AIR QUALITY ASSESSMENT FOR TASHKENT

and THE ROADMAP FOR AIR QUALITY MANAGEMENT IMPROVEMENT IN UZBEKISTAN

June 2024

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MINISTRY OF ECOLOGY, ENVIRONMENTAL PROTECTION AND CLIMATE CHANGE OF THE REPUBLIC OF UZBEKISTAN

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Air Quality Assessment for Tashkent and the Roadmap for Air Quality Management Improvement in Uzbekistan

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PROGREEN

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Acronyms and Abbreviations

A2W	Air-to-Water
AEL	Associated Emission Level
AQ	Air Quality
AQG	Air Quality Guidelines
AQI	Air Quality Index
AQM	Air Quality Management
AQP	Air Quality Plan
BAT	Best Available Technique
BREF	Best Available Techniques Reference Document
CAMx	Comprehensive Air Quality Model with Extensions
CAPEX	Capital Expenditure
CLRTAP	Convention on Long-Range Transboundary Air Pollution
COP	Coefficient of Performance
DNSH	Do No Significant Harm
EEA	European Environmental Agency
EIA	Environmental Impact Assessment
ELV	Emission Limit Value
EPA	Environmental Protection Agency
ESCO	Energy Service Company
ETS	Emissions Trading System
EU	European Union
GAINS	Greenhouse Gas and Air Pollution Interactions and Synergies
GBD	Global Burden of Disease
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GHS	Global Human Settlements
GIS	Geographic Information System
IEA	International Energy Agency
IED	Industrial Emissions Directive
IHD	Ischemic Heart Disease
IT	Interim Target
LCOH	Levelized Cost of Heating
LEZ	Low-Emission Zone
LRI	Lower Respiratory Infection
MAC	Maximum Allowable Concentration
MoEEPCC	Ministry of Ecology, Environmental Protection, and Climate Change
MoH	Ministry of Health
MOZART	Model for Ozone and Related Chemical Tracers
OECD	Organisation for Economic Co-operation and Development
OPEX	Operational Expenditure
PaMs	Policies and Measures
PM	Particulate Matter
RL	Reference Level
SFH	Single-Family House
TPP	Thermal Power Plant
TTC	TashTeploCentral
TTE	TashTeploEnergo
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
Uzhydromet	Uzbekistan's Center of Hydrometeorological Services
Uzstat	Statistics Agency of the Republic of Uzbekistan
VSL	Value of Statistical Life
WACCM	Whole Atmosphere Community Climate Model
WHO	World Health Organization
WRF	Weather Research and Forecasting

Signs and Units

°C	Celsius
°F	Fahrenheit
g/GJ	Grams per Gigajoule
km^2	square kilometer
m/s	meters per second
MW	Megawatt
t	ton
t/yr	ton per year
$\mu g/m^3$	Microgram per cubic meter
µm	Micron

Executive Summary

Objective of the report

This report summarizes the main results from a technical assessment of air quality in Tashkent (Part I) that informed the definition of sectoral policies and measures (PaMs) in the roadmap for air quality management (AQM) improvement in Uzbekistan (AQM roadmap, Part 2). The report is part of a series of underlying studies on air quality in Central Asia that inform the dialogue with the government and pave the way for a comprehensive regional air quality assessment. The technical assessment for Tashkent aims to assess the air quality in the city using a scientific approach to air quality analysis, with a main focus on particles with diameter less than 2.5 microns (µm) ($PM_{2.5}$). $PM_{2.5}$ has been identified as the pollutant of the gravest health concern according to the World Health Organization (WHO) and is globally considered to be a critical air pollutant for which concentration targets need to be put in place.

The technical assessment is the analytical foundation for the identification of key sources of air pollution for which PaMs are suggested in the AQM roadmap. In addition, the main objectives of the AQM roadmap are to provide initial suggestions for reforms and support the development of a long-term and holistic AQM vision in Uzbekistan that can serve as a platform for further discussion with the relevant government stakeholders. The AQM roadmap outlines and elaborates on priority measures in the short and medium term to strengthen overall AQM in Uzbekistan, suggests approaches to streamline stakeholder engagement and inter-ministerial coordination, and identifies potential priority areas for investments in air quality improvement.

Air quality assessment for Tashkent

Ambient $PM_{2.5}$ concentrations in Tashkent peak in the winter months and substantially exceed international air quality standards. The annual average $PM_{2.5}$ concentration in Tashkent exceeds over six times the WHO's annual average guideline of 5 µg/m^3. Existing information and studies on air quality in Tashkent are limited and therefore, there was a need for a comprehensive analysis of the air quality situation in Tashkent that could identify the main sources contributing to air pollution in the city.

The health impact assessment shows considerable health and economic impacts of $PM_{2.5}$ ambient air pollution in Tashkent. The assessment of the health impacts of ambient PM2.5 air pollution in Tashkent conducted during this study estimated that about 3,000 premature deaths could be attributable to PM2.5 pollution annually in Tashkent, leading to losses of welfare of population estimated at US$488.4 million per year. This high-level health impact assessment of air pollution in Tashkent used data for 2019 from the Global Burden of Disease (GBD) database,[1] which is a reference for assessments of air pollution's health impacts. The availability of local health impact data would greatly improve the health assessment's granularity.

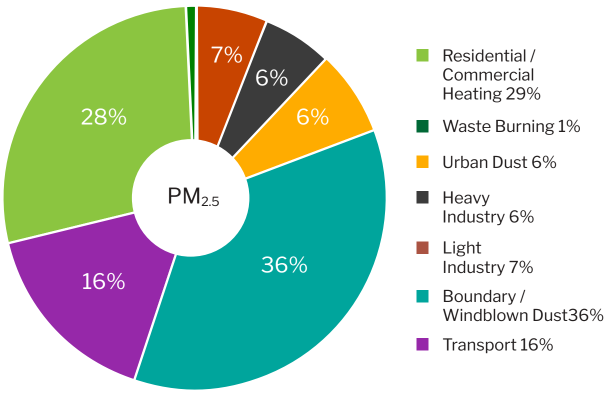
The peak $PM_{2.5}$ concentrations in Tashkent occur in the winter months suggesting a major contribution of residential and commercial heating to $PM_{2.5}$ pollution. In addition to heating, various other sources of $PM_{2.5}$ emissions and their contributions to ambient concentrations have been assessed in this study. With the help of a detailed emission inventory, developed as part of the study, and pollution modeling, pollution maps have been produced presenting spatial and temporal distributions of both emissions and ambient concentrations.

The modeled $PM_{2.5}$ concentrations from this study matched well with the concentrations reported by the monitoring networks. To validate the performance of the model, monthly modeled concentrations were compared with the actual $PM_{2.5}$ concentrations from the analyzed

1 https://www.healthdata.org/research-analysis/gbd.

air quality monitoring data. The modeled $PM_{2.5}$ concentrations showed a 93 percent match with the concentrations reported by the monitoring networks, providing confidence in the accuracy of the modeling results despite data limitations. The modeling identified source contributions to $PM_{2.5}$ concentrations in Tashkent, providing valuable information to support AQM policy formation (Figure ES.1).

Figure ES.1: Source contributions to annual average $PM_{2.5}$ concentrations in Tashkent



Source: World Bank.

Windblown $PM_{2.5}$ — $PM_{2.5}$ particles carried by wind into Tashkent as a result of natural dust storms, from adjoining areas such as agricultural and open fields, and from various commercial activities outside the defined airshed — has the highest contribution to annual average $PM_{2.5}$ concentrations. The contribution of windblown dust to $PM_{2.5}$ concentrations is the highest in the summer months when concentrations are generally lower. Combustion of fuels for heating, especially coal, is the leading contributor to $PM_{2.5}$ concentrations in the winter in Tashkent—accounting for nearly 45 percent of $PM_{2.5}$ concentrations in the city in some winter months, which is when peak $PM_{2.5}$ concentrations are reported. Therefore, measures related to cleaner heating will have an impact on $PM_{2.5}$ pollution during periods when the highest $PM_{2.5}$ concentrations are reported. Transport is another important contributor to $PM_{2.5}$ concentrations in Tashkent and is the second most important anthropogenic source of $PM_{2.5}$ pollution.

Because there is no linear correlation between $PM_{2.5}$ emissions and $PM_{2.5}$ concentrations, therefore the share of an emission source to total $PM_{2.5}$ emissions could differ from the contribution of the same source to $PM_{2.5}$ concentrations. The translation of emissions into concentrations is affected by a number of factors including the location of the emissions source, characteristics of the source (height of emissions release, temperature and velocity of gases, and so on), meteorological conditions, and topography. Therefore, to determine how emissions translate into concentrations, modeling needs to be conducted as it was done in this study.

Residential and commercial heating and transport are the anthropogenic sources that contribute the most to $PM_{2.5}$ emissions in Tashkent. The largest $PM_{2.5}$ emissions source annually in Tashkent, albeit mostly concentrated in the winter months, is the heating sector—responsible for nearly one-third of total annual $PM_{2.5}$ emissions. The second largest $PM_{2.5}$ emissions source is transport, accounting for 25 percent of the total annual $PM_{2.5}$ emissions in Tashkent. Taken together, heavy and light industry is the third largest $PM_{2.5}$ emissions source in Tashkent, contributing 22 percent to the total $PM_{2.5}$ annual emissions. Urban dust from construction activities and resuspension of dust from roads account for 18 percent of the total annual $PM_{2.5}$ emissions in Tashkent.

The results from the technical assessment laid the foundations for further air quality analyses for Tashkent and can serve as an example for similar assessments in other Uzbek cities. The suggested next step is to assess the impact of a variety of emission reduction measures on pollutant concentrations and greenhouse gas (GHG) emissions and determine the ones that reduce $PM_{2.5}$ concentrations the most while also providing important benefits for climate change mitigation. A cost-effectiveness analysis of emission reduction PaMs is needed to identify which measures reduce air pollution the most at the least cost, to prioritize the implementation of various emission reduction options. In addition to the cost-effectiveness analysis, an evaluation of implementation modalities for the different emission reduction measures could consider responsible institutions for implementation, enforcement, monitoring and reporting, coordination, and sources of financing for the measures. Completing the steps outlined above will help define PaMs to be implemented as a priority and will provide the tools for dynamic calibration of PaMs to improve air quality, thus fully reflecting the complex nature of AQM.

Roadmap for AQM improvement in Uzbekistan

The AQM roadmap consists of measures addres-sing the main components of an effective AQM system and elaborates PaMs in the key sectors responsible for air pollution. The AQM roadmap provides an initial overview and suggestions for necessary improvements in the AQM system in Uzbekistan and serves as a starting point for more detailed discussions on AQM with government stakeholders. All components of the AQM system in Uzbekistan can be further developed and strengthened—AQM policies and legislation, technical infrastructure and capacities, planning and implementation of PaMs, and financing and investments. Even though implementing PaMs to reduce pollutant emissions is at the core of the AQM system, the most optimal results of PaMs' implementation are achieved only when all components of the AQM system are developed. Figure ES.2 summarizes the suggested measures for AQM improvement in Uzbekistan for the main components of the AQM system.

Figure ES.2: Suggested measures in the AQM roadmap to strengthen Uzbekistan AQM system components

AQ monitoring	• **Develop** an AQ monitoring network modernization plan • **Install** automatic AQ monitoring stations and establish/update AQ laboratories
AQ standards	• **Update** national AQ standards in line with international best practices • **Develop** $PM_{2.5}$ national standards
Emission inventory	• **Update** and strengthen the emission inventory system to meet international best practices • **Develop** technical expertise for emission inventory management
Data management	• **Establish** a comprehensive and user-friendly AQ data management system • **Establish** capacities to perform AQ analyses such as modeling and AQ forecasting
AQM policies	• **Develop** a national AQM strategy • **Strengthen** regulations and local capacities for AQM planning • **Establish** an AQM coordination mechanism
Sectoral policies	• **Implement** policies and measures for key sources: industry, transport, heating, and windblown dust • **Emissions** control and cleaner industrial production • **Pilot** greening interventions
Communication	• **Strengthen** AQ information dissemination to the public • **Improve** communication on AQ matters across institutions
Financing	• **Establish** financing mechanisms and coordinate the design of the financing mechanisms with GHG emission reduction targets • **Introduce** AQ improvement activities in green taxonomy
Investment	• **Investing** in emission-reduction measures in priority sectors • **Budgetary** support to implement key policy reforms

Source: World Bank.

Improving air quality requires a balanced app-roach as well as policy reforms and investments in emission reduction measures across sectors. The technical assessment for Tashkent identified windblown dust, heating, transport, and industry as the main sources of $PM_{2.5}$ pollution and therefore, the AQM roadmap is focused on PaMs in those sectors. Implementing PaMs in each of the sectors requires careful planning, design, and optimization of resources—technical, human, and financial. Hence, prioritization of PaMs and the respective policy reforms and investments to support PaMs' implementation are key tasks in operationalizing the AQM roadmap.

Additional analyses are needed to assess the sources of windblown dust that affect air quality in Uzbekistan and pilot greening interventions could demonstrate the potential of greening measures to reduce the transport of windblown dust into cities. The occurrence of dust storms is well documented in Central Asia. Moreover, agriculture plays a significant role in Uzbekistan's economy and can also be a source of windblown dust. Studies generally agree that greening measures can mitigate dust transport into cities; however, the design of greening measures is highly location specific and depends on the types of measures, including species selection and space availability for greening, as well as availability of water resources to maintain green areas. Moreover, it is likely that reducing the amount of windblown dust transported to Uzbekistan might require a combination of local, national, and transnational measures.

There are four general options to reduce emissions from heating; however, additional analyses are needed to design the most optimal regulatory and funding framework for efficient implementation of those options in Uzbekistan. The technical options to reduce emissions from the heating sector are improving the quality of fuels used, improving the efficiency of heating appliances, implementing energy efficiency measures, and switching to cleaner heating alternatives. Regulatory changes are required to support efficient implementation of some of the measures. Financial assistance to households to afford up-front investments in energy efficiency and cleaner heating is also needed, especially to support vulnerable households. The design of the regulatory framework and the financial assistance programs require further analysis of the local context and implementation modalities.

Measures to reduce transport emissions are a combination of national and local actions and hence, appropriate coordination is needed to facilitate and control transport measures' implementation. Measures to reduce transport emissions include setting standards for vehicles and fuels, regulating vehicle imports, improving the attractiveness and emission profile of public transport, incentivizing nonmotorized means for urban mobility, and implementing a low-emission zone (LEZ). LEZ is a common measure to reduce emissions in cities, but it is typically implemented after vehicle and fuel standards and vehicle measures are put in place. In addition, implementing an LEZ restricts mobility options for parts of the population and hence, adequate options for public transport and/or nonmotorized urban mobility need to be provided. Furthermore, the proper designation of LEZs requires detailed analyses on traffic flows, modal splits, air quality, and population exposure impacts.

Improving air quality in Uzbekistan to meet international standards requires significant investment and optimization of resources. An upcoming World Bank report[2] estimated that around €690 million of up-front investments are needed for the key emission sectors in Tashkent, to bring the $PM_{2.5}$ annual average concentration in the city below the WHO's interim target (IT) 1 of 35 $\mu g/m^3$. Recognizing that the financing of air quality improvement measures is unlikely to be secured only through public funding, the AQM roadmap highlights potential sources of funding for the suggested PaMs. Funding sources include private capital mobilization, public-private partnerships, concessional loans, financing from development partners and philanthropic organizations, and innovative financing mechanisms such as green credits, green bonds, and development of green taxonomy for air quality improvement projects. Detailed discussion on financing of air quality improvement PaMs is envisioned as a next step after the suggested PaMs in the AQM roadmap have been discussed with government stakeholders.

Immediate actions are needed to reduce exposure to harmful air pollution of the population. Therefore, the AQM roadmap

2 World Bank. Forthcoming. Understanding Air Quality in Central Asia.

highlights priority PaMs to be implemented in the next one to two years. The objective of the suggested short-term priority actions is to ensure an enabling framework for AQM which is key for the sustainable and systematic improvement of air quality. In addition, links with recently issued Presidential decrees that have provisions for improved AQM have been considered in the selection of the short-term priority actions described in Figure ES.3.

Figure ES.3: Suggested short-term priority actions

AQM legislation, policies, and planning

- Update national air quality standards to include standards for $PM_{2.5}$.
- Develop a national AQM strategy.
- Reform legislation on pollution fees and taxes (compensation payments).
- Establish an AQM coordination mechanism.

PaMs in the industrial sector

- Strengthen industrial emissions regulations, including the industrial permitting process.
- Mandate the installation, operation, and maintenance of highly efficient emissions control and automatic emission reporting equipment at key industrial enterprises.

PaMs in the transport sector

- Establish a work plan and coordinate with relevant institutions to advance legislation on reducing transport emissions.

PaMs in the heating sector

- Identify priority interventions and policies to address air pollution from heating informed by a study on fuels and appliances used for residential and commercial heating in a targeted area—for example, Tashkent.

PaMs to reduce windblown dust

- Pilot greening interventions in a city (for example, Tashkent) and analyze the impact on air quality.

Stakeholder Engagement and Communication

- Strengthen air quality information communication to the general public.

Source: World Bank.

It is important that sectoral PaMs and investments run parallel to the strengthening of the overall AQM system in the country. Strengthening the components of the AQM system can inform where investments are needed and can provide the necessary information for evaluating the impact, effectiveness, and the need for calibration of those investments. The natural next step is discussing the measures suggested in the AQM roadmap within the Ministry of Ecology, Environmental Protection, and Climate Change (MoEEPCC) and in government to agree on priority measures to invest in. Once a list of priority measures is agreed upon, assessment of implementation modalities, quantification of costs, and identification of sources of financing could follow. These processes might eliminate some measures from the initial list due to currently unsurmountable implementation barriers or prohibitively high costs. However, it is important that clear timelines and institutions responsible for the implementation of the final list of measures are established so that the implementation of PaMs brings the expected benefits of improved air quality and reduced GHGs.

PART 1:
Air Quality Assessment for Tashkent

1.1. Purpose of the Air Quality Assessment for Tashkent

According to the latest World Bank report on the global health cost of particles with diameter less than 2.5 microns (μm) ($PM_{2.5}$) air pollution,[3] Uzbekistan has the second highest annual average $PM_{2.5}$ concentration among the countries in Central Asia. The report estimates that the annual average $PM_{2.5}$ concentration in Uzbekistan in 2019 was 34.8 micrograms per cubic meter (μg/m³)—nearly seven times over the World Health Organization (WHO) annual average $PM_{2.5}$ guideline[4] of 5 μg/m³. In addition, the health cost of PM2.5 exposure in Uzbekistan was estimated at 7.3 percent of gross domestic product (GDP)—the highest among the Central Asian countries[5].

The technical analysis conducted in this study focuses on Uzbekistan's largest and most populous city — Tashkent. Existing information and studies on air quality in Uzbekistan in general and in Tashkent in particular before the current analysis were limited. Some studies focused on industrial pollution, and others on general air quality assessment. In addition, the two automatic air quality monitoring stations with continuous monitoring in Tashkent became operational only in March 2021, which means that time series from continuous monitoring of air pollutants was not available until then.

There was a need for a comprehensive analysis of the air quality situation in Tashkent. This analysis utilized all available data and resources to produce a local emissions inventory to be used as input to a state-of-the-art pollutant transport modeling. The comprehensive assessment that this study undertakes follows a scientific approach to air quality analysis and provides robust results to support the evidence on the air quality situation in Tashkent.

This study has the following main objectives:

- To collect and consolidate all available data and information—both locally sourced data and data from global databases—about the key emissions sources of $PM_{2.5}$ in Tashkent
- To create the first spatially and temporally dynamic $PM_{2.5}$ emissions map of Tashkent
- To conduct the first state-of-art air pollution modeling over the entire Tashkent airshed to identify source contributions to ambient $PM_{2.5}$ concentrations and suggest priority sectors where emission reduction measures could be implemented
- To conduct an initial assessment of the health impact from ambient $PM_{2.5}$ pollution in Tashkent.

The study focuses on $PM_{2.5}$ as the pollutant of the gravest health concern according to the WHO.[6] In addition, the study focuses on ambient $PM_{2.5}$ concentrations and does not consider indoor air pollution. $PM_{2.5}$ is associated with causing cardiovascular (ischemic heart disease), cerebrovascular (stroke), and respiratory impacts due to the ability of particles to not only penetrate deep into the lungs but also enter the bloodstream. Moreover, morbidity and mortality from cardiovascular and respiratory diseases are linked to both long-term and short-term exposure to $PM_{2.5}$. Furthermore, exposure

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3 World Bank. 2022. The Global Health Cost of $PM_{2.5}$ Air Pollution: A Case for Action Beyond 2021. International Development in Focus. Washington, DC: World Bank.

4 WHO (World Health Organization). 2021. WHO Global Air Quality Guidelines: Particulate Matter ($PM_{2.5}$ and PM10), Ozone, Nitrogen Dioxide, Sulfur Dioxide and Carbon Monoxide. WHO.

5 The health cost of $PM_{2.5}$ exposure in other Central Asia countries ranges from 5.1 percent of GDP in the Kyrgyz Republic to 6.7 percent of GDP in Kazakhstan.

6 WHO. Type of pollutants. https://www.who.int/teams/environment-climate-change-and-health/air-quality-and-health/health-impacts/types-of-pollutants.

to high $PM_{2.5}$ levels has been linked to a range of health outcomes such as adverse obstetric and postnatal metabolic health outcomes,[7] lung cancer,[8] increased resistance to antibiotics,[9] and dementia.[10]

In addition, $PM_{2.5}$ is globally accepted as a criteria air pollutant as there is a wide scientific agreement about its impact on health and welfare. $PM_{2.5}$ has important relations with other criteria air pollutants such as sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) since photochemical reactions in the atmosphere lead to the secondary formation of $PM_{2.5}$ by SO_2 and NO_2 precursors. Hence, policies and measures (PaMs) to reduce the concentrations on $PM_{2.5}$ have important implications for the concentration reductions of other criteria air pollutants.

Fulfilling this study's objectives strengthens the evidence base regarding sources of air pollution in Tashkent. The study follows a common approach to analyzing urban air quality. The analysis focuses on a key air pollutant—in this case $PM_{2.5}$—and examines the available air quality monitoring data. The study then compiles an emission inventory for the key $PM_{2.5}$ emission sources. The emission inventory, coupled with meteorological data, is then used in chemical transport modeling to assess the dispersion of $PM_{2.5}$ pollution over Tashkent, identify pollution hotspots, and determine source contributions to $PM_{2.5}$ concentrations. All these steps can support further evaluation of emission reduction measures and inform decisions in setting policy priorities to improve air quality in Tashkent. In addition, the air quality modeling conducted in the study can serve as a baseline for assessing the effectiveness of future emissions reductions measures.

The structure of Part I is as follows: It begins by providing context for the air pollution situation in Tashkent (Chapter 1.2). The report continues by describing the methodology used for the technical assessment in this study (Chapter 1.3) and summarizes the results from the $PM_{2.5}$ emissions sources' analysis (Chapter I.4) and from the conducted modeling identifying source contributions to $PM_{2.5}$ pollution in Tashkent (Chapter 1.5). Chapter 1.6 recaps the study's main findings and concludes with suggestions for next steps and how the study's results can be used and further developed. Annex 1 and Annex 2 are complementary to Chapter 1.3 and provide more details on the methodology and data used in the technical assessment.

7 Kaur, K., C. Lesseur, M. Deyssenroth, I. Kloog, J. Schwartz, C. Marsit, J. Chen. 2022. "$PM_{2.5}$ Exposure during Pregnancy Is Associated with Altered Placental Expression of Lipid Metabolic Genes in a US Birth Cohort." Environmental Research 211.

8 Ibid.

9 Zhou, Z., Shuai, X., Lin, Z., Yu, X., Ba, X., Holmes, M.A., Xiao, Y., Gu, B. and Chen, H. 2023. "Association between Particulate Matter $(PM)_{2.5}$ Air Pollution and Clinical Antibiotic Resistance: A Global Analysis." The Lancet Planetary Health 7: 649–659.

10 Wilker, E.H., Osman, M. and Weisskopf, M.G. 2023. "Ambient Air Pollution and Clinical Dementia: Systematic Review and Meta-analysis. The BMJ.

1.2. Background to Air Pollution in Tashkent

This chapter provides context for $PM_{2.5}$ pollution in Tashkent and its impact on health and includes four subsections. Section 1.2.1 describes the general characteristics of Tashkent such as location, population, and topography. Section 1.2.2 summarizes the performed analysis of key meteorological parameters that influence the dispersion of air pollutants in Tashkent. Section 1.2.3 provides a general overview of the air quality monitoring infrastructure in Tashkent and the conclusions of the $PM_{2.5}$ monitoring data analysis. Section 1.2.4 summarizes the results from the conducted ambient air pollution health impact assessment for Tashkent.

1.2.1 General context

Tashkent is the capital and largest city in Uzbekistan with a population of nearly 3 million in 2022.[11] Tashkent's urban area spans over 330 km^2 at an average altitude of 455 m. The city is situated in the well-watered and fertile plains of the Chirchiq river and its tributaries and is just 13 km from the border with Kazakhstan (Figure 1).

[11] Tashkent City Department of Statistics. https://toshstat.uz/uz/.

Figure 1: Location and topography of Tashkent

Source: Google Maps.

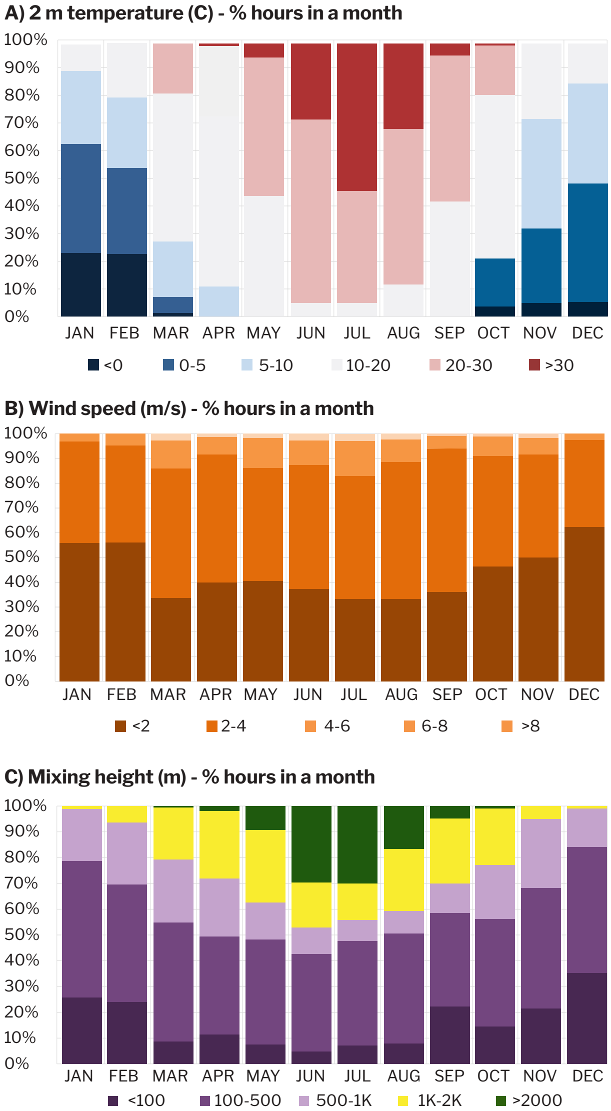
1.2.2 Meteorology

Meteorological parameters are a key input in air dispersion modeling. Tashkent's climate is characterized by cold winters and long, hot, and dry summers. Average daily temperature lows in the winter months are about −2°C, whereas average daily temperature highs in the summer reach 36°C. In addition, during the coldest winter months of January and February, temperatures are below 0°C for over 20 percent of the hours in a month and are generally below 10°C throughout the winter months which emphasizes the strong demand for heating in the winter (see Figure 2a). Wind speeds in Tashkent are low in the winter months—under 2 m/s for over 50 percent of the time in winter. The highest wind speeds are recorded in the summer months of June, July, and August (see Figure 2b). Moreover, there are minimal diurnal differences in wind speeds in the winter months. These factors are unfavorable for pollutants' dispersion in the winter and assist the trapping of air pollution over the city.

Another key parameter for the dispersion of air pollutants is the mixing height. The mixing height indicates the height above ground of the vertical mixing of air, including suspended particles. A parcel of air will rise up in the atmosphere as long as it is warmer than the ambient temperature. However, once the parcel of air becomes colder than the temperature of the surrounding ambient environment, its rise will slow down and eventually stop. It is at this point that the parcel of air has reached the maximum mixing height beyond which there is no more possibility to disperse further up in the atmosphere.

As shown in Figure 2c, the mixing height in Tashkent is the lowest in the month of December — over 30 percent of the hours in December have a mixing height under 100 m. Overall, winter and some fall months are characterized by lower mixing heights and small diurnal differences in the mixing height than spring and summer months when the mixing height is much higher. Low mixing height, combined with low wind speeds in the winter, especially in December, are conducive to trapping pollution over Tashkent.

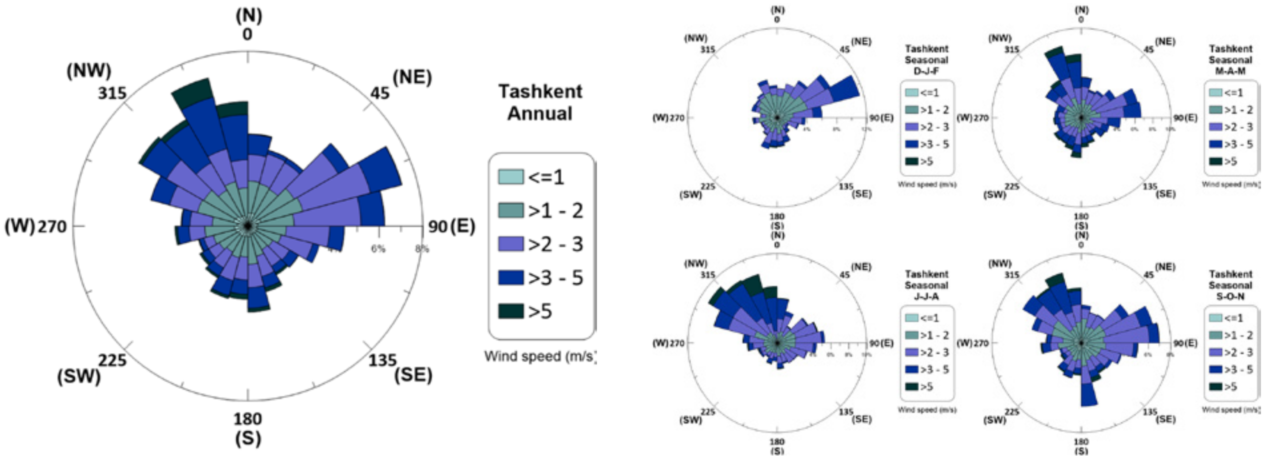
Figure 2: **Modeled hourly temperatures in Tashkent at 2 meters height (a.), wind speeds (b.), and mixing height (c.) by month, % of hours in a month**



Source: Weather Research and Forecasting (WRF) model.

The dominant wind directions in Tashkent on an annual average are winds coming from the northwest, followed by winds coming from the northeast (see Figure 3). Winds coming from the northwest have the highest wind speeds (the dark blue areas in Figure 3). Winds coming from the northwest are the dominant winds in the spring, summer, and fall, whereas winds from northeast prevail in the winter months (see Figure 3, bottom). Wind speeds are the lowest in the winter months and the highest in the summer. Therefore, while low wind speeds trap pollution in the city during winter, higher wind speeds in the summer have the potential to bring particles into Tashkent, especially from areas to the west of the city.

Figure 3: Wind directions in Tashkent: annual average (left), seasonal* (right)



Source: WRF model.
Note:
**D-J-F* are December, January, and February
M-A-M are March, April, and May
J-J-A are June, July, and August
S-O-N are September, October, and November.

Figure 4: Locations of air quality monitoring stations in Tashkent

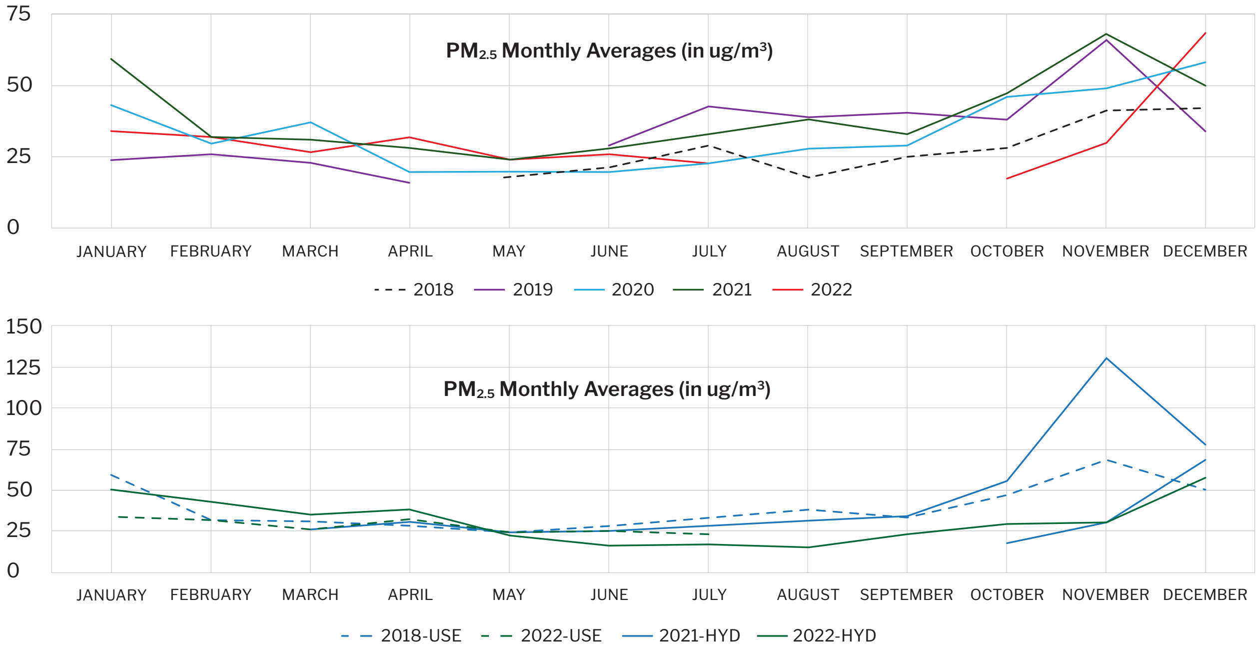
Source: Google Maps.
Note: Green pins represent the locations of the two automatic, reference grade Uzhydromet stations, and the blue pin is the automatic reference grade station of the US Embassy. The yellow dots are the 13 manual air quality stations in Tashkent operated by Uzhydromet. The manual stations, however, do not perform continuous monitoring and do not monitor $PM_{2.5}$ and thus, data from the manual stations were not used in this study.

1.2.3 Air quality data analysis

This study analyzed all available $PM_{2.5}$ monitoring data for Tashkent from automatic reference grade stations with continuous monitoring. Three automatic air quality stations in Tashkent meet international monitoring standards (Figure 4). Two are managed by Uzbekistan's Center of Hydrometeorological Services (Uzhydromet) and the other by the US Embassy in Tashkent using Environmental Protection Agency (EPA) reference equipment and methods. The Uzhydromet stations started monitoring $PM_{2.5}$ in March 2021, whereas the US Embassy station began in May 2018.

The air quality station at the US Embassy in Tashkent provides the longest time series of $PM_{2.5}$ monitoring data using reference grade methods. Figure 5 shows the monthly $PM_{2.5}$ average from the US Embassy station for 2018–2022 and the data from all three automatic stations (US Embassy and average of the two Uzhydromet stations) in 2021 and 2022. Data from Uzhydromet stations are missing for January and February 2021 as the stations became operational in March 2021. US Embassy $PM_{2.5}$ data are missing for August and September 2022.

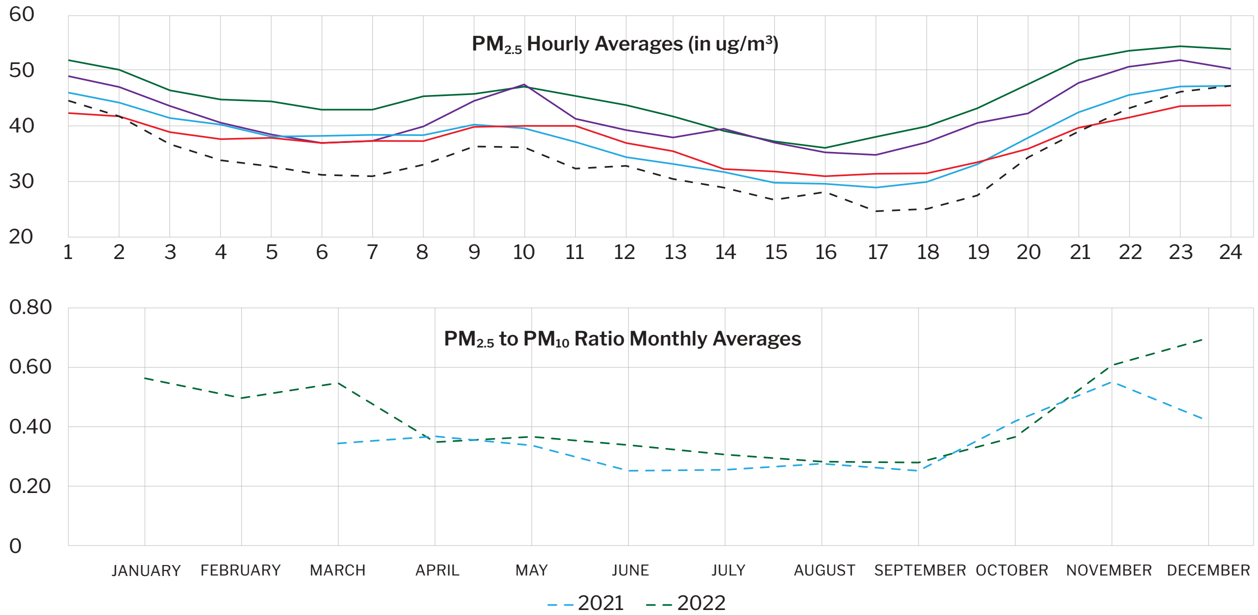
Figure 5: $PM_{2.5}$ **monitoring data for Tashkent: US Embassy monthly averages for 2018–2022 (top), US Embassy and Uzhydromet stations monthly averages for 2021–2022 (bottom)**



Source: US Embassy, Uzhydromet.

As shown in Figure 5, the peak $PM_{2.5}$ monthly average concentrations occur in the winter months, namely in November, December, and January. Annual average $PM_{2.5}$ concentrations in the years with full data coverage range from 31.4 μg/m³ (Uzhydromet station in 2022) to 39.3 μg/m³ (US Embassy station in 2021). Therefore, average annual $PM_{2.5}$ concentrations in Tashkent could exceed by over seven times the WHO guideline value for the protection of human health of 5 μg/m³ and are higher than even the least strict WHO $PM_{2.5}$ interim target (IT)—IT1 of 35 μg/m³. Additional analysis of the monitoring data, presented in Figure 6, provides further details about air pollution patterns and potential sources.

Figure 6: $PM_{2.5}$ **hourly averages for 2018–2022 (top) and** $PM_{2.5}$ **to** PM_{10} **monthly ratios for 2021–2022 (bottom)**



Source: US Embassy, Uzhydromet.

$PM_{2.5}$ hourly average data from the US Embassy's station show that peak $PM_{2.5}$ concentrations occur at night (after 8 p.m.) and in the morning (8–10 a.m.). Such dynamics of the hourly $PM_{2.5}$ trends might point to residential heating in particular having an important impact on $PM_{2.5}$ concentrations in Tashkent as the hourly peaks correlate with times when people are at home (at night) or when people have fired their stoves in the morning. The nighttime hourly peaks also correlate with the times of the day with lower mixing heights in Tashkent which is a condition conducive to trapping pollution. Morning traffic might also affect the observed peak in $PM_{2.5}$ concentrations over 8–10 a.m.

Another evidence for the impact of heating on $PM_{2.5}$ concentrations is the dynamics in the monthly ratios of $PM_{2.5}$ to PM10. As demonstrated in Figure 6, during the winter months, $PM_{2.5}$ is the dominant fraction of particulate matter (PM) pollution in Tashkent. Combustion of solid fuels is associated with higher emissions of finer particles, including $PM_{2.5}$. On the other hand, the share of $PM_{2.5}$ in PM_{10} reduces to about 20 percent, indicating the dominance of larger particles (for example, windblown dust and resuspended dust from roads) in the warmer months.

1.2.4 Health impacts of PM2.5 ambient air pollution in Tashkent

The WHO's annual average $PM_{2.5}$ guideline is 5 μg/m³, whereas the annual population-weighted average $PM_{2.5}$ concentration estimated for Tashkent is 38.8 μg/m³ — over seven times above the WHO guideline. The modeling results presented in Chapter 1.5 show that the WHO guideline is not achieved in any of 1 x 1 km grids that the Tashkent airshed was divided into.

Recognizing that the WHO guideline is extremely difficult to achieve in many places around the world, interim targets (ITs) for reaching the guideline were established. The first WHO IT (IT1) is annual average $PM_{2.5}$ concentration of 35 μg/m³.[12] Since the modeling conducted for this study developed spatial and temporal concentration maps for Tashkent and the modeling utilized a gridded population geographic information system (GIS) layer, it was possible to analyze in how many urban grids with a size of 1 km2 the concentrations were lower than the WHO's IT1[13] and how many people live in those grids.

The analysis showed that annual average $PM_{2.5}$ concentrations were below the WHO's IT1 in 39 percent of the urban grids in Tashkent. However, only 17 percent of the city's population lives in those grids and therefore, 83 percent of Tashkent's population lives in the 1 km² grids with the highest levels of air pollution that cause the largest health impacts.

The following data and information were used to estimate the impact of ambient $PM_{2.5}$ pollution in Tashkent on health:

- **Population data**, including by age groups, were taken from the Statistics Agency of the Republic of Uzbekistan (Uzstat).[14]
- **Economic data**. GDP data for Uzbekistan were obtained from the World Bank's global database,[15] whereas value of statistical life (VSL) estimates were obtained from the Organization for Economic Co-operation and Development (OECD).[16]
- **Population-weighted $PM_{2.5}$ annual average concentration.** The conducted modeling allowed for the estimation of the population-weighted $PM_{2.5}$ annual average concentration for Tashkent that equaled 38.8 μg/m³.
- **Relative health risks** of diseases associated with $PM_{2.5}$ ambient pollution were obtained from the global burden of disease (GBD) database.[17]

[12] The WHO does not provide a timeline for reaching the IT as it is up to national legislation to suggest such a timeline. EU legislation, for instance, states that noncompliance with air quality standards should be kept as short as possible. The main objective of air quality plans in the EU is then to assess what a reasonable period for reaching compliance is.

[13] The modeling showed that the WHO's IT2 guideline value was not met in any of the grids in Tashkent's airshed.

[14] https://stat.uz/en/official-statistics/demography.

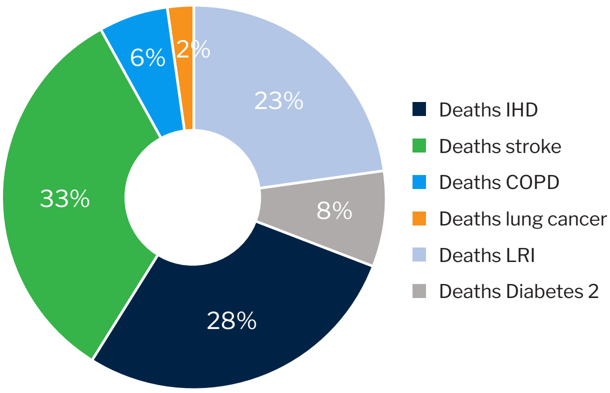
[15] https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=UZ.

[16] https://read.oecd-ilibrary.org/environment/mortality-risk-valuation-in-environment-health-and-transport-policies/recommended-value-of-a-statistical-life-numbers-for-policy-analysis_9789264130807-9-en#page2.

[17] https://ghdx.healthdata.org/record/ihme-data/gbd-2019-relative-risks.

The attributable mortality for Tashkent caused by an annual average population-weighted $PM_{2.5}$ concentration of 38.8 µg/m³ is 3,042 premature deaths per year. The highest number of premature deaths attributed to $PM_{2.5}$ ambient air pollution is caused by stroke, followed by ischemic heart disease (IHD) and lower respiratory infections (LRIs).

Figure 7: Annual mortality in Tashkent attributable to $PM_{2.5}$ pollution, by cause



Source: Original elaboration for this publication based on Global Burden of Disease (2019), Uzstat, and World Bank data.

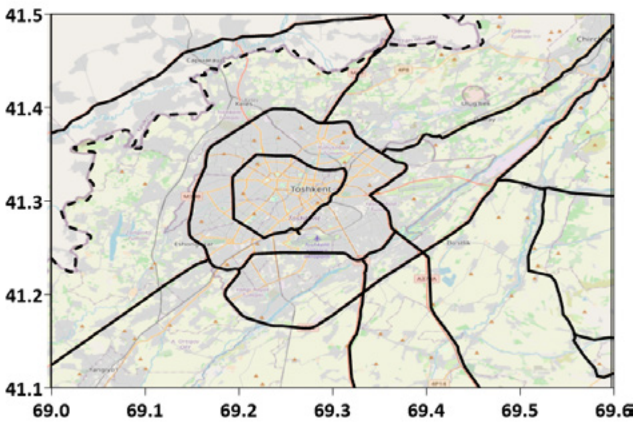
In addition to the impacts of $PM_{2.5}$ ambient air pollution on annual mortality in Tashkent, this study estimated the economic impact of both mortality and morbidity attributable to $PM_{2.5}$ pollution in the city. Using the OECD recommended VSL figures and assuming that the morbidity costs are 10 percent of mortality costs, the average annual economic costs of $PM_{2.5}$ ambient air pollution in Tashkent are estimated at US$ 488.4 million, which is equivalent to 0.7 percent of Uzbekistan's GDP.

This high-level health impact assessment of air pollution in Tashkent was conducted using a mix of local data and data on air pollution's health impact from the GBD. Availability of detailed epidemiological local data will greatly improve the health impact assessment, but in the absence of such, best efforts were made to use verified data from international studies and databases. Therefore, the results presented here should be interpreted considering that Tashkent/Uzbekistan-specific health data and information were not available for this health impact assessment.

1.3. Methodology for the $PM_{2.5}$ Assessment

This study compiled all available data and information for the main $PM_{2.5}$ emissions sources in the Tashkent airshed and mapped those sources at a spatial resolution of approximately 1 by 1 km and a temporal resolution of 1 hour. The mapped area, that is, the defined airshed in Figure 8, covered a total of about 2,400 km² and included the whole urban area of Tashkent and the surrounding areas where emissions sources that might affect air quality in the city are located. High-resolution layers with key data (for example, on population, land use, and built-up area) allowed the estimation of emissions for each grid (approximately 1 km²) in the airshed, thus enabling the creation of the first spatially and temporally dynamic emissions map for the Tashkent airshed.

Figure 8: **Tashkent's airshed defined for this study**



Source: World Bank and OpenStreetMap.
Note: Solid lines represent primary roads, dashed line—international border.

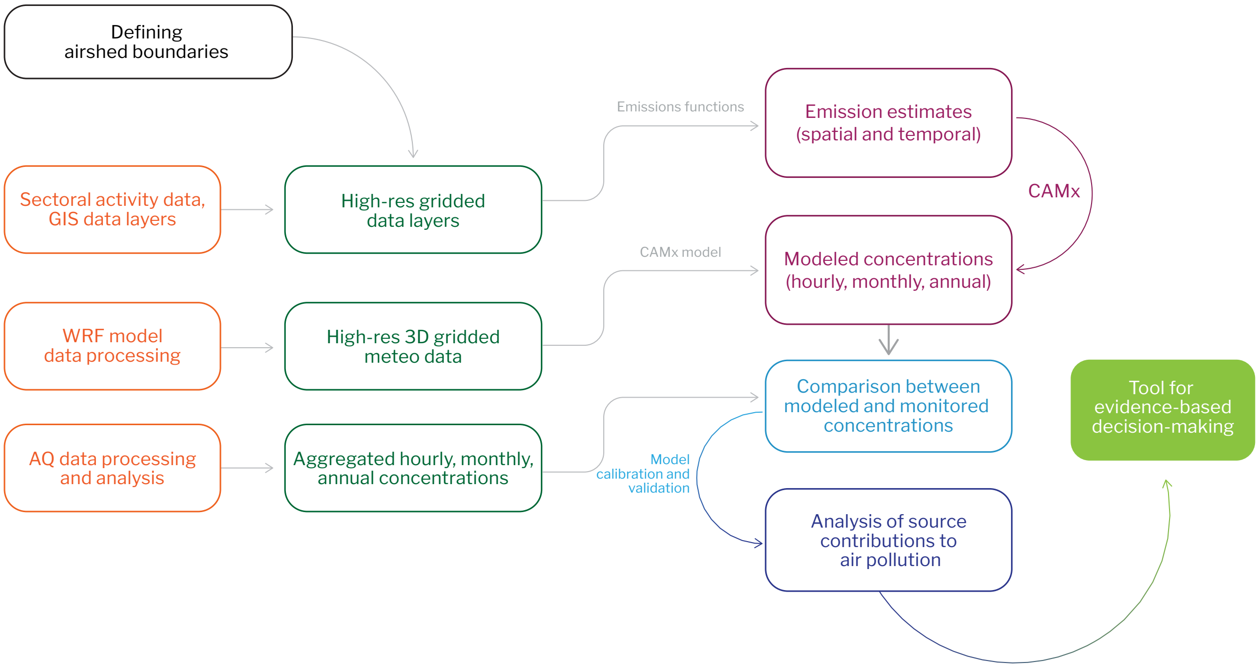
The Comprehensive Air Quality Model with extensions **(CAMx) modeling system was used to simulate the dispersion of $PM_{2.5}$ pollution over the airshed and to identify the contributions of key emissions sources to $PM_{2.5}$ concentrations.**[18] This dynamic emissions map, coupled with 3D meteorological gridded data from the WRF model, was used in chemical transport modeling.

Emissions were calculated for the following key emission sources: heating, road transport, industry, open waste burning, brick kilns, quarries, and the airport. In addition, the study analyzed the contributions to $PM_{2.5}$ concentrations in Tashkent of urban sources of dust (construction activities and road dust resuspension) and sources from areas outside the Tashkent airshed (referred to as windblown dust). A detailed description of the emission estimations by sources is provided in Annex 1.

To achieve high-resolution data and allow for dynamic spatial and temporal emission estimates and pollution modeling, this study used a combination of locally obtained data, data from global databases, and published literature. Moreover, satellite data and data from globally recognized models were used to strengthen the foundations for the modeling conducted in this study. The complete methodology and data resources used in the emissions' analysis and in the chemical transport modeling are described in Annex 1 and Annex 2 and the key components of the methodology are illustrated in Figure 9.

[18] As mentioned previously, emissions (the substances emitted directly from different sources) do not translate directly into concentrations (the pollution the population is exposed to). Therefore, a source with high emissions might not affect concentrations as much as a source that has lower emissions but more unfavorable dispersion characteristics (for example, low height of emissions' release).

Figure 9: **Schematic illustration of the study's main components**



Source: World Bank.

1.3.1 Data limitations

Despite best efforts to collect data from local and global sources, some important data limitations had to be overcome in this study:

- Lack of local data for the amount and types of fuels/energy sources used for residential and commercial heating
- Lack of local data on the types of residential and commercial heating appliances used for solid fuel (coal and biomass) combustion
- Lack of traffic-related information such as traffic counts and shares of light-duty to heavy-duty vehicles
- Lack of detailed data on fuel use and available abatement technologies at different industries
- Lack of local emission factors, for instance, for residential heating
- Lack of longer time series of $PM_{2.5}$ monitoring by Uzhydromet in Tashkent
- Lack of local data on the health impact of air pollution.

To address those challenges, data from international sources and global databases such as International Energy Agency (IEA) data and, when needed, expert judgment were used. In the case of $PM_{2.5}$ monitoring, data from the US Embassy monitoring station were also utilized in addition to data from Uzhydromet stations. With regard to the health assessment of air pollution in Tashkent, health impacts from the global reference database of the GBD were used, taking into account Tashkent and Uzbekistan-specific parameters such as the age structure of the population and GDP.

1.4. $PM_{2.5}$ Emissions Sources Analysis: Results

The largest $PM_{2.5}$ anthropogenic emission source in Tashkent, albeit mostly concentrated in the winter months, is the heating sector—responsible for nearly one-third of the total annual $PM_{2.5}$ emissions. The second largest $PM_{2.5}$ emissions source is transport, accounting for 25 percent of the total annual $PM_{2.5}$ emissions in Tashkent. Taken together, heavy and light industry is the third largest $PM_{2.5}$ emissions sources in Tashkent, contributing 22 percent to the total $PM_{2.5}$ annual emissions. Urban dust from construction activities and resuspension of dust from roads account for 18 percent of the total annual $PM_{2.5}$ emissions in Tashkent (see Table 1).

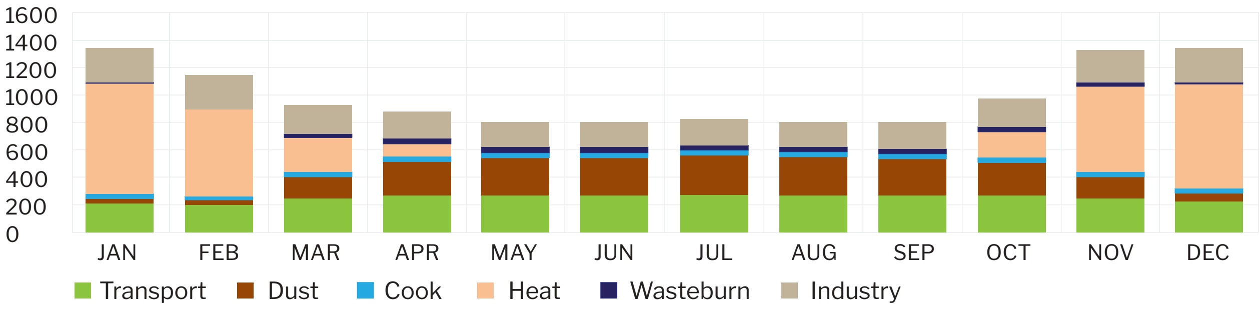
Table 1: **$PM_{2.5}$ emission estimates for Tashkent**

Emissions source	Description	$PM_{2.5}$ emissions, tons/year
Heating	Includes emissions from residential and commercial heating and cooking	3,800
Transport	Includes all road transport and emissions from the airport	3,050
Industries	Includes emissions from the thermal power plant (TPP), other industries, quarries, brick kilns, and diesel generators at commercial buildings	2,700
Urban dust	Includes emissions from construction activities and resuspended dust from roads	2,150
Open waste burning	Includes emissions from open waste burning around the airshed	350
Total		**12,050**

Source: World Bank.
Note: Windblown dust is a source of direct $PM_{2.5}$ concentrations and therefore, it is not included as an emissions source. In addition, $PM_{2.5}$ particles in windblown dust occur due to both natural events and anthropogenic activities. Windblown dust is included in the modeling as $PM_{2.5}$ loads for each airshed's grid estimated from the global Model for Ozone and Related Chemical Tracers (MOZART)/ Whole Atmosphere Community Climate Model (WACCM).

Emissions levels throughout the year are not constant — for instance, heating emissions occur only in winter months. Therefore, it is important to analyze the temporal distribution of emissions sources. Figure 10 shows that heating emissions are dominant in the winter months and can account for about 60 percent of monthly $PM_{2.5}$ emissions in the winter. Transport emissions are fairly constant throughout the year, while urban dust emissions are higher in the summer months than in the winter months because of increased construction activity and higher dust resuspension from roads. Industrial emissions have a relatively stable share in total emissions in the different months of the year.

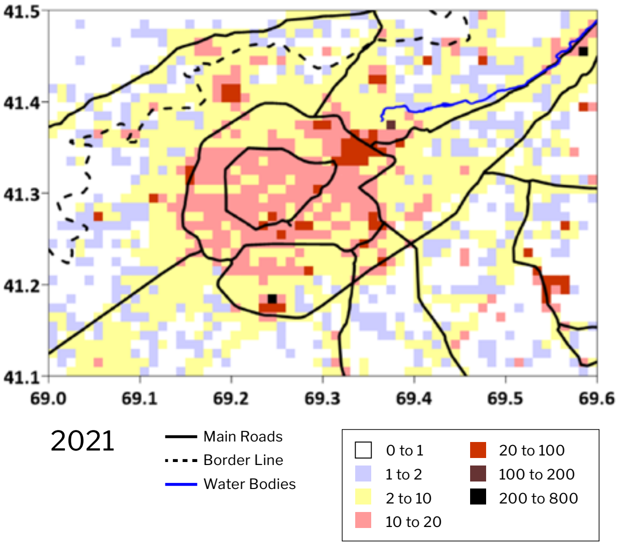
Figure 10: **Monthly variations in $PM_{2.5}$ emissions in Tashkent**



Source: World Bank.

In addition to temporally distributing $PM_{2.5}$ emissions in Tashkent, this study mapped emissions from the different emissions sources at an approximately 1 km² resolution. The baseline year for the emissions mapping was 2021. Figure 11 shows the annual average spatial distribution of $PM_{2.5}$ emissions in Tashkent for 2021.

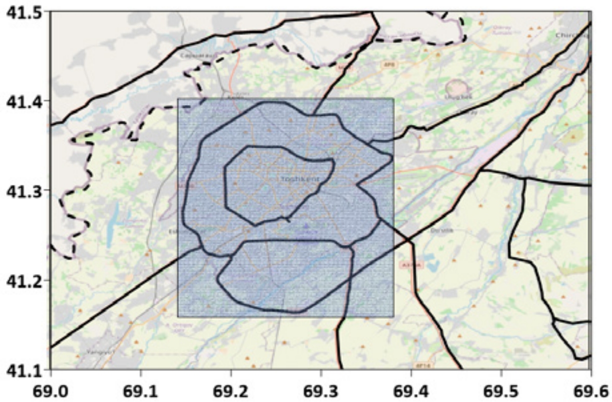
Figure 11: Annual average $PM_{2.5}$ emissions map, Tashkent, 2021 (tons/grid/year)



Source: World Bank.

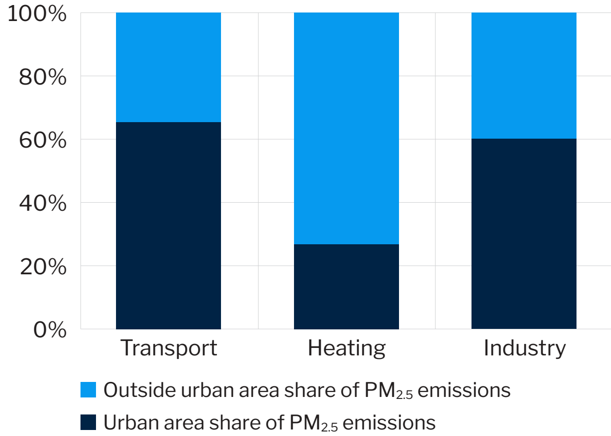
Figure 11 shows that there are scattered emissions hotspots in Tashkent's airshed — namely, in the city's northeast, close to the second ring road, and in the highly industrial Yangikhayot district in the south. Further analysis of $PM_{2.5}$ emissions' spatial distribution in Tashkent's airshed divided the airshed into an urban area (the blue area on Figure 12) and an outside urban area. Figure 13 shows that most emissions from the heating sector occur outside of the Tashkent urban area while most of the transport and industrial $PM_{2.5}$ emissions occur within Tashkent's urban area. The majority of residential emissions occur outside of the Tashkent urban area because there is no district heating network outside of the urban area, which means that households use individual heating sources. In addition, information provided by MoEEPCC suggested that numerous greenhouses located around Tashkent's urban area use coal for heating. Therefore, the use of solid fuels (coal, biomass) for residential and commercial heating is assumed to be higher in the areas outside the urban center, which fits with observations on the ground.

Figure 12: Tashkent urban area (in blue) and outside urban area



Source: Open Street Maps.

Figure 13: Share of $PM_{2.5}$ emissions in the urban area and outside urban area in Tashkent



Source: World Bank.

1.5. $PM_{2.5}$ Modeling: Results and Source Contributions

There is no linear correlation between $PM_{2.5}$ emissions and $PM_{2.5}$ concentrations. The translation of emissions into concentrations is affected by a number of factors including the location of the emissions source, characteristics of the source (height of emissions release, temperature and velocity of gases, and so on), meteorological conditions, and topography. Therefore, to determine how emissions translate into concentrations, modeling needs to be conducted taking all these considerations into account.

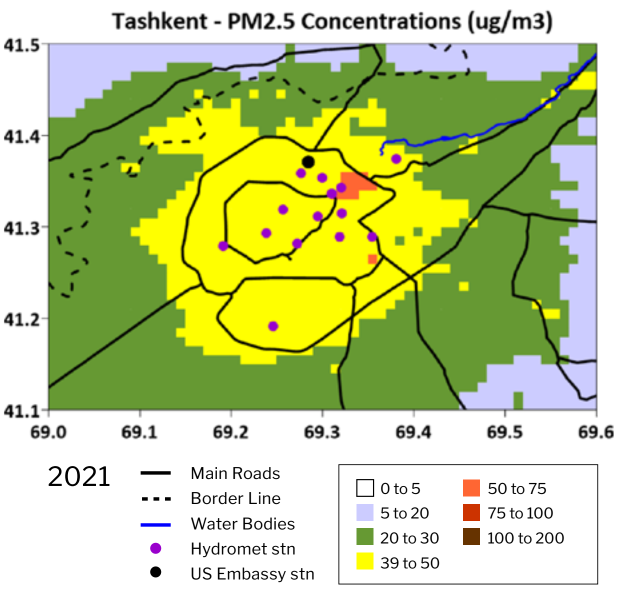
Moreover, modeling can provide useful information about spatial distribution of air pollution and hence about population exposure to pollution. This chapter describes the results from the chemical transport modeling using the CAMx system, coupled with WRF meteorological data, conducted in this study.

1.5.1 $PM_{2.5}$ dispersion

The spatially and temporally dynamic emissions map was coupled with spatially and temporally dynamic meteorological data layer to allow for high-resolution modeling at an hourly scale. The CAMx, which incorporates meteorological inputs from the WRF model, was used in this study. The approach to modeling is described in detail in Annex 1.

Figure 14 illustrates the annual average $PM_{2.5}$ pollution dispersion across Tashkent's airshed for 2021, whereas Figure 15 shows the average monthly $PM_{2.5}$ pollution dispersion in the city. Average $PM_{2.5}$ concentrations were modeled and are available for each grid of the airshed (approximately 1 km2 resolution). The model considers the impact on $PM_{2.5}$ concentrations of both direct $PM_{2.5}$ emissions and secondary formation of $PM_{2.5}$ in the atmosphere through chemical reactions of SO2 and NOx.

Figure 14: Modeled annual average $PM_{2.5}$ dispersion in Tashkent in 2021



Source: World Bank.

The modeled $PM_{2.5}$ pollution dispersion in Tashkent's airshed demonstrates that $PM_{2.5}$ concentrations peak in the winter months, in line with what has been reported by air quality monitoring networks. In addition, $PM_{2.5}$ concentrations in the city, especially during winter, are well above WHO guidelines. Moreover, modeling of pollution dispersion is useful for identifying pollution hotspots within an urban area. The modeling results for Tashkent shown in Figure 15 illustrate that $PM_{2.5}$ concentrations are generally higher in the city's eastern part and especially in the northeast close to the second ring road.

Figure 15: Modeled average $PM_{2.5}$ dispersion in Tashkent in 2021, by month

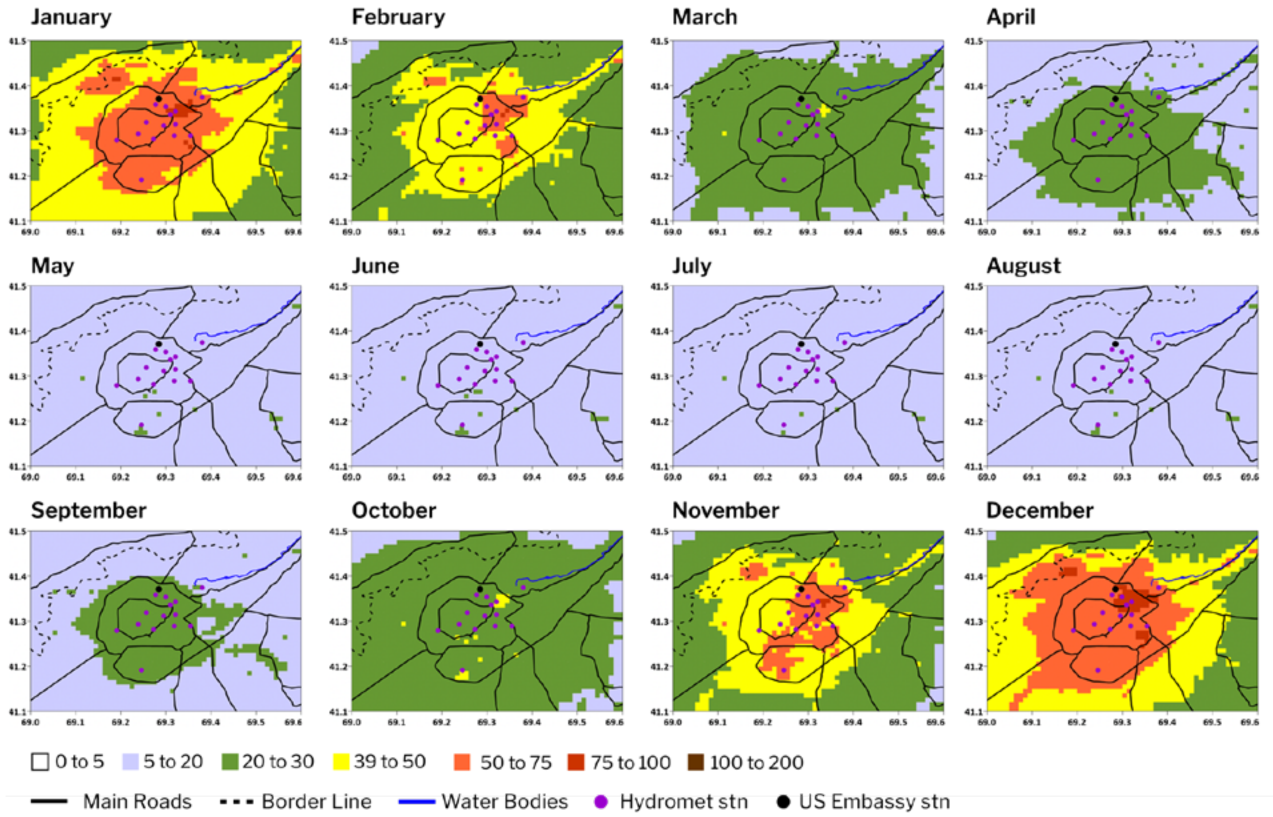
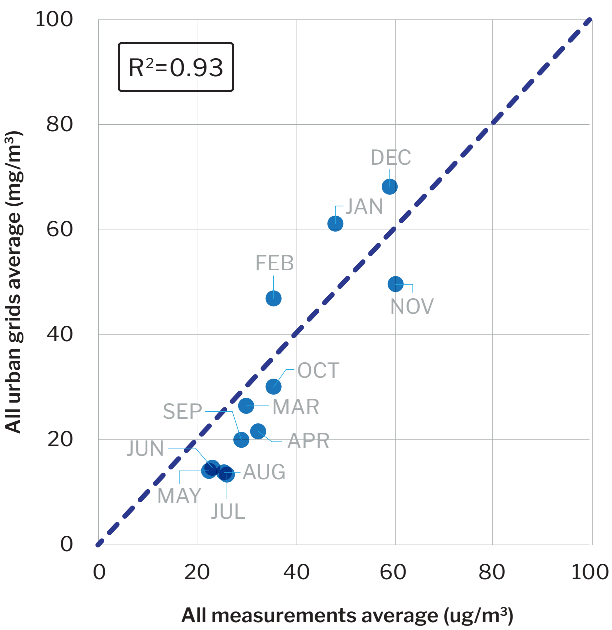


Figure 16: Modeled and monitored $PM_{2.5}$ concentrations in Tashkent



Source: World Bank.
Note: Blue dots are the modeled monthly concentrations, and the dashed line is the trend in the average monitored concentrations.

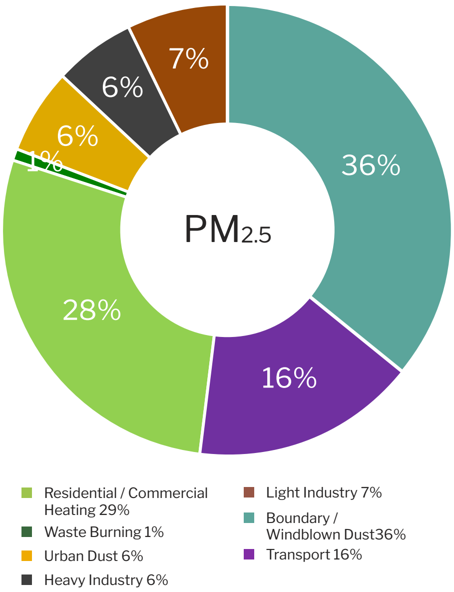
1.5.2 Comparison with air quality monitoring data

A general practice in modeling is to compare modeled concentrations of pollutants with the actual concentrations' measurements from air quality monitoring. The modeling results show a good fit (R^2 = 0.93, that is, 93 percent fit) with the collected monitoring data which suggest that the simulation conducted in this study closely approximates the observed $PM_{2.5}$ levels and dynamics in Tashkent in 2021 (Figure 16).

1.5.3 Source contributions to $PM_{2.5}$ concentrations

The modeling conducted in this study allowed the identification of source contributions to $PM_{2.5}$ concentrations on an annual (Figure 17) and a monthly basis (Figure 18). As discussed in Chapter 1.4, emissions sources have varying temporal intensities throughout the year and therefore, it is expected that sources' contributions to $PM_{2.5}$ concentrations will also vary in the different months and seasons.

Figure 17: Modeled source contributions to average annual $PM_{2.5}$ concentrations in Tashkent (%)

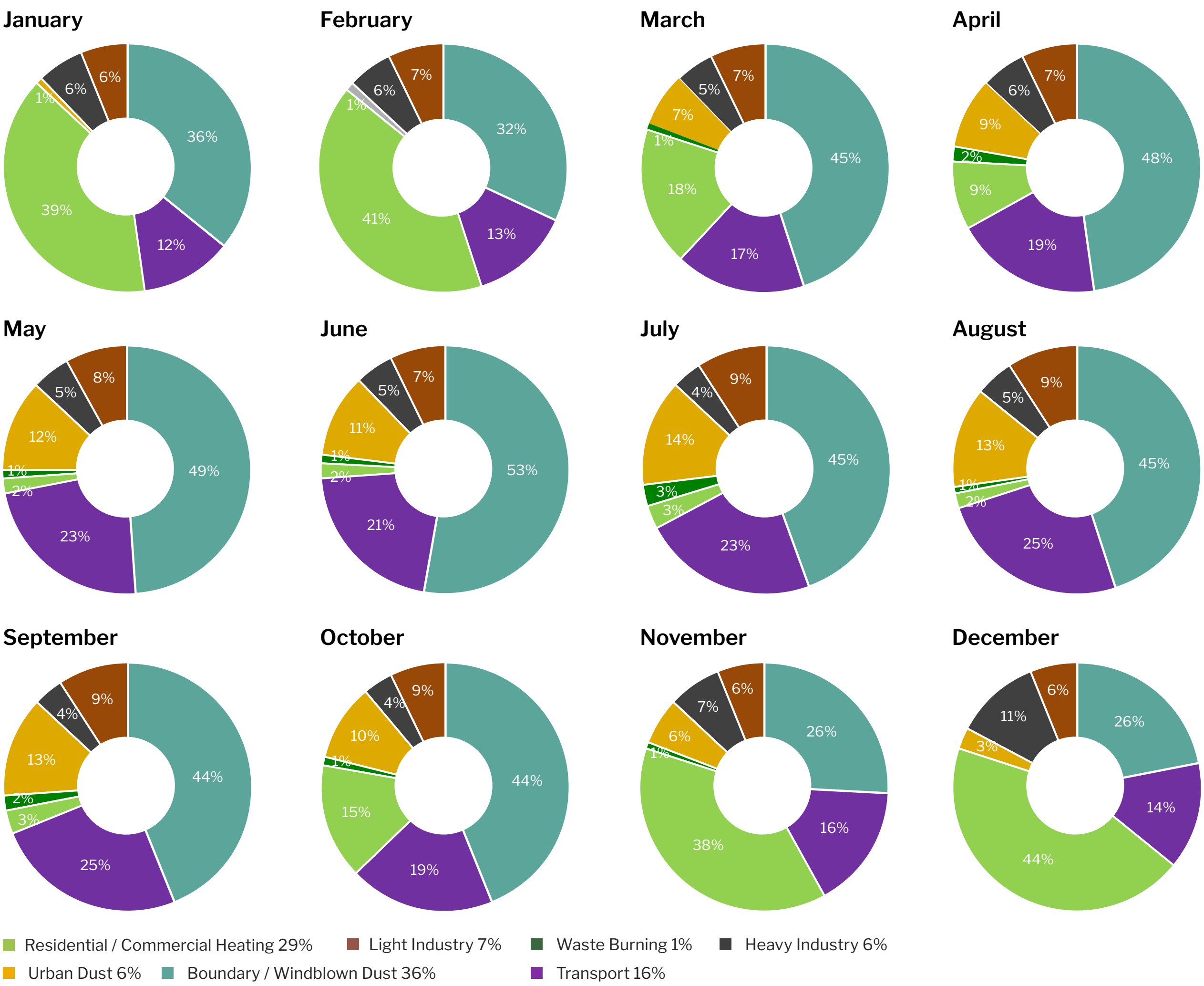


Source: World Bank.

As shown on Figure 17, windblown dust[19] has the highest contribution to annual average $PM_{2.5}$ concentrations. Residential and commercial heating is the anthropogenic source with the highest contribution to average annual $PM_{2.5}$ concentrations and is responsible for 28 percent of average annual $PM_{2.5}$ concentrations. In the winter, the contribution of heating to average monthly $PM_{2.5}$ concentrations surpasses the contribution of windblown dust and can reach nearly 45 percent in some winter months (for example, December). On the other hand, the contribution of windblown dust to average monthly concentrations peaks in the summer months when it could account for over half of the $PM_{2.5}$ pollution in Tashkent (for example, June).

19 Windblown dust (boundary) represents particles carried by wind into Tashkent from the adjoining areas such as agricultural and open fields, for instance.

Figure 18: Modeled source contributions to average monthly PM2.5 concentrations in Tashkent (%)



Source: World Bank.

The contribution of transport to $PM_{2.5}$ concentrations varies from 12 percent in the winter to 25 percent in the late summer and early fall. The contribution of transport to $PM_{2.5}$ concentrations in Tashkent grows in the months when heating is not used, highlighting again that heating is the main contributor to $PM_{2.5}$ concentrations in Tashkent in the winter. Transport is the second most important anthropogenic contributor to $PM_{2.5}$ concentrations in all seasons, and in the summer, transport is the second largest source of $PM_{2.5}$ pollution after windblown dust.

The contribution of industry (heavy and light industries combined) to $PM_{2.5}$ concentrations is relatively stable at 12 to 13 percent throughout the year but peaks to 17 percent in the winter due to larger loads at the thermal power plant (TPP) plant (for example, December). Apart from the winter months when there is higher demand for TPP-produced energy, the impact of the numerous light industries in Tashkent combined is larger than the impact of the heavy industries operating in the city (the TPP plant, a metal factory, and a foundry were included in the heavy industry category).

The contribution of urban dust originating from construction activities and resuspended particles from roads to $PM_{2.5}$ concentrations peaks in the summer and early fall at 13–14 percent due to increased construction activities and road dust resuspension because of dry weather conditions. The contribution of open waste burning to $PM_{2.5}$ concentrations is small and relatively constant throughout the year—estimated at 1 or 2 percent.

1.6. Summary and Suggested Next Steps

The results from this study laid the technical foundations for further air quality analyses for Tashkent and supported the development of the AQM roadmap with regard to sectoral interventions. The study conducted analysis of air quality and meteorology trends, created a spatially and temporally dynamic emissions map, and modeled the contributions to $PM_{2.5}$ concentrations in Tashkent of different sources. In this way, the most important analytical work in preparing an air quality plan was performed by this study.

The next step is to assess the impact on pollutant concentrations of a variety of emission reduction measures and determine the ones that reduce $PM_{2.5}$ concentrations the most. Given the large contribution of the heating sector to peak winter $PM_{2.5}$ concentrations in Tashkent, it is likely that the most impactful measures will be related to adopting cleaner residential and commercial heating options. Nevertheless, this study has shown that the contribution of other sources such as transport and industry, as well as sources from outside Tashkent, are also important. Therefore, it is likely that to comply with international air quality standards, a balanced approach to air quality improvement that includes PaMs across different sectors will be needed.

In addition, it is important to assess the impact of PaMs to reduce $PM_{2.5}$ concentrations on green-house gas (GHG) emissions. Priority sources of $PM_{2.5}$ and GHGs in Tashkent differ and hence, co-benefits and trade-offs between air quality and climate change mitigation policies have to be considered. It has been shown that co-benefits are maximized if there are strong air pollution and climate change policies that are implemented jointly to harness win-win opportunities and efficiently manage trade-offs.[20]

Determining the PaMs with the highest $PM_{2.5}$ concentrations' reduction potential does not necessarily mean that those measures are the most cost-effective ones to be implemented. There might be a variety of measures with lower pollution reduction potential that are more cost-effective and if implemented together could bring substantial reduction in air pollution. Therefore, a cost-effectiveness analysis of emission reduction PaMs is integral to air quality planning.

A cost-effectiveness analysis combines the results from modeling the impact of emission reduction measures with the results of economic and financial analyses on the costs of those measures. This study compiled a baseline emissions inventory which can be used in modeling the impact of emission reduction measures. Each measure needs to be defined in a way that allows the calculation of emission estimates that can be compared to the baseline. Then, modeling, using the new emission estimates from the emission reduction scenarios should be performed to assess the impact of the given measure(s) on $PM_{2.5}$ concentrations. Cost and technical data for the emission reduction measure(s) should also be collected for the financial and economic analyses. For instance, the financial analysis of an emission reduction measure replacing a coal stove with a heat pump needs the following information: the price of coal, the typical efficiency of a coal stove used in Uzbekistan, the price of the coal stove, the operation and maintenance expenses of the coal stove, the price of electricity, typical efficiency of a heat pump on the domestic market, the price of the heat pump, and the operation and maintenance expenses of the heat pump.

20 Peszko, Grzegorz, Markus Amann, Yewande Awe, Gary Kleiman, and Tamer Samah Rabie. 2022. Air Pollution and Climate Change: From Co-Benefits to Coherent Policies. International Development in Focus. Washington, DC: World Bank.

Moreover, the economic analysis of the same measure requires data also on societal impacts from implementing the measure such as change in health outcomes, impacts on GHG emissions, and health and carbon costs. The results of the economic and financial analyses can then be presented as money spent to improve air quality by 1 $\mu g/m^3$ which can inform the prioritization of emission reduction measures according to their cost-effectiveness.

The most cost-effective PaMs might not be the easiest and quickest ones to implement. Therefore, analysis of implementation modalities is also an essential aspect of air quality planning. There is no harm in implementing PaMs that would bring some air quality benefits quickly and relatively easily even if they are not the most cost-effective ones. A comprehensive analysis of implementation modalities also includes sources of financing for the given policy and measure, responsibilities for enforcement, monitoring, and reporting.

The process of air quality planning involves a wide range of assessments — from technical to financial, economic, policy, and regulatory analyses. This study provides a solid basis for the technical aspect of air quality planning which following assessments can build on. Completing the steps outlined above will help define PaMs to be implemented as a priority and will provide the tools for dynamic calibration of PaMs to improve air quality in Tashkent, thus fully reflecting the complex nature of air quality management (AQM).

PART 2:

Roadmap for Air Quality Management Improvement in Uzbekistan

2.1. Introduction

2.1.1 Objectives of the roadmap

The roadmap for AQM improvement in Uzbekistan (AQM roadmap) outlines PaMs for all components of the AQM system. The AQM roadmap is focused on definition of PaMs for AQM improvement as a first step to supporting a more detailed discussion with government stakeholders about operationalizing the agreed priority actions. Apart from the definition of PaMs, further discussions and analyses are needed to provide better granularity for the priority PaMs such as required capacities and resources, implementation costs, and financing and implementation options. The AQM roadmap thus serves as a framework to structure the discussion about PaMs' implementation.

The technical air quality assessment for Tashkent is the analytical foundation to determine the key sectors for which PaMs need to be defined in the AQM roadmap. The core of air quality improvement efforts is reducing emissions from key sources. Therefore, the technical air quality assessment for Tashkent was undertaken to identify the sources contributing the most to $PM_{2.5}$ pollution in Uzbekistan's largest city. The results from the assessment informed the sectoral focus of PaMs in the AQM roadmap.

The aims of the AQM roadmap are

- To outline and elaborate on priority measures in the short and medium term to strengthen overall AQM in Uzbekistan,
- To contribute to reforms and to an updated AQM legal and policy framework that would facilitate improvements in air quality in the country,
- To suggest approaches to streamline stakeholder engagement and inter-ministerial coordination for AQM,
- To identify potential priority areas for investments in air quality improvement, and
- To support the development of a long-term AQM vision.

As the main institution responsible for AQM in Uzbekistan, the suggested actions in the roadmap focus on items for which the execution primarily falls under the jurisdiction of MoEEPCC. Therefore, the latest relevant Presidential decrees regarding MoEEPCC functions and discussions with MoEEPCC on priorities in the ministry's work plan were also considered in drafting this AQM roadmap.[21]

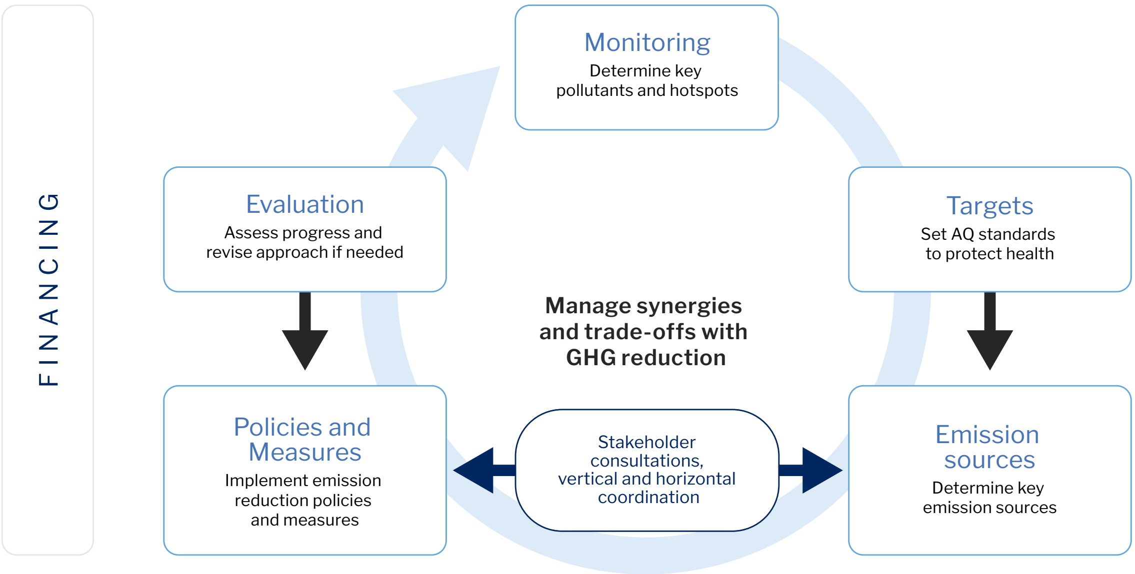
AQM is a cross-sectoral issue and hence, areas for which coordination is needed are also flagged, with MoEEPCC playing a leading coordination role. The ultimate goal of the roadmap is to support the establishment and functioning of a holistic AQM framework that includes all relevant components of an effective AQM system as presented in Section 2.1.2.

2.1.2. Components of an effective AQM system

Effective AQM systems that at the same time can be dynamically calibrated to address new and emerging challenges and / or accommodate improved knowledge and research on air quality typically consist of several inter-linked components (Figure 19). While the implementation of PaMs to reduce air pollutants' emissions to the atmosphere plays a central role in improving air quality, the design of adequate PaMs might not be effective in the absence of appropriate AQ monitoring, progressive targets and standards for air quality, and detailed analysis of emission sources' contributions to pollutant concentrations. While they do not directly reduce emissions, they set the foundation for the appropriate and cost-effective design, planning, prioritization, and implementation of emission reduction PaMs.

21 Presidential decrees No. 81 and No. 171 of May 31, 2023, and Presidential Decree 300 of September 11, 2023.

Figure 19: Components of an effective AQM system



Source: World Bank.

- **Monitoring.** The AQM cycle begins and ends with monitoring that provides reliable data on the extent of air pollution and the progress made to improve air quality. The existence and extent of air pollution—and hence the need for PaMs to be adopted—are detected by AQ monitoring. Moreover, the progress made to improve air quality is also verified by AQ monitoring.
- **Target setting.** Targets are generally the regulatory instruments to encourage the implementation of measures to improve air quality. The main types of targets are AQ standards to protect human health and emission limit values (ELVs) to ensure limits to pollution from enterprises. The main reason why PaMs to reduce air pollution are designed is to achieve the set targets. Therefore, the stringency of the targets will inform the level of ambition of PaMs—AQ standards or ELVs that allow for a relatively high levels of pollution will naturally yield PaMs with more moderate impacts on air quality and consequently on human health.
- **Emission sources' analysis.** The analysis of the contributions of different emission sources to overall air pollutants' concentrations is instrumental in AQM. Such analysis allows for the identification of priority emission sources for which interventions need to be focused. In the absence of emission sources' analysis, the design of PaMs might not focus on the most important emissions sources in terms of reducing air pollutants' concentrations, which might lead to the adoption of cost-inefficient PaMs.
- **Implementing PaMs to reduce emissions.** Once the prioritization of emission sources is conducted, decision-makers can design and implement emission reduction interventions, commonly referred to as PaMs. Implementing PaMs is at the core of efforts to improve air quality. Nevertheless, PaMs' design and implementation might be inefficient if the AQM system's components discussed previously are not in place. Important considerations in the design of PaMs are identifying the opportunities for synergies with GHG emissions reductions and managing potential trade-offs with GHG emissions reductions.
- **Evaluating the progress and effects of PaMs.** Periodic evaluation of the progress in PaMs' implementation as well as the effects of PaMs' implementation is needed to assess the PaMs' effectiveness and, if needed, revise or calibrate the adopted PaMs. AQ monitoring data play a key role in evaluating the progress and effects of PaMs' implementation.

- **Stakeholder consultations and communication.** Stakeholder consultations and communication are an integral part of every component of the AQM process but are especially important when identifying the priority emission sources and agreeing on PaMs to be implemented. Stakeholder consultations and communication are also important tools for raising awareness about the sources of air pollution and for providing public buy-in for PaMs.
- **Financing the functioning of the AQM system.** Financial resources are needed for every component of the AQM system—from installing and maintaining reliable AQ monitoring stations to implementing PaMs. Hence, ensuring adequate financing for the different components of the AQM system is a key prerequisite for the efficient functioning of the whole system.

2.1.3. Structure of the AQM roadmap

The AQM roadmap categorizes the AQM system components into technical, PaMs, and financing and investment. The AQM roadmap thus consists of measures addressing the following topics within the AQM system components:

Technical:

(a) Setting up of national AQ monitoring

(b) Updating AQ standards

(c) Setting up a robust air pollutants' emissions inventory system in close link with the GHG emissions inventory

(d) Establishing integrated AQ data management and analysis that could also support the development of air dispersion modeling and AQ forecasting

PaMs:

(e) Developing AQM policies and planning

(f) Implementing PaMs in key sectors

(g) Engaging with stakeholders, communication, and public awareness

Financing and investment:

(h) Financing of the AQM system and AQ improvement measures

(i) Investments and policy reforms.

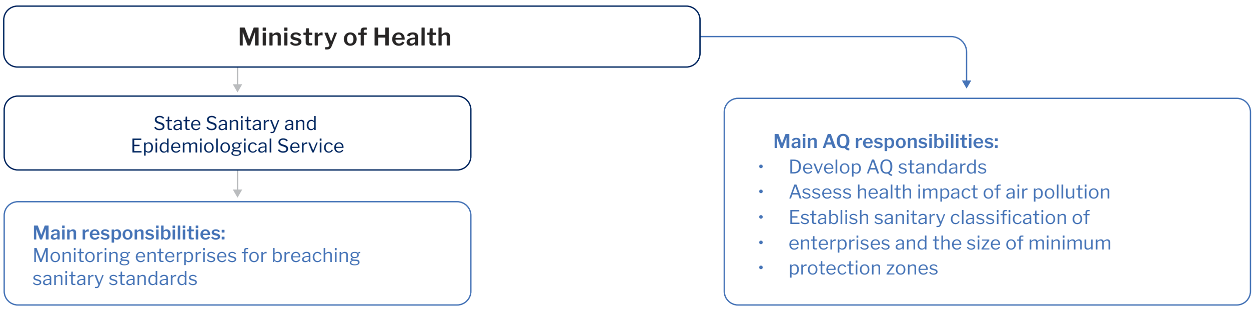
The structure of Part 2 is as follows: Chapter 2.2 provides an overview of institutional arrangements for AQM in Uzbekistan. Chapter 2.3 describes the rationale for the selection of technical AQM system components to be included in the AQM roadmap, Chapter 2.4 then focuses on the suggested PaMs in the AQM roadmap, and Chapter 2.5 outlines considerations for AQM financing and investments. All the suggested measures outlined in Part 2 are then summarized in a table format in Chapter 2.6. The table contains information on the measures' description, rationale, priority level, and suggestions for responsible institutions and supporting institutions to implement the measures.

2.2. Overview of Institutional Arrangements for AQM in Uzbekistan

The main institutions at the national level involved in AQM in Uzbekistan are MoEEPCC and the Ministry of Health (MoH). MoH's main responsibility for AQM is to set the air quality standards[22] for the protection of human health (see Figure 20).

The air quality standards in Uzbekistan take the form of one-time, daily, monthly, and/or annual average maximum allowable concentrations (MACs). Uzbek legislation lists MACs for 485 substances, but MACs are missing for $PM_{2.5}$ which is the pollutant posing the most serious health concern according to the WHO. MACs for other key pollutants are higher than WHO guidelines and, in many cases, higher than international limit values. For instance, PM10 daily MAC in Uzbekistan is 300 μg/m^3 which is over six times higher than the WHO PM10 daily guideline value.

Figure 20: Main AQM responsibilities of MoH



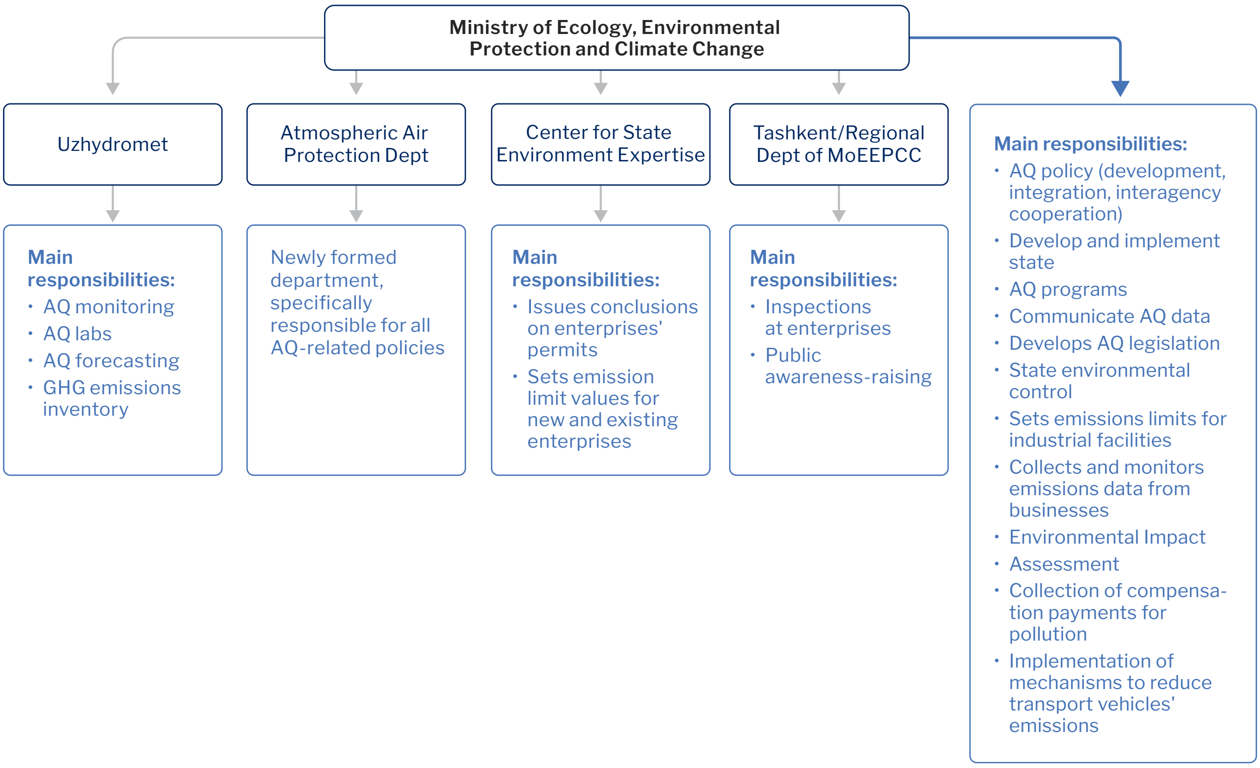
Source: World Bank.

MoEEPCC is responsible for formulating and implementing environmental policies and regulations in Uzbekistan, including those related to AQM. MoEEPCC is also in charge of the national Environmental Impact Assessment (EIA) process, which involves establishing air pollutants' emission limits for industrial facilities. Uzhydromet, under MoEEPCC, is responsible for air quality monitoring and forecasting.

In January 2023, the status of the former State Committee on Ecology and Environmental Protection was upgraded to a ministry, and in May 2023 the functions of the ministry were updated when the Ministry of Natural Resources became MoEEPCC. There is a separate department within MoEEPCC—the Atmospheric Air Protection Department—which reports directly to one of MoEEPCC's deputy ministers. The Center for State Environmental Expertise which is subordinate to MoEEPCC is responsible for issuing enterprises' permit conclusions and setting ELVs for newly commissioned and existing enterprises. In addition, MoEEPCC has regional branches that are mainly responsible for inspections at enterprises regarding their emission limits as well as awareness-raising activities, including on air quality. Tashkent city has its own MoEEPCC department—the Tashkent City Department of MoEEPCC (see Figure 21).

[22] SanPin No. 0053-23 from August 7, 2023, hygienic standards for the content of harmful and toxic substances, producer microorganisms, bacterial preparations, and air ions in the atmospheric air of residential areas. https://lex.uz/docs/6676993

Figure 21: **Main AQM responsibilities of the MoEEPCC**



Source: World Bank.

The main legal document on air quality in Uzbekistan is the Law on Atmospheric Air Protection.[23] The Law on Atmospheric Air Protection outlines the AQM system in the country and regulates the overall protection of atmospheric air, emission limits, and implementation of pollution control measures. The laws on Environmental Protection[24] and on Ecological Control[25] set the general principles of environmental protection, including with regard to air quality. Uzbekistan has ratified the United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement but has not yet become a party to the United Nations Economic Commission for Europe (UNECE) Convention on Long-Range Transboundary Air Pollution (CLRTAP). However, the feasibility study on becoming a party to CLRTAP was included in the Environmental Protection Concept by 2030, approved by the President in October 2019. Uzbekistan is thus not submitting air pollutant emission inventories to CLRTAP. Moreover, the last GHG emissions reported to UNFCCC are for 2012.

MoEEPCC's responsibilities with regard to AQM are largely related to controlling emissions from enterprises through specific emission limits and through the EIA procedures. MoEEPCC also collects compensation payments for emissions from industries and fines if enterprises' emission limits are exceeded. Nevertheless, there is no legal responsibility for MoEEPCC, its regional branches, or local or regional authorities to develop air quality plans if pollutant concentrations breach the national air quality standards. In many countries, air quality plans are the main AQM policy tools and include specific measures that authorities implement to reduce air pollution.

Recent changes introduced in Presidential Decree 171 from May 31, 2023,[26] defined additional responsibilities for AQM for MoEEPCC, especially in the area of reducing transport vehicles' emissions. The Presidential

[23] Law on Atmospheric Air Protection (No. 353-I from December 27, 1992). https://lex.uz/acts/58400.
[24] Law on Environmental Protection (No. 754-XII from December 9, 1992). https://lex.uz/ru/docs/7065.
[25] Law on Ecological Control (No. ZRU-363 from December 27, 2013). https://lex.uz/acts/2304949.
[26] Presidential Decree 171 "On measures for the effective organization of activities of the Ministry of Ecology, Environmental Protection and Climate Change". https://lex.uz/ru/docs/6479136.

Decree stipulates that by December 2023, MoEEPCC, along with the Ministry of Internal Affairs and the Ministry of Transport, should develop economic mechanisms to reduce vehicle emissions. The proposed measures in those mechanisms include introducing mandatory ecological certification for vehicles using gas, gasoline, and diesel engines for state and corporate entities as well as voluntary certification for legal and individual entities. Compensation pollution fees will be reduced for vehicles with ecological certification, compared to the vehicles that do not meet the specified standards. Additionally, modern laboratory infrastructure is planned to be established for vehicles' emission measurement, and ecological monitoring of transportation vehicles is planned to be enhanced. The final normative rules and economic mechanisms to reduce vehicular emissions will be submitted for approval to the Cabinet of Ministers.

In addition to developing mechanisms to reduce vehicular emissions, Presidential Decree 171 stipulated that MoEEPCC should install display boards in Tashkent that provide continuous information about air pollution. Thus, MoEEPCC's role in air quality data management is strengthened as MoEEPCC is obliged to not just perform air quality monitoring through Uzhydromet but also disseminate the data to the general population.

Due to the complex nature of air pollution, responsibilities for improving air quality span across institutions. For instance, the Ministry of Construction and Communal Services plays an important role in regulating the residential sector in Uzbekistan which is the largest contributor to $PM_{2.5}$ pollution in Tashkent in the winter as shown in this study. On the other hand, the Ministry of Internal Affairs controls atmospheric air pollution during the exploitation of motor vehicles and is responsible for the periodic vehicle inspections in Uzbekistan. At the local level, institutions involved in AQM include the regional branches of MoEEPCC and Uzhydromet. The regional MoEEPCC and Uzhydromet branches are mainly responsible for inspecting enterprises and air quality monitoring, respectively. Municipalities also play a role in AQM as they are responsible for urban planning, traffic management, communal and heating services, and so on.

2.3. Technical Components in the Suggested AQM Roadmap

Although the technical components of the AQM system do not directly reduce emissions and consequently pollutants' concentrations, they establish the foundation for the implementation of polices and measures (PaMs) that directly improve air quality. The technical components of the AQM system provide the necessary data and information to design PaMs, such as pollution levels, pollution hotspots, key emission sources, and the capability for conducting AQ forecasts. On the other hand, AQM system's technical components discussed in this chapter provide the basis for establishing the regulatory framework for AQM such as AQ standards and ELVs. The implementation of PaMs is still possible without having the technical components of the AQM system in place, but it is likely that PaMs' Implementation will be ineffective and inefficient, including cost-inefficient.

2.3.1 AQ monitoring

As illustrated in Figure 19, AQ monitoring provides the foundation of the overall AQM system. AQ monitoring allows for the identification and localization of air pollution. Data from AQ monitoring help identify the pollution hotspots and the trends in air quality over time as well as assist in tracking progress of PaMs implementation.

In general, there are four main types of AQ monitoring: manual, automatic (including mobile automatic), and through sensors and satellites. Each type of AQ monitoring has its own benefits—scope, cost, accuracy, and so on. However, modern AQ monitoring networks are built around automatic AQ monitoring stations and could often incorporate lower cost AQ sensors, if deemed necessary.

In addition, the development of national AQ monitoring networks is based on agreed vision and procedures for the deployment of AQ monitoring stations. Developed AQ monitoring networks (for example, in the European Union [EU] and United States) are based on methodologies that include description of the pollutants to be monitored, procedures for the number of AQ monitoring stations needed, the type of AQ monitoring stations, criteria for the location of AQ monitoring stations, and so on.

The number of AQ monitoring stations is usually based on population density and there are requirements for a certain number of stations per a given number of inhabitants which are often linked to concentration thresholds (a range in pollutant concentrations for which it is deemed necessary to perform monitoring). AQ monitoring stations are generally classified into industrial, traffic oriented, urban background, and rural background. A national AQ monitoring network should include each type of station. In addition, pollution hotspots can include a mix of the different types of AQ monitoring stations, depending on the main sources of pollution. Locating an AQ monitoring station also requires considerations regarding macroscale siting (for example, in which city/area a station should be located and what type of station is needed) as well as microscale siting (for example, appropriate air flow around the sampling inlets, access to electricity, and distance from pollution sources). All these requirements should be described in an official document—an adopted methodology and/or other legal document.

Apart from AQ monitoring stations, an AQ monitoring network requires accredited laboratories. These laboratories could perform periodic calibration and maintenance of the stations and undertake additional analyses of pollutants (for example, heavy metals, PAH, and chemical component of PM samples).

Automatic AQ monitoring stations are expensive, which often limits the number that a country can deploy in a given city/area. This is why lower cost AQ sensors monitoring some key pollutants such as $PM_{2.5}$ and NO_2 are increasingly being integrated into AQ monitoring networks. The main advantage of the AQ sensors is that due to their lower costs many of them can be deployed in a given city/area, thus providing important spatial information for air pollution in different locations. The main disadvantage of the AQ sensors is that they are not as accurate as the automatic AQ monitoring stations in measuring concentrations. Nevertheless, the accuracy and the possibilities for calibration of AQ sensors have improved, which makes AQ sensors a possible solution for expanding the availability and accessibility of air quality data.

Key recommendations

- Develop air quality monitoring network modernization plan.
- Update legislation on the air quality monitoring network in line with the modernization plan.
- Install air quality monitoring stations in line with modernization plan.
- Establish/update laboratories to support the functioning of the air quality monitoring network.

2.3.2 AQ standards

AQ standards are fundamental targets in the overall AQM system cycle presented in Figure 19. The main objective of AQ standards is to protect human and ecosystems' health. The scientific research on the health impacts of air pollution has advanced significantly and it is important that national AQ standards keep up with the accumulated knowledge on the topic.

There are numerous substances that pollute the air, but to have an efficient AQM system in terms of both monitoring pollutants and developing air protection policies, it is prudent to focus national AQ standards on the most important air pollutants from a health perspective and deal with other air pollutants on a case-by-case basis. The WHO considers that six key air pollutants cause the largest health damage—$PM_{2.5}$, PM_{10}, ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and carbon monoxide (CO). Based on the latest scientific research from across the world, the WHO updated its air quality guidelines (AQG)[27] in 2021 as presented in Table 2.

Table 2: WHO updated AQG 2021

Pollutant	Averaging period	AQG	IT	Pollutant	Averaging period	AQG	IT
$PM_{2.5}$	24 hours	15 μg/m³ 3–4 exceedance days per year	IT1: 75 μg/m³ IT2: 50 μg/m³ IT3: 37.5 μg/m³ IT4: 25 μg/m³	**NO_2**	24 hours	25 μg/m³ 3–4 exceedance days per year	IT1: 120 μg/m³ IT2: 50 μg/m³
	Calendar year	5 μg/m³	IT1: 35 μg/m³ IT2: 25 μg/m³ IT3: 15 μg/m³ IT4: 10 μg/m³		Calendar year	10 μg/m³	IT1: 40 μg/m³ IT2: 30 μg/m³ IT3: 20 μg/m³
PM_{10}	24 hours	45 μg/m³ 3–4 exceedance days per year	IT1: 150 μg/m³ IT2: 100 μg/m³ IT3: 75 μg/m³ IT4: 50 μg/m³	**O_3**	Maximum daily 8-hour mean	100 μg/m³ 3–4 exceedance days per year	IT1: 160 μg/m³ IT2: 120 μg/m³
	Calendar year	15 μg/m³	IT1: 70 μg/m³ IT2: 50 μg/m³ IT3: 30 μg/m³ IT4: 20 μg/m³		Peak season*	60 μg/m³	IT1: 100 μg/m³ IT2: 70 μg/m³
CO	24 hours	4 mg/m³ 3–4 exceedance days per year		**SO_2**	24 hours	40 μg/m³ 3–4 exceedance days per year	IT1: 125 μg/m³ IT2: 50 μg/m³

Source: WHO.
Note: * Average of daily maximum 8-hour mean concentration in the six consecutive months with the highest six-month running average O_3 concentration.

[27] https://www.who.int/news-room/feature-stories/detail/what-are-the-who-air-quality-guidelines

In addition to the pollutants in Table 2, the European Environmental Agency (EEA) considers six more air pollutants to be priority pollutants and suggests reference levels (RLs)[28] as shown in Table 3. The pollutants are benzo[a]pyrene (BaP), benzene (C_6H_6), lead (Pb), Arsenic (As), Cadmium (Cd), Nickel (Ni).

Table 3: EEA estimated RLs for other key pollutants

Pollutant	Averaging period	RL (ng/m³)	Pollutant	Averaging period	RL (ng/m³)
BaP	Calendar year	0.12	**As**	Calendar year	6.6
C_6H_6	Calendar year	1.7	**Cd***	Calendar year	5
Pb*	Calendar year	0.5	**Ni**	Calendar year	25

Source: EEA.
Note: *WHO AQG are set at the same level.

National AQ standards generally strive to achieve a healthy environment by limiting air pollution. However, in many countries, AQ standards do not match WHO guidelines but rather adopt some of the WHO's ITs (see Table 2) due to local circumstances (for example, significant transboundary pollution). Nevertheless, international best practice shows that national AQ standards should focus on key air pollutants and be reviewed periodically to account for any new scientific knowledge that has become available or any significant changes in emission sources. The ultimate goal of national AQ standards is to match WHO guidelines of air pollution considered to not cause significant damage to human health. It is recognized that the contribution of windblown dust in Uzbekistan is considerable—as shown in Figure 17, windblown dust contributes to 36 percent of annual average $PM_{2.5}$ concentrations in Tashkent which by itself is larger than WHO's $PM_{2.5}$ guideline. Therefore, authorities in Uzbekistan could consider a staged approach to updating the national AQ standards by first aligning the AQ standards with the WHO's ITs because of the large contribution of windblown dust.

Key recommendations

- Update national AQ standards in line with international best practices.
- Include standards for $PM_{2.5}$.

2.3.3 Emissions inventory

A robust and reliable air pollutants' emissions inventory provides the backbone of any AQM system. The emissions inventory has multiple uses, including the following:

- **Determining the key emission sources for different air pollutants**. Source apportionment studies based on emission inventories can determine the contribution of different sources to air pollutants' emissions and allow for the identification of priority emission sources.
- **National and local air quality policies planning.** Knowledge of the key emission sources can then inform targeted policies to tackle emissions from those sources so that air quality is improved in an efficient and cost-effective way.
- **Conducting health impact studies.** Emission estimates are at the core of conducting health impact studies. In addition to local health data, any health impact assessment requires a robust and reliable local emissions inventory.
- **Conducting AQ dispersion modeling and forecasting.** The results from the emissions inventory are a key input into AQ dispersion modeling and forecasting. The more detailed

[28] World Health Organization (WHO) air quality guidelines (AQGs) and estimated reference levels (RLs) — European Environment Agency (europa.eu).

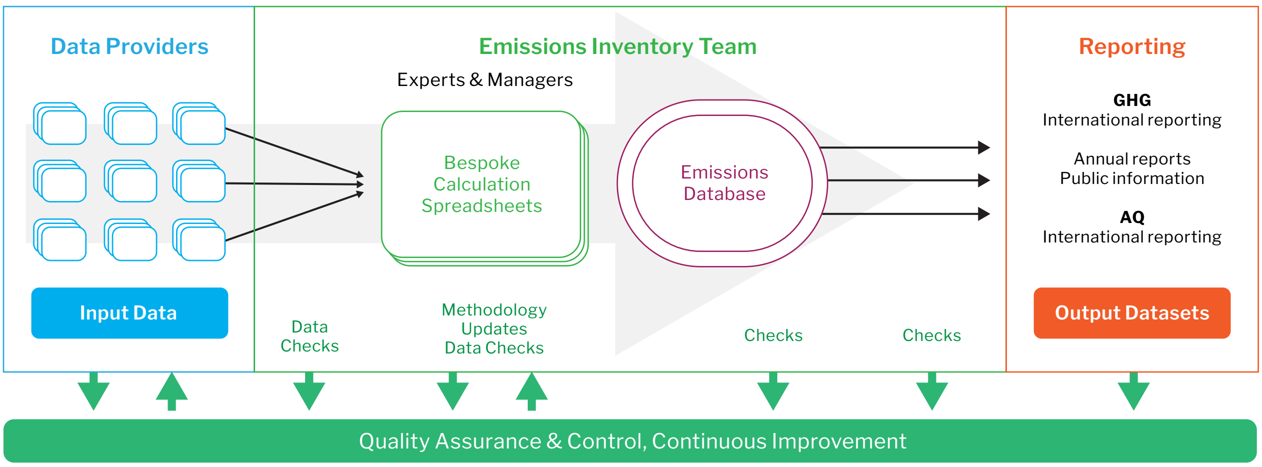
and accurate the emissions inventory, the closer to the actual air quality situation the AQ modeling results would be. An emissions inventory with good resolution and sufficient detail can be used to create local emission maps, which can then feed into AQ modeling at different scales—city, regional, national, and so on. In addition, the emission inventories can be utilized to estimate emissions projections based on different scenarios—for example, 'business as usual' and impact from implementing certain PaMs.

- **International reporting.** An emissions inventory is a key component of international reporting. Similar to the requirements of UNFCCC, it is the obligation of the parties to CLRTAP to annually report national emissions of various pollutants using standard methodologies and reporting formats.
- **Public information, communication, and awareness raising.** The results from the emissions inventory can be used as a public communication and awareness-raising tool. The emissions inventory can be used to disseminate information about the key sources of air pollution in a given area, the intensity of emissions, and the results from projection and forecasting analyses.

International best practice stipulates that for the emissions inventory to be considered robust and reliable, it has to be consistent, comparable, transparent, complete, and accurate. Therefore, the development and update of the AQ emissions inventory system require solid design, planning, and technical capacity (see Figure 22).

The emissions inventory system needs to bring together data from different institutions, often in different formats. The emissions inventory system also requires technical expertise for analyzing the input data, performing emissions calculations, providing quality control and assurance, and describing assumptions used. Nevertheless, the emissions inventory system does not need to be a complex one. Some of the best practice emissions inventory systems globally are based on Excel spreadsheets. It is important that the emissions inventory system is simple so that the people working with it can easily use, maintain, update, and develop it. In addition, there are international best practices and guidelines that can be used to structure the emissions inventory process in a consistent and reliable manner. Moreover, as a large share of the input data and calculation methodologies for the AQ emissions inventory overlaps with the GHG emissions inventory, it is resource effective to maximize synergies in the compilation of the two inventories.

Figure 22: Data flows in a standard emissions inventory system



Source: Aether.

Key recommendations

- Update and strengthen the emission inventory system to meet international best practice.

2.3.4 Data management and analysis

An expanded AQ monitoring network and a strengthened emissions inventory system will increase the amount of data being processed which in turn will require optimized data management. Data management relates to the collection, storage, processing, analysis, and dissemination of data. A properly designed data management system could also allow for real-time data sharing (for example, on monitoring of industrial emissions) and more complex analyses such as conducting AQ dispersion modeling and AQ forecasting. The data management system could be part of a unified environmental database or could be a dedicated AQ data management system. Moreover, a well-designed data management system can support the operation of the Situation Center suggested to be established under MoEEPCC by providing access to all relevant data and thus aiding the Situation Center's work in overall environmental monitoring and analysis but also in disseminating information to the public.

In addition to compiling an emissions inventory, another key analytical task in AQM is performing AQ modeling. AQ modeling requires systematic input of different data (for example, emissions, meteorological, topography, and GIS-based data) and therefore, a well-functioning data management system providing easy access to the required data to modelers is fundamental for carrying out AQ modeling. AQ modeling is mainly used to conduct:

- **Source apportionment studies** to determine the contribution of different emission sources to air pollution (to the concentrations of air pollutants). Hence, AQ modeling can identify the priority sources to be tackled so that concentrations of air pollutants are be reduced.
- **AQ forecasting.** AQ forecasting requires data on future meteorological conditions and ideally data on future emission levels of different sources. Access to such data can allow AQ forecasting which in turn is a powerful public communication and decision-making tool. For instance, AQ forecasting can be used to 'switch on' the implementation of AQM measures (for example, traffic regulation measures, restrictions on industrial activities, restriction on certain fuels used for residential heating) if it is expected that high pollution episodes can occur in the next days. In addition, disseminating the results of AQ forecasting can inform people of ways to avoid high exposure to air pollution.
- **Scenario modeling.** One of the most powerful uses of AQ modeling is to model scenarios. The scenarios could be of different nature, but they all support policy making. For instance, AQ modeling can be used to model the expected impact on air pollution from infrastructure projects (for example, a new ring road) or implementing a low-emission zone (LEZ). AQ modeling can also be used to project air quality under different scenarios and ambition levels (for example, 'business as usual', ambitious scenario of measures' implementation, and moderately ambitious scenarios of measures' implementation), thus assisting decision-makers in choosing the most optimal scenario under current constraints.

Apart from detailed and reliable data, AQ modeling requires obtaining AQ modeling software, having the technical infrastructure to use the software, and having trained staff who can work with the selected AQ model(s). Developing AQ modeling capacities might take time and therefore, careful examination of the scope of AQ modeling, the resources, and capacities needed is fundamental to provide a solid base to develop AQ modeling in the country.

Key recommendations

- Establish a comprehensive and easy-to-use data management system.
- Establish needs and capacities to perform A modeling, including forecasting.

2.4. Policies and Measures in the Suggested AQM Roadmap

The implementation of Policies and Measures (PaMs) to reduce emissions from key sectors and/or mitigate the impact of pollution sources such as windblown dust is the core of the AQM system. The implementation of PaMs brings air quality benefits. However, as previously mentioned, PaMs' implementation that is not based on solid technical background is likely to not achieve the desired outcomes cost effectively. This chapter considers AQM policies and planning in general and provides suggestions for PaMs for the key sectors identified in the technical assessment for Tashkent, presented in Part I.

2.4.1 AQM policies and planning

The main use of AQ data from AQ monitoring, emission estimates, and AQ modeling is to inform policy making and facilitate the implementation and evaluation of measures. Therefore, strengthening AQM policies and capacities at the national and local levels for planning AQ improvement measures' implementation is the ultimate result of improved data collection and analysis.

The vision for the overall AQM framework development could be articulated in a national AQM strategy that might outline the direction of work in the area of AQM. The AQM strategy should be consulted with a wide range of stakeholders, ranging from institutions and academia to businesses and civil society. Once an AQM strategy is agreed upon and adopted, a review of the current legal framework could be undertaken to update it, where needed, to be in line with the adopted AQM strategy.

As with any other environmental aspect, AQ is regulated through laws and regulations. Hence, a core activity in strengthening the overall AQM is the further development of the AQM legal framework. The AQM legal framework includes not only the Law on Atmospheric Air Pollution but any other legal act that relates to some aspects of AQM such as AQ standards, institutional mandates for AQM, EIAs, sectoral legislation of key emission sources, and fiscal legislation on pollution fees and taxes. All these regulations have to be reviewed and updated in line with the national vision for development of the AQM framework, articulated in the AQM strategy.

Revising pollution fees and charges to provide clear incentives for enterprises to reduce pollution and improve performance by setting the level of pollution fees and taxes over the marginal abatement costs could be a particularly impactful update to the legal framework to incentivize enterprises to invest in cleaner production. To start with, Uzbekistan needs to reform the current system of pollution fees and charges—instead of focusing on a long list of air pollutants, the reformed system could focus on the key pollutants in terms of impact of health. Thus, the system will be simplified which will facilitate monitoring and enforcement. The simplified and better enforceable system of pollution fees and charges, coupled with updated level of fees and charges, could encourage enterprises to reduce emissions of key pollutants. In addition, developing a section of green taxonomy for AQ improvement projects could attract funding from additional sources for such projects.

Air pollution is a local issue — the people living in areas with high air pollution are the ones suffering the most from it — however, national-level institutions and regulations are an integral part of the overall AQM. For instance, AQ monitoring networks are generally managed at the national level, some key legislation is passed at the national level, and the overall responsibility for AQM rests typically with ministries of environment. In addition, implementing measures to improve AQM is highly dependent on the local political and economic interests. Strong leadership and vision supported by efficient institutional coordination are required to facilitate the measures' implementation. Therefore, there is a need for vertical coordination on AQM between national and local institutions.

Just like national AQM is usually directed through an AQM strategy, local AQM plans are typically the main strategic tools of local authorities. The local AQM plan usually covers an AQM zone/agglomeration. Hence, establishing AQM zones/agglomeration could be considered as a possible update to the legal framework. Most countries with developed AQM systems require local authorities where air pollution above the national standards is observed to draft local AQM plans. AQM plans describe the scale of the problem; identify the key sources that contribute to high air pollution; develop PaMs to tackle pollution from the key sources; and provide an action plan with clear responsibilities, timelines, and sources of financing for the PaMs. The AQM plan is a dynamic document which is updated periodically to address any changes in the local context, evaluate the implementation of PaMs, and adopt new PaMs if necessary.

In addition to local AQM plans, an important instrument for reducing air pollution for local authorities is the implementation of emergency air quality measures. Emergency measures to address short-term episodes of air pollution adopted by local authorities typically involve actions aimed at reducing pollutant emissions, minimizing exposure, and protecting public health. The triggering of emergency air pollution measures is typically based on predefined thresholds or criteria established by authorities. For instance, the implementation of emergency air pollution measures can be triggered by a certain level of an Air Quality Index (AQI), surpassing thresholds of certain key air pollutants, unfavorable meteorological conditions, and/or AQ forecasting. For emergency measures to be proactive, rather than retroactive, forecasting capabilities need to be developed—for example, meteorological and air quality forecasting. Emergency measures to respond to short-term air pollution episodes can include several actions such as temporary traffic measures, including the promotion of alternative transport means, restrictions and bans on using certain fuels in residential and commercial buildings, and restrictions on industries. Nevertheless, the design of an emergency measure or a mix of measures should be based on a combination of technical analyses, enabling regulatory frameworks, risk assessments, and public health considerations to identify the most appropriate and location-specific emergency measures.

Technical capacities at the local level for design of emergency short-term air pollution measures; drafting or overseeing of the drafting of local AQM plans; and implementation, evaluation, and update of the plans are required. In many countries, it is general practice that the staff at local environmental departments are responsible for several environmental aspects; however, in areas with high air pollution it is recommended that dedicated AQ staff are available locally. Moreover, it is not uncommon for local AQ issues to be covered in a unified environmental management plan. In either case, supporting local capacities of municipal employees to work consistently on AQM issues is advisable.

Air pollution is a cross-sectoral issue. Air pollution does not originate only from the environmental sector but also from energy, transport, agriculture, and others. Hence, in addition to the vertical coordination between national and local levels of government, horizontal coordination between different sectoral ministries and agencies is needed to tackle air pollution efficiently and comprehensively. A national AQ Council with representatives from key sectoral institutions that has a clear and strong mandate to influence AQM actions is a viable mechanism for ensuring adequate coordination on AQM and facilitating the implementation of PaMs.

Air pollution is also a global issue. Air pollution does not recognize borders and hence, activities in one country can have an impact on AQ in its neighboring countries. Therefore, international and regional cooperation on AQM is needed to holistically tackle air pollution. This is especially the case in places like Central Asia that are prone to significant transboundary pollution episodes such as from dust storms. Becoming a party to international treaties, such as CLRTAP, is also a way to participate in international cooperation on AQM.

Key recommendations

- Develop a national AQM strategy.
- Review and update relevant legislation in line with the adopted AQM. Pay particular attention to legislation on pollution fees and taxes and development of green taxonomy for AQ improvement projects.
- Strengthen regulations and local capacities for AQM planning, including establishing AQM zones/ agglomerations.
- Develop local emergency measures for short-term air pollution episodes.
- Establish an AQM coordination mechanism.
- Engage in international/regional cooperation in the area of AQM.

2.4.2 PaMs for key sectors

Implementation of PaMs in key sectors is fundamental to improving air quality. Typically, PaMs need to be implemented across a variety of sectors to achieve significant reduction in air pollution. This AQM roadmap focuses on the key sectors contributing to $PM_{2.5}$ pollution and the respective suggested PaMs.

2.4.2.1. PaMs in the industrial sector

The industrial sector is typically in the focus of the general public when it comes to air pollution. The pollution from the industrial sector is easily visible and the scale of emissions is large. However, the industrial sector is often not the main contributor to urban pollutant concentrations, particularly $PM_{2.5}$, as demonstrated in the technical assessment for Tashkent (see Section I.5.3). Nevertheless, PaMs in the industrial sector are key components of overall AQM for the following reasons:

- The industrial sector is a large emission source of both air pollutants and GHGs and therefore could provide opportunities for synergies between air quality and climate change PaMs.
- It is generally easier to manage industrial emissions as there are only a certain number of industrial installations within a given area as opposed to thousands of individuals engaging in activities polluting the air such as using fossil fuels for heating and for transport.
- Managing emissions from the industrial sector is under the jurisdiction of MoEEPCC.

Industries in Uzbekistan, especially large in-dus-trial installations of categories I and II, are subject to environmental permitting. Permits are the key tools for policy makers to limit industrial emissions. Therefore, strengthening industrial permitting processes is a key policy measure. Inspiration and benchmarking with advanced industrial emission management systems (for example, as in the EU) could be used to strengthen the permitting process and overall industrial emissions regulations in Uzbekistan (see Box 1). The permitting process in Uzbekistan can be strengthened in a number of ways such as the following:

- **Setting Emission Limit Values (ELVs) based on best available techniques (BATs)** approaches where an enterprise in a specific industry should comply with ELVs that correspond to the best available technologies on the market for the specific industry. Adopting such an approach involves update of legislation as well as development and adoption of reference documentation for BATs in various sectors.
- Similar to ELVs based on BATs, **the introduction of a 'green certification' system** based on assessing the compliance of technological processes in industries with environmental standards and requirements and environmental labeling of products and services could be considered. In this case, an update of environmental standards and requirements will be needed.
- Alternatively, **the methodology for setting ELVs could be updated** to promote the setting of stricter ELVs rather than ELVs based on historical performance or on self-calculations. Introducing requirements for installation

of highly efficient emissions control and abatement technologies would also lead to setting stricter ELVs.

- **The adoption of an integrated permitting process** that considers environmental impacts from industrial activities in a holistic manner can also lead to reduced industrial emissions—for instance, if integrated permitting includes energy efficiency requirements, those could in turn promote lower emission processes.

In addition to strengthening regulations and the permitting process, the most certain way to reduce and/or eliminate emissions from the industrial sector is to use renewable energy and green technologies in industries. However, there might be multiple challenges to the use of renewable energy in industries such as preexisting conditions, stranded assets, costs, and process and infrastructure requirements. Therefore, when a switch away from fossil fuels is not possible in the short term, then a range of PaMs can be implemented to limit industrial emissions.

For instance, ensuring that industries use up-to-date emissions control and abatement technologies is a key part of industrial emission management. Emissions control and abatement technologies are end-of-pipe solutions, but utilizing up-to-date emission controls is mandatory especially in cases where industries are not able to switch to zero-emission production processes. Emissions can be reduced by a large factor if efficient emissions controls are installed, operated, and maintained properly.

Automatic emissions monitoring, especially at large polluters (category I and II enterprises), facilitates the enforcement work of authorities. Industries with automatic emissions monitoring are much less likely to switch off their emissions control and abatement equipment and surpass their ELVs. Until automatic emissions monitoring is installed at all targeted installations, regular inspections have to be conducted to guarantee that industries are operating in line with the issued permit requirements and additional obligations.

The ultimate goal of PaMs in the industrial sector is to encourage cleaner and zero-emission production. As mentioned above, this might not be possible in the short or even the medium term. Nevertheless, PaMs could still be designed to incentivize industries to gradually move toward cleaner production. Such PaMs could include reforming pollution taxes and charges to incentivize industries to reduce emissions of key air pollutants, introducing a carbon tax that makes the use of fossil fuels more expensive, and/or setting up a market-based instrument such as emissions trading system (ETS) that could include different air pollutants and GHGs. A detailed analysis and stakeholder consultations can inform the choice of the most suitable instrument or combination of instruments.

Installing emissions control equipment and fuel switching are often costly endeavors. Therefore, access to financing would facilitate such investments. Authorities could consider various options for incentivizing investments in cleaner production. Options for green financing could be explored in coordination with the Ministry of Economy and Finance, commercial banks, development partners, and other funding institutions.

Achieving industrial emission reductions requires a holistic approach spanning from strengthening of regulations to providing incentives for the adoption of green technologies and cleaner production. Regulations related to permitting procedures, approaches to setting ELVs, and efficient emissions control play an instrumental role in establishing an enabling regulatory environment for incentivizing emission reductions in industries. The adoption of BATs, albeit a long process, has also proved its effectiveness in reducing industrial emissions. In addition, setting up long-term finance opportunities for industries to invest in emission reduction technologies and processes is a key task to support such investments and contribute to the overall market development for clean industrial technologies and production processes.

Box 1: Industrial emissions regulation in the EU

The Industrial Emissions Directive (IED)[29] adopted in 2010 is the main instrument in place in the EU to control and mitigate the environmental and human health impacts from industrial emissions. The IED regulates around 52,000 of the largest industrial installations in the EU covering a range of agro-industrial sectors. The general objective of the IED is to prevent, reduce, and eliminate as far as possible emissions into air, water, and soil and remediate soil pollution arising from industrial activities.

The IED is based on several pillars:

Integrated permits. Industrial permits must take the whole environmental performance of the plant into account. This covers emissions to air, water, and land; generation of waste; use of raw materials; energy efficiency; noise; prevention of accidents; and restoration of the site upon closure.

BAT. The permit conditions including ELVs must be based on the adoption of BAT. To define BAT and the BAT-associated environmental performance at the EU level, the EU Commission, together with representatives from industry and environmental organizations, develops BAT Reference Documents (BREFs) and the resulting BAT conclusions. The IED then requires that the BAT conclusions are the reference for setting permit conditions.

Environmental inspections. The IED stipulates that a system of environmental inspections is set up and inspections are carried out at least once every one to three years.

Public participation. The IED requires that the public has the right to participate in the decision-making process and to have access to permit applications, the actual permits, and the results from inspections.

The EU conducted an evaluation of the IED in 2020 and reported that because of the IED, by 2017, air pollutants' emissions of the covered installations had decreased between 40 percent and 75 percent depending on the pollutant. Overall, the evaluation process emphasized the important role the IED played in the reduction of air pollutant emissions in the EU.

Key recommendations

- Strengthen industrial emissions regulations, including the industrial permitting process.
- Mandate the installation, operation, and maintenance of highly efficient emissions control and automatic emission reporting equipment at key industrial enterprises.
- Promote cleaner industrial production through regulatory (for example, stricter emission limit values, adoption of BAT), fiscal (for example, progressive pollution fees and charges, carbon tax, targeted financing), and/or market-based instruments (for example, ETS).
- Identify key priority policies and measures to reduce air pollution from industry.

2.4.2.2. PaMs in the transport sector

Transport is an important source of air pollution in each city worldwide. Transport is the second largest anthropogenic source of air pollution and the second largest GHG source in Tashkent (see Annex 3). Therefore, reducing transport emissions and encouraging sustainable urban mobility are key measures to improve urban air quality and reduce GHGs at the same time.

There are generally four groups of transport PaMs to reduce emissions of air pollutants:

(a) **Vehicle and fuel standards** are the foundation of transport policies to reduce emissions. Fuel standards mainly relate to the sulfur content of fuels used in transport. Regulations could prohibit the use of fuels not meeting certain standards for sulfur content. Vehicle standards can take the form of vehicle emission standards for newly registered vehicles, maximum emission levels of in-use vehicles, and/or fuel economy vehicle standards. In general, strengthening vehicle and fuel standards requires detailed

[29] https://environment.ec.europa.eu/topics/industrial-emissions-and-safety/industrial-emissions-directive_en

assessment of the current vehicle fleet and fuels used. Regulations can then be strengthened and/or adopted based on the outcomes of such an assessment.

(b) **Vehicle measures** aim to reduce the emissions of the vehicle fleet. Vehicle measures can include requirements for vehicles' retrofit with emission control equipment or promotion of low-emission vehicles (for example, hybrid and electric vehicles). In addition, policies targeting the trade of vehicles can be introduced such as maximum vehicle age for imported vehicles or restriction on the import of specific vehicles (for example, diesel vehicles without emission control equipment and diesel light-duty vehicles). Similar to adopting vehicle and fuel standards, a detailed understanding of the current vehicle fleet and vehicles' maintenance practices is required to implement vehicle measures. For instance, if removing emission controls from vehicles (for example, catalysts and diesel particulate filters) is identified as an issue, then mandating and improving the system of periodic technical inspections could be considered. In addition, emission checks on the road could also be introduced to enforce the implementation of vehicle measures. The foundation of vehicle measures is to ensure that vehicles operate according to their manufacturing specifications. A vehicle with a removed diesel particulate filter might have emissions that are several-fold higher than a vehicle with properly functioning filter and hence, identifying such vehicles and ensuring that vehicles operate at least according to their manufacturing specifications is a key task of introducing vehicle measures.

(c) **Low-emission urban transport** measures are focused on improving the attractiveness of public transport, promoting hybrid and electric vehicles, and encouraging nonmotorized mobility options in cities. Such measures are optimized if urban transport demand management is also implemented. Improved urban transport reduces the number of private vehicles on the road and consequently—congestion. This not only saves emissions of air pollutants and GHGs but also contributes to more livable cities and better quality of life. Public transport could be made more attractive than using a private vehicle to commute in the city by making the commute using urban transport quicker or at least as quick as using private vehicles, ensuring comfort, timeliness, and accessibility. Improving the attractiveness of public transport could include optimizing timetables and routes to match the daily transport demands of citizens; establishing bus lanes or providing preferential access of urban transport vehicles; increasing parking fees for private vehicles; providing Wi-Fi connection in urban transport vehicles; setting up options for e-ticketing and combined public transport tickets; and establishing and maintaining a public transport app with up-to-date information about timetables, routes, estimated time of travel, and so on. In addition, the use of modern and low-emission vehicles further increases the attractiveness of public transport. To use electric vehicles, the charging infrastructure should also be developed. Other forms of urban mobility could be promoted in parallel to improving the attractiveness of public transport. Increased share of nonmotorized transport means (for example, walking and cycling) contributes to the reduction of air pollutants and GHGs and provides health benefits from increased levels of physical activity. Cycling can be promoted by setting up an integrated and safe network of bicycle lanes and bicycle parking connecting the key points of interest within the city. In addition, bicycle sharing could also be established—by the public or the private sector or as a public-private partnership. Increasing pedestrian areas, improving sidewalks, and enhancing overall accessibility are measures that could promote higher rates of walking in the city.

(d) **LEZs** are often implemented after vehicle and fuel standards as well as vehicle measures are already put in place. LEZs define certain geographical areas in urban agglomerations that may only be entered by vehicles meeting predefined emission standards. It is understood that Presidential Decree 171 of May 31, 2023, stipulated for restrictions on vehicle movement in Tashkent city center during designated hours to be introduced by the end of 2023. This is in essence similar to the principles of introducing a LEZ. It should be noted that the most optimal design and implementation of LEZs requires substantial analyses of the local context such as traffic flows, purpose of urban journeys, impact on air quality, and population exposure to air pollution from introducing a LEZ. The enforcement of LEZs, on the other hand, requires the development of technical infrastructure such as recognizing license plates, installing cameras, and optimizing notifications for breaching the LEZ rules. In addition, implementing a LEZ has a social effect as it restricts mobility options for parts of the population and hence, adequate options for public transport and/or nonmotorized urban mobility need to be provided. Therefore, the decision to introduce a LEZ should be coupled with a well-targeted information campaign that clearly explains the LEZ rules and why an LEZ needs to be implemented. These considerations should be taken into account when designing traffic restrictions and/or introducing a LEZ in Tashkent and other cities in Uzbekistan.

Some of the measures suggested above require actions at the national level (for example, vehicle and fuel standards, vehicles' import regulations), whereas others are in the jurisdiction of local authorities (for example, improved public transport and establishment of LEZs). In addition, public transport can also be funded either directly through government or through competitive governmental programs for which local authorities can apply. Therefore, the need for a coordination mechanism between national- and local-level authorities is essential to facilitate the efficient implementation and enforcement of emission reduction measures.

The systematic analysis of pollution reduction from the transport sector will inform 'Transport Sector Greening strategy' and different investment alternatives. These are generally in the jurisdiction of the ministries of transport and internal affairs. However, Presidential Decree 171 of May 31, 2023, tasked MoEEPCC with several obligations to facilitate emission reductions from the transport sector:

(e) Drafting legislation on the collection of environmental fees on motor vehicles

(f) Introducing legislation on regulating the movement of motor vehicles that do not meet certain environmental standards

(g) Designating certain urban areas as 'ecological zones' where the movement of motor vehicles is restricted

(h) Suggesting areas where fast charging stations for electric vehicles are to be established.

Measures to reduce air pollution from transport as outlined in Presidential Decree 171 of May 31, 2023, are currently being developed by authorities in Uzbekistan. The Cabinet of Ministers adopted a resolution on control of transport emissions on March 29, 2024.[30] The resolution's objective is to reduce air pollution from vehicles by 2030. The resolution provides for the classification of vehicles into ecological categories (green, yellow, and red). A vehicle's ecological category will be determined during periodic technical inspections after which a vehicle sticker will be issued to specify the ecological category the vehicle falls into. The vehicle stickers will then facilitate the implementation of ecological transport system in Uzbekistan that aim to restrict the movement of polluting vehicles. The first phase of the ecological transport system will be implemented in Tashkent (2024–2026), the second in Nukus (2026–2028), and the third phase will include all other regions of Uzbekistan (2028–2030). Ecological compensation payments for vehicles operating in an ecological zone but not meeting its requirements will also be introduced.

To fulfill the obligations with regard to reducing emissions from the transport sector, MoEEPCC would have to coordinate its work with a number of institutions — Ministry of Transport, Ministry of Internal Affairs, Ministry of Energy, and local authorities. The March 29, 2024, resolution on control of transport emissions introduced new obligations for MoEEPCC in the area of managing air pollution

30 https://lex.uz/ru/docs/6858809

from transport—to develop a monitoring system detecting violations in the ecological transport system zones. In addition, a dedicated transport sector study to assess the impact of different PaMs on air pollution from transport could be conducted by MoEEPCC and the other relevant national and local authorities. The study could focus on analysis of the transport sector in a target area, for instance, Tashkent, and assess the applicability and effectiveness of PaMs in the four general groups of transport PaMs presented above.

Key recommendations

- Establish a work plan for identification of priority policies and measures in the transport sector and coordinate with relevant authorities to advance legislation on reducing transport emissions.

2.4.2.3. PaMs in the heating sector

The AQ assessment for Tashkent showed that heating on solid fuels (for example, coal, biomass) contributed up to 45 percent to $PM_{2.5}$ pollution in some winter months. There are different approaches to reducing heating emissions: emissions can be reduced if better quality fuels and/or appliances are used, heating demand and consequently emissions can be decreased by implementing energy efficiency measures, and emissions can be reduced or eliminated by switching to cleaner or zero-emissions heating practices. There are four general options to reduce emissions from heating:

- **Improving the quality of fuels used.** The main instrument to improve the quality of fuels used for residential heating is to set quality standards for those fuels. Fuel quality standards could be set for the most polluting fuels—coal and biomass-based fuels. Fuel quality standards typically mandate a minimum level of fuel quality such as calorific value, ash content, sulfur content in the case of coal fuels, and calorific value and moisture content in the case of biomass fuels. Fuels not meeting the defined quality standards would not be allowed to be placed on the market. Typically, enforcement and control of solid fuels quality standards at the point of sale has proven more practical than enforcement at the user level. Moreover, the use of certain fuels can be restricted or banned altogether in air pollution hotspot areas.
- **Improving the efficiency of heating appliances.** The efficiency of heating appliances can be improved by mandating minimum efficiency standards for heating appliances, especially those on solid fuels. Appliances not meeting the minimum efficiency standards will not be allowed to be placed on the market. Technical specifications to inform the minimum efficiency standards should be developed based on the local context and market for heating appliances. A market surveillance authority can then be responsible for enforcing the minimum heating appliances' standards. The standards for heating appliances' efficiency typically set minimum coefficients of performance (COPs) and maximum thresholds for pollutant emissions for different types of heating appliances. Improving fuel quality standards and the efficiency of heating appliances require changes in regulations and additional enforcement of the new standards but do not introduce major changes in the methods used for heating — households and businesses can continue using their current heating practices provided that the fuel and/or the heating appliance meet the standards.
- **Switching to cleaner heating alternatives.** Switching to cleaner heating alternatives implies changes in heating practices and, like in the case of energy efficiency, typically requires up-front investment that many households and businesses cannot afford; therefore, financing is needed for incentivizing the switch to cleaner heating appliances. The minimum efficiency standards discussed above usually apply to new heating appliances and hence, regulations for existing appliances should also be developed. Typically, regulations targeting the switch to

cleaner heating in existing buildings allow for a transition period when users of inefficient heating appliances are provided with some time and often financial support to switch to a more efficient and cleaner heating appliance. In addition, certain polluting fuels and appliances can be restricted or banned altogether in an air pollution hotspot area—financial mechanisms should be developed to support the adoption of cleaner heating in such areas. The use of cleaner heating means can also be encouraged through legislation that regulates the permitting process of new buildings. For instance, new buildings might be mandated to be connected to central heating networks, when those are available, or use a certain share of renewable energy, including for heating or not allow the use of certain fuels for heating. Cleaner heating alternatives could also be promoted by fiscal measures such as reduced value added tax and/or reduced property tax if the property uses clean or zero-emission heating.

- **Implementing energy efficiency measures.** Improving buildings' energy efficiency is typically considered a 'no regrets' measure as it saves energy, decreases energy bills, and reduces emissions of both air pollutants and GHGs. Buildings' energy efficiency standards are usually set in energy efficiency legislation and/or building codes. Typically, new buildings are required to meet high energy efficiency standards. However, improving energy efficiency of existing buildings can also be encouraged through a mix of regulatory and financial instruments. For instance, existing buildings of different types might be mandated to achieve certain levels of energy efficiency by a given date and these requirements could be coupled with various financial mechanisms targeted at people of different income levels that reduce the cost of energy efficiency measures.

Transition to sustainable heating in Uzbekistan faces several challenges, such as low energy prices, lack of infrastructure, lack of financing, and behavioral inertia. A comprehensive response requires long-term policies, regulations, infrastructure planning, programs with incentives and financing, communication and outreach, and training. Higher-level sector reforms involve many stakeholders and, if well coordinated, can incentivize market-based uptake of sustainable heating solutions. Measures to reduce emissions in the heating sector require some regulatory changes and financial assistance to households and businesses to afford up-front investments in energy efficiency and cleaner heating that pay off over time. The design of regulations and financial incentives requires additional analyses of the local context, including cost-effectiveness analysis of the different options.

Detailed information on the residential heating sector in Uzbekistan is not available which impedes policy making. Therefore, MoEEPCC, together with Ministry of Energy, Ministry of Agriculture, and local authorities, could create an action plan to reduce heating emissions based on a dedicated assessment of the heating methods used by businesses and population in a target area, for instance, Tashkent and surrounding areas. Such a study could take the form of a survey that collects data on key heating characteristics:

- Type of heating used—from a central or an individual source
- Fuel used for heating (for example, district heating, gas, coal, heating oil, biomass, and so on)
- Heating consumption in natural units or in heating expenses
- If an individual heating system is used, type and efficiency of the heating system—coal/biomass stove or boiler, heating oil radiator, electric radiator, air conditioner, and so on
- Type of building—single or multi-family; commercial or residential
- Energy efficiency of the building—no energy efficiency implemented, partial energy efficiency (wall insulation or roof insulation), or full energy efficiency
- Types of windows—wooden, PVC, aluminum, double glazed, and so on
- Size of the dwelling/commercial building in m^2
- Size of the heated area in m^2.

The suggested study will inform a prioritization of the alternative heating options and allow to design a targeted policy reform to create incentives to reduce pollution for the priority

contributors, both residential and commercial. An action plan that is based on the study will prioritize cost-efficient interventions to reduce air pollution from heating and create a consultation platform for main stakeholders for regulation of pollution from area sources, including heating. Moreover, economic incentives that could spur demand for sustainable healing could be developed in parallel to the ongoing work of the Ministry of Energy on fuel subsidies' elimination.

Various heating technologies on the market are less polluting than the use of coal and biomass in inefficient appliances. Therefore, identifying the optimal option or options to be supported by policies, regulations, and financial assistance is a key task for policy makers. Cost-effectiveness analysis can identify the cheapest options among a variety of alternatives to achieve a certain policy goal—in this case, to reduce emissions of air pollutants and GHGs. Thus, cost-effectiveness analysis can be used to provide initial prioritization of measures to be implemented. The final decision on which measures will be actively pursued by policy makers would also consider issues such as technological availability, need for additional regulations, financial assistance, protection of vulnerable households, implementation, enforcement, and monitoring arrangements. Box 2 and Box 3 provide summaries of World Bank cost-effectiveness analyses that support the design of measures to reduce air pollution from the residential heating sector in other Central Asia countries.

Box 2: Costs of cleaner residential heating measures in Bishkek, Kyrgyz Republic

The ongoing World Bank assessment 'Heating Options Study for Bishkek' estimated the financial and economic levelized cost of heating (LCOH) for different heating options. Financial and economic LCOHs are common approaches used to evaluate the expenses and investments as well as the economic benefits of switching to cleaner heating options. The assessment then ranked the available alternatives to replacing coal heating in single-family houses (SFHs) with the goal to show which alternatives maximize emission reductions and economic benefits at the least cost.

Considering up-front investments needed to switch to a cleaner heating option (the capital expenditure [CAPEX]) and the costs of fuel, operation and maintenance (operational expenditure [OPEX]), and disposal, the financial LCOH for all SFH heating options shows that only electric boilers are financially cheaper than the use of coal for heating in the baseline. This is due to the high up-front expenses to install/connect the alternative heating options. However, the economic LCOH for SFHs that also considers economic benefits from reduced GHG emissions and in turn carbon costs and improved health outcomes, that is, reduced costs for health care, shows all options outperforming the baseline use of coal boilers. While gas options still show higher fuel costs and heat pump options still show higher CAPEX costs, these cost increases compared to the use of coal for heating are exceeded by the savings in carbon emissions and health impacts from $PM_{2.5}$.

An alternative heating options ranking, compared to the baseline use of coal for heating in SFH, was performed combining the results from the financial and economic LCOH analyses.[9] For SFHs, electric boilers rank as the top option to replace use of coal for heating, followed by air-to-water (A2W) heat pumps. However, it should be noted that to achieve the full potential of savings a baseline level of building, energy efficiency is needed, which is not the case in all SFHs.

Table 4: Ranking of heating options to replace coal in single-family house (SFHs) in Bishkek

	Financial LCOH Difference from Coal	Economic LCOH Difference from Coal	Household OPEX Affordability: Fuel and Maintenance Costs	Availability of Service/ Technology	CO_2 Savings Potential Compared to Coal	$PM_{2.5}$ Savings Potential Compared to Coal	Overall Rank
SFH Options	US$/m²	US$/m²	US$/m²	Description	ton CO_2/ year/1,000 US$	g $PM_{2.5}$/ m²/ US$	All ranks weighted equally
New Gas Boiler	4.15	(7.20)	3.23	Gazprom service area	3.69	0.20	3
New Gas Boiler + EE	20.96	(0.33)	5.51		0.82	0.04	7

	Financial LCOH Difference from Coal	Economic LCOH Difference from Coal	Household OPEX Affordability: Fuel and Maintenance Costs	Availability of Service/ Technology	CO_2 Savings Potential Compared to Coal	$PM_{2.5}$ Savings Potential Compared to Coal	Overall Rank
W2W Heat Pump	6.23	(10.47)	2.07	Limited by geothermal potential	2.98	0.12	4
W2W Heat Pump + EE (Coal to W2W+EE Scenario)	22.77	(5.21)	2.18		0.91	0.04	6
W2W Heat Pump + EE (Gas to W2W+EE Scenario)	20.87	(5.84)	2.25		0.99	0.04	5
A2W Heat Pump + EE	5.10	(11.86)	2.02	Anywhere	3.07	0.12	2
Electric Boiler	1.75	(10.75)	3.06		10.01	0.41	1

Source: World Bank.

Box 3: Costs of cleaner residential heating measures in Kazakhstan

The World Bank report 'Clean Air Cool Planet: Integrated Air Quality Management and Greenhouse Gas Reduction for Almaty and Nur-Sultan*—Volume II' concluded that improved/more efficient coal stoves and boilers in SFHs and switch from coal heating to cleaner heating options in multi-family buildings are the most cost-effective measures to reduce air pollutant and GHG emissions in Almaty and Astana from a public policy perspective. However, for private households to implement cleaner heating measures, the incentive gap between using cheap coal and switching to more expensive alternatives needs to be filled. The report analyzed the fiscal impact of direct subsidies to households to cover up-front (CAPEX) costs for switching to cleaner heating with and without introducing a CO_2 tax.[31]

Table 5: Estimated possible fiscal impact of closing the incentive gap for cleaner residential heating in Astana and Almaty, (€, millions)

			Astana	Almaty
	Without carbon tax	**With a carbon tax of €20 per ton COz**	**Without carbon tax**	**With a carbon tax of €18 per ton COz**
Annual existing fossil fuel subsidies implied by the current tariffs for space heating of households and enterprises (room for repurposing subsidies)	**-40.3**	**-40.3**	**-268.0**	**-268.0**
Incentive gap: Annual additional capex costs to households and enterprises for low-pollution space heating (over 10 years)	-4.3	-3.2	-9.1	-7.4
Annual budget revenues from a COz tax on emissions from space heating	0.0	124.8	0.0	111.8
Net fiscal impact in the scenario with public financing to close the incentive gap (without reforming implicit fuel subsidies)	**-44.6**	**81.3**	**-277.1**	**-163.6**

Source: GAINS-Policy calculations. Note: Negative numbers = fiscal expenditures.

31 https://elibrary.worldbank.org/doi/abs/10.1596/37938.

The study suggests a large potential for policy reforms to bridge the incentive gap while improving fiscal position, efficiency, and quality of heating services in buildings as well as social protection of the citizens of Almaty and Astana. The level of current polluting subsidies in the two cities dwarfs additional subsidies that the study estimated would be needed to encourage households to switch to cleaner heating options. Additional subsidies for up-front investments (CAPEX) to switch to a cleaner heating alternative estimated initially at €9.1 million per year in Almaty and €4.3 million in Astana (both over 10 years) could equalize the annual costs of cleaner heating in buildings with the annual cost of the currently cheapest polluting options—use of coal. This difference between existing 'brown' and potential 'green' subsidies—though roughly estimated—illustrates a scope for repurposing public expenditures from subsidizing polluting activities to subsidizing investments in more sustainable and efficient heating.

On the other side, introducing a CO_2 tax strengthens incentives to switch to cleaner fuels and technologies and raises additional government revenues to help vulnerable households and firms adjust to higher fuel prices. In Astana, a carbon tax of €20 per tCO_2 embedded in fossil fuels would not only reduce the need for annual investment subsidies by almost 30 percent but also yield annual revenues of about €125 million per year. In Almaty, a carbon tax of €18 would reduce the need for subsidies by almost 20 percent while yielding annual revenues of about €112 million per year. Therefore, the CO_2 tax would be more than enough to finance additional subsidies for switching to cleaner heating in the two cities.

Note: *At the time of publication, Astana was called Nur-Sultan.

Key recommendations

- Develop an action plan for priority interventions and policies to address air pollution from heating informed by a study on fuels and appliances used for residential and commercial heating in a targeted area-for example, Tashkent.

2.4.2.4. PaMs to reduce windblown dust

The AQ assessment for Tashkent showed that more than one-third of $PM_{2.5}$ pollution on an annual basis comes from particles transported into the city from outside its boundaries—windblown dust. In some summer months, the contribution of windblown dust to $PM_{2.5}$ concentrations is above 50 percent. Therefore, measures to reduce the amount of dust being transported to the city have to be designed.

However, multiple potential sources of windblown dust can contribute to $PM_{2.5}$ concentrations — from natural dust events and dust from barren and agricultural lands to particles from industrial sources transported for hundreds of kilometers. A particularly important source of dust storms in the region is the Aral Sea. In addition, agriculture plays a significant role in the Uzbekistan's economy and can also be a source of dust events. Therefore, it is important to further analyze the sources of windblown dust that affect air quality in Tashkent and other Uzbek cities. It is likely that reducing the amount of windblown dust transported to Uzbek cities might require not only local and national measures but also transnational measures.

A specific measure that could reduce the amount of windblown dust transported to Uzbek cities is implementing targeted greening measures. Studies generally agree that greening measures can mitigate dust transport into cities; however, the design of greening measures is highly location specific and depends on the types of greening measures, including species selection and space availability for greening, as well as water availability to maintain green areas. Hence, a city-specific assessment of the potential of greening measures to reduce the transport of windblown dust is needed. In addition, greening not only provides air quality benefits but also contributes to a healthier environment and microclimate. Therefore, piloting greening interventions while systematically analyzing the impacts on air quality could provide useful information for scaling up and/or modifying greening interventions to maximize the benefits for air quality.

Key recommendations

- Pilot greening interventions in a city (for example, in Tashkent) and analyze the impacts on air quality.

2.4.3 Stakeholder engagement and communication

As the main goal of AQ policies is to protect human health, the general public should be informed not only about the state of air quality to make decisions how to limit exposure to air pollution but also on the rationale behind and the progress of PaMs implementation. The communication of AQ data can take various forms targeting different sections of the population. AQ applications have become increasingly popular, especially among the younger generation. More traditional communication channels include installing boards displaying AQ information in popular areas in the city as well as including AQ information in news (for example, in the weather forecast section) or publishing daily AQ bulletins. Developing AQ forecasting capacities will further aid AQ information communication as it will provide a forward-looking and actionable information to assist in people's personal decisions on limiting exposure to air pollution.

Communication of AQ data and information is also needed at an institutional level and to promote stakeholder engagement. Strengthened communication could also facilitate the operation of an AQ coordination mechanism and ultimately improve stakeholder engagement. Arrangements for sharing data across institutions can be made, especially if a well-functioning AQ data management system is established as suggested in Section 2.3.4. There are various uses of AQ information within institutions. For example, automatic alerts can be built into the system, and when pollutant limit values are exceeded, an alert could be sent to the local environmental department which then might choose to take certain measures. In addition, periodic AQ data analyses can be shared between institutions that could support PaMs' implementation and impact assessments. For instance, AQ data can be shared between MoEEPCC, local authorities, Ministry of Transport, and Ministry of Internal Affairs on the impacts from implementing a transport LEZ in a city. Such type of data sharing facilitates the assessment and calibration of PaMs.

Key recommendations

- Strengthen AQ information communication to the general public.
- Strengthen AQ information communication across institutions.

2.5. Financing and Investments

2.5.1 AQM Financing

A key pillar in the overall AQM system is financing of the system's components. Coordination with institutions, especially with the Ministry of Economy and Finance, is needed to analyze the financial needs for improving AQ in the country and for the potential sources of financing. The financial needs can be established based on the objective adopted in a national AQM strategy, whereas coordination can be strengthened if an AQ coordination mechanism is established.

Financing of the AQM system might come from a variety of sources and the choice of financing depends on the specifics of the policy and measure to be implemented. Functions and obligations of regulatory and local authorities are usually financed from the budget. However, equipment and infrastructure improvements can also be financed through projects, development programs, concessional financing, and loans. The implementation of PaMs can be financed in various ways depending on the specific PaM. For instance, the private sector could finance installation of emission control equipment, targeted financing and loans could be used to incentivize the switch to cleaner heating in households and businesses, and projects and development programs could be utilized to finance clean urban transport and the supporting infrastructure. Public-private partnerships could also be explored for the financing of PaMs to improve urban transport, whereas energy service companies (ESCOs) could be mobilized to deliver energy efficiency and heating improvements to households and businesses. In addition, innovative financing mechanisms such as green financing and green loans can be devised to support PaMs' implementation.

Developing green taxonomy rules can also encourage financing of AQ improvement projects by the private sector. A green taxonomy is a standardized green classification system that translates environmental objectives into criteria for specific economic activities for investment purposes. Green taxonomy is a tool for policy makers to encourage sustainable activities, to prevent 'greenwashing' and direct private sector investments toward sustainable activities that achieve environmental objectives. Uzbekistan is already working on the development of green taxonomy. MoEEPCC's Air Protection Department is part of the governmental working group on developing Uzbekistan's green taxonomy which is a clear sign that air pollution is an important environmental objective that the green taxonomy needs to address.

An environmental objective included in benchmark green taxonomies (for example, the EU green taxonomy) is pollution prevention and control. AQ improvement projects will generally address the environmental objective of pollution prevention and control but can also provide co-benefits for other environmental objectives such as climate change mitigation and circular economy. The World Bank is supporting the establishment of green taxonomy in Uzbekistan and has proposed one of the taxonomy's environmental objectives to be pollution prevention and control.[32]

In addition to focusing on key environmental objectives, the World Bank Guidance Note suggests that Uzbekistan's green taxonomy is guided by three main principles:

- Make significant contribution to environmental objectives.
- Do no significant harm (DNSH) to other environmental objectives.
- Comply with minimum social safeguards.

Thus, assuming that pollution prevention and control is one of the environmental objectives to be included in Uzbekistan's green taxonomy, any AQ improvement activity and project would also have to meet the

[32] World Bank. 2023. Guidance Note on Uzbekistan Green Taxonomy.

taxonomy's main principles. The Guidance Note on Uzbekistan's Green Taxonomy suggests that the taxonomy is activity based and at the beginning uses qualitative assessment criteria. Table 6 presents some suggestions for green taxonomy qualitative assessment criteria for AQ improvement activities. Table 7 provides some sample AQ improvement activities and suggestions for their assessment against green taxonomy criteria.

Table 6: Assessment criteria for air quality improvement activities in Uzbekistan's green taxonomy

Environmental objective: Pollution prevention and control **Sector: Air quality**		
Main principle	**Assessment criteria**	**Response**
Make significant contribution to environmental objectives	▪ Does the activity reduce emissions of air pollutants? or ▪ Does the activity improve data and information availability regarding air quality? or ▪ Does the activity contribute to improved access to information and improved awareness about air quality?	Yes or No ('Yes' responses indicate alignment with principle)
DNSH to other environmental objectives	▪ Does the activity impede the achievement of other environmental objectives or does it have negative impacts on other environmental objectives?	Yes or No ('No' indicates alignment with principle. If 'Yes', see criteria below)
	▪ If the activity has negative impacts on other environmental objectives, can this harm be mitigated?	Yes or No ('Yes' classifies the activity as 'amber')
Comply with minimum social safeguards	▪ Does/Is it possible for the activity to comply with minimum social safeguards?	Yes or No ('Yes' indicates alignment with principle)

Source: Based on inputs from Guidance note on Uzbekistan Green Taxonomy (World Bank).

Table 7: Sample air quality improvement activities in the context of green taxonomy

Environmental objective: Pollution prevention and control **Sector: Air quality**			
Sector: Air quality	**Significant contribution to pollution prevention and control**	**DNSH**	**Social safeguards**
Install, operate, and maintain highly efficient emissions control and automatic emission reporting equipment at key industrial enterprises	To ensure significant contribution to pollution prevention, emission control devices should have a minimum efficiency requirement. *Set minimum efficiency requirements based on the efficiencies of a sample of best available emission control devices on the market.*	Emission control devices require energy to operate which might increase GHG emissions depending on the fuel source used for energy generation. Emission control devices reduce emissions of SO_2 and NOx which are climate coolants. *Assess the impact of additional energy use for operating the emission control devices on GHG emissions.*	*Set minimum standards for social safeguards.*

Environmental objective: Pollution prevention and control Sector: Air quality			
Sector: Air quality	**Significant contribution to pollution prevention and control**	**DNSH**	**Social safeguards**
Adoption of BATs at industrial enterprises	Sectoral BREFs need to establish BAT-associated emission levels (AELs). Existing BREFs (for example, in the EU) could be used as a benchmark. *Set a requirement for air emissions to be within BAT AELs.*	The evaluation of the EU's IED showed that the BAT approach was successful at significantly cutting air pollutants' emissions but had a lower impact on GHG emissions and other environmental objectives (for example, water consumption, circular economy). No negative impacts on other environmental objectives from BAT adoption was found, though. *If applicable, set additional requirements for GHG emissions reduction and/or water consumption and/or waste generation and/or resource efficiency.*	*Set minimum standards for social safeguards.*
Promote the use of cleaner heating alternatives in households	Since there are different cleaner heating technologies, the impact on pollution prevention depends on technical specifications of each heating technology. Technical specifications of various heating appliances are available internationally for benchmarking (for example, EU directives and regulations). *Develop a catalogue of cleaner heating technologies and provide minimum technical specifications (for example, appliance efficiency, fuel requirements, and emission levels).*	Some heating technologies are CO_2 neutral but contribute to air pollution—for example, biomass-based stoves and boilers. Others use fossil fuels (for example, gas) but reduce air pollution compared to the use of coal and biomass. *Consider the impact on GHG emissions of different heating technologies when developing the catalogue of cleaner heating technologies.*	*Set minimum standards for social safeguards.*

Source: Based on inputs from Guidance Note on Uzbekistan Green Taxonomy (World Bank).

Key recommendations

- Establish financing mechanisms for the components of an AQM system.
- Introduce air quality improvement activities in green taxonomy.

2.5.2 Investments and policy reforms

Strengthening the AQM system and improving air quality require investments and policy reforms. An upcoming World Bank report estimates that around €690 million of up-front investments are needed for the key emission sectors in Tashkent to bring the $PM_{2.5}$ annual average concentration in the city to the WHO's IT1 of 35 μg/m³. In addition to investments in interventions in key emission sectors, policy reforms are needed to update and strengthen the regulatory framework for AQM and facilitate emission reductions in key sectors. There are a number of potential areas where investments and policy reforms might be needed, but in the context of limited resources available, it is prudent to prioritize AQM investments and policy reforms.

It is essential to invest in a strengthened regulatory enabling environment for improved AQM in Uzbekistan. An updated regulatory and legal framework is the foundation for further developing the AQM system in Uzbekistan—for instance, updating air quality standards plays a key role in the AQM regulatory environment. Another important investment area is improving technical capacities and infrastructure for AQM. Those could include investments in expanding the air quality monitoring network, upgrading air quality laboratories, strengthening the emission inventory capacities, and developing AQM capacities at the national and local levels.

Ultimately, investments in emission reductions across sectors are what drive air quality improvement. The abovementioned investments and policy reforms can be categorized as 'soft investments' in the sense that they do not directly reduce pollutants' emissions. In addition to those 'soft investments', direct investments to reduce emissions are needed. Those investments are likely to require a larger financial resource than the 'soft investments' and hence, careful prioritization is necessary to optimize the cost-effectiveness of the investments. In any case, investments in emission reductions in key sectors should go hand in hand with policy reforms that facilitate and incentivize the uptake of emission reduction measures by the private sector.

The type of investment and consequently the potential sources of financing of the investments in the key emission sectors differ. Emission reduction investments in the industrial sector could focus on financing the adoption of green technologies and cleaner production and might require a mix of private, public, and commercial financing. Low-emission transport would require incentives for cleaner vehicles and transport modes as well as investments in infrastructure that could involve a mix of private, public, and concessional financing. Similarly, reducing residential and commercial heating emissions would require incentives for the uptake of cleaner heating technologies and investments in infrastructure that could be achieved by public, private, ESCO, and commercial financing. Given the dominant contribution of windblown dust to $PM_{2.5}$ concentrations as identified in the technical assessment for Tashkent, piloting greening measures would require investments in analyses for the types and location of greening interventions, implementation of those interventions, and infrastructure development to support and maintain urban greening that are likely to be supported by public and project financing. Moreover, setting up innovative financing mechanisms such as green bonds and green credits and developing a green taxonomy for air quality improvement could provide additional financing options.

Key recommendations

- Identify investments and policy reforms for improved air quality.
- Prioritize the identified investments and policy reforms and secure funding for the prioritized investments.

2.6. Suggested AQM Roadmap

Table 8 summarizes the suggested measures for AQM improvement in Uzbekistan, focusing on measures where MoEEPCC could play a leading or coordinating role in implementation and highlighting the cross-sectoral nature of implementing air quality improvement measures. Table 8 provides a short description and rationale for the suggested measures, indicates the priority level for each measure, and suggests responsible institutions for the measures' implementation and potential sources of financing. Measures' priority levels are an indication of how essential they are for the functioning of the overall AQM system and do not consider readiness and feasibility for implementation or available financing and human resources. The AQM roadmap provides a basis for dialogue on those issues and discussion of implementation and financing modalities is the next step after prioritization of measures from the suggested AQM roadmap is performed together with government stakeholders. Measures with the priority level 'Immediate' need to be implemented as soon as possible and are essential for the efficient functioning of the overall AQM system. Measures with the priority level 'Immediate to Medium' are key for the overall functioning of the AQM system, but their execution might require that some of the measures with 'Immediate' priority have been implemented first or are being implemented. Measures with the priority level 'Medium' are important for the functioning of the AQM system but do not have to be implemented as soon as possible and/or would benefit if measures labeled as 'Immediate' or 'Immediate to Medium' have been implemented or are being implemented.

Table 8 provides general suggestions for potential sources of financing of each measure; however, financial arrangements should be discussed in greater detail once measures are prioritized together with government stakeholders. Generally, measures that relate to updating and strengthening of policies and legislation could be financed by the budget with possible technical assistance support from development partners, international cooperation projects, and/or philanthropic organizations. Procurement of equipment for public authorities could be financed from the budget or on a project basis through support from development partners, international cooperation projects, and philanthropic organizations. Measures that concern the private sector could be financed by the private sector, commercial sector (banks), public-private partnerships, through fiscal measures (in essence, from the budget) and by innovative financing mechanisms such as green bonds and credits or as part of green taxonomy for air quality improvement. Ultimately, a system for financing of air quality improvement projects needs to be developed that can efficiently and transparently manage, utilize, and disburse funding from the different potential sources that might be available.

Transport measures are not included in Table 8 as the recent developments in legislation are in line with the PaMs discussed in Section 2.4.2.2.[33] Additional discussions and support can be provided for the actual implementation of the foreseen measures—classifying vehicles into ecological categories, ensuring the necessary capacities for performing periodic technical inspections, designing the enforcement and monitoring network with regard to vehicular restrictions in cities, and including the design of ecological compensation payments for vehicles. Implementing the envisioned transport measures, especially establishing the enforcement and monitoring system, requires financial resources, the need for which could also be a subject of future discussions.

[33] Resolution of Cabinet of Ministers of Uzbekistan on control of transport emissions adopted on March 29, 2024: https://lex.uz/ru/docs/6858809.

Table 8: Suggested Roadmap for AQM Improvement in Uzbekistan

Measure	Description and rationale	Priority(*)	Suggested responsible institutions	Potential sources of financing
Air quality monitoring				
Develop air quality monitoring network modernization plan.	Developing an AQ monitoring network modernization plan is a key step in setting the scope, objectives, and direction for the development of the AQ monitoring network in Uzbekistan. The plan should describe the number of AQ monitoring stations to be deployed, the pollutants to be measured, the locations, and types of the AQ stations. Based on the scope of AQ monitoring network modernization, the appropriate number of supporting laboratories, as well as trained staff, can be established. The plan could also outline the need for update of legislation and/or methodologies and/or procedures.	Immediate	MoEEPCC Uzhydromet	Public (from budget) Technical assistance could be provided through projects of development partners and/or philanthropic organizations and/or international cooperation projects.
Update legislation on the air quality monitoring network in line with the modernization plan.	The relevant legislation on assessment of air quality through air quality monitoring would have to be updated based on the adopted AQ monitoring network modernization plan. Procedures for locating AQ monitoring stations should be clearly described, including both macroscale and microscale sitting requirements for AQ monitoring stations. In addition, procedures for the organization of overall air quality assessment and maintenance of the AQ monitoring network would have to be updated.	Immediate to Medium	MoEEPCC Uzhydromet	Public (from budget) Technical assistance could be provided through projects of development partners and/or philanthropic organizations and/or international cooperation projects.
Install air quality monitoring stations in line with the modernization plan.	Installation of AQ monitoring stations will likely occur over time depending on the scope of AQ monitoring network modernization. Installation of AQ monitoring stations involves, among others, the selection of suitable sites for AQ monitoring stations, the procurement of equipment, the installation of the equipment and supporting infrastructure, calibration of the equipment, and sampling and reporting of data.	Medium	MoEEPCC Uzhydromet	Public (from budget) Project based (including projects by development partners and philanthropic organizations)
Establish/update laboratories to support the functioning of the air quality monitoring network.	In parallel with the installation of AQ monitoring stations, the update and/or establishment of AQ laboratories needs to be performed. As a minimum, an AQ monitoring network requires a calibration laboratory where stations are periodically calibrated as well as regional chemical laboratories where additional analyses of pollutants are performed. The update/setup of AQ laboratories involves, among others, securing space for the laboratories, if needed, procuring the necessary equipment, installing and calibrating the equipment, training staff to work with the equipment, and accrediting the laboratories to meet international standards.	Medium	MoEEPCC Uzhydromet	Public (from budget) Project based (including projects by development partners and philanthropic organizations)
Air quality standards				
Update national AQ standards in line with international best practices; include standards for $PM_{2.5}$.	AQ standards are fundamental components in the overall AQM system. AQ standards are set with the main goal to protect human and ecosystems' health. Therefore, instead of focusing on a long list of air pollutants, international best practices focus on key pollutants with the gravest health impact. Other pollutants are dealt with on a case-by-case basis depending on intensity of emission sources, potential exposure, and other considerations. The WHO considers $PM_{2.5}$, PM_{10}, O_3, NO_2, SO_2, and CO as the main air pollutants, causing the majority of health damage. Particular focus is placed on $PM_{2.5}$ and hence, it is imperative that Uzbekistan adopts a $PM_{2.5}$ standard.	Immediate	MoH MoEEPCC	Public (from budget) Technical assistance could be provided through projects of development partners and/or philanthropic organizations and/or international cooperation projects.

Measure	Description and rationale	Priority(*)	Suggested responsible institutions	Potential sources of financing
Emissions inventory				
Update and strengthen the emission inventory system to meet international best practice.	The emissions inventory system is the backbone of any AQM system. It is used to determine key emission sources and their contributions to air pollution; support AQM policy making; allow health impact assessment, emissions projections, and AQ modeling studies; satisfy international reporting requirements; and inform the public and raise awareness. A review of the current setup for compiling emission inventories in Uzbekistan could identify the gaps, the need for update of emission calculation methodologies, needs for resources and technical expertise, involvement of main institutions responsible for sectoral data collection and dissemination, and the appropriate level of coordination with the GHG inventory and set the level of ambition for the emissions inventory system update. International best practices, including emissions calculation methodologies, are available and can inform and support the update and strengthening of the emissions inventory process in Uzbekistan.	Immediate	MoEEPCC Uzhydromet	Public (from budget) Technical assistance could be provided through projects of development partners and/or philanthropic organizations and/or international cooperation projects.
Data management and analysis				
Establish a comprehensive and easy-to-use data management system.	AQM is largely based on data—data on pollutants' concentrations, emissions, meteorology, and so on. Expanding the AQ monitoring network and strengthening the emissions inventory system will increase the needs for data collection, storage, processing, analysis, and dissemination. Therefore, a comprehensive and easy-to-use data management system should be put in place to facilitate AQM. A well-functioning data management system can also allow for conducting detailed AQ analyses, unify environmental data management, share information within institutions and with other institutional databases, and disseminate, including interactively, information to the public. A comprehensive data management system will also support the work of the suggested Situation Center to be established under MoEEPCC.	Immediate to Medium	MoEEPCC Uzhydromet Ministry of Emergency Situations	Public (from budget) Technical assistance could be provided through projects of development partners and/or philanthropic organizations and/or international cooperation projects.
Establish needs and capacities to perform AQ modeling, including forecasting.	AQ modeling is a key analytical component of the overall AQM. AQ modeling is heavily based on the input of reliable data and therefore, putting in place a comprehensive data management system will enable for capacities for AQ modeling to be established. In addition to having a well-developed data management system, AQ modeling software and technical capacities to perform AQ modeling are also needed and should be assessed before setting up AQ capabilities. AQ modeling can be used in various different ways, most notably to conduct source apportionment studies that identify the key contributors to air pollutants' concentrations; AQ forecasting that can serve as both a decision-making and a public communication tool; and scenario modeling to aid the choice of optimal AQM PaMs.	Medium	MoEEPCC Uzhydromet Ministry of Emergency Situations	Public (from budget) Technical assistance could be provided through projects of development partners and/or philanthropic organizations and/or international cooperation projects.

Measure	Description and rationale	Priority(*)	Suggested responsible institutions	Potential sources of financing
AQM policies and planning				
Develop a national AQM strategy.	A national AQM strategy sets the vision for the scope and direction of efforts to improve air quality at the national level. It would be beneficial if the process of drafting the AQM strategy is consultative so that buy-in is ensured from a variety of stakeholders—institutions, academia, businesses, and civil society.	Immediate	MoEEPCC	Public (from budget) Technical assistance could be provided through projects of development partners and/or philanthropic organizations and/or international cooperation projects
Review and update relevant legislation in line with the adopted AQM. Pay particular attention to legislation on pollution fees and taxes and development of green taxonomy for AQ improvement projects.	The legal framework should be reviewed and updated in line with the vision for AQM in the country. There might be legal acts or part of legal acts that are no longer aligned with the AQM vision and/or there might be a need to draft new/additional legislation to facilitate the implementation of the AQM strategy. For instance, revising pollution fees and taxes to provide clear incentives for enterprises to reduce pollution and improve performance by setting the level of pollution fees and taxes over the marginal abatement costs could incentivize enterprises to invest in cleaner production. In addition, developing a section of green taxonomy for AQ improvement projects could attract funding from additional sources for such projects.	Immediate to Medium	MoEEPCC Ministry of Economy and Finance	Public (from budget) Technical assistance could be provided through projects of development partners and/or philanthropic organizations and/or international cooperation projects.
Strengthen regulations and local capacities for AQM planning, including establishing AQM zones/agglomerations.	Parallel to reviewing national-level legislation, the capacities of local authorities for AQM planning could be evaluated and updated where needed. Most developed AQM systems divide the country into AQM zones/agglomerations that are responsible to draft and implement local AQM plans that adopt PaMs to improve air quality in the given territory.	Immediate to Medium	MoEEPCC Regional and city authorities	Public (from budget) Technical assistance could be provided through projects of development partners and/or philanthropic organizations and/or international cooperation projects.
Set up a mechanism for local authorities to implement emergency air quality measures in response to short-term air pollution episodes.	Emergency measures to address short-term episodes of air pollution adopted by local authorities typically involve actions aimed at reducing pollutant emissions, minimizing exposure, and protecting public health. The triggering of emergency air pollution measures is typically based on predefined thresholds or criteria established by authorities. Emergency measures to respond to short-term air pollution episodes can include several actions such as temporary traffic measures, including the promotion of alternative transport means, restrictions and bans on using certain fuels in residential and commercial buildings, restrictions on industries, and so on. Nevertheless, the design of an emergency measure or a mix of measures should be based on a combination of technical analyses, enabling regulatory frameworks, risk assessments, and public health considerations to identify the most appropriate and location-specific emergency measures.	Immediate to Medium	MoEEPCC Regional and city authorities	Public (from budget) Technical assistance could be provided through projects of development partners and/or philanthropic organizations and/or international cooperation projects.

Measure	Description and rationale	Priority(*)	Suggested responsible institutions	Potential sources of financing
Establish an AQM coordination mechanism.	Air quality is a cross-sectoral issue that requires solid coordination and cooperation to efficiently implement PaMs. Appropriate level of cooperation could be achieved by establishing an AQM coordination mechanism as deemed effective. The AQM coordination mechanism could be with high-level representation and supported by expert technical working groups or another structure of the coordination mechanism can be set up. The AQM coordination mechanism could be used as a venue to discuss important AQM issues such as the AQM strategy, the need for update of the legal framework, government roles and responsibilities, and so on.	Immediate	MoEEPCC - lead institution. However, higher-level support and buy-in are needed for the AQM mechanism to be effective.	Public (from budget) Technical assistance could be provided through projects of development partners and/ or philanthropic organizations and/or international cooperation projects.
Engage in international/regional cooperation in the area of AQM.	Air pollution does not recognize borders and therefore, cross-border cooperation in AQM could facilitate the exchange of data, know-how, and expertise and ultimately facilitate implementation of PaMs. Becoming a party to key conventions, such as CLRTAP, could also contribute to strengthening important AQM processes such as updating the emissions inventory system, for example.	Medium	MoEEPCC	Public (from budget) Technical assistance could be provided through projects of development partners and/ or philanthropic organizations and/or international cooperation projects.
PaMs in the industrial sector				
Strengthen industrial emissions regulations, including the industrial permitting process.	The design of the industrial emissions regulations and the permitting process are fundamental in how effective industrial emission reduction policies and control are. Well-designed permitting process could encourage cleaner industrial production, reduce emissions, improve resource use, strengthen accountability, and improve transparency. Consideration needs to be given to aspects such as strengthened process and capacities for setting of ELVs, emissions monitoring and reporting, use of emission control technologies, and integration of all environmental aspects in permitting. The EU experience in managing industrial emissions could serve as a potential benchmark for the strengthening of the industrial emissions regulations in Uzbekistan.	Medium	MoEEPCC	Public (from budget) Technical assistance could be provided through projects of development partners and/ or philanthropic organizations and/or international cooperation projects.
Mandate the installation, operation, and maintenance of highly efficient emissions control and automatic emission reporting equipment at key industrial enterprises.	Emissions control and abatement technologies are end-of-pipe solutions but could be made mandatory for industries with large emissions (for example, category I and II industries), which are not able to switch to zero-emission production processes. Emissions can be reduced by a large factor if efficient emissions controls are installed, operated, and maintained properly. Automatic emission reporting, on the other hand, can ensure transparency and immediate feedback on the efficiency and use of emissions control equipment. Requirements for the installation, operation, and maintenance of emissions control and emission reporting equipment could also be included in the setting of ELVs and/or in industrial permits.	Immediate—the activity is currently ongoing.[34]	MoEEPCC	Private (enterprises could be required to install emission controls as part of their permits) Commercial (loans for installation of emission controls at enterprises) Green financing (bonds, credits)

[34] Pursuant to Presidential Decree No. 81 and Presidential Resolution No. 171 dated May 31, 2023.

Measure	Description and rationale	Priority(*)	Suggested responsible institutions	Potential sources of financing
Promote cleaner industrial production through regulatory (for example, stricter ELVs, adoption of BAT), fiscal (for example, progressive pollution fees and charges, carbon tax, targeted financing), and/or market-based instruments (for example, ETS).	The most efficient industrial emissions management systems provide both regulatory requirements to limit emissions but also incentives for enterprises to reduce emissions through a variety of instruments—fiscal and/or market based. Inter-ministerial and stakeholder discussions will be needed to adopt the most relevant approach to promote cleaner industrial production in Uzbekistan.	Immediate to Medium	MoEEPCC Ministry of Investment, Industry and Trade Ministry of Economy and Finance	Public (through fiscal measures) Market based (in the case of market-based instruments) Technical assistance could be provided through projects of development partners and/or philanthropic organizations and/or international cooperation projects.
PaMs in the residential heating sector				
Identify priority interventions and policies to address air pollution from heating informed by a study on fuels and appliances used for residential and commercial heating in a targeted area—for example, Tashkent.	The conducted AQ assessment for Tashkent showed that heating on solid fuels (for example, coal, biomass) contributed up to 45 percent to $PM_{2.5}$ pollution in some winter months. Detailed information on the heating sector is not available and therefore, MoEEPCC, together with the Ministry of Energy and local authorities, could commission a study to assess the heating methods used by the population and by commercial actors in a target area—for instance, Tashkent. This study could inform an action plan for sustainable heating addressing key challenges, including low energy prices, lack of infrastructure, lack of financing, and behavioral inertia, and prioritizing the cost-efficient interventions to reduce air pollution from heating. This action plan will create a consultation platform for main stakeholders for regulation of pollution from heating. Economic incentives that could spur create demand for sustainable healing taking into account air pollution reduction criteria could be developed in parallel to the ongoing work of Ministry of Energy on fuel subsidies elimination. Inter-institutional cooperation and coordination could inform the adoption of PaMs in the heating sector such as improving the quality of fuels used for heating, improving the efficiency of heating appliances, switching to cleaner heating alternatives, and implementing energy efficiency measures.	Immediate to Medium	Ministry of Energy, MoEEPCC, Ministry of Agriculture, and local authorities	Public (from budget) Technical assistance could be provided through projects of development partners and/or philanthropic organizations and/or international cooperation projects.
PaMs to reduce windblown dust				
Pilot greening interventions in a city (for example, Tashkent) and analyze the impact on air quality	Analyzing the results from the AQ assessment performed for Tashkent as well as the wind patterns in the city could inform the selection of areas where greening interventions can be performed with the goal to reduce dust transport to the city. The impact on air quality can then be tracked using AQ monitoring, modeling, and other adequate analytical tools. The results from the pilot greening interventions can inform future greening measures to improve air quality in cities. In parallel, it is important to further analyze the sources of windblown dust that impact air quality in Tashkent and other Uzbek cities to design adequate PaMs. The origins of dust can be studied by analyzing performing chemical source apportionment studies and/or by conducting back-trajectory modeling.	Immediate Medium	MoEEPCC Uzhydromet Local authorities	Public (from budget) Project based (including projects by development partners and philanthropic organizations) Technical assistance could be provided through projects of development partners and/or philanthropic organizations and/or international cooperation projects.

Measure	Description and rationale	Priority(*)	Suggested responsible institutions	Potential sources of financing
Stakeholder engagement and communication				
Strengthen AQ information communication to the general public.	Support AQ information communication using various means: dedicated website(s), AQ apps, boards displaying AQ information in popular areas in the city, including AQ information in news (for example, in the weather forecast section) and publishing daily AQ bulletins. Developing AQ forecasting capacities will further aid AQ information communication as it will provide a forward-looking and actionable information to assist in people's personal decisions on limiting exposure to air pollution. Some AQ information communication (for example, from AQ monitoring stations) can be established relatively quickly, whereas for other types of communication (for example, AQ forecasting), additional capabilities as described in this roadmap should be established first.	Immediate to Medium	MoEEPCC Uzhydromet	Public (from budget) Project based (including projects by development partners and philanthropic organizations) Technical assistance could be provided through projects of development partners and/or philanthropic organizations and/or international cooperation projects.
Strengthen AQ information communication across institutions.	Set up channels for AQ information communication across institutions for various potential uses such as ▪ Alerts and notifications when pollutant limit values have been exceeded, ▪ Periodic reports on the state of AQ, and ▪ Periodic reports to assess the impact of PaMs implementation in specific cases. Some of the advanced inter-institutional AQ information communication might require a functioning data management system.	Medium	MoEEPCC Uzhydromet	Public (from budget) Project based (including projects by development partners and philanthropic organizations) Technical assistance could be provided through projects of development partners and/or philanthropic organizations and/or international cooperation projects.
AQM financing				
Establish financing mechanisms for the components of an AQM system.	Financing the components of the AQM system can come from a variety of sources—both budgetary and external. However, the financing needs for supporting the AQM system have to be established to support analysis of where the financing might come from. The financial needs can be established based on the ambition adopted in a national AQM strategy. After the financial needs are estimated, financing mechanisms for the components of the AQM system can be established in close cooperation with the Ministry of Economy and Finance. Green taxonomy rules and innovative financing mechanisms such as green financing and green loans could also be considered to support PaMs' implementation.	Medium	Ministry of Economy and Finance	Public (from budget) Project based (including projects by development partners and philanthropic organizations) Technical assistance could be provided through projects of development partners and/or philanthropic organizations and/or international cooperation projects.

Measure	Description and rationale	Priority(*)	Suggested responsible institutions	Potential sources of financing
AQM investments and policy reforms				
Prioritize investments and policy reforms for improved air quality.	Policy reforms are needed to update and strengthen the regulatory framework for AQM and facilitate emission reductions in key sectors. There are a number of potential areas where investments and policy reforms might be needed, but in the context of limited resources available, it is prudent to prioritize AQM investments and policy reforms. Both 'soft' investments and policy reforms in the sense that they do not directly and direct investments to reduce emissions from key sources are needed need to improve air quality. Investments in emission reductions across sectors are likely to require a larger financial resource than the 'soft' investments and hence, careful prioritization is necessary to optimize the cost-effectiveness of the investments. In any case, investments in emission reductions in key sectors should go hand in hand with policy reforms that facilitate and incentivize the uptake of emission reduction measures by the private sector.	Immediate	MoEEPCC	Public (from budget) Technical assistance could be provided through projects of development partners and/or philanthropic organizations and/or international cooperation projects.

Note: * Measures with the priority level 'Immediate' need to be implemented as soon as possible and are essential for the efficient functioning of the overall AQM system.
Measures with the priority level 'Immediate to Medium' are key for the overall functioning of the AQM system, but their execution might require that some of the measures with 'Immediate' priority have been implemented first or are being implemented.
Measures with the priority level 'Medium' are important for the functioning of the AQM system but do not have to be implemented as soon as possible and/or would benefit if measures labeled as 'Immediate' or 'Immediate to Medium' have been implemented or are being implemented.

2.7. Discussion: Short-Term Priority Actions

The suggested AQM roadmap might serve as a platform for further dialogue with government authorities on setting up a holistic and effective AQM system in Uzbekistan. The AQM roadmap suggests a number of measures for each component of the AQM system to support this discussion. However, it is recognized that authorities have an obligation to act on improving air quality and consequently protecting the health of citizens. Therefore, this chapter suggests potential short-term actions that can be implemented as a priority in the next one to two years and highlights links with recently issued Presidential decrees that have provisions for improved AQM and for implementation of sectoral PaMs (Table 9).

Table 9: Suggested short-term priority actions

Measure	Rationale for prioritization in the short term	Suggested responsible institutions	Potential sources of financing
AQM legislation, policies and planning			
Update national AQ standards to include standards for $PM_{2.5}$.	$PM_{2.5}$ is the air pollutant with the greatest damage to human health and hence, it is imperative that Uzbekistan adopts a $PM_{2.5}$ standard. In addition, adopting a national $PM_{2.5}$ standard will support the implementation of the measure for warning of the population for fine particles pollution during dust storms as envisioned in the Presidential decree on the implementation of the Uzbekistan 2030 strategy.[35]	MoH MoEEPCC	Public (from budget) Technical assistance could be provided through projects of development partners and/or philanthropic organizations and/or international cooperation projects.
Develop a national AQM strategy.	A national AQM strategy sets the vision for the scope and direction of efforts to improve air quality at the national level. The AQM strategy could include provisions for the strengthening of key components of the AQM cycle such as AQ monitoring, emission inventory compilation, and reporting as well as detailed PaMs for the key sectors contributing to air pollution.	MoEEPCC Uzhydromet	Public (from budget) Technical assistance could be provided through projects of development partners and/or philanthropic organizations and/or international cooperation projects.
Reform legislation on pollution fees and taxes (compensation payments).	Instead of focusing on a long list of air pollutants, the reformed system could focus on the key pollutants in terms of impact of health. To provide clear incentives for enterprises to reduce pollution and improve performance pollution, fees and taxes should be set over the marginal abatement costs. Implementation of this measure will support efforts to update compensation payments as described in Resolution 202 of the Council of Ministers from April 12, 2021.	MoEEPCC	Public (from budget) Technical assistance could be provided through projects of development partners and/or philanthropic organizations and/or international cooperation projects.

[35] Presidential decree "About State program for implementing the Uzbekistan 2030 strategy" from February 21, 2024: https://uza.uz/ru/posts/o-gosudarstvennoy-programme-po-realizacii-strategii-uzbekistan-2030-v-god-podderzhki-molodezhi-i-biznesa_570600.

Measure	Rationale for prioritization in the short term	Suggested responsible institutions	Potential sources of financing
Establish an AQM coordination mechanism.	Air quality is a cross-sectoral issue that requires solid coordination and cooperation to efficiently implement PaMs. Appropriate level of cooperation could be achieved by establishing an AQM coordination mechanism. The AQM coordination mechanism could be used as a venue to discuss important AQM issues such as the national AQM strategy, the need for update of the legal framework, government roles and responsibilities, and so on.	MoEEPCC Cabinet of Ministers President's Administra-tion	Public (from budget) Technical assistance could be provided through projects of development partners and/or philanthropic organizations and/or international cooperation projects.
PaMs in the industrial sector			
Strengthen industrial emissions regulations, including the industrial permitting process.	The design of the industrial emissions regulations and the permitting process are fundamental in how effective industrial emission reduction policies and control are. Well-designed permitting process could encourage cleaner industrial production, reduce emissions, improve resource use, strengthen accountability, and improve transparency. Implementation of this measure could also support the development of the proposed methodological manual on the calculation of GHG emissions by category I and II enterprises.	MoEEPCC	Public (from budget) Technical assistance could be provided through projects of development partners and/or philanthropic organizations and/or international cooperation projects.
Mandate the installation, operation, and maintenance of highly efficient emissions control and automatic emission reporting equipment at key industrial enterprises.	Emissions control and abatement technologies are end-of-pipe solutions but could be made mandatory for industries with large emissions (for example, category I and II industries), which are not able to switch to zero-emission production processes. Emissions can be reduced by a large factor if efficient emissions controls are installed, operated, and maintained properly. Automatic emission reporting, on the other hand, can ensure transparency and immediate feedback on the efficiency and use of emissions control equipment. Requirements for the installation, operation, and maintenance of emissions control and emission reporting equipment could also be included in the setting of ELVs and/or in industrial permits.	MoEEPCC	Private (enterprises could be required to install emission controls as part of their permits) Commercial (loans for installation of emission controls at enterprises) Green financing (bonds, credits)
PaMs in the transport sector			
Establish a work plan and coordinate with relevant institutions to advance legislation on reducing transport emissions.	Coordination with relevant institutions and local analyses could inform the choice of transport PaMs to be adopted: vehicle and fuel standards, vehicle measures, low-emission urban transport, and establishment of LEZs. While the main jurisdiction on the implementation of those measures falls on other institutions, MoEEPCC can take an active role in coordinating the process. Implementation of this measure will support MoEEPCC on fulfilling its obligations to facilitate emission reductions from the transport sector as described in Presidential Decree 171 of May 31, 2023.[36]	MoEEPCC Ministry of Transport Ministry of Internal Affairs Ministry of Energy Local authorities	Public (from budget) Technical assistance could be provided through projects of development partners and/or philanthropic organizations and/or international cooperation projects.

36 Presidential decree "On measures for the efficient organization of work of the Ministry of Ecology, Environmental Protection and Climate Change" from May 31, 2023: https://lex.uz/ru/docs/6479136.

Measure	Rationale for prioritization in the short term	Suggested responsible institutions	Potential sources of financing
PaMs in the heating sector			
Identify priority interventions and policies to address air pollution from heating informed by a study on fuels and appliances used for residential and commercial heating in a targeted area—for example, Tashkent.	The AQ assessment for Tashkent showed that heating on solid fuels (for example, coal, biomass) contributed up to 45 percent to $PM_{2.5}$ pollution in some winter months. Detailed information on the heating sector is not available and therefore, MoEEPCC, together with the Ministry of Energy and local authorities, could commission a study to assess the heating methods used by the population and by commercial actors in a target area—for instance, Tashkent. This study could inform an action plan for sustainable heating addressing key challenges, including low energy prices, lack of infrastructure, lack of financing, and behavioral inertia, and prioritizing the cost-efficient interventions to reduce air pollution from heating.	MoEEPCC Ministry of Energy Ministry of Agriculture Local authorities	Public (from budget) Technical assistance could be provided through projects of development partners and/or philanthropic organizations and/or international cooperation projects.
PaMs to reduce windblown dust			
Pilot greening interventions in a city (for example, Tashkent) and analyze the impact on air quality.	Analyzing the results from the AQ assessment performed for Tashkent as well as the wind patterns in the city could inform the selection of areas where greening interventions can be performed with the goal to reduce dust transport to the city. The impact on air quality can then be tracked using AQ monitoring, modeling, and other adequate analytical tools. The results from the pilot greening interventions can inform future greening measures to improve air quality in cities.	MoEEPCC Uzhydromet Local authorities	Public (from budget) Project based (including projects by development partners and philanthropic organizations) Technical assistance could be provided through projects of development partners and/or philanthropic organizations and/or international cooperation projects.
Stakeholder engagement and communication			
Strengthen AQ information communication to the general public.	Support AQ information communication using various means: dedicated website(s), AQ apps, boards displaying AQ information in popular areas in the city, including AQ information in news (for example, in the weather forecast section), and publishing daily AQ bulletins. Developing AQ forecasting capacities will further aid AQ information communication as it will provide a forward-looking and actionable information to assist in people's personal decisions on limiting exposure to air pollution. Some AQ information communication (for example, from AQ monitoring stations) can be established relatively quickly, whereas for other types of communication (for example, AQ forecasting), additional capabilities as described in this roadmap should be established first. Implementation of the measure will support warning of the population for fine particles pollution during dust storms as envisioned in the Presidential decree on the implementation of the Uzbekistan 2030 strategy.[37]	MoEEPCC Uzhydromet	Public (from budget) Project based (including projects by development partners and philanthropic organizations) Technical assistance could be provided through projects of development partners and/or philanthropic organizations and/or international cooperation projects.

[37] Presidential decree "About State Program for Implementing the Uzbekistan 2030 Strategy" from February 21, 2024: https://uza.uz/ru/posts/o-gosudarstvennoy-programme-po-realizacii-strategii-uzbekistan-2030-v-god-podderzhki-molodezhi-i-biznesa_570600.

In addition to the suggested short-term priority actions in Table 7, recently published decrees call for the short-term implementation of various other AQM measures. MoEEPCC has been tasked to develop a methodological manual for GHG emission estimation of category I and II enterprises. This methodological manual could potentially be expanded to cover air pollutants, thus supporting the strengthening of the ELV setting process. Moreover, the Resolution of the Cabinet of Ministers of the Republic of Uzbekistan "On measures to reduce the negative impact of vehicles on atmospheric air" provides for the establishment of vehicle emissions' monitoring posts in cities to detect and restrict the movement of vehicles not meeting the existing vehicle emission standards. Implementation of this measure could inform the need to revise vehicle emission standards to reduce emissions of harmful air pollutants.

The most recent Presidential decree on the implementation of the Uzbekistan 2030 strategy[38] **provides for the immediate implementation of measures related to dust and transport emission reductions.** The decree provides for establishing regional alert systems to warn the population of PM pollution as a result of dust storms. In addition, the decree stipulates that implementing dust control measures becomes mandatory for construction sites with areas over 500 m^2. Furthermore, the decree mandates a set of transport measures to be implemented in Tashkent such as restricting movement of cargo vehicles (over 10 tons) in peak hours and introducing a car-free day at least one working day a month. Moreover, the most impactful measure that the decree envisions is the staged restriction of the use of transport vehicles not meeting the Euro 5 emission standard in Tashkent, Nukus, and main regional cities by 2030.

Improving air quality is a long-term task; however, the suggested short-term actions described above could initiate a comprehensive process of effective AQM that establishes strong legal framework and achieves emission reductions from key sources. As previously mentioned, ensuring an enabling regulatory framework for AQM is key for the sustainable and systematic improvement of air quality. However, the measures that directly reduce emissions are the ones that bring about the actual air quality improvement. Therefore, the suggested short-term priority actions are a combination of 'soft' PaMs and PaMs that directly reduce emissions.

[38] Presidential decree "About State Program for Implementing the UZBEKISTAN 2030 Strategy" from February 21, 2024: https://uza.uz/ru/posts/o-gosudarstvennoy-programme-po-realizacii-strategii-uzbekistan-2030-v-god-podderzhki-molodezhi-i-biznesa_570600.

Conclusions and a Way Forward

This report consists of a technical assessment of air quality in Tashkent using state-of-the-art modeling tools, followed by a suggestion for the AQM roadmap to contribute to reforms and support the development of a long-term and holistic AQM vision. The findings from the technical assessment for Tashkent and the main components of the AQM roadmap are summarized below.

The technical assessment for Tashkent compiled all available data and information for the main $PM_{2.5}$ emissions sources in the Tashkent airshed and mapped those sources at a spatial resolution of approximately 1 by 1 km and a temporal resolution of 1 hour. This dynamic emissions map, coupled with 3D meteorological gridded data from the WRF model, was used in chemical transport modeling with the CAMx modeling system to simulate the dispersion of $PM_{2.5}$ pollution over the airshed and to identify the contributions of key emissions sources to $PM_{2.5}$ concentrations.[39]

$PM_{2.5}$ concentrations in Tashkent peak in the winter months and substantially exceed international air quality standards — for instance, the annual average $PM_{2.5}$ concentration in Tashkent is above 30 μg/m³ which exceeds over six times the WHO's annual average guideline of 5 μg/m³. This study estimated that around 3,000 premature deaths can be attributed to current levels of $PM_{2.5}$ pollution in Tashkent. As much as there are unfavorable meteorological conditions limiting the dispersion of air pollutants in Tashkent in the winter, such as low wind speeds and low mixing heights, anthropogenic sources have an important contribution to air pollution.

Overall, comparing the modeled $PM_{2.5}$ concentrations from this study with the monitored concentrations from Uzhydromet's and US Embassy's automatic air quality monitoring stations shows a 93 percent fit of the modeled and monitored data. Therefore, the modeled concentrations capture both the seasonal and spatial variations of air pollution in Tashkent as reported by the air quality monitoring networks. This underlines the robustness of the conducted modeling and hence the reliability of the study's findings.

Windblown dust—particles carried by wind into Tashkent from dust storms, adjoining areas such as agricultural and open fields, and a variety of emission sources outside the studied airshed — has the highest contribution to annual average $PM_{2.5}$ concentrations. The contribution of windblown dust to $PM_{2.5}$ concentrations is the highest in the summer months when concentrations are generally lower. Additional research on the origins of windblown dust that is transported to Tashkent as well as on the feasibility of implementing greening measures to mitigate the effects of windblown dust on $PM_{2.5}$ concentrations in the city is needed to design appropriate abatement measures.

Combustion of fuels for heating, especially coal, is the leading contributor to $PM_{2.5}$ concentrations in the winter in Tashkent — accounting for nearly 45 percent of $PM_{2.5}$ concentrations in the city in some winter months. In addition, the modeling demonstrated that the majority of coal use occurs outside of the urban area. Thus, coal combustion even outside Tashkent's urban area has a significant impact on $PM_{2.5}$ concentrations in the city boundaries. $PM_{2.5}$ pollution in Tashkent peaks in the winter months and thus, given the significant contribution of heating to $PM_{2.5}$ concentrations, reducing the emissions from this sector is a priority.

[39] As mentioned previously, emissions (the substances emitted directly from different sources) do not translate directly into concentrations (the pollution the population is exposed to). Therefore, a source with high emissions might not affect concentrations as much as a source that has lower emissions with more unfavorable dispersion characteristics (for example, low height of emissions' release).

Transport is the third largest contributor to $PM_{2.5}$ concentrations in Tashkent and is the second most important anthropogenic source of $PM_{2.5}$ pollution. The contribution of the industrial sector (heavy and light industries combined) is relatively stable throughout the year at about 12–13 percent. The other sources of $PM_{2.5}$ pollution in Tashkent have generally lower contributions. Urban dust from construction activities and resuspended dust from roads contribute about 6 percent to annual average $PM_{2.5}$ concentrations in Tashkent.

Tackling the sources of air pollution in Tashkent and other Uzbek cities requires the implementation of emission reduction PaMs in the key sectors responsible for air pollution. Implementing PaMs to reduce pollutant emissions is at the core of AQM systems. However, the AQM system works efficiently only if all components of the system are developed, including technical and financial components, in addition to PaMs. The AQM roadmap thus outlines and elaborates on priority measures in the short and medium term to strengthen overall AQM in Uzbekistan and bring it in line with components of an effective AQM system. The AQM roadmap suggests actions in the areas of expanding air quality monitoring, strengthening air quality legislation, namely setting standards, and developing AQM policies and technical capacities as well as approaches to financing the identified measures. Moreover, the AQM roadmap suggests approaches to streamline stakeholder engagement and inter-ministerial coordination and identifies potential priority areas for investments in air quality improvement.

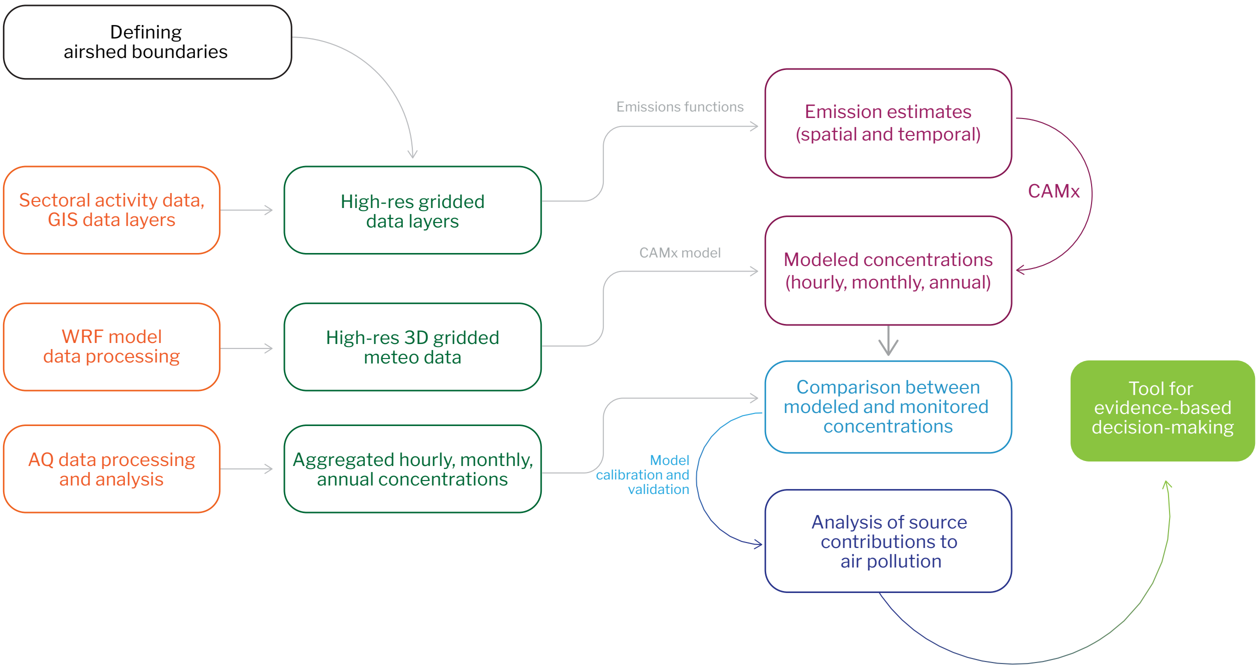
Improving air quality requires policy reforms and investments in emission reduction measures across sectors. Reducing emissions from the heating sector typically involves improving the quality of fuels used, improving the efficiency of heating appliances, implementing energy efficiency measures, and switching to cleaner heating means. The applicability, costs, and implementation modalities of these technical approaches to reduce heating emissions should be further studied. In addition, the use of solid fuels for heating in the commercial sector should be assessed in detail to design appropriate PaMs to limit the use of polluting fuels in the commercial sector. Measures to reduce transport emissions include setting standards for vehicles and fuels, regulating vehicle imports, improving the attractiveness and emission profile of public transport, incentivizing nonmotorized means for urban mobility, and implementing a LEZ. Cooperation and coordination of relevant institutions are necessary for identifying appropriate transport PaMs in the Uzbek context. Strengthening the industrial permitting process, adopting BATs, and incentivizing cleaner production are the main measures to reduce emissions from the industrial sector.

Nevertheless, it is important that sectoral PaMs and investments run parallel to the strengthening of the overall AQM system in the country as the components of the AQM system can inform where investments are needed and can provide the necessary information for evaluating the impact, effectiveness, and the need for calibration of those investments. The next step is discussing the measures suggested in the AQM roadmap within MoEEPCC and in government to agree on priority measures to invest in. Once a list of priority measures is agreed upon, assessment of implementation modalities, quantification of costs, and identification of sources of financing could follow. These processes might eliminate some measures from the initial list due to currently unsurmountable implementation barriers or prohibitively high costs. However, it is important that clear timelines and institutions responsible for the implementation of the final list of measures are established so that the implementation of PaMs brings the expected benefits of improved air quality and reduced GHGs.

Annex 1. Methodology and Data Used

This annex describes the approaches to emissions calculations and photochemical modeling used in this study. Figure A1.1 provides a schematic illustration of the methodology used in this study.

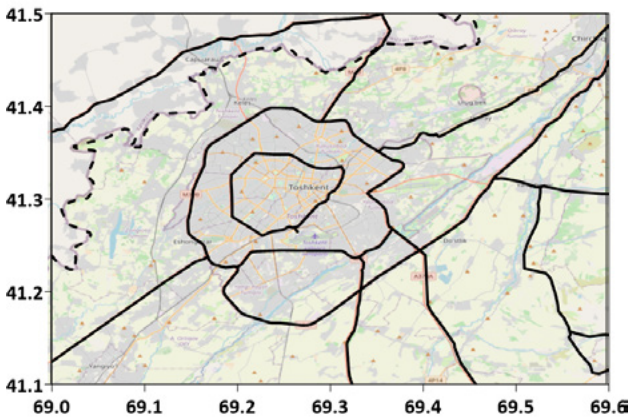
Figure A1.1: Schematic illustration of the study's methodology



Definition of the airshed's boundaries

An initial task was to define the area to be studied, that is, the airshed, in a way that captures emissions dispersion from sources that possibly affect air quality in Tashkent. Geo-scanning of Tashkent and the surrounding area using Google Earth was performed to identify potential emissions sources. The selected airshed spans 60 x 40 grids with a total area of about 2,400 km^2 (Figure A1.2). The area covers the main Tashkent city area and the neighboring regions with industrial estates, brick kilns, quarries, the existing airport, the new airport under construction, and waste management facilities—sources that might have an impact on air quality in Tashkent.

Figure A1.2: Tashkent's airshed



Source: World Bank and OpenStreetMap.

Note: Solid lines represent primary roads, dashed line—international border.

Since the spatial grid resolution for this study is 0.01°; that is, each grid is equivalent to 1 km2, all the collated information and analyzed results from the study are maintained in standard GIS-ready formats at this grid resolution. The GIS formats also allow for 3D modeling techniques to be used. Hence, the following key data layers for air pollution analysis are available for each grid cell of the defined airshed:

- Meteorological data layer
- Population layer
- Road network layer
- Level of urbanization layer
- Land use layer
- Topography layer
- Points of commercial activity layer (industries, hospitals, hotels, fuel stations, malls, markets, office complexes, banks, cafes, restaurants, convenience stores, and so on).

The high-resolution layers with key data allowed the estimation of emissions for each grid, thus enabling the creation of a spatially and temporally dynamic emissions map for the airshed (see Chapter I.3). The data from the resulting air pollution modeling are also available for each grid cell of the studied airshed and allow to spatially and temporally present the study's results (see Chapter I.4).

Data resources

To achieve high-resolution data and allow for dynamic spatial and temporal emission estimates and pollution modeling, this study used various sources of data—a combination of locally obtained data, data from global databases and published literature. Moreover, satellite data and data from globally recognized models were used to strengthen the foundations for the modeling conducted in this study.

Locally obtained data included the following:

- Air quality monitoring data from Uzbekistan's Center of Hydrometeorological Services (Uzhydromet), including data from the two reference automatic air quality stations in Tashkent.
- Data from Uzstat, including data on freight and passenger movement and number of registered vehicles.
- Information from TashTeploCentral (TTC) and TashTeploEnergo (TEC)[40] on the state, future development, and modernization of the district heating network in Tashkent.

In addition, the study utilized information from a number of global databases listed below:

- **AirNow.** The US Department of State's web-based platform for publishing air quality data from US EPA reference grade monitoring stations deployed at US embassies around the world. Data were obtained from the US Embassy air quality monitoring station in Tashkent.
- **IEA.** Energy policy review for Uzbekistan, including data on energy balance, fuels used, district heating and transport.
- **STATISTA.** A commercial data service site, which provides information on vehicle sales, registration by vehicle type and year, population, and GDP.
- **OpenStreetMap (OSM) database.** Used for information about the road network, covering highways, arterial, and feeder roads as well as for information about commercial activity points such as hotels, hospitals, apartment complexes, industries, parking lots, fuel stations, malls, markets, office and commercial complexes, banks, cafes, restaurants, and convenience stores.
- **European Space Agency (ESA)'s Global Human Settlements (GHS) Program.** Used for information on the built-up urban area in the airshed for the years of 1975, 1990, 2000, and 2014.
- **LANDSCAN program.** Provided information on gridded population at a 30-second resolution for the entire city airshed. This database uses official estimates from the respective governments at the district and ward levels, which is further segregated to finer grids using information on commercial, land use, and night light data fields.

[40] Uzbekistan Tashkent District Heating Modernization: Stakeholder Engagement Plan. June 2018.

- **FlightStats.** A commercial data service, which provides information on domestic and international flight schedules for airports in the airshed.
- **Google Earth.** Used for information on features of interest, identified while scanning the airshed, for which GIS fields are not readily available.
- **MOZART/WACCM modeling system.** Used for the analysis of the boundary conditions—determining the pollutant fluxes from surrounding areas into the defined airshed.
- **WRF modeling system.** All meteorological data were processed through the WRF modeling system at a spatial resolution of 0.01° and at a one-hour temporal resolution.
- **Greenhouse gas and Air pollution Interactions and Synergies (GAINS) model.** An emission factors database was extracted from the GAINS modeling system for the baseline emissions inventory.
- **Washington University in St. Louis.** The university runs a program for long-term $PM_{2.5}$ concentration data based on a global chemical transport model coupled with satellite retrievals.

Relevant data from published literature were also retrieved, including

- Industry data, including information on industries per district in Tashkent[41] and the TPP plant;[42]
- Waste data, including composition and characteristics of municipal solid waste;[43] and
- Public transport information used for assumptions in modal splits in Tashkent.[44]

Emissions calculations

The emission calculations utilized data from the different sources, described below, as well as expert judgment for spatially and temporally distributing emissions across the airshed. The emissions calculations' methodology for the main emissions sources is described in the sections below.

Heating

The main activity data needed for the estimation of heating emissions are the energy consumption for heating by fuels and the types of heating appliances used. Due to the lack of official data on those, the heating emissions estimates used a number of data sources to spatially and temporally distribute emissions as accurately as possible.

With regard to residential heating, Tashkent has the largest district heating network in Uzbekistan, but according to IEA, district heating meets about 40 percent of total heating demand in the city.[45] Therefore, this study assumes that buildings in Tashkent that are not connected to the district heating network (see Figure A1.3, top) use individual heating systems. Due to lack of detailed local data on residential heating, the estimated final consumption in the residential sector in an IEA report[46] was used as a proxy for the residential heating methods in Tashkent (see Figure A1.3, bottom).

41 Tolkacheva, G. A. 2007. "Problems of Air Quality in Tashkent City." Environmental Simulation Chambers: Application to Atmospheric Chemical Processes : 379–392. https://link.springer.com/chapter/10.1007/1-4020-4232-9_32.
Shardakova, L., and L. Usmanova. 2006. "Assessment of the Impact of Industrial Sources on Urban Air Quality in Tashkent." Air, Water and Soil Quality Modelling for Risk and Impact Assessment: 125–134. https://link.springer.com/chapter/10.1007/978-1-4020-5877-6_11.

42 Matjanov, E. 2019. "Gas Turbine Efficiency Enhancement Using Absorption Chiller." Case study for Tashkent CHP. Energy. https://www.sciencedirect.com/science/article/abs/pii/S0360544219323205?via%3Dihub.

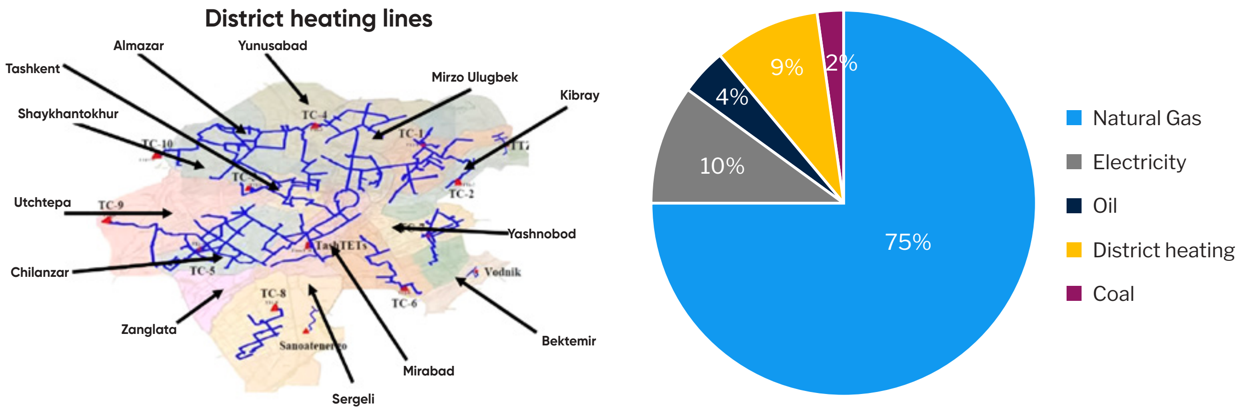
43 Tursunov, O., and N. Abduganiev. 2019. "A Comprehensive Study on Municipal Solid Waste Characteristics for Green Energy Recovery in Urta-Chirchik: A Case Study of Tashkent Region." Materials Today: Proceedings: 67–71. https://www.sciencedirect.com/science/article/abs/pii/S2214785319337915?via%3Dihub.

44 Berdiyorov, A., et al. 2021. "A Sustainable Model of Urban Public Mobility in Uzbekistan." IOP Conference Series: Earth and Environmental Science. https://iopscience.iop.org/article/10.1088/1755-1315/822/1/012008

45 IEA. 2022. Uzbekistan 2022: Energy Policy Review. https://www.iea.org/reports/uzbekistan-2022.

46 Ibid.

Figure A1.3: **District heating network in Tashkent (left) and final consumption in the residential sector by fuel (right)**



Source: TTC, TEC (left), IEA (right).

The modeling assumes that the need for residential heating is present when hourly ambient air temperatures are below 15°C and heating needs intensify the lower the hourly ambient temperatures are. It is also assumed that when coal is used for residential heating, the coal is combusted in standard heating stoves with no emissions control. The emissions factor for the coal stoves with no emissions control was taken from the GAINS database and equaled 480 g/GJ.

In addition to residential heating, information from MoEEPCC provided at a later stage in the technical assessment process suggests that there are a number of greenhouses outside Tashkent's urban area that use coal and in some cases fuel oil. More data and information are needed to comprehensively include the greenhouses in the emission inventory and modeling. Particular needs are establishing the location of the greenhouses, the types and amounts of fuels used, and the types of heating appliances.

Road transport

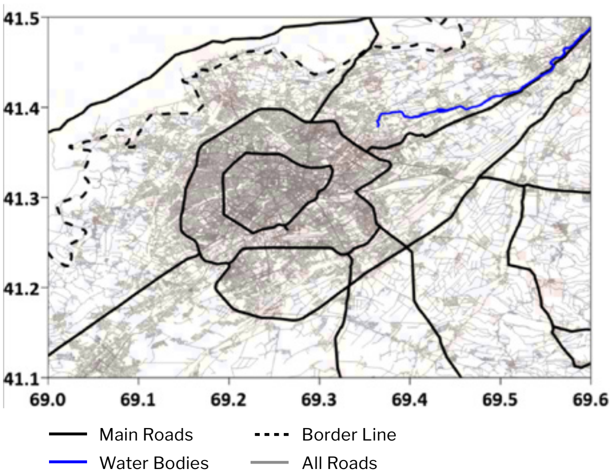
The main source of road transport data was the data on transported cargo and passengers published by Uzstat. The structure of the vehicle fleet in Tashkent airshed was then estimated proportionally from the national data on cargo moved (tons/day) and passengers transported (million passenger-km). Due to lack of Tashkent-specific data, some assumptions had to be made based on reviewing transport reports for Tashkent.[47] Thus, it was assumed that 10 percent of the total cargo moved in Uzbekistan passed through Tashkent airshed and 26 percent of the total passenger trips in the country happened in Tashkent airshed.

To spatially and temporally represent emissions from road transport and in the absence of traffic count data at different locations in Tashkent, a number of assumptions had to be made about the traffic flows in the city. The detailed, high-resolution layers of the road network, population, urbanization levels, and points of commercial interest were used to simulate traffic flows in the Tashkent airshed by developing traffic flow calculations as functions of a combination of parameters. For instance, heavy-duty traffic was assumed to use the primary roads and travel to and from the different industries in and around the city and private vehicle traffic was primarily flowing to and from points of interest (office complexes, commercial areas, hospitals, and so on). In terms of temporal distribution of traffic flows, morning and afternoon rush hours were modeled using office complexes, industries, and different institutions as indication of where traffic is flowing to (for example, to and from work/school), and an increase in traffic was simulated to occur on the main roads connecting Tashkent with the airport around the times of flight arrivals and departures.

47 Uzstat. Transport. https://stat.uz/en/official-statistics/services. Berdiyorov, A., et al. 2021. "A Sustainable Model of Urban Public Mobility in Uzbekistan." IOP Conference Series: Earth and Environmental Science. https://iopscience.iop.org/article/10.1088/1755-1315/822/1/012008

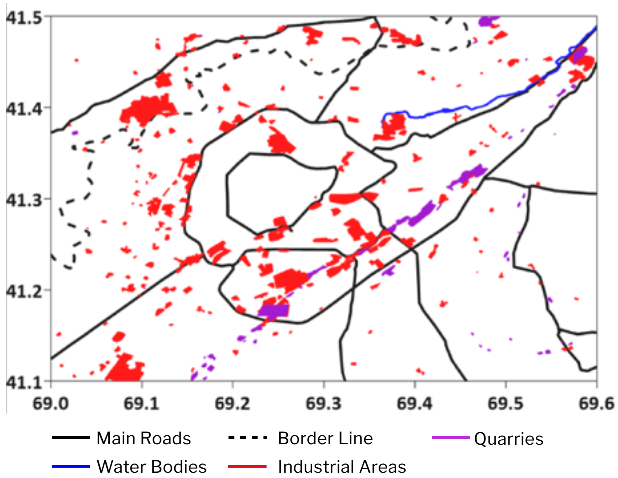
In general, traffic flows were spatially and temporally distributed along 1,160 km of primary roads, 570 km of secondary roads, 9,600 km of tertiary roads, and 3,680 km of other roads across the defined airshed (Figure A 4).

Figure A1.4: Road network in the Tashkent airshed



Source: World Bank.

Figure A1.5: Locations of the industrial areas in the Tashkent airshed



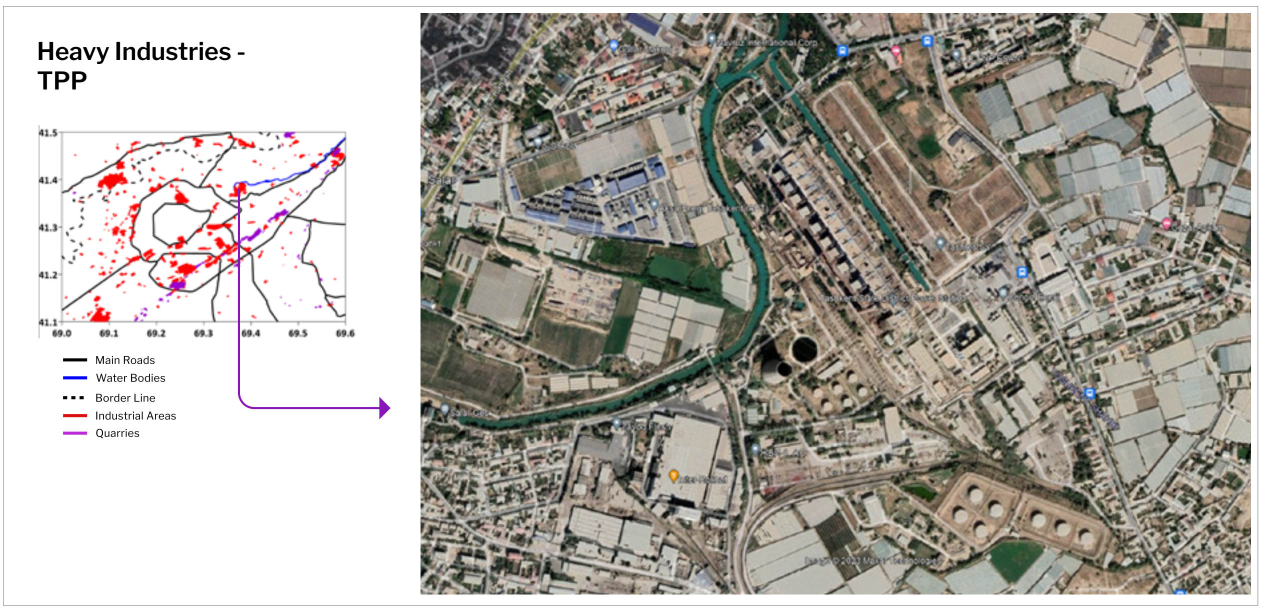
Source: World Bank.

Industry

The identified industrial areas in Tashkent are shown in Figure A1.5. The industries in Tashkent were divided into two categories — heavy industry and light industry. Heavy industries include the TPP, a metal factory, and a foundry (see Figure A1.6), the remaining industrial areas were included in the light industry category.

Emissions for heavy industries were primarily calculated based on the plants' production data and information from IEA's energy balance for Uzbekistan. The remaining industrial energy consumption in the energy balance was then attributed to the light industries.

Figure A1.6: Heavy industry in Tashkent



Heavy Industries - Metal factory

Heavy Industries - Foundry

Source: World Bank and Google Earth.

Industrial areas are also important when simulating traffic flows as the traffic flows' functions assume heavy-duty vehicle traffic primarily going to and from industrial areas as well as some private vehicle traffic going to and from industrial areas (for example, for work and commercial activities).

Open waste burning

Air pollution from the waste sector mainly occurs through open waste burning. The estimation of $PM_{2.5}$ emissions from open waste burning used a published analysis on municipal solid waste in Tashkent.[48]

Brick kilns

Emissions from brick production arise from the fuels used in the kiln and the open-air drying of the bricks. There are two brick kiln complexes in the defined airshed, mainly outside of Tashkent city (Figure A1.7). The estimation of emissions from brick kilns used assumed production given the kiln areas as measured using Google Earth and the relevant emission factor for brick production of this scale (approximately 20,000 bricks per day).

48 Tursunov, O., and N. Abduganiev. 2019. "A Comprehensive Study on Municipal Solid Waste Characteristics for Green Energy Recovery in Urta-Chirchik: A Case Study of Tashkent Region." Materials Today: Proceedings: 67–71. https://www.sciencedirect.com/science/article/abs/pii/S2214785319337915?via%3Dihub

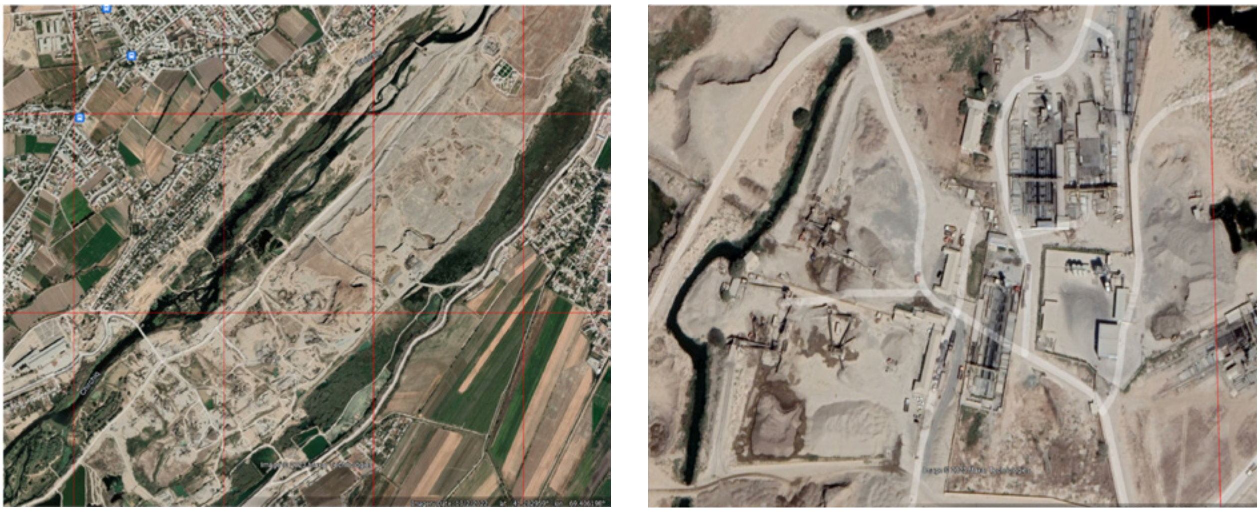
Figure A1.7: Brick kilns in Tashkent's airshed

Source: Google Earth.

Quarries

The location of quarries in Tashkent's airshed is shown with purple in Figure A1.5. Emissions from quarries arise from the crushing equipment using fossil fuels (for example, predominantly diesel) and emissions from the open quarry area (Figure A1.8). Google Earth imaging was used to identify the production practices at the quarries and their surface area (total of 24.1 km^2). Global databases and emission factors specific for quarries were used to estimate emissions from this source.

Figure A1.8: Quarries in Tashkent's airshed



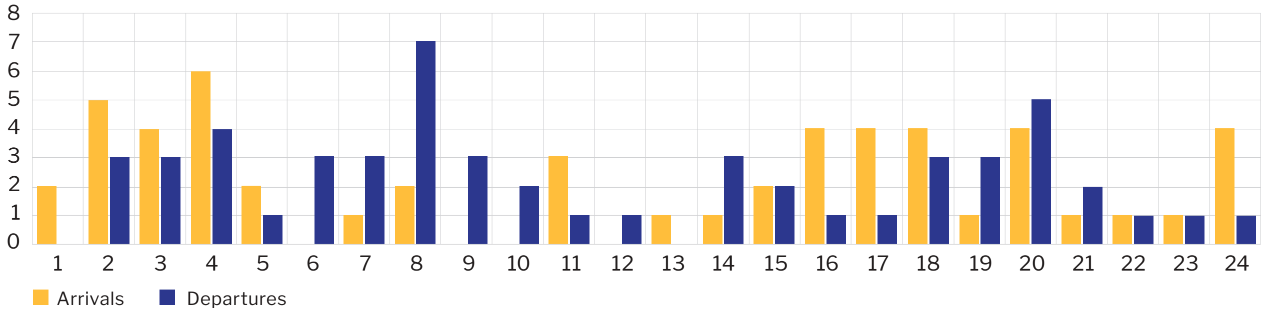
Source: Google Earth.

Islam Karimov Tashkent International Airport

Based on information about landings and take-offs, standard emission factors used for landings, take-offs, passenger, and freight shuttling were applied to estimate emissions from airport operations. The exact number of landings and take-offs per hour was obtained from the commercial flight database FlightStats[49] (Figure A1.9). The data on landings and take-offs were also incorporated into the traffic flows' functions—an increase in traffic on the main roads connecting Tashkent city and the airport was modeled around the time of landings and take-offs.

[49] https://www.flightstats.com

Figure A1.9: Hourly landings and take-offs at Islam Karimov Tashkent International Airport



Source: FlightStats

Note: Hours of the day represented on the horizontal (x) axis, number of arrivals/departures—on vertical (y) axis.

Analysis of other sources of $PM_{2.5}$ pollution

$PM_{2.5}$ pollution can also occur due to natural dust events and dust transport as well as from other urban-level activities such as construction and road dust resuspension. For this study, urban dust was defined as resuspension of dust on the roads and dust from construction activities occurring inside the defined airshed presented on Figure A1.2. On the other hand, boundary or windblown dust represents dust coming from outside the defined airshed (outside the area pictured on Figure A1.2) due to natural dust events, $PM_{2.5}$ transport from barren, agricultural land or emission sources located outside the airshed, and so on.

Urban dust

Urban dust consists of two main components—resuspension of dust on roads and dust from construction activities. Road dust resuspension is a function of silt loading on the roads, mix of vehicles on the roads (represented as fleet average vehicle weight), and vehicle-km-traveled. Data on vehicle fleet and vehicle-km-traveled were estimated from the available transport data published by Uzstat.

Similarly, for construction dust, the calculation is a function of the amount of area under construction and a coefficient for the expected dust erosion. The amount of area under construction was assumed to be the annual difference in the built area reported in the ESA's GHS Program.

The study utilized the calculation method for urban dust standardized by US EPA in its US-AP42 protocol.[50] Dust resuspension following the US-AP42 protocol is a standard urban dust resuspension calculation method applied by institutions and academia around the world. In addition, the urban dust emissions are suppressed in the modeling whenever the grid experiences rain or some precipitation and therefore, urban dust contribution to $PM_{2.5}$ concentrations is assessed dynamically considering the meteorological conditions.

Windblown dust

Natural dust events and dust transport from barren, agricultural land and commercial activities outside the defined airshed giving rise to windblown dust affect $PM_{2.5}$ concentrations across the globe. Global model data show that windblown dust is an important contributor to $PM_{2.5}$ concentrations in the Central Asia region. The Global Burden of Disease-Major Air Pollution Sources (GBD-MAPS) database estimates that 44 percent of $PM_{2.5}$ concentrations in Central Asia are attributed to windblown dust.[51]

The boundary conditions for the air quality modeling in Tashkent were taken from the MOZART/WACCM global model[52] which is one of the models and pre-processors included in the CAMx modeling system used in this study. Given the well-documented occurrence of dust events in the region, it is assumed that most of the boundary activity is windblown dust.

50 US EPA. AP42 protocol. https://www3.epa.gov/ttnchie1/ap42/ch13.

51 Washington University in St. Louis. Atmospheric Composition Analysis Group: GDB-MAPS – Global. https://costofairpollution.shinyapps.io/gbd_map_global_source_shinyapp/.

52 https://www2.acom.ucar.edu/gcm/waccm.

The analysis for Tashkent uses the calculations from the global model MOZART/WACCM, in which the windblown dust is calculated using two main factors—presence of dry and dusty land and the wind speeds above a certain threshold for the dust to uplift, entrain, and get transported. In this way, the model dynamically calculates for each grid of the defined airshed the $PM_{2.5}$ load that is attributable to windblown dust. The MOZART/WACCM model is well-established and has multiple applications globally, including in areas like the Sahara, the Gobi, and the Middle East.

CO_2 emissions estimation

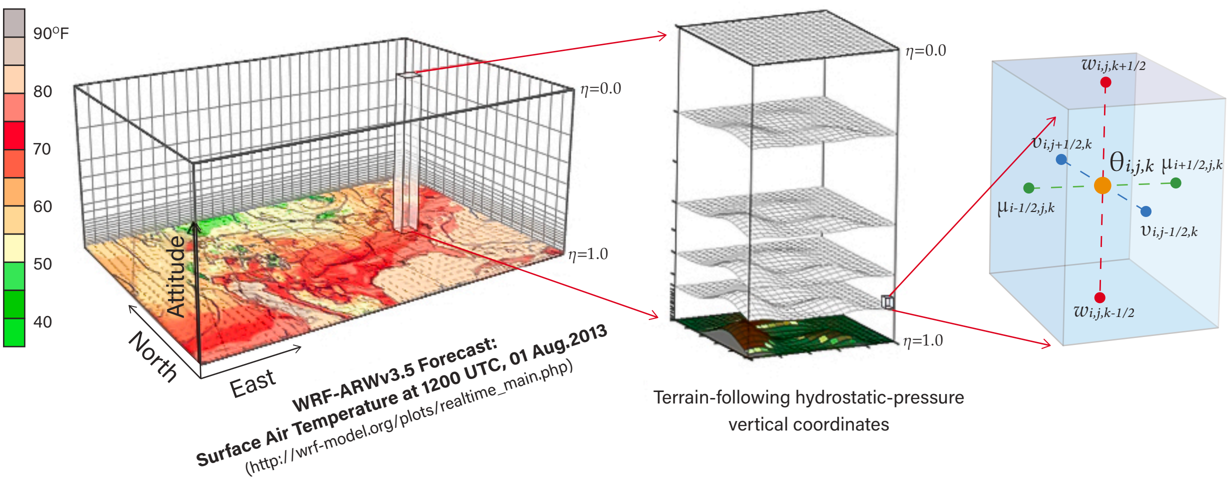
The baseline CO_2 emissions in Tashkent use the same activity data as that used for the $PM_{2.5}$ emissions calculations, presented above. CO_2 emissions are directly proportional to the carbon content of fuels and therefore, CO_2 emissions in Tashkent were calculated from the compiled energy and fuel data described above.

Approach to modeling

Modeling of air pollution utilizes meteorological data and emissions data to simulate the dispersion of air pollution over an airshed. Using the approaches for emissions calculations presented above, this study created a spatially and temporally dynamic emissions map for the defined airshed. The emission data were then coupled with spatially and temporally dynamic meteorological data layer to allow for high-resolution modeling at an hourly scale. This study used CAMx, which incorporates meteorological inputs from the WRF model.

There are several chemical transport models available with varying degrees of complexities in handling and processing the emissions and providing the final output in the form of concentrations. These range from simple box models to moderate physics and chemistry models using Lagrangian and Gaussian solvers to Eulerian models that are capable of processing the emissions in a 3D setting considering both advection and chemical transformations to the fullest extent possible. CAMx is an open-source, Eulerian state-of-the-art modeling system which aids in evaluating not only total concentrations but also in apportioning sources and regions at regional and urban scales and at multiple time scales and therefore was deemed as the most appropriate model to fulfill the study's objec-tives. The CAMx modeling system has several applications as federal- and state-level case studies in the United States and multiple research applications worldwide.

Figure A1.10: 3D meteorological modeling with WRF model

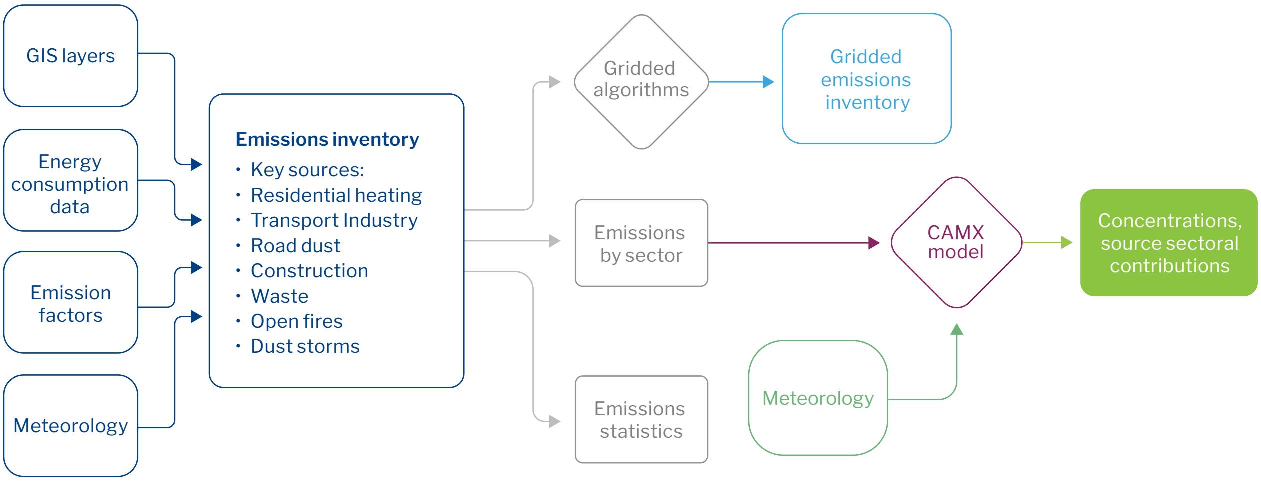


Source: WRF model.

WRF is a state-of-the-art mesoscale numerical model widely used for atmospheric research. WRF is used in a number of national meteo-rological centers across the world. With the help of the WRF model, 3D meteorological data were prepared for this study. The meteorological data are available at a spatial resolution of 0.01° and at a one-hour temporal resolution. The 3D meteorological modeling that was conducted using WRF allows for the consideration of topography's impact on meteorological parameters and provides realistic simulations of the relevant meteorological conditions for air pollution modeling (Figure A1.10).

The CAMx model is a state-of-the-art photo-chemical model for simulating dispersion of air pollutants over varying scales—ranging from micro (neighborhood) to macro (continent) scale. CAMx is supported by a number of institutions, including the US EPA. The CAMx modeling system has a complex modular architecture that combines inputs from other modeling systems (such as WRF) and user pre-processed data. The core components of CAMx include input data for emissions calculations (for example, energy consumption data and emissions factors), GIS layers, and meteorological data that are then processed by CAMx to result in modeled pollutant concentrations and source sectoral contributions to those concentrations (Figure A1.11).

Figure A1.11: Schematic diagram of the CAMx modeling system



Source: CAMx model.

As mentioned above, the WRF model was the source of meteorological input data to CAMx. With regard to emissions data, emissions are treated in two main ways in CAMx:

- Gridded emissions that are released in each 3D cell of the defined airshed
- Point emissions for which each emitting stack is associated with coordinates and a time-varying emission function.

Residential, commercial, mobile, non-industrial, small industrial, and natural emission sources were defined as gridded emissions and are characterized by space- and time-varying emission rates. The emission rates are influenced by the additional layers included in CAMx for this study such as population distribution, housing density, road transport network, and vegetative cover.

Large stationary sources such as the TPP, for instance, were modeled as point emissions. In contrast to gridded emissions, the point emissions are associated with a specific location, but the emissions rates are still time varying. The plume rise from point emissions sources is determined by CAMx and depends on stack-specific parameters such as height, diameter, velocity, and temperature of exiting gases. These parameters coupled with the ambient meteorological conditions provide the individual temporal emission rates of each point source.

Moreover, CAMx has a built-in module for PM source apportionment to identify the sources of PM pollution. CAMx uses multiple tracer families to identify the sources of primary PM emissions and secondary formation of PM in the atmosphere. By including secondary formation of PM, CAMx simulates the actual atmospheric chemistry and provides a robust source apportionment analysis which is an essential tool for decision-making in AQM.

Annex 2. References to Global Databases Used in the Study

- AirNow, US Department of State, https://www.airnow.gov/?city=Tashkent&country=UZB;
- IEA, energy policy review for Uzbekistan https://www.iea.org/reports/uzbekistan-2022;
- STATISTA: a commercial data service site https://www.statista.com;
- OpenStreetMap (OSM), road network database https://www.openstreetmap.org;
- ESA's GHS Program, information on built-up urban area https://ghsl.jrc.ec.europa.eu/datasets.php;
- LANDSCAN program, information on gridded population https://landscan.ornl.gov/;
- FlightStats, a commercial data service with information on domestic and international flight schedules https://www.flightstats.com;
- Google Earth, information on features of interest for which GIS fields are not readily available: https://earth.google.com/web/;
- WRF modeling system, meteorological data processing https://www.mmm.ucar.edu/models/wrf;
- Greenhouse gas and Air pollution Interactions and Synergies (GAINS) model, emission factors database https://gains.iiasa.ac.at/models;
- Washington University in St. Louis, long-term global $PM_{2.5}$ concentration data https://sites.wustl.edu/acag/datasets/.

Annex 3. CO_2 Emissions in Tashkent

To evaluate the overlap or lack of the key air pollution and GHG emissions sources, in addition to compiling activity data about the main $PM_{2.5}$ emissions sources in Tashkent and estimating the emissions from those sources, this study estimated CO_2 emissions. The resulting emissions estimates are presented in Table A3.1. For a description of the methodology used for the emissions estimates, see Annex 1.

The largest source of annual CO_2 emissions in Tashkent is transport, accounting for almost half of the emissions in the city. The industrial sector is the second largest source of CO_2 emissions in Tashkent and is responsible for just over 40 percent of annual emissions. Burning coal in the heating sector is the third most important source of CO_2 emissions in Tashkent. The ranking of CO_2 emission sources differs from that of $PM_{2.5}$ emission sources. Heating is the largest $PM_{2.5}$ emission source (third largest CO_2 emission source), followed by transport (the largest CO_2 emission source) and industry (the second largest CO_2 emission source).

Table A3.1: Estimated CO_2 emissions in Tashkent in 2021

Emissions source	Description	CO_2 emissions, tons/year
Heating	Includes emissions from residential and commercial heating and cooking	710,350
Transport	Includes all road transport and emissions from the airport	3,071,300
Industries	Includes emissions from the TPP, other industries, quarries, brick kilns, and diesel generators at commercial buildings	2,671,700
Open waste burning	Includes emissions from open waste burning around the airshed	2,200
Total		**6,455,550**

Source: World Bank.

The emissions calculations show a common but important discrepancy between the priority emissions sources for GHGs and for air pollution (in this case $PM_{2.5}$). This discrepancy highlights the need to design integrated air pollution and GHG reduction PaMs to maximize co-benefits and efficiently manage trade-offs stemming from differences in priority sources to be addressed. A key trade-off between air pollution and climate change policies is the use of biomass for heating. The use of biomass for heating is a key source of $PM_{2.5}$ emissions, but if biomass is sustainably sourced, it is considered to be climate neutral. However, the use of biomass for heating in Uzbekistan is low and hence, reducing fossil fuel use in heating and transport and incentivizing cleaner industrial production will ensure co-benefits that contribute to achieving both local air quality and climate change mitigation objectives.

Air Quality Assessment for Tashkent and the Roadmap for Air Quality Management Improvement in Uzbekistan

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