.

6. FUTURE WORK

The near-term future work will focus on a city-level analysis of potential air quality measures and the assessment of their interactions with climate mitigation measures and policies in the cities of Almaty and Nur-Sultan. The future work will include the following:

- **City-level emission inventories.** The collection of emission inventories for Almaty and Nur-Sultan will provide the characteristics of major local sources of direct emissions of $PM_{2.5}$ and its precursors (SO_2 and NOx) potentially affecting population exposure in targeted cities, subject to data availability.
- **Potential for abatement technologies in industry.** Information on the use of abatement technologies available to power/heating plants and industrial enterprises will be collected so that the potential for the implementation of abatement technologies can be assessed.
- **Source apportionment studies and/or airshed-level pollution dispersion modeling.** In the absence of source apportionment studies that analyze the chemical components of PM samples in Kazakhstan, source apportionment can be modeled using GAINS. In addition, dispersion models available in GAINS can be used to simulate how the implementation of selected abatement measures on selected sources would reduce the concentration of $PM_{2.5}$ for people living in different parts of the polluted airshed.
- **Importance of sulfates in the overall toxicity in $PM_{2.5}$ will be considered, subject to data availability.** The main sources of sulfates are fossil fuels, and thus, reducing fossil fuel use can reduce $PM_{2.5}$ toxicity while at the same time providing synergies with climate change mitigation.
- **City-level modeling of cost-effective technical measures to reduce population exposure to $PM_{2.5}$ and their impacts on GHG emissions, resulting in AQM Technical Road Maps for the cities of Almaty and Nur-Sultan.** In this report, cost-effective measures to reduce population exposure to $PM_{2.5}$ were modeled on the mean national level with simplified assumptions about pollution dispersion from the emission sources. Important local differences exist, however, in the local emission sources, availability/costs of fuels and abatement measures, meteorological conditions, and topography. Therefore, the city-level GAINS model will be run for the two largest cities in Kazakhstan, Almaty and Nur-Sultan, and will inform the AQM Technical Road Maps.
- **Analysis of policy instruments to incentivize economic agents (firms and households) to undertake measures to reduce $PM_{2.5}$ population exposure.** While some policy instruments must be applied at the national level, some can be applied by affected municipalities and *akimats*, such as Almaty and Nur-Sultan. The analysis can include a mix of air pollution and climate policy instruments calibrated to harness synergies and manage trade-offs between the two goals of sustainable development.
- **Review of institutional arrangements and capacity-building needs in Almaty and Nur-Sultan.** Institutional setup, capacities, resources, and needs in Kazakhstan should be evaluated for improved environmental management. As discussed in Section 5.4, sufficient institutional capacity and efficient institutional arrangements are key to successful policy implementation and achievement of expected results.
- **Review and potential applicability of environmental instruments to reduce air pollution and mitigate climate change.** Such review could consider fiscal instruments and other incentives to encourage the implementation of measures and behavioral changes.

This report is a synthesis of the key findings and recommendations of a study carried out in FY21 under the World Bank's Advisory Services and Analytics (ASA) Program "Central Asia: Climate and Environment Program." The ASA aims to strengthen the capacity of Central Asian countries to achieve sustainable and resilient economic growth. It covers several Trust Funds-supported activities. This report was financed by the Multi-Donor Trust Fund for Climate Support Facility of the World Bank to share knowledge and promote integrated air quality management (AQM) and climate change mitigation.

This report provides an overview of air quality and main emission sources in Kazakhstan, assesses air pollution and climate change interactions by applying the GAINS-country modeling, and presents the least-cost measures to reduce $PM_{2.5}$ exposure in Kazakhstan and their impacts on greenhouse gas emissions. It further analyzes the policy context on AQM and climate change in the country. Recommendations on integrated AQM and climate change mitigation and future work are also presented.

This national scoping study will be followed by GAINS-city and GAINS-policy modeling to identify cost-effective technical measures and policy actions to reduce population exposure to $PM_{2.5}$ and their impacts on greenhouse gas emissions, resulting in Air Quality Management Road Maps for Kazakhstan's cities of Almaty and Nur-Sultan.

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