



Smog in Bishkek: Myths and Reality

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August 2021

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This research was carried out with a grant provided by the American University of Central Asia for the purpose of conducting research on the issue of air quality in Bishkek city, the Kyrgyz Republic.

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Abstract

Main objective of the research is to improve current understanding of the causes and impacts of the winter air pollution in Bishkek. Analysis of the extreme pollution events in Bishkek during the observed period showed that the impact of the climatic conditions on air pollution level in Bishkek is very significant.

Based on the inventories of air pollution in other countries and approximate quantification of the major PM_{2.5} sources in Bishkek, we came up to the following estimates:

- The source contributing most to anthropogenic PM_{2.5} pollution in Bishkek during the average heating season is "Households and other buildings not connected to CHP";
- Next most important source is CHP. However, it is difficult to estimate how much CHP contributes to the PM_{2.5} levels in Bishkek without detailed information on the effectiveness of the emission control system installed at the plant;
- Third most important source of the PM_{2.5} winter pollution is road transport.

The coal-based emission has increased by 22% in last six years. The coal consumption has been increasing and the data shows that this growth trend has been stable.

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List of abbreviations

ADB	Asian Development Bank
AQI	Air Quality Index
CHP	Central Heat and Power Plant
DAQI	Daily Air Quality Index
EPA	United States Environmental Protection Agency
HCOH	Formaldehyde
IEA	International Energy Agency
KIHS	Kyrgyz Integrated Households' Survey
KRSU	Kyrgyz Russian Slavonic University
NO _x	Mono-nitrogen oxides – nitric oxide and nitrogen dioxide
NSC	National Statistics Committee of Kyrgyzstan
PA	Public Association
PM	Particulate Matter
PM _{2.5}	Particulate matter with diameter less than 2.5 microns
PM ₁₀	Particulate matter with diameter less than 10 microns
US	United States
USA	United States of America
VSL	Value of Statistical Life
µg	Microgram, one millionth (1×10 ⁻⁶) of a gram

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Research outline

The air pollution situation in Bishkek in the recent winter periods was unprecedented. For significant periods of time, the Air Quality Index of Bishkek city topped the global air quality index (AQI) rankings. Local sensors registered several days where readings exceeded 500 μg for $\text{PM}_{2.5}$, much higher than the hazardous level of 300 μg . Air pollution is a major threat to human health and a leading cause of death and disease globally. An estimated 7 million premature deaths globally are linked to air pollution, mainly from heart disease, stroke, chronic obstructive pulmonary disease, lung cancer, and acute respiratory infections (WHO 2016). Kyrgyzstan is among the countries affected by this crisis. Data from the Kyrgyz Hydrometeorological Service (Kyrgyzhydromet) and independent researchers confirm that during the winter months, the concentration of dangerous air pollutants such as fine particulate matter ($\text{PM}_{2.5}$) and nitrogen oxides in Bishkek regularly exceeds WHO guidelines and Kyrgyz Government target values. Frequent temperature inversions in Bishkek contribute to exacerbating the problem. In recent months, several episodes of extremely high concentrations have landed Bishkek at the top of the AirVisual ranking for the cities with the worst air quality around the world (iqair.com). Cases of child asthma and respiratory disease related morbidity increase annually (NSC 2020). Independent research on air pollution in Kyrgyzstan has been carried out by researchers at different universities and civil society organizations since the early 2010s.

Data on $\text{PM}_{2.5}$ is available from a growing network of independently operated low-cost sensors, which are however of uncertain quality. In February 2019, the US Embassy installed a high quality Beta Attenuation Monitor on its premises and is making data available online at www.Airnow.gov for analysis. Data on $\text{PM}_{2.5}$ from low-cost monitors installed around Bishkek by civil society and private individuals is available also online through a platform with open environmental data specialising on air quality data called www.Sensor.Community (previously known as www.Luftdaten.info). Several private organizations around Bishkek have installed $\text{PM}_{2.5}$ sensors on their premises and the data is available through the websites of sensor manufacturers such as Purple Air. However, there is no quality control of the data from these individual sensors. Data on other pollutants such as nitrous oxides, sulphur dioxide, and ground level ozone is only available from individual sensors of Kyrgyzhydromet and KRSU. Recently, Public Association Movegreen in partnership with KyrgyzHydromet has launched a new platform www.aq.kg where air pollution and climatic data from multiple sensors is available in real-time mode. However, historical data is not yet accessible. The research team obtained available data and conducted analyses to provide insights into the levels and the frequency of pollution events, as well as the key factors leading to winter air pollution in Bishkek.

The problem with winter air pollution is a regular subject for active public discussions in Bishkek for the last several years. To date, there is no clear understanding of the major sources of the pollution, as there are divided opinions on that among stakeholders and

experts. Currently, data on air quality comes from many sources, including low-cost monitors as well as professional sensors. All of them show very high level of air pollution in Bishkek during winter months. However, there are still many gaps in the analysis of this problem. Our research will build on accumulated data and knowledge, but will make further steps forward in answering specific questions that were not answered yet.

In the beginning of 2021, PA Movegreen and environmental activist Pavel Isaenko published new reports which highlighted significance of the thermal inversions in the winter smog formation in Bishkek. Thus, Movegreen report for the winter season of 2020-2021 (Movegreen 2021a) indicated that PM_{2.5} average daily concentrations in December 2020 and January 2021 exceeded the respective Kyrgyz standards in the range from 8 to 12 times. NO₂ average monthly concentrations were 1.2 to 3.5 times higher than should be. Especially high concentration were observed in the town center where monthly concentrations of NO_x and HCOH were exceeded for up to 6 times. Highest PM concentrations were observed during the timeslot from 18.00 till 01.00. In other report (Movegreen 2021b) it was noted that the periods of highest PM concentrations coincided with the days with average temperature colder than -5, leading to suggestion that cold spells could be linked with cases of smog. Pavel Isaenko (Isaenko 2021) also suggested that the geographical and meteorological features of the Chuy valley play a tangible role in Bishkek's predisposition for air pollution. Earlier Oleg Podrezov (Podrezov 2018) revealed that winter meteorological conditions in Bishkek are very conducive for smog.

Main objective of the current research is to improve the understanding of the causes and impacts of the winter air pollution in Bishkek. In particular, our research will look at the following major questions:

1. What is the correlation between the temperature inversions and cases of high levels of air pollution in Bishkek?
2. Which of the major winter air pollution sources (Central Heat Plant, vehicles, households' heating) are the most important factors in winter smog?
3. What are the economic costs of air pollution in Bishkek?

Changes made

During the research activities no major alterations from the proposed research outline were made. However, field measurements of the vehicle emissions from their tailpipes were not implemented due to reluctance of the laboratories' personnel and technical difficulties to conduct such measurements. Instead, research team agreed to get access to the existing data on vehicle emissions. Such approach proved to be more effective both time wise and logistically.

Work completed

Desk review

In general, there are not many publications on air pollution in Kyrgyzstan. The bulk of the materials were published in Russian. Therefore, all the relevant recent publications on the topic of air pollution in Bishkek were checked by the research team to delve deeper into the study topics and understand the current gaps in the knowledge and research. Thus, most recent Movegreen reports, publications of Oleg Podrezov from the Kyrgyz Russian Slavonic University, and civil environmental activist Pavel Isayenko were downloaded and studied. Latest updates in the news related to air pollution in Kyrgyzstan were also studied thoroughly. The topic of air pollution in Bishkek is quite acute and there are many stakeholders and interested parties with various opinions on the subject.

Activities on data collection

Data collection is one of the main bottlenecks that intricate research activities in the Kyrgyz Republic. We contacted all relevant stakeholders to get available information and data. The following organizations were contacted:

1. National Statistics Committee. They gave us information on number of passenger cars registered in Bishkek, statistics on import of coal in recent years, data on number of households officially registered in Bishkek, share of households using coal and firewood for heating purposes;
2. Database from the Kyrgyz Integrated Household Survey (KIHS) was also purchased from the NSC for three most recent available years – 2017, 2018, 2019 (this database was already shared with colleagues from the AUCA economic department). The KIHS database provides in-depth data about households in all regions and towns of the country;
3. Data on quality and quantity of the coal used by Central Heat Plant (ТЭЦ) was received from the JSC “Electric Stations”;
4. Field survey was conducted by AUCA students to estimate average fuel consumption and mileage covered by average Bishkek car drivers. For this survey a short questionnaire was developed by researchers;
5. Data on vehicle emissions were received from the “Kochkortehosmotrservis LLC” (one of the laboratories that conduct measurements of the vehicle emissions in Bishkek). The staff of this laboratory was very cooperative and provided their data on free-of-charge basis. Due to this cooperativeness, there was no need for research team to organize separate field measurements of the vehicle emissions;
6. Meteorological data was acquired with the help of the specialised Russian meteorological platform that provides climatic data on post-soviet countries on free-of-charge basis. In particular, research team downloaded available climatic

data for the years 2019, 2020 and 2021 for two weather stations – Bishkek and Baitik;

7. Available air pollution data was screened and the researchers decided to select the sensor installed at the USA Embassy in Bishkek. Data from Kyrgyzhydromet sensor was not easily accessible. ADB-purchased sensors started monitoring only in spring 2021. US Embassy started monitoring of the air pollution in Bishkek in February 2019, therefore our study also focused namely on the period from February 2019 till July 2021.

Conducted analysis

What is the correlation between the temperature inversions and cases of high levels of air pollution in Bishkek?

Contemporary public discussions of the air pollution very often refer to the Air Quality Index (AQI). AQI is relatively new term which was introduced by United States Environmental Protection Agency (US EPA). EPA defines U.S. AQI as a daily color-coded index designed to communicate whether air quality in a given location is healthy or unhealthy for people. AQI for particulate matter is given below (taken from <https://www.air-now.gov/aqi/aqi-basics/>).

Daily AQI Color	Levels of Concern	Values of Index	Description of Air Quality
Green	Good	0 to 50	Air quality is satisfactory, and air pollution poses little or no risk.
Yellow	Moderate	51 to 100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
Orange	Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
Red	Unhealthy	151 to 200	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Purple	Very Unhealthy	201 to 300	Health alert: The risk of health effects is increased for everyone.
Maroon	Hazardous	301 and higher	Health warning of emergency conditions: everyone is more likely to be affected.

It should be noted that the interconnection between AQI and pollution level from Particulate Matter (PM) is not a straightforward one. The following table is based on EPA reference document (US EPA 2018) and provides detailed correspondence between AQI categories and PM pollution levels:

Table 1: AQI Scale and corresponding PM concentrations (source: EPA)

AQI Scale	Particulate Matter (μg per cubic meter)	
	PM2.5 [24-hour]	PM10 [24-hour]
Good (up to 50)	0 – 12	0 -54
Moderate (51 – 100)	12.1 – 35.4	55 - 154
Unhealthy for sensitive groups (101 – 150)	35.5 – 55.4	155 - 254
Unhealthy (151 -200)	55.5 – 150.4	255 - 354
Very unhealthy (201 – 300)	150.5 – 250.4	255 - 424
Hazardous (301 – 500)	250.5 – 500.4	425 - 604

Apart from the AQI there are other alternative air quality scales used in the world. One of such alternative air quality scales was developed in the United Kingdom and titled as Daily Air Quality Index (DAQI). DAQI scale is shown below in the Table 2:

Table 2: DAQI Scale and corresponding PM concentrations (source: <https://uk-air.defra.gov.uk/air-pollution>)

Index	1	2	3	4	5	6	7	8	9	10
Band	Low	Low	Low	Moderate	Moderate	Moderate	High	High	High	Very High
μgm^{-3}	0-11	12-23	24-35	36-41	42-47	48-53	54-58	59-64	65-70	71 or more

US Embassy sensor data were screened and filtered as follows: PM_{2.5} hourly concentrations showed in the downloaded Excel file as “invalid”, “missing” and “suspect” were deleted; negative PM_{2.5} concentrations were replaced by 0 μg . Further analysis of the datasets downloaded from the USA Embassy sensor revealed that winter air pollution levels

in Bishkek are extremely high and on a number of occasions the hourly PM_{2.5} concentrations in Bishkek even exceeded the maximum level of 500.4 µg. Quick analysis showed the following lows and highs of PM_{2.5} concentrations observed in Bishkek as per USA Embassy sensor data:

In 2019 – the lowest hourly concentration was registered on July 01, 2019 at 07.00 and was equal to 5 µg; the highest hourly concentration was observed on December 17, 2019 at 14.00 and was equal to 753 µg.

In 2020 – the lowest hourly concentration of 0 µg was registered in 832 cases (10 times in winter); the highest hourly concentration was observed on December 22, 2020 at 14.00 and was equal to 785 µg.

In 2021 – the lowest hourly concentration of 0 µg was registered in 14 cases (8 times in winter); the highest hourly concentration was observed on January 03, 2020 at 15.00 and was equal to 917 µg.

To narrow the scope of our analysis we focused only on extreme hourly raw concentrations and namely on cases of highest concentrations exceeding the threshold of 500 µg within the period from 01 October till 30 April in each year from 2019 till 2021 (to date). In 2019 there were registered 4 such cases (all in December), in 2020 there were 5 (also in December), and in 2021 there were 40 cases (all in January).

Our idea was to study these cases of abnormally high pollution levels and to see whether there were observed cases of temperature inversion, before, during and shortly after the extreme air pollution events. Analysis of the average monthly temperatures at two meteorological stations, Bishkek (760 meters above sea level) and Baitik (1580 meters above sea level), was done to understand how temperatures at these two stations relate to each other in various seasons. As the table below shows, in summer the difference between two stations was well above 6.5 °C which is normal, as the temperature tends to decrease with elevation (Encyclopedia Britannica 2021). However, in winter this difference dropped very drastically and in January 2021 the difference became even negative, meaning that the average daily temperatures in Baitik were warmer than in Bishkek (interestingly, namely January 2021 was the month when there were registered 40 out of 49 cases of extreme winter pollution since February 2019). Such unusual situation with the negative temperature difference between Bishkek and Baitik could be explained only by the influence of the thermal inversion – a natural meteorological phenomenon when the lowest layer of the air (the part of the atmosphere that is closest to the ground) becomes colder than the upper layers of air, whilst in normal conditions the near-ground air should be warmer than the upper air layers (Encyclopedia Britannica 2021). In other words, thermal inversion enables the colder air near the ground to get trapped under the warmer air

masses above it under specific conditions. Such conditions in Bishkek during cold season are facilitated by frequent long spells of still weather with no or very low winds and the presence of mountains that further hinder any mixture of the air masses. Perova (Perova 2013) gave a detailed explanation of these circumstances which make Bishkek and Chuy valley in general a place very suitable for frequent winter inversions. Table below provides detailed information regarding average monthly temperatures in Bishkek and Baitik.

Table 3: Average monthly temperatures in Bishkek and Baitik weather stations since 2019

Month	Year	Bishkek av t	Baitik av t	Differ-ence	Year	Bishkek av t	Baitik av t	Differ-ence
January	2019	1.4	-2.9	4.3	2020	-1.7	-5.6	3.9
February	2019	0.5	-3.1	3.6	2020	3.7	0.1	3.6
March	2019	9.8	3.5	6.3	2020	8.2	2.5	5.7
April	2019	13.2	8.1	5.1	2020	14.1	8.7	5.4
May	2019	18.1	11.8	6.3	2020	19.5	13.3	6.2
June	2019	23.2	16.8	6.4	2020	22.9	16.0	6.9
July	2019	28.7	21.9	6.8	2020	25.7	18.4	7.3
August	2019	25.6	18.7	6.9	2020	24.4	17.4	7
Septemb.	2019	18.6	12.6	6.0	2020	17.4	11.0	6.4
October	2019	12.6	7.1	5.5	2020	10.1	4.3	5.8
Novemb.	2019	1.4	-1.2	2.6	2020	0.6	-3.6	4.2
Decemb.	2019	1.1	-1.4	2.5	2020	-5.6	-5.9	0.3
Annual								
January	2021	-3.8	-3.4	-0.4				
February	2021	3.9	0.0	3.9				
March	2021	6.0	1.5	4.5				

April	2021	13.1	7.0	6.1				
May	2021	20,5	13,6	6,9				
June	2021	24,6	17,6	7				
July	2021	28	20,7	7,3				

Our further screening of the temperature records registered during selected 49 cases of extreme air pollution brought the results summarized in the table 4 below (most relevant temperature readings related to the time of recorded smog extremes were selected):

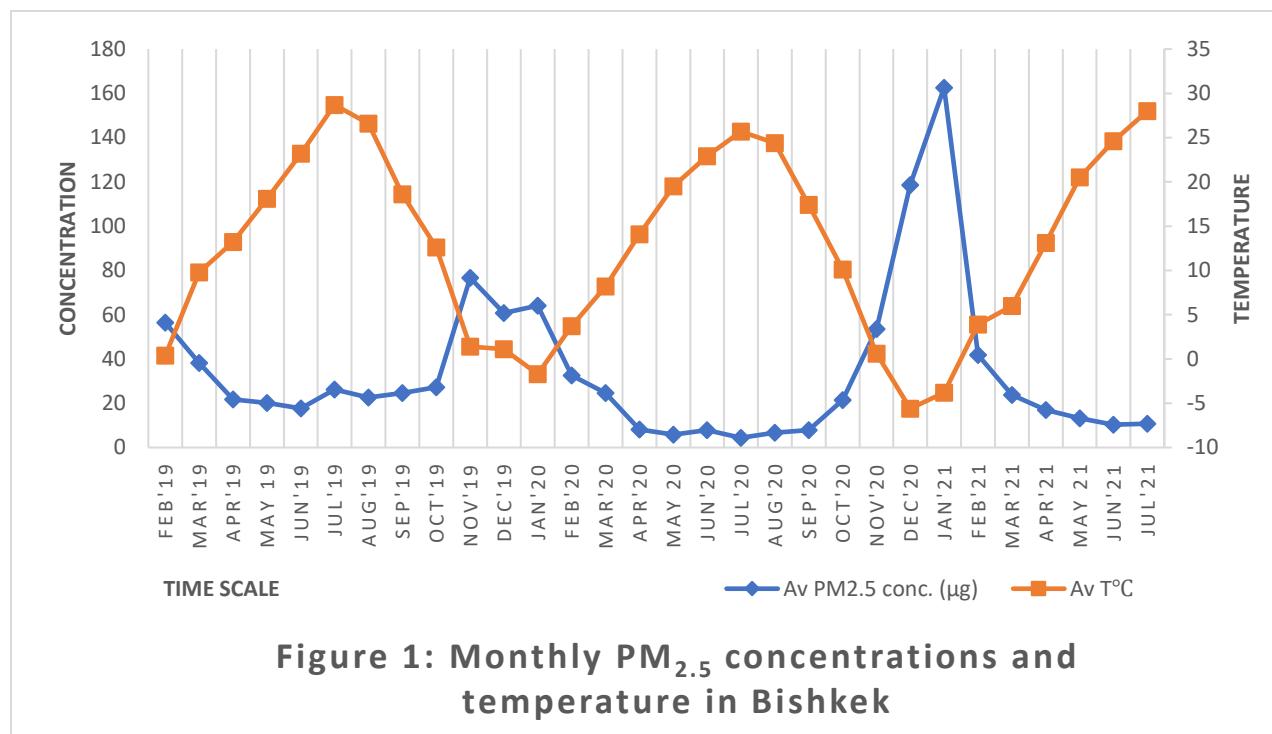
Table 4: Extreme PM_{2.5} pollution cases and related climatic parameters

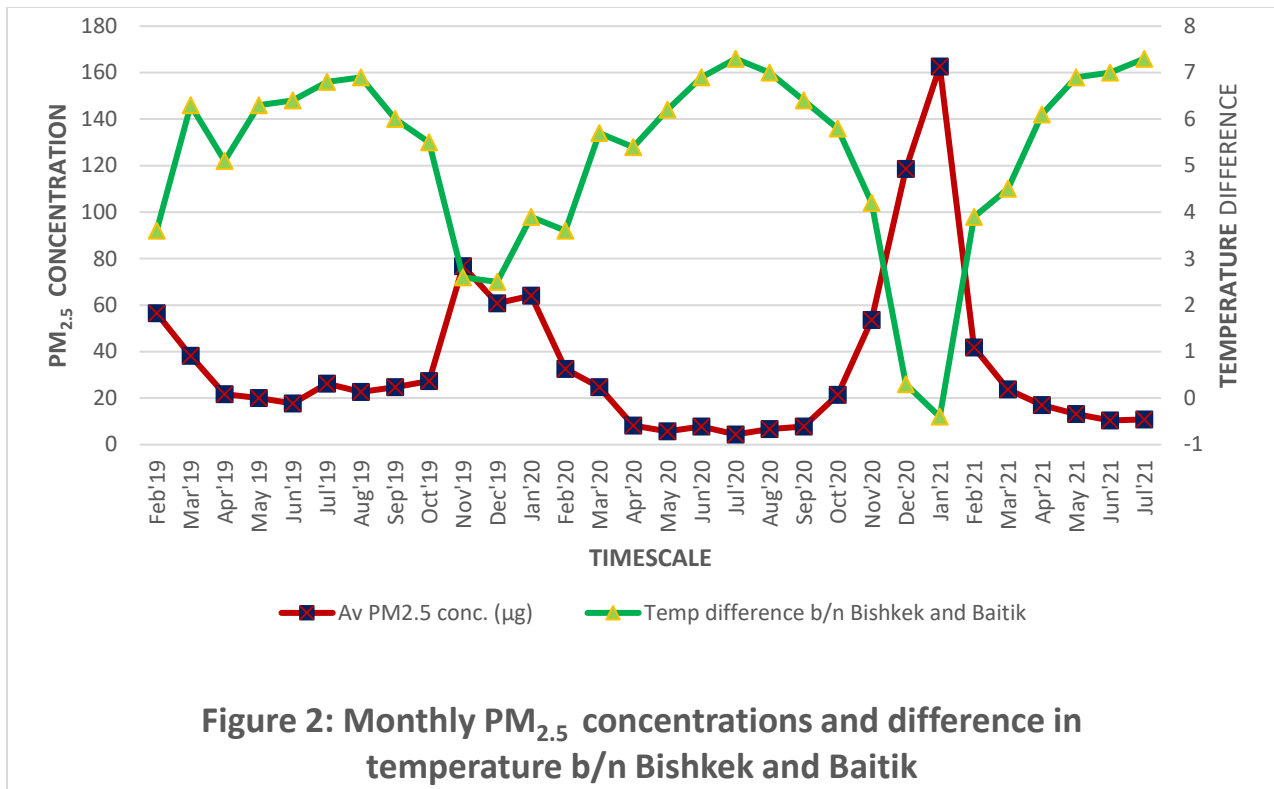
##	Year	Date	Time	PM _{2.5} conc., µg per m ³	Bishkek temp., °C, during related time points	Baitik temp., °C	Inversion cases observed in previous 36 hours	Snow/rain or fog in previous 120 hours
1, 2	2019	Dec. 01	15.00 16.00	603 576	12.00 – 3.8 15.00 – 7.1 18.00 – 0.8	12.00 – 6.6 15.00 – 8.1 18.00 – -0.9	Yes	Yes
3, 4	2019	Dec. 17	14.00 15.00	753 533	12.00 – - 4.3 15.00 – 0.3 18.00 – -2.4	12.00 – 2.3 15.00 – 4.4 18.00 – -3.5	Yes	Yes
5	2020	Dec. 18	17.00	778	06.00 - -11.6 18.00 – -0.9 21.00 – - 4.2	06.00 - -10.1 18.00 – -7.5 21.00 – ---	Yes	Yes
6, 7, 8	2020	Dec. 22	14.00 15.00 16.00	785 637 518	12.00 – -4.8 15.00 – -2.0 18.00 – -4.8	12.00 – -0.9 15.00 – -0.4 18.00 – - 7.5	Yes	Yes
9	2020	Dec. 26	15.00	644	09.00 - -3.2 12.00 – -0.2 15.00 – 2.4	09.00 - -2.8 12.00 – -2.8 15.00 – ----	Yes	Yes
10, 11, 12, 13	2021	Jan. 02	17.00 18.00 19.00 20.00	673 747 713 587	12.00 – -9.2 15.00 – -3.8 18.00 – -7.9 21.00 – -13.1	12.00 – -1.0 15.00 – 2.1 18.00 – -7.6 21.00 – -7.0	Yes	Yes
14, 15, 16,	2021	Jan. 03	14.00 15.00 16.00	631 917 501	03.00 – -13.6 06.00 – -13.7 09.00 – -15.3	03.00 – -8.1 06.00 – -8.4 09.00 – -9.0	Yes	Yes

17, 18, 19 20			17.00 18.00 19.00 23.00	721 889 710 579	12.00 -- -9.0 15.00 -- -6.6 18.00 -- -10.5 21.00 -- -13.7	12.00 -- 0.8 15.00 -- 1.8 18.00 -- -7.6 21.00 -- 1.8		
21 22 23 24 25 26	2021	Jan. 04	05.00 06.00 08.00 13.00 14.00 15.00	709 736 559 649 556 758	03.00 -- -14.7 06.00 -- -15.1 09.00 -- -16.8 12.00 -- -11.0 15.00 -- -8.7 18.00 -- -12.2	03.00 -- -8.4 06.00 -- -9.6 09.00 -- -8.4 12.00 -- 2.9 15.00 -- 3.1 18.00 -- -5.2	Yes	Yes
27	2021	Jan. 05	19.00	738	18.00 -- -7.4 21.00 -- -11.1	18.00 -- -6.1 21.00 -- -11.3	Yes	Yes
28	2021	Jan. 07	16.00	511	15.00 -- -9.2 18.00 -- -11.4	15.00 -- -8.4 18.00 -- -9.6	Yes	Yes
29 30 31	2021	Jan. 08	16.00 17.00 18.00	533 692 645	09.00 -- -11.7 15.00 -- -3.6 21.00 -- -10.9	09.00 -- -14.2 15.00 -- -6.1 21.00 -- -13.4	Yes	Yes
32 33	2021	Jan. 16	19.00 20.00	599 549	09.00 -- -1.6 12.00 -- 14.6 21.00 -- 7.9	09.00 -- -10.4 12.00 -- -12.4 21.00 -- 5.2	Yes	Yes
34	2021	Jan. 17	20.00	826	06.00 -- 2.8 21.00 -- 1.0	06.00 -- 4.8 21.00 -- -0.8	Yes	Yes
35	2021	Jan. 19	21.00	648	06.00 -- 4.8 21.00 -- 6.3	06.00 -- 0.5 21.00 -- 0.2	Yes	Yes
36	2021	Jan. 21	16.00	671	09.00 -- 0.1 15.00 -- 10.4	09.00 -- 2.0 15.00 -- 8.4	Yes	Yes
37	2021	Jan. 22	08.00	707	06.00 -- -0.8 09.00 -- -1.2	06.00 -- 0.6 09.00 -- -4.8	Yes	Yes
38 39 40	2021	Jan. 26	15.00 21.00 22.00	666 744 622	12.00 -- -3.1 18.00 -- -4.3 21.00 -- -8.4	12.00 -- 2.0 18.00 -- -6.4 21.00 -- -7.6	Yes	Yes
41 42 43 44	2021	Jan. 27	01.00 02.00 13.00 15.00	511 715 645 561	00.00 -- -10.9 03.00 -- -10.5 12.00 -- -4.4 15.00 -- -2.0	00.00 -- -7.0 03.00 -- -6.6 12.00 -- 2.1 15.00 -- 3.4	Yes	Yes
45	2021	Jan. 28	14.00	505	12.00 -- -2.5 15.00 -- -2.7	12.00 -- 2.5 15.00 -- 3.5	Yes	Yes
46 47	2021	Jan. 29	17.00 20.00	508 691	15.00 -- 5.4 21.00 -- -4.2	15.00 -- 5.6 21.00 -- -5.2	Yes	Yes
48	2021	Jan. 30	18.00	501	09.00 -- -4.1 18.00 -- 5.6	09.00 -- 2.4 18.00 -- -1.6	Yes	Yes
49	2021	Jan. 31	16.00	624	09.00 -- 3.4 15.00 -- 16.8	09.00 -- 1.2 15.00 -- 8.5	Yes	Yes

The above table clearly demonstrates that all 49 cases of extreme PM_{2.5} pollution in Bishkek during the period from February 2019 were preceded by temperature inversion events within 36 hours period. Another finding is that within 5 days before those extreme pollution events there were also observed cases of snow/rain/fog in Bishkek. Typically (but not always), extreme pollution events were accompanied also by elevated humidity of the air (higher than 60%), high atmospheric pressure (above 703 mm Hg) and sub-zero temperatures. For example, there was no snow before January 2, 2021 (during the “dirtiest week on record”), but there were registered multiple occasions of dew point to be closer than 2°C to the air temperature. Under such conditions weather becomes very conducive to the formation of thick fogs (<https://glossary.ametsoc.org/wiki/Fog>). Indeed, in January 2021, a lot of foggy days were registered in the Bishkek weather station.

Figures 1 and 2 below further show how PM_{2.5} concentrations and temperature changed over the observed period in Bishkek.





Analysis of Figures 1 and 2 reveals that the PM_{2.5} pollution correlates with temperature – the colder is the air temperature, the worse is the air pollution in Bishkek. Thus, 2 months with highest PM_{2.5} concentrations (tangibly exceeding 100 µg) coincided with 2 coldest months during the observed period – December 2020 and January 2021. Interestingly, Figure 2 showed even better correlation of the PM_{2.5} concentrations with the difference in temperatures between Bishkek and Baitik. In particular, it turned out that the months with least temperature difference (i.e. most prone to inversion occurrences) were also the “dirtiest” months on record. It is also important to note that the average annual PM_{2.5} concentrations in Bishkek for the observed period were the following (based on USA Embassy sensor):

2019 (February-December)	– 35,4 µg/m ³ ;
2020	– 28,5 µg/m ³ ;
2021 (January-July)	– 39,6 µg/m ³ .

According to US AQI scale these levels of pollution correspond to the air quality categories 2 and 3 – moderate and unhealthy for sensitive groups. By UK DAQI scale these levels are interpreted as low and moderate.

According to IQAir ranking (<https://www.iqair.com/world-most-polluted-cities>) the most polluted city in the world in 2020 was Hotan/China with the average annual PM_{2.5} concentration of 110.2 µg/m³. City #50 in this list – Aksu/China – had the average concentration of 58,4 µg/m³. Bishkek is on 160th place with 43.5 µg/m³. Such cities as Karachi/Pakistan, Doha/Qatar, Kabul/Afghanistan, Ulanbaatar/Mongolia, Kolkata/India, Urumqi/China have worse air quality than Bishkek. Almaty/Kazakhstan is on 203th place with the average concentration of 39,3 µg/m³. Majority of cities in the top-200 are from China and India.

Which of the major winter air pollution sources (Central Heat Plant, vehicles, households' heating) are the most important factors in winter smog?

To assess the contribution made by Central Heat and Power Plant (CHP) analysis of the pollution levels during specific periods was conducted. Particularly, the below key dates related to the work of the CHP were taken into consideration (based on CHP public announcements):

- May 17 – June 17, 2021 – Annual break in supply of hot water;
- April 06, 2021 – Shutdown of the heating season;
- October 09, 2020 - Start of the heating season;
- June 01 – June 30, 2020 - Annual break in supply of hot water;
- April 04, 2020 - Shutdown of the heating season;
- March 24, 2020 - Restart of the heating due to cold weather
- March 19, 2020 - Shutdown of the heating season;
- November 01, 2019 - Start of the heating season;
- 06 May – 06 June, 2019 - Annual break in supply of hot water;
- March 18, 2019 - Shutdown of the heating season

Further, PM_{2.5} concentrations and relevant climatic parameters were checked to understand to what extent CHP contributed to the air pollution in Bishkek during/before/after the above key CHP-related events. Below table provides detailed information on the indicators that were selected:

Table 5: Air pollution and selected climatic parameters before and after key events at CHP in Bishkek

Key event	Date(s)	Av PM _{2.5} conc. before and after the key dates (µg)	Difference in PM _{2.5} levels	Av T°C before and after the key dates	Av humidity before and after	Average wind speed before and after

Annual break in supply of hot water	May 17 – June 17, 2021	June 7 -16 – 9.77 µg / June 21 – 30 – 11.36 µg	1.59 µg / 16.3%	23.9°C / 24.0°C	35% / 37%	1.5 / 1.3
Shutdown of the heating season	April 06, 2021	25.03-03.04 – 13.28 µg / 11.04-20.04 – 20.1 µg	6.82 µg / 51.4%	7.4°C / 15.1°C	71% / 54%	1.4 / 1.4
Start of the heating season	October 09, 2020	28.09 – 07.10 – 12.63 µg / 12.10 – 21.10 – 23.77 µg	11.14 µg / 88.2%	10.7°C / 12.9°C	71% / 54%	1.2 / 0.9
Annual break in supply of hot water	June 01 – June 30, 2020	08.06 – 17.06 - 4.73 µg / 06.07 – 15.07 – 4.77 µg	0.04 µg / 0.8%	22.2°C / 25.3°C	42% / 37%	1.5 / 1.1
Shutdown of the heating season	April 04, 2020	26.03 – 02.04 - 22.89 µg / 09.04 – 16.04 – 9.56 µg	13.33 µg / 58.3%	9.6°C / 8.2°C	59% / 84%	1.0 / 1.2
Restart of the heating due to cold spell	March 24, 2020	26.03 – 29.03 - 27.57 µg / 19.03 – 22.03 – 15.58 µg	11.99 µg / 76.9%	8.3°C / 12.4°C	54% / 65%	0.9 / 1.5
Shutdown of the heating season	March 19, 2020	20.03 – 22.03 - 14.82 µg / 13.03 – 15.03 – 21.5 µg	6.68 µg / 31.1%	12.3°C / 10.9°C	66% / 48%	1.6 / 1.3
Start of the heating season	November 01, 2019	04.11 – 08.11 - 43.2 µg / 21.10 – 25.10 – 33.5 µg	9.7 µg / 28.9%	3.0°C / 9.5°C	83% / 53%	0.9 / 0.8
Annual break in supply of hot water	06 May – 06 June, 2019	10.06-16.06 – 16.24 µg / 27.05 – 02.06 – 19.42 µg	3.18 µg / 16.4%	20.3°C / 23.2°C	50% / 41%	1.6 / 1.0
Shutdown of the heating season	March 18, 2019	25.03-31.03 – 22.53 µg / 04.03 – 10.03 – 43.68 µg	21.15 µg / 93.9%	13.7°C / 5.2°C	58% / 80%	1.6 / 0.9

The above table shows that the CHP seems to make a significant impact on the air quality in Bishkek, especially during the start and shutdown of the heating season. Before/after these events the air quality fluctuates quite dramatically, sometimes even to the levels above 90%. In absolute terms, changes in PM_{2.5} pollution levels before/after key events in CHP operations ranged from 0.04 µg after the annual break in supply of hot water in June 2020 till 21.15 µg after the shutdown of the heating season in March 2019. However, it should be noted that during the heating periods it is difficult to clearly distinguish the CHP contribution to the air pollution from the contribution of the residential sector. Significance of the winter heating factor in air pollution in Bishkek is highlighted in Figure 3, which indicates diurnal variations of the PM_{2.5} concentrations during heating and warm seasons. “Winter” pollution patterns are strongly influenced by emissions from the coal-combustion households.

Furthermore, analysis of the diurnal PM_{2.5} fluctuations also indicates likely tangible influence of the mountain and valley breezes – with a mild breeze from the mountains towards valley reducing the PM levels in the early hours and the opposite breeze increasing the air pollution in the second half of the day.

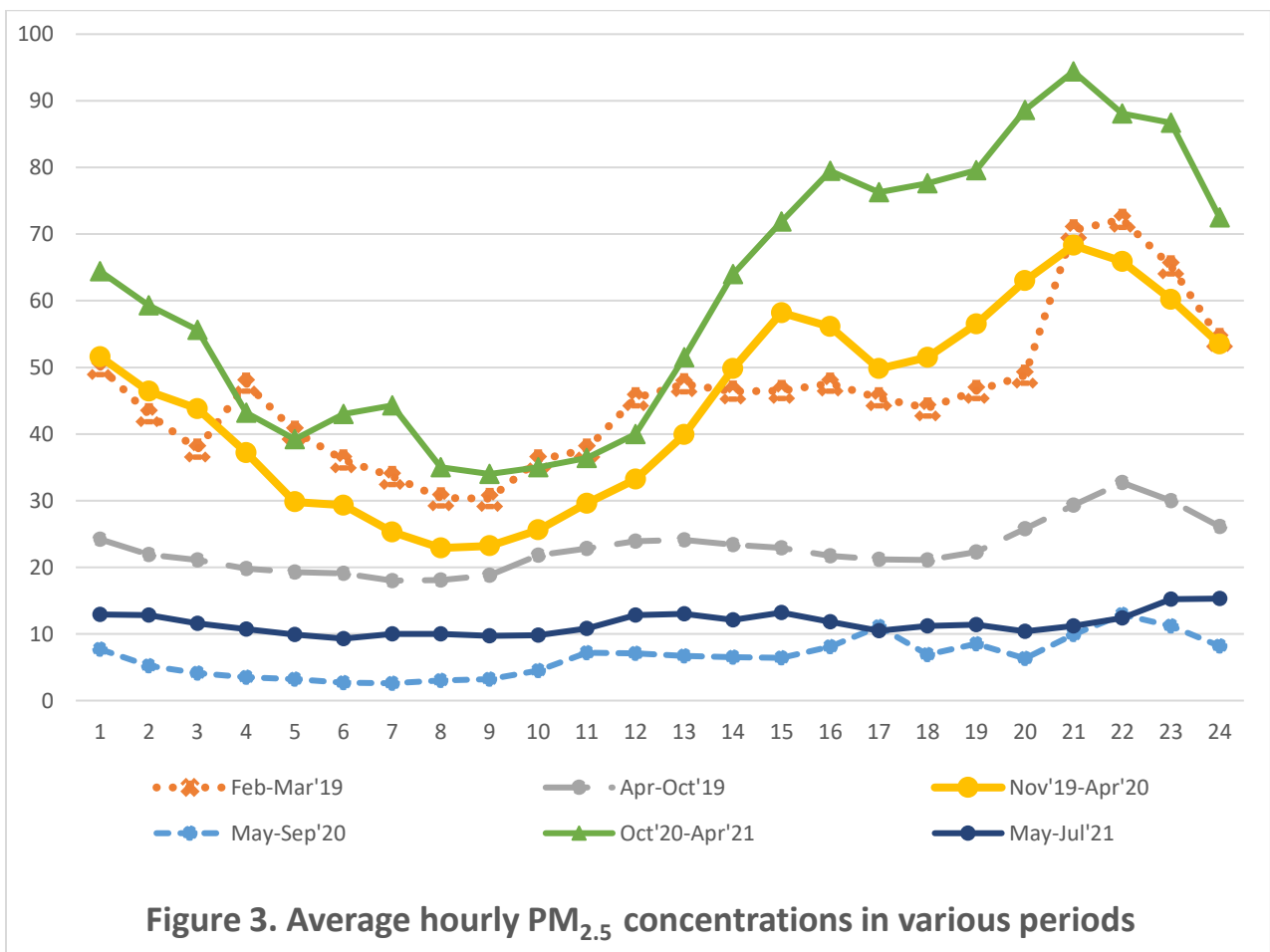


Figure 3. Average hourly PM_{2.5} concentrations in various periods

To assess PM_{2.5} emissions in Bishkek from major sources we did the following calculations:

The CHP coal consumption during the heating period in recent years was around 820 000 tons (according to the CHP letter). The emission factor for power plants in USA working on coal is estimated to be around 1.1 kg per ton of the burned coal (US EPA 2018b). Therefore, we can estimate that around 902 tons are emitted on average by Bishkek CHP during typical heating season from October till March based on the assumption that the average effectiveness of filter systems at power plants usually reaches 98-99% (Zhang 2016). However, it should be noted that the effectiveness of the emission control system at Bishkek CHP might be lower than 98-99%. The height of the exhaust pipes at CHP is another important factor that facilitates the dissipation of the CHP emissions in the air. During the typical heating season CHP burns around 4743 tons and 899 tons of coal per day during warm period (based on 2019 annual consumption and 173 to 193 ratio of heating and no-heating days within a year). Below is given table showing average PM_{2.5} concentrations in Bishkek during heating seasons and warm seasons:

Table 6: Average PM_{2.5} concentrations on and off CHP heating season in Bishkek

Period	Average PM_{2.5} concentration
February 06 – March 31, 2019	46
April 01 – October 31, 2019	22.9
November 1, 2019 – April 30, 2020	44.6
May 1 – September 30, 2020	6.5
October 1, 2020 – April 30, 2021	60.7
May 1- July 31, 2021	11.6

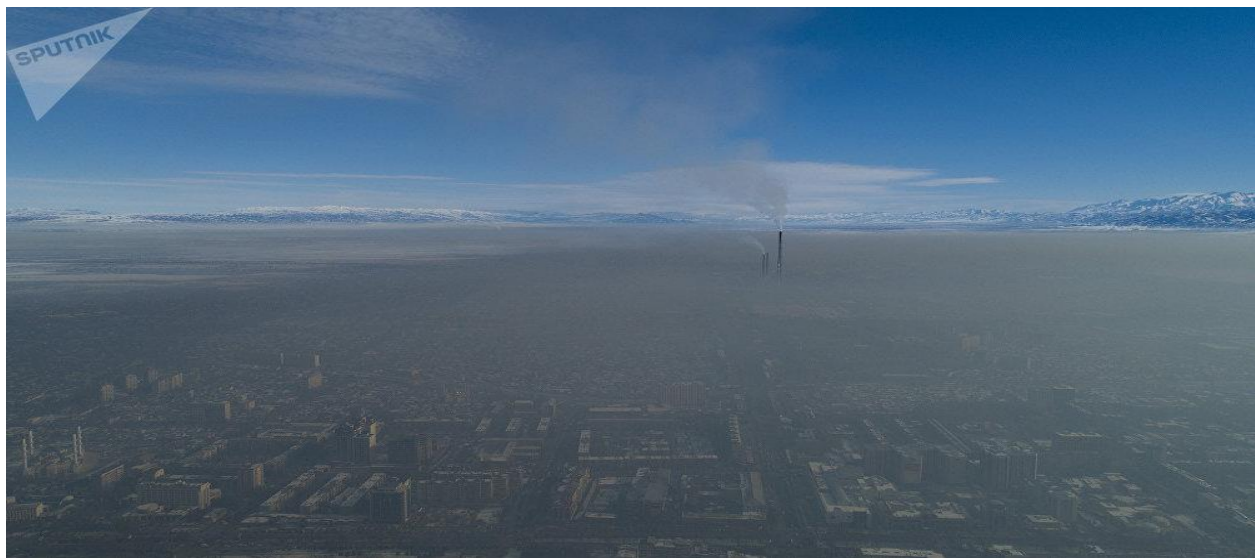


Figure 4. Winter smog in Bishkek (taken from Sputnik.kg website)

Coal consumption for heating by private households can be roughly estimated on the basis of the quantity of individual residential houses – 104 448 (according to the letter from the Mayor’s Office) and the average coal consumption by households – in the range from 2,6 tons (World Bank 2020) to approximately 3,27 tons (Camp Alatoo 2016). For our calculations we will use the mean between these two estimates – 2.935 tons per household. Based on the assumption that 85-90% of the private houses use coal as a major fuel, the approximate coal consumption by private sector in Bishkek during the heating season can be estimated to be around 266700 tons. Further, we used the weighted PM_{2.5} emission factor of 13.7 kg per ton of the bituminous coals (Champion et al, 2017). As a result, we came up to 3 654 tons of PM_{2.5} emissions into the air in Bishkek during the heating season from the private households. It should be noted, however, that the emission factor for Karakeche coal could significantly differ from the one referenced above. Thus, according to a recent Russian study (OAO MNIIECO, 2014) the emission factor of the brown coal with similar to Karakeche properties (humidity around 20% and calory content of 4240 Kcal per kg) could be as high as 68 kg per ton of the burnt coal.

To estimate emissions from vehicles we took the NSC statistics on the number of private cars in Bishkek in 2019 – 324 200 units. One of the main methods for evaluation of PM_{2.5} emissions from the road transport is based on using of emission factors for vehicle per kilometer driven. We used the emission factor of 0,02 g per vehicle per kilometer (Ferm and Sjoberg, 2015). The approximate mileage of Bishkek drivers was estimated to be around 175 km per week based on survey conducted by AUCA students (see the summary table in the Annexes). Further calculations brought to the estimated PM_{2.5} emissions from private vehicle to be around 29.5 tons during the period from October till March. This figure seems to be very understated, but on the other hand it provides a good insight into the potential contribution of the transport sector towards PM_{2.5} pollution in Bishkek.

Vehicle emissions in the Kyrgyz Republic are regulated by the Customs Union requirements, and in particular by a specific Technical Order #018 (Customs Union 2011). Annex#8 of this technical order lists specific requirements for vehicles:

Table 7. The content of carbon monoxide in the exhaust gases of a vehicle with gasoline or gas engines

Category and equipment of the vehicle (ecological class)	Engine speed	CO, by volume, %
M and N, not equipped with neutralization system for the exhaust gases	Minimal	3,5
	Elevated	2,0

M and N, equipped with neutralization system for the exhaust gases (ecological classes 2 and lower)	Minimal	0,5
	Elevated	0,3
M and N, equipped with neutralization system for the exhaust gases (ecological classes 3 and higher)	Minimal	0,3
	Elevated	0,2

Table 8. Smokiness of the exhaust gases of a vehicle with diesel engine

For engines of ecological class 3 and lower	
For engines with turbine	2,5
For engines without turbine	3,0
For engines of ecological class 4 and above	1,5

As it is seen from the above tables, the scope of vehicle pollutants subject to control in the Kyrgyz Republic is very limited. Unlike Europe and other developed countries, in Kyrgyzstan, as well in other Eurasian Economic Union countries there is a specific emission requirement for vehicles without catalytic converters. The laboratories implementing the technical inspection of the road transport check only the carbon monoxide content in the exhaust of the gasoline-powered cars, and smokiness level of the exhaust in the diesel-powered vehicles. Other major transport-related pollutants, such as NO_x, Particulate Matter, Hydrocarbons are not regulated. Moreover, diesel-powered vehicles are not checked for specific pollutants at all. It is important to highlight that diesel vehicles were responsible for 97% of the PM_{2.5} exhaust emissions from road traffic and 90% of the NO_x emissions in Europe (Harrison 2017).

Analysis of the data from one of the Bishkek-based laboratories (see relevant table in Russian in the Annexes) shows that 58% out of 76 vehicles tested exceeded the requirements set in the country for exhaust gases. The most critical factor leading to the increased air pollution from vehicles seems to be the absence of the catalytic converters,

as all 36 vehicles lacking the converters failed to comply with the set target values. Interestingly, lack of converters had a much stronger effect for petroleum-powered vehicles (3.76 for cars with converters, and 0.48 for cars without a converter) than for diesel-powered vehicles (5.16 and 1.92 respectively).

Local expert in the field of technical inspection of cars in Bishkek that was interviewed during our field work estimated that at least 30% of the gasoline vehicles in the country do not have catalytic converters. For diesel vehicles this figure is at least 60%, as some categories of the vehicles are not equipped by catalytic converters by producers (e.g. Kamaz trucks) or have intentionally dismantled converters (e.g. Mercedes minibuses). In a survey conducted by AUCA students 63 out of 100 vehicle drivers (mainly passenger car drivers were interviewed) confirmed the presence of the catalytic converter. It is also worth to mention that one of the international studies found that catalytic converters reduce number of particles emitted from gasoline vehicles by 65% (Whelan 2013).

What are the economic costs of air pollution in Bishkek?

The researchers find that there is a casual link between income per capita and emission per capita. In case of Kyrgyzstan, this is true as well, so the increasing incomes cause the increase of consumption that leads to higher emissions levels. For instance, a wealthier family builds a new house or extends the existing one so the demand for heating grows.

The literature shows that lifestyle and structure of the population are major drivers (Das & Paul, 2014). The lifestyle factors, for instance, are recreation and housing. For example, high awareness of the climate change can lead to the household's decisions that reduce the CO₂ emissions regardless of the income. For example, a wealthier family invests more in energy efficient housing so contrary to the conventional wisdom, the increasing income leads to a lower emission. However, today we do not have any reliable knowledge about the interaction between climate change awareness and household behavior patterns in Kyrgyzstan

In recent years, the coal consumption by the households have been increasing. The major drivers of this increase include income growth that leads to more new houses and also unreliability of the of the electricity supply (Sabyrbekov & Ukueva, 2019).

Kyrgyz Household Integrated Survey (KHIS)

The KHIS started in 2003 and implemented by the National Statistics Committee. The KHIS is quarterly survey and covers about 5,000 households. The KHIS is the largest panel survey in the country. The sample of the KHIS is drawn using stratified two-stage

random sampling, based on the results of the 1999 population census. The KIHS aims to measure consumption-based poverty in the country and collects detailed data on expenses and consumption by households.

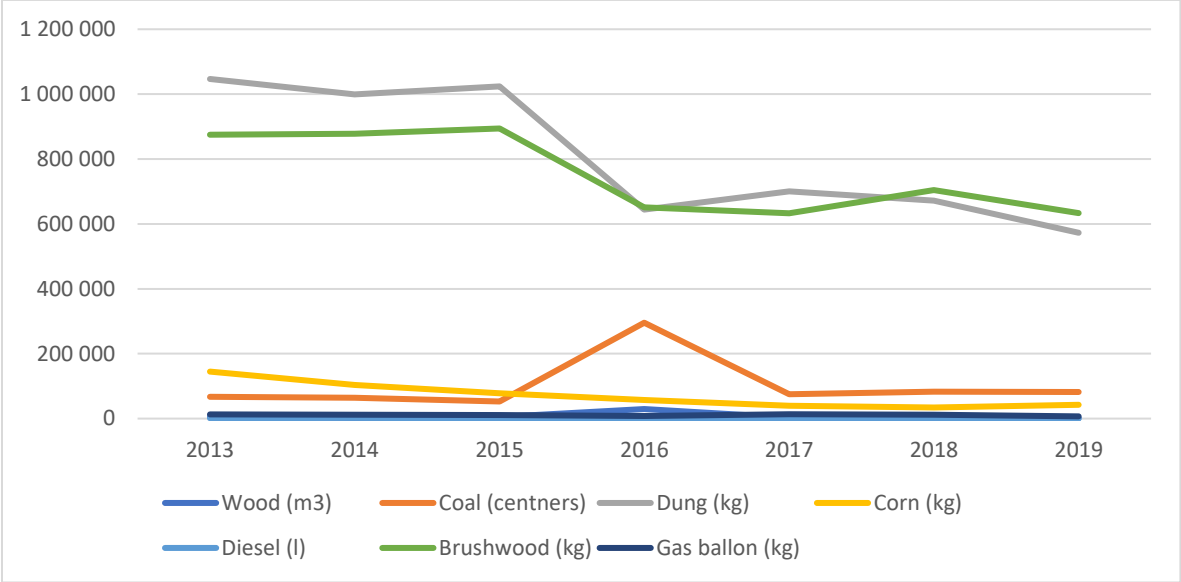


Figure 5. Total consumption of energy source by households by KIHS 2013 - 2019. Source: authors' calculations¹

The data from KIHS shows the households use five main energy sources: wood, coal, dung, corn, diesel, brushwood and LPG. In period of 2013 – 2019 the quantities of brushwood and dung have declined, while the coal consumption increased (Figure 5). The total consumption of coal in 2013 was 67,137 centners and rose to 82,038 centners in 2019 (Table 9). So the consumption of coal increased by 22% in six years. Despite the highest quantities of brushwood and dung the energy content is low and their decreasing trend probably related to the income growth.

¹ 2016 is clear outlier, probably to data measurement misspecification

Table 9. Total and mean consumption of energy products. Source: authors' calculations from KIHS

	Total	Mean	Total	Mean	Total	Mean	Total	Mean	Total	Mean	Total	Mean	Total	Mean	
Fuel type\Year	2013	2013	2014	2014	2015	2015	2016	2016	2017	2017	2018	2018	2019	2019	
Wood (m3)	5,960	0.84	2,304	0.38	4,866	0.83	29,449	2.08	3,052	0.62	6,098	1.08	1,633	0.28	
Coal (centners)	67,137	4.78	63,816	4.88	52,738	4.09	295,50	9	23.80	74,806	5.80	82,693	5.90	82,038	5.81
Dung (kg)	1,046,6	128.0	999,55	127.4	1,023,8	123.4	644,29	118.6	700,74	138.0	671,32	136.0	572,69	137.4	
Corn (kg)	89	7	1	0	77	0	4	9	9	2	5	1	2	7	
			104,03												
Corn (kg)	144,833	73.17	5	60.77	77,888	57.49	57,145	55.66	39,823	48.80	34,215	42.24	42,214	50.08	
Diesel (l)	676	34.44	2,205	60.87	416	42.57	771	85.10	1	0.50	10	5.00	5	1.13	
Brushwood (kg)	874,565	61.97	8	55.72	894,204	57.27	2	56.22	4	59.76	3	64.82	8	60.78	
			878,29				651,37		632,80		704,33		633,33		
Gas ballon (kg)	12,981	4.86	11,727	4.56	11,396	4.30	7,947	4.18	13,454	39.37	12,332	4.68	6,868	4.48	

The coal-based CO₂ emissions per household in 2013 were 3,241 kg and reached 3,958 kg in 2019 (Table 10). The KIHS does not report the calorific value nor where the coal was purchases, so we used a general 2.42kg CO₂ output level per 1 kg of burned coal.

Table 10. Coal consumption and emissions. Source: authors' calculations based on KIHS

	2013	2014	2015	2016	2017	2018	2019
Total coal (kg)	6,713,686	6,381,628	5,273,837	7,984,575	7,480,595	8,269,317	8,203,813
Total CO2 emissions (kg)	16,247,120	15,443,540	12,762,686	19,322,672	18,103,040	20,011,747	19,853,227
Per household coal use	1,339	1,275	1,051	1,592	1,491	1,649	1,636
Per household emissions	3,241	3,085	2,544	3,853	3,609	3,990	3,958
Number of households	5013	5006	5016	5015	5016	5016	5016

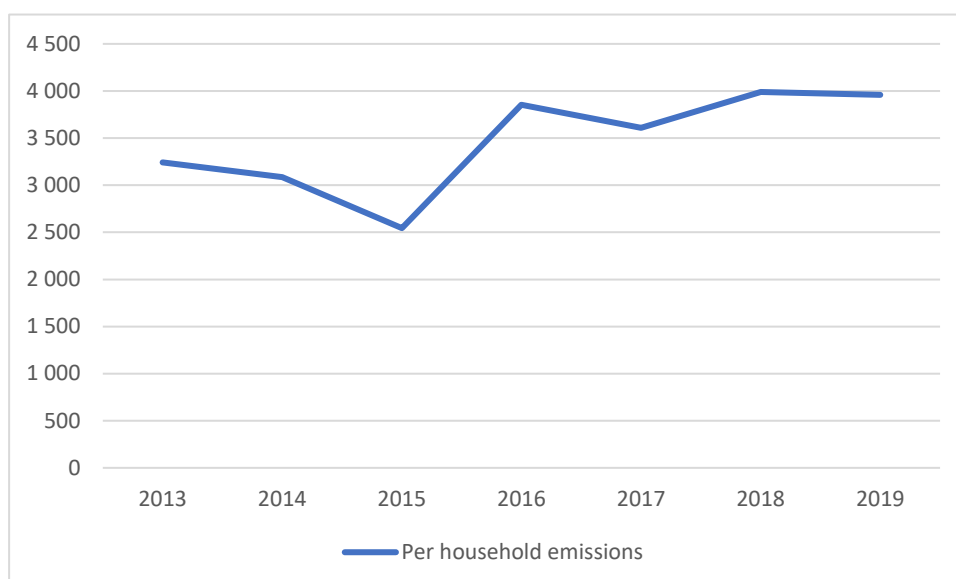


Figure 6. Per household CO2 emissions from coal consumption. Source: authors' calculations based on the KIHS data

The time-series data from KIHS shows that the emissions from coal consumptions dipped in 2015 to increase and the rising trend was stable in the recent years (Figure 6).

Cost of Air Pollution

Polluted air has significant economic costs. In 2015 WHO estimated that the cost of premature death and disability from air pollution in Europe is close to USD 1.6 trillion (WHO Regional Office for Europe OECD, 2015). The latest macroeconomic studies in Europe show that increase in PM 2.5 concentration leads to decrease in real GDP due to reduction of labour productivity (Dechezleprêtre, Rivers, & Stadler, 2019). The immediate effects of the air pollution on the economy can be traced through increase of mortality and migration; reduction of hours worked per worker due to absenteeism; reduction of productivity to worsening cognitive abilities; decreasing productivity of natural ecosystems. Moreover, the evidence shows that high levels of air pollution are associated with higher crime rates and unethical behavior (Lu, 2020).

Therefore, the economic appraisal is a key part of the decision-making process for policymakers to develop sustainable policy measures. The standard measure of air pollution cost is done using the Value of Statistical Life (VSL). The VSL measures the reduction cost of the mortality risk, specifically it is calculated from an individual's willingness to pay for decrease in mortality risk and then the number is averaged over the population. The VSL has been estimated and available in many high-income countries.

The economic model of VSL is based on changes of utility in relation to changes of probability of dying.

$$U = p * u_m(w) + (1 - p) * u_s(w) \quad (1)$$

where U is indirect utility, p is the probability of mortality risk in the period, $u_m(w)$ is the utility of wealth if the person dies in the current period, and $u_s(w)$ is the utility of wealth if the individual survives within the period. The detailed introduction into the model is available in (Hammitt, 2000). The VSL is widely used in cost-benefit analysis for policy assessment of air pollution reduction measures (Robinson, Hammitt, & O’Keeffe, 2019). The standard steps of the cost-benefit analysis include eight major steps.

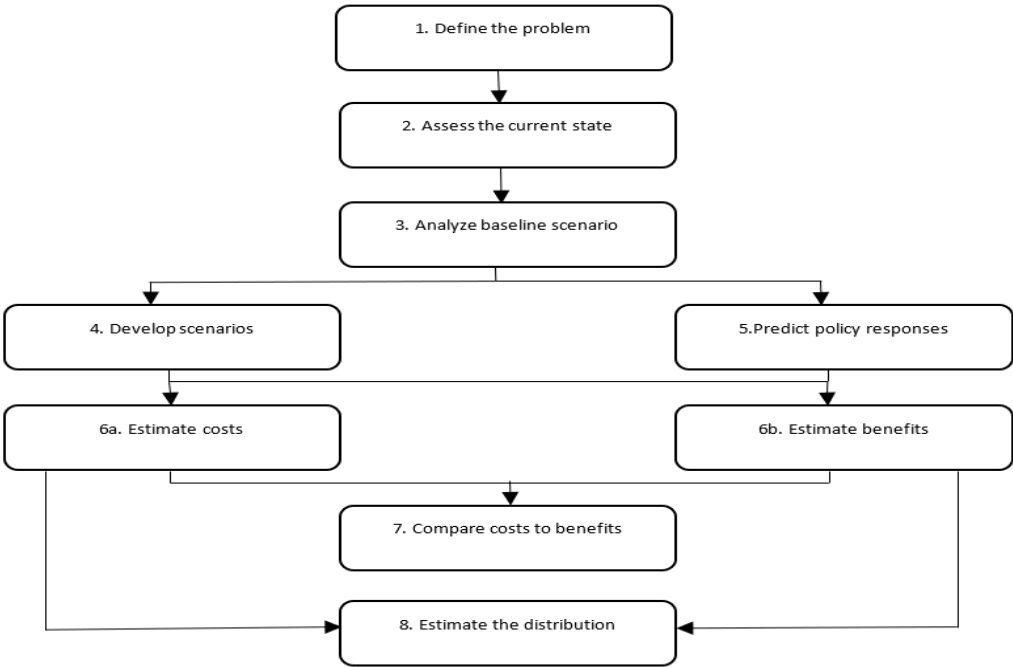


Figure 7. Steps in cost-benefit analysis. Adapted from Robinson, Hammitt, & O’Keeffe (2019)

Typically, in air pollution reduction strategies the VSL is used to assess damage caused by current levels of pollution (step 2 and 3 in Figure 7). After the assessment is complete, the VSL estimates can be used to calculate costs and benefits of the proposed policy options (steps 6a and 6b in Figure 7).

Economic cost of air pollution in Bishkek

To this date there have been no estimates of the economic cost of air pollution in Kyrgyzstan. Therefore, this is the first study to calculate the air pollution cost. Unfortunately, as many low-income countries, the Kyrgyz Republic does not have an official VSL number for the national cost-benefit studies. Ideally, we would like to observe the

individual preferences for risk reduction in Kyrgyzstan using field studies. However, due to the project resources and epidemiological situation is not realistic.

Therefore, the value-transfer is used from high-income countries to low-income countries while correcting for income level. The value transfer formula is below

$$VSL_{KG} = \left(\frac{GDP\ per\ capita_{KG}}{GDP\ per\ capita_{HIC}} \right)^e * VSL_{HIC} \quad (2)$$

where VSL_{KG} is VSL in Kyrgyzstan and HIC variables are parameters of a high-income country. The e is income elasticity. VSL based on the U.S. uses elasticity of 1.5 while the OECD based studies use elasticity of 1.0 and the literature suggest that the mean elasticity is 1.5 with median of 1.4 (Robinson, Hammitt, Cecchini, et al., 2019).

Before the VSL could be estimated we must make sure that the GDPs are inflation adjusted, i.e. use the same currency base year for both countries. GDP deflator or a consumer price index (CPI) are widely used tools. For purposes of this study we use numbers based on constant 2010 USD (see Table 11).

Table 11. Calculation of VSL for Kyrgyzstan

GDP per capita KG in 2019 (constant 2010 USD)	1,116.35 8
GDP per capita US in 2019 (constant 2010 USD)	55,753.1 44
Elasticity	1.5
VSL USA	10,000,000
VSL Kyrgyzstan	\$28,333

Table 12. VSL-based annual air pollution cost from number of deaths

PM2.5 Annual Average Exposure Concentration	32.8 µg/m3		70 µg/m3	
Population Risk or estimated number of deaths	1,162	1,081	1,819	1,772

VSL-based annual air pollution cost	32,923,467	30,628,45	51,538,543	50,206,8
		8		71

This is an example of the standard VSL which does not differentiate age groups. Another approach is the use of the value of statistical life-year (VSLY), which adjusts for the age.

$$VSLY = VSL / Life_expectancy \quad (3)$$

The national life expectancy in Kyrgyzstan for 2020 year was 71.5 years. Based on the above data we can estimate that $VSLY = \$396$. Considering that the population of Bishkek and Kyrgyzstan in general is young, then we expect that the value will be higher if VSLY is used in contrast with the use of VSL. As we get the age-detailed population census data for Bishkek, we can accurately estimate the VSLY.

The presented above VSL-based costs have to be treated with caution since it is based on the mortality risk which was derived from available data on PM concentrations. While we do not expect the drastic changes, we realize that as we get more data from remaining sensors the costs may change. Moreover, the economic cost of the air pollution is undervalued because the VSL-based cost does not account for the morbidity and labor productivity loss.

Conclusions

Analysis of the extreme pollution events in Bishkek during the observed period showed that the impact of the climatic conditions on air pollution level in Bishkek is very significant. In 2019 there were registered 4 cases of extreme air pollution (all in December), in 2020 there were 5 (also in December), and in 2021 there were 40 cases (all in January). All 49 considered winter cases of abnormally high PM_{2.5} concentration recorded by the USA Embassy sensor since February 2019 were shortly preceded by temperature inversion events in Bishkek.

Another finding is that before those extreme pollution events there were also observed cases of snow/rain/fog. Interestingly, there was no snow or rain before the "dirtiest" week on record in the first decade of January 2021, but there were documented multiple occasions of fog occurrence in the beginning of January. We also noticed that beginning of January 2021 was a period of high atmospheric pressure which signals presence of the strong anticyclone.

Precise quantification of the PM pollution is very difficult and expensive exercise. Furthermore, even upon rigorous research the uncertainty level still could be very high. For example, one UK study reported the uncertainty of PM_{2.5} emissions calculations to be around 50% (AQEG 2012). Therefore, it makes sense to look at PM apportionment results in other countries in order to better understand the general situation with air pollution sources in

Bishkek. Figures 8 and 9 below show the main sources of PM_{2.5} emissions in Europe and USA.

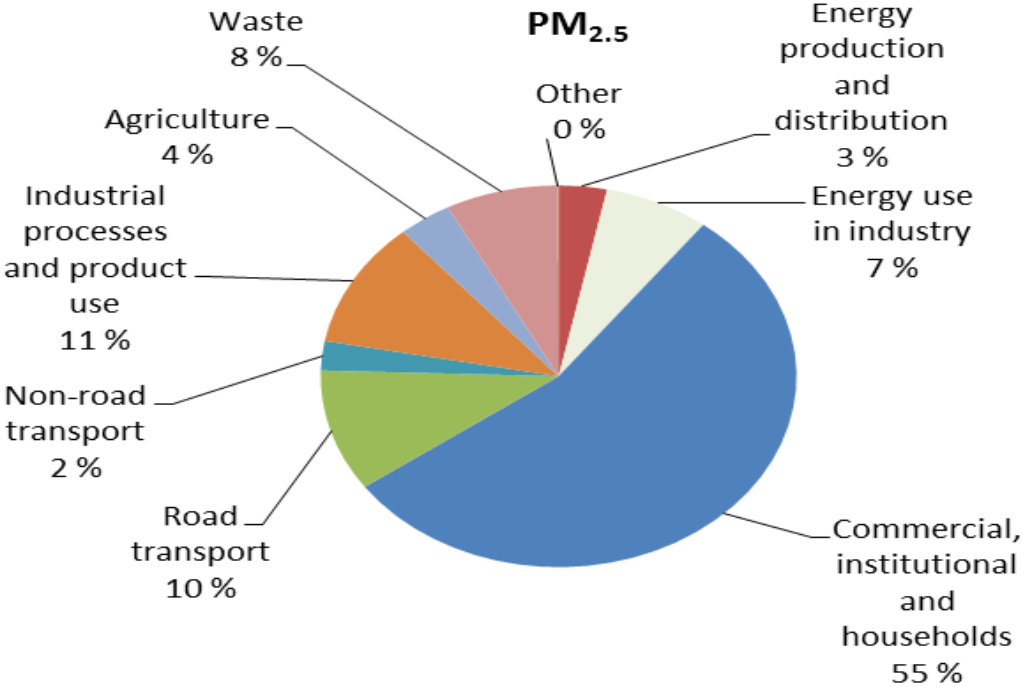


Figure 8. PM_{2.5} emissions in the EU: share by sector group (source: EEA 2021)

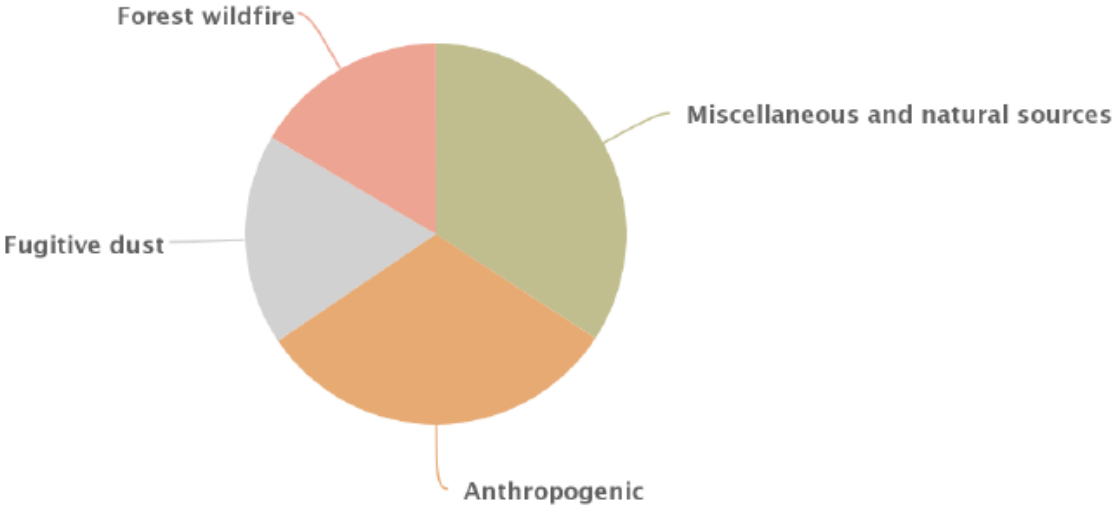


Figure 9. Relative PM_{2.5} emissions in USA (source: US EPA 2018b)

As we see from Figure 8, households contribute most to the PM_{2.5} total emissions in Europe. Taking into account that winter temperatures in Bishkek are significantly lower, and that households supposedly combust much more coal than in Europe, and that energy efficiency

of local heating stoves is rather low, we can reasonably assume that in Bishkek the contribution of households could be even higher than in Europe. Interestingly, as Figure 9 shows, anthropogenic sources are not a dominating factor in total PM_{2.5} emissions in the United States, on the contrary, non-anthropogenic sources constitute the largest share by far. Based on the inventories of air pollution in other countries and approximate quantification of the major PM_{2.5} sources in Bishkek, we came up to the following estimates:

- The source contributing most to anthropogenic PM_{2.5} pollution in Bishkek during the average heating season is “Households and other buildings not connected to CHP”;
- Next most important source is CHP. However, it is difficult to estimate how much CHP contributes to the PM_{2.5} levels in Bishkek without detailed information on the effectiveness of the emission control system installed at the plant;
- Third most important source of the PM_{2.5} winter pollution is road transport.

The economic cost of air pollution section looked at the consumption of the energy products using the KIHS data and calculated the coal-based CO₂ emissions by households. The Kyrgyz households emit high number of CO₂ when burning coal.

The coal-based emission has increased by 22% in last six years. The coal consumption has been increasing and the data shows that this growth trend has been stable. Moreover, now we do not have more detailed information about the used coal and such important data as calorific value is missing.

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Annexes

Part of the survey results table among Bishkek drivers.

	Car	Engine volume	Year	Purpose	Fuel	Fuel volume	Mileage	Catalyst
1	Toyota Camry	2	2009	в личных целях [жеке максаттар үчүн]	АИ-92	30	50	Да[Ооба]
3	Toyota Camry	2.4	2009	как общественный транспорт [коомдук тран	АИ-92	30	250	Да[Ооба]
4	Mercedes-Benz E class w212r	2.0	2013	в личных целях [жеке максаттар үчүн]	АИ-95;АИ-98	6	100	Да[Ооба]
5	Mazda 626	2.0	1990	оба варианта [эки вариант тен]	АИ-92	10	100	Да[Ооба]
9	Honda Odyssey	2.3	2003	в личных целях [жеке максаттар үчүн]	АИ-92	10	50	Да[Ооба]
10	Honda Survey	2.4	2008	в личных целях [жеке максаттар үчүн]	АИ-92	60	100	Да[Ооба]
11	Honda Famos	0.6	2003	в личных целях [жеке максаттар үчүн]	АИ-95	10	100	Да[Ооба]
12	Lexus 570	5.7	2014	в личных целях [жеке максаттар үчүн]	АИ-95	100	100	Да[Ооба]
13	Тойота хайландер	3.5	2010	оба варианта [эки вариант тен]	АИ-95	20	100	Да[Ооба]
14	Тойота хайландер	3.5	2010	оба варианта [эки вариант тен]	АИ-95	20	100	Да[Ооба]
15	Mercedes Benz E350	3.5	2010	в личных целях [жеке максаттар үчүн]	АИ-92;АИ-95	50	1500	Да[Ооба]
16	Mercedes Benz	6.5	2012	в личных целях [жеке максаттар үчүн]	АИ-98	80	1000	Да[Ооба]
17	Toyota land cruiser	4.6	2020	в личных целях [жеке максаттар үчүн]	Дизельное топли	50	1000	Да[Ооба]
19	Hyundai i10	1.2	2011	оба варианта [эки вариант тен]	АИ-92;АИ-95	12	350	Да[Ооба]
20	Toyota	2.4	2014	в личных целях [жеке максаттар үчүн]	АИ-95	15	100	Да[Ооба]

Данные для исследования по качеству воздуха (для АУЦА).

Марка авто	Год произ-водства	Вид топ-лива	Объем двигателя	Показатели по выхло-пам, CO	Показатели по дымности	Наличие ка-таллизатора
Toyota Camry	2013	Бензин	2500	0,3		Да
Toyota Camry	2016	Бензин	2500	0,2		Да
Toyota Camry	2013	Бензин	2500	0,4		Да
Toyota Camry	2011	Бензин	2500	0,3		Да

Toyota Camry	2014	Бензин/ Ги-брид	2500	0,1		Да
Toyota Camry	2013	Бензин/ Ги-брид	2500	0,2		Да
Toyota Camry	2003	Бензин	2400	0,7		Да
Toyota Camry	2005	Бензин	2400	0,8		Да
Toyota Camry	2001	Бензин	3000	0,7		Да
Toyota Camry	2003	Бензин	2400	0,9		Да
Toyota Camry	2010	Бензин	2500	4		Нет
Toyota Camry	2002	Бензин	2400	4,9		Нет
Toyota Camry	2004	Бензин	2400	4,7		Нет
Toyota Camry	2011	Бензин	2400	3,8		Нет
Toyota Camry	2002	Бензин	2400	3,9		Нет
Toyota Camry	2005	Бензин	2400	4,1		Нет
Toyota Camry	2014	Бензин	2500	3,7		Нет
Mercedes-Benz, Бус	2008	Дизель	2200		2,4	Да
Mercedes-Benz, Бус	2006	Дизель	2970		2,1	Да
Mercedes-Benz, Бус	2009	Дизель	2200		2	Да
Mercedes-Benz, Бус	2002	Дизель	2148		3,2	Да
Mercedes-Benz, Бус	2002	Дизель	2148		2,3	Да
Mercedes-Benz, Бус	2010	Дизель	2148		1,9	Да
Mercedes-Benz, Бус	2008	Дизель	2970		1,6	Да
Mercedes-Benz, Бус	2007	Дизель	2148		2,3	Да
Mercedes-Benz, Бус	2006	Дизель	2148		4,4	Да
Mercedes-Benz, Бус	2001	Дизель	2148		2,6	Да
Mercedes-Benz, Бус	2010	Дизель	2148		3,7	Нет
Mercedes-Benz, Бус	2002	Дизель	2874		4,6	Нет
Mercedes-Benz, Бус	1998	Дизель	2874		4,9	Нет
Mercedes-Benz, Бус	1996	Дизель	2299		5,2	Нет
Mercedes-Benz, Бус	2007	Дизель	2148		4,6	Нет
Mercedes-Benz, Бус	2009	Дизель	2148		4,3	Нет
Mercedes-Benz, Бус	2011	Дизель	2148		4,3	Нет
Mercedes-Benz, Бус	1999	Дизель	2874		5,2	Нет
Mercedes-Benz, Бус	2000	Дизель	2148		4,7	Нет
Mercedes-Benz, Бус	1992	Дизель	2299		5,9	Нет
Lexus, GX	2005	Бензин	4700	0,6		Да
Lexus, GX	2008	Бензин	4700	0,3		Да
Lexus, GX	2008	Бензин	4700	0,3		Да
Lexus, GX	2004	Бензин	4700	0,5		Да
Lexus, GX	2006	Бензин	4700	0,5		Да
Lexus, GX	2008	Бензин	4700	0,3		Да
Lexus, GX	2005	Бензин	4700	0,6		Да
Lexus, GX	2005	Бензин	4700	0,4		Да
Lexus, GX	2003	Бензин	4700	0,6		Да
Lexus, GX	2009	Бензин	4700	0,2		Да
Lexus, GX	2005	Бензин	4700	2,2		Нет
Lexus, GX	2003	Бензин	4700	2,5		Нет
KAMAZ	1992	Дизель	10850		6	Нет

KAMAZ	1999	Дизель	10850	5,6	Нет
KAMAZ	1994	Дизель	10850	5,8	Нет
KAMAZ	1996	Дизель	10850	6,2	Нет
KAMAZ	2001	Дизель	11760	4,8	Нет
KAMAZ	2001	Дизель	11760	4,6	Нет
KAMAZ	1998	Дизель	10850	5,5	Нет
KAMAZ	1991	Дизель	10850	6,4	Нет
KAMAZ	1991	Дизель	10850	5,8	Нет
KAMAZ	1996	Дизель	10850	6,3	Нет
KAMAZ	1999	Дизель	10850	5,1	Нет
KAMAZ	2005	Дизель	11760	3,9	Нет
KAMAZ	2005	Дизель	11760	3,3	Нет
KAMAZ	1994	Дизель	10850	5,9	Нет
KAMAZ	1992	Дизель	10850	6,1	Нет
KAMAZ	1998	Дизель	10850	5,4	Нет
KAMAZ	1998	Дизель	10850	5,2	Нет
VOLVO	2013	Дизель	12780	1,8	Да
VOLVO	2013	Дизель	12780	1,3	Да
VOLVO	2015	Дизель	12780	0,9	Да
VOLVO	2005	Дизель	12777	2,1	Да
VOLVO	2013	Дизель	12780	1,2	Да
DAF	2013	Дизель	12900	1,2	Да
DAF	2013	Дизель	12900	1,4	Да
DAF	2014	Дизель	12900	1,2	Да
DAF	2015	Дизель	12900	0,95	Да
DAF	2015	Дизель	12900	0,85	Да

Part of the Excel File with PM2.5 concentration downloaded from the US Embassy

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1														
2	Site	Parameter	Date (LT)	Year	Month	Day	Hour	NowCa	AQI	AQI Cat	Raw Co	Conc. U	Duratic	QC Nar
1245	Bishkek	PM2.5 - Principal	30.03.2019 5:00	2019	3	30	5	13,6	54	Moderate	13	UG/M3	1 Hr	Valid
1246	Bishkek	PM2.5 - Principal	30.03.2019 6:00	2019	3	30	6	12,3	51	Moderate	11	UG/M3	1 Hr	Valid
1247	Bishkek	PM2.5 - Principal	30.03.2019 7:00	2019	3	30	7	11,6	48	Good	11	UG/M3	1 Hr	Valid
1248	Bishkek	PM2.5 - Principal	30.03.2019 8:00	2019	3	30	8	12,8	52	Moderate	14	UG/M3	1 Hr	Valid
1249	Bishkek	PM2.5 - Principal	30.03.2019 9:00	2019	3	30	9	14,9	57	Moderate	17	UG/M3	1 Hr	Valid
1250	Bishkek	PM2.5 - Principal	30.03.2019 10:00	2019	3	30	10	14,6	56	Moderate	15	UG/M3	1 Hr	Valid
1251	Bishkek	PM2.5 - Principal	30.03.2019 11:00	2019	3	30	11	15,4	58	Moderate	17	UG/M3	1 Hr	Valid
1252	Bishkek	PM2.5 - Principal	30.03.2019 12:00	2019	3	30	12	15,2	58	Moderate	15	UG/M3	1 Hr	Valid
1253	Bishkek	PM2.5 - Principal	30.03.2019 13:00	2019	3	30	13	14,1	55	Moderate	12	UG/M3	1 Hr	Valid
1254	Bishkek	PM2.5 - Principal	30.03.2019 14:00	2019	3	30	14	15,1	57	Moderate	17	UG/M3	1 Hr	Valid
1255	Bishkek	PM2.5 - Principal	30.03.2019 15:00	2019	3	30	15	14,3	56	Moderate	13	UG/M3	1 Hr	Valid
1256	Bishkek	PM2.5 - Principal	30.03.2019 16:00	2019	3	30	16	13,1	53	Moderate	11	UG/M3	1 Hr	Valid
1257	Bishkek	PM2.5 - Principal	30.03.2019 17:00	2019	3	30	17	13,1	53	Moderate	13	UG/M3	1 Hr	Valid
1258	Bishkek	PM2.5 - Principal	30.03.2019 18:00	2019	3	30	18	12,7	52	Moderate	12	UG/M3	1 Hr	Valid
1259	Bishkek	PM2.5 - Principal	30.03.2019 19:00	2019	3	30	19	13,8	55	Moderate	16	UG/M3	1 Hr	Valid
1260	Bishkek	PM2.5 - Principal	30.03.2019 20:00	2019	3	30	20	21,1	70	Moderate	28	UG/M3	1 Hr	Valid
1261	Bishkek	PM2.5 - Principal	30.03.2019 21:00	2019	3	30	21	24,5	77	Moderate	28	UG/M3	1 Hr	Valid
1262	Bishkek	PM2.5 - Principal	30.03.2019 22:00	2019	3	30	22	47,2	130	Unhealthy	70	UG/M3	1 Hr	Valid
1263	Bishkek	PM2.5 - Principal	30.03.2019 23:00	2019	3	30	23	48,1	132	Unhealthy	49	UG/M3	1 Hr	Valid

Part of the Excel File with climatic parameters on Bishkek

6	#																		
7	Местное время в Би	T	Po	P	Td	Diff	U	DD	Ff	#10	#3	N	WW	W1	W2	Tn	Tx		
968	01.01.2021 18:00	-8,2	709,4	781,3	-8,8	0,6	96	Ветер, дующий с юго-вост	1			Небо не видно из-за тумана	Туман или	Туман или	Туман или	Туман или	Туман или	Туман или	
969	01.01.2021 15:00	-7,6	708,3	779,8	-8,5	0,9	93	Ветер, дующий с северо-з	1			Небо не видно из-за тумана	Туман или	Туман или	Туман или	Туман или	Туман или	Туман или	
970	01.01.2021 12:00	-8,7	708,4	780,1	-9,0	0,3	98	Ветер, дующий с северо-з	1			Небо не видно из-за тумана	Туман или	Туман или	Туман или	Туман или	Туман или	Туман или	
971	01.01.2021 09:00	-8,9	706,7	793,4	-9,2	0,3	98	Ветер, дующий с севера	1			100%	Дымка.	Туман или	Облака покрывали более по				
972	01.01.2021 06:00	-8,2	706,0	777,4	-8,4	0,2	98	Штиль, безветрие	0			Небо не видно из-за тумана	Туман или	Туман или	Туман или	Туман или	Туман или	Туман или	
973	01.01.2021 03:00	-8,4	706,5	778,1	-8,7	0,3	98	Штиль, безветрие	0			Небо не видно из-за тумана	Туман или	Туман или	Туман или	Туман или	Туман или	Туман или	
974	01.01.2021 00:00	-8,0	707,1	778,6	-8,6	0,6	96	Ветер, дующий с северо-з	1			Небо не видно из-за тумана	Туман или	Туман или	Туман или	Туман или	Туман или	Туман или	
975	31.12.2020 21:00	-7,6	707,8	779,4	-8,2	0,6	96	Ветер, дующий с северо-з	2			Небо не видно из-за тумана	Туман или	Туман или	Туман или	Туман или	Туман или	Туман или	
976	31.12.2020 18:00	-7,9	708,4	780,1	-8,5	0,6	96	Ветер, дующий с запада	1			Небо не видно из-за тумана	Туман или	Туман или	Облака покрывали более по				
977	31.12.2020 15:00	-6,7	707,9	779,2	-8,7	2,0	86	Ветер, дующий с запада	1			Облаков нет.	Дымка.	Облака по	Облака покрывали более по				
978	31.12.2020 12:00	-7,6	709,0	780,7	-8,6	1,0	93	Ветер, дующий с запада	1			100%	Видимости	Туман или	Облака покрывали более по				
979	31.12.2020 09:00	-8,4	709,3	781,3	-9,1	0,7	95	Ветер, дующий с востока	1			Небо не видно из-за тумана	Туман или	Туман или	Облака покрывали более по				
980	31.12.2020 06:00	-7,2	709,6	781,1	-7,4	0,2	98	Ветер, дующий с юго-вост	1			100%							
981	31.12.2020 03:00	-7,2	709,6	781,2	-8,1	0,9	93	Штиль, безветрие	0			100%							
982	31.12.2020 00:00	-7,0	709,3	780,8	-7,9	0,9	93	Ветер, дующий с юго-запа	2			100%							
983	30.12.2020 21:00	-8,2	709,3	781,2	-8,8	0,6	96	Ветер, дующий с северо-з	1			Облаков нет.							
984	30.12.2020 18:00	-4,8	708,9	779,7	-7,6	2,8	81	Ветер, дующий с северо-з	1			Облаков нет.	Видимости	Облака по	Облака покрывали половин				
985	30.12.2020 15:00	-1,8	707,8	777,7	-6,7	4,9	70	Ветер, дующий с северо-з	2			Облаков нет.							

Часть анкеты

2. ЖИЛИЩНО-КОММУНАЛЬНЫЕ РАСХОДЫ

Сейчас я хотел (а) бы подробно записать все жилищно-коммунальные расходы относительно жилья, в котором Вы проживаете.

1. Были ли у Вас за прошедший квартал расходы на приобретение топлива и сжиженного газа или потребление на отопление и личные нужды? (сюда включаются приобретения в качестве подарка)

Да.....1

Нет.....2 ⇒ вопрос 2

- 1.1 Какие виды топлива Вы приобрели и как израсходовали?

№/п	Вид топлива		Какое количество было куплено ?	Стоимость (сомов)	Сколько было получено в качестве подарка ?	Сколько заготовили сами? (собрали сами, из запасов)	Какое количество было израсходовано на отопление и для приготовления пищи?
1	А		3	4	5	6	7
1	Дрова (куб.м)	В прошлом м-це					
2		Два месяца назад					
3		Три месяца назад					
4	Уголь каменный(ц)	В прошлом м-це					
5		Два месяца назад					
6		Три месяца назад					
7	Торф (кг)	В прошлом м-це					
8		Два месяца назад					
9		Три месяца назад					
10	Керосин	В прошлом м-це					
11		Два месяца назад					

12	(л)	Три месяца назад					
13	Мазут	В прошлом м-це					
14	(л)	Два месяца назад					
15		Три месяца назад					
16		Кизяк	В прошлом м-це				
17	(кг)	Два месяца назад					
18		Три месяца назад					
19		Куку	В прошлом м-це				
20	рузное буды лье (кг)	Два месяца назад					
21		Три месяца назад					
22		Соляр	В прошлом м-це				
23	ка (л)	Два месяца назад					
24		Три месяца назад					
25	Хво рост (кг)	В прошлом м-це					
26		Два месяца назад					
27		Три месяца назад					

28	Балон-	В прошлом м-це					
29	ный сжиж.1	Два месяца назад					
30	6 Газ (кг)	Три месяца назад					
31	КС (сумма строк 1-30)						