The Economic Cost of Air Pollution in Ulaanbaatar

Putting Ulaanbaatar USD 4 billion in red per year

November 2020

Associate
Munkhzul Boldbaatar
munkhzul.b@micc.mn

Analyst
Bat-Amgalan Zorigt
batamgalan@micc.mn

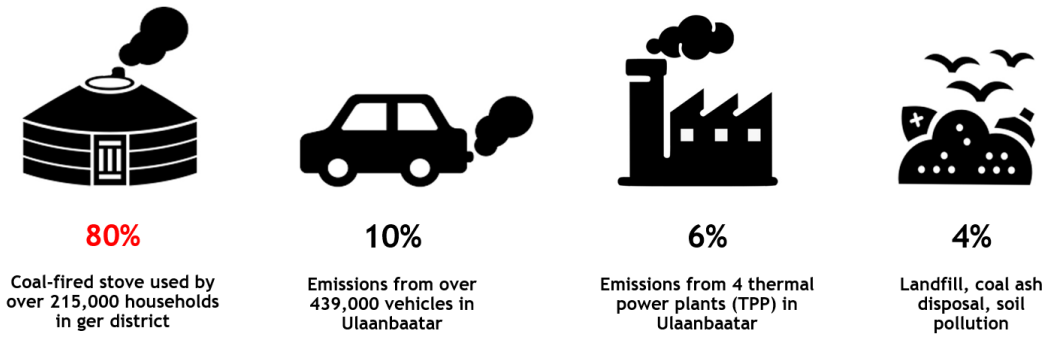
Table of Contents

Table of Figures

1. Ulaanbaatar Air Pollution Overview

Mongolia's capital city of Ulaanbaatar is one of the most polluted in the world, especially during the winter heating season. Ulaanbaatar's high levels of air pollution are largely driven by inadequate infrastructure and limited access to the city's central heating system, which forces ger district residents to use low-grade unprocessed coal for heat during the winter months. Furthermore, most of the thermal power plants in the city are coal-fired. Thus, with coal as the primary source of energy, Ulaanbaatar suffers from toxic air as its growing number of households burn more coal every year. It is estimated that during winter, approximately 80% of the air pollution in Ulaanbaatar comes from the coal-fired stoves used by the 215,000 ger area households. Therefore, this study focuses on coal consumption in Ulaanbaatar, estimates the annual emissions of primary pollutants, and assesses the total economic costs associated with coal use (i.e. both direct and indirect). All of which emphasizes the need to shift away from coal and towards cleaner energy sources.

Figure 1. Causes of air pollution in Ulaanbaatar

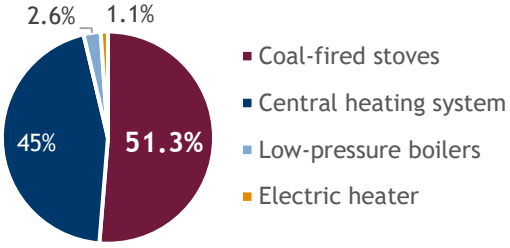


Source: www.agaar.mn, illustrated by MICC

2. Coal Usage in Ulaanbaatar

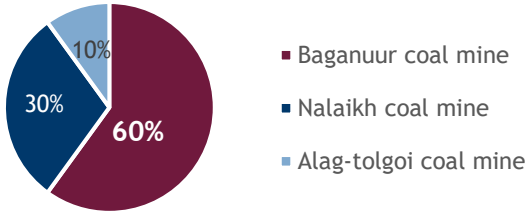
We estimate that Ulaanbaatar's total annual coal consumption by both ger district households and thermal power plants is approximately 6 million tonnes. Of the 6 million total tonnes, ger district households consume a mere 12% or approximately 725,000 tonnes, however, these households are estimated to create 80% of the air pollution in UB during the heating season due to uncontrolled emissions. In contrast, while thermal power plants (TPPs) burn significantly more coal, TPPs use electrostatic precipitators (ESP) to filter and prevent 99% of coal ash from entering the atmosphere. In addition, over half of Ulaanbaatar's households are not connected to the central heating system, and thus use inefficient conventional coal-fired stoves for heat. Until 2019, ger district households sourced coal from the Baganuur (lignite), Nalaikh (lignite), and Alag-Tolgoi (sub-bituminous) coal deposits. Baganuur coal is the lowest and cheapest grade of coal. It is a smoky brown coal that constitutes approximately 60% of coal supply in Ulaanbaatar. Compared to other grades of coal, Baganuur coal releases the highest amount of soot and smoke into the atmosphere when burned, aggravating the air pollution problem.

Figure 3. Heating sources of households in Ulaanbaatar



Source: NSO

Figure 2. Types of coal used in Ulaanbaatar (before 2019)



Source: NSO, MICC estimate

The table below compares the elemental and proximate analyses of unprocessed coals from above mines.

Figure 4. Elemental and proximate analysis of coals used by ger households in UB

Coal by mines	Coal type	Carbon content (%)	Moisture as-received (%)	Ash air dried (%)	Volatile matter dry ash free (%)	Higher calorific value (kcal)[1]
Alag-Tolgoi	Sub-bituminous	63.5	N/A	8.1	47.0	6,090
Nalaikh	Lignite	58.6	21.5	16.0	47.6	5,532
Baganuur	Lignite	54.0	29.5	14.7	48.3	4,948

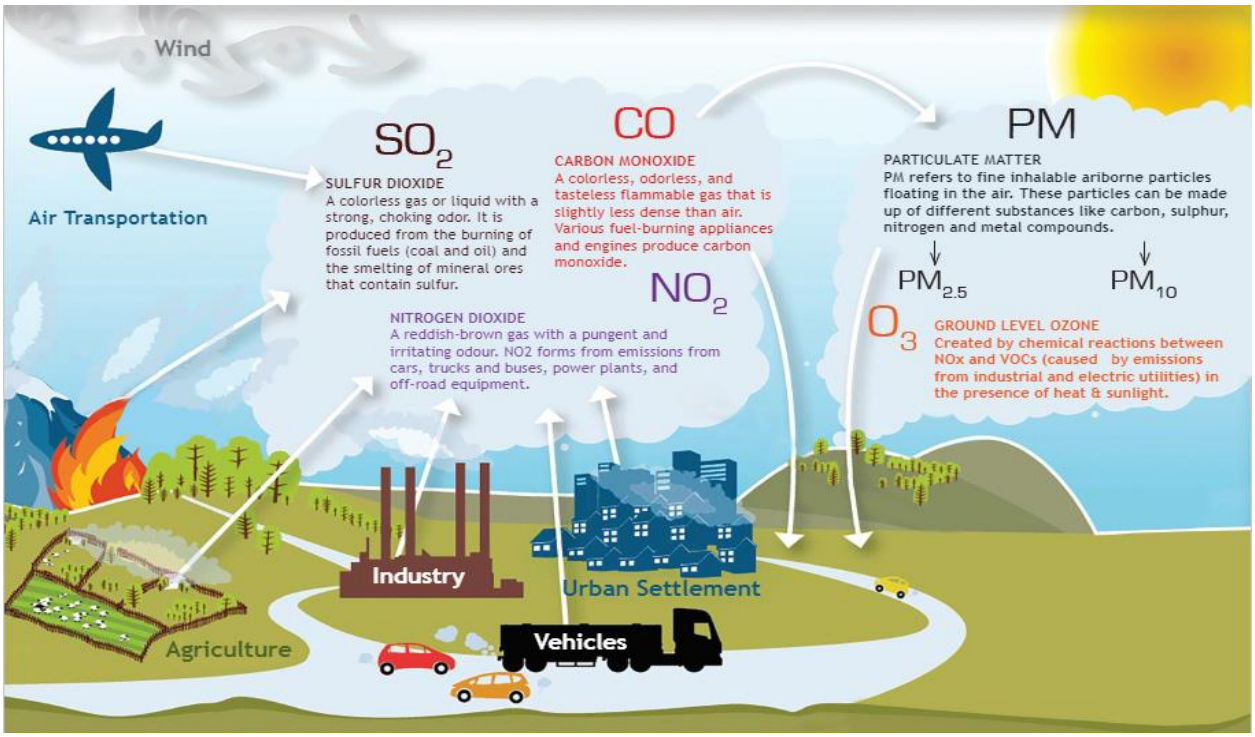
Source: MDPI International Journal of Environmental Research and Public Health, Tavan Tolgoi Tulsh study, MICC estimate

Despite the fact that higher quality coals such as coal from Alag-Tolgoi (sub-bituminous) have higher carbon contents, less volatile matter, and potentially lower uncontrolled emission factors, particulate matter (PM) emissions from coal combustion are influenced more by the configuration or type of stove the coal is burned in rather than the type of coal itself. Because solid fuels do not contain inherently unburnable smoke[2]. In other words, PM emissions are higher in stoves that fail to match with the fuel used. Therefore, sizable PM emissions reductions can only be fully realized if both higher quality coals and more efficient stoves are custom-matched.

3. Air Pollutants and Air Quality Index

There is a strong correlation between Ulaanbaatar's air pollution and coal consumption by ger area households. For the past several years, particulate matter levels have been 6 to 9 times the safe levels outlined by the Mongolian National Standard (MNS) and World Health Organization (WHO). In December and January, Ulaanbaatar's average PM10 level is over 6 times the WHO 24-hour mean permissible level. In addition, the average fine particulate PM2.5 level is nearly 9 times the WHO 24-hour mean permissible level. On January 30, 2018, PM2.5 levels reached a record of 3320 µg/m3 or 133 times the 24-hour mean level deemed safe by the WHO. This is clear evidence of a public health crisis.

Figure 5. Air pollutants types



Source: Zorig Foundation 2019

[1] The modified Dulong equation is used to calculate the higher calorific value (HCV) of biomass (International Flame Research Foundation 2014; Heaven et al. 2011; Milledge and Heaven 2015).

[2] https://openknowledge.worldbank.org/bitstream/handle/10986/31774/Beyond-the-Last-Mile-Piloting-High-Efficiency-Low-Emissions-Heating-Technologies-in-Central-Asia.pdf?sequence=1&isAllowed=y

Particulate matter PM2.5:

The average PM2.5 level in Ulaanbaatar is 89 µg/m3, while the MNS and WHO state permissible levels of PM2.5 are 25 µg/m3 and 10 µg/m3, respectively. Thus, UB's annual mean PM2.5 level is nearly 9 times the WHO standard. On average, 9 months have average PM2.5 levels that exceed the WHO 24-hour mean permissible level (6 months in case of MNS 24-hour mean). Therefore, 24-hour mean PM2.5 levels exceed the WHO guideline level more than 180 days a year. Exposure to these fine particles leads to a variety of health problems such as increased respiratory symptoms, decreased lung function, and premature death in people with heart or lung disease. Fine particles also are the main cause of reduced visibility or haze in Ulaanbaatar.

Particulate matter PM10:

The average PM10 level in Ulaanbaatar is 128 µg/m3, while the MNS and WHO air quality guidelines state acceptable levels of PM10 are 50 µg/m3 and 20 µg/m3, respectively. Therefore, annual mean levels of PM10 are over 6 times the WHO annual mean permissible level. During all months, Ulaanbaatar's monthly average PM10 levels were above the WHO 24-hour guideline level. The size of particles is directly linked to their potential for causing health problems. As a result, these particles pose a massive health risk as they can get deep into the lungs and even bloodstream. Numerous studies found there is a positive association between PM10 exposure and lung cancer.

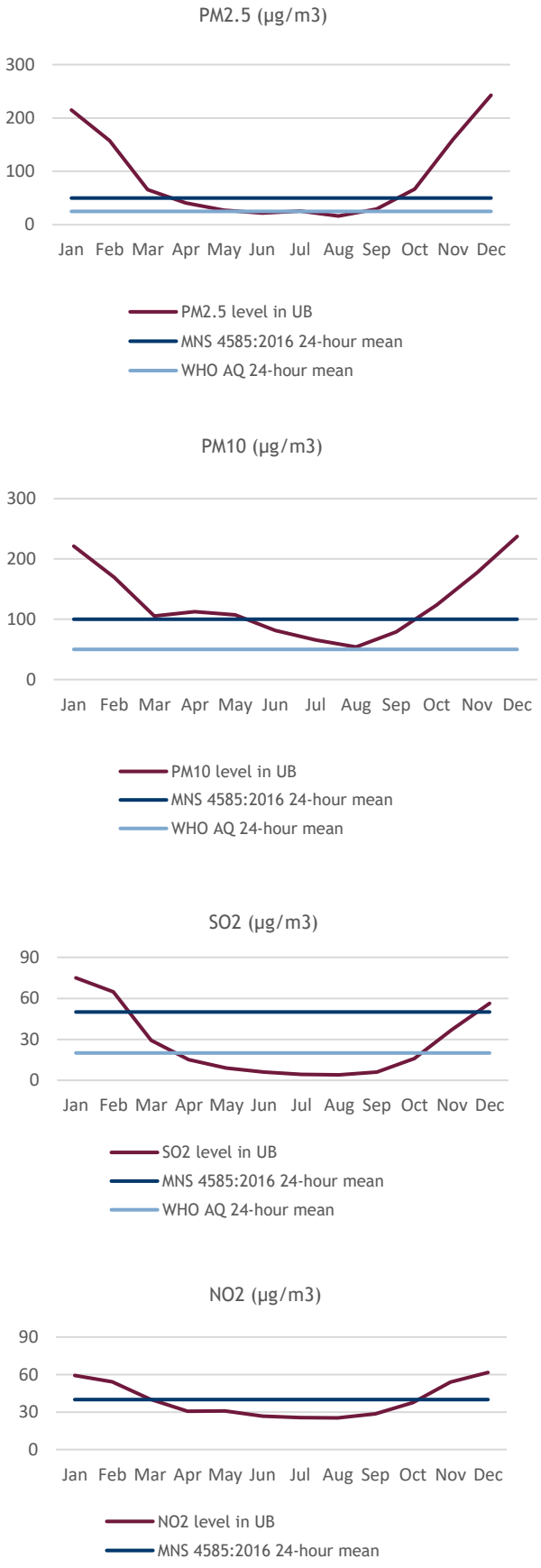
Sulfur dioxide (SO2):

Ulaanbaatar's annual average level of SO2 is 27 µg/m3, while the WHO annual permissible level is 20 µg/m3. On average, 5 months have average SO2 levels that exceed the WHO 24-hour mean permissible level (3 in case of the MNS standard). January is the worst month, in which Ulaanbaatar's SO2 level is nearly 4 times the WHO 24-hour guideline level. Sulfur dioxide is a respiratory irritant, causing irritations of the skin and mucous membranes of eyes, nose, throat, and lungs. Prolonged exposure to high levels is linked to a higher risk of heart attack.

Nitrogen dioxide (NO2):

Ulaanbaatar's average annual level of NO2 is 39.6 µg/m3, just under the MNS and WHO annual permissible limits of 40 µg/m3. However, on average, 4 months have average NO2 levels that exceed the MNS 24-hour mean permissible level. Nitrogen dioxide inflames the lining of the lungs and reduces immunity to lung infections. Also, it can cause problems such as wheezing, coughing, colds, flu, and bronchitis.

Figure 6. Levels of air pollutants in Ulaanbaatar



Source: NSO

Air Quality Index (AQI):

During the heating season, Ulaanbaatar's air pollution level or AQI can exceed 700 or levels 40% above what is considered hazardous. Annual average AQI levels were 332 and 328 in 2017 and 2018, respectively. Both years' annual levels were unhealthy. Ulaanbaatar's air quality index is largely driven by high levels of particulate matter, especially levels of PM2.5. For instance, if there was no particulate pollution, Ulaanbaatar's annual average AQI would be 121. Moreover, it is estimated that over 92% of total particulate emissions come from coal consumption in the ger area households.

Figure 7. AQI Classification, AQI in Ulaanbaatar (2017 and 2018)

AQI values	Levels of health concern
0 to 50	Good
51 to 100	Normal
101 to 250	Unhealthy for sensitive groups
251 to 400	Unhealthy
401 to 500	Very unhealthy
501 <	Hazardous

Source: Ministry of Environment and Tourism

Year/Month	2017	2018
January	792	776
February	536	568
March	204	238
April	258	206
May	214	252
June	198	144
July	130	80
August	94	102
September	148	146
October	248	256
November	464	420
December	696	744
Annual average	**332**	**328**

Source: MICC Estimate

4. Pollutant Emissions and Ash Disposal

In this section, uncontrolled emission factors of lignite and sub-bituminous coals are used to estimate the total emissions of criteria air contaminants since combustion in conventional stoves used by ger district households is uncontrolled (i.e. absent of any air pollution control equipment). These factors are from the United States Environmental Protection Agency's "AP-42: Compilation of Air Emission Factors".

Emissions from ger district households

A staggering amount of coal ash waste from ger district households is collected by garbage trucks and ultimately dumped in landfills. It is estimated that, during the heating season, ger district coal residuals constitute nearly half of the total waste in Ulaanbaatar city. Households typically use 10-15kg sacks, usually the same sacks they bought their coal in, to dispose of coal residuals. Garbage trucks then collect these sacks along with other solid waste and haul the collected waste to landfill sites just outside of Ulaanbaatar.

Annually, more than 104,000 tonnes of coal ash waste are disposed of at landfill sites near Ulaanbaatar. Considering the average density of lignite coal ash, the amount of ash disposed of in one year is equivalent in size to 5 Mongolian Stock Exchange buildings. Unfortunately, the dry coal ash dumped at landfill sites is untreated and continues to contribute to air pollution when stirred up by wind. In addition, ger district coal usage emits over 23,000 tonnes of criteria pollutants into the air, as shown by Figure 9 below. The two largest contaminants are particulate matters (nearly 11,000 tonnes emission) and sulfur oxides (over 9,500 tonnes emission).

Figure 8. Ash waste dumped at "Tsagaan Davaa" landfill site, located in less than 10 km from the city center

Source: MICC

Emissions from thermal power plants

It is estimated that the annual consumption of 6 million tonnes of coal results in more than 942,000 tonnes of coal ash waste in Ulaanbaatar city. Over 838,000 tonnes of coal ash or 89% of the total coal ash residuals are generated by thermal power plants. However, thermal power plants capture most of this ash and sell approximately 40,000 tonnes of fly ash to cement manufacturers and dispose of the remainder in surface impoundments or ash ponds near the plants.

Thermal power plants capture this ash through the use of electrostatic precipitators (ESPs), which filter out 99% of fine particles before emissions are released into the atmosphere. However, it is estimated that a total of 82,000 tonnes of other criteria contaminants are still released into the atmosphere, of which 63,700 tonnes are sulfur oxides and 15,300 tonnes are nitrogen oxides.

Figure 9. Emissions by pollutants

Pollutant	Ger district households [tonnes]	Thermal power plants [tonnes]	Total [tonnes]
PM2.5	2,893	235[1]	**3,128**
PM10	8,098	671[1]	**8,769**
SOx	9,540	63,678	**73,218**
NOx	2,230	15,308	**17,538**
CO	593	1,584	**2,177**
VOC	112	528	**640**
Ash waste	104,286	838,311	**942,597**

[1] Thermal power plants use ESPs to remove 99% of ash particles, and thus have lower particulate emission. However, it is assumed that currently TPPs do not have desulfurization or denitrification filter technologies.

Source: MICC estimate

As illustrated in the above figure, except for particulates, thermal power plants create about 83.7% of the total emissions. However, particulate emission from ger area constitute 92.4% of the total particulate emissions.

Carbon footprint

In addition to criteria air pollutants and coal ash residuals, a large amount of carbon dioxide (CO2), a greenhouse gas (GHG), is released into the air as a result of coal use. Using typical carbon dioxide emission factors for lignite and sub-bituminous coals by US EPA, MICC estimates that over 12.88 million tonnes of CO2 are released annually from the combustion of 6 million tonnes of coal in Ulaanbaatar city. About 12.1% or 1.56 million tonnes of CO2 are released from the ger area. The average ger district household emits more than 7.2 tonnes of CO2 per year from coal use.

5. Direct Costs of Air Pollution

Financial Cost of Coal Usage

The retail coal market constitutes a large part of the economy and ger household expenditures during the heating season. The United Nations Development Programme (UNDP) estimates that ger district households spend 17.5% of their total annual income on heating or coal purchases. The total spending on coal consumption by ger district households is estimated to be approximately MNT 178 billion per year. To put it another way, the average retail price of coal per kilogram was MNT 246 and over 215,000 households burned nearly 725,000 tonnes of coal in 2018.

In addition, thermal power plants burned approximately 5,275,000 tonnes of coal in 2018 at an average FOB price of MNT 29,960 per tonne. Therefore, thermal power plants spend approximately MNT 158 billion per year on coal. Thus, total annual spending by households and TPPs on coal is about **MNT 336.4 billion**.

Public Expenditures

Between 2008 and 2016, total government expenditures associated with air pollution reduction efforts were approximately MNT 16.4 billion per year.

Figure 10. Government expenditures for air pollution reduction, 2008-2016 (MNT billion)

Implementing agency	Revenue expenditures	Investment expenditures	Total
Ministry of Environment and Tourism	4,264	16,645	20,908
Ministry of Construction and Urban Development		990	990
Ministry of Energy		31,959	31,959
Clean Air Foundation	93,454		93,454
Total	**97,718**	**49,594**	**147,311**
Yearly average	**10,858**	**5,510**	**16,368**

Source: Ministry of Finance, compiled by UNDP

The majority of the funds were spent by the Clean Air Foundation, a special foundation created by the Government of Mongolia (GoM) that was granted a mandate to deal with air pollution issues. The foundation implemented various initiatives and measures including but not limited to subsidies for energy-efficient stoves, refined coal consumption, ger house insulation for improved energy-efficiency, and activities associated with replacing certain ger households' heat boiler systems with connections to the central heating system. The foundation was closed in November 2015 due to widespread concerns regarding the misuse of funds as a result of weak controls and monitoring mechanisms.

Figure 11. Clean Air Foundation expenditures, 2011-2015

Year	Expenditures
2011	MNT 31.4 billion
2012	MNT 24.6 billion
2013	MNT 22.9 billion
2014	MNT 9.2 billion
2015	MNT 5.3 billion
Total	**MNT 93.45 billion**

Source: Ministry of Finance, compiled by UNDP

Between 2008 and 2016, Mongolia received about USD 60 million (MNT 87 billion) in external assistance from various funding partners including but not limited to the Asian Development Bank, World Bank, Japan International Cooperation Agency, and Millennium Challenge Corporation.

Currently the National Program on Reduction of Air and Environmental Pollution (NPRAEP), adopted by the GoM in 2017, is being implemented in two stages: Stage 1 (2017-2019) and Stage 2 (2020-2025) with comprehensive objectives to improve air quality nationwide. Ban of raw coal consumption and distribution of refined coal from Tavan Tolgoi Tulsh LLC is a part of the program and is currently underway. As the UNDP recently stated in its review[3] on public expenditure on air pollution in Mongolia, the total cost of the program is estimated to be about USD 4.1 billion (MNT 9.8 trillion) over the life of the program, an average of **MNT 1.09 trillion** in public expenditures per year.

[3] United Nations Development Programme (2019) 'Air Pollution and Costs of Inaction or Ineffective Measures in Mongolia: Public Expenditure Analysis.'

6. Indirect Costs of Air Pollution

Cost of Mortality

Exposure to high levels of air pollution can lead to increased mortality rates in the affected areas. According to a joint World Bank and Institute of Health Metrics and Evaluation report (2016), over 2,400 people died in Mongolia due to air pollution in 2013. These deaths resulted in welfare losses for Mongolia worth MNT 4.10 trillion, or 6.9% of GDP[4]. Moreover, News.mn reported that the number of air pollution related deaths rose to 4,000[5] per year in 2018. Using the same framework as the World Bank, these 4,000 deaths deprived Mongolia of **MNT 6.83 trillion** in 2018.

Implicit Cost of Coal Usage

In addition to the financial costs of coal, using coal for heat is labor intensive. The process of heating a home with a coal stove can take a person between 30 minutes and 1 hour per heating, with houses requiring up to three heatings per day during the coldest times of a year. MICC estimates that a single household spends approximately 293 man-hours during the heating season tending to coal stoves. Considering the average income of residents in Ulaanbaatar, the implicit value of time spent supporting coal use for ger district households is approximately **MNT 505 billion** per year or MNT 2.3 million per household per year.

Thus, the total economic cost of coal consumption is MNT 3.1 million per ger district household per year, with MNT 800,000 of that being direct spending on coal and MNT 2.3 million being the value of time spent dealing with coal. In contrast, the average apartment spends much less on heating due to lower energy tariffs (i.e. MNT 5,500 per month for a typical 41-80 square-meter apartment in Ulaanbaatar) and because there is no need to spend time tending to coal stoves. As a result of this inequality between heating gers and apartments, there is a need for a national policy that reduces the disproportionate burden of heating currently placed on ger households.

Healthcare Expenditure

Expenditures on healthcare are also higher as a result of increased health problems due to air pollution. Exposure to air pollution has been clearly linked to lung cancer, stroke, and a variety of other diseases. According to UNICEF, air pollution in Ulaanbaatar was responsible for MNT 18.44 billion in healthcare related spending in 2016. Between 2014 and 2016, this cost grew by 8% per year. Therefore, it is estimated that air pollution was responsible for **MNT 21.6 billion** in healthcare expenses in 2018.

Figure 12. Healthcare expenditure calculation

Year	2014A	2015A	2016A	2017F	2018F
Total Expenditure	MNT 15.74B	MNT 12.31B	MNT 18.44B	MNT 19.96B	MNT 21.61B

Source: MICC estimate

Impact on Housing Prices

Air pollution also adversely impacts the price of housing in an area. Studies from the United States, China, and Colombia all indicate there is a strong correlation between housing prices and ambient air pollution levels. In these three countries, prices increased between 0.7% and 2% for every 1-unit reduction in PM10 levels. Residents are willing to pay this premium for a variety of reasons, such as cleaner air lowers a person's chance of contracting some of the health effects from air pollution.

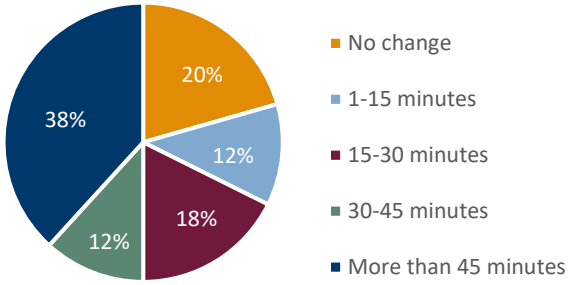
In 2015, M.A.D., a real estate firm based in Ulaanbaatar, estimated the value of the Mongolian real estate market to be MNT 4 trillion or MNT 278,000 per square meter. Adjusted for increases in housing stock, housing price index changes, and FOREX, the 2018 value of this market was estimated to be MNT 5.9 trillion or MNT 362,000 per square meter. Using data from the NSO, Ulaanbaatar is home to 47% of the real estate market by square meters, so the Ulaanbaatar real estate market is then worth MNT 2.77 trillion MNT. If PM standards set by the WHO were met, the Ulaanbaatar real estate market could realize gains of **MNT 1.17 trillion.**

[4] World Bank and Institute for Health Metrics and Evaluation (2016) 'The Cost of Air Pollution: Strengthening the Economic Case for Action.'
[5] https://news.mn/r/2025002/

Cost of Traffic Caused by Air Pollution

Increased levels of air pollution are also linked to increased commute times in Ulaanbaatar. This link exists because many residents now drive or take other forms of public transportation instead of walking to minimize exposure to toxic air and many residents have moved outside the city center to reduce exposure as well. According to a survey administered by MICC, 88% of survey respondents said air pollution caused them to change how they commute in Ulaanbaatar and 33% of respondents stated they had moved as a result of air pollution.

Figure 13. Increase in commute time due to air pollution



Source: MICC survey

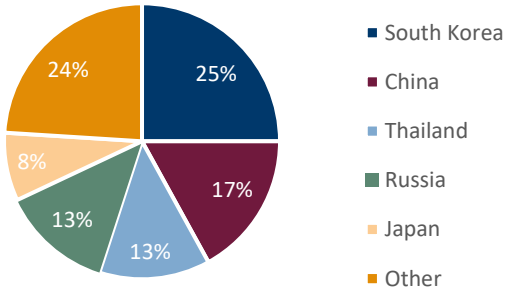
As a result, the survey found the average commute time had increased by 9 minutes in Ulaanbaatar. Considering average monthly income in Ulaanbaatar, the average cost of 9 minutes is MNT 1,039 per person. When average commuting time is increased by 9 minutes across the total number of Ulaanbaatar residents aged 20-59 who most likely commute on daily basis, the total value of time lost to longer commutes due to air pollution is estimated to be **MNT 306 billion** per year.

Cost of Fleeing to Other Countries

32% of MICC survey respondents stated they had left the country either permanently or for some period of time during the winter because of air pollution. This seasonal and permanent emigration negatively impacts the economy of Mongolia as the country is deprived of the productivity and economic contributions of these emigrants.

The estimated number of departures out of the country due to air pollution can be reasonably calculated using travel data from the NSO. During the spring and fall months of 2018, times with low levels of air pollution, the average number of people leaving the country per month was 32,800[6]. In contrast, the average number of people leaving the country during the winter when air pollution is highest was 42,067 per month, which is a difference in monthly departures of 9,267. To adjust for increases stemming from holiday travel, only 32%, the percentage of survey respondents who stated they left the country due to air pollution, of this increase was deemed attributable to air pollution. Consequently, it is estimated that approximately 8,807 people leave the country during the 3 winter months because of air pollution. MICC then found the average cost of a round-way ticket to the most common international destinations to be MNT 2.90 million and Mongolians typically spend an average of MNT 4.21 million once abroad. Therefore, the total costs associated with residents leaving the country due to air pollution is estimated at **MNT 62.6 billion** per year.

Figure 14. Most common international destinations



Source: MICC survey

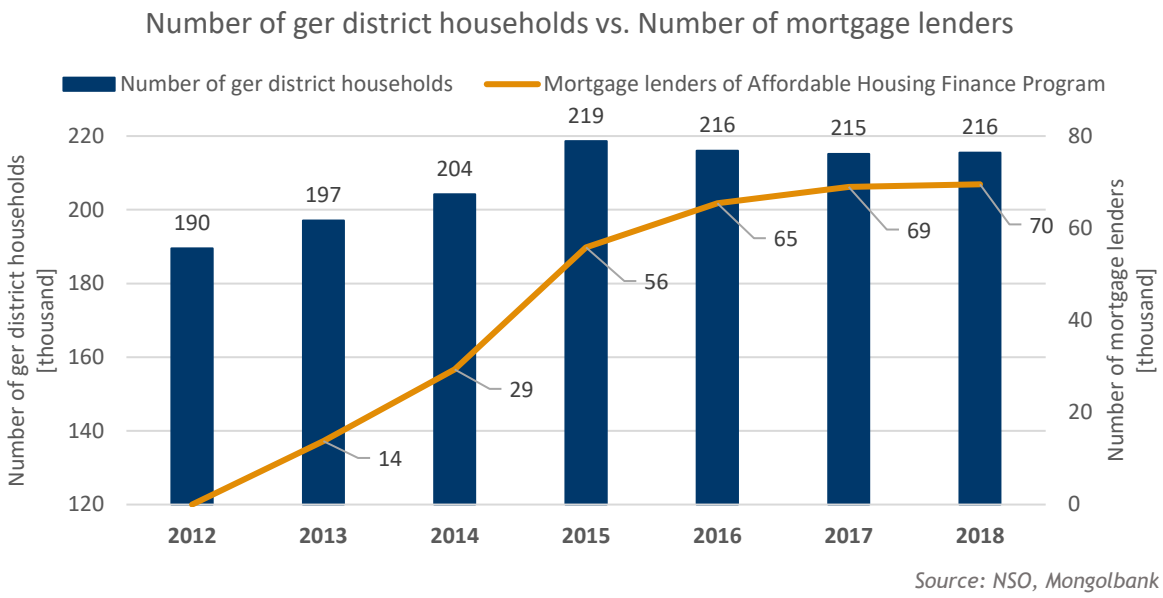
Cost of Affordable Housing Finance Program

The Affordable Housing Finance Program was approved as part of the Pricing Stabilization Program and was implemented in 2013 by the Bank of Mongolia in conjunction with the Ministry of Construction (now the Ministry of Construction and Urban Development). The purpose of the program is to reduce environmental and air pollution by providing low-interest mortgage loans to ger area residents. The program has been funded

[6] The average number of passengers during the summers months was ignored as this number is inflated by an influx of tourists.

partially by the issuance of sovereign bonds and treasury bonds, which have effectively increased the money supply in the economy. Specifically, between 2013 and 2018, the Central Bank steadily increased its money supply by 2.7 times, resulting in 1.9 times weakening of the MNT against USD and increased interest costs or losses on USD denominated sovereign bonds. During this time, the Government of Mongolia effectively borrowed, on average, at annual interest rates between 15-16% and then loaned to commercial banks at 4-5%, who issued mortgage loans to ger district residents at annual interest rates between 8-9%. The approximately 11% interest gap between the government bonds and loans to commercial banks represents a substantial cost for the Government of Mongolia. Over the 6-year life of the program, over MNT 3.74 trillion has been lent out and annual loses of **MNT 428 billion** have been incurred from differences in bond interest rates.

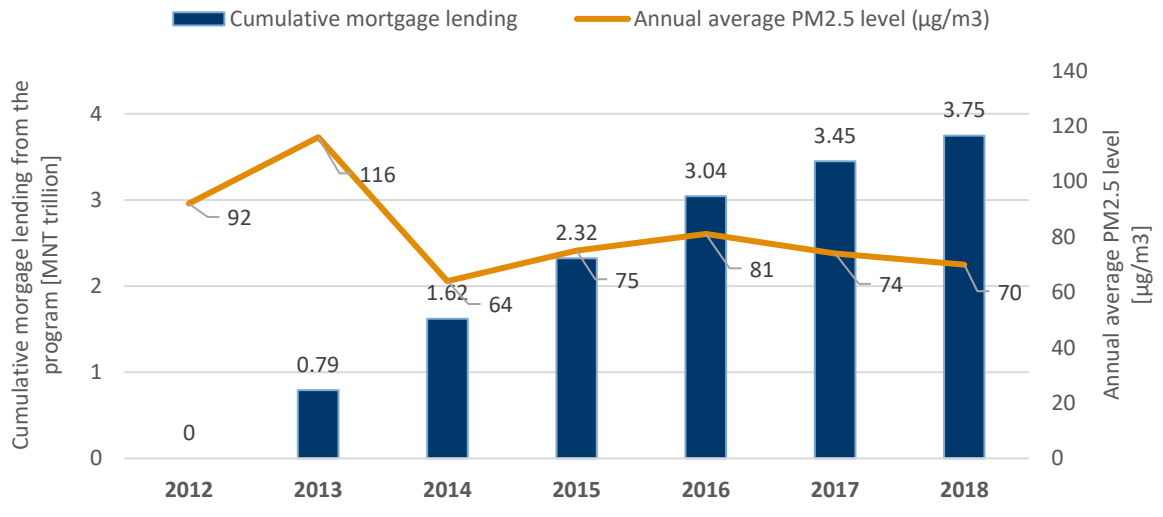
Figure 15. Number of ger district households vs. Number of mortgage lenders over time



Source: NSO, Mongolbank

The figure above shows that the number of ger district households has grown, in general, since the start of the mortgage program despite the fact the number of mortgage lenders reached nearly 70,000 as of the end of 2018.

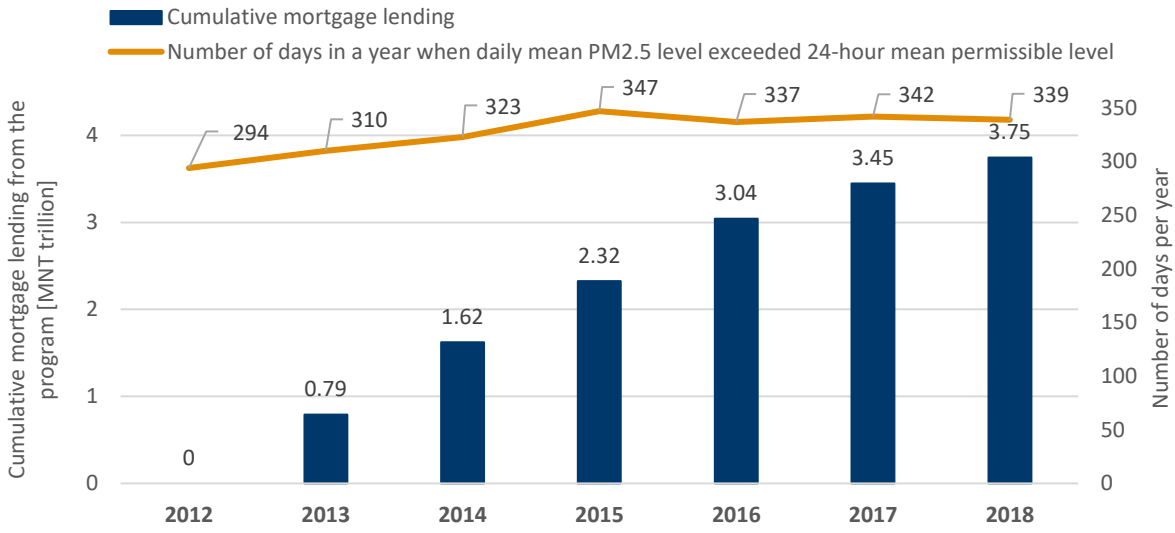
Figure 16. PM2.5 level vs. Cumulative mortgage lending



Source: NSO, Mongolian Mortgage Corporation

As of the end of 2018, the program had lent out nearly MNT 3.75 trillion. However, as the figure below illustrates, the number of days when daily mean PM2.5 levels exceeded the 24-hour mean level permissible set by the Mongolian Agency of Standardization grew to 339 days in 2018 compared to 294 days in 2012. This indicates that Ulaanbaatar has not become cleaner despite MNT 3.75 trillion in spending to help move Mongolians into more efficient and less polluting homes.

Figure 17. Cumulative mortgage lending vs. Number of days when daily mean PM2.5 level exceeded the permissible level



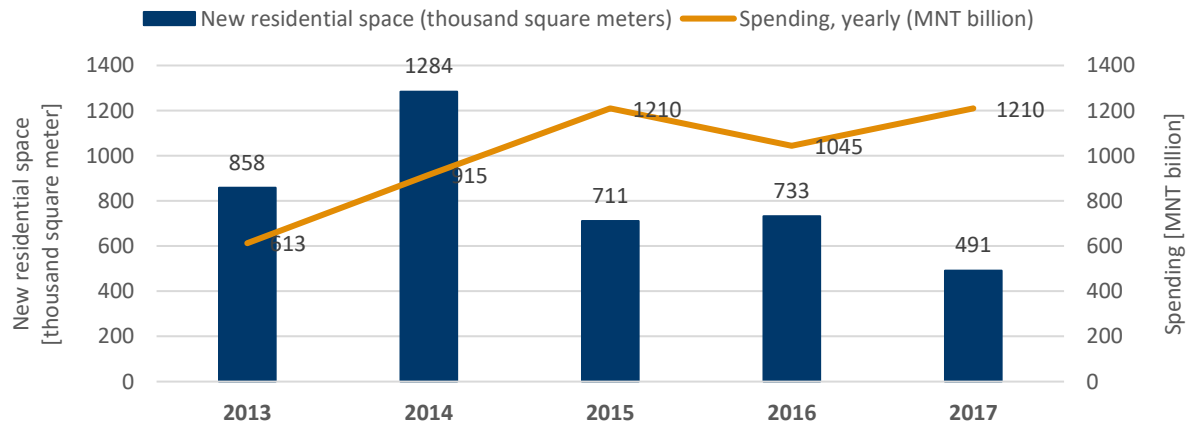
Source: NSO, Mongolian Mortgage Corporation

Impacts of construction activities on air quality in UB

Between 2013-2017, nearly MNT 5 trillion was spent building and commissioning new residential buildings in UB, creating 4 million square meters of new space. As UB continues to expand, the heavy construction associated with expansion will continue to create a significant amount of dust and particulate matter. Such particulates are created by building demolitions, alternation of earthworks, transportation of building materials, and other construction related activities.

According to the US EPA, heavy construction creates 0.3 kg of suspended particulate matter per square meter per month of activity. Assuming a typical residential building is 17 floors and built on a 0.1-hectare plot, it can be estimated that total particulate emissions from residential building construction in UB is about 170 tonnes per year or equal to about 1.6% of the total particulate emissions from the ger areas. Although emissions from construction activities are not the primary focus of this study, such emissions during dry and warm summers can be considerable and constitute a more significant portion of total emissions.

Figure 18. New residential building space and spending on new residential buildings between 2013-2017



Source: NSO

7. Conclusion

Mongolia is a developing country with a heavy reliance on coal for its energy and heating needs. Ulaanbaatar alone consumes roughly 6 million tonnes of coal annually. Furthermore, it is estimated 80% of Ulaanbaatar's air pollution comes from coal burned in the heating stoves of ger district homes.

During the heating season, the UB air quality index often surpasses 700, indicating a clear public health crisis. Furthermore, UB's annual coal consumption of 6 million tonnes results in more than 942 thousand tonnes of coal ash waste, 104 thousand tonnes of which are dumped into landfills with no attempt to contain the hazardous nature of the ash, leading to increased air pollution throughout the year. Additionally, more than 105 thousand tonnes of air contaminants (i.e. particulates, sulfur oxides, nitrogen oxides, carbon monoxide, and volatile organic compounds) are released into the atmosphere annually as a result of UB's coal use, illustrating a grave need to shift away from dirty fossil fuels and towards clean energy.

MICC calculated the economic costs of air pollution in Ulaanbaatar by looking at both the direct and indirect costs of air pollution. The total economic cost of these is estimated to be about **MNT 10.75 trillion or USD 4 billion** per year (Figure 19). The costs examined were made with reasonable assumptions. There may be other indirect costs incurred from air pollution that do not have obvious or quantifiable costs and are therefore not captured in this estimate. Thus, the true total economic cost of air pollution in UB may be higher than this estimate.

Figure 19. Costs of air pollution

Costs	MNT billion
Economic cost of coal usage	841
Public expenditure	1,089
Cost of mortality	6,830
Healthcare expenditure	22
Impact on housing prices	1,170
Cost of traffic caused by air pollution	306
Cost of fleeing to other countries	63
Cost of Affordable Housing Finance Program	428
Total, per year	**10,748**

This study clearly illustrates Ulaanbaatar's reliance on coal as a primary energy source, specifically in the ger district households, has a significant economic impact on all Mongolians. The public is entitled to clean air and government institutions at all levels are acutely aware of this. However, past government initiatives to combat air pollution have yielded poor results. Moreover, government subsidies designed to mitigate air pollution, particularly the Affordable Housing Finance Program, have been ineffective as such programs have benefited intermediary institutions more than ger district households and Mongolians suffering from toxic air. As shown in Figure 15, the number of ger district households has grown despite spending nearly MNT 3.75 trillion on affordable housing financing in 2018. Additionally, Figure 17 shows Ulaanbaatar has not seen any significant change in the number of days with acceptable levels of air pollution. Additionally, other government programs like the NPRAEP (2017-2025) may not be entirely efficient. According to the UNDP's cost-benefit analysis of the NPRAEP, the program was too broad and costly, required appropriate prioritization of activities, robust monitoring mechanisms, and fundamental reforms with respect to governance and transparency in order for it to be implemented successfully.

In conclusion, Mongolia must develop mid and long-term strategies for its energy policy and understand the environmental impacts of those strategies. Comprehensive programs such as the NPRAEP are unnecessarily costly, and at the same time have minimal immediate impacts. Refined coal distribution may yield mild reduction in soot and particulates in the short-run. But it does neither have long-term potential to significantly reduce emissions nor promise pro-poor or inclusive economic growth for low-income households. In other words, ger district household welfare will not be improved and tariff inequality will persist. Therefore, energy strategies aiming to transition towards cleaner fossil fuels (e.g. natural gas heating, liquefied petroleum gas heating) and renewable energy sources must be designed and implemented as early as 2020. It is recommended that such transformation initiatives should first focus on ger areas by directly aiming at and supporting ger households' transitions to cleaner energy.