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# Evaluation on Health Impact of Government Support for GER (Traditional Dwelling) District's Electricity Night Rates in Ulaanbaatar City

Erdenekhuu Nansalmaa

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EVALUATION ON HEALTH IMPACT OF GOVERNMENT SUPPORT FOR *GER*  
(*TRADITIONAL DWELLING*) DISTRICT'S ELECTRICITY NIGHT RATES IN  
ULAANBAATAR CITY

By

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B.A., NATIONAL MEDICAL UNIVERSITY OF MONGOLIA

A Thesis Submitted to the Graduate Faculty  
of Georgia State University in Partial Fulfillment  
of the  
Requirements for the Degree  
MASTER OF PUBLIC HEALTH

ATLANTA, GEORGIA  
20045

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**TITLE OF THESIS:**

HEALTH IMPACT ASSESSMENT OF GOVERNMENT SUPPORT FOR *GER* (*TRADITIONAL DWELLING*) DISTRICT'S ELECTRICITY NIGHT RATES IN ULAANBAATAR CITY

**STUDENT'S NAME:**

Erdenekhuu Nansalmaa

**THESIS CHAIR:**

Professor Michael P. Eriksen, Sc.D

Professor John Steward, MPH

**ABSTRACT**

During the last 10 years, air pollution has become one of the major public health problems in Ulaanbaatar city of Mongolia, and concentrations of pollutants were measured 3 to 50 times higher than WHO recommendation. This devastating air pollution is produced mostly by thousands of families who migrated from countryside and live in *gers* (traditional dwellings) in the suburban area which is not connected to the central heating system, and nearly all of them burn coal to keep them warm. Due to air pollution, residents living in Ulaanbaatar city suffer health problems that equal to the smoking of 4-5 packs of cigarettes. During the winter time, PM<sub>10</sub> hourly average concentrations increased to 2,300 µg/m<sup>3</sup>, and daily average became over than 1,000 µg/m<sup>3</sup> in the most polluted parts of the city. At present, Mongolian government has accepted that the health of Mongolian residents has deteriorated at an alarming level.

In January of 2011, Mongolian Parliament approved the Law on Reduction of Air Pollution in the Capital City to control air pollution and eliminate the gaps in practice. One main provision of this law was to improve *ger* district electricity transmission and distribution network and reduce the night-time price of electricity by 50 percent. Therefore, this study aimed to estimate direct health benefits of Government Provision on cutting electricity payment by 50 percent during the night time and analyze the efficiency of this program on reducing air pollution and its related health impact.

The study result showed when this new regulation is fully implemented in the *ger* districts, the annual consumption of coal and wood would be decreased by about 550,000 tons and 415,000 tons, accompanied by massive reduction of the emission. These changes would lead into noteworthy health benefits such as 15.7 and 17.4 percent of reduction of total and infant mortality rates and 4.3 and 4.7 percent decrease of cardiovascular and respiratory disease morbidity cases, annually.

**Key words:** *air pollution, coal and wood burning, smog, particulate matter, electricity heating*

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## CHAPTER I. INTRODUCTION

*“Mongolia may be best known for its endless steppe and nomadic culture, but a significant demographic shift is underway in which rural residents are crowding into urban centers. Especially in the capital Ulaanbaatar city” (Pearly Jacob, 2011).*

### 1.1 Background

During the last 10 years, air pollution has become the biggest public health issue in Ulaanbaatar city of Mongolia, and each year air is getting more polluted. Pollutant levels are 3 to 50 times higher than WHO recommendations (World Bank Report, 2008 and Appendix C).

Ulaanbaatar is located in a valley within the northeastern mountainous area of Khentii; the city lies about 1,300 meters above sea level at the foot of the mountain Bogd Khan Uul. The surrounding mountains, with peaks up to 2,800 meters, partially block the air flow and increase warm air accumulation within this valley area (Appendix D). The area was designed to be a pleasant environment for nomads to settle down in earlier centuries, and it was not meant to handle today’s crowded population. The annual average temperature is presently around 0°C, and monthly average temperatures are typically -20°C for winter months such as January and February. Night time temperatures can go as low as -40°C in Ulaanbaatar area, making it the world’s coldest capital city.

Since Ulaanbaatar is the coldest capital city in the world, the majority of air pollution comes from a great demand for heating facilities, including apartments, which are connected to central heating systems, and *gers* (Mongolian national dwelling), which are not connected to a central heating system and use individual stoves to heat and cook. Mongolian traditional dwelling “*ger*”

is a portable, felt-covered, wood lattice-framed dwelling structure, and during winter time another layer of felt is added (Appendix A).

During the winter months that stretch from early October to the end of April, especially in the evening and early morning, air pollution becomes so harsh that it is not even necessary to use modern instruments to understand how badly the city air is polluted (Appendix D). This devastating air pollution is produced in part by cars and coal-fueled power plants, but mostly by hundreds of thousands of families who migrated from the countryside and live in *gers* in the north suburban area of the city, which is not connected to the central heating system. Nearly all these families, around 95% of ger area households use coal and firewood for heating and cooking, when 5% use sawdust, dung or paper, 2% briquettes and some 0.2% burn anything they can obtain, which may range from paper and twigs to plastic, used oil, tires, and other garbage (World Bank, 2008).

More than 130,000 *gers* comprise the largest source of ground level pollution in UB. Since *ger* heating system's (stoves) have short stacks (2-3 meters), emissions stay low and close to people's quarters (World Bank, 2009). Thick, pungent smoke which travels throughout the city chokes the throats of the city residents, and people have been breathing toxic and polluted air for the last 10 years. One other source of air pollution, the power plants, although they have large emissions, have a relatively smaller effect on the average ground level pollution because of their tall stacks (100–250 meters). However, they put out large concentrations of pollutants occasionally when power plant smokes hit the ground during unstable meteorological conditions.

Since the 1990's, migration to the city has increased, and Ulaanbaatar's population is exploding. It has risen more than 60 percent in the past 20 years, according to the National Statistical Office of Mongolia.

Due to continuing internal migration, rapid urbanization, increasing use of cars and other vehicles, constrained geographic limits of the city, and greater demand for heating during one of the coldest winters in the world, the pollution levels have risen and *ger* districts, which are the main areas where families who migrated from countryside settle, have become the major source and victim of air pollution (Ministry for Nature and Environment, 2003 and ADB, 2005).

Today, Mongolian government has accepted that the health of Mongolian residents has deteriorated at an alarming level. Due to air pollution, residents living in Ulaanbaatar city suffer health damage which equates to smoking 4-5 packs of cigarettes per day. In recent years, the number of newborns with permanent lung-defects has increased and the urban population suffers 6-15 times more respiratory and lung diseases than the rural population (Burmaa B, 2001).

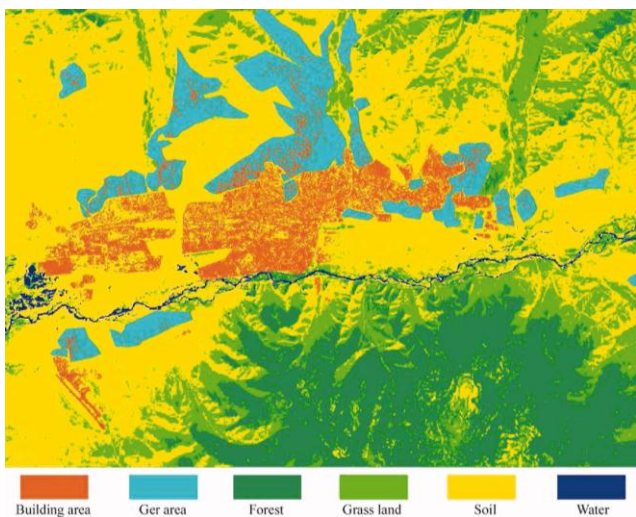
According to the Institute of Public Health of Mongolia, pollution related morbidity due to acute and chronic diseases, including respiratory and cardiovascular diseases has increased dramatically since 1996. Cancer incidence rates have abruptly increased in the last 10 years as well as mortality rates due to diseases related to air pollution (Institute of Public Health, Mongolia, 2008).

Measurements carried out in Ulaanbaatar city indicated that particulate matter (PM) (primary PM<sub>10</sub>, PM<sub>2.5</sub>, and secondary PM due to SO<sub>2</sub> and NO<sub>x</sub> emissions) is certainly the most serious air pollution component. The main sources of ground level PM<sub>2.5</sub> (fine particle) concentrations were primary carbonaceous particles from coal combustion for heating and cooking in *ger*

district areas. Suspension of dust from streets and other surfaces contributed to larger, yet also harmful, coarse particles which contribute up to 50% of the total annual average PM10 concentrations. During the winter time, PM10 hourly average concentrations are at least as high as  $2,300 \mu\text{g}/\text{m}^3$ , and daily averages above  $1,000 \mu\text{g}/\text{m}^3$  are observed in the most polluted parts of the city. Meanwhile, the standard PM10 hourly and daily concentrations are  $150 \mu\text{g}/\text{m}^3$  (USEPA Standard) and  $100 \mu\text{g}/\text{m}^3$  (Mongolian Air quality Standard) respectively (World Bank, 2009).

These episodes of extreme pollution occur regularly and often throughout the winter periods, caused by the special climatic and meteorological situation of Ulaanbaatar, and bring the annual average concentration to its very high level. Besides the cold climate, the lack of precipitation contributes to conditions for suspension of dust from the ground and streets, and the topography creates periods of calm with temperature inversions that trap the pollutant emissions within a relatively thin layer near the ground, thus creating very high ground level concentrations of pollutants that the population is exposed to. Low wind conditions typically occur in the late winter evenings at the same time as the heating and cooking demands are highest; this

**Figure 1.** Geographical overview of Ulaanbaatar city



combination results in periods of extremely high air pollutant concentrations. The wind direction and speed distribution for Ulaanbaatar city is consistent throughout whole city because the main wind direction is aligned with the valley axis from the northwest area to the southeast (Figure 1). Low wind speeds, below 2 m/s, occur close

to 40% of the time, providing frequent potential for high pollution levels (Ekhmaa, S. 2006). As mentioned above, due to complex factors such as overpopulation (more than half of the city's population is living in 0.3% of its area) massive usage of coal and wood for heating, and social factors such as poverty and lack of management of air pollution, the air pollution in Ulaanbaatar city has become the biggest threat to the people of the city, including newborns and children who are future of the Mongolia.

During the past years, Mongolian Government proposed a number of programs to decrease the air pollution with financial and professional support from international organizations. Main actions under Government programs were: improving coal quality as well as efficiency of heating boilers and household stoves and furnaces, implementing vehicle emission control and banning system and increasing use of electricity for heating and cooking in Ger districts. In 2010, the government adopted a clean air amendment along with a new law based on the “polluters pay” principle. The “Law on Air Pollution Fee” would force heavy polluters such as power plants, coal mines, and even car drivers to pay fines, but the modalities of the law are still unclear and loopholes remain. Some analysts noticed that the plans against air pollution were perfect on paper, but misguided in implementation; the plans did not address the real problem - how to phase out the inefficient stoves used by the city's tens of thousands of poor families, which are churning out thick black smoke 24 hours a day. For example, the government spent seven billion *tugrug* (Mongolian currency, equals to \$7 million USD) between 2007 and 2009 to produce briquettes and pressed coal. Unfortunately, they did not reduce the smog because the *ger* stoves were not designed to use them and price of these fuels was not affordable for the poor people and poor families (Mongolian National Audit Office, 2010). Also, WHO consultants

noticed that a lack of management and administration led to poor integration of programs and funds from international organizations and the Mongolian government and poor results in air improvement.

## **1.2 Study Purpose**

Because past programs have not had a significant positive effect on decreasing air pollution and because of the increasing evidence of pollution's impact on the health of Ulaanbaatar city's population, the Mongolian people are demanding that their Government take decisive steps to end more than 15 years of wasted and sluggish efforts. In January of 2011, Mongolian Parliament approved the Law to Reduce Air Pollution in the Capital City which serves mainly to comprehensively regulate air pollution and eliminate the gaps in practice. One main provision of this law is improving *ger* district electricity transmission and distribution network and reduce the price of the night-time use of electricity by 50 percent. This support will be enacted during the winter of 2011-2012 (Office of the President, 2011).

Also, the law sets the territory line which is called "special zone" where the *ger* districts are located and where most of law's provisions will be implemented. Moreover, the law prohibits burning raw coal and other waste matter in the special zone and doing anything that releases pollutant chemicals in the air. The law also promotes the use of alternative sources for heating as well as improving *ger* insulation to save energy and warmth.

The government hopes that this Law will help them eliminate Ulaanbaatar city air pollution by the year 2014, only 2 years after the law was enacted. Researchers note that eliminating *ger* district based air pollution requires comprehensive and efficient management. In order to meet the Mongolian standard in Ulaanbaatar city for the most harmful particulates, PM<sub>2.5</sub>, emissions

must be reduced by 80 percent. As expected, reducing emissions in the *ger* areas by half yields an improvement in PM concentrations by about one-third, which is much greater than similar emissions reductions in other source sectors (Sarath Guttikunda, 2007).

Therefore, this study aims to estimate direct health benefits of the Government Provision on cutting electricity payment by 50 percent during the night time and analyze the efficiency of this program on reducing air pollution and its related consequences, such as health impacts.

### **Research Question**

Does the implementation of the regulation that reduces cost of electricity by fifty percent during the night time have significant in decreasing *ger* households' utility expenses and reducing air pollution associated with coal and wood utilization for heating and cooking?

***Null Hypothesis:*** Implementation of the regulation that reduces cost of electricity by fifty percent during the night time has no effect in decreasing *ger* households' utility expenses and reducing air pollution associated with coal and wood utilization for heating and cooking.

***Alternative Hypothesis:*** Implementation of the regulation that reduces cost of electricity by fifty percent during the night time has significant in decreasing *ger* households' utility expenses and reducing air pollution associated with coal and wood utilization for heating and cooking.



## CHAPTER II. REVIEW OF LITERATURE

### 2.1 Air Pollution and Ulaanbaatar City

The quality of air, both indoors and outdoors, is closely related to the morbidity and mortality of respiratory and cardiovascular diseases. Therefore, air pollution is an important determinant of population health and is estimated to cause approximately 2 million premature deaths worldwide per year (WHO, 2008).

"**Air pollution**" means particles or gases in the air that are not part of its normal composition, and these particles or gases are called "**air pollutants.**" Air pollution has plagued communities since the industrial revolution and even before and can be natural, such as that from volcanoes and forest fires, or human-made. However, during the past hundred years, air pollution created by humans has become a major, persistent problem, and humans are the main victim of this serious problem.

Due to massive urbanization and industrial development, air pollution has been and still is one of the biggest health problems in the world. Air is contaminated with smoke and harmful gases, such as oxides of carbon, sulfur and nitrogen (HEI, 2010). The most common air pollutants that draw intense concern include particulate matter (PM), ozone (O<sub>3</sub>), carbon monoxide (CO), sulfur dioxide (SO<sub>2</sub>), nitrogen dioxide (NO<sub>2</sub>), lead (Pb), volatile organic compounds (VOCs), and polycyclic aromatic hydrocarbons (PAHs) (WHO, 2008).

In the earlier centuries, combustion of fossil fuels was the main source of pollution, and it remains a significant problem in developing countries from Asia to Africa. Rapid urbanization of cities combined with growing demand for energy resources and exponential growth in vehicle

use contribute to deteriorating air quality in urban areas. Along with lack of infrastructure to accommodate the escalating traffic volume and population number, increased consumption of coal and other fossil fuels is the main cause of air pollution in urban areas (HEI, 2010).

In developing countries, industries are often located in towns and cities as they once were during the western industrial revolution and contribute, together with the burning of coal in homes for domestic heat, to very high levels of urban air pollution. In 1952, during the foggy conditions in London, air pollution escalated to a very high level and resulted in 4000 extra deaths (Logan, 1953).

From past experience in Western countries (London fog, Chicago and Los Angeles smoke), it is clear that substantial increase in the combustion of fossil fuels for power generation and transportation can improve economic conditions but can also, if not controlled, have important negative consequences for human health and environmental quality (Beelen R, et al, 2008; Bell ML et al, 2004; Brook RD et al 2008; Dockery DW et al 1993).

Mongolia is experiencing rapid rates of urbanization similar to other Asian countries. A large percentage of this urbanization is occurring in the country's capital, Ulaanbaatar city. Devastating air pollution in the city is caused by the growing number of automobiles and industries in addition to the expanding growth of *ger* districts, which are a major cause of today's problem of air quality.

Another major cause of the air pollution problem in Ulaanbaatar city was the active internal migration in last 10 years caused by 1) higher incomes in towns compared to villages; 2) increased employment opportunities; and 3) bankruptcy of rural herders mostly due to harsh winters. Also, a combination of the city's relative geographic isolation and lack of government

policy preventing or managing internal migration to cities spurred the growth of *ger* areas of Ulaanbaatar (World Bank, 2008).

According to the Asian Development bank Technical report, there were three main sources producing air pollution in Ulaanbaatar city. The first were stationary sources, which included three coal-fired thermal power plants, coal fired boilers used to heat building complexes and stoves in the *ger* districts. Because of poor planning demonstrated by the location of *ger* districts and power plants, emissions from these sources travel over the entire city. The emission of smoke dust was 62,000 tons from the power plants, 12,000 tons from local coal fired boilers and 10,000 tons from the *ger* districts (World Bank, 2009).

The second were field sources, which included power stations' coal ash reservoirs, dust from the degraded and eroded lands, and waste dumps. There were 65 hectares of coal ash reservoir in the power plants in Ulaanbaatar. In winter, three power plants emit 60 tons of ash, 4.5 million cubic meters of smoke and 6 kg of dioxide gas. The third main source was mobile sources, which include motor vehicle air pollutants such as benzene, lead and NO<sub>2</sub> (World Bank, 2009).

Heating in the *ger* districts was provided by over 130,000 individual household stoves using an estimated 0.6 million tons of coal per year due to cold and long winters and lack of general heating and electricity systems in these areas. On average, *ger* areas were estimated to consume 5 tons of coal and 3.0 m<sup>3</sup> of fuel wood per year (World Bank, 2008).

Studies showed that sulphuric dioxide (SO<sub>2</sub>), carbon monoxide (CO) and air particulate matters (PM) were the main constituents of air pollution besides nitrogen dioxide (NO<sub>2</sub>) and lead in Ulaanbaatar city area and were directly related to respiratory and cardiovascular diseases (Enhjargal A, 2006 and Burmaa B, 2005). Fuel combustion was the primary source of a large

number of health-damaging air pollutants, including fine and respirable particulate matter (PM<sub>2.5</sub> and PM<sub>10</sub>), carbon monoxide (CO), sulfur dioxide (SO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>), volatile organic compounds (VOCs), ozone (O<sub>3</sub>), and atmospheric lead (Ministry for Nature and Environment, 2003 and Jinsang Jung et al, 2010). One study proved that lead amounts in the air and soil were 2 and 1.5 times higher than Mongolian standards, and blood levels of lead were also high among the children participated in this study. The main reason for high levels of lead in the blood was lead content in the polluted air (Burmaa B, 2005). Due to their size and high risk to damage in cardiopulmonary system, PMs attract huge attention from researchers and policy makers. PMs have become the major pollutant in Ulaanbaatar, especially in the most polluted parts of the city, and annual average concentrations of PM<sub>10</sub> were 2-10 times higher than Mongolian and International Air Quality Standards (AQS). Annual average concentrations of PM<sub>10</sub>, measured at the National University of Mongolia campus area located in the east of city center were as high as 141, 157 and 279 µg/m<sup>3</sup> for 2006, 2007 and 2008 respectively.

According to the National Air Quality Office of Mongolia, SO, CO and PM<sub>10</sub> highest daily concentrations were reached 117, 14.8 and 1620 µg/m<sup>3</sup> in the moderately polluted areas, and these pollutants peak during winter, similar to other pollutants SO<sub>2</sub> and NO<sub>2</sub>.

## **2.2 Health Impacts of Air Pollution**

During the smog episodes in European cities like London that occurred in the winters of 1952 and 1958, it became evident that air pollution has a serious impact on health. Analysis of data for the London winters of 1958–1971 showed that mortality was associated with air pollution over the entire range of ambient concentrations, not just with episodes of high pollutant concentrations (Ostro, 1984).

Epidemiological studies over the past years have provided enough evidence on the health effects of air pollution and provided a rich basis for predicting adverse outcomes that are associated with exposure to air pollution, especially particulate matter as well as carbon-oxides (C Arden Pope et al., 2004 and Abbey DE et al., 1995). The health effects caused by air pollutants may range from subtle biochemical and physiological changes to difficulty breathing, wheezing, coughing and aggravation of existing respiratory and cardiac conditions. These health effects result in more problems such as increased medication use, increased doctor or emergency room visits, more hospital admissions and even premature death due to chronic diseases (Marco Martuzzi et al., 2002 and Health Canada, 2006). To study ambient air particulate matter influencing the development of cardiovascular disorder, Qinghua Sun et al ( 2005), used an animal model and confirmed that sub-chronic exposure to environmentally relevant particulate matter, even at low concentrations, altered vasomotor tone and potentiated atherosclerosis and vascular inflammation. The prevalence of chronic phlegm, a major symptom of chronic respiratory disease indicating long-term exposure to inhaled irritants, which is also one of the main complaints of Ulaanbaatar city's population, was found to be associated with exposure to combustion source air pollution both in qualitative and quantitative comparisons of measured concentrations of air pollution. Studies in North America and Europe that controlled for major potential confounding factors, including tobacco smoking and indoor air pollution from the burning of solid fuels, reported relative risk for chronic respiratory diseases were estimated between 1.1 and 5.0 besides an increased risk for children to develop COPD later in life (Aaron J. Cohen et al, 2005 and Stephen I. Rennard et al., 2008).

As increasing evidence links PMs, more specifically PM<sub>2.5</sub>, to various respiratory and cardiac effects, strong attention is paid to the exposure assessment of PM<sub>2.5</sub> and its cardiopulmonary impacts (Villeneuve PJ, 2002; Goldberg et al., 2001; Janssen et al., 2002; Magari et al., 2002). One study on the long term effect of PMs proved that long-term PM exposures were most strongly associated with mortality attributable to ischemic heart disease, dysrhythmias, heart failure, and cardiac arrest. Moreover, for these cardiovascular causes of death, a 10  $\mu\text{g}/\text{m}^3$  elevation in fine PM was associated with 8% to 18% increases in mortality risk and 8% increase on lung cancer mortality risk (C Arden Pope et al., 2004 and C Arden Pope et al., 2002). A more recent study which included 65,893 postmenopausal women without previous cardiovascular disease, found out that each increase of 10  $\mu\text{g}/\text{m}^3$  of PM<sub>2.5</sub> was associated with a 24% increase in the risk of a cardiovascular diseases (hazard ratio, 1.24; 95% confidence interval [CI], 1.09 to 1.41) and a 76% increase in the risk of death from cardiovascular disease (hazard ratio, 1.76; 95% CI, 1.25 to 2.47) (Miller KA et al, 2007).

The results of The National Morbidity, Mortality and Air Pollution Study Part II which combined data from the largest 20 and 90 cities were consistent with the above studies and showed an average approximate 0.5% increase in overall mortality for every 10  $\text{mg}/\text{m}^3$  increase in PM<sub>10</sub> and concluded that elderly people were most vulnerable to air pollution (Jonathan M Samet et al, 2000).

A recent report presented that air pollution components have systemic effects that affect lung and cardiovascular disease and also reach the brain and affect the central nervous system. These effects have a chronic character, beginning in early childhood, and take years to accumulate, and develops through several cellular and molecular pathways (Michelle L. Block et al., 2009).

Many studies also concentrated on the health impact of air pollution on pregnancy and early childhood development and showed sufficient evidence to support a causal relationship between PMs and respiratory deaths in the postneonatal period (Bobak M et al., 1999 and Reinhard Kaiser et al., 2004). The possible impact of CO and PM<sub>10</sub> on premature birth and birth defects was studied by Ritz et al. (2000) in Southern California, and after adjusting for a number of biologic, social, and ethnic covariates, they found that premature births were associated with CO and PM<sub>10</sub> concentration in the first gestational month (95% CI, 1.06-1.26) and during late pregnancy (95% CI, 1.09-1.33). Similar studies from Asia (Lin et al., 2001) and Canada (Liu et al., 2003) concluded that preterm birth is correlated with air pollutant concentration such as SO<sub>2</sub> and CO level during the last month of pregnancy.

One recent study found that retinal arteriolar diameter among participants who lived in areas with elevated levels of residential air pollution was narrowed and air pollution had strong relationship with atherosclerotic changes in retinal vessels. Data showed that a 3 µg/m<sup>3</sup> rise in long-term air pollution concentrations estimated at participants' homes was associated with a 0.8 µm (6%) decrease in retinal arteriolar diameter. (Sara D, Adar et al., 2010).

While there are a lot studies about air pollution's impact on specific health issues, some studies concentrated on the effect of air pollution on overall population health and wellbeing as well as economy. After running regression models on compiled data from 211 county units in the 51 U.S. metropolitan areas, C Arden Pope et al, estimated that a decrease of 10 µg per cubic meter in the concentration of fine particulate matter was associated with an estimated increase in life expectancy of 0.61±0.20 year (P = 0.004), which means a reduction in exposure to ambient fine-particulate air pollution could contribute to significant and measurable improvements in life

expectancy in the USA. According to this study, life expectancy in 51 U.S. cities increased nearly three years over recent decades, and approximately five months of that increase came as a result of cleaner air (Pope CA et al., 2009). At the global level, the WHO estimated that 1.4% of all deaths and 0.8% of disability-adjusted life-years (DALY) were the result of particulate air pollution (WHO, 2002).

Research based on nearly 4 million people in Barcelona, found that reducing current level of air pollution ( $50 \mu\text{g}/\text{m}^3$ ) to the WHO standards ( $20 \mu\text{g}/\text{m}^3$ ) would result in about 3,500 fewer annual deaths which is about 12% of all deaths among people 30 years and older; this estimate includes 520 deaths due to short-term exposure of air pollution. In addition, it is estimated that this reduction would mean a total of 1,800 fewer hospitalizations for cardio-respiratory diseases, a total of 5,100 fewer cases of chronic bronchitis symptoms among adults, a total of 31,100 fewer cases of acute bronchitis among children, and a total 54,000 fewer asthma attacks per each year among children and adults (Nino Künzli and Laura Perez., 2007).

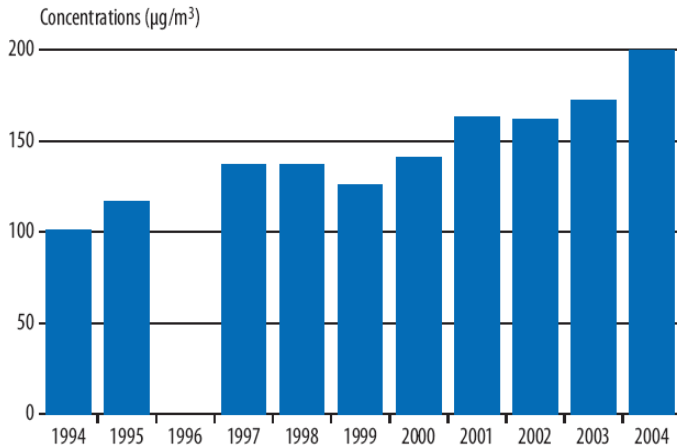
### **2.3 Ulaanbaatar Air Pollution Impact on City Population**

Ulaanbaatar city is one of most polluted cities in the world and each year this pollution has been increasing (Figure 2). Air pollution concentration in PMs (400-1000),  $\text{SO}_2$  (124), CO and NOs are 20-50, 5, 4 and 4 times higher than WHO guidelines, respectively, and people in Ulaanbaatar city live in these conditions for 6 to 9 months each year (Appendix B). However, there are not enough comprehensive epidemiological studies conducted in Mongolia to assess the impact of air pollution on population health of the city.



Most of the air pollution health impact studies in Mongolia are more concerned with the respiratory diseases and their relation to air pollution (Burmaa & Enkhtsetseg 1996; Spickett et

**Figure.2**  
**Trend of Annual Averages of Suspended Particular Matter or Total Suspended Particulates in Ulaanbaatar**



Source: Ekhmaa (2006).

al, 2002; Saijaa 2004; Tseregmaa, 2003). These studies found that the respiratory disease incidence, chronic respiratory symptoms, asthma occurrences and prevalence of respiratory disease among urban population were significantly related to air pollution. The highest correlation was observed for the occurrence of asthma for people between ages 25 and

64 and bronchitis for infants less than one year old (Burmaa et al, 2001).

There is not much relevant data about relationship between cardiovascular disease and air pollution in Mongolia. Sh. Enkhtsetseg et al (2001) conducted a survey on health impacts assessment of air pollution and cardiovascular and respiratory system diseases in two cities and concluded that excessive concentration of air pollutants, specifically NO<sub>2</sub> and SO<sub>2</sub>, have played a significant role in increased respiratory and cardiovascular morbidity within the population. Moreover, according to Tsegmid and others, NO<sub>x</sub> was reported to cause 11.9% of total cancer incidence in Mongolia (Tsegmid S et al., 2002). In 2002, a WHO sponsored study of air quality conducted in two different areas including Ulaanbaatar city reported a strong statistical link

between air pollution and respiratory disease requiring hospitalization among children (Burmaa B. et al., 2002).

There are not many other studies except World Bank and ADB reports and guidelines about Mongolian air pollution status and its impact on population health in terms of life expectancy, DALY, QALY, hospital admissions and health cost.

#### **2.4 Health Impact Assessment and Air Pollution**

Scientists and public health agencies have increasingly engaged in the assessment of the potential public health impact of specific policy or programs. Such assessments consist of the translation of research findings into a rough quantification of the total health problem in a given region, country, or city that may be attributable to specific action or policy. Therefore, as stated in 1999 Gothenburg consensus statement, the health impact assessment (HIA) can be used to objectively evaluate the potential health effects of a project or policy before it is built or implemented in order to provide recommendations to increase positive health outcomes and minimize adverse health outcomes (CDC, 2011).

A major benefit of the HIA process is that it brings public health issues to the attention of persons who make decisions about issues that fall outside of traditional public health arenas, such as transportation or land use. Thus HIA is an effective tool to inform the policy makers and public effectively about the approximate size of health problems.

Therefore, in 1999, WHO defined HIA as “a combination of procedures, methods, and tools by which a policy, program, or project may be judged as to its potential effects on the health of a population, and the distribution of those effects within the population” (WHO, 2011).

Similarly to environmental impact assessments (EIAs), which are mandated processes that focus on environmental outcomes such as air and water quality, HIAs focus on health outcomes such as obesity, physical inactivity, asthma, injuries, social equity, and morbidity and mortality rates. HIAs for air pollution have been applied to various geographic scales ranging from rough global assessments to more sophisticated international, national or local studies.

Several HIAs have recently been conducted in Europe for which different estimates of the burden of air pollution were provided for the city of Barcelona, Spain and eight of the largest cities in Italy (Laura Perez, 2009; Marco Martuzzi et al., 2002). All of these studies showed that the overall health burden attributable to air pollution arose principally from effects on mortality in adults with both short and long-term exposure to particulate matter, plus ozone. Based on these studies, the European Network of Health Information System estimated that 11,000 premature deaths in Europe could be prevented annually if long-term exposure to PM<sub>2.5</sub> was reduced to 20 µg/m<sup>3</sup>, and a 10 µg/m<sup>3</sup> reduction in the daily 8-hour moving average concentrations of ozone could reduce death. The evaluation was based on a total population of almost 39 million inhabitants and concluded that on average, life expectancy of a 30-year-old person could be prolonged, depending on the geographic area, by 2 to 13 months if PM<sub>2.5</sub> concentrations did not exceed 15 µg/m<sup>3</sup> (ENHIS, 2006).

Also, one very interesting and effective HIA was the London Mayoral Strategy on Air Quality conducted by the London Health Commission. It concluded that the strategies proposed by Mayor of London would affect the population health positively and reduce air pollution (London Health Commission and the Environment Committee of the Assembly, 2001).

A study which estimated the impact of outdoor and traffic-related air pollution on public health in Austria, France, and Switzerland, found that air pollution caused 6% of total mortality or more than 40,000 attributable cases per year in these countries (Paul Filliger et al., 1999). About half of all mortality caused by air pollution was attributed to motorized traffic, and also more than 25,000 new cases of adult chronic bronchitis, more than 290,000 episodes of children bronchitis, more than 0.5 million asthma attacks, and more than 16 million person-days of restricted activities were attributed to traffic related air pollution. Moreover, Clean Air for Europe Cost-Benefit Analysis estimated the health burden of outdoor air pollution based on level of emissions projected to 2020 for all of Europe and by member states with respect to different legislation policies. It aimed to develop a long-term, strategic and integrated policy advice to protect against significant negative effects of air pollution on human health and the environment (CAFÉ, 2005).

In the USA, it was proven that health impact assessments are valuable as a public health tool in decision-making processes; recently, several health impact assessments on proposed programs, such as National Petroleum Reserve-Alaska Development Oil Alaska Plan (2007) and Arctic Shelf Continental Gas and Oil Program, led to substantial proposal improvement by identifying the potential for adverse health impacts (Minerals Management Service Alaska OCS Region, 2007 and U.S. Bureau of Land Management, 2007).

Although many public health institutions and agencies have increasingly engaged in assessment of public health impact of ambient air pollution, in developing countries including Mongolia, there has not been enough progress using this method to assess program or policy beneficiary in terms of increasing health and life expectancy.

## CHAPTER III. METHODOLOGY

### 3.1 Study population

A total of 1.2 million people in Ulaanbaatar city, the capital of Mongolia, who were affected by the air pollution of *ger* district area, were included in this study population to assess the health impact of the recently passed “Law on Reduction of Air Pollution of Ulaanbaatar City”. Study population distribution compared to total population of Mongolia is presented in Table 1.

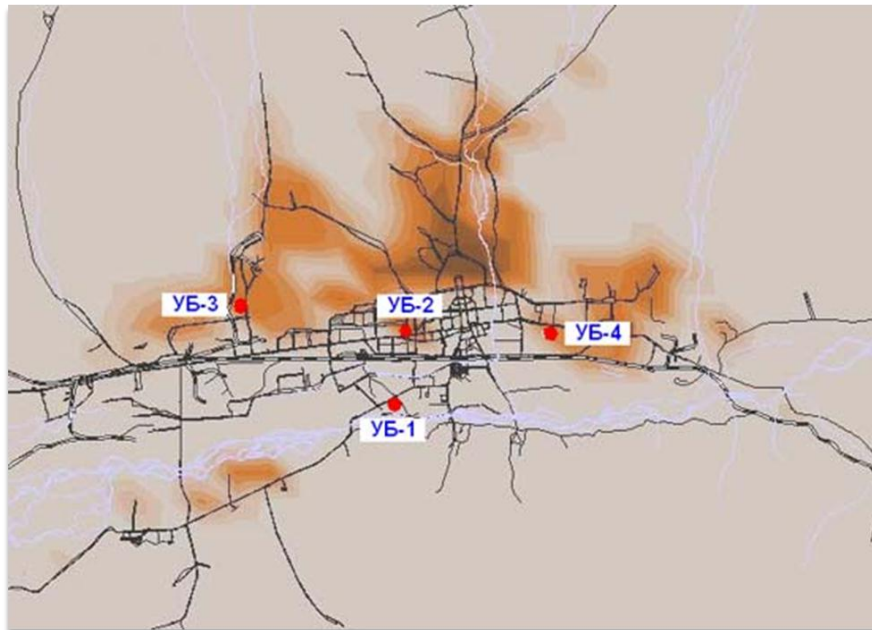
**Table 1. Population distribution of the study area (2010)**

		Settled population	Percentage of total population	Population density (per km <sup>2</sup> )	Settled area (km <sup>2</sup> )
1	Mongolia	2,900,000	100%	1.6 person	1,564,100 (100%)
2	Ulaanbaatar city	1,200,000	41.3%	210 person	4,700 (0.3%)
3	Ger district	700,000	24.1% (58.3% of city population)	487 person	

More than 60% of *ger* area population is poor, and each family has about 4 members. According to Household Socioeconomic Survey (2008), *ger* area households are larger, younger, less educated, poorer, and more reliant on social services than households in apartment areas and about 59 percent of working age *ger* area residents had not worked during the previous 12 months. Rates of employment in *ger* areas vary according to the source of the data, but unemployment rates tend to be higher in the *ger* areas than in apartment areas or other areas outside the capital. *Ger* area median household income (including cash, in-kind, and bonuses) in Ulaanbaatar is 2,496,897 tugrug (MNT) per year (206,000 per month) which is 2 times lower than median apartment household income (4,800,000) (World Bank, 2009). In line with the recent growth of *ger* areas, a high proportion of residents are migrants, and over 50 percent of those in *ger* area came from outside UB.

### 3.2 Data Source

The study was based on the existing research from time series analysis and cohort studies, in addition to health impact assessments undertaken to reduce programs or policies' negative



**Figure 3.** Air pollution monitoring sites in Ulaanbaatar. Orange color is shown *ger* districts location which mostly are in north side of the city.

effects on population health in contrast to assessing impact of recently approved law of Mongolian Government on Reduction of Air Pollution in Ulaanbaatar city. To assess the cost effectiveness of cutting electricity costs, local data

including market price of coal and woods as well as electricity were obtained. Existing air quality data of Ulaanbaatar city were obtained from National Air Quality Monitoring Office of Mongolia, which collected data through five main air quality monitoring stations: UB1-south station, UB-2-west Bayangol intersection, UB3-nearest apartment complex in *ger* area, UB4-east area apartment complex of 13<sup>th</sup> district, UB5-north station in *ger* area (Figure 3).

### 3.3 Exposure selection

To assess air pollution exposure, the long-term average PM10 concentration was used an indicator of exposure because of data availability and its unique complex formation from different air pollutants. Air particulate matter was considered as the most useful marker indicating air pollution in other health impact assessments, thus PM10 was used to describe the

burden of urban air pollution in Mongolia. Benefits were estimated comparing the current levels of PM10 to the expected levels of air pollution following the implementation of the law provision to reduce the night electricity price.

### **3.4 Data analysis**

To assess the health impact of this provision of Law on air pollution the concentration response function (CRF) method used in the several health impact studies, such as the Barcelona air pollution assessment (Laura Perez et al., 2009 and Giles LV et al, 2010) was adopted. This method requires three basic pieces of information, namely 1) the current total prevalence of a health problem in the study population, 2) the current level of pollution and the expected future level to derive the change in the concentrations that people are exposed to, and 3) the quantitative data about the association between exposure to air pollution and the occurrence of health outcomes. To assess the health effects as a result of simulated emissions reduction, we used Population weighted average exposure (PWE) which were calculated in a World Bank 2009 study. Because pollution and people are unevenly distributed across UB, their exposure levels are different, depending on where they live, the *population weighted average exposure, PWE*, which sums up the average pollution concentrations in 1 km<sup>2</sup> cells on a distribution map (a grid of 1 km<sup>2</sup> cells in the six central districts of Ulaanbaatar) multiplied by the total number of persons in each cell and divided by the total population, is used.

Based on the selected mean of concentration response function (mean of relative risk), and the health impact is estimated separately for each health outcome based on attributable risk for each given health indicator with following formula ( $AR = (RR-1)/RR$ ).

Estimated avoided cases were calculated on the basis of Ministry of Health's Health 2009 data (Ministry of Health, 2010) using the estimated PWE mean reduction. The heating season was defined as September to May, a total 9 months or 271 days and not to overestimate the expected benefit, we adopted the minimum mean of the of exposure-response functions from the reviewed literatures. Benefits, such as expected reduction in mortality and disease incidence, were calculated on the basis of attributable risks for the exposed population. This study focused on two main types of health outcomes relevant for air pollution exposure in terms of the severity and burden that they represent: (1) all-cause and infant mortality as well as mortality due to cardiovascular and respiratory diseases and (2) morbidity, including chronic respiratory and cardiovascular diseases.

## **CHAPTER IV. RESULTS**

### **4.2 Calculation and comparison the cost of coal and electricity usage for heating**

Average monthly income of median household is around 200,000 *tugrug* (MNT) (\$180 USD) in *ger* district area, and this income is 43% less than that in apartment area households (World Bank, 2010). In 2010, 1tonne of coal was 65,000 tug (\$55) and 1m<sup>3</sup> of wood was 84,500 tug (\$75) and on average, a *ger* household was estimated to consume 5 tons of coal and 3.0 m<sup>3</sup> of fuel wood per year, mostly for heating in winter (World Bank, 2008). On average, one household spends 578,500 MNT (\$500) per year for heating and cooking (Table 2). On average, the existing price for 1kilowatt (kw) electricity is 64 MNT during the day (8 am to 11 pm) and 38 MNT (11pm to 8 am) during the night in Ulaanbaatar city. If we assume that people would use electricity just for heating with 2000 watt oil heater for 24 hours, after the implementation of the



new law provision, one household would pay much less for electricity than it would before (Table 2).

**Table 2. Average spending for solid fuels and electricity for heating purpose**

	Solid fuel expenditure			Electricity expenditure		
	Coal (MNT)	Wood (MNT)	Total (MNT)	Before the Law implementation	After the Law implementation	Difference
<b>per day (winter)</b>	2,500	500	<b>3,000</b>	24 hour x 2kwt = (day 15hours x 2kw x 64MNT) + (night 9 hours x 2kw x 38MNT) = <b>2,604 MNT</b>	24hour x 2kwt = (day 9 hours x 2kw x 64MNT) + (night 15 hours x 2kw x 19MNT) = <b>1,722 MNT</b>	<b>882</b>
<b>per month (winter)</b>	50,000	15,000	<b>65,000</b>	78,120	51,660	<b>26,460</b>
<b>per year</b>	5tn x 65,000 = 325,000	3m <sup>3</sup> x 84,500 = 253,500	<b>578,500</b>	705,684	466,662	<b>239,022</b>

When we compare the average spending for coal and wood against spending for electricity after the new law implementation, 111,838 MNT per year, 38,340 MNT per month and 1,278 MNT per day will be saved for heating during the cold season, respectively (Table 3). When we compare this spending with the annual median household income of *ger* area which is 2,496,897 MNT, one household would spend 4.5% less (18.7%) than they previously spent for coal and wood (23.2%) to heat and cook.

**Table 3. Comparison between the solid fuel and electricity utility cost**

		Average spending for heating		
		per day (winter)	per month (winter)	per year (MNT)
1.	Coal + Wood	3,000 MNT	65,000 MNT	578,500 MNT
2.	Electricity	1,722 MNT	51,660 MNT	466,662 MNT
3.	Difference	<b>1,278 MNT</b>	<b>13,340 MNT</b>	<b>111,838 MNT</b>

### 4.3 Current air quality and impact of cutting the electricity utility price on air pollution

The data for the two last years indicates that PM10 concentration has increased each year in Ulaanbaatar city, specifically in *ger* districts as well as in surrounding areas. Table 4 shows monthly average PM concentrations for 2009 and 2010. The results show that the PM10 has a very strong seasonal variation, high during winter and low during summer months. Monthly average PM10 concentrations reached close to 500  $\mu\text{g}/\text{m}^3$  in December 2009 and according to the World Bank (2009) data, the main contributor to the fine fraction particles was coal and wood burning (50%), while the suspension of dry dust, partly from road surfaces and partly from open soil surfaces, contributes mainly to the coarse fraction in all seasons but also contributes to the fine fraction.

**Table 4. Monthly average of PM10 in Ulaanbaatar city (2010)**

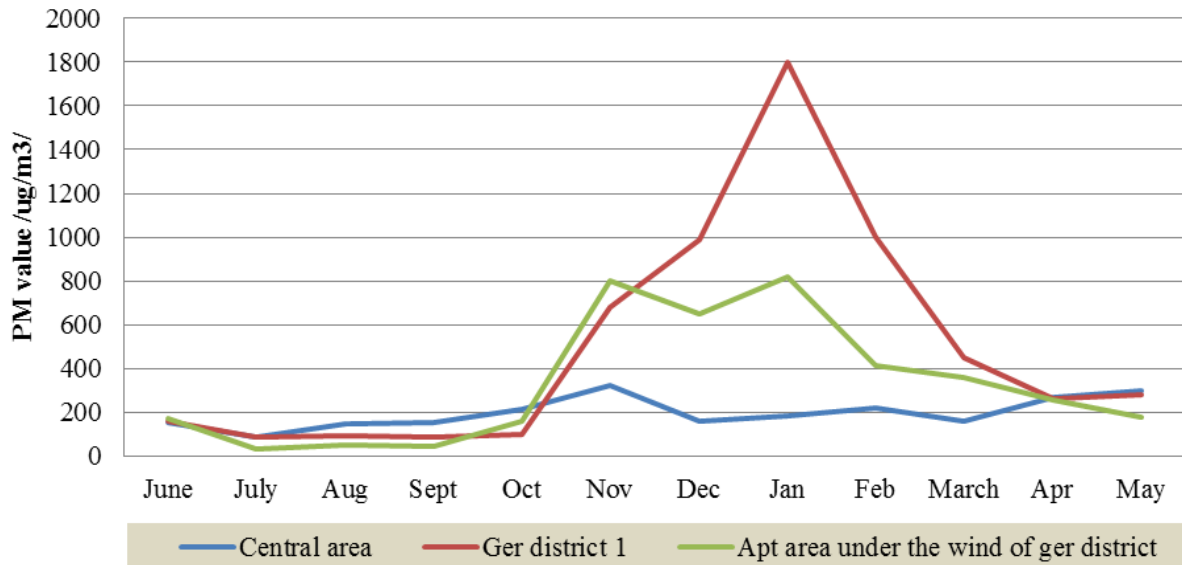
	2009					2010					Mean value
	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	Apr	May	
Average	35	94.4	87.6	265	475	483	409	184.5	136	69	223
Lowest	ND*	52.2	ND	48.5	65	48	72	ND	29	ND	31.47
Highest	52	156	322	540	1740	953	433	400	205	236	503.7

Source: National Air Quality Office of Mongolia (Naqo.mn), \* ND – data not available

According to the Ministry for Nature and Environment (2010), air pollutants derived from *ger* districts have covered 90% of the city area and exposed about 95% of population, while more than 60% of this population has been living and working continuously for more than 6 years in areas with PM10 values greater than 100  $\mu\text{g}/\text{m}^3$ . Studies showed that about 50% of average PM air burden throughout the entire city area was generated from *ger* areas. 87% of PM concentration in *ger* district areas was generated by coal and wood combustion (Lodoyosamba S. et al., 2009 and World Bank, 2009).

The **Figure 4** shows that monthly average concentrations of PM10 reached the highest level during the coldest season between December and February, also the highest level was registered in *ger* district area compared to city central area where most government buildings are located

**Figure 4. PM10 LEVEL IN DIFFERENT AREAS OF ULAANBAATAR CITY (2006)**



Data source: *Lodoyosamba S. et al., Study of PM air pollution baseline and source appointment in Ulaanbaatar city, Mongolia.*

and there are no *gers*. The difference between *ger* districts and city central area on PM10 level is not notable during the warm periods between May to September (2 to 55  $\mu\text{g}/\text{m}^3$ ), but the difference becomes significantly higher from November (360  $\mu\text{g}/\text{m}^3$ ) and is highest in January (1620  $\mu\text{g}/\text{m}^3$ ) when all households in *ger* district area burn coal for heating to survive the coldest season.

These daily levels massively exceed the Mongolian air quality standard (100  $\mu\text{g}/\text{m}^3$ ), as well as the WHO guideline value (50  $\mu\text{g}/\text{m}^3$ ), and the European Limit value (40  $\mu\text{g}/\text{m}^3$ ) (Appendix B). Therefore, the present PM10 level in Ulaanbaatar city was several times higher than in other

polluted cities in the world (Appendix 2) and the highest interim target value ( $70 \mu\text{g}/\text{m}^3$ ) of WHO guideline.

After studying pollution source, researchers found out that 48% and 87% of the burden of PM<sub>10</sub> and PM<sub>2.5</sub> concentration were generated from coal and wood combustion during the cold season, while these numbers gone down to 4% and 10% during the summer time, respectively. During the summer, PM levels are much lower than those in winter, and 79% to 91% of PM concentration of air pollution level is generated from road dust and soil (Lodoyosamba S et al, 2009). Therefore, these numbers indicate that if we could eliminate coal and wood emission from *ger* areas, air quality of Ulaanbaatar city will be improved significantly, and winter average PM levels might go down from  $400 \mu\text{g}/\text{m}^3$  to  $200 \mu\text{g}/\text{m}^3$ .

After implementation of the new law provision, the cost of electricity for heating was found to be reduced (Table 2). The total amount of discounted electricity cost was estimated to be much lower than previous electricity costs and the current solid fuel costs, and it is more likely that the law for reduced electricity cost will make heating more affordable for *ger* district households.

Due to its relationship to total PM concentration and its association with cold season and reloading of stoves, we can assume that air pollution in the city would be decreased by at least 50% after the introduction of night electricity cost exemption regulation. Significant improvement in air quality was observed after the Irish Government banned marketing, sale, and distribution of coal within the city of Dublin. Before the 1990 ban on the sale of coal, coal-related combustion was a major source of ambient air pollution in Dublin. Just after the introduction of the ban, mean black smoke concentration in winter time fell by about two-thirds ( $85.4 \mu\text{g}/\text{m}^3$  to  $25.4 \mu\text{g}/\text{m}^3$ ; 74.8%) and sulfur dioxide level decreased by 35%, respectively.

Following this improvement, during the initial 72 month period after the ban, total mortality decreased by 6% as well as respiratory and cardiovascular deaths decreased by 16% (95% CI, 12–19%) and 10.3% (95% CI, 8–13%), respectively (Clancy L, et al., 2002).

In Ulaanbaatar, residential wood heating is an important contributor to winter time air pollution, because the intake fraction of PM<sub>2.5</sub> from wood smoke is higher compared with PM<sub>2.5</sub> from other sources, including traffic (Ries et al. 2009). This suggests that reducing wood usage along with coal burning for heating and cooking can effectively reduce PM exposures including PM<sub>2.5</sub>. After implementation of a community-wide woodstove exchange program, which replaced nearly 1200 old stoves (which is 90% of all stoves) with EPA-certified units in Libby, Montana, PM<sub>2.5</sub> levels decreased by 20% during the intervention period and led to improvement of health outcomes, such as decreased reporting of childhood wheeze (OR = 0.75 per 5µg/m<sup>3</sup> reduction in ambient PM<sub>2.5</sub>; 95% CI, 0.56–1.00), upper respiratory infections, and bronchitis (Bergauff M et al., 2008). In 2008, World Bank estimated that the reduction in the number of *ger* stoves by 30%, 50% and 80% would result in 17%, 28.4% and 45.5% decline in PM<sub>10</sub> average concentration and proved that the *ger* interventions would cause the largest reduction in the PWE of PM<sub>10</sub>. For example, a 30% reduction in *ger* emissions would result in a reduction in the population weighted exposure of PM<sub>10</sub> by 17%, compared to a maximum average concentration reduction of 19% from other sources (Appendix 3). Therefore, the health benefits from the implementation of law provision which promised discounted electricity price for *ger* area households were calculated based on the assumption that the provision would decrease Ulaanbaatar city air pollution by 50%.

#### **4.4 Estimated health impact of this provision**

A large number of studies have been conducted around the world and documented a consistent association between elevated ambient PM levels and increased rates of mortality, respiratory infections, number and severity of asthma attacks, and the number of hospital admissions. We reviewed PM related epidemiological and health impact studies in order to assess the possible outcome of the law adoption. These studies have shown that air pollution levels, including PM levels, have a great impact on population health outcomes such as mortality rate (Aaron J. Cohen et al, 2005; Ari Rabl, 2006), respiratory diseases (Laura Perez et al., 2008; R Martinez et al., 2007) and other outcomes (Sram RJ et al., 2005; Krewski D et al., 2009; Kukkonen J, et al., 2005, Eftim SE et al, 2008).

Most health impact studies used population weighted average exposures (PWE), which are basically calculated using the dispersion model, to assess the health effects as a result of simulated emissions reductions. The population weighted average is a good estimate for the exposure that the population as a whole experiences in Ulaanbaatar, and this indicator is used for estimating the resulting population wide health effects of the reduced PM concentrations.

According to the World Bank study, the PWE in 2007 for PM<sub>10</sub> was 76.7 µg/m<sup>3</sup> and for PM<sub>2.5</sub> was 37.6 µg/m<sup>3</sup> while the maximum grid average concentrations were 211 µg/m<sup>3</sup> and 106 µg/m<sup>3</sup>, respectively. These results were higher than both Mongolian (50µg/m<sup>3</sup>) and WHO (20µg/m<sup>3</sup>) standards.

**Table 5. Estimation of health benefits of providing discounted electricity for ger households**

Health indicators (2009)	Ulaanbaatar city		Concentration response function of PM10			
	ratio	case number	per 10µg/m <sup>3</sup> reduction		per 38.3 µg/m <sup>3</sup> reduction	
			RR*	AR <sub>1</sub>	AR <sub>2</sub>	Estimated benefits
<b>Formula for calculation</b>	r	N	RR	((RR-1)/RR)*100	38.3*AR <sub>1</sub> /10	(AR <sub>2</sub> * N)/100
Total mortality rate (per 10000 population)	58.85	6426	1.043	4.1	<b>15.7%</b>	1015 <sup>1</sup>
Infant mortality rate (per 1000 live births)	18.0	548	1.048	4.6	<b>17.54%</b>	96 <sup>2</sup>
Respiratory diseases (per 10000 pop)	2.46	269	1.013	1.3	<b>4.92%</b>	13 <sup>3</sup>
Cardiovascular diseases (per 10000 pop)	18.60	2031	1.009	0.9	<b>3.42%</b>	69 <sup>3</sup>
<b>Morbidity (per 10000 population)</b>						
Respiratory diseases	860.1	93929	1.0131	1.3	<b>4.95%</b>	4652 <sup>4</sup>
Cardiovascular diseases	679.7	74231	1.0125	1.2	<b>4.73%</b>	3510 <sup>4</sup>

Source: <sup>1</sup> –Kunzli et al, 2000; <sup>2</sup>- Lacasana et al, 2005; <sup>3</sup>- Pooled, WHO Europe, 2004; <sup>4</sup>- Pooled, WHO, 2006

\* - Smallest mean of the RRs are selected from the literature review on the basis of estimating health effects

According to our assumption of the law’s impact on air pollution, average PWE of PM10 would be decreased from 76.7 µg/m<sup>3</sup> to 38.4 µg/m<sup>3</sup>. Maximum average PWE level, mainly registered in ger areas, would decline from 211µg/m<sup>3</sup> to 105µg/m<sup>3</sup>. The estimated health impacts of exposure reduction to ambient concentrations of PM10 were based on the above mean reduction of PM10 by 38.3 µg/m<sup>3</sup>. We used minimum value of concentration response functions to calculate Attributable Risk (AR) for selected health indicators (Table 5). After adjusting ARs with reduction level, we found that after the discounted electricity utilization for heating in ger households, approximately 1013 annual deaths, about 15.7% of all natural deaths, and around 96 infant deaths, which is 17.5% of annual infant deaths, could be avoided. Respiratory and CV diseases cases would be decreased by about 4652 and 3510 cases annually (Table 5).

## CHAPTER V. DISCUSSION AND CONCLUSION

### 5.1 Discussion

This study aimed to evaluate the health impact of the recently approved law provision on reduction of the electricity night rate by fifty percent to restrict *ger* households' use of coal and wood for heating and cooking purposes, which is the main source of Ulaanbaatar air pollution. The study results indicate that enforcement of this regulation could help the Mongolian government to reduce air pollution derived from the *ger* districts, specifically in winter time, and health benefits will be substantial when this regulation is fully implemented in all *ger* areas.

Air pollution in Ulaanbaatar is still extremely high due to ineffective efforts of the Mongolian government to reduce air pollution by implementing different unsuccessful projects on improved heating stoves, producing cleaner fuels such as semi-coked coals and other kinds of coal briquettes, which has consumed millions of *tugrugs*. Thus, in January of 2011, Mongolian parliament approved the Reduction of Air Pollution Law which integrated all previous separate regulations and procedures related to air pollution control. Besides reducing existing night tariffs of electricity by 50 percent, this law will take measures to ensure the operation of electricity meters and electricity substations, resolve financial issues with the state budget adjustment, establish a National Committee on Reduction of Air Pollution under the Parliament, and take legal action against officials and citizens breaking the law (Mongolian Parliament, 2011). Therefore, the analysis examined the rationale and context of the plan to provide discounted electricity, particularly with regard to its contribution to reducing air pollution and improving the population health as well as possible challenges for implementing the new law.



Households in *ger* districts use low quality heat from coal and wood burning stoves, and residents have to get up several times at night to maintain the fire, while apartment dwellers enjoy less expensive high quality heating. Due to affordability and availability, *ger* households use solid fuels rather than electricity, even though they know that emission from coal burning causes health complications (World Bank, 2009). Therefore, in this assessment, the first question was that whether the *ger* district households would be willing to use electricity if the government reduced the cost of night electricity by 50%. The price difference is the most important factor for the adoption of this regulation, since most of the *ger* district households have low income, and calculation of the expected cost after discount showed that there will be a significant difference in daily and monthly costs during the heating seasons.

After implementation of the regulation on discounted electricity tariff, the total annual savings will be 111,838 MNT (\$90 USD) (difference of 4.5%), which may sound very small (Table 3). But about 60% of *ger* households live in the poorest condition and still use a high amount of their annual income for heating to survive harsh winters (Takuya Kamata et al, 2010). With a daily savings of 1,278 MNT, people could buy 1 loaf of bread (550-600 MNT) and 1lb of meat (600 MNT) which are the basics of a daily meal for most families in *ger* areas. We also assume that savings of about 112,000 MNT per year would provide more financial flexibility for families in *ger* areas. But, in the first year, if there is no other external donor or other organizations funding or financial support to implement this regulation, each household needs to buy at least 2 electricity heaters of 60,000 MNT each.

Also, with the reduction of coal and wood usage, the ash and waste amount will significantly decrease, and more money might be saved due to reduced expenditure for waste transportation.

Thus, we assume that in terms of economic benefits, this regulation is affordable, specifically poor families.

The second question is whether or not this regulation will decrease air pollution and how significant would the benefits be. As stated above, use of coal and wood, the primary source of indoor heating during the winter season, is gravely affecting the health of the city population. The emissions from extensive coal usage in the Ulaanbaatar city have greatly contributed to devastating air pollution. Previous study results showed that if emissions from *ger* heating (stoves, stoves with heating walls, low pressure boilers) are reduced by 50%, the annual average concentrations of PM<sub>10</sub> will be reduced by about 33% in the entire city, and 18-33 million dollars will be saved in health care costs (World Bank, 2009). Moreover, according to these estimates, Mongolian standards for PM<sub>10</sub> can be reached if emissions from power plants, heat only boilers, *ger* heating and dust were reduced by 80%. This reduction in air pollution would result in visible air quality improvement as well as long term population health benefits.

Due to availability of data, we used PM<sub>10</sub> concentration to assess the health impact of the potential air pollution reduction with the proposed regulation. Because of the difficulties involved in measuring morbidity, the majority of studies have used mortality indicators, and results have shown strong associations between daily mortality rate and daily particulate concentration, whether measured in TSPM or PM<sub>10</sub> (Braga ALF et al, 2001; Goodman PG et al, 2004; Arden Pope et al, 2002; Clancy L et al, 2002). Our results showed that the implementation of this new regulation would reduce total mortality by 15.7% and infant mortality by 17.5% per annum. We assume that the estimated reduction in infant mortality was much higher than other health indicators, including mortality due to cardiovascular (4.9%) and respiratory diseases

(3.4%), because of infant susceptibility to air pollution (Penna ML et al, 1991; Janet Currie et al, 2005).

According to our assessment, the accumulated evidence of many years indicates that children's health is adversely affected by air pollution levels in the short and long term. Children's physiological distinctions, like ongoing process of lung growth and development, incomplete metabolic systems, immature host defenses, high rates of infection by respiratory pathogens and activity patterns, lead to higher exposure to air pollution and higher doses of pollutants reaching the lungs. This increases susceptibility of young children to pollutants (WHO, 2005; Perera FP et al, 2006). Moreover, the changes that occur due to air pollution in pre- and postnatal periods and during early childhood development, such as reduced functional reserve of the lungs, could lead to enhanced susceptibility during adulthood to ageing and infection as well as to other pollutants, such as tobacco smoke and occupational exposures (Wright JM et al, 2004; Porterfield S. et al, 1994; Koller K et al, 2004; Edwards SC et al, 2010).

In this analysis, we used the exposure-response functions applied several assessments, including the Barcelona Health Impact assessment (2005), which calculated the number of premature deaths due to air pollution exposure, new cases of chronic bronchitis, and hospital admissions for respiratory and cardiovascular diseases. Although in the calculation of health benefits, we estimated a 50% reduction in air pollution, which might be lower than expected, and adopted minimal mean of available exposure response functions, the expected health impacts were not minor or unnoticeable. Approximately, more than 8000 cases of cardiorespiratory diseases and 1000 cases of mortality, including 96 infant deaths could be avoided in the short term due to the implementation of this program. High rates of cardiovascular mortality and morbidity in

Ulaanbaatar city related with extremely high level and long duration of air pollution are consistent with findings of Pope et al (2011) who confirmed that cardiovascular mortality and morbidity as a major health outcome of long term exposure to moderate air pollution. Greater health relative risks were observed in studies with longer-term exposures. As Pope and his colleagues (2004) showed, long term exposure to PMs, especially to fine particulate, is an important risk factor for cause-specific cardiovascular disease mortality. Our estimation of health impact was based on these health impact assessments conducted in Europe and United States with low levels of PMs while PM levels of Ulaanbaatar city is much higher. Therefore, actual health benefits from this regulation must be much higher than our estimation. Because, the studies which the mean of relative risks were adopted in this study, were done in US and European context where air pollution level are much lower ( $<100\mu\text{g}/\text{m}^3$ ) than today's Ulaanbaatar level ( $>200\mu\text{g}/\text{m}^3$ ). Moreover, the benefits which would come due to improved indoor air quality following the use of electricity for heating, was not calculated here in this study.

Although eliminating *ger* area emissions cannot reverse physiological damage that have already developed, it could help to lessen and prevent future health disorders and susceptibility to disease due to air pollution in long term. Therefore, although we did not calculate the long term health impact in this study, we assume that the long term health benefits of this program would be greater and socioeconomic status would also improve. Specially, people who have a chronic condition, such as unstable coronary plaques, congenital defects, or deficiencies including respiratory organs, pregnant women and children in pre and postnatal periods will greatly benefit from this program. As mentioned here, there are many other benefits including decreased rate of

lung cancer, asthma related diseases and increased life expectancy could be gained from this regulation. Therefore, we limited the number of health end points, because one of our main limitations was the lack of background data in Ulaanbaatar city when it comes to prevalence rates for different diseases, hospitalization rates and data on its relationship with air pollution.

Utilizing electricity instead of coal and other solid fuels for heating and cooking purposes in *ger* households would bring many advantages in terms of health benefit. For example, the amount of household wastes, specifically ash wastes from coal and wood burning will significantly decrease which could also help to decrease the air pollution around the city, because ash and dust generate significant amount of air pollution during the warmer season as well as winter time (World Bank, 2009). Once the ash amount within *ger* area decreases, the payment for the waste transportation would also decrease and accumulation of the waste within the city also would decrease. Therefore, ash or dust travelling throughout city in windy and dry conditions, which are common in spring time, would also decrease. Demand for wood in the *ger* areas would also decrease and could save more than 260,000 m<sup>3</sup> of wood.

Overall, if this regulation was implemented and fully covered the *ger* area, it will contribute greatly to the effort to reduce Ulaanbaatar city air pollution as well as to improve the population health and wellbeing. A similar result, but not for PM level, was observed in an intervention study which assessed the impact of the introduction of restriction of fuel oil with a sulfur content of more than 0.5% by weight for all power plants and road vehicles in Hong Kong. This regulation led to a 45% average reduction in SO<sub>2</sub>, followed by a significant decline in the average annual trend in deaths from all causes (2.1%; p=0.001), respiratory (3.9%; p=0.0014) and cardiovascular (2.0%; p=0.0214) diseases (Hedley AJ, 2002).

But there are still some concerns and uncertainty. First, if this change of using electricity for heating can provide similar or higher warmth during the winter cold months in Mongolia. Because, there is no other study evaluated how much electricity and heaters would be required to heat average size Mongolian *ger* and estimated heaters efficiency.

Previous attempts failed because of weak management and inappropriate or unintegrated efforts against the air pollution. For example, the government invested millions in private sectors to develop nonsolid and effective fuels and to make *ger* households use them, but fuel switching was not easy to achieve because the cost of heating with raw coal was low compared with “improved” fuels and all alternatives were more expensive. In this case, unless incomes increase in the future or other arrangements are made to bring down costs (subsidies, or more fuel-efficient burning, or both), it is unlikely that inter-fuel substitution can achieve rapid market penetration.

Lodoysamba Sereeter, an expert on urban air pollution at the National University of Mongolia, recently told to news reporters that “Ninety percent of our urban air pollution is from the *ger* stoves and less than 10 percent from cars and power plants... The government spent seven billion MNT between 2007 and 2009 to produce briquettes and pressed coal. Unfortunately they don't reduce the smog because the *ger* stoves aren't designed to use them" (Kitty Hamilton, 2011).

Therefore, there is uncertainty about the government's ability to successfully implement this regulation. According to various sources, implementing this regulation there will require more energy sources, and the additional electricity load of heating *ger* area households has been

estimated at roughly 600 megawatts, or double the existing generation capacity in the whole country (World Bank, 2008).

Moreover, despite the extensive coverage of electricity in the *ger* areas, the lack of capacity of electricity supply and unreliable service remain major challenges, often resulting in power outages (PREGA (2006). The key issues with the electricity supply in *ger* areas are insufficient capacity of transformers and substations, and poor service quality due to the capacity shortage. Besides this, about 8,000 (6.15% of *ger* households) families in *ger* areas still do not have electricity in Ulaanbaatar, and the engineering department of the city estimated that about 2.8 billion MNT would be necessary to provide electricity to these households.

Since today's electricity generating capacity cannot meet this expected demand, the government proposed to build a fifth Electric Power Station in Ulaanbaatar and investments for developing this entire infrastructure will amount to more than 1.68 trillion MNT (about \$1.30 billion), which is an unbearable burden on today's government. Thus, the government aimed to resolve financial issues with the State Budget adjustment as well as to establish the National Committee against Air Pollution under the Parliament which would take legal actions against officials and citizens who break the law. Another uncertainty is how we will manage the families who cannot afford their even the discounted monthly electricity payment and who use plastics and other garbage products such as junk tires, which are most hazardous for human health as well as for environment, for fuel. Meanwhile, as mentioned in other health impact assessments (Marco Martuzzi et al., 2002 and 2003; Aunan K et al, 2004; CAFÉ, 2005), we attempted to use the best available quantitative and nonquantitative evidence along with our ability to judge the current, past and future facts and evidence to produce the most accurate assessment despite possible

uncertainties, even though there was lack of integrated data on air pollution and pollutants as well as Ulaanbaatar city health indicators.

Moreover, we also identified the possible side effects of implementing this regulation. Soil in *ger* areas is polluted badly because all *ger* households do not have a connection to the general sewer system and each household has own land dug backhouse or dunny. Without any improvement, like a connection to general sewer system, already severely polluted soil conditions in *ger* areas will be worsen and will become one of the main causes of many other health consequences, such as asthma related and infectious diseases. Without carefully planned strategy reduced night tariff of electricity in Ulaanbaatar city might attract countryside people and increase the rate of internal migration to the city.

## **5.2 Conclusion**

Regulatory interventions, which have been the primary focus of air quality management, are essential in reducing ambient pollutant levels and, consequently, health impacts among the public. The study results indicate that the government regulation on reducing existing night tariffs of electricity by 50 percent will contribute significantly to the effort against air pollution in Ulaanbaatar city. Estimation shows that after the full implementation of this regulation, most households in *ger* areas would adopt electricity as a main source for heating, and this change would lead to a minimum 50% reduction on air pollution, specifically winter time air pollution. If the regulation fully covered the *ger* area, annual consumption of coal and wood would decrease by about 550,000 tons and 415,000 tons, followed by massive reduction of emissions. These changes would lead to noteworthy health benefits such as 15.7% and 17.4% reduction in total and infant mortality cases along with 4.3% and 4.7% decrease in cardiovascular and



respiratory disease morbidity cases annually. To complement progress made through regulation, interventions at the community and individual levels should be given great attention and should be implemented under strong leadership along with effective management and carefully planned perspectives on future city development and population health.

### **5.3 Recommendation**

- Although regulation implemented in *ger* area, there would be many families who cannot afford the electricity and these households would produce the most hazardous emissions due to burning hazardous elements such as plastics and junk tires. Since the night utilization is so low and much energy is wasted during the night, there is enough capacity to provide these families electricity free of charge during the winter as in the regulation.
- Resettling the *ger* area residents into apartments connected to main heating and sewer system is most potential long-term air pollution solution among the proposed solutions. The government should lead this program preventing future consequences on population health, the costs of which would be much higher than today's housing expenses. Thus, it is reasonable for the government to reimburse families in *ger* areas who wish to move to apartments. *Ger* districts, which are face of Mongolian nomad culture, could then be settled to sub Ulaanbaatar areas, especially the southeast area which is the most appropriate area in terms of improved infrastructure, such as general heating and sewer systems. This could be a historical attraction.
- Since none of the past interventions had any targeted level of expected air quality to measure effectiveness of the program, the main policy recommendation is to select abatement measures based on an analytical framework that allows policy makers to

estimate the overall effect of pollution reduction measures on air pollution. While data problems can cause estimates to vary significantly, the discipline of comparing measures and results should help to get programs started, provide feedback, manage expectations, and continuously improve an air pollution abatement program.

- Health impact assessments can be a main tool to identify the possible gaps and consequences of the program as well as evaluate its efficiency. As a result of the complexities of Ulaanbaatar's air pollution problems, reducing the air pollution will unavoidably be a multiyear effort involving experimentation, mechanisms for continuous improvement, financing, and sustained support from all citizens of Ulaanbaatar. In this case, health impact assessment type studies will be the most informative and effective tools of communication with the all related stakeholders including general public and policy makers.

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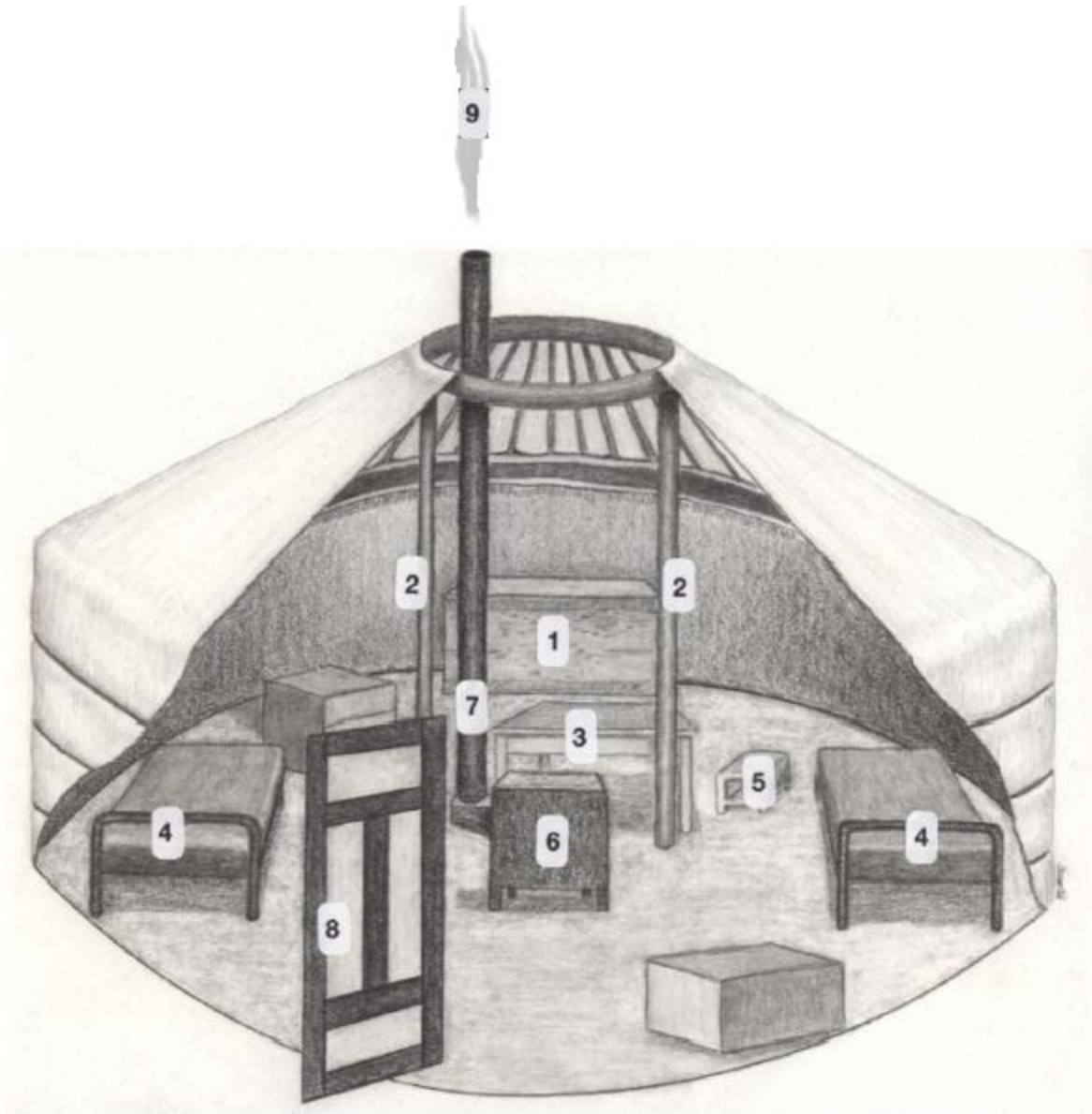


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## APPENDICES

### APPENDIX A. OVERVIEW OF GER STRUCTURE



**Note:** Objects in figure are 1) chest, 2) roof support, 3) table, 4) bed, 5) stool, 6) stove, 7) chimney, 8) door (ajar, hinge on right side) and 9) smoke from *ger* stove

## APPENDIX B. AIR QUALITY STANDARDS AND GUIDELINES FOR PM

### *Particulate Matter -PM*

The tables below summarize Mongolian air quality standards (AQS) as well as WHO guidelines, USEPA standards and EU limit values (LV) for PM10 and PM2.5 and international standards for SO2 20. WHO Guidelines are the lowest. They represent the levels where effects are very small, and should be considered as goals for the future. WHO has established Interim Targets (IT-1-3), realizing that in many developing countries, the WHO guideline cannot be met in the short term.

**Table B1. Various guidelines, standards and limit values for PM2.5 and PM10**

	Guidelines, standards and limit values (ug/m3)			
	PM2.5 average values		PM10 average values	
	Annual	24 hour (daily)	Annual	24 hour (daily)
Mongolian Standards, 2007	25	50	50	100
WHO Guidelines, 2005	10	25	20	50
WHO Interim Targets (IT)				
IT1	35		70	150
IT2	25	75	50	100
IT3	15	50	30	75
U.S. EPA AQS, 2006	15	37.5		150
European Union Standard	20	35		

*Source:* WHO (2006). WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide: Global update 2005. Summary of risk assessment. Assessed at [http://whqlibdoc.who.int/hq/2006/WHO\\_SDE\\_PHE\\_OEH\\_06.02\\_eng.pdf](http://whqlibdoc.who.int/hq/2006/WHO_SDE_PHE_OEH_06.02_eng.pdf).

**Table B2. Basis for WHO Air Quality Guidelines (AQG) and Interim Targets (IT)**

WHO AQG & Interim Targets	Basis for selected level
Interim target -1 (IT1)	These levels are associated with about 15% higher long-term mortality risk relative to the AQG level
IT2	In addition to other health benefits, these levels lower the risk of premature mortality by approximately 6% (2–11%) relative to the IT-1 level
IT3	In addition to other health benefits, these levels reduce the mortality risk by approximately 6% (2–11%) relative to the IT-2 level.
Air Quality Guideline	These are the lowest levels at which total, cardiopulmonary, and lung cancer mortality have been shown to increase with more than 95% confidence in response to long-term exposure to PM2.5.

*Source:* Michal Krzyzanowski and Aaron Cohel (2008). Update of WHO Air Quality Guidelines. *Air Qual Atmos Health* 1:7–13. DOI 10.1007/s11869-008-0008-9

## APPENDIX C. COMPARISON OF COUNTRY PM LEVELS

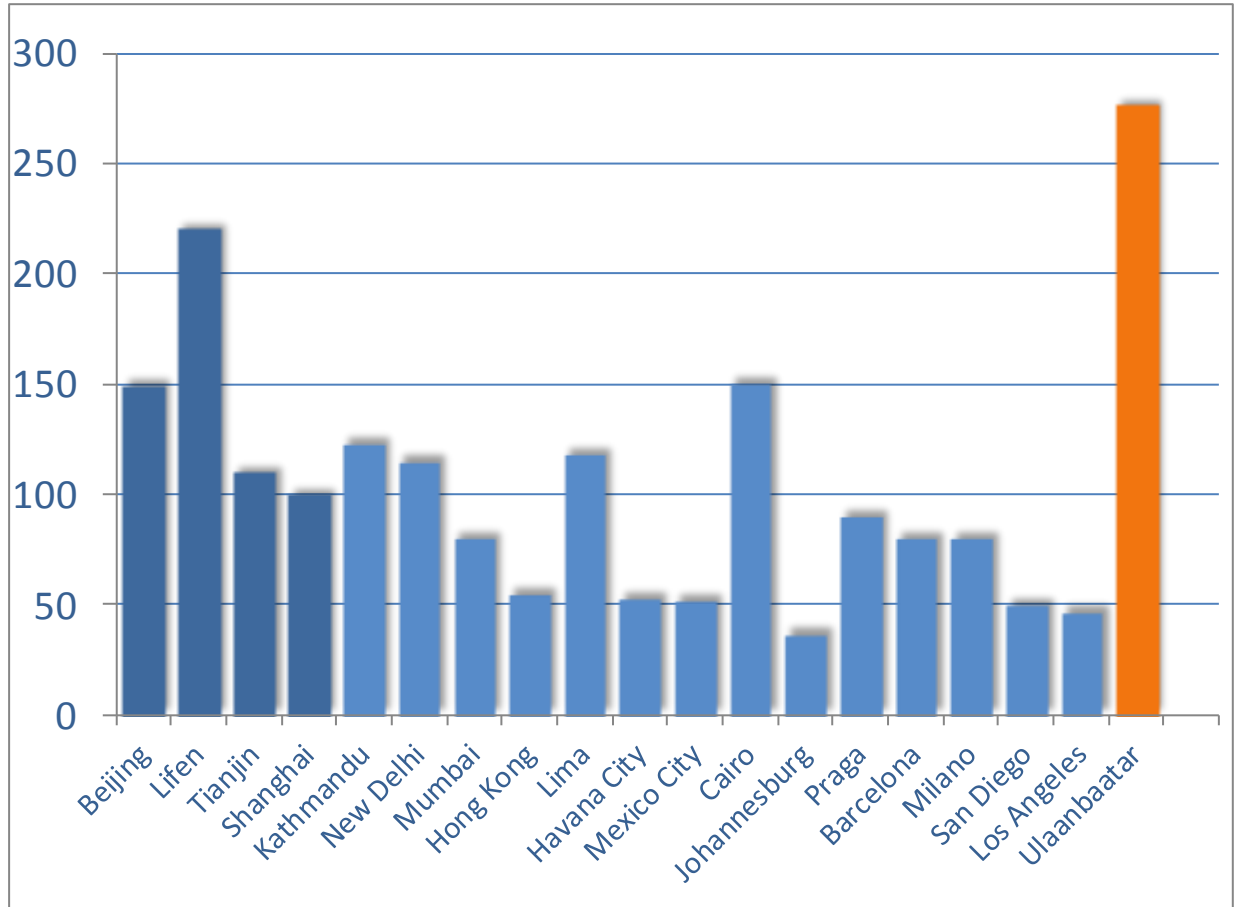
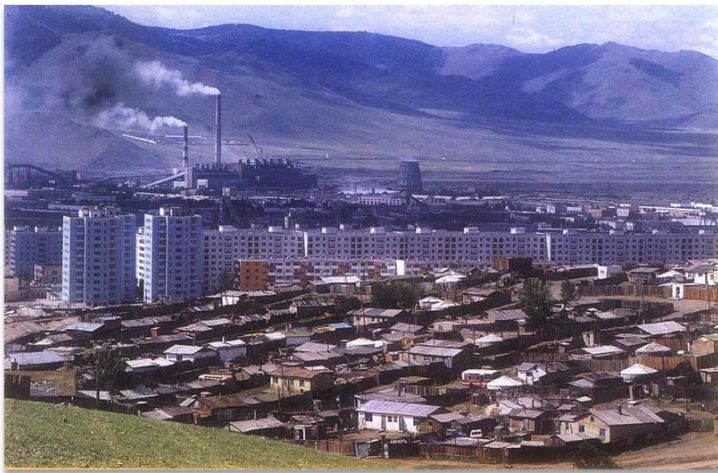


Figure shows annual average PM10 Concentrations Observed in Selected Cities worldwide based on 2004/2005/2006 data.

*Source:* China Environmental Yearbook 2005 and WHO 2005, World Bank 2009.

## APPENDIX D. OVERVIEW OF CURRENT AIR POLLUTION IN ULAANBAATAR



**Picture D-1.** General picture of ger area and nearest apartment district in west north of the city (Summer time)



**Picture D-2.** Same site with Pic D-1, but in winter time. Emission smog from ger household stoves covered the city.



**Picture D-3.** The surrounding mountains, with peaks up to 2,800 meters, partially block the air flow and increase warm air accumulation within this valley area where Ulaanbaatar city is located. This condition traps air smog within this area and causes accumulation of air pollutant.  
*Source:* Sarath Gutkinda, 2008