Mongolia
Heating in Poor, Peri-urban Ger Areas of Ulaanbaatar

Asia Sustainable and Alternative Energy Program
Sustainable Development Department
East Asia and Pacific Region
The World Bank

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Photographs[1]

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Abbreviations, Units

AQD	Air Quality Division (UBMG)
ASM	Agency for Standardization and Metrology
ASTAE	Asia Sustainable and Alternative Energy Program (World Bank)
BEEC	Building Energy Efficiency Center, of the Mongolian University of Science and Technology
CHP	Combined Heat and Power
DAF	Dry Ash Free
DH	District heating system
GTZ	Gesellschaft fur Technologische Zusammenarbeit GMBH, German Consulting Firm,
HOB	Heat only Boiler
HVAC	Heating, Ventilating, and Air Conditioning
LPB	Low Pressure Boiler, for use in ger area households
MMCG	Mongolian Marketing Consulting Group
OBA	Output Based Aid
PIU	Project implementation Unit
PM	Particulate Matter (generic name for emissions of small particulates)
RB	reference burner
SCC	Semi-coked coal
SSIA	State Specialized Inspection Agency
TSP	Total Suspended Particulates
UB	Ulaanbaatar
UBCAP	Ulaanbaatar Clean Air Project
UBMG	Ulaanbaatar Municipal Government

Currency

1 US$ = 1200 Mongolian Tugrug (over the period of 2007 - 2008)

Acknowledgements

This report is a summary of several activities funded by the Asia Sustainable and Alternative Energy Program (ASTAE) under a project entitled, "Energy Efficient and Cleaner Heating in Peri Urban Areas of Ulaanbaatar". It is part of a World Bank response to the Government of Mongolia's request to mobilize a wide range of resources to develop and support abatement measures for air pollution in Ulaanbaatar. The wide range of activities is called the Ulaanbaatar Clean Air Program, and includes support from the Government of Netherlands (through this ASTAE project and through a separate Government-executed, Bank administered trust fund project "NEMO"), Japan (through a Government-executed, Bank administered trust fund project "Capacity Building for the Development of Carbon Financing Projects in Mongolia", Korea (through a Bank executed trust fund project "Korea-Bank Environmental Partnership"). The Bank has also been asked by the Government to prepare an investment project – the proposed UB Clean Air Project. In addition, the Bank assists the Government in raising awareness among external and internal financiers of opportunities to support abatement measures and is working closely with ADB, EBRD, GTZ, JICA, and many other partners.

This ASTAE activity greatly benefited from cooperation and input of a wide range of stakeholders including the National Committee on Coordination, Management, and Oversight of Activities of Government Agencies with regard to the Implementation of the Government Policy on Air Pollution Reduction (NCC), chaired by the Minister of Mineral Resources and Energy (MMRE) and vice-chaired by the General Manager of Ulaanbaatar City Administration, Ulaanbaatar Municipality (Department of Urban Development and Ulaanbaatar Environmental Protection Bureau), Ministry of Mineral Resources and Energy, Ministry of Nature, Environment and Tourism, various local fuel manufacturers, the Mongolia Stove Manufacturers Association, World Vision, and the donor community. In addition, preliminary observations from EBRD's fuel and stove tests (March - April 2009) have been incorporated into this report; it is understood a full report will be published in the near future. There are numerous other stakeholders from universities, institutes and air pollution experts who contributed their time and comments to these activities for which the authors are most grateful.

The report[2] was prepared under the guidance of Gailius J. Draugelis, Task Team Leader of the ASTAE assignment and Ulaanbaatar Clean Air Program. Mr. Robert van der Plas, Consultant, integrated and edited various consultant inputs for this report, and authored many of its conclusions. He was also responsible for technical advice on stoves and fuels programs, directing the fuel consumption tests, stakeholder analysis, design of the output based aid approach and potential investment project components, and coordination and review of inputs on the standards assessments and training. Mr. Voravate Tuntivate, Consultant, directed the work of the 1,000 household survey and authored the parts of this report on the household survey. Messrs. Liu Feng, World Bank Senior Energy Specialist, and Mr. Tumentsogt Tsevegmid, World Bank Infrastructure Specialist, prepared the Beijing Case Study and applications for Ulaanbaatar on electrical heating. Mr. Crispin Pemberton Pigott, Consultant, prepared the standards assessment, laboratory

[2] This report is largely based on the findings of the 1,000 household survey and accordingly referenced findings from the other ASTAE activities. The conclusions are those of the authors alone and any errors are to be attributed to the authors only. The report begins with market information including demographics, types of housing and heating systems, types of fuel currently reported to be used, quantities of fuels used, and then reviews the capacity to realize air quality improvements through the production of better stoves and fuels.

assessment for testing, testing protocol, and provided training to stoves manufacturers. Mr. Helmut Vierrath contributed to assessments of various semi-coke production proposals and technical advisory support on gasification. Mr. Jostein Nygard, World Bank Senior Environmental Specialist and co-manager of several UBCAP activities, and Mr. Jitendra Shah, World Bank Senior Environmental Sector Coordinator, contributed comments and guidance to the project. Mr. Byambabaatar Ichinkhorloo, Program Assistant, provided invaluable insights and logistical support. Ms. Sunjidmaa Jamba, Partnership Coordinator, advised on communications matters. The peer reviewers were Jeremy Levin, Sr. Technical Specialist, South East Asia Region, World Bank, and Douglas F. Barnes, World Bank Consultant. The team is also thankful to Arshad Sayed, Mongolia Country Manager, for his thoughtful advice and support. The project was launched in Fall 2007.

Executive Summary

Household heating in *ger* areas[3] of Ulaanbaatar contributes to a large extent to the overall air pollution in the city. The use of coal in simple heating stoves results in high levels of particulate matter air pollution (PM[4]). Updated estimations of these air pollution levels have recently been made[5,6] and will be published shortly. These estimates show that ger area household heating contributes about 45% - 70% of the $PM_{2.5}$ concentrations, as an overall annual average for the whole city. The actual impact depends on the time and the location in the city, but is generally highest in ger areas. Ger heating systems are burning continuously during the winter season and their contribution to the overall air pollution level then reaches 70% and more in the ger areas and up to 60% in the city center. Although these results are still preliminary and need to be verified, they indicate the gravity of the problem: Ger area heating systems are a major contributor to the air pollution and associated health problems in Ulaanbaatar city. Heating expenses surveyed for this report comprise about 21% of the annual income of the poorest fifth of the ger population and 15% for the next fifth. Yet during winter months heating expenditure represents 42% of monthly income for the poorest and almost 26% for the next fifth. Thus, heating systems in ger areas not only need to be cleaner, they also need to be affordable.

The findings of the ASTAE[7] activities that are summarized in this report lead to the conclusion that it is possible to develop a program aiming to provide cleaner, affordable heating to ger areas in Ulaanbaatar, but that there remain significant technical and financial barriers to an immediate successful roll-out. Realizing the need to involve many approaches and partners to address Ulaanbaatar's complex air pollution problems, this report is designed to provide background information for those who are interested in either the market or non-market based approach for providing cleaner and more energy efficient heating stoves and cleaner fuels. Other related programs or projects that could also directly benefit from this report would include improved insulation for gers, public information dissemination and awareness campaigns aimed at educating the public about the health problems associated with air pollution. This report presents:

- ✓ market data on ger households – affordability, fuel consumption, perceptions of various pollution abatement measures in the six closest ger districts – to introduce statistically relevant data for any abatement program
- ✓ a concept and road map for a market-based approach to introduce new equipment that can burn fuel, new or old, more cleanly. Features include:
  - ➔ setting targets for cleaner systems based on their impact on air pollution
  - ➔ a standards development, testing and unified certification program for new equipment, with a focus on safety and emissions rather than fuel efficiency alone

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[3] A ger is the traditional Mongolian tent used by herders; ger areas in Ulaanbaatar are sections of town where people settled in their ger, and gradually construct wooden or brick houses. The infrastructure for public services in ger areas is weak, with access to electricity but not to water or sewerage.

[4] The term 'particulates' includes a large number of condensed liquid droplets, not only particles of 'dust'. PM_{10}, the fraction of particles under 10 micrometer in diameter is considered the threshold of major health consequences, even moreso the fraction of finer particles, $PM_{2.5}$, below 2.5 milimeters in diameter.

[5] Norwegian Institute of Air Research, under contract with the World Bank

[6] Draft Updated Urban Air Pollution Analysis for Ulaanbaatar, NILU/World Bank, due June 2009.

[7] Asia Sustainable and Alternative Energy Program, World Bank.

and an enforcement mechanism to address non-compliant products and manufacturers

- ➔ a targeted subsidy program with a independent verification system to make new systems affordable *and to remove old equipment from use*
- ➔ a technical assistance program for research and development of new equipment and fuels in Mongolia
- ➔ monitoring and evaluation system generating feedback to perfect systems
- ➔ a public awareness program through mass media
- ➔ use of grassroots public participation approaches to encourage participation of the ger area residents in pollution abatement programs

- ✓ a combustion testing protocol to test emissions of fuel-stove combinations and preliminary results
- ✓ international experience: a case study on electrical heating in Beijing and information on solid fuel stoves in other countries

It should be noted that this study focuses only on stove-fuel issues and although medium term options such as apartments, electrical heating, heat pumps, and district heating are briefly addressed in this report, they largely fall outside the scope of this study.

There has been much debate on where to place emphasis – on more efficient stoves or cleaner fuels. Several pilots and small commercial ventures in both have taken place in the past, and both have yielded limited success only. Currently, the focus appears to be more on development of cleaner fuels. The findings of the ASTAE activities however conclude that both are equally important: it is the combination of the stove and the fuel that will determine the impact on reducing air pollution levels in the city. *Before further recommendations about endorsing or supporting new fuels or particular stove models can be made, better testing is needed to identify combinations with good potential to reduce emissions*.

This report focuses on reducing outdoor air pollution, as this is the major cause of health problems for the population of Ulaanbaatar. Indoor air pollution is not the focus of this study as the high outdoor air pollution level is considered the primary cause of indoor air pollution, provided stoves and chimneys work well[8].

Key Findings. The following are key findings of the ASTAE activities[9] carried out during the 2007/2008 winter season:

- Ger area household heating systems are part of the problem *and* part of the solution for cleaner air in Ulaanbaatar. When designing a clean heating policy one should look at the complete heating *system* rather than its isolated elements (e.g. fuel, appliance, insulation of the dwelling, etc.). The cleanliness of the heating system depends on both the fuel

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[8] ESMAP: Impact of Improved Stoves on Indoor Air Quality in Ulaanbaatar, Mongolia, Report 313/05, 2005

[9] A total of six activities were carried out: (i) 1000 household ger area survey (Dec 2007 – Feb 2008) to establish a baseline and learn about household perception and attitudes; (ii) 60 household consumption test (Jan – March 2008) to measure consumption and user feedback of different fuels in different stoves under real life conditions; (iii) Laboratory assessments and development of a standard testing methodology (Dec 2007); (iv) Capacity building for better stoves among stove designers and stove producers (Feb 2008); (v) Stakeholder project design and structured brainstorming workshop (Oct 2007); and (vi) Interviews with WB team experts during missions.

efficiency (amount of fuel used to produce a certain heat) and the combustion efficiency (amount of emissions per quantity of fuel used), and this is determined by the characteristics of both the stove and the fuel.

- *A market-based approach for reducing air pollution from ger area heating systems is the sustainable strategy to switching fuels and stoves.* However, based on best available data, *technical solutions to reduce emissions from coal-fired ger heating systems are possible, but are not available on the market*. Although technical designs exist that could combust raw lignite much more cleanly than current heating systems, these are not commercially present in Mongolia.[10] There is also insufficient supply of reliable alternative fuel. However, *based on previous experience no one solution or abatement measure has been shown to have a major impact alone – to have a large impact, a combination of pollution abatement measures will be needed. Not all abatement measures need to be identified to get started, but systems should be designed to ensure success.*
- An win-win combination would be to obtain stove models that have low fuel consumption and low emissions, using the least cost fuels. Among the many other characteristics, the main interest for households will be low fuel expenses to improve affordability.
- *Many new initiatives intend to bring new fuels on the market without considering the stoves that will have to use these fuels; before entering the market, these fuels should be tested in different stoves to ensure that they indeed reduce emissions compared to raw coal and traditional stoves.* No fuel-stove combination currently available in Ulaanbaatar has been shown to meet prevailing emission standards.
- *When developing a package of pollution abatement measures, their impact on overall air pollution should be estimated to ensure the government's investment will meet expectations.*
- *Reliable fuel-stove tests of heating systems should be performed in Ulaanbaatar* but due to a lack of laboratory equipment and experience with testing protocols very few good results are available in Ulaanbaatar. Such tests require measuring emissions from different fuels in various heating appliances currently used in ger areas as well as measuring equipment and techniques tailored to these systems.
- *A public awareness and participation program is needed.* A pollution abatement program is not only a technical and financial challenge; civil society, especially the poor residents in ger areas, needs to be convinced to change to a more environmentally healthy behavior.
- *The current market for heating appliances and fuels is large and becoming diverse, but the current emissions standards and programs do not systematically promote the least polluting combinations.* At least 20,000 new stoves and Low Pressure Boilers (LPBs) are sold each year and in addition new heating walls are installed; the estimated value was more than MNT 2 billion (about US$ 1.6 million equivalent) in the 2007/8 heating season. Based on the results of the household survey, the total fuel consumption in the six ger areas in Ulaanbaatar was estimated at 546,000 t of coal for the 2006/7 heating season with a value of about US$ 16 million. In addition a total of 611,000 m^3 or about 415,000 tons of wood were used with a value of about US$ 30 million. Limited regulatory tools exist such

[10] Recently some prototypes have surfaced in UB.

as some technical standards for stoves and fuels, but these are not used and in addition, it is not even possible to measure compliance for a lack of adequate laboratory capacity.

- Developing products acceptable to the market that comply with the Government's environmental goals requires a *rethinking of the current product emissions standards and enforcement*, *starting with an interim performance targets* that can eventually be accepted as new standards following the Mongolian regulatory process. *Enforcement* of these standards requires a combination of administrative controls and market-based incentives.
- *Markets for heating appliances are rapidly changing in line with housing preferences and this increases pollution levels.* Greater numbers of households are living in more permanent dwellings now, which are larger and more comfortable than gers but require more heating fuel. Already, 10% of surveyed households use low pressure boilers consuming on average 6.2 t of coal/season, as compared to 3.5 t/season for individual ger stoves (77% higher fuel consumption). The relative increase in emissions from these devices is unknown. The use of heating walls is important also and almost as many households have a heating wall as live in a ger; heating walls consume 4.5 t/season and provide more comfort than individual stoves (30% higher fuel consumption than a ger stove). Only 16% of households living in a detached house do not have a heating wall or a low pressure boiler. The testing protocols that determine emissions factors for fuel – applicance combinations will need to be adjusted to the actual fueling practices of these appliances, which are different from stoves.
- *Purchasers of new heating appliances and fuels generally consider several important factors beyond pollution and safety in their purchasing decisions.* Such factors could be construed as a barrier to greater penetration of cleaner alternatives, e.g. compared to raw coal certain briquettes require that larger volumes of ash to be disposed of, or other briquettes take much longer to ignite due to the low content of volatiles in the fuel. Factors to consider are therefore :
    - cost of fuel and appliance;
    - convenience level: (i) amount of ash and ash disposal system; (ii) ease of cold start up, frequency of re-fueling; (iii) heating power and controllability of the heat output; (iv) fuel durability and storage; and (v) indoor smell;
    - cooking utility and appearance;
    - release of smoke through the chimney (contribution to air pollution).

- *Market-based approaches to disseminate cleaner heating systems are preferred over non-market based approaches* such as stove giveaways; the latter are risky and have already resulted in failure when earlier applied in Ulaanbaatar. Command and control approaches, such as banning raw coal, could be considered as complements to market-based approaches, but these should be carefully examined in terms of the risk of leakage (the risks of bypassing enforcement systems) and the reliable supply of affordable alternatives. If rapid penetration is desired of better heating systems than are now available in Ulaanbaatar:
    - *Artisanal manufacturing is neither going to have sufficient capacity* to design and supply the market quickly nor to produce at sufficient scale to bring down unit costs. Different solutions may be required such as collaboration with foreign

manufacturers and/or substantial technical and financial assistance to present manufacturers.

- o *Subsidies are very likely to be required due to affordability constraints* for parts of the ger area population. This report recommends an assisted market-based approach to promote cleaner heating systems; households will have a choice of heating system; manufacturers can produce the heating system they prefer; subsidy vouchers would be offered to households for the purchase of appliances that comply with low emission standards. If practically implementable, higher voucher values could be applied for lower-emission heating systems. This is considered to be an *Output-Based Aid* (OBA) approach. Reduced coal consumption would also reduce CO2 emissions for which global mechanisms exist to capture the value.
- o *Mechanisms and incentives for the removal of existing heating appliances* should be developed to ensure that they are taken off the market, such as providing incentives for households to sell their old systems when switching to new ones..
- o *Calibrating the amount of subsidy will depend also on the end-points and objectives of the policy.* If reduction in health impacts of air pollution is an end point, it will be important to determine the share of air pollution that comes from ger heating systems. Current estimates of annual average concentrations vary but appear high and this will help to determine the amount of resources justified for the desired effect. This is beyond the scope of this ASTAE activity but is being undertaken in cooperation with Ministry of Nature and Environment / NAMHEM, the National University of Mongolia, the Public Health Institute, JICA, GTZ and the World Bank in a separate activity of the Ulaanbaatar Clean Air Program.

Key Policy Recommendations and Moving Forward: This report outlines the basis for a program to replace stoves and introduce new fuels as one of the pollution abatement options. The program can be supported by two recommended policy options:

- The first policy recommendation is to develop and enforce technical standards for fuel-stove combinations specifically for use in ger districts, perhaps first by setting interim targets and testing new enforcement mechanisms. Complementary fuel substitution policies could be considered; these are not specifically addressed in this report as they are currently being studied as part of the EBRD TA Project – the UB Clean Air Initiative[11]. Providing assistance to Mongolian stove producers for the production of better heating systems and possibly linking them up to international counterparts should be part of the program. This will first require setting up emission testing capacity, which does not exist yet in Ulaanbaatar.
- The second policy recommendation is to actively promote households to switch to better fuel-stove combinations – once these have been identified. This includes organizing a large-scale publicity and awareness campaign, and realize a support mechanism to assist poor households in quickly adopting the measures to clean up the air they breathe. This report suggests using a subsidy voucher system based on the Output-Based Aid approach that earlier showed promising results in Ulaanbaatar, linking producer outputs to subsidies.

[11] A report will be issued shortly on the preliminary results of testing different fuels in a traditional stove and one improve stove.

- The third policy recommendation is to select abatement measures based on an analytical framework that allows policymakers 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 will help to get programs started, provide feedback, manage expectations, and continuously improve an air pollution abatement program. Due to the complexities of UB's air pollution problems, reducing its air pollution will unavoidably be a multi-year effort involving some experimentation, mechanisms for continuous improvement, financing and sustained support from all citizens of Ulaanbaatar.

1. Background & Introduction

Air quality in Ulaanbaatar is deteriorating very rapidly. During the past few years complaints about air pollution in the city have increased exponentially, especially during the winter months. Several causes of air pollution problems in the city have been identified, most of which relate to the burning of coal. Coal is not only used in the power plants but also in the ger areas, where households have to rely on small stoves to keep warm during the winter months. Consensus points to the use of raw coal for heating by ger areas residents as one of the main culprits.

Ulaanbaatar city itself is surrounded by mountains, which makes air pollution problems in the city more acute. The city essentially consists of two main areas, namely the city center with high rise office and apartment buildings, and surrounding ger areas with mainly low rise -- one storey -- detached house and gers. Ger areas have grown rapidly both in terms of size and in terms of population, mainly due to poor rural economic conditions resulting in a rural exodus. Currently, 60% of Ulaanbaatar's population lives in the ger areas - and the proportion is still growing. Since ger area residents have no access to the district heating system, they have to depend on their own heating systems. They mainly use raw coal and wood as these are the cheapest sources of heating energy available. These stoves are inefficient in terms of fuel use and in terms of combustion quality.

As a result of the growing ger area population, the use of coal increased and so did severity of the the air pollution. Several proposals aimed to directly reduce air pollution in the city have been discussed, including imposing a ban on the uses of raw coal, introducing cleaner-burning briquettes, introducing of semi-coked coal, replacing existing inefficient heating stove with fuel-efficient stoves[12], and resettling ger area households into apartment buildings However, to date there has been very limited information -- and the bulk of the information available is unverifiable -- regarding consumer preferences and willingness to switch to alternative stove and fuels, the estimated number of stoves that must be replaced, and the estimated total coal used for heating. This report focuses on filling in the information gaps that may be needed to formulate appropriate policies and/or action aimed at promoting improved heating appliances and fuels.

It has also been recognized that exposure to airborne pollutants, primarily fine particulates such as $PM_{2.5}$ and PM_{10} is a serious health hazard for all city residents, not just ger area residents. In addition, air pollution has a serious negative impact on the economy. A separate report on measuring air quality in Ulaanbaatar and estimating the impact on public health is forthcoming.

Structure of the Activities and Report

A series of activities was launched by the World Bank, with generous support of the Asia Sustainable Energy Program (ASTAE) to develop baseline information to design a large-scale program to introduce cleaner heating systems between October 2007 and June 2008. Results of consumption tests could not have been made possible without financial and expert support from the Ulaanbaatar City Administration.[13] Further essential assistance and collaboration was obtained from GTZ, JinSun Energy Co, and World Vision.

[12] There are several other proposed solutions that are being discussed and debated such as, providing subsidized electricity for ger heating and moving ger residents into apartments. However, the full analysis of what may be longer term alternativesare beyond the scope of this study.

[13] Mr. Munkhbataar, Director Mr. Batsaikhan Chultemsuren, Officer of Department for Urban Development; Mrs. Manaljav Zoljarghal, Chief of the Air Quality Division.

This report is designed to provide background information for those who are interested in either the market or non-market based approach for providing cleaner and more energy efficient heating stoves and cleaner fuels. Other related programs or projects that could also directly benefit from this report would include improved insulation for gers, public information dissemination and awareness campaigns aimed at educating the public about the health problems associated with air pollution.

This report summarizes information derived from the ASTAE supported activities and provides preliminary recommendations on the next steps toward the design of lower emission alternatives in Ulaanbaatar.

The activities included:

- A sample survey of 1,000 households, conducted in December 2007 The survey is designed to collect data from the representative sample of households that live in the ger areas located surrounding the city center. Ulaanbaatar districts that are located outside the city (e.g., Baganuur) or far from the city center have been excluded from this study, because the use of raw coal by residents in those districts have no or small direct impact on air pollution in the city itself.
- Consumer tests carried out from January – March 2008; A sample of households used different stoves and different fuels; a total of 4 groups of 15 households participated (60 in total), using 4 different stoves and 5 different fuels mostly over 2 week periods for a different stove-fuel combination (10 weeks in total);
- Laboratory assessments of the same fuel-stove combinations, with an intention to determine the relation between fuel consumption and emissions;
- Technical stove design assessment capacity building among stove designers and stove producers, with a view to promote better stove designs in terms of fuel consumption and in terms of reduced emissions;
- Stakeholder project design and structured brainstorming workshop on improved stoves with selected participants.
- Interviews with WB team experts during missions, in particular with clean coal experts[14], a gasification expert[15], and environmental experts[16].

The first and second activity were carried out by: MMCG[17] carried out the household survey in January 2008 and BEEC[18] the consumption tests. The other activities were carried out by individual international consultants.

The *household survey* in the ger areas of Ulaanbaatar (December 2007 – January 2008) allows: (1) estimating the total number of traditional heating stoves that are currently used by households living in the in ger areas; (2) establishing a baseline of heating fuels used by household with traditional heating stoves; (3) gaining more understanding regarding households' perception and

[14] Masaki Takahashi, World Bank power / boiler specialist; J-Coal consultants, World Bank consultants.
[15] Helmut Vierrath, coal gasification expert, World Bank consultant.
[16] Jostein Nygard, Jitu Shah, World Bank air pollution specialists, and Tony Whitten, World Bank biodiversity expert; and Steinar Larssen, air pollution expert, World Bank consultant.
[17] Mongolian Marketing Consulting Group
[18] Building Energy Efficiency Center, of the Mongolian University of Science and Technology

attitude toward their existing traditional heating stove, improved stoves, and alternative heating fuels; (4) assessing households ability and willingness to switch from using traditional stove heating to an improved stove; and (5) identifying barriers that may inhibit households from switching to an improved stove. An updated list of all households from all ger area Khoroos was used to identify 1000 sample households using Simple Random Sampling (SRS) technique; this gave a maximum sampling error of 3%. The following sample was used:

Table 1: Household Survey sampling details

District	*Sample size*	*Representative nr of households*
Bayangol	73	7,369
Bayanzurkh	250	25,235
Songinokhairhan	231	23,317
Sukhbaatar	173	17,463
Chingeltei	193	19,482
Khan-Uul	80	80,75
Total	1000	100,941

Source: MMCG

A draft questionnaire was developed by the project team and handed over to the selected survey firm. The firm organized focus group discussions to modify the text of the questionnaire and field tested the questionnaire in 100 households with a view to both test the questionnaire and the surveyors. A public feedback meeting was held at the UBMG building to discuss the questionnaire with interested organizations and individuals prior to field testing the questionnaire. The survey was carried out by the selected firm which also entered the data into the computer and checked for inconsistencies. The project team analyzed the data and wrote the survey report. The questionnaire and tabulated survey results are available from ASTAE. Annex A provide important information on statistical methods used.

Households' coal consumption and expenditure in the survey are based on the recollection of last heating season -- on coal consumption and expenditure from September 2006 to April 2007 -- of responding households. The estimated weight of coal per bag and size of firewood per bag are based on the following assumption: One bag of raw coal equals 17 kilogram, 20 bags of firewood equals one cubic meter. Since the questions are based on recollection from previous heating season, it was not possible for interviewers to weigh fuels during the interviews. Furthermore, raw coal, firewood, compressed coal, and coal briquettes (except Korean briquettes) bought and sold in the market are based on estimated weight and estimated size in cubic meters in the case of firewood.

Raw coal or firewood loaded/piled up on the large (often Russian) truck is considered to weigh about 5 tons for coal or 5 cubic meters for firewood. Raw coal or firewood loaded/piled up in a smaller (often Chinese) truck is considered to weigh about 2 or 3 tons or about 2-3 cubic meters for firewood. Consumers are usually informed about the weight in tons when buying raw coal by the truck-load but this is not otherwise verified. Although raw coal or firewood bought and sold in small bags can be weighed by the user, this is not usually done either. Consumers who purchase raw coal or firewood by the bag usually rely on traders to tell them the weight; bag sizes are standard but may change from year to year. Data collected from field interviews with fuel traders in Ulaanbaatar, indicate that to sell raw coal in bags, traders usually divide truck-loads into small bags: one ton of raw coal can be divided into approximately 60 bags. As a result, the survey assumes that one bag of raw coal weights about 16.7 Kilograms. Similarly, to sell firewood in bags, fuel traders usually divide one cubic meter of firewood into 20 bags. As a result, the survey assumes that 20 bags of firewood equal to one cubic meter.

The *consumption test* in the ger areas of Ulaanbaatar (December 2007 – March 2008) allows: (i) estimating the ger area household consumption levels for different fuel-stove combinations and determine heating costs; (ii) determining the relative fuel consumption for each fuel type compared to raw coal for each of the most commonly used stoves on the market; (iii) verifying fuel savings for the different improved stoves; and (iv) gaining more understanding regarding households' perception and attitude toward their existing traditional heating stove, improved stoves, and cleaner heating fuels. This will help to establish the baseline for heating fuels and stoves used by households at this time and allow verification of the consumption aspects of the household survey. The firm selected for the work was given a set of questionnaires for field-testing and modification; it collected all test data, analyzed these, and wrote a report. A committee consisting of UBMG, WorldVision, and WB staff preselected the Khoroos where the consumption tests took place. Bayanzurh District, Khoroo 9, Khan-Uul District, Khoroo 8, Songinokhairkhan District, Khoroo 1, and Chingeltei District, Khoroo 18.

Four different groups of 15 households participated: one group used the MG – 203 stove from JinSun Energy Co for 2 weeks. The other three groups each had a different stove and participated for 8 weeks. A traditional stove (that participating households already owned), a TT0-3 stove that was newly purchased from the market, and a GTZ improved stove (donated by GTZ) were used in the tests to reflect the common stoves and the best improved stoves currently available. The 45 households first used raw coal for the first 2 week period, sawdust briquettes during the second period of 2 weeks, coal briquettes during the 3rd period of 2 weeks, and a range of fuels during the 4th period of 2 weeks[19]. Enumerators visited all household every day to check the fuel consumption by weighing the fuel; a short in-depth interview or appreciation survey about the fuel and the stove was carried out at the end of each period. Indoor and outdoor temperatures were recorded and the moisture content and calorific value of the fuels were measured.

Table 2: Fuel and Stove combinations applied

Stove type (15 each)	*2 weeks*	*2 weeks*	*2 weeks*	*2 weeks*	*1 week/or 2 days*
Traditional	Nalaikh	Sawdust briquette	Compressed coal briquette	Compressed coal briquette	1 hh, SCC-briq
GTZ	Nalaikh	Sawdust briquette	Compressed coal briquette	Compressed coal briquette	3 hh, SCC-briq 1 hh, SCC
TT-03	Nalaikh	Sawdust briquette	Compressed coal briquette	Compressed coal briquette	1 hh, SCC-briq 1 hh, SCC
MG-203	Yontan briquette				

Source: BEEC

[19] Fuels tested were: raw coal from the neighborhood sales points; Yontan coal briquette manufactured by Sunjin Energy Co., Ltd ; Coal briquette manufactured by Burhany Gal Co., Ltd; Saw dust briquette "Talst" manufactured by Ulziit Tuv Co., Ltd; Raw coal sprinkled with "Clean Coal" liquid; Coal briquette manufactured by Tanu Fuel Co., Ltd; Semi-coked briquette manufactured by MAK Co., Ltd ; Semi-coke coal manufactured by MAK Co., Ltd. Fuel choice was agreed upon with UBMG, and all briquettes needed to comply with the National Standard for solid fuel, MNS 5679: 2006

The *laboratory test* of the same stove-fuel combinations as in the consumption test (March 2008) could only be partly completed. The idea was that standardized laboratory tests of stove-fuel combinations would yield both fuel consumption data and emission data (combustion efficiency, CO, PM). With these data it would have been possible to correlate emissions with fuel consumption, which is essential for assessing different corrective air pollution measures. However, two problems prevented these tests from taking place: (i) some essential equipment was not available, in particular a scale capable of weighing the stove and measurement equipment (> 100 kg) during the emission measurements (to determine the actual fuel consumption and power output) and a meter capable of measuring real-time PM emissions; and (ii) a standard methodology and the capacity to carry out these measurements.

Although a standard methodology was developed by the ASTAE consultant and generally accepted by the main laboratories in UB, lack of equipment and trained personnel prevented the tests to be carried out systematically and scientifically. Nevertheless, UBMG staff (Air Pollution Division) carried out some tests with different fuels in the traditional stove and although the results were indicative only, they suggested an important conclusion. See Annex B for the testing protocol.

The *training of stove designers and producers* (March 2008) took place to provide stove makers with information about different stove and combustion technologies. Traditional and currently available improved stove models burn raw coal not very cleanly compared to a simple locally-built reference burner.[20] The main difference between the reference burner and normal coal stoves is the direction and flow of exhaust gases: in the traditional stove, hot exhaust gases escape from the combustion zone straight into the chimney, whereas in a down draft mode exhaust gasses pass through the hot combustion zone before exiting the chimney thereby breaking down and igniting most of the pollutants. In a normal stove, the combustion zone is at the bottom of the fuel bed with poorly burning coal above it, whereas in a downdraft stove the fuel burns on the bottom of the fuel bed with the flames passing away from the unburned fuel. It was decided to share these principles with the stove community in Ulaanbaatar in two steps: (i) discuss and agree on the methodology for testing fuel consumption and emissions with the laboratories that are interested in this type of work; and (ii) organize a two day training workshop with follow up factory visits for interested individuals and firms to demonstrate down draft principles and discuss how these could be applied to normal heating stoves.

As part of the practical testing that took place in the laboratory, it was demonstrated that conditioning of the coal could also yield substantial benefits. Breaking up the coal lumps into smaller pieces of 2-3 cm would is also improve the combustion efficiency. The explanation is that the air flow is better regulated and more complete combustion takes place. This is valid only for a properly designed stove: air leaks through holes in the stove body will negate the improvements.

Although it was shown that simple stove models can drastically reduce emissions without changing the fuel (other than conditioning), no new commercial stove models have been designed so far. This is the responsibility of the private sector and although a few much cleaner burning models did surface in the following season, their quality was highly variable and they have not been taken into production. With the current attitude of the Government, it remains unclear if a stove development and promotion activity can be included under a proposed project.

[20] The reference burner demonstrated a reduction in particulate and CO emissions of >90%.

A *structured brainstorming workshop* took place to discuss a 360 degree experience from all stakeholder groups with promoting improved heating stoves (October 2007). A number of Khoroo chairmen, the stove NGO association, stove producers, households, MNE, UBMG, the stove PIU, and some NGOs participated in the workshop. The objective was to obtain feedback on the effectiveness of the past improved stoves program and obtain guidance for restructuring. See Annex C for more details and results of the structured brainstorming workshop.

Finally, many discussions in person and by e-mail took place to discuss findings and brainstorm about alternative approaches; this contributed to shaping the current report with the results incorporated throughout the report.

The EBRD TA project organized tests of different fuels in a traditional stove and a GTZ improved stove in March – April 2009 with the World Bank's stove consultant present. Although results are not yet available, it is expected they will be published in the near future. Nevertheless, these were important first tests that could kick start needed development of appropriate fuel-stove combinations. In order to scale up development of fuel-stove combinations that deliver large emissions reductions, more testing is needed. This entails testing more combinations, including models not yet commercially available: the semi-coked fuel, raw coal briquettes, wood briquettes, raw coal and wood were tested only in traditional stoves and one type of improved stove. For example, significant emissions reductions were obtained in South Africa using bituminous coal and a 'downdraft' stove.[21] A preliminary downdraft stove model was developed during the ASTAE training activities in Ulaanbaatar but is not yet commercially available. This is an indication that scaled up testing is needed to identify good fuel-stove combinations. The testing should be done through an independent testing center with appropriate equipment and using a standard testing protocol.

Summary Results

The following provides a summary of the data collection effort undertaken, divided into three parts: (i) data about the market for stoves and fuels; (ii) data about the perception and attitudes of ger district residents about fuels and stoves; and (iii) results of the tests whereby a number of households used different stove-fuel combinations.

Market Data. The 1,000 household survey in UB's closest 6 Khoroo provides a better understanding and statistical data about the use of stoves and fuels as well as perceptions of ger area residents. The main findings are listed below. Households living in the six surveyed ger areas can be classified into four mutually exclusive groups based on heating system, type and size of dwelling unit:

(1) households living in a ger and using a heating stove with chimney;

(2) households living in small detached house and using a heating stove with chimney to directly heat their home;

(3) households living in a medium size detached house and using a stove attached to a heating wall; and

(4) households living in a larger detached house and using a low pressure boiler attached to a system with circulating water and radiators.

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[21] University of Johannesburg's SeTAR Centre.

Comparison of fuel consumption and expenditure among these groups of household show that household fuel consumption and fuel expenditure are positively correlated with the heating system, the type and size of home. As expected, households living in the ger spend and use the least amount of heating fuels and households living in a detached house use more fuel and spend more on heating. Almost all households use raw coal as the main heating fuel and use firewood to start the fire, although some households use firewood to supplement raw coal.

During the heating season from September 2006 to April 2007 households consumed on average about 4.2 t of raw coal and about 4.7 m^3 of firewood. The estimated total expenditure per household during the heating season is US$ 146 for raw coal and US$ 70 for firewood. The survey also shows that lower income households in the ger areas spend a significant amount of money to heat their ger/home, with an extremely high financial burden for households in the bottom fifth income quintile that spend as much as 40% of their monthly winter income on heating fuels. Households in the top income quintile spend only 9% of their monthly income on heating fuels.

The current number of briquette users is very low, with only 1.6% of households in the six surveyed ger areas reported that they use briquettes all the time although another 3.6% are occasional users. In all, about 5,000 households have used or are using briquettes at any time during the current heating season. The number of households that have been exposed to or have used briquette has doubled from the previous heating season. Briquette appears to be gaining popularity quickly. However the pattern of briquette usage from previous heating season seems to suggest that households are either still testing these new products or could not find a steady supply.

It is estimated that there are about 104,000 stoves currently in use by the households in the six surveyed ger areas. A small number of households have two stoves and some use the extra stove to heat an extra space such as a business/kiosk or garage. During the past five years, it is estimated that at least 11,500 stoves have been added each year. There has not been any systematic disposal of old or unused stoves. Based on the survey it is estimated that about 24,000 households still have their old stoves in possession. Although these old stoves are not in working condition, it is not known how many of these could be reconditioned or recycled. The survey also confirms that many households sold their old stoves to other households, which means that a used stove market exists. This has implications for any plan that includes reconditioning and recycling old stoves, possibly also collecting and crushing them to take them out of service.

Perception and Attitude. The majority of households in the six surveyed ger areas appear to be satisfied with their existing stove and/or heating system. However when asked if they would be interested in changing their current stove, 52% of the households in the six surveyed ger areas respond affirmatively and of those 56% were interested in changing to an improved stove. The main reasons for willingness to change stoves are the desire to reduce the heating bill and a high expectation of the performance of improved stoves.

Attitudes expressed by surveyed households show that they know about air pollution problems in the city and that the use of raw coal contributes to air pollution problem in the city and is harmful to their health. Households also show willingness to reduce raw coal consumption, adopt alternative heating stoves and/or fuels. The general attitude toward improved stoves is positive. There is no apparent negative opinion toward improved stoves. With regard to briquettes, the majority of households have very little information or ideas about briquettes. However, a significant portion of households indicated their willingness to try briquettes and they believe that briquettes are less polluting than raw coal.

Survey results further indicate that households are quite willing to take action to help solve or alleviate air pollution problems in the city. However, it appears that households have no clear idea about costs and benefits and they have also no idea about the impact of the proposed solutions or actions. For example, the survey finds that about 60% of the households agree with the statement indicating that he/she would really like to only use electricity to heat his/her home/ger; a small number (less than 50%) think that it is cheaper to use electricity to heat home/ger than using raw coal. In reality, the use of electricity for heating, even at the reduced evening tariff, would be more expensive than using raw coal and traditional stoves.

Household Fuel Consumption Tests. The consumption tests showed that considerable differences in fuel consumption exist between fuels and between stoves. As an example, improved stoves consumed on average 380 MJ per day[22] compared with 425 MJ per day for a traditional stove. It was also shown that the energy consumption of a particular type of coal briquettes was 15% higher than raw coal in a traditional stove but only 5% higher in an improved stove. In short, the energy consumption depends on both the stove and the fuel. Participating households had clear preferences for different fuels and to a lesser extent for different stoves.

It is necessary to measure emissions in addition to energy consumption, but this could not be done for a lack of laboratory equipment. Emissions from combustion of different fuels in different stoves should be measured, to determine which stove-fuel combination provides the least emissions of undesired substances, such as CO, H_2S, TSP[23], PM_{10} and $PM_{2.5}$. A standard testing protocol was discussed with the laboratories that are interested in this type of work. Although there have been some previous emission tests, the results cannot be used because the testing protocol did not include all the necessary measures. A limited number of measurements were taken by the study consultant and the Air Quality Division of the UBMG showing that current fuels and stoves do not comply with the prevailing standards. The impact can be smelled and seen every cold day.

[22] Across all fuels and all households in the sample

[23] Total Suspended Particulate matter

2. Demographic, Housing, and Socio-Economic Information

Administratively, Ulaanbaatar Municipality consists of 9 Districts, which are divided into 120 Khoroo. The latest available Census (2003) estimated the total population in Ulaanbaatar at 192,900 households.[24] In general, Ulaanbaatar city can be divided into two main areas namely, city center area and ger areas. The city center area is comprised mainly of high rise and apartment buildings while the ger area is comprised mainly of low rise -- one storey -- detached houses and gers. Ger areas spread out into a wide area stretching from around the city center to the outskirt and the suburb of the city. The most recent Population Census reveals that there are about 124,000 households in the Ger areas. However, the main ger areas surrounding the center city encompass about six districts and 74 Khoroo.[25] The ASTAE survey focuses on these ger areas only because of their direct impact on air quality in the city. *This survey data differs from consensus knowledge that the actual population is larger*; however, for study purposes, the sampling frame for the survey used up to date Khoroo Registration lists that may exclude the newest immigrants who may have decided not yet to register and it also excludes the ger areas that are further away from the city center. *However, the proportions and findings are expected to be the same for those households not included in the sample*.

This chapter provides detailed demographic information as well as socio-economic characteristic of the households that live in these six ger areas. Since type of dwelling is closely related to the type of heating system and its fuel consumption, the analysis of the type, size of ger/home and types of heating stoves and how these are used to provide heat for the occupants are also described in this chapter.

2.1 General Characteristics of Ger areas

Based on the most recent administrative record kept by Khoroo governors, there are 100,941 households currently living in the six ger areas of the survey sample. During the past decade, ger areas in Ulaanbaatar have been expanding both in terms of area and population, mainly due to migration of the rural population into the city. In addition, due to the recent rapid economic growth, Ulaanbaatar's center city started to expand into the ger areas. High rise apartment buildings and new modern housing units have been built in several ger area areas. However, given the size of ger areas and especially, the socio-economic status of a majority of the ger area population, it is unlikely that high rise apartment buildings and new modern housing complexes will completely over take ger areas in the near future.

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[24] Mongolia National Statistical Office, "Statistical Year Book, 2003." The figure reflects population estimate at the end of 2003.

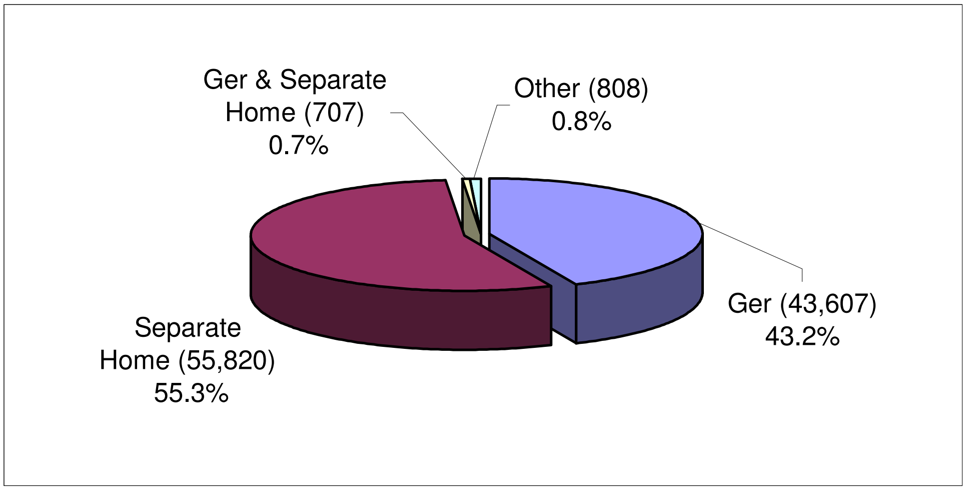
[25] There are a few districts, which are located further away from the city center. These districts are excluded from this study. This is because the uses of heating stove by households in these far districts have limited impact on air pollution problems in the city.

Photograph 1 - Ger area scenery

2.2 Total Number of Households and Type of Dwelling Unit

A typical characteristic of ger areas in Ulaanbaatar is that dwellings are distinctively different from those in the center of the city. Ger areas consist mostly of small plots called *Hashaa* with single one storey wooden homes and/or felt tents (gers), enclosed by a wooden fence. The majority of households living in the ger areas have access to electricity but not to district heating. Furthermore, most households in ger areas still do not have in-door running water and sewage services and have to rely on communal standpipes and individual outhouses. With respect to types of dwelling in the ger areas, the survey confirms that about 43% of households in ger areas are currently living in the ger type of dwelling unit, and slightly more than half (55%) of the households are living in the regular home dwelling type. Recently settled households live in a ger but over the course of several years they start building a fixed home as these are more spacious and comfortable. Slightly less than one percent (0.7%) of the households in ger areas occupies both a ger and a single dwelling unit/home, i.e., ger with some form of passage connecting to another ger or fixed structure home type of dwelling unit.

Figure 1 Types of dwelling Unit



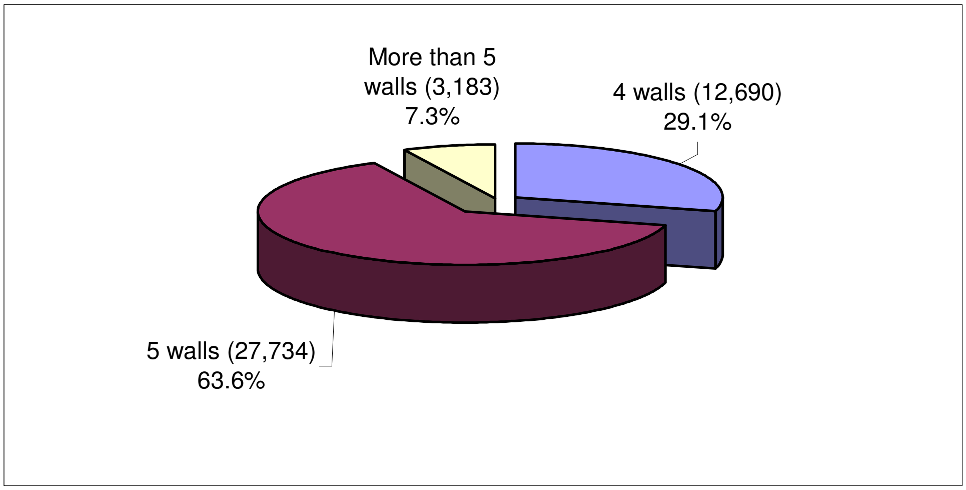
Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

2.2.1 Characteristics of Ger Households

The survey results reveals that there are about 43,607 households currently living in a ger type of dwelling unit or using a ger as their main dwelling during the winter months. Almost all of the households (93%) that live in ger own their ger and about 5% rent the ger that they are living in. The remaining small numbers of households that live in ger receive some type of assistance or are allowed to use the ger for free. As depicted in Figure 2, the majority (64%) of the gers has 5 walls, and 29% has 4 walls. Only about 5.5% have 6 walls. The total area for 5 wall gers is estimated to be 28 square meters.[26]

[26] The diameter for typical 5 wall gers is about 5.6 to 6 meters, depending on the erected height of the ger.

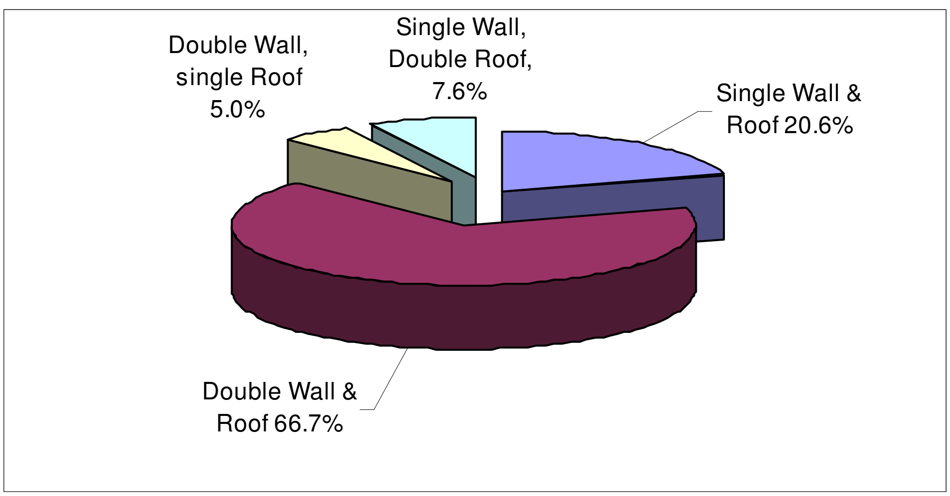
Figure 2 Size of Ger



Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

With regard to the felt used to cover the ger, about three-fourths of the gers (or about 38,772 to 40,122 gers) have double layers of felt covering the wall and the roof, respectively. The remaining 14,000 gers have only one layer felt covering the wall for insulation. Almost all (92%) of the gers have some type of cover for the skylight of the ger to retain heat. For the flooring, the vast majority of gers (or 82%) have a wooden floor, almost 16% have an earthen floor, and the remainder of the ger uses a concrete/cement slab as floor.

Figure 3 Wall and Roof Coverage of Ger



Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

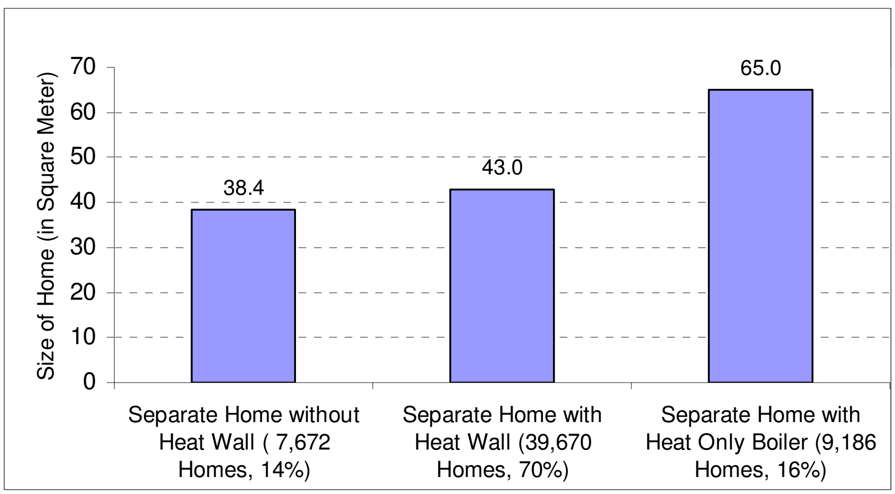
Close to three-quarters of the gers have double layers of wall or roof and two-thirds have a double layer felt cover for both wall and roof of the ger. About one-fifth (or 11,124 gers) have only one layer of felt coverage for both wall and roof (see 3) which results in poorly insulated gers that are not well equipped to provide comfort for the occupants during the long and cold winter months in

Mongolia.[27] Felt covers have a limited lifetime and need to be replaced regularly due to deterioration from accumulated moisture.

2.2.1 Characteristics of Separate Home (Single Dwelling, Non Ger Unit/Home)

As pointed out in Section 2.2 that about 56% of households in the six surveyed ger areas live in single dwelling unit/home (commonly called a 'separate home' using the direct Mongolian to English translation), which amounts to about 56,528 separate/single family dwelling units/homes in the six surveyed ger area. A separate/single home in the ger areas is relatively small in size. The average number of rooms excluding kitchen and toilet is about two. Some 80% of all separate homes in the ger areas have only one or two rooms. The average total living areas excluding kitchen and toilet is only 46 square meters or 495 square feet. Almost all homes have one floor, only 7% of the homes have a second storey. Similar to the ger, almost all homes in the ger areas are owner occupied. About 95% of the homes are owned by the households and 3% of the households rent it. The remaining 2% are living rent free or receiving some type of assistance that allows them to live for free. All but three respondents interviewed consider their home to be winterized. The three respondents indicated that the homes they live in during the winter months are considered to be summer home (i.e., not winterized).

Figure 4 Size of Single Family Home



Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.
Note: Size of home in square meters exclude kitchen and bathroom.

The 56,528 detached houses in the six surveyed ger areas can be divided into three groups, based on the size of their home and the type of heating system. Detached houses are equipped with a stove with or without a heating wall[28], or with a low pressure boiler. The largest group, 70% of the detached house, use a heating wall and have a floor space of about 42 square meters; 14% of detached houses have no heating wall and show a floor space of 38 square meters, indicating that

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[27] It should be noted that the survey neither collected the information concerning the quality and thickness of the felt that are used to cover wall and roof of the ger, nor the tightness of coverage that may prevent heat losses by allowing cold air to be blown into the ger.

[28] A hollow interiror heat-retaining wall through which flue gasses from the stove escape into the atmosphere; this is used to heat the house. This practice is often seen in Russia.

income is a factor that determines whether households can afford a heating wall. Some 16% of the households with a detached house have a low pressure boiler and have on average 65 square meters floor space.

2.3 Characteristics of Households in the Ger areas

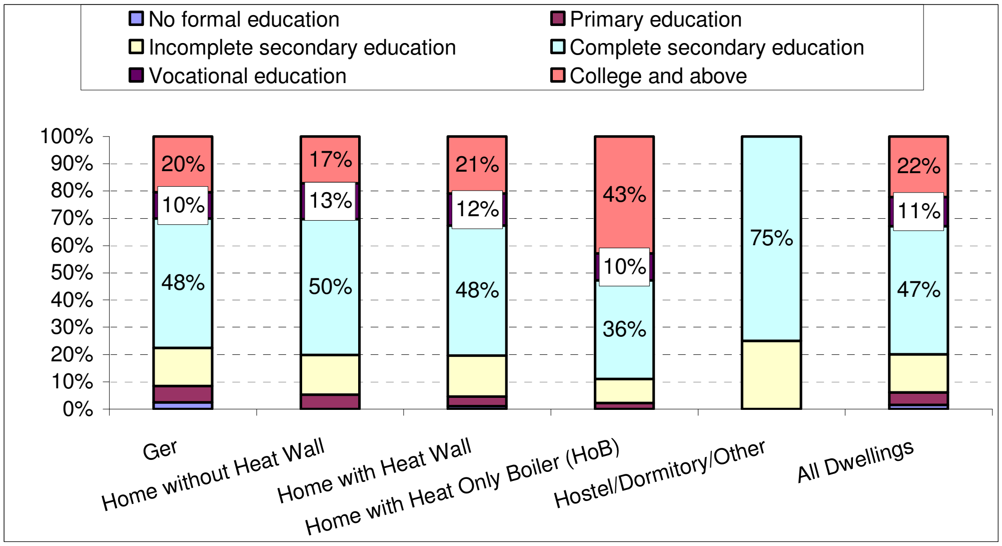
The average household size in the six surveyed ger areas is slightly more than four persons. The average total household monthly income is estimated at 242,788 Tg per month. About a fifth of the households are headed by a female. The highest educational level of the household head, living in the ger and households living in the separate/single home using stove, both with and without a heating wall, are quite similar. However, a larger portion households living in a single home with low pressure boilers have high level of education. Overall, households living in the single home and which use low pressure boilers are distinctly richer and better educated than other households. A small number of households that live in the dormitory/hostel/other un-specified type of home are the poorest (financially) and least educated. However, the largest numbers of households that live in the ger are generally the poorest as well. It should also be noted that households living in a ger or single home using stove without heating wall have disproportionately high portion of female headed households. Female headed households among these two groups accounts for more than 12,000 households.

Table 3: Socio-Economic information of Households in the Ger areas

		Single Separate Home Using Stove				
	Ger	without Heating wall	with Heating wall	LPB	Dormitory/ Hostel/ Other	Total
Total Number of Ger/Home	43,607	7,672	39,670	9,186	808	100,941
Total Household Monthly Income	206,519	240,836	261,005	341,842	198,248	242,788
Family Size (in persons)	4.4	4.3	4.4	4.5	3.8	4.4
% of Homes Female Head of Household	24%	28%	15%	10%	13%	19%

Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

Figure 5 Educational Attainment of Head of Household



Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

2.4 Conclusion

Analysis of the socio-economic characteristics of households in the ger areas confirms that a large number of households are relatively poor. The majority of poorer households tend to live in a ger and not in a detached single family house. Although gers are designed to withstand very cold weather, one-third have only one layer of felt covering the wall or one layer of felt covering the roof top, or only one layer of felt covering both wall and roof top while two-thirds have a double layer covering the roof and the wall. *Financially better off households tend to live in detached house. Among households that are currently living in a detached single family home, the poorest households use heating stoves without heating walls.* Households that live in a detached house and use heating stoves without heating walls have slightly higher income than households that live in a ger. The two remaining financially better off groups of households live in bigger homes and use a heating stove with a heating wall, and those who live in the largest homes use low pressure boilers for heating. The poorest households in the six surveyed ger areas account for less than one percent of all households in the ger areas; they have the lowest income and education level, and live in a hostel/dormitory/other unspecified type of dwelling unit.

3 Heating Stove Ownership and Preferences

Apartment buildings, stores, and businesses in the city center are heated through a district heating system whereby water is heated from a central location (combined heat and power plants) and distributed through a system of pipes. A stove [29] is the primary heating device for all households in the ger areas because they do not have access to the district heating system. Heating stoves are used in a variety of ways to provide heat. Stoves can be used directly for space heating, or a heating wall is attached to the stove for better heat distribution. Heating walls are traditionally used in cold northern climates such as Russia; they consist of a double wall through which flue gasses escape and exchange heat before exiting the chimney. Heating stoves are also used to boil/heat water and cook food in the winter. Some stoves have a hot water distribution system and radiators to heat the house. This is commonly known in Mongolia as a low pressure boiler. Pictures of these stoves are presented below.

Heating stoves have always been used in Mongolia to survive the harsh winters. However, during the past seven or eight years a few new models of heating stoves were introduced. They are commonly known as improved stoves[30], designed to reduce the fuel consumption and CO_2 emissions. As a result, stoves that were used before the introduction of improves stove are typically called traditional stoves.[31] Only very recently, just in the past year, improved stoves have been discussed as a tool to reduce air pollution. This is technically quite possible, not only through a lower fuel consumption (higher fuel efficiency), but also through a better combustion efficiency of the fuel so that a lower level of pollutants is emitted. In an effective improved stove both would ideally be employed to minimize the level of emissions.

Heating of homes starts in late September/early October and lasts until late April. Early and late in the heating season homes are heated part of the day and night, not continuously. During this time wood is often used, simply because a wood fire is easier to start and gives more rapid heat than coal. During the middle of the winter, homes are heated 24 hours per day and coal is generally used; it is not always easy to start the fire, but once it is lit it will burn for a long time, longer than a wood fire.

This chapter provides the estimated number and types of stove that are currently being used as well as the estimated number of stoves that can be used in the six surveyed ger areas. It also provides descriptive analysis regarding profiles and characteristics of stove users, type of stoves and how stoves are used to heat the ger/home. The last section discusses householders' perception of the performance of their existing stove, households' knowledge and perception of improved stoves as well as their willingness or tendency to switch to improved stoves.

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[29] Broadly defined to include individual stoves, stoves with heating walls and LPBs.

[30] The Ministry of Nature and Environment introduced, through a GEF supported project four different improved stoves models that had been identified through a competition among stove manufacturers; all four models were found in the sample survey. GTZ has recently introduced a new model improved stove with a brick lining to retain heat longer, but this model was not found in the survey. More recently, the Korean firm Jin Sun introduced a different improved stove in Ulaanbaatar based on its experience in Korea; this stove was found in the sample.

[31] Typical stoves whether traditional or improved are primarily made of either cast iron of metal sheet or both. Some heating stoves are metal shells lined with bricks, which have been classified as traditional stoves. However, some consumers identify traditional stove that has brick lining as the 'brick stove'.

Photograph 2 - Traditional stove in ger

Photograph 3 - TT03 stove in market

Photograph 4 - Heating wall stove

Photograph 5 - Back side of heating wall

Photograph 6 - Low pressure boiler, note water pipes

3.1 Estimated Number of Heating Stoves

The survey found that there are about 103,971 heating stoves, of which 100,941 are used to heat the home/ger during the winter months. Another 2,120 heating stoves are used by the households to heat their home business, kiosk, or garage. The remaining 909 stoves are owned by the households as the second stove. These 909 stoves are in working condition, but they are not being used. As shown in Table 4, the overwhelming majority of stoves are traditional stoves. The survey reveals that traditional stoves account for 88% of all stoves that are either being used and/or owned by the households living in the six surveyed ger areas.

Table 4: Estimated Total Number of Stoves in the Ger areas Around City Center

	Number of Stoves Being Used to Heat		Second Stove Owned by the Household	Total Number of Stoves in 6 Ger areas	Percent
	Home/Ger	Home Business /Kiosk/Garage			
Traditional Stove					
Metal/Cast Iron	75,706	505	1,615	77,826	74.9%
Brick Stove	8,984	101	202	9,287	8.9%
Sawdust Stove	3,937	-	-	3,937	3.8%
Total	*88,627*	*606*	*1,817*	*91,050*	*87.6%*
Improved Stove					
TT-03	1,110	101	-	1,211	1.2%
G2-2000	707	-	-	707	0.7%
EB-1	101	-	-	101	0.1%
BONA-2	101	-	-	101	0.1%
Total	*2,015*	*101*		*2,120*	*2.1%*
Korean Stove	1,110	101	-	1,211	1.2%
Small LPB[1/]					
Made Locally	7,268	-	202	7,470	7.2%
Imported	1,918	101	101	2,120	2.0%
Total	**100,941**	**909**	**2,120**	**103,971**	**100%**

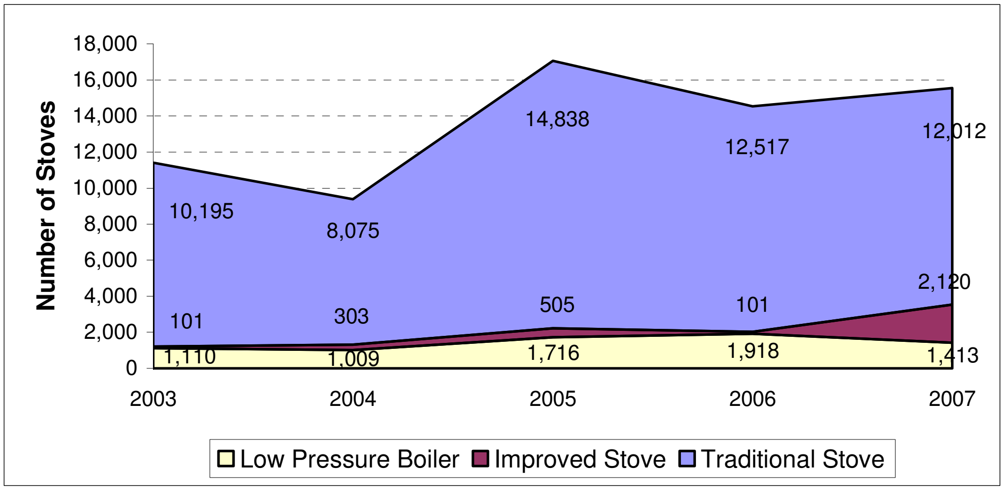
Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

Note: Small low pressure boilers (LPB) refers to stove with low pressure boiler with hot water distribution system used to heat home.

3.2 Estimated Age of Heating Stoves

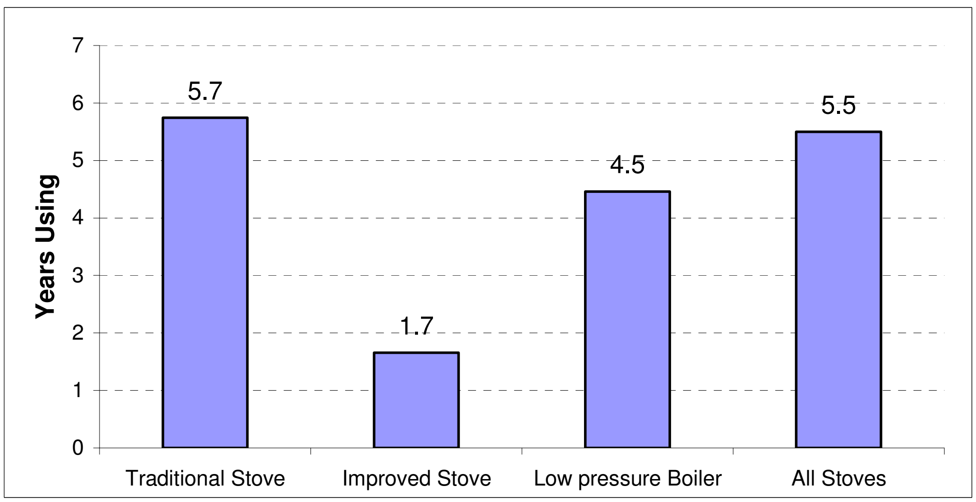
Traditional stoves have been around for a very long time and can last for decades. The survey found that about 10,200 households (or 11.5% of the households that use a traditional stove) have been using the same stove for over 10 years; and another 11,500 stoves are about 7 to 10 years old. About 25% of all traditional stoves that are currently being used are over seven years old. Although the average age of a traditional stove is about 5.7 years, the median age of traditional stove is only four years. This means that about 44,300 stoves are under four years old - or in other words, quite new. It is estimated that during the past five years (2003 to 2007) an average of about 11,500 traditional stoves are added each year to provide heat for the residents in the six surveyed ger areas. The survey did not collect information that would distinguish the approximate portion of these new stoves bought for replacement or for new households. However, there are about 3,300 households have lived in a house for only one year and about 2,000 reported that their stove is one year old or less. It is therefore reasonable to conclude that at least 20% of new stoves added last year are used in the new households or new ger/home or newly occupied ger/home.

Figure 6: Number of Stoves Increase per Year from 2003 to 2007



Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

Figure 7: Number of Years Household Using Current Stove



Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

Table 5: Age of Stove

	Traditional stove	Improved stove	Low pressure boiler (LPB)	Total
One Year	12,012 13.6%	2,120[1/] 67.7%	1,413 15.4%	15,545 15.4%
Two Year	12,517 14.1%	101 3.2%	1,918 20.9%	14,536 14.4%
Three Year	14,838 16.7%	505 16.1%	1,716 18.7%	17,059 16.9%
Four Year	8,075 9.1%	303 9.7%	1,009 11.0%	9,387 9.3%
Five Year	10,195 11.5%	101 3.2%	1,110 12.1%	11,406 11.3%
Six Year	5,148 5.8%	0 0.0%	303 3.3%	5,451 5.4%
Seven Year	4,139 4.7%	0 0.0%	404 4.4%	4,543 4.5%
Eight Year	3,634 4.1%	0 0.0%	202 2.2%	3,836 3.8%
Nine Year	505 0.6%	0 0.0%	101 1.1%	606 0.6%
Ten Year	7,369 8.3%	0 0.0%	202 2.2%	7,571 7.5%
Over10 Years	10,195 11.5%	0 0.0%	808 8.8%	11,003 10.9%
Total	88,627	3,130	9,186	100,943

Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

Note: This figure includes 1,110 Korean Stove.

The second most popular type of stove is a small *low pressure boiler* (i.e. small furnace connected to a low pressure hot water distribution system including radiators. Typically, such low pressure boilers (LPB) use the traditional coal fired stove as the boiler to which a hot water distribution system with pipes and radiators is added. Almost all of the LPB are built locally although a small number is imported from China. LPB systems provide the highest level of comfort for ger area homes: not only is the heat most evenly distributed throughout the house, it needs to be operating around the clock to prevent pipe-bursts.

Currently, there are about 9,590 homes in the six surveyed ger areas that have an LPB for heating. Stoves with LPB account for *11% of all heating stoves*. Most low pressure boilers are relatively new. The survey reveals that about three quarter of low pressure boilers (or about 7,165 LPB systems) have been installed during the past 5 years. *Due to its popularity and the fact that only 16% of households living in a fixed home already have a low pressure boilers, it is therefore, expected that the uses of low pressure boilers will increase significantly in the near future.*

The survey also reveals a relatively small number of *improved heating stoves*, despite the fact that these have been on the market for several years. The average age of improved stoves is slightly less than two years old; about 34% of improved stove is only one year old or less. This suggests that after a few years of promotion, improved stoves may just have begun to gain some support from consumers. A Korean improved stove model has been introduced on the market last heating season and gained some acceptance among ger areas households. The survey reveals that about 1,200 households are using this Korean stove that is designed to be used with a specific size of honey comb coal briquette only and cannot burn other fuels.

Table 6: What Household Did with Previous Stove

	Number of Stoves
Sold as Scrap metal	4,240 4.2%
Throw Away	15,949 15.8%
Gave to Relative/Friend for Free	12,315 12.2%
Sold it to Another Household/Person	4,441 4.4%
Still Using Stove That We Have Bought	38,963 38.6%
Still Have the Old Stove[1/]	23,822 23.6%
Other	1,211 1.2%

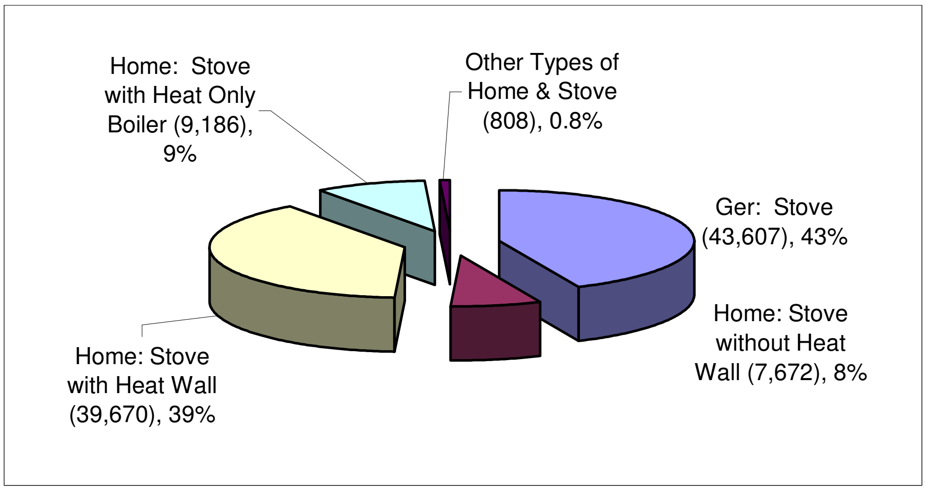
Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.
Note: [1/] The majority of these stoves are not being used; and are not in good working condition

Although heating stoves last a long time, the issues of disposing or recycling old and/or unused stoves, should be one of the concerns when replacing inefficient stoves with more efficient ones. It is plausible that old and inefficient stoves are sold to lower income households, in which case these are not withdrawn from the stock of stoves and continue to pollute the air. The survey reveals that about 23,822 households (or 24% of the households) in the six surveyed districts still keep their old stoves, even though they use new stoves. Although these old stoves are not in good working condition, it is not known whether or how many of these stoves can be reconditioned or reused. The survey also finds that about 16,756 households (or about 17%) reported that they gave away or sold their old stove for re-use. This implies that up to 17 % of stoves in the six ger areas are used or second hand stoves. Almost an equal number of old un-used stoves 15,949 stoves end up in the dump or in the trash pile and only 4% of old stoves are sold as scrap metal. In short, it is estimated that no more than 23,822 stoves could potentially be refurbished again for usage or about 23,800 households could claim that they have two stoves. It is not known whether any of the 15,949 old stoves that were thrown away could be refurbished again.

3.3 Types of Heating Stoves and the Households that Uses Heating Stove

In general, how heating stoves are used is closely associated with the types and size of dwelling units. Based on the survey, types of home and stove can be classified into four major categories (see Figure 8).

Figure 8: Type of Dwelling Unit and Heating System



Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.
Note: Homes refer to separate or single family home.

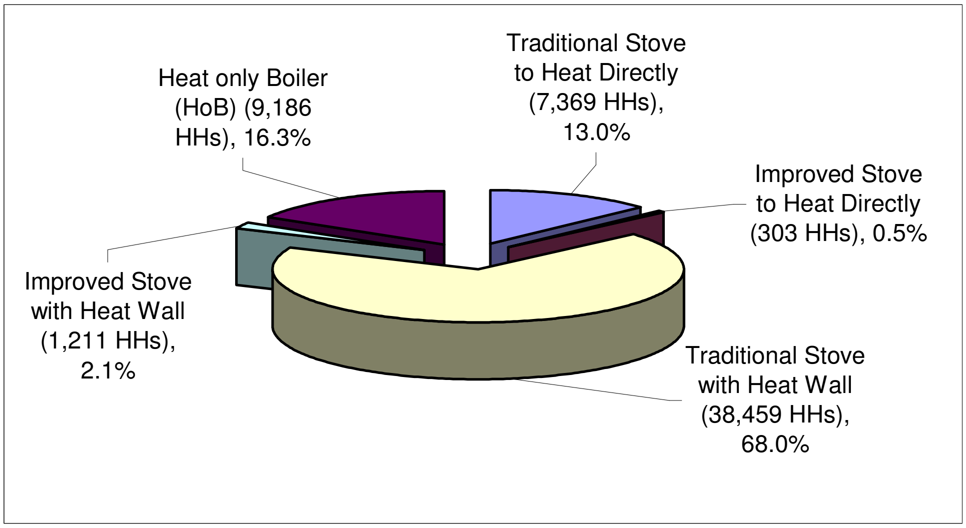
3.3.1 Heating Stove Used in the Ger

All of the 43,607 households currently living in a ger use a heating stove to cope with the cold winters. Of all stoves used by ger households (or about 88%) use traditional heating stove which is made of metal sheet or cast iron. The second most popular stove among ger households is a sawdust stove. Sawdust stoves are considered as another variation of traditional stoves, also made of metal sheet or cast iron, but the primary fuel is sawdust. It is estimated that about of 8% of the households living in ger use a sawdust stove. The remaining 4% of the households uses brick stove, the recently introduced Korean stove and improved stove such as, TT-03, G2-2000, and EB-1. It is interesting to note that the newly introduce Korean stove appears to have gained acceptance among the households living in the ger. Based on the survey over 900 (or about 2%) of the households that live in a ger currently use a Korean stove.

3.3.2 Heating Stove Used in Separate/Single Home

Of the 56,528 households that currently live in a detached house in the six surveyed ger areas 65% (or about 36,944 households) use a traditional heating stove made of metal sheet or cast iron, and 15% (or 8,378 households) use a traditional stove made of brick. Households that are using low pressure boilers accounts for another 16% (or 9,185 households). The remaining 4% (or 2,020 households) use an improved stove. The number of sawdust stove users that live in a detached house is very small.

Figure 9: Type of Heating System in a detached house



Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

Furthermore, the survey also finds that most households living in a detached house tend to have a heating wall attached to their stove for more efficient heating in their home. Households living in a detached house have more flexibility in installing and/or using home heating equipment but they mostly use a traditional or improved stove. For example, a large number of households use a traditional stove with heating wall, or a low pressure boiler (LPB). As shown in Figure 9, about 70% (or 39,760 households) of the households that live in a detached house use traditional; or improved stove with a heating wall, and another 16% (or 9,186 households) use low pressure boilers. The remaining 7,369 households use stove to directly heat their home (i.e., without heating wall).

The differences between households that use stoves with and without heating wall are quite clear. Data collected from the survey suggests that households that use a stove with a heating wall tend to live in bigger home and are financially better off than households that use stove without heating walls. Households that use a stove directly for space heating tend to live in a one room home. Of households that have only one room, about 37% have a heating wall and 63% do not. The average size of home with a heating wall is about 43 square meters, whereas the average size of home without a heating wall is 38 square meters. The average total household monthly income of households that use stoves without heating walls is also significantly lower than households that use stove with heating wall. In addition, about 28% of households that use heating stoves without heating walls are headed by single females.

Table 7: Percent and Number of Households with Male/Female Head of Household

	Ger	Detached house Using			Total
		Stove without Heating wall	Stove with Heating wall	LPB	
Male Head of Household	75.7%	72.4%	85.5%	90.1%	80.7%
Female Head of Household	24.3%	27.6%	14.5%	1.1%	19.3%
Household Income/Month	206,519	240,836	261,005	341,842	243,147*
Size of Home (in square meter)	5 walls	38.4	43.0	65.0	45.9*
Total Households	43,607	7,672	39,670	9,186	100,134

Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007. *Average values.

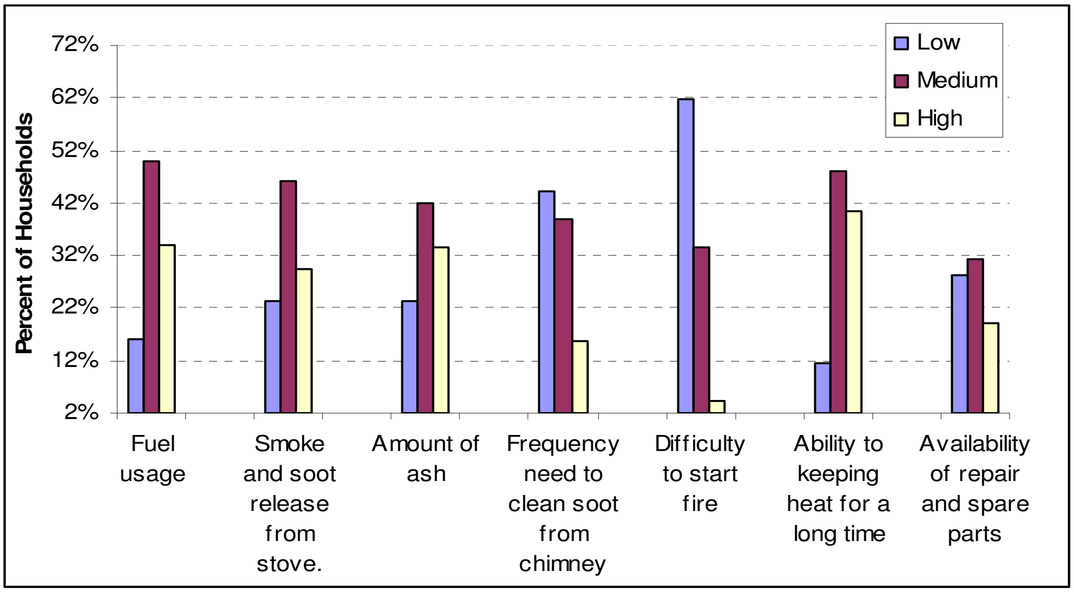
Households with a low pressure boilers live in a larger home than households with or without heating wall and are financially better off than the rest (see Table 7). This finding is not unexpected since a low pressure boilers is a better and more convenient system compared to a stand-alone stove or stove with heating wall to distribute heat in a larger home and is more expensive than other types of heating systems. It should also be noted that traditional stoves have been part of Mongolian life-style for a long time and it is appropriate for heating a ger or small area house. However, life style and living arrangements are beginning to change: close to 60% of the households in the six surveyed ger areas no longer live in the ger but in a detached house. Furthermore, with increasing economic prosperity many households started to either expand/rebuild/construct larger houses. As a result, the typical traditional stoves are no longer appropriate for them and they are looking for alternatives, which they found in a heating wall or a low pressure boilers. However, it is questionable that everyone will be able to move into to bigger home in the near future and this transition may take some time to come. Furthermore, currently almost all of the heating systems including low pressure boilers and heating walls still use traditional stoves to heat/boil water.

3.4 Households Perception on the Performance of Existing Stoves

The survey reveals that by and large *the majority of households are satisfied with the performance of their current stove; this is a traditional stove for most of the households*. The survey identifies seven aspects of stove performance: (1) fuel usage, (2) smoke and soot release from stove, (3) amount of ash left from fuel burning, (4) frequency of cleaning soot from the chimney, (5) difficulty to start the fire, (6) ability of stoves to retain heat for a long time, and (7) availability of spare parts and/or repairs.[32] Given these seven aspects of stove performance, the survey finds that only about one third to half of households think that their stove performances on each of these points are in the middle range, i.e., acceptable.

[32] A significant number of surveyed households -- accounting for 22% -- answer "do not know," on the question regarding availability of spare parts and/or repairs. This finding could be interpreted that at least 22% of the households have not faced any problems of spare parts and repair.

Figure 10: Household Opinion on the Performance of His/Her Heating Stove



Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

Out of all the seven aspects of stove performance raised, starting the fire is the least concern; about 95% of the households believe that it is not difficult to start fire for their stove. With respect to fuel usage, smoke and soot, and ash left in the stove, only a third – ranging from 29% to 34% -- of the households believe that their stove uses too much fuel, releases a lot of smoke and soot, and/or leaves behind a lot of ash. On the contrary, only 16 to 23% of the households believe that their stove has low fuel use, releases low levels of soot and smoke, and/or leaves behind low levels of ash.

In all about 65 to 70% of the households believe that their stove uses a low to medium level of fuel, emits a low to medium level of soot and smoke, and produces low to medium level ash.[33] This finding implies that a majority of households do not appear to be very concerned about fuel usage, smoke and soot, and ash produced by their stove. Perhaps one of the key findings regarding stove performances is that about 40% of the households believe that their stove can retain heat for a long time, where as only 11% of the households believe that their stove cannot retain heat for a long time.

The following sub-sections compare: (1) perception on the performance of stoves among households with a traditional, improved or Korean stove, and households that use low pressure boilers (LPB); (2) perception on the performance of traditional stove among users who live in ger, single family home that use a stove with and without heating wall; (3) perception of fuel consumption among stove owners in different income quintiles; and (4) the results of the consumption tests of different fuels and stoves. A comparison of the perception of stove performance for traditional and improved stove users must be made with caution because the

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[33] When combining (a) households that report that their stoves use low levels of fuel, release low levels of soot and smoke, and create low quantities of ash with (b) households reporting medium levels for each of the three aspects of stove performance.

number of improved stove observations in the sample is too small to provide meaningful and statistically significant results.

3.4.1 Perception on the Performance of Stoves Among Different Types of Stove Users

Comparing of households' perception of their stoves performance between households that use a stove or a low pressure boiler reveals significant differences. A large number of households (57% and 64%) using a low pressure boilers believe that their stove uses a lot of fuel but can retain heat for a long time, while only a third (32% and 38%) of households with a traditional stove think that similarly. This is to be expected since households that use low pressure boilers live in larger homes than those with a traditional stove. As a result, low pressure boiler users do in fact use more fuel than traditional stove users. Moreover, typical low pressure boilers distribute heat more evenly and retain heat for a longer period of time through the hot water pipes/radiators.

About smoke and soot released and the chimney cleaning frequency, the perception of low pressure boilers appears to be contradictory. About 44% of households using low pressure boilers believe that their stove releases a lot of smoke and soot, but only 4% believe that they have to clean their chimney very often. A possible explanation for this apparent contradiction could be the following: low pressure boilers users may expect a lot from their rather expensive heating systems; most low pressure boilers are still relatively new and do not emit so much soot; or it has to do with the design of the flue/vent for smoke of the low pressure boilers system.

Perception of improved stove users regarding fuel usage and capacity of stoves to retain heat for a long time appears to be distinctly different from all other stove users. More than half (55%) of the improve stove users perceive that the fuel usage is low while a third of improved stove users perceive that the improved stove has a low capacity to retain heat for a long time. Perception of improved stove users on the capacity to retain heat for a long time appears to suggest that improved stove does not perform better than traditional stoves in this regard.

Survey results show that 70% of improved stove users think that the improved stove has medium to high capacity to retain heat, while about 90% of traditional, low pressure boilers and Korean stove users think that their stove has that capacity. Although survey results seem to suggest that improved stove does not retain heat very well, this finding must be taken with caution. This is due to the fact that the heat retention length of a stove depends not only on the stove itself, but also on several other factors such as, size of home, level of insulation, and the relative temperature of the home (outside versus inside). Moreover, due to a very small sample size of improved stove users it is not possible to control all other factors when comparing users' perception on this issue. With respect to smoke and soot released and ash problem, households think that improved stoves perform better than traditional stoves and low pressure boilers, but Korean stoves gain the most approval from the users.

Table 8: Perception on the Performance of Stoves

	Traditional Stove	Improved Stove	LPB	Korean Stove
Fuel Usage				
Low	16%	55%	9%	36%
Medium	52%	15%	34%	46%
High	32%	30%	57%	18%
Do not know	0.2%	0%	0%	0%
Ability to keep heat for a long Time				
Low	12%	30%	7%	9%
Medium	50%	30%	30%	64%
High	38%	40%	64%	27%
Do not know	0.5%	0%	0%	0%
Smoke and soot release from Stove				
Low	22%	50%	18%	82%
Medium	48%	35%	39%	9%
High	29%	15%	44%	9%
Do not know	1.3%	0%	0%	0%
Amount of Ash				
Low	22%	40%	22%	73%
Medium	43%	35%	34%	0%
High	33%	25%	41%	18%
Do not know	0.9%	0%	3%	9%
Frequency need to clean soot Soot from chimney				
Low	43%	50%	57%	82%
Medium	40%	30%	37%	18%
High	17%	20%	4%	0%
Do not know	0.8%	0%	1.1%	0%
All Households	88,626	2,019	9,186	1,111

Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

These findings suggest that a campaign targeting smaller market segments such as low pressure boiler users will be more effective if they focus on a boiler/stove that uses less fuel and emits low levels of soot and smoke. On the other hand a campaign targeting traditional stove users will be more effective if they focus on stoves that can retain heat for a very long time. In addition, proponents of improved stoves should be very careful in making claims about heat retention. Although the claim is true, in practice the capacity of stove to retain heat for a very long time also depends on many other factors discussed above.

3.4.2 Perception on the Performance of Stove Among Traditional Stove Users

The survey finds that there is no significant difference in the perception regarding fuel usage among households with traditional stoves in the ger and in single family homes with or without heating wall. This would be right since the stoves used are essentially the same. With regard to the issues of smoke and soot released from stove the survey finds that about the same proportion of households – 27% to 29% of households -- in all three groups believe that smoke and soot released from their stove is high. Similarly, about 22% to 24% of households in all three groups believe that

that smoke and soot released from their stove is low. However, only 9% of households that use a stove with a heating wall believe that they need to clean soot from the chimney very often. This perception is similar to that of the low pressure boilers users. The low frequency of requirement to clean soot from the chimney could be due to the design of the flue/vent of the heating wall heating system.

However, one of the important findings is the perception of households on the ability of stove to retain heat for a long time. The survey shows that 35% of the households living in the ger and only 26% of the households in a house without heating wall believe that their stove can retain heat for a long time. By contrast about 43.5% of the households that use stove with heating wall believe that their stove can retain heat for a very long time. This finding implies that single family homes without a heating wall may require a heating system to help distribute heat more evenly throughout the home. This is so since about 37% of homes without a heating wall have more than one room and because more than half live in a home that is larger than 42 square meters. Furthermore, it appears that gers may retain heat better than detached houses, and a heating wall is good at distributing heat inside the home.

Therefore any marketing campaign targeting the smaller market segment such as, single family homes without a heating wall should emphasize stoves with greater capacity to distribute heat evenly. Furthermore, improved stoves together with an energy efficient heating wall should be explored and introduced.

Table 9: Perception on the Performance of Stove among traditional stove users

		Separate/Single Home using Stove	
	Ger	**Without Heating wall**	**With Heating wall**
Ability to keep heat for a long time			
Low	12%	22%	10%
Medium	53%	50%	47%
High	35%	26%	43%
Do not know	0.5%	1.3%	0.3%
Smoke and soot release from Stove			
Low	24%	22%	24%
Medium	45%	49%	49%
High	29%	28%	27%
Do not know	1.6%	1.3%	0.8%
Frequency need to clean soot Soot from chimney			
Low	31%	45%	56%
Medium	45%	30%	34%
High	23%	25%	9%
Do not know	0.9%	--	0.8%
All Households	43,607	7,672	39,670

Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

3.4.3 Perception on the Performance of Stove Among Income Quintile

As earlier presented, households from different income classes bear disproportionate burdens on heating expenditures. This is reflected in the perception of households that are financially worse off versus financially better off. As shown in Table 9, about 43% and 45% of household in the bottom income quintile believe that their stove uses a medium level of fuels and high level of fuel, compared to 54% and 28% of households in the top income quintile that think that their stove use medium and high level of fuels, respectively. This finding confirms that any campaign to promote fuel saving stove will be more effective among lower income households than higher income households.

Table 10: Perception on Fuel Usages of Existing Stove (percent of Households)

Income Quintile (Tg/.per month)	**Less than 111,330**	**111,331 to 172,660**	**172,661 to 233,990**	**233,991 to 325,860**	**More than 325,860**	**Total**
Fuel Usage						
Low	11.9	15.3	15.2	18.6	18.5	15.9
Medium	42.6	51.5	51.3	50.8	53.5	49.9
High	45.0	33.2	33.0	30.7	28.0	34.0
Do not know	0.5	--	0.5	--	--	0.2

Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

3.6 Households' Preferences and Willingness to Change Type of Stove

Although the majority (about 65% to 70%) of the households in the six survey districts appears to be satisfied with the overall performance of their stove, slightly more than half are nevertheless interested in changing their current stoves. A total of 52,287 households in the six surveyed ger areas indicate that they are interested in changing their stoves and 71% of these households would even like to change it in the near future. Furthermore, the majority of these households are interested in changing to an improved stove. The main reason for willingness to change stoves appears to lie on the desire to reduce the heating bill as well as a high expectation of the performance of improved stoves. The survey shows that the average monthly income of households that are interested in changing their stove is slightly lower than average, but these households spend slightly more on raw coal than the average of all households living in the six surveyed ger areas.

Table 11: Number of Households Interested In Changing Current Stove

	Interested in Changing Current Stove			
	Yes	**No**	**Have not thought about it**	**Total**
Number of Households	52,287 51.8%	47,039 46.6%%	1,615 1.6%%	100,941 48.2%
Household Income/Mo	234,585	251,669	249,704	242,788
Expenditure on Raw Coal (in Tg/. from Sept 06 to Apr 07)	178,222	170,462	179,906	174,766

Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

The reasons cited by those who are not interested in changing stoves are that they are used to using the current stove (94%), their stoves are still good (83%), or they find it difficult to install a new stove (33%).

There is not much difference in the profiles regarding type and size of home and the heating system used by households that are or are not interested in changing their stove. For example, 42% and 43% of households that are interested in changing a stove live in the ger or single family home using stove with heating wall respectively, compared to 45% and 35% of households that are not interested in changing a stove live in the ger or single family home using stove with heating wall respectively (see Table 12).

Table 12: Number of Households Interested In Changing Current Stove by Type of Dwelling

	Yes	**No**	**Have not thought about it**	**Total**
Ger	42.3%	44.6%	31.3%	43,607
Home without Heating wall	8.9%	6.2%	6.3%	7,671
Home with Heating wall	42.9%	35.0%	50.0%	39,690
Home with LPB	5.4%	13.1%	12.5%	9,185
Hostel/Dormitory/Other	0.6%	1.1%		808
All Types of Dwelling	52,287 100%	47,039 100%	1,615 100%	100,941 100%

Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

Table 13: Number of Households Interested In Changing Current Stove by Type of Dwelling

	Yes	No	Have not thought about it	Total
Ger	50.7%	48.1%	1.2%	100%
Home without Heating wall	60.5%	38.2%	1.3%	100%
Home with Heating wall	56.5%	41.5%	2.0%	100%
Home with LPB	30.8%	67.0%	2.2%	100%
Hostel/Dormitory/Other	37.5%	62.5%	--	100%
All Types of Dwelling	52,287 51.8%	47,039 46.6%	1,615 1.6%	100,941 100%

Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

However, it is interesting to note that households interested in changing stoves have slightly lower incomes than households that are not interested in changing stoves. This may be due to the fact that households that are interested in changing heating stove spend more on raw coal for heating during the seven months heating period than households that are not interested in changing stove, 178,000 versus 170,000 Tg/.respectively. The survey finds no different in age and education of the head of households between there two groups.

Table 14: Type of Stove Preferred by Households Interested in Changing Stove

	Ger	Home without Heating wall	Home with Heating wall	Home with LPB	Hostel/Dormitory/Other	All Types of Dwelling
Traditional stove	1,413 6.4%	404 8.7%	1,110 5.0%	- 0.0%	- 0.0%	2,927 5.6%
Improved Stove	15,545 70.3%	2,221 47.8%	9,388 41.9%	1,918 67.8%	303 100.0%	29,375 56.2%
Briquette Stove /Korean Stove/	3,129 14.2%	404 8.7%	1,413 6.3%	101 3.6%	- 0.0%	5,047 9.7%
Sawdust Stove	1,817 8.2%	- 0.0%	707 3.2%	- 0.0%	- 0.0%	2,524 4.8%
Low Pressure Boiler	202 0.9%	1,615 34.8%	9,791 43.7%	808 28.6%	- 0.0%	12,416 23.7%
Total	22,106 100%	4,644 100%	22,409 100%	2,827 100%	303 100%	52,289 100%

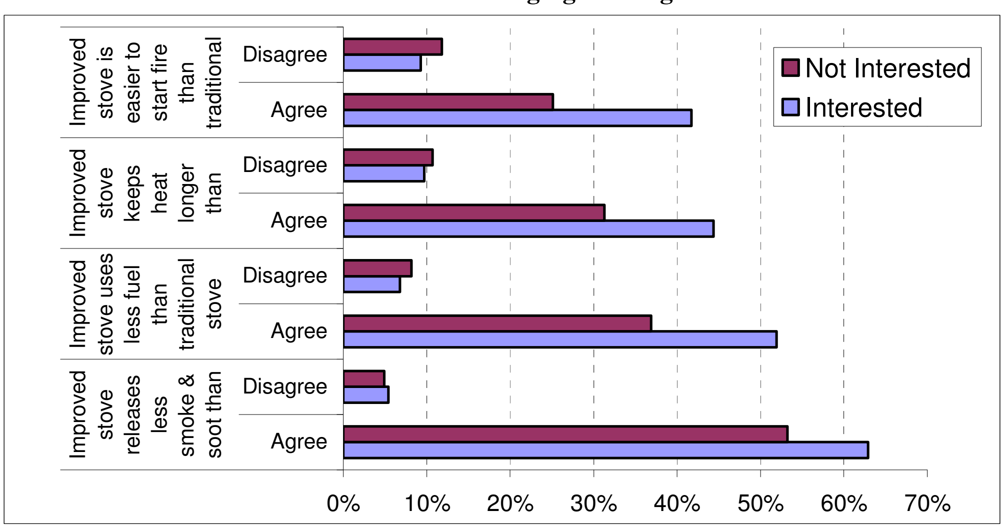
Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

Further comparison reveals that households living in a detached family home without a heating wall are more likely to be interested in changing their stove than households that live in other types of home and using different types of heating system. The odds that households living in a single family home without heating wall to answer “yes” are 0.6, where as the odds that households with heating wall and households living in a ger to answer “yes” are 0.56 and 0.51 respectively (see table 13). Although indicating interest does not always translate into action, the finding gives some indication for the total number of potential households that could be targeted first for any improved stove promotion program/project.

The survey also finds that interest in improved stoves among households that are interested in changing their heating stove are quite high and spread across the board, see Table 14. About 56% of households that are interested in changing their current stove chose an improved stove rather than one of the other stove models possible. The proportions of households that are interested in improved stoves are as high as 70% among households living in the ger to a low of 42% among households living in single home with heating wall. The second choice of heating stove/system is the small low pressure boiler.

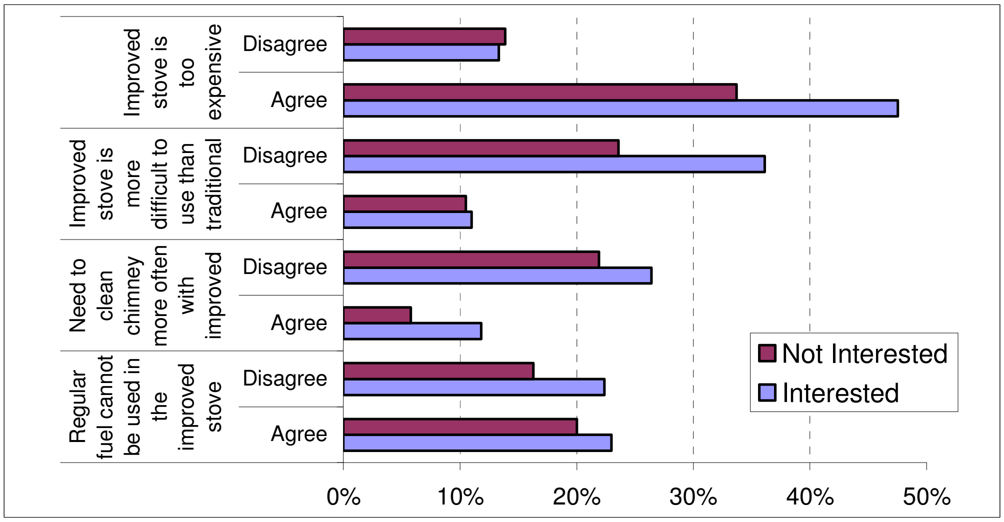
Households that would like to change their stove appear to have more faith in the performance of improved stoves. Comparison of the perception of improved stove performance between households that are or are not interested in changing stoves shows significant difference on all aspects of improved stove.

Figure 11
Figure 11: Opinion on Improved Stove – Households Interested and Not Interested In Changing Heating Stove



Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

Figure 12: Opinion on Improved Stove – Households Interested and Not Interested In Changing Heating Stove



Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

As shown in Figures 11 and 12, a larger portion of households that are interested in changing stoves have a more favorable opinion toward performance of improved stove and are more knowledgeable about improved stoves. For example, 52% of households that are interested in changing stoves believe that improved stoves use less fuel than traditional stoves; meanwhile only 37% of households that are not interested in changing stoves believe that improved stove use less fuel than traditional stove. On the price of improved stoves, close to half of all households interested in changing stoves believe that improved stoves are very expensive, while only a third of their counterparts believe the same.

Regarding the time frame for changing to a new stove, about 71% would like to change their stove in the near future. A closer look at the households that are interested in changing stoves in the near future reveals that these households have had a very high expenditure on raw coal during the past heating season. In fact, their expenditure on raw coal was significantly higher than average. As a result, when combined with their faith in the performance of improved stoves, it appears that households are concerned about their heating bills and would like to reduce their heating bills very soon. Furthermore these households are in better financial position than those with longer term plan for replacing their heating stove. The results suggest that should credible information be effectively communicated to households on effective heating systems, there would be a willingness to consider switching to improved systems.

Table 15: Income and Raw Coal Expenditure of Households Interested in Changing Stove in the Short and Long Term

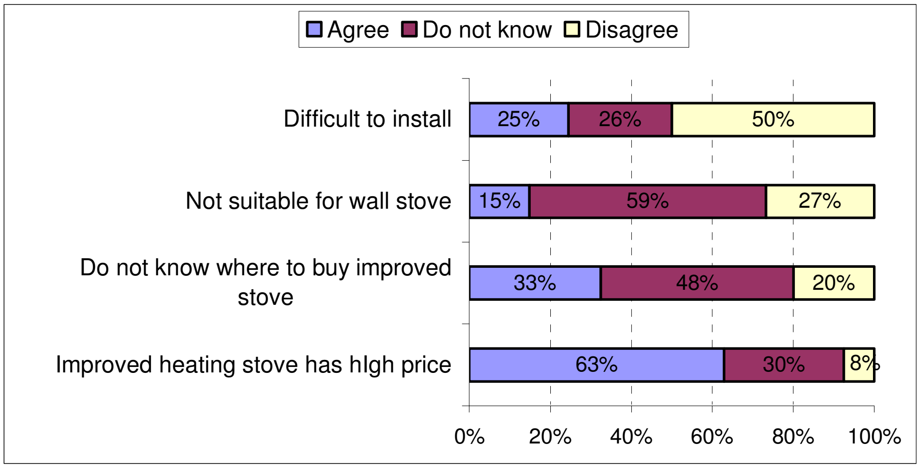
	Household Income/Month (in Tg/.)	Expenditure on raw Coal from Sept 06- Apr 07 (in Tg/.)
Short term	237,298.34	184,525.77
No. of Households	37,146	36,238
Long term	227,929.47	162,509.72
No. of Households	15,141	14,536
Short & Long Term	234,585.35	178,222.96
No. of Households	52,287	50,773
All Households in six Ger areas	242,788	175,968.21

Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

3.7 Perceived Obstacles for Replacing Stoves

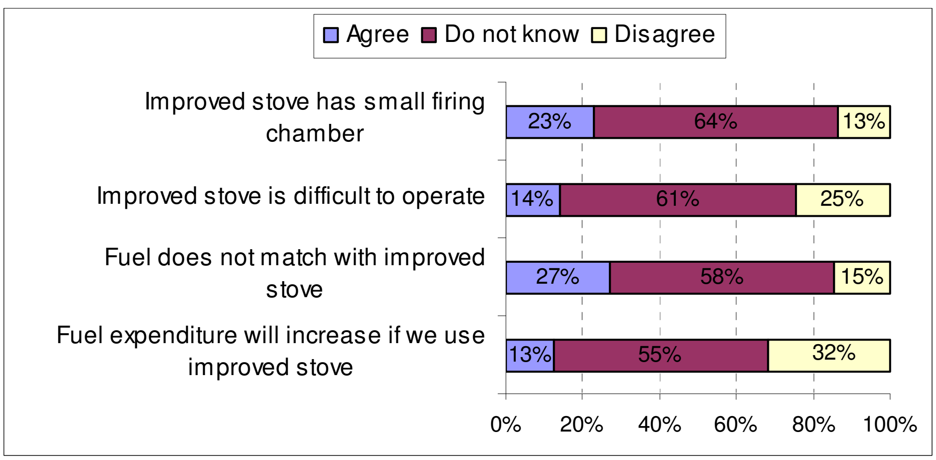
General perceptions of the public at large concerning obstacles to changing to improved stoves are a perceived high price and a lack of information on where to purchase an improved stove. However, the biggest problems are the lack of knowledge about improved stoves. Slightly more than half of the households surveyed gave "do not know" answers on almost all of the questions aimed at evaluating perceived obstacles that might prevent or inhibit households to change to improved stoves. The large numbers of households that answer "do not know" suggests that these households are either indifferent to changing to improved stove or have very limited information on improved stove. In general about 28% of the households have never heard about improved stove before.

Figure 13: Perceived Obstacle for Changing Stove



Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

Figure 14: Perceived Obstacle for Changing Stove - 2

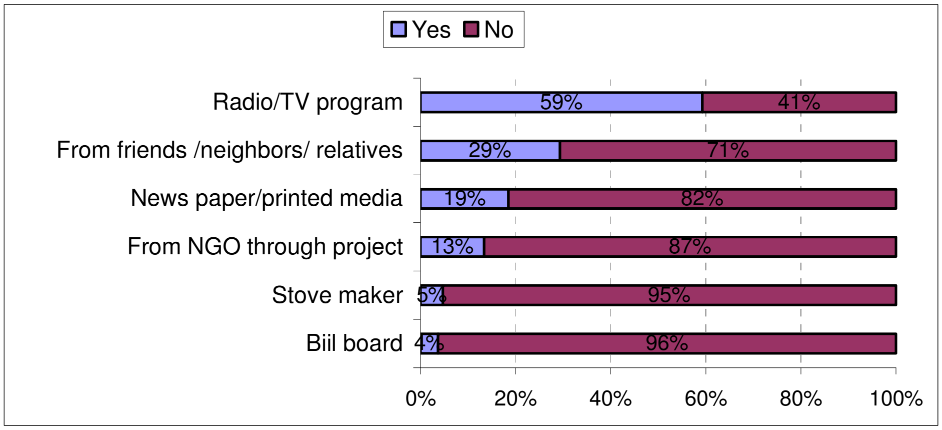


Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

3.8 Sources of Information on Improved Stoves

As expected radio and television are the most effective means for disseminating information about improved stoves. As shown in Figure 15, most households in the six surveyed districts heard about improved stoves from radio and/or television. Word of mouth from friends/ relatives/neighbors is the second most important source of information for households in the ger areas. Since the majority of households still have a very limited knowledge about improved stoves, future information campaigns should not only make sure that all of the media are used but also that more detailed information is disseminated, about the qualities and characteristics of the stove as well as on where to obtain them.

Figure 15: Sources of Information on Improved Stove



Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

3.9 Conclusion

About 100,941 stoves are currently used by the households in the six surveyed ger areas to heat their home, 909 stoves are used to heat home businesses, kiosks, or garages, and another 2,100 stoves are owned but used only occasionally. During the past five years about 11,500 stoves have been added each year. There has not been any systematic disposal of old or unused stoves. Based on the survey it is estimated that about 23,822 households still have their old stoves in possession. Although these old stoves are not in working condition, it is not known whether or not or even how many of these can be reconditioned or recycled. Survey results also confirm that many households sold their old stoves to other households, which means that a second hand or used stove market exist. However, the used stove market appears to be even more informal than the market for new stoves. Nevertheless, this fact effectively downplays the importance of the *Golomt* or spirit that was believed to be present in the stove and which needed to be preserved.

Survey results also confirm that stoves and type and size of dwelling units are closely related. Households living in a ger or a small, one room type of detached house use a heating stove to heat their home directly. Households living in a larger house tend to use heating stoves with a heating wall. The largest and more modern separate/single home uses low pressure boilers. *Survey data also suggests that although the majority of the households in the six surveyed ger areas appear to be satisfied with their existing stove and/or heating system, they are also interested in changing it in the future.* Maybe they are waiting for much better stove models to appear?

Although the penetration of improved stoves among ger areas households is still low, the majority of the households interested in changing stoves are interested in changing to an improved stove model. *The main reasons for willingness to change stoves are the desire to reduce the heating bill and a high expectation of the performance of improved stoves.* The results appear to indicate that credible information communicated through grassroots efforts and credible channels will generate an interest in switching to new systems.

However, the credibility of information is currently hampered by a lack of effective testing. Much hear-say information and results from poorly performed tests is in circulation and given more authority than the results of the few existing credible tests would indicate. As will be explained in Chapter 5, with the current state of laboratory testing capability it is very difficult to determine which stove and fuel combination will have the highest impact on the air quality in Ulaanbaatar, and households are right when they want to wait for changing their stoves until better models are available.

4. Heating Fuels Consumption and Expenditure[34]

The main type of fuel used to heat dwellings in the six surveyed ger areas is raw coal. Firewood is also used, but it is used primarily to start the fire; and some households use it to supplement raw coal. In addition to coal, a small number of households also use sawdust, coal briquettes, and animal dung. The following sections provide the analysis of the types of fuels including coal, firewood, sawdust and briquette used by households in the six surveyed ger areas. An analysis of household consumption and corresponding expenditures for heating fuels is given as well. Table 28 at the end of this chapter shows that households spent on average about 20% of their reported income on heating fuels; for the poorest percentile this is about 40%, which clearly demonstrates the severity of the winter as households have no choice but to heat their homes. The analysis also includes households' perception of different types of briquettes. Before the results of the survey are given, a short introduction is made about the technical issues related to stoves and air quality.

4.1 Heating Systems and Emissions

Stoves used by the majority of ger area residents are generally not optimized for low-emission coal burning. The level of emissions is a factor of the fuel efficiency (quantity of fuel used to heat the house) and the combustion efficiency (quantity of emissions per unit of fuel used). Thus far, only fuel efficiencies have been tested in previous programs and laboratory capacities will need to be improved to perform robust combustion efficiency tests. Such combustion tests include measuring emission factors CO, NO_x, H_2S, PM.

There is no proper air control to improve the combustion efficiency of traditional stoves and the exhaust gases remain quite dirty. In other words, the designs are not really adequate to allow to proposal of the current improved stove models as a tool for significantly reducing air pollution to the point that it makes a noticeable difference in air quality. It is understandable that further improvements to the combustion efficiency of the stoves have not been made as it was not possible to test this in a laboratory for a lack of appropriate equipment. Moreover, as became obvious during the consumption tests, the fuel consumption depends on both the stove and the fuel. It remains necessary to test the performance of different stove and fuel combinations. In what follows, feedback from the surveys is given on the quantities of fuels used by type of stove, type of fuel, type of house, and characteristics of the households.

4.2 Type of Fuels Used By Households

The survey confirms that raw coal and firewood are the main fuels used to keep ger areas residents warm. As shown in Table 16, raw coal is the most popular heating fuel among households living in the six surveyed ger areas. Firewood is used to start fire and some households use it to supplement raw coal. A small portion of households also use sawdust, animal dung, and briquettes. The survey also encountered two households from the sample of 1,000 households or 0.2% that use anything that can burn, primarily to supplement raw coal, one of which has a very low income.[35] Because only two out of the 1,000 household sample were observed to use whatever they can get their hands on, it cannot be concluded with statistical confidence that the financial or socio-economic status of the estimated 202 households out of the total in Ulaanbaatar is similar to the 2 found.

[35] Based on the sampling design, one sampled household represents 101 households.

However, it is reasonable to conclude that a large part of these 202 households use anything that burns to supplement their heating fuels simply because they cannot afford to pay for conventional fuels.

Table 16: Type of Heating Fuels Used by the Household

Coal	Firewood	Sawdust	Briquette	Dung	Anything that Burn
95,793	95,995	5,249	1,817	4,542	202
94.9%	95.1%	5.2%	1.8%	4.5%	0.2%
100,941	100,941	100,941	100,941	100,941	100,941

Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

Coal from Nalaikh appears to be the most popular among households in the 6 surveyed ger areas. The second and third most popular raw coal is from Baganuur and Alagtolgoi, respectively. As depicted in Table 17, ger area households rely on coal from several sources during the whole heating season. Typically households will use raw coal from various sources especially when they buy coal in bag. However, for those who purchase coal in large quantity, which can last for the whole heating season will undoubtedly use coal from one source for the entire heating season.

In the winter 95% of ger area households use coal and firewood for heating and cooking, 5% use sawdust and/or dung and paper, 2% briquettes; and some 0.2% burn "anything they can obtain", which may range from paper, twigs to plastic, used oil, tires and other garbage. The results of the survey clearly show that use of low-grade fuels is not widespread; the fear that numerous households, particularly on the outskirts of town, would use such fuels thereby considerably worsening air pollution is not substantiated by this survey.

Table 17: Sources of Coal Used by the Households

Coal From:	Number of Households	Estimated Heating Value kcal/kg	MJ/kg	Moisture content (%)
Nalaikh	72,778 76.0%	3508	14.7	27
Alagtolgoi	14,636 15.3%	6186	25.9	10.7
Sharyn gol	2,725 2.8%	3510 *)	14.7	
Baganuur	24,226 25.3%	3524	14.7	33
Total	95,793	n/a		

Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.
Calorific values were measured by BEEC as part of the ASTAE consumption tests.
Note: Households may use more than one type of coal.
*) Coal from Sharyn gol was not found during BEEC consumption tests and therefore not tested; this is a subbituminous coal with calorific value similar to Bagannuur and Nailakh.

Firewood, together with paper is mainly used to start the fire; coal is somewhat difficult to light and requires another fuel to be burning already. Most households use firewood for this purpose. In addition, when the outside air temperature is not so low (- 10 C), many households use firewood instead of coal: the wood gives a rapid burst of heat that is enough to heat the home for an acceptable time. It should be noted that with the use of semi-coked coal that is difficult to light, the use of firewood and starter fluids are likely to increase. The types of wood mainly used are Larch (76.8%) and Pine (51.0%). Some 4.6% say that they use construction or packaging wood (pallets) and 2.4% sticks of wood and bark (most likely collected or gathered by the user).

4.2.1 Fuel Prices and Quantities used

The price and quality of coal also varies depending on the source of coal. Most coal comes from the Nalaikh mines that are some 25 -30 km from the city center. Officially these mines are closed but some 76% of households indicate that they use this type of coal. 15.3% indicate that they use higher quality coal from Alagtolgoi[36], and 25.3% say that they use coal from Baganuur (the CHP plants use Baganuur coal) and 2.8% from Sharyn gol. Table 3 shows the characteristics of a few fuels used in Ulaanbaatar for heating. The price of raw coal from Baganuur tend to be the lowest since it has the lowest heating value, ranging only from 3,300-3,800 kilo-calories per kilogram. Baganuur is about 120 km from Ulaanbaatar and most of the coal is brought in by train. The most expensive coal is the coal from Alagtolgoi, not only because it has the highest heating value, also because it comes from the longest distance. Because of the price and quality, raw coal from Alagtolgoi is preferred among higher income households. About 12% of the top fifth and 10% of the fourth income quintile use raw coal from Alagtolgoi more often than households in other

[36] "Higher quality" means it has a lower volatiles content and is easier to ignite and burn. It is an arbitrary definition that has nothing to do with the actual quality of the coal, its calorific value, its sulphur or other contaminant content.

income classes. However, only 4% and 6% of households in the bottom first and second income quintile, respectively use raw coal from Alagtolgoi more often than households in other income classes.

Coal from Nalaikh during the 2006/07 heating season cost about MNT 35,000 per ton delivered at the household. During the 2007/08 season, the price ranged from MNT 50,000 per ton at the onset of the season to MNT 65,000 per ton at the height of the winter (in February). Poorer households cannot afford to buy a truck load and normally buy coal in bags every day or every few days. At the start of the 2007/08 heating season, the price of a 17-18 kg bag was about MNT 1200 and this increased to MNT 1800 in February. It is noted that the previous heating season the price of a bag was about the same but it contained more coal: four years ago, the average bag weighed about 30 kg. The price of an 8 kg bag of wood was MNT 1000 in December, MNT 1200 in January and MNT 1500 in February.

At the start of the 2007/2008 heating season, the cost of coal was 2.6 MNT/MJ purchased per truckload and 3.5 MNT/MJ purchased by the bag of coal; the cost of wood was 7.8 MNT/MJ.[37]

4.3 **Fuel & Stove Supply Chains**

4.3.1 Fuel

Households can purchase coal in bags of about 17-18 kg from a limited number of distributors in each khoroo; distances are short and sometimes children are sent to buy coal bags using a small wheelbarrow. Typically households buy one bag per day during the pre- and after season and two bags during the peak of the winter. Coal can also be bought from wholesalers who use Chinese trucks with a carrying capacity of about 2.5 t of bulk coal or Russian trucks with 5 t. Many households will buy their coal at the end of September when it starts to get colder. There are only a limited number of such wholesale spots in Ulaanbaatar. Loaded mainly with Nalaikh coal, trucks line the road waiting for customers, particularly richer households ready to buy their coal for the whole heating season. Some wholesalers convert bulk loads into bags here too and it is possible to buy a truck loaded with bags as well; clients are both households and distributors.

Transporters load their trucks at the mine site using manual labor. They may make more than one round-trip per day. There are no statistics on the number of actors in the supply chain and a rough estimate is the following: hundreds of truck owners, hundreds of wholesalers, plus 5-10 retailers per khoroo.[38] Coal lumps loaded on the trucks are generally too large to be used directly in the stove and need to be reduced in size; this is done by the distributor before putting it in bags in the khoroo, or by the household at home.

4.3.2 Stoves

Stoves are mainly purchased at the central market (Narantuul) and to a lesser extent from stove manufacturers, and recently also from a group of middlemen associated with certain stove manufacturers, the "Ger Stove Association". There are about 40 stove manufacturers, most of which operate as family businesses that also produce other steel products and whose main outlet is on the central market. In total there are about 150,000 ger area household stoves in use, of which about 49% have a stand alone stove, 42% have a heating wall, and 9% have an LPB. The

[37] Coal: 14.7 MJ/kg and wood 15.5 MJ/kg, both air dry.

[38] 120 khoroo in Ulaanbaatar. The authors note that the European Bank for Reconstruction and Development has commissioned a study that will assess semi-coke options for use in ger areas.

combined replacement value of these stoves could be as much as US$ 20 million. The reported production capacity for all producers combined is about 6 – 10 thousand winter stoves per year, and this includes traditional and improved stoves. Improved stoves are made by the same stove manufacturers who also make traditional stoves. Stoves are mainly sold during the period just before the winter season starts, from late August, although they are available throughout the year. In early September, 100s can be found at any time at the central market while during the remainder of the year there are only several 10s available.

Of the six improved stove models available on the market today, three are made by a number of producers as an open source stove model (TT-03, G2-2000, and GTZ improved stove) and three are more of a proprietary stove model and are mainly made by the inventor - manufacturer of the stove (Bona -2, EB-1, and MG203). No inventory is made of the low pressure boilers; it is expected that consumers contact a shop specialized in this type of equipment who assembles all parts and designs a custom made system for the client.

In 2007, traditional stoves were sold for about MNT 30 – 35 thousand and improved stoves for MNT 60 - 100 thousand. The consumer has to transport the stove to his home, which is not an easy task as some of the stoves may approach 100 kg. Prices in 2008 have gone up considerably given a worldwide increase in steel prices.

In addition to a stove, most consumers also need to buy a stove pipe or chimney of about 3 m length when used in a ger. This can be purchased from the stove manufacturers or from a supplier who is located next door on the market. Depending on the thickness of the chimney, the price households pay is MNT 8,000 – 10,000; most chimneys have 2 or 3 parts.

The Ger Stove Association was recently created to be an intermediary between producers of improved stoves and clients. Manufacturers have no time to find new clients or to service stoves when necessary and they have contracted the association to do this on their behalf. At the same time, the association tries to convince households to buy an improved stove and/or to install a heating wall. Given that heating walls are a temporary solution and many households will adopt a low pressure boiler in the future, it might be considered trying to convince households to leapfrog to low pressure boilers and skip heating walls: a heating wall increases the fuel consumption and does not improve the combustion efficiency of the stove.

4.4 Heating Habits

The heating season in Mongolia can be divided into two periods, the cold months in the fall and spring season and the very cold months during the winter season. The cold months in the fall usually begin in Mid September to the middle or the end of October, and the cold months in the Spring begins around March and April. The very cold months in winter usually extend from November to end of February when temperatures rise above -20 C.

These cold weather conditions require that households keep their homes reasonably warm and comfortable during the winter months, or at least livable depending on whether the households can afford it. Table 18 shows the average number of times households add fuels during the 24 hours period in the fall and spring season (i.e., cold months), and during the winter months (i.e., very cold months): the average number of times households add fuel for heating during the fall and spring month is 2.3 time during the 24 hours period, and double this during the winter months. The survey finds no relationship between the number of times households add fuels and income of the households, or with the number of persons in the household. The number of times households adds fuels are the same among all income classes. This finding implies that the households add fuels only when they really need it. The survey did not collect or measure average temperature inside ger/home. Therefore, it is unclear whether households add fuels only when needed are to prevent excessive heat inside ger/home, or simply to maintain minimum level of comfort inside ger/home.

Table 18: Average Number of Times Household Add Fuels during 24 Hours

Time Period	**Number of Times Household Add Fuels** (Sept, Oct 06, and (Mar, Apr 07)	**Number of Times Household Add Fuels** (Nov, Dec 06 and Jan, Feb 07)
06:00-16:00 O'clock	.97	1.74
16:00-22:00 O'clock	.71	1.60
22:00-06:00 O'clock	.63	1.26
06:00-06:00 O'clock	2.31	4.60
Total Households (Users Only)	80,450	96,096

Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

Table 19: Number of Household Use Supplemental Heating

In winter does your household use any other additional heating other than stove?	Number of Households (%)
Heat Pump	505 0.5%
Gas Space heater	1211 1.2%
Electric Space Heater	5148 5.1%
Total Households	100,941

Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

Although the weather especially during the winter is very cold, it appears that households in the six surveyed ger areas rely primarily on traditional heating fuel, which is raw coal. The survey finds that a very small number of households use any other heating devices to provide supplemental heat. About 7% of the households report that they used other heating devices to their heating stove or low pressure boilers. As expected, the most popular supplemental heating device is an electric space heater, but some households indicated to use a gas space heater and a small minority perhaps of well-off households indicated to use a heat pump.

4.5 Estimated Quantity of Raw Coal Consumption and Expenditure

As already pointed out, the vast majority of households in the six surveyed ger areas use raw coal and firewood as the main source of fuel for heating. On the average households in the six surveyed ger areas use about 4.19 tons of raw coal and spend about 174,767.Tg. from September 2006 to April 2007. The survey estimates that the overall raw coal consumption covering the same period for all households living in entire six surveyed ger areas is about 399,601 tons.

Comparison of coal consumption and expenditure by income quintile show that household in the bottom income quintile or the poorest households consume the least amount of coal as well as spend the least amount of money for raw coal. Households in the higher income quintiles consume more raw coal and also spend more money on raw coal. Raw coal consumption and expenditure are positively correlated with household income. As income rises households would tend to use and spend more on raw coal for heating. However, the narrow range of raw coal usage between the bottom and top income quintile (poorest and the richest households) suggests that demand for raw coal is income inelastic. Consequently, any changes in income may result in only a small increase in coal consumption. It further suggests that the amount of raw coal used by the household tends to be near the bare necessity level.

Table 20: Household Coal Usage (t) and Expenditure (Tg) by Income Quintile

From Sept 2006 to April 2007

Monthly Income by Quintile	Total Expenditure For Coal (in Tg/)	Average Coal (t) Used per Household	Total Coal Used by All Households
<= 111,330 Tg/.	153,275	3.29	61,117
Valid N	18,371	18,573	18,573
111,331 - 172,660 Tg/.	168,993	3.76	71,350
Valid N	18,977	18,977	18,977
172,661 - 233,990 Tg/.	170,912	4.12	76,122
Valid N	18,371	18,472	18,472
233,991 - 325,860 Tg/.	182,726	4.81	95,659
Valid N	19,885	19,885	19,885
> 325,860 Tg/.	196,169	4.92	95,354
Valid N	19,482	19,381	19,381
Total	174,767	4.19	399,601
Valid N	95,086	95,288	95,288

Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

Note: Valid N refers to number of households that reported amount of coal usage and expenditure for coal.

Although the poor spend less on raw coal to heat their homes, the amount of money they spend on raw coal accounts for a larger portion of their income than the rich. The disproportionate financial burden of the heating bill exists not only among the rich and poor within the ger areas, but also between households that live in the ger and those that live in the central part of Ulaanbaatar. This is simply because heating bills for district heating are much lower than heating bills for those who must use coal in individual stoves to stay warm; as is often the case, also in Mongolia those with the poorest service (ger area households) here too pay the dearest.

4.5.1 Comparison of Raw Coal Usage Among Households Living in Different Types of Dwelling Unit

Typically household demand for raw coal depends on several factors including income of the household, price of coal, type and size of home, and type of heating equipment and desired level of comfort. By controlling for the size and type of home and type of heating equipment, households can be divided into five mutually exclusive groups. Incidentally, these five mutually exclusive groups are also positively correlated to household income. Consumption of raw coal and associated expenditures as well as household monthly income among the five groups are significant different. As shown in Table 22 and Table 23, raw coal usage and expenditures appear to form a linear trend against income quintile, or type of dwelling unit. The lowest consumption is for ger households, which used 3.49 tons of raw coal during the cold season from September 2006 to April 2007. Households in small dwellings– typically only one to two rooms, single family home with the traditional stove show a raw coal consumption level of about 3.90 tons for the same period. For households that live in the larger single family home and use stove with heating wall for heating, the amount of raw coal consumption increase to 4.49 tons per household. Finally, the amount of raw coal consumption among households that live in the largest single family homes and use low pressure boilers jumps to about 6.17 tons of raw coal per household. In summary, the finding appears to confirm that there is a strong relationship between the amount of coal used and the type and size of home and the type of heating system attached to stove.

Although the average coal consumption per household living in a ger is the lowest, the total coal consumption by all 40,000 households in this group accounted for 137,211 ton, or the second largest. The highest overall coal consumption was realized by households that live in a single family home with a heating wall. It is estimated that this group of households consumed about 174,122 ton between September 2006 and April 2007. The total number of households in this group is also close to 40,000. *Therefore, any short-term action aiming at solving air pollution due to raw coal usage must target these two groups of households in order to have the largest impact. Long-term action should also consider households adopting LPB (low pressure boilers), as this is the most comfortable heating solution for ger area households.*

Table 21: Household Raw Coal Usage and Expenditure by Type of Dwelling Unit and type of stoves and LPB
(From Sept 2006 to April 2007)

Type of Dwelling and Heating System	**Average Household Monthly Income**	**Total Expenditure For Coal** (in Tg/)	**Average Raw Coal Used (t) per Household**	**Total Coal Used (t) by All Households**
Ger	206,519 43,607	162,087 39,266	3.49 39,367	137,211 39,367
Home without Heating wall	240,836 7,672	176,073 7,167	3.90 7,167	27,939 7,167
Home with heating wall	261,005 39,670	176,870 38,862	4.49 38,963	175,122 38,963
Home with LPB	341,842 9,186	219,385 8,984	6.17 8,984	55,435 8,984
Hostel/Dormitory/Other	198,248 808	182,125 808	4.82 808	3,895 808
Total	242,788 100,941	174,767 95,086	4.19 95,288	399,601 95,288

Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

Box 4.1

Analysis of variance reveals that the differences in coal consumption among households by type of dwelling unit and using different heating systems are statistically significant, F-stats is 47.36. An orthogonal contrast of coal consumption between household living in a ger and a home without heating wall is statistical significant at 0.11, t-stats =1.58.

4.5.2 Comparison of Raw Coal Usage Among Different Types of Stove

Aside from type and size of home and income level of the household, the type of stove is also one of the main determinants for the level of raw coal consumption. Section 4.3.1 has already provided extensive discussion of raw coal usages among households that live in different type and size of dwelling (ger/home) using different type of heating system i.e., with/without heating wall, or low pressure boilers. This section provides direct comparison of raw coal usages among households that use traditional stove, improved stove, and low pressure boilers.[39] A separate study focusing on comparing fuel usage by traditional and improved stoves is being carried out parallel to this study. The Korean stove is considered to be a type of improved stove, but it is specifically designed for use with one specific size of honey comb shaped coal briquette. Therefore, the Korean stove is not included in the raw coal consumption and expenditure in this section.

(From Sept 2006 to April 2007)

Table 22: Household Raw Coal Usage and Expenditure by Types of Stove and LPB

Type of Dwelling and Heating System	**Average Household Monthly Income**	**Total Expenditure For Coal** (in Tg/)	**Average Raw Coal Used (t) per Household**	**Total Coal Used by All Households**
Traditional Stove	229,355	169,587	3.97	335,460
	89,737	84,286	84,488	84,488
Improved Stove	389,186	194,444	4.79	8,706
	2,019	1,817	1,817	1,817
Low Pressure Boiler (LPB)	341,842	219,385	6.17	55,435
	9,186	8,984	8,984	8,984
All Stoves	242,788	174,767	4.19	399,601
	100,941	95,086	95,288	95,288

Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

[39] The comparison is made without controlling all other factors that are known to influence consumption. It very important to recognize that detailed analysis within the group of improved stove users must be made with caution. The number of sample households that use an improved stove is too small to provide meaningful statistical results. Nevertheless, this section is written in the interests of providing full information on the survey results.

Box 4.2

Analysis of variance shows that the differences in raw coal usage among the three different types of stoves, including traditional stove and improved stove are statistically significant, F-stats is 45.08. However, an orthogonal contrast comparing raw coal consumption between households that use traditional or improved stoves shows that the differences are not statistical significant, the t-stats=1.51, at 0.15 level of significance. It is important to emphasize that this comparison does not control for other factors such as size and type of dwelling unit that may also influence coal consumption. Furthermore, the number of cases representing households that use improved stove is very small, only 2% of the entire sample. As a result, it is not possible to divide households with an improved stove into smaller sub-groups in order to control for other determinant factors that may influence coal consumption.

Comparison of raw coal consumption among households that use a traditional stove, improved stove or low pressure boilers shows that improved stoves users consume significantly more raw coal than traditional stove users but less than households with a low pressure boilers. This finding contradicts the conventional notion that improved stoves save fuel compared to the traditional stove. However, as pointed out, the stove type is only one of many factors that influence the amount of fuel used to heat ger/home. Other important factors that must be taken into account include income of the household, type and size of home, how stoves are used (with/without heating wall), and preferred level of comfort. As shown in Table 23, it appears that *improved stove users are financially better off than most other households with a traditional stove* and this may well explain why their unit consumption is higher. As discussed in Section 4.3 raw coal usage is positively correlated to income and it is therefore reasonable to conclude that higher income households will tend to consume more fuel than lower income households. Aside from the fact that 70% of improved stove users are in the top two – fourth and fifth -- income quintiles, most of the improved stove users live in a larger house, which also tend to lead to higher fuel consumption. About 60% of improved stove users live in a detached house with heating wall and about 35% of improved stove users live in a ger, which use the least amount of fuels among the three types of dwelling units.

4.6 Estimated Quantity of Firewood Consumption and Expenditure

On average a household used about 4.68 Cubic Meters of firewood and spent about 84,853Tg for firewood during the heating season from September 2006 to April 2007. Firewood usages per household ranged from 4.3 to 5.0 m^3 and the spending range from about 80,000 to 90,000 Tg. for the entire seven months period. Overall a total of 441,147 m^3 of firewood were used by all households in the six surveyed ger areas during these months.

As discussed in Section 4, raw coal is the primary source of heating fuels among households in the ger area, and firewood is generally used to start the fire. However, some households may also use firewood to supplement raw coal and/or for cooking, particularly at the beginning and the end of the heating season. Typically, firewood sold in bags is used specifically to start the fire. However, some households purchase wood as logs or otherwise big sizes of firewood; they can either use the wood to provide heat or split it in smaller pieces to start the fire. Based on the amount of firewood used, and household expenditure on firewood, it appears that the vast majority of households use firewood to start the fire. Furthermore, the estimated number of households that use firewood is also the same as the number of households that use raw coal, which also suggest that firewood is used complementary to raw coal.

Table 23: Household Firewood Usage and Expenditure by Income Quintile

From Sept 2006 to April 2007

	Total Expenditure on Firewood (Tg/.)	**Average Firewood Used (m^3) per Household**	**Total Firewood Used (m^3) by All Households**
Less than 111,330 Tg/.	88,098.38 18,674	5.05 18,876	95,369 18,876
111,331 - 172,660 Tg/.	90,815.11 18,371	4.96 18,472	91,669.57 18,472
172,661 - 233,990 Tg/.	85,174.44 18,169	4.84 18,371	89,004.73 18,371
233,991 - 325,860 Tg/.	78,761.72 18,775	4.27 19,280	82,362.81 19,280
More than 325,860 Tg/.	81,639.47 19,179	4.31 19,179	82,741.34 19,179
Total	84,852.80 93,169	4.68 94,178	441,147.50 94,178

Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

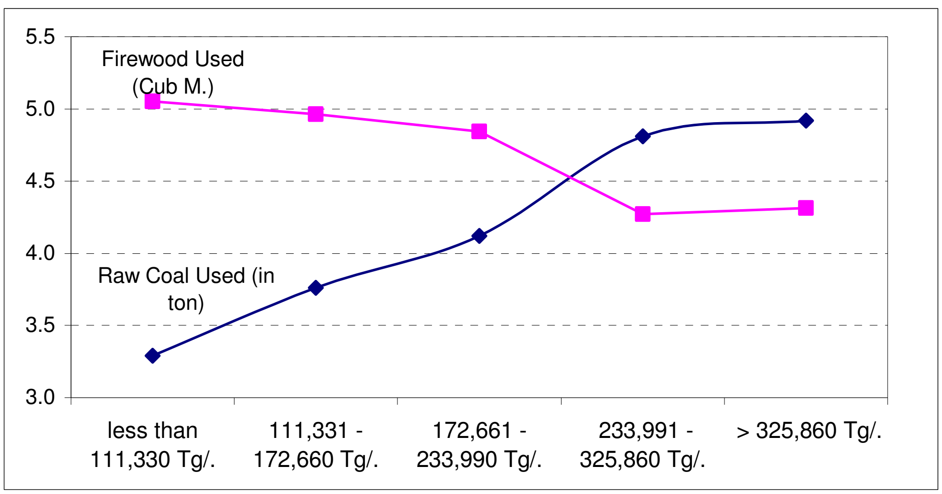
Comparison of firewood consumption and expenditures among income quintile reveals that firewood usages vary only slightly among income quintiles. However, firewood usages are negatively correlated with income; households in the lower income quintiles use more firewood than households in the higher income quintile. The average volume of firewood consumed per household from September 2006 to April 2007 ranged from a high of 5 m^3 among the bottom income quintile to 4.3 m^3 among the top income quintile households. Very small variations of firewood usage among different income quintiles suggest that demand for firewood is income inelastic.

Table 24: Household Firewood Usage and Expenditure by Type of Dwelling
(From Sept 2006 to April 2007)

	Total Expenditure (in Tg/.)	**Average Firewood Used (m^3) per Household**	**Total Firewood Used (m^3) by All Households**
Ger	85,070.18 38,257	4.82 38,761	186,947.78 38,761
Home without Heating wall	103,623.66 7,167	5.53 7,268	40,154.33 7,268
Home with Heating wall	80,842.53 37,853	4.40 38,257	168,465.48 38,257
Home with LPB	86,065.56 9,085	4.61 9,085	41,875.37 9,085
Hostel/Dormitory/Other	82,300.00 808	4.59 808	3,704.53 808
Total	84,852.80 93,169	4.68 94,178	441147.5 94,178

Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

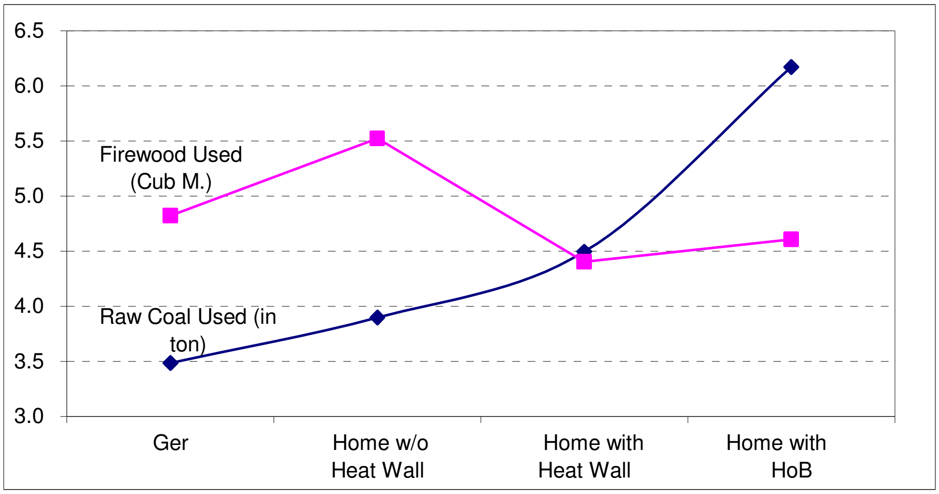
Figure 16: Comparison of Firewood and Raw Usage per Household by income Quintile
From Sept 2006 to April 2007



Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

Firewood consumption is negatively correlated to type and size of home as well as to heating system used in the home. Households living in a ger and households living in a single family home without heating walls use more firewood than households living in single family home using stove with heating walls and households living in the larger single family homes using low pressure boilers.

Figure 17: Comparison of Firewood and Raw Coal Usage per Household by Type and Size of Home and Heating System
From Sept 2006 to April 2007



Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

The negative correlation between firewood usage and income, and type and size of home and heating system is in contrast with raw coal usage which shows positive correlation with income as well as type and size of home and heating system. As a result of these consumption patterns, we may conclude that these two complimentary fuels are negatively related: that is, households using more raw coal tend to use less firewood and vice versa. In practice, households using more raw coal for heating are likely to keep the fire in the stove alive more often, thus would require fewer times to start a new fire. On the other hand households that restart fewer times or use less raw coal will allow fire to die down more often; consequently they would need to start fire more often, which means using more firewood.

4.7 Briquette Users, Consumption and Expenditure

The current estimated numbers of briquette users is very low, only 1.6% of households in the six surveyed ger areas reported that they use briquettes all the time, and another 3.6 % are occasional users. In all about, 5,249 households have used or are using briquettes at any time during the current heating season. The number of households that have been exposed to or have used briquette has doubles from the previous heating season. Briquette appears to be gaining popularity quickly. However the pattern of briquette usage from previous heating season seems to suggest that households are either still testing these new products or could not find a steady supply.

Table 25: Estimated Number of Households Using Briquettes
(Fall 2007 and part of Winter 2008)

	Compress Coal	Sawdust Briquette	Korean Briquette	All Types of Briquette
Use All the Time	606	--	1,009	1,615
	0.6%		1.0%	1.6%
Use Some of the Time	--	303	303	606
		0.3%	0.3%	0.6%
Rarely Use	1,716	202	1,110	3,028
	1.7%	0.2%	1.1%	3.0%
All	100,941	100,941	100,941	100,941

Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

The numbers of households that used any type briquette during the last heating season covering September 2006 to April 2007 are estimated to be about 2,624 households, of which 2,200 used a small quantity. The total spending for briquettes for the entire seven month ranged from only 1,200 to 20,000 Tg. The small amount of money spent on briquette during the last heating season may due to the fact that households were testing new product.

Table 26: Estimated Number of Households
(Between September 2006 – April 2007)

Type of Briquettes	Households
Compressed coal	1,110
	1.1%
Sawdust Briquette	505
	0.5%
Yontan /Korean Briquette	1,009
	1.0%
Total Briquette Users	2,624

Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

4.8 Perception On Performance of Briquette Users[40]

The number of briquette users is very low and not all of the households that have used briquette gave their opinions. Therefore, the interpretation of the results, which is based on a very small subset of the data, must be made with caution since the results constitute a very large sampling error.

As a result, no inferences should be made to the general population. However, responses from the small number of briquette users may shed some light regarding the acceptance of users and

[40] Users in this section include those who have used briquette. The vast majority of users in the sample are those who have used it once or more. There are only two cases which households have used briquette for the entire heating season.

performance of these new products.[41] Results from the survey which aims to evaluate users' perception on cost, availability and performance of briquettes including: briquette burning time, heat emitted from briquette, emission of particulates are presented in the following sub-section.

[41] A separate study focused on the performances of briquettes and perception of users in parallel to this study. Readers who are interested in these issues should consult the report from that study.

Box 4.3: Briquetting.

A realistic medium-term alternative fuel is in the form of briquettes. There are several types already available on the market, some of these produced on a small-scale in Ulaanbaatar. Laboratories from both the ERDC and the Academy of Sciences have tested some of these briquettes for their composition but standardized combustion tests have not been carried out. Three generic types can be distinguished:

- Densified coal powder briquettes. These are made of pulverized coal, mixed with chemical additives to improve the combustion characteristics, and a binder is added; for some briquettes the binder is clay. Two forms are generally used: pillow-shaped, which are known in the West for barbequeing, or cylindrical with vertical holes that are often used in Northern China and other Asian countries for heating[1]. The coal can come from any source and it is best to compact at the mine itself as the density of the briquette is higher than of the raw coal and this decreases transportation costs. A joint Mongolian-Korean company has developed (with assistance from Korea) a production line of Yontan briquettes with a 120,000 t/yr capacity (1 shift) mixing coal residue with 30% clay. A special stove is needed and the ash residues are considerable; the briquette burns without smoke; it would be sold for the about same price per unit weight as raw coal. Several companies produce pillow shaped briquettes and an association has been created: the Association of Environmentally Clean Fuel Producers, with 7 members.

- Semi-coked coal (SCC) has been pilot-produced in China and in Russia with coal from Mongolia; initial laboratory tests show that it is an acceptable fuel to households; a 10 kg sample has been converted at a professional coking plant in Russia and gave good result, a clean burning light fuel with a high calorific value as tested by the ERDC. However, SCC briquettes are more difficult to ignite in a traditional stove. The investment costs for a 150,000 t/yr coking and briquetting company have been estimated at $31.5 million. At least three companies are considering the production of SCC (or - briquettes) for the next heating season.

- Biomass briquettes burn more cleanly than coal in a traditional stove and do not emit SO_x and hardly any NO_x although PM maybe similar to coal briquettes. The key factor here will be resource availability and an assessment of the wood industries should be carried out to determine the long-term residue flows and locations. One company operates a 2000 t/yr pilot plant at Tunkhel where large quantities of sawdust are readily available; it is currently considering scaling up; another company imports similar sawdust briquettes from Russia. A more sustainable option to provide a steady flow of wood for the production of briquettes in the longer term are the community managed forests and/or the fire prevention activities in the North (Selengue) where large quantities of wood are destroyed every year that instead could be transformed into briquettes; this would provide large-scale employment opportunities in areas normally devoid of jobs. The composition of the briquettes has been tested but combustion tests have not been carried out; the producer carried out a limited household acceptance test with success last winter season.

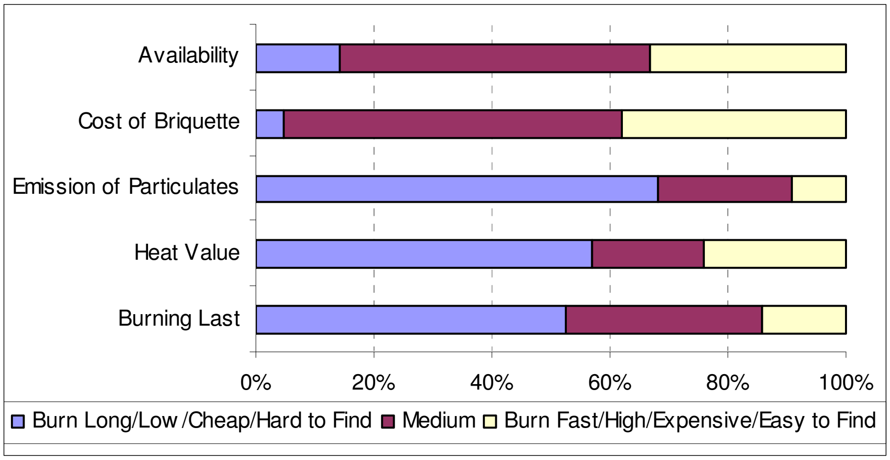
- Although not strictly briquettes, conditioned coal should be included as well: this is coal broken up in standard pieces, preferably 2-3 cm diameter. They could also be sprayed with a fluid to reduce certain emissions.

Tests to characterize environmental performance have not been carried out and it is thus impossible to indicate which briquettes have a positive or a negative environmental impact. As noted before, this performance also depends on the stove or boiler that is used to combust the fuel. It is likely that there is not one “winner” briquette, but several types that each could appeal to different clients. Briquettes that satisfy environmental and economic criteria should be promoted and those that fail should be prevented from entering the market. As a baseline it would therefore be necessary to compare the different briquettes on an equal footing: composition, consumption and emission tests following the standard testing protocol. Limited testing shows that the stove technology is a critical factor in controlling emissions and thus focus only on the composition of the fuel would limit large potential emissions reductions.

4.8.1 Compressed Coal Briquettes.

About half to a third of compressed coal briquette users think that compressed coal burns longer than raw coal, has a lower heating value, and emits less particulates. About cost, very few briquette users think that it is cheap, but about half of briquette users think the price is moderate or on par with raw coal. In term of availability most compressed coal users think it is not difficult to find.

Figure 18: Perception of Compressed Coal Users

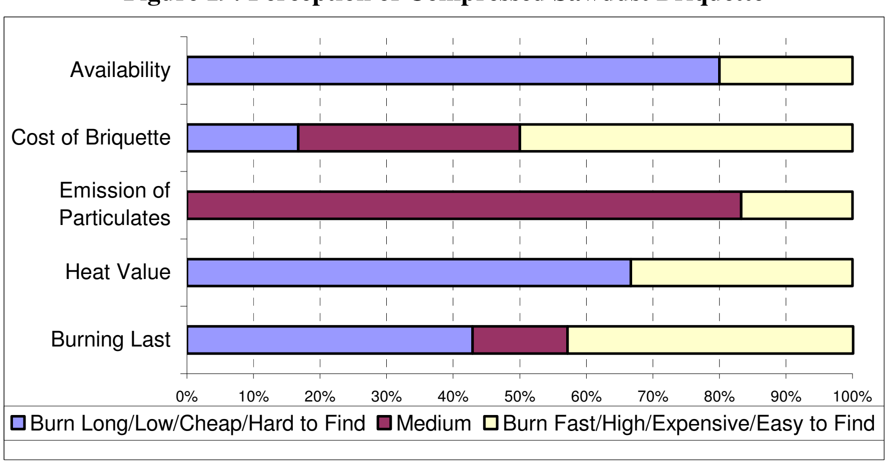


Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

4.8.2 Sawdust Briquette.

Perception of sawdust briquette users is slightly different. It appears that when compared with raw coal about 40% of sawdust briquette users think that sawdust briquettes last a long time, close to two-third think that it has low heating value, and the vast majority thinks that it has medium level emission of particulate. In term of cost, half of the sawdust briquette users think that it is expensive and about a third think that the price is moderate. Furthermore it appears that the availability of sawdust briquettes is still very limited. About 80% of those who have used it think it is difficult to find sawdust briquette in the market.

Figure 19: Perception of Compressed Sawdust Briquette



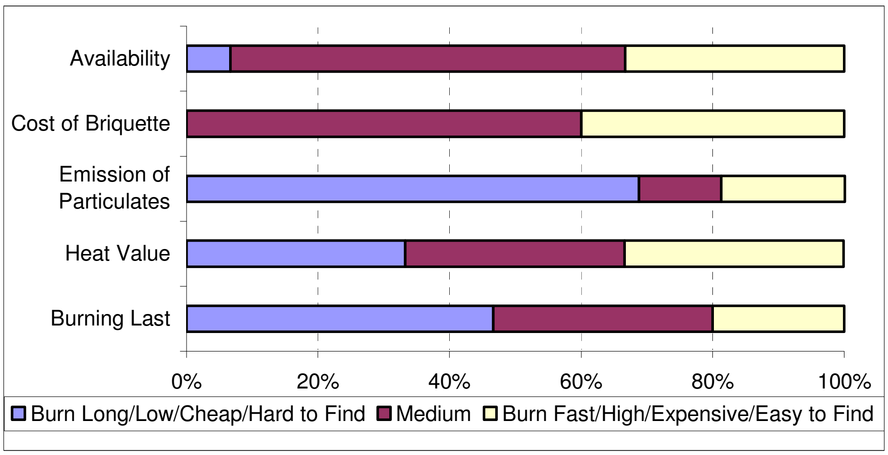
Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household

Perception Survey, December 2007.

4.8.3 Korean Briquette.

In term of the length of burning, perception of Korean briquette users is similar to two other types of briquette. However, users' perception on the heating value of Korean briquette is split equally three ways. Slightly more than a third of Korean briquette users think that emission of particulates is medium to low. Cost-wise, none of the users think that Korean briquette is cheap and about 60% thinks that the price is competitive to raw coal and not difficult to find in the market.

Figure 20: Perception of Compressed Korean Briquette



Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

When comparing user perceptions of sawdust with other briquettes, it appears that households with sawdust briquettes are not very positive about two key factors of desirable fuel characteristics: capacity to burn for a long time, and heating value. The majority of sawdust briquette users think the heating value of sawdust briquettes is low. Moreover, about half of the households that use sawdust briquettes think that sawdust briquettes burn very quickly.

Box 4.4: Sawdust briquettes

Sawdust is a source of energy that is available in large quantities from sawmills; it can be converted into a briquette that was highly appreciated by participating households in the consumption tests. Sawdust becomes a sustainably produced fuel if it is the result of sustainable forest management practices. It is confirmed that the Northern forests as a commercial venture whereby communities that manage the forests convert residues into briquettes could supply a large quantity of the ger area heating fuel requirement on a sustainable basis[42]. As with any other fuel used in Ulaanbaatar, emission testing has not been carried out.

[42] Sources: FAO: Capacity Building and Institutional Development for Participatory Natural Resource Management and Conservation in Forest Areas in Mongolia; GTZ: Program Conservation and Sustainable Development

4.9 Quantitative and Qualitative Results of Consumption Tests

Consumption tests were carried out by households and showed considerable performance differences between the traditional and select improved stoves. Results of the consumption tests were in-line with the results of the household survey. During the consumption tests, households used different stoves and fuels and their consumption was recorded over two week periods. Patterns identified during the household survey were confirmed by the results of the more practical consumption tests: the amount of coal used varies by type of stove, by household, and by income level, but wood use was fairly constant. Both the TT-03 and the GTZ stove are generally more fuel efficient than the traditional stove, although the savings level varies per type of fuel. Wood is mainly used for starting the fire and its consumption is significantly lower when sawdust briquettes are used as a fuel.

The objectives of the consumption tests were to assess, based on common household use rather than in laboratories, consumption levels and user appreciation; it did not look at emission levels. While it is true that if stove A uses 100 kg of raw coal and Stove B uses 80 kg of raw coal for the same heating task, emissions are likely to be 20% lower when stove B is used. However, the implicit assumption is that stove B has the same emissions per kg of fuel burned, which limited testing showed to be not necessarily true. A stove may have higher fuel efficiency but lower combustion efficiency. The combustion efficiency therefore needs to be tested as well because it is this efficiency that determines the level of emissions per unit of fuel burned. Therefore, for a complete picture, the emissions for all stove fuel combinations will need to be tested in the future. Until today, this has not been carried out comprehensively, and it will be difficult to pronounce which stove has lower emissions.

The following table 27 shows the relative fuel consumption compared to the traditional stove, normalized for a temperature difference of 40 degree Celsius[43]. The table shows that it matters quite a bit which fuel is used in which stove. A full report on the consumption tests is available from ASTAE.

[43] The average fuel consumption over 14 days for users with a TTO3 or GTZ stove is compared to the average consumption for the users with a traditional stove, for a particular fuel, and measured during the same time period. The data are corrected for temperature variations (and average temperature difference of 40 Celcius is taken between outside and inside temperature).

Table 27: Fuel Consumption relative to the Traditional Stove

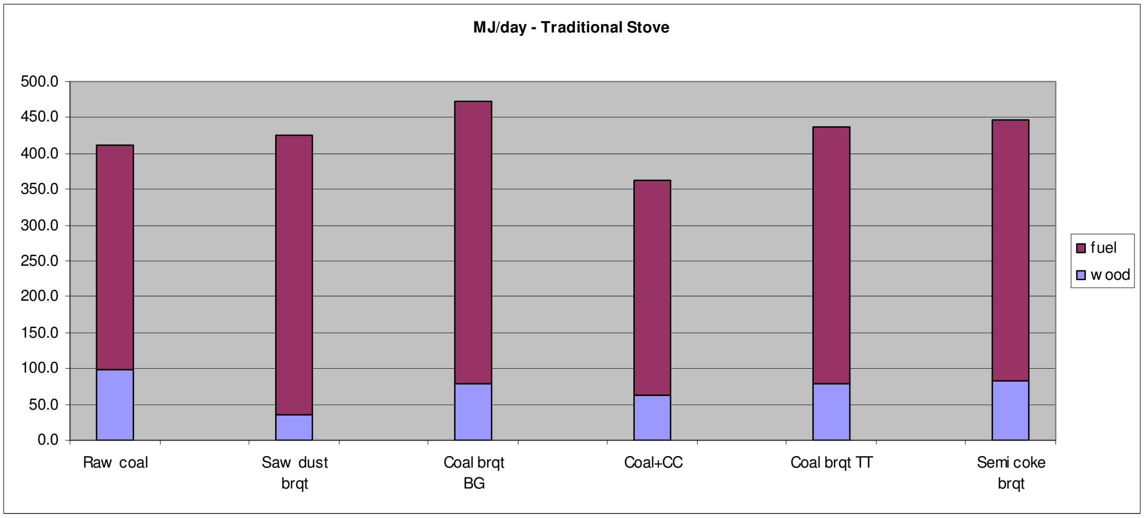
Stove	*fuel used*	*firewood*
	Raw coal	
TT03	-8%	-7%
GTZ	-4%	-5%
	Sawdust briquette	
TT03	-11%	-34%
GTZ	-4%	+23%
	Coal briquettes A	
TT03	-17%	-5%
GTZ	-13%	-18%
	Coal+ sprayed Clean Coal liquid	
TT03	-4%	+21%
GTZ	-8%	+52%
	Coal briquette B	
TT03	+4%	-5%
GTZ	-7%	+5%

Source: BEEC, 2008

The TT-03 and the GTZ stove are slightly more fuel efficient than the traditional stove, with a range of 4-17% fuel savings and 5-34% wood savings depending on the type of main heating fuel used. Nevertheless, an increased wood consumption is also noted, particularly in combination with coal briquettes that were treated with a chemical compound for both improved stoves, and with sawdust briquettes for the GTZ stove.

Figure 21 below shows the energy consumption in the traditional stove, with the blue part of the bar the energy contained in the wood (for starting the fire) and in red the energy contained in the fuel; as in the previous table, the energy use is normalized for a standard comfort level. It is noted that compared to raw coal, only coal with sprayed clean coal fluid consumes less energy, all other fuels consume more energy. The average energy consumption for the six fuels used in the traditional stove is about 425 MJ per day. It is particularly noted that the energy consumption of semi-coked coal is higher compared to raw coal.

Figure 21: Energy use in a traditional stove (MJ/day)

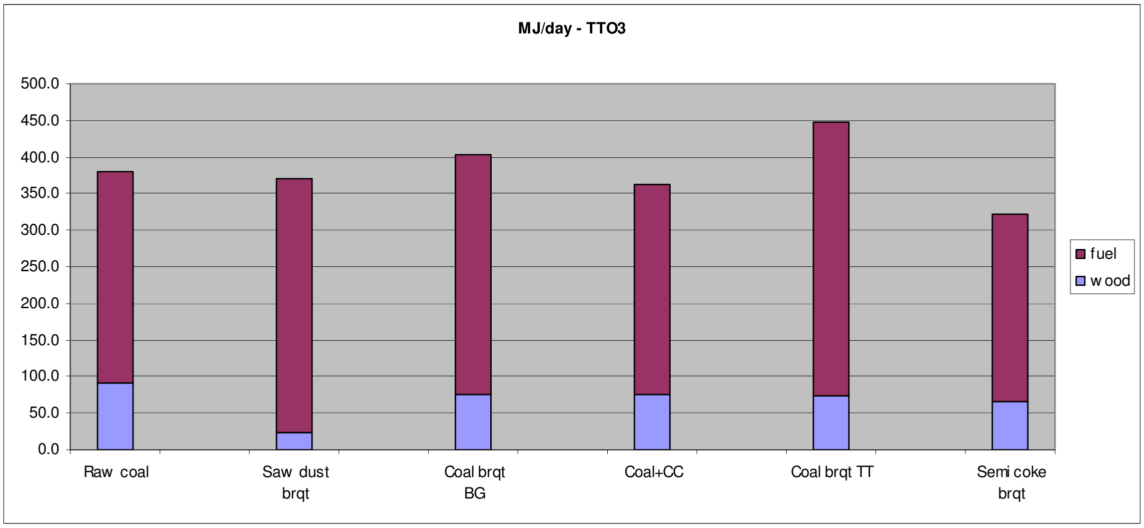


Source: BEEC, 2008

Figure 22 shows the same information for the different fuels used in a TT-03 stove. It is shown that the average energy consumption over the six fuels is about 380 MJ per day, or about 11% lower consumption than for the traditional stove, but with differences for each fuel-stove combination. For example, with the semi-coked coal briquette, more SCC energy was used than raw coal in the traditional stove, but less SCC energy than raw coal in the TT-03. The second observation is that the energy consumption for three fuels is lower than for raw coal: sawdust briquettes, briquettes sprayed with clean coal liquid, and semi-coked coal briquette. This provides the basis for two additional findings:

- that it is important to test the stove-fuel combinations;
- that household knowledge of how to use fules most efficiently in their appliances can have an impact on fuel use.

Figure 22: Energy use in a TT-03 stove (MJ/day)



Source: BEEC, 2008

It must be noted that there were too few observations for semi-coked coal due to a lack of availability of the fuel. However, there were sufficient observations for other fuels.[44] Some 8 households tested briquettes of mixed semi-coked coal with yellow clay and clean coal liquid, experimentally produced in China by a Mongolian company that wants to promote SCC. About 30 percent of those briquettes had crumbled completely before they could be used. Upon discussion with the company, 2 households further tested lumped semi-coke coal (not in briquette form). The semi-coke briquettes were more fragile than the other coal briquettes, but had a higher heating value and retained heat longer, particularly in the TT-03. Based on the limited experience during the tests, it appeared that semi-coke coal is better to be used directly instead of in the form of briquettes. The tests with semi-coked coal and semi-coked coal briquettes will have to be repeated at a later time: no conclusions can be drawn and the results are only indicative at this stage due to the limited number of observations.

Sawdust briquettes are produced by drying, heating and pressing the sawdust; advantages are, according to the manufacturer: no smoke, no mix of other substances, very little ash, fully combusted, suitable for any type of stove, high calorific value, easy ignition, easy utilization, keeping heat long, no air pollution. Households liked this fuel[45], as indeed it ignited easily with little wood, but they also noted that it burned out relatively quickly (but giving off much heat). Some households talked to the manufacturer after the tests and requested more sawdust briquettes against payment.

Two different coal briquettes were tested; they are made by pulverizing coal, mixing with clay and supplemented liquid and compressing. The level of compaction and adhesion of the briquettes differed and manufacturer B's briquettes were well compressed and hard, but the manufacture A's

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[44] 15 households x 14 days = 210 observations for a fuel-stove combination.
[45] A survey was held at the end of the testing period.

briquettes easily collapsed. In order to improve the fuel combustion, company A used a Korean-made clean coal liquid, and company B a Chinese made liquid. The survey at the end of the testing period showed that users' opinions were that much more firewood was needed for ignition, and that it takes time and effort to learn how to use thse fuels. However, when finally burning, they gave off good heat and kept hot for a long period and can be used as a substitute for coal. The main problems observed were it would not ignite easily and has a high level of ash. Many users also complained that ash smelled strongly.

One can conclude that:

(i) *the combination of stove and fuel are important*, as the consumption levels are quite different for different stove –fuel combinations; and

(ii) even more importantly, *tested improved stoves and improved fuels are not adequate solutions to clean up the air in Ulaanbaatar* as the resulting relative fuel consumption is not much different from the consumption obtained in a traditional stove. Even if all households were to use an improved stove as they are on the market today, a 10% fuel reduction is not going to make a major difference in air pollution in part because there is insufficient evidence to substantiate that a 10% reduction in fuel use means a 10% reduction in particulate emissions. A significantly more efficient and clean fuel (i.e. reduced emissions) and a significantly more efficient improved stove (i.e., reduced fuel consumption) will be needed if stoves or fuels are to be considered a solution for air pollution control.

4.10 Household Total Expenditure for Heating Fuels[46]

As shown in this Chapter, the overwhelming majority of households in the six surveyed district sused raw coal as their main heating fuel and spent a significant amount of money on raw coal. In addition, they also incurred expenditure for firewood, mainly for starting the fire. A few households have also tried some types of briquettes. As shown in Table 28, the poorest households spend an extraordinary percentage of their reported income on heating fuels. It is estimated that from September 2006 to April 2007 each household spent a total of 257,582 Tg for all fuels to heat his/her ger/home. About 67% of this amount was spent for raw coal and the remaining 32% was spent on firewood. The quantity of briquettes used was only small and thus expenditures for briquettes were insignificant when compared to raw coal and firewood expenditure.

[46] The survey reveals that there are a small number of households that use sawdust as their main heating fuel. However, the survey did not collect household expenditure on saw dust. Therefore, total expenditure for heating fuels in this section does not include households that use sawdust.

Table 28: Total Household Heating Expenditure for All Fuels (Raw Coal Firewood, and Briquettes) from September 2006 to April 2007

Monthly Income by Quintile	Total Expenditure for Heating Fuels	Total Expenditure per Heating Month	Heating Expenditure as% of Monthly Income
<= 111,330 Tg/.	241,101.67	34,443.10	42.3%
111,331 - 172,660 Tg/.	256,806.72	36,686.67	25.8%
172,661 - 233,990 Tg/.	254,388.95	36,341.28	17.6%
233,991 - 325,860 Tg/.	257,259.80	36,751.40	12.9%
> 325,860 Tg/.	277,121.09	39,588.73	8.7%
Total	257,581.39 94,481	36,797.34 94,481	20.7% 94,481

Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

As shown in Table 28, the total amount of household expenditures for heating fuels including raw coal, firewood, and briquettes from September 2007 to April 2008 amount to about 36,797 Tg per heating month per households. Based on the reported cash income collected from the survey, household monthly expenditure for heating fuels from September 2007 to April 2007 accounts for 20.7% of household monthly income showing that heating fuel expenditure poses a very large burden on poor households. Households whose cash income falls in the bottom income quintile spend more than 40% of their monthly income for heating fuels during the seven months heating period. The situation is significantly better among households in the second lowest income quintile. However, household heating fuels expenditure for the richest top income quintile and second highest income quintile accounts for slightly less than 9% and 13% of their monthly income, respectively.

Any increase in heating fuels due to a colder winter than expected will have a significant impact on low income households. Households in the bottom two income quintiles and in particular the poorest income quintile will have very few alternatives that moreover do not appear to be acceptable solution anyway. For example, households may reduce heating fuel consumption in response to price increase. Unfortunately, poor households have already used heating fuel to the bare necessity level. As a result, households may not have much room to reduce their fuel consumption. Some households may reallocate their monthly spending, but most poor households have already spent a very large portion of their income for food. This means that poor households may have to decide between food and heat. It is also conceivable that poor households may move down the fuel ladders or find some other coping strategies including using unconventional approaches such as, burning trash, old tires, etc. to keep warm. Luckily, the survey shows (see

Chapter 4.1), that not many households (0.2%) reported to use non-coal/firewood alternatives thus far.

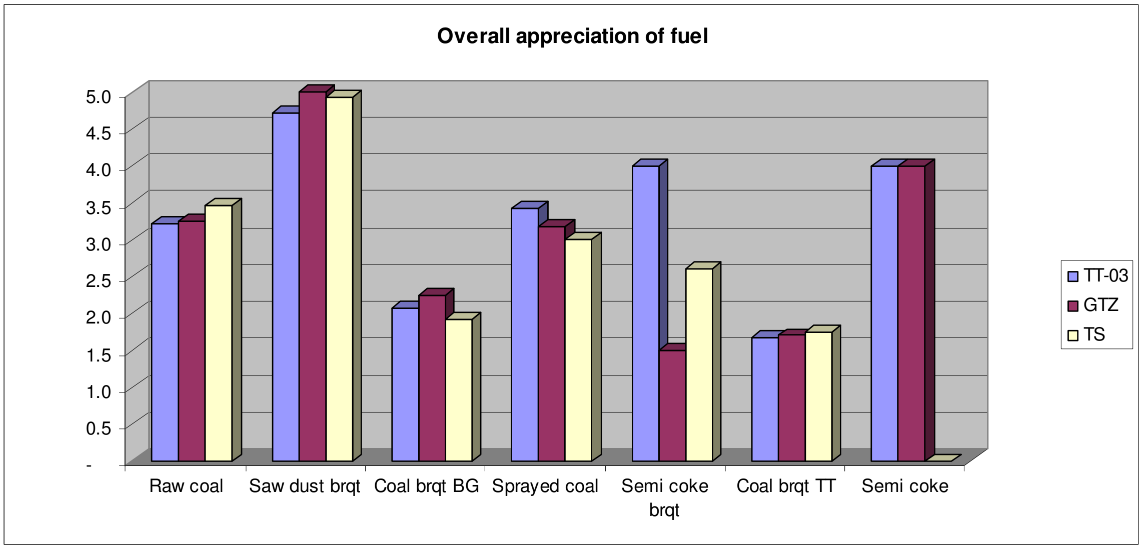
4.11 Conclusion

The survey confirms that just about every household in the six surveyed ger areas use raw coal as main heating fuel. It is estimated that about 399,601 ton of raw coal were used by all households in the six surveyed ger areas during the last heating season, which lasted from September 2006 to April 2007. On an average, households consumed about 3.9 tons of raw coal and spent about 174,767 Tg during the last heating season. As expected coal from Nalaikh is the most popular, coal from Baganuur ranks as the distant second most popular one. The survey also reveals that *demand for raw coal is positively related to income, type and size of home*. However coal usages vary only slightly among poor households living in the ger or small detached house and rich households living in a larger detached house. This pattern of raw coal consumption implies that *demand for raw coal is rather inelastic*. This can easily be understood since one simply has no choice but to heat the house; the alternative is to not survive the severe winter.

Firewood is also used by just about every households living in the six surveyed ger areas; it is mainly used to start the fire. It is estimated that about 441,147 m^3 of firewood were used by all households in the six survey ger areas during the last heating season. During this period each household used about 4.68 m^3 of firewood and spent about 84,853 Tg. *In contrast to raw coal, firewood is negatively correlated to income and type and size of home*. As a result of these consumption patterns, we may conclude that these two complimentary fuels are negatively correlated. Households that use more raw coal would tend to use less firewood and vice versa. In practice, households that use more raw coal for heating are very likely to leave the fire in the stove to be alive more often, thus they would require fewer times to start a new fire. On the other hand households that use less raw coal allow the fire to die down more often and consequently these households would need to start fire more often which means more firewood.

Briquettes (including compressed coal, Korean briquettes, and sawdust briquettes) are also used, but by a very small number of households. Among households that used briquettes during the last heating season, only a handful used briquettes as their only heating fuel. Judging from the reported quantity of briquette used and amount of money spent on briquette, it appears that the vast majority of households that used briquettes during the last heating season was either testing the briquettes or could not find steady supply of briquettes to continue using it. However, perception of households that used sawdust briquettes suggest that these burn fast and have a low heating value.

Figure 23: Overall appreciation of the fuels



Source: BEEC, 2008

Figure 23 above shows the overall appreciation of the fuels for each of the different stoves as expressed by the households at the end of the comsumption tests. Raw coal and sprayed coal score about equally, with minor differences between the different stoves, and compressed coal and semi-coked coal briquettes score less well than raw coal; sawdust briquettes scored the highest and were the preferred fuel for the participating households, irrespective of the stove model used. Semi-coked coal could score higher than raw coal when in lump form, but this result needs to be treated with caution as there were not many test data: this will need to be confirmed through additional tests.

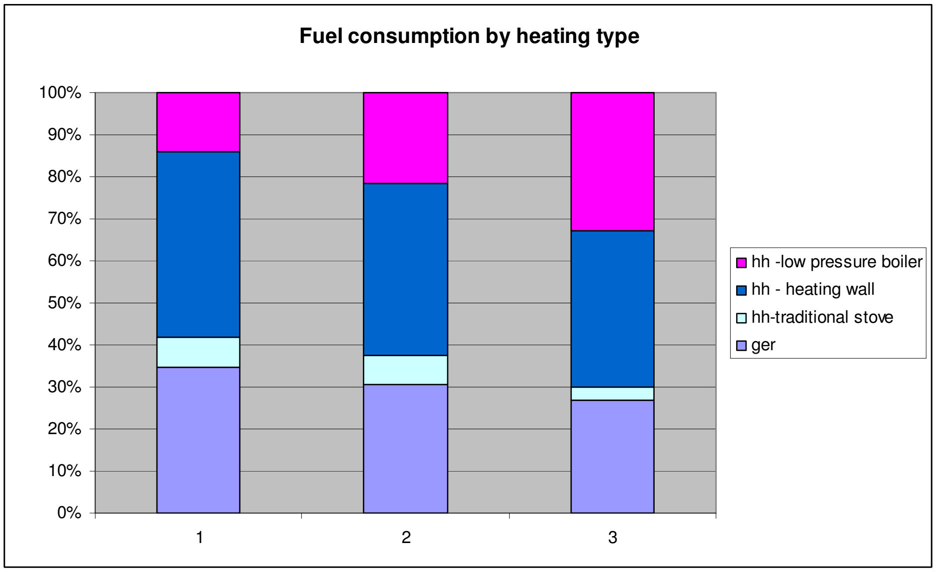
The survey also confirms that *lower income households in the ger areas spend amore than significant amount of money to heat their ger/home*. Households in the bottom fifth income quintile have an extremely high financial burden: during the seven month period – September 2007 to April 2008 – households in the bottom fifth income quintile spent about 40% of their monthly income for heating fuels including raw coal and firewood. On the contrary households in the top income quintile spend only 9% of their income each month for heating fuels.

This information is particularly important for indicative estimates of subsidy programs. Fuel subsidies currently contemplated[47] involve provision of subsidized raw lignite for processing into semi-coked coal. However, this subsidy would benefit richer households more as they use more fuel than poorer households. Targeted fuel subsidies, for example toward provision of free fuel for the lowest quintile, could run the Government MNT 3.8 billion per annum, covering 15% of total raw coal consumption for ger area household heating[48]. Stove subsidies involve a one-time capital grant that could cost approximately MNT 8.1 billion if low-emission stoves cost about twice the current market price for traditional stoves[49]. Targeting mechanisms are especially difficult for fuel subsidies in other countries and usually involve a number of administrative measures and

[47] Based on interviews with Government officials.
[48] Assuming that briquettes are equally priced as raw coal (2007/2008 price data), MNT 60,000 per t.
[49] Assuming all stoves costing MNT 60,000 to be replaced (135,000) at 50% subsidy.

assessment of taxes on polluting fuels. Chapter 8 discusses issues and options on moving forward with a program to support cleaner, affordable heating.

Figure 24: Fuel Consumption by Heating Type



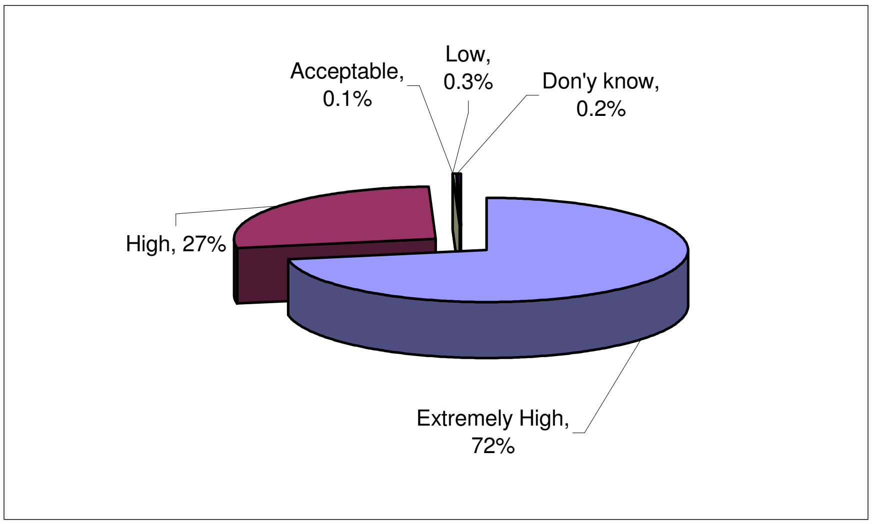
Source: BEEC, 2008

Finally, a trend should be highlighted: the move towards more fuel consuming heating appliances that provide more comfort, particularly low pressure boilers. These larger LPB-fitted homes consume more than twice what ger households use to heat their ger. Combined with another trend - constructing single fixed family houses and moving out of the gers - implies that the importance of the different heating appliances will evolve over time. See Figure 24 for 10 year projections of the aforementioned trends. Whereas fuel consumption in ger and heating wall households are almost equally important now and households with a low pressure boiler or a traditional stove contribute very little to the overall fuel consumption, in the future the consumption from low pressure boilers will be growing the fastest and become more important than both ger households and non-heating wall households combined. It is therefore necessary to focus on low pressure boilers and ensure that these are low-emission and high-efficiency. The proposed standards should certainly take this into account.

5. Attitude about Air Pollution, Alternative Fuels & Stoves

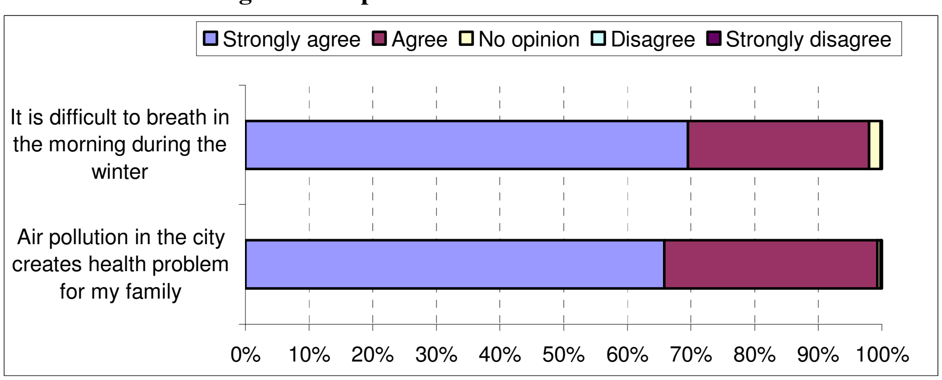
Virtually all households in the six surveyed ger areas think that air pollution in Ulaanbaatar is high. In fact, about 72% of the households think that air pollution in Ulaanbaatar is extremely high and another 27% think that air pollution problem is high. Everyone also agrees that due to pollution problem in the city, it is very difficult to breath in the morning during the winter. Furthermore, everyone also agrees that air pollution in the city creates health problems for family members.

Figure 25: Opinion on Air Pollution Problem



Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

Figure 26: Opinion on Air Pollution Problem

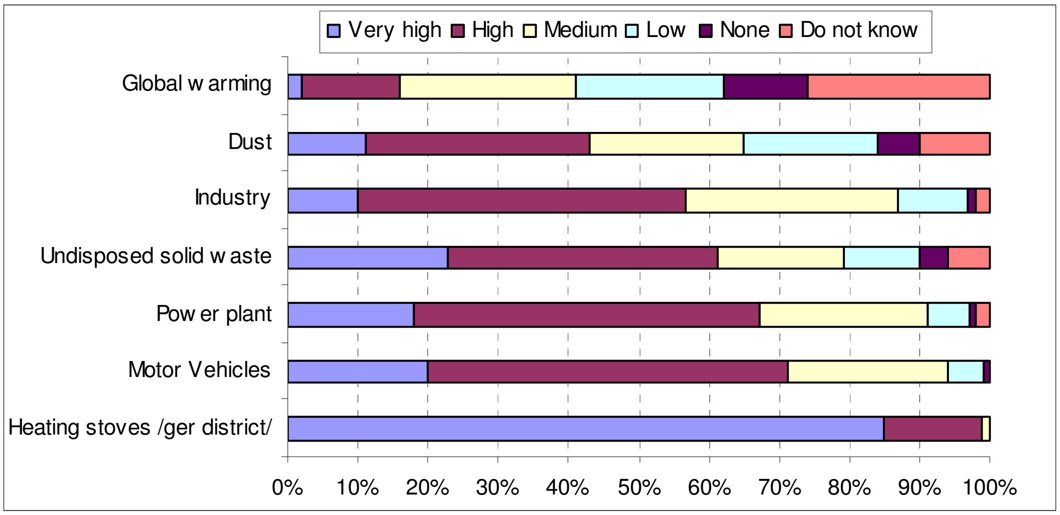


Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

5.1 Perception on the Causes of Air pollution

The survey lists several possible causes of air pollution and asks responding households to identify the main culprits. Results indicate that virtually all households in the six ger areas are aware that the use of stoves and raw coal for heating contributes to air pollution in the city. As depicted in Figure 26, households believe that the contribution of stoves to air pollution is very high. About 85% of the households believe that uses of raw coal and heating stove by ger households have a very high contribution to air pollution and another 14% believe that it has high contribution, but only one percent thinks that it has medium contribution.

Figure 27: Opinion of Sources Contributing to Air Pollution

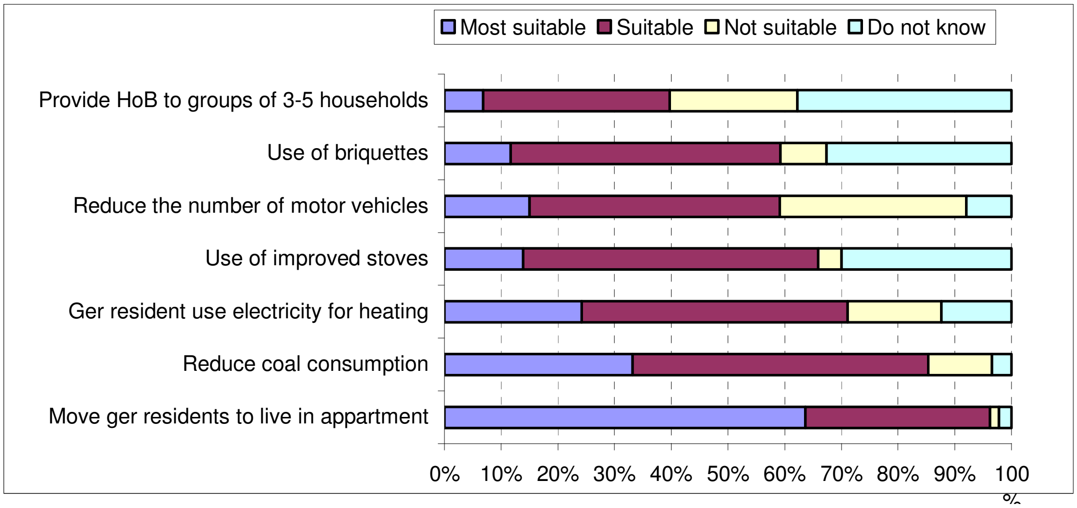


Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

Aside for the uses of raw coal and heating stove, the vast majority households also find that motor vehicles, power plants, un-disposed solid waste, industry, and dust also contribute to air pollution problem in the city. However, only about 10 to 20% of the surveyed households think that these causes have a very high contribution to air pollution.

The survey gauges households' opinion on several different courses of action that may reduce air pollution in the city and finds that almost everyone (96%) thinks that moving ger residents to live in apartments is the most suitable action to reduce air pollution in the city. Other courses of action which the majority of survey households (ranging from 60 to 85% of the households) believe to be very suitable are: (1) reduce raw coal consumption, (2) ger areas residents use electricity to heat their home, (3) use improved stove, (4) reduce number of motor vehicles, and (5) use briquette instead of raw coal.

Figure 28: Opinion on Course of Action to reduce Air Pollution



Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

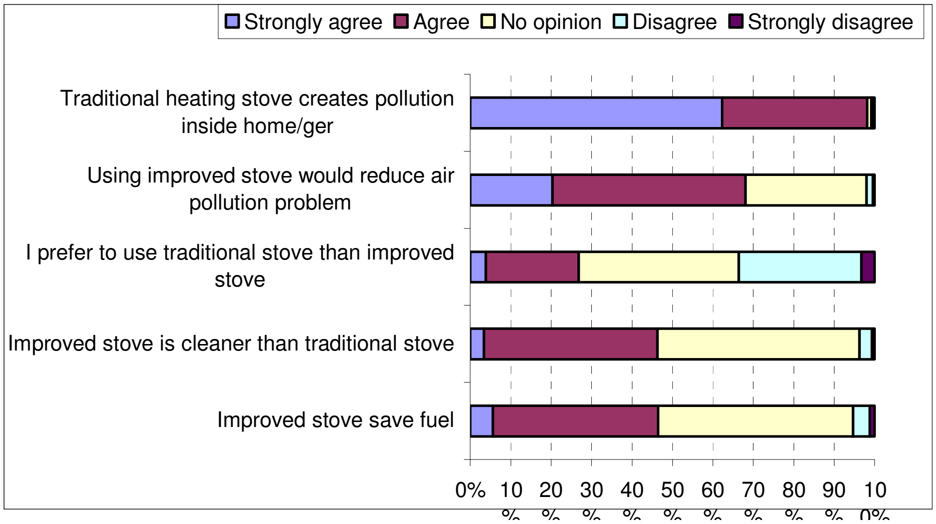
The findings confirm that households are very well aware of air pollution problems as they are all experiencing these problems themselves. They also know of the health risks their family is facing. Furthermore, it appears that ger areas households are well informed as well as are mindful of public discussions concerning causes and solution to air pollution problems in the city.

5.2 Attitude toward Heating Stove

Households' attitude toward the uses of heating stove and raw coal provide further evidence that households know of the health risk they are facing. They are also well informed of pollution problem as well as the public discussion on pollution issues. The survey finds that just about everyone agrees – more than 60% strongly agree and 30% agree – that traditional stove creates air pollution inside the home/ger.

However, survey data also seems to indicate that less than half of the households have confidence in the performance of improved stoves. As shown in Figure 28, slightly less than half of the household agree that improved stove save fuel or are cleaner than traditional stoves.

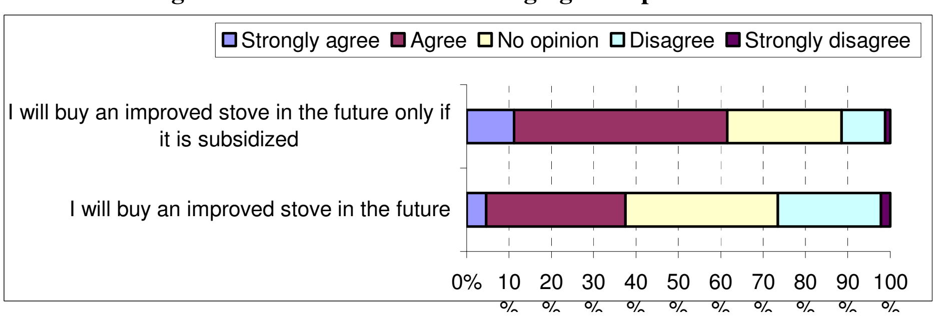
Figure 29: Attitude toward Heating Stove



Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

Although only close to half of the households have confidence in the performance of improved stoves, about 70% of the households agree to the statement suggesting that using improved stoves would reduce air pollution problems. This finding is encouraging for proponents of improved stoves. Additional evidence on household attitude toward using traditional stoves also implies that households may believe that improved stoves are a better alternative to reduce air pollution than continue using traditional stoves. This is because only a third of the household agree to the statement suggesting that he/she prefers to use a traditional stove compared to an improved stove.

Figure 30: Attitude toward Changing to Improved Stove



Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

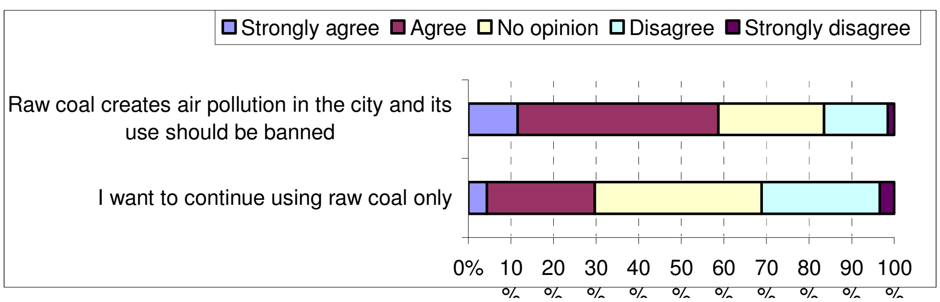
A significant portion of households, including half of the households that that expressed "no opinion" and the small portion of households who disagreed must be convinced in the future that improved stove saves fuels, are cleaner burning than traditional stoves and would help reduce air pollution in the city. It is interesting to note that only a very small portion of household have a negative opinion on improved stoves. Only 2-3% of the households disagree that improved stoves will help reduce air pollution problem, or are cleaner burning than traditional stoves, and/or save fuel.

With respect to the tendency to change to improved stoves, the survey finds positive responses regarding willingness to change for the better and close to 40% agree with the statement indicating that he/she would like to buy an improved stove in the future. In addition, a larger portion (more than 60%) agree with the statement indicating that he/she will buy improved stove in the future only if it is subsidized.

5.3 Attitude toward Raw Coal, Briquettes, and Using Electricity For Heating

Attitudes toward raw coal seem to reflect the fact that households are well informed about the health threat from using raw coal. The majority of surveyed households (60%) agree with the statement indicating that raw coal creates air pollution in the city and its use should be banned. Such a call indicates there is little or no awareness that there are several alternatives to consider including that it could be the stove, not the fuel that creates the pollution – by burning fuel badly. However, at present households do not feel they have lot of alternatives. Nearly no one has seen a clean-burning stove. The majority of the households do not know anything regarding the performances of briquettes, which could be a best potential alternative to raw coal. The household survey in the six ger areas reveals that the majority of households ranging from 50 to 70% of the households have no opinion about the performances or quality of any types of briquette (coal and/or sawdust). However, there is one positive note. That is only a small portion of households ranging from 5 to 9% disagree with the statements indicating that coal briquettes are less polluting than raw coal, briquette burns fast and has low heating value, and sawdust briquette is more expensive than raw coal.

Figure 31: Attitude toward Raw Coal

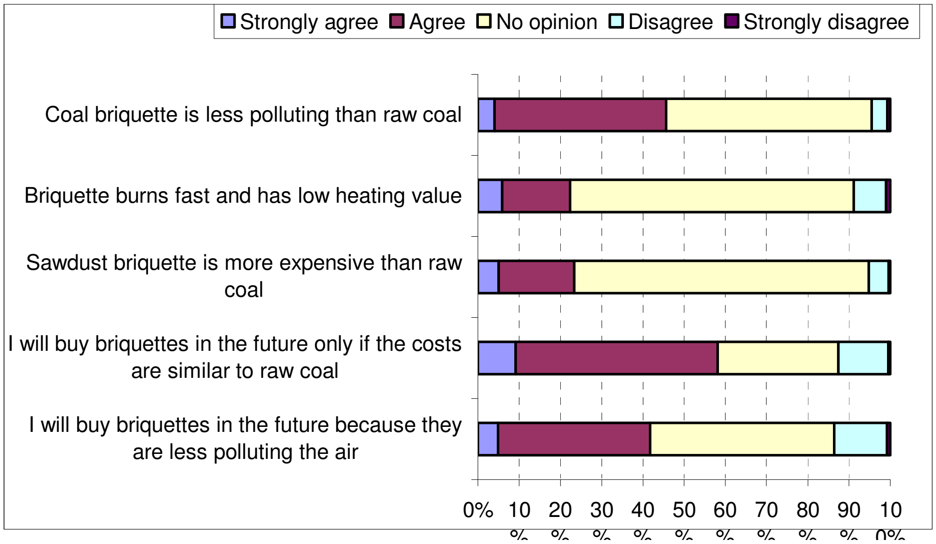


Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

This finding confirms that briquette products are very new and are not yet widely available in the market. As a result, very few households have had exposure to the new products. As typical with new products and market acceptance, it is very important to prevent any initial bad impression of briquettes to be formed among potential users. Empirical evidence elsewhere has shown that it is difficult and will take a long time to erase or alter the initial bad impression of consumers on any new products. So far, about 40% of the households agree that briquettes are less polluting than raw coal and almost an equal number of households agree that they will buy briquettes in the future because these are less polluting than raw coal. In addition, more households agree with the statement indicating that he/she will buy briquettes if the price of briquette is on par with raw coal. These findings are very promising for briquette producers and others who would like to promote briquettes.

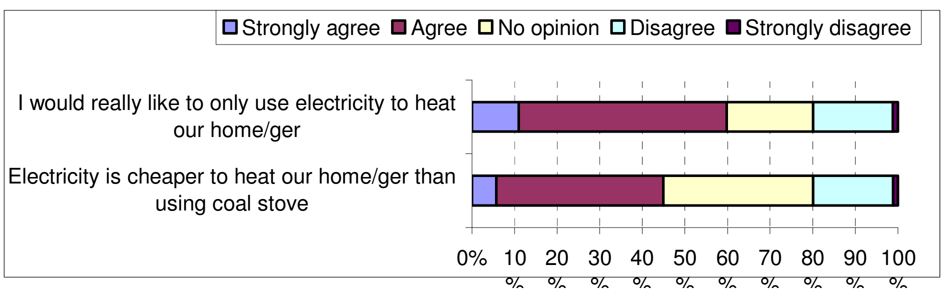
Figure 31 provides feedback on briquettes from the household survey; this is the opinion of households who not necessarily used briquettes before, unlike the households during the consumption tests. Households think that briquettes burn slower, are less expensive than coal, and they are more likely to use briquettes if these are cheaper than coal; they also think that briquettes are equally polluting as coal. This means that the real features of briquettes will need to be advertised, once the test results are fully known: level of pollution, duration of the burn, and costs.

Figure 32: Attitude toward Briquettes



Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

Figure 33: Attitude toward Electricity for Heating



Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

Electricity is not currently used by many ger areas households for heating and only a small number of households use electric space heaters as supplemental heating source. The survey finds that about 60% of the households agree with the statement indicating that he/she would really like to only use electricity to heat his/her home/ger; a small number (less than 50%) think that it is cheaper to use electricity to heat home/ger than using raw coal. The question should be raised how well they are informed about the tariffs and the costs of electricity: the use of electricity for heating, even at the reduced evening tariff, would be more expensive than they currently experience with raw coal and traditional stoves.

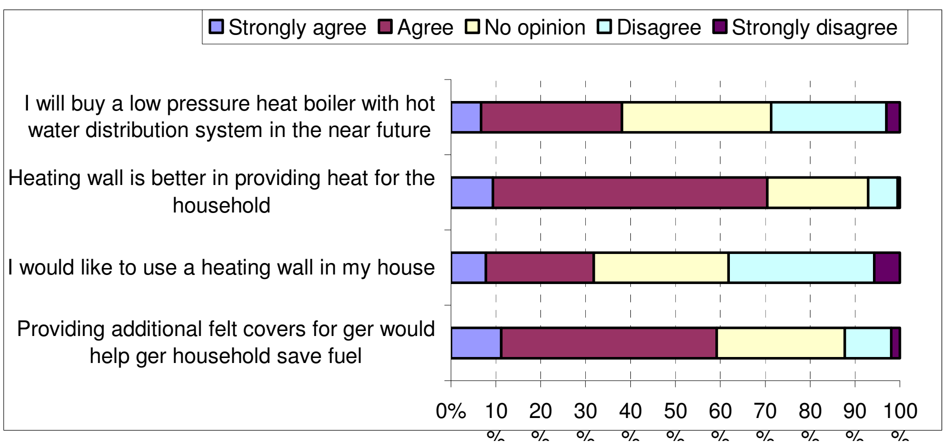
Box 5

Electricity has been mentioned as the preferred alternative for ger area heating. See Annex D for a Case study on electric heating in Ulaanbaatar and in Beijing, China. In summary, electric heating is interesting from the point of view of consumers, but has a few important economic consequences: (i) The electricity generation capacity would need to be doubled to cope with the evening heating peak, at a cost of about US$1.4 billion; (ii) the cost of electric heating is considerably higher than the cost of heating with coal. The total subsidy needed for all ger area households to use electric heaters at similar costs as coal stoves would be roughly 54 million US$ per heating season.

5.4 Other Attitudes

Other findings on the household attitude confirm that a significant number of households are interested in alternative heating devices/systems that would provide more comfort and better living conditions. Aside from using electricity to heat a significant number of households, close to 40% are also interested in buying low pressure boilers with a hot water distribution system. About 70% of the household think that (i.e. agree with the statement) heating walls are better at providing heat for the household than stoves only but only a third would like to use in their home. This contradiction may due to the fact that a heating wall is not applicable for gers and installing a heating wall requires significant home remodeling. With respect to providing felt covers for gers, the majority of surveyed households agree that it would help save fuel.

Figure 34: Other Attitudes



Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

6. Knowledge about Air Pollution from Stoves and Fuels

6.1 Laboratory Tests

One of the tools that were planned to be used to further quantify air pollution measures were *laboratory tests* of the same stove-fuel combinations as in the consumption test (March 2008). These tests would have quantified emissions by type of pollutant as a function of the fuel consumption. The idea is that standardized laboratory tests on stove-fuel combinations would yield both fuel consumption data and emission data (combustion efficiency, CO, PM). With these data it would be possible to correlate emissions with fuel consumption that is essential for assessing different corrective air pollution measures. However, two problems prevented these tests from taking place: (i) some essential equipment was not available, in particular a scale capable of weighing the stove and measurement equipment (> 100 kg) during the emission measurements (to determine the actual fuel consumption and power output) and a meter capable of measuring real-time PM emissions; and (ii) a standard methodology and the capacity to carry out these measurements.

Although a standard methodology was developed by the ASTAE consultant and agreed on with the main laboratories in UB, non-available equipment and lack of qualified personnel prevented the tests to be carried out systematically. Nevertheless, UBMG staff (Air Pollution Division) carried out some tests with different fuels in the traditional stove and although the results were indicative only, they suggested an important conclusion.

When considering emission reductions, it is risky to dissociate the fuel from the stove; both should be looked at simultaneously rather than a focus exclusively on the stove or exclusively on the fuel – as has been the case in the past. Emissions will therefore need to be tested in a qualified laboratory, using the standard testing methodology, and quantified for possible fuel – stove combinations to identify the optimal solutions for air pollution reduction.

The testing of stoves so far has been done with air quality protocols in mind but in the absence of a proper testing methodology. Stove developers were trying to obtain low CO levels per m^3 of chimney gases, without reference to the number of m^3 involved. Unfortunately this indicates nothing at all about the cleanliness of the burn nor about the total emissions. As an example, if for stove A emissions were x g/m^3 and for stove B 0.75x g/m^3, the conclusion was that stove B would be the cleaner stove in terms of emissions; however, this is wrong if stove A consumed more fuel than stove B or if the total volume of gases (higher dilution factor) through the chimney was much higher for stove A than for stove B. In other words, it is necessary to correlate emissions to the quantity of fuel used for producing these emissions. This has not been done in earlier tests and as a result, previous emission measurements can unfortunately not be used at all to compare the emission output from different stoves.

For large-scale applications such as power plants, one would normally design a furnace to be optimized for a fuel of specific characteristics, but for simple households stoves costing less than US$ 50 per unit this is usually not done. Heating stoves should be treated exactly as other appliances, with enforced standards achieving expected emission and performance outcomes. The important parameter is the emission factor, which is the rate of emissions per unit fuel consumed [g pollutant per m3/s emitted in the stove pipe per g of fuel used per s]; this parameter needs to be established for all stove and fuel combinations so that an assessment can be made of the environmental performance of the different options.

The CO/CO_2 ratio is an indicator of combustion efficiency, but most previous tests did not measure the CO_2 level (which is hard to detect directly) or measure the oxygen level (from which the CO_2 can be inferred). As a result, nothing can be deducted from those particular tests about the combustion efficiency or the stove pipe losses (which can be calculated from a combination of the stove pipe temperature and the excess air level). CO can be taken as a rough proxy for PM emissions until equipment arrives to carry out real-time PM emissions from the stove-pipe exhaust gases[50].

An important outcome of the ASTAE supported technical work has been: (i) a thorough discussion of the existing protocol with testing laboratories in Ulaanbaatar, and (ii) an agreement about standard protocols for thermal efficiency tests and emissions tests based on per unit heat produced or fuel burned. The testing protocol that was agreed on is presented in Annex B and the necessary lab equipment in Annex E.

What must be discontinued is the reporting of CO levels without the dilution factor; not only is it misleading, even the wrong conclusions can be drawn. Particulate emissions must be made cold and diluted before measuring them. This means samples have to be drawn from the stove pipe, cooled, diluted, and then measured by one of several means:

- The dilution has to be measured by checking the CO_2 or O_2 level before and after the dilution takes place so that it can be quantified. Then the gas is sampled for particulates based on a gas flow rate and the quantity in the original sample calculated.
- The alternative is to do gravimetric (mass measurement) samples where all or various sizes of particles can be trapped on a filter. In such a measurement the mass of the particles is weighed with a microgram scale. The total mass of particulates does not specify the type of particulates, however by using a series of 2 or 3 filters, at least their size and relative mass of each size fraction can be determined.

Under the current circumstances, a combination of measures taken by collaborating laboratories in Ulaanbaatar would give useful results:

- The nuclear physics laboratory at NUM can do gravimetric measurements but does not have equipment to dilute stove pipe exhaust gases: needed are twin O_2 or CO_2 measuring devices and a source of compressed air with a bubble meter to calibrate the flow, or a calibrated pump.
- CLEM can carry out stove performance tests using a TESTO 350 XL although stoves need to be placed on a 150 kg scale capable of at least 20 gram accuracy, which until only recently not been available. CLEM can also do TSP tests at the same time; such test takes 20 minutes to complete so with one test per hour during a 4 - 5 hour test period would be manageable with the existing particulate equipment. This will only give the total 'hot' particulate measurement (no condensed particulates) however no equipment modification is required.
- UBMG/AQD could carry out the same tests using their newly acquired Dusttrack that can measure one PM fraction at the same time; measuring PM 2.5 would be a priority. The purpose of these tests is to crosscheck the work done by CLEM and to establish the

[50] Stoves with low CO emissions will also have low PM emissions.

general relationship between the CLEM TSP measurement and the real time PM 2.5 levels.

- NUM enables its diluted gravimetric PM measurements and collaborates with UBMG or CLEM to establish the general relationship between the real time PM 2.5's and the gravimetric 2.5's per cubic meter of stack gas, with the excess air being tracked all the while by the TESTO 350 XL.

UBMG/AQD carried out tests of 12 fuels in a TT-03 stove, the Yontan briquette in the MG-203 stove, and Nalaikh coal in a reference burner. The precise conditions under which these tests were carried out are unknown other than the tests were for two hours only. Since fuel use was not recorded, a correction was calculated based on the assumption that all heat generated in the fire came from Carbon[51]. The resulting CO/CO_2 ratio is given in Figure 35 below:

Figure 35: CO/CO2 ratio for different fuels

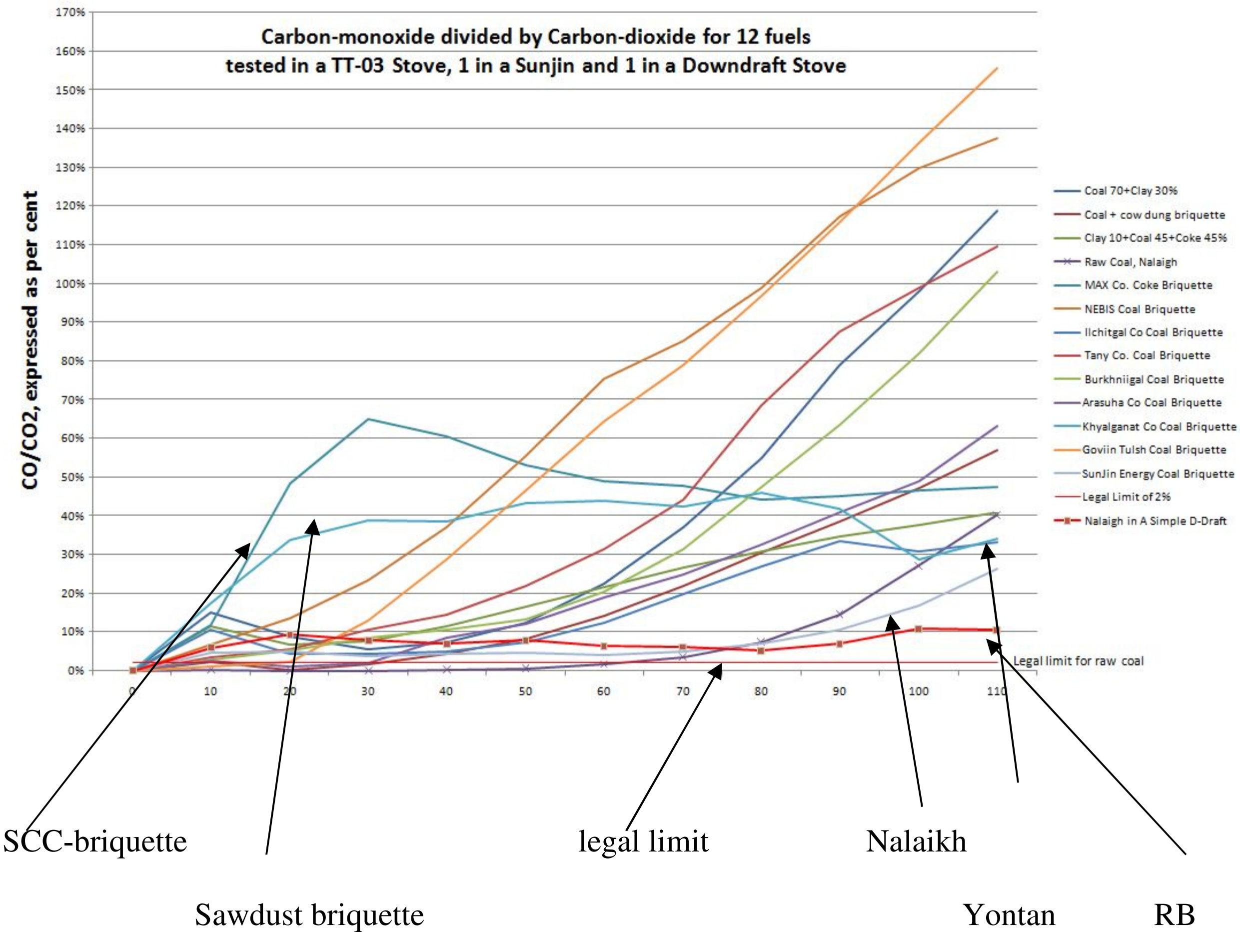


Figure 34 is very dense, but the lessons learnt are simple: emissions from fuels tested far exceed the current standard, although for one or two stove models the emission level is only a factor of ten

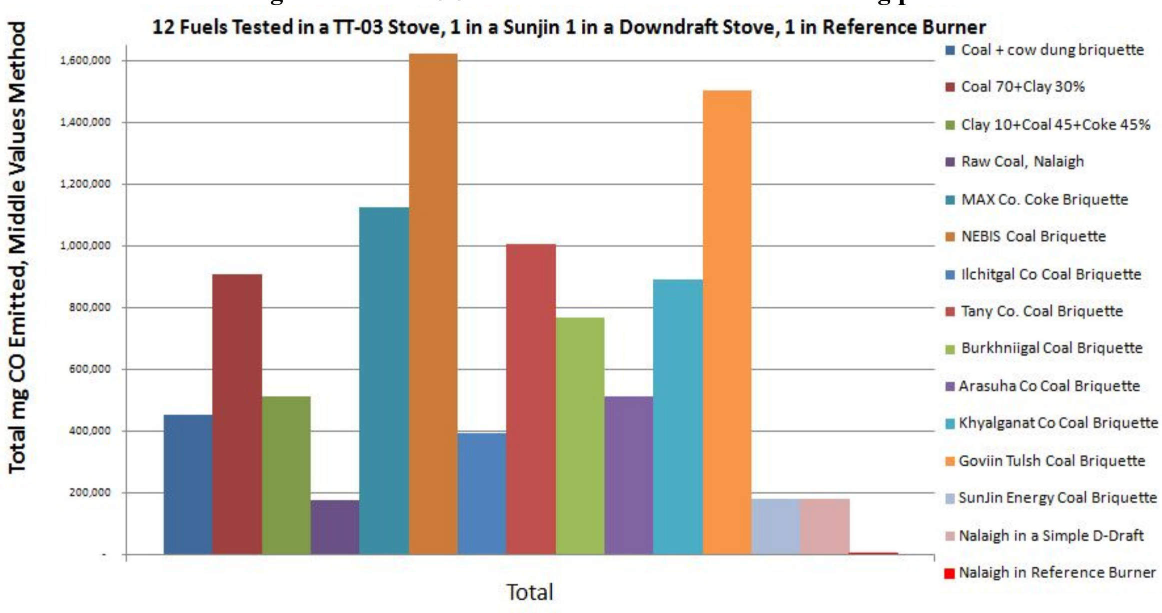
[51] The reaction of burning coal yields CO_2 and H_2O; if the quantity of emitted CO_2 is measured, the quantity of carbon needed for this emission can be calculated knowing the carbon content of the coal.

higher. A few further observations can be made on this Figure. First, a full test should last about 4-5 hours, until the fuel is fully combusted; this is based on both the household survey and the consumption tests that indicated that stoves are normally refueled after 4-6 hours. In the above presented tests results, only the first 2 hours are shown in the graph; this is the likely reason that for some of the fuels the ratio still increases[52]. Figure 36 shows the accumulated total emissions over the 2 hour testing period. This should be considered over the full firing cycle, in which case some of the fuels will show much higher emissions (particularly the fuels for which the CO/CO_2 ratio is still increasing towards the end of the 2 hour measuring period).

Second, the red horizontal line at 2% CO/CO_2 on a volumetric basis is the legal limit for emissions from raw coal (lignite) in burners below 80 kW; this limit is 4% for wood and 0.5% for anthracite. None of the fuels comes close, which means that under actual conditions, all fuels exceed the legal emission limit. Raw coal from Nalaikh appears to be a relatively clean fuel, on par with the Yontan briquette, at least compared to briquettes of raw coal mixed with clay and chemical additives. The only two fuels for which the CO/CO_2 ratio appears to be decreasing within two hours are sawdust briquettes and SCC briquettes, but the CO/CO_2 ratio is still 20 times too high compared to the legal limit.

Finally, the reference burner shows that it is possible to burn raw coal at a CO/CO_2 ratio close to the legal limit. The reference burner was built specifically to demonstrate that raw coal can be combusted relatively cleanly in a device that is adapted to the fuel.

Figure 36: total CO emissions over the 2 hour measuring period



For the TT-03 stove, the following emission patterns are observed:

(i) low emissions for 70-80 minutes, then increasing rates; during the low-emission phase, emissions are roughly in-line with the standard of permissible emissions; the increasing

[52] A typical curve would start at zero emissions on start-up, then increase to a peak level, to finally decrease to zero emissions when all fuel is spent and the stove is cold again.

rates should peak and then die down (when all the fuel is spent); the fuels that behave like this are the Yontan briquette and Nalaikh raw coal;

(ii) constant emissions for an extended period, after a gradual build-up of 10-20 minutes; however, the level is at least 20 times the permissible standard; this is for sawdust briquettes. and SCC briquettes; and

(iii) all other fuels show increasing emission values from the start, with 40-60 times the permissible levels after some 2 hours after the start-up; eventually they should peak; this behavior is observed for all other coal and briquettes: coal + cow-dung mixture, coal + 30% clay mixture, 45% coal + 45% coke + 10% clay mixture.

Data presented here should be interpreted with much care until more detailed systematic tests have been completed; the preliminary conclusions are two-fold: (i) it appears possible to burn Nalaikh coal in simple stoves with reasonable emissions as presented in the legal emission limits; (ii) most "improved fuels" that are currently being investigated emit more CO than untreated Nalaikh coal; since CO emissions are related to PM emissions in poor combustion conditions, it is thus likely that PM emissions of the new fuels are higher than for raw coal. Further combustion tests should be carried out, including measurements of fuel consumption and CO, PM emissions.

Another reason for quickly retesting these fuels and stoves is the following: measurements showed that the composition of exhaust gases is far from ideal. As an example, the level of hydrogen was relatively high; one would expect this to ignite and burn immediately, but this apparently was not the case. Another observation is that the stove pipe temperature is too low (below 100 C) for at least two improved stove models. With such low temperatures, exhaust gases will condense and drip down into the stove, creating all sorts of problems with corrosion, further emissions, etc. These are clear signs that the fuel and the stove are not necessarily well adapted to one another and that an effort is required to research better stoves for the fuels at hand. This similarly applies to the stoves to be used with SCC: a good device needs to be identified before marketing the fuel on a large scale.

As a matter of urgency, it is therefore necessary to repeat the tests in a regular laboratory, fully applying the testing protocol, and using appropriate equipment. The conclusions are far going, as they seem to suggest that the current research into new fuels may not be an efficient use of funds. It also seems to suggest that further research in higher performance stove-fuel combinations is warranted, as it should be possible to beat the 2% CO/CO_2 legal limit.

This report did not address indoor air pollution although there is smoke in the igniting phase of the stove. Earlier efforts looked at indoor air pollution and concluded that, given that stoves are normally attached to chimneys, the effect of these stoves on indoor air pollution is generally minimal. This is true only on two conditions: one is that all exhaust gasses indeed escape into the ambient air; for this, the chimney needs to be closely fit to the stove and should not leak air. The second is that the stove itself is well made; the standard MNS 5216 2002 sets the quality of domestic burners for solid fuels including fuel efficiency standard. However, in practice often the chimney leaks and/or the stove is not well made and gases may leak into the indoor atmosphere. Therefore, emissions may indeed pollute the indoor air directly and this is particularly worrisome: CO emissions are deadly even at relatively low concentrations.

However, all exhaust air exits into the outdoor environment and becomes a problem for the city as a whole instead of a problem for the single household that operates the stove. For this reason, outdoor air pollution is more important that cleaning up the indoor air – in fact, indoor air becomes automatically cleaner when better stove and fuels are used.

A common mistake of stove developers is that they include a damper at the stove-pipe to slow down the burning rate of the fuel; however, exhaust gases then are unable to escape and are vented into the room and the choked fire will produce more CO than normal. Elevated levels of CO are very dangerous indeed, but can be corrected by introducing a primary air controller to regulate the flow of oxygen to the combustion zone. Indoor air is also indirectly influenced by the air quality outdoors: the combustion air needed is sucked into the house and carries with it the outdoor air pollution. This could pose problems particularly in gers where the indoor air volume is small and is replaced at a high rate. If the stove and chimney are well sealed, indoor air pollution is not an issue. Therefore, priority in a future program should be given to cleaning up the outdoor air.

6.2 Initial results of training to stove manufacturers

A two-day training of stove designers and producers took place in March 2008 to demonstrate to them that traditional and currently available improved stove models burn raw coal not very cleanly compared to a simple locally-built reference burner. The main difference between the reference burner and these coal stoves is the direction and flow of exhaust gases: in the stove, hot exhaust gases escape from the combustion zone straight into the chimney, whereas in a down draft mode exhaust gasses pass through the hot combustion zone before exiting the chimney thereby breaking down and igniting most of the pollutants. Stove producers were not aware of these issues but showed a great interest to learn more about the principles behind it.

It was decided to share these principles with the stove community in Ulaanbaatar in two steps: (i) the methodology for testing fuel consumption and emissions was discussed with the laboratories that are interested in this type of work; and (ii) a two day training workshop with follow up factory visits was held for interested individuals and firms to demonstrate down draft principles and discuss how this could be applied to heating stoves.

As part of the practical testing that took place in the laboratory, it was demonstrated that conditioning of the coal could also yield substantial benefits. Breaking up the coal lumps into smaller pieces of 2-3 cm would is also improve the combustion efficiency. The explanation is that the air flow is better regulated and more complete combustion takes place. This is valid only for a properly designed stove: air leaks as result of holes in the stove body will render the results negative.

Although it was shown that simple stove models can drastically reduce emissions without changing the fuel (other than fuel conditioning), it is not known if new stove models have been designed since the training course. It is the responsibility of the private sector to develop such stove models and although a few models did surface in 2008 and again when the EBRD's March-April 2009 tests took place, their quality was highly variable and they have not been taken into production.

6.3 Recent fuel-stove testing results and recommendations for scaled up testing

The EBRD performed fuel-stove testing in March-April 2009. The Bank's stove expert was present at the tests. This section shares some indicative results observed by the World Bank consultant and recommends scaled up fuel-stove testing. The results will be treated comprehensively in EBRD's forthcoming report.

As an example of the importance of testing, preliminary results observed from recent testing indicated that emissions from semi coked coal are low, lower than raw coal, during the normal operating state when the fuel is left to burn out, but the start-up phase gave high emissions because lighting the fuel was difficult and large amounts of wood were necessary over a longer period of time than for raw coal. The resulting net emission reduction, therefore, was not yet convincing and needed more testing to understand the behavior, especially in other stoves and low pressure boilers. Another result was that emissions from wood and wood briquettes were higher than from coal. These are valuable indications that validate the hypothesis that fuel-stove combinations need to be tested together.

To scale up testing, the next series of fuel-stove testing should consider incorporating the following recommendations:

(i) Continued testing is required and particularly for new fuels and test these in different stoves. It is very interesting that a compressed raw coal briquette has now been produced; the coal is dried, homogenized, pulverized and densified into a uniform shape; additives could be added (is not done now). Such briquettes have an attractive appeal and look more modern that the other densified clay-briquettes that have been for sale for a few years now by the members of the Environmentally Friendly Briquettes Association. In addition, these briquettes or pellets are much cheaper to produce than SCC or SCC briquettes. In the right stove, they could burn more cleanly because of their predictable form and density. Different stove models have surfaced that apply different combustion principles; although these stoves have not been fully tested, their capacity to reduce pollution levels is promising, particularly during start-up and steady-state conditions

(ii) Any tests performed should reflect actual practices from the way the stoves are used in practice. Tests should be seen as the starting point of a more systematic effort to address emissions from individual household heating systems in ger areas. Household heating systems are actually more complicated to improve than popular perception suggests. Even large heat-only boilers use a standard fuel and are designed to operate within a limited range of operational conditions, whereas household stoves have more variable operating conditions. For example, even the fuels put in the stove may differ from time to time, and frequent starts and restarts are made. This makes designing a stove that performs well under this range of operating conditions a complex task.

(iii) The Government should insist on use of a standard protocol designed for small household heating stoves and behaviors for the tests; A testing protocol has been designed and presented in Annex B for consideration. This protocol reflects largely the heating cycle as practiced by households, from start-up, rapid heating up, slowly cooling down, and then refuelling and letting burn until the fire dies; a complete cycle may take more than 5 hours to finish. Emissions should be measured during all phases of the test to determine the accumulated level of emissions (Emission Factor), and this can be represented for the heat delivered, or for the quantity of fuel used or the energy content of the quantity fuel used. As a result of these tests, EFs can be compared for different stoves and different fuels to determine the fuel-stove combination that yields the lowest emissions.

(iv) The protocol for stoves connected to a heating wall and for furnaces with hot water circulation systems should now also be established.

(v) All the testing should be carried out in a properly equipped laboratory, available for those willing to test new fuels or new stoves. If this is not done, a solution will depend on the willingness of expertise outside Mongolia to carry out tests, and this will always be a second best solution;

(vi) The testing protocol such as the one proposed in Annex B could be used systematically to make test data consistent and comparable;

(vii) Provide sufficient time to test complete cycles of fueling and refueling (about more than 5 hours per test) because emission characteristics differ during the fueling cycle: visual and tested indications show that the largest emissions appear during the start-up of the stove and during refueling;, it appears that for traditional stoves the start-up emissions are very high and that during normal steady-state conditions emissions continue to increase;

(viii) Test the emissions levels of front and back lighting of the stove; with the fuel in the middle of the combustion chamber, one can light the fuel at the back (near the chimney) or at the front (near the fuel door and ash tray); it appears that back lighting promotes significantly cleaner combustion and reduces emissions. When more test data are available to demonstrate this significant difference, an information campaign should immediately be launched to promote back lighting and the reasons why. This would be a zero-cost solution to immediately reduce emissions from ger heating stoves. This is also most likely to work for all stoves and all fuels. Although back lighting as a practice initially might be somewhat more difficult to get used to for the household, once they master it they are likely to be willing to continue using it. An added benefit is that this practice reduces heat losses up the chimney and there will be an increase in fuel efficiency as the ignition period is extended. The explanation for this phenomenon is that if the fire is started at the end of the stove and the fuel pile, near the chimney, the flame front will travel through the pile of fuel towards the door at the front of the stove. All combustion gasses will therefore have to travel through the hot combustion zone where much of the PM can be destroyed;

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6.4 Conclusion

Based on the attitude expressed by surveyed households, it is clear that they know about air pollution problems in the city and how harmful this is to their health. They also understand that through the use of raw coal they themselves contribute to air pollution problems in the city. *Households also show willingness to adopt solutions such as alternative heating stoves and/or fuels. The general opinion toward improved stoves is positive and there is no apparent negative opinion toward improved stoves.* With regard to briquettes, the majority of households have very little information or ideas about briquettes. However, *a significant portion of households indicate their willingness to try briquettes and they believe that briquettes are less polluting than raw coal.* These findings are very promising for briquette producers and others who would like to promote their use.

The missing link is a scientific confirmation of the impact of the different stoves and fuels on air pollution reduction. This will need to be developed as soon as possible, and in any case it is recommended that fuels and stoves are fully characterized before they are allowed to hit the market. The tests that have recently been carried out are a confirmation of this conclusion.

7. Combustion Efficiency, Verification and Enforcement of Stove and Fuel Standards

This chapter provides a theoretical introduction to combustion issues and emissions, with a view to create more understanding not only about the issues involved, but also about standards and why it is important to address these technical issues through standards. While it is true that standards so far failed to regulate the equipment and the fuels used in the ger area heating systems in Ulaanbaatar, there is no reason why this cannot change in the future. The example of standards for kerosene stoves in South Africa is relevant for the case in Ulaanbaatar.

7.1 Principles of Combustion Efficiency

Combustion or burning entails a number of complex chemical reactions between a fuel and an oxidant resulting in the production of heat and/or light in the form of either a glow or flames. In a complete combustion reaction, a compound reacts with an oxidizing element, such as oxygen, and the products are compounds of each element in the fuel with the oxidizing element. For example:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + \text{heat}.$$

In reality, combustion processes are neither perfect nor complete. In flue gases from the combustion of coal or carbon compounds (hydrocarbons, wood etc.), both unburned carbon (as soot) and carbon compounds (CO and others) will be present. Also, when air is the oxidant, some nitrogen will be oxidized to various nitrogen oxides (NO_x).

The combustion efficiency expresses how clean the burn of the fuel was. The less clean, the more complex compounds of NO_x, SO_x, H_2S and particulate matter (PM) will be present. H_2S is more important than SO_2 because SO_2 is linked to the fuel contents and H_2S is related to combustion efficiency. Therefore, it is important to carry out combustion tests to measure these compounds and emissions. This needs to be done for different fuels and for different stoves.

Coal in Mongolia is typically composed of Carbon, moisture (30%), ash (5% for Alagtolgoi - 10% for Nalaikh), Sulphur (0.4%), volatiles (40-45%), and other substances or compounds. What is important is the level of moisture: this needs to be evaporated before the coal can burn well, and this reduces the effective heat output. The quantity known as lower heating value (LHV) (or net calorific value) is determined by subtracting the heat of vaporization of the water vapor from the higher heating value. This treats any H_2O formed as a vapor. The energy required to vaporize the water therefore is not realized as useful heat.

The ash level is important too, as this does not burn and so it does not contribute to the heat output. Briquettes normally have a high ash level (20-40%); although the heating value (per kg) of a high ash content fuel will be lower, the ash may retain some of the heat and release this over time: heat retention may be higher than fuels with a lower ash content. The volatiles will burn off immediately and determine to a certain extent how easily the coal fire can be ignited; a high volatile coal can normally be easily ignited.

Coal briquettes typically have a high ash content as clay is mixed into a coal slurry to form briquettes. At the same time, some additions such as calcium-rich compounds can be mixed in to contain the sulphur when the combustion takes place, reducing the SO_x emissions. When these briquettes are burnt, the original shape of the briquette may still be present in the stove due to the high ash content. Sawdust briquettes will have very low ash content and high volatile content: they burn quickly without leaving a lot of ashes. Semi-coked coal is coal that is heated so that the moisture and the volatiles are removed. The result is a higher carbon content fuel that is normally difficult to light and that burns hotter than raw coal.

Incomplete combustion occurs when there isn't enough oxygen to allow the fuel to react completely with the oxygen to produce CO_2 and H_2O, also when the combustion is quenched by a heat sink such as a cold solid surface (starting up of the stove). When a fuel burns poorly in the air, the reaction will yield CO_2 and H_2O, CO, pure carbon (soot or ash) and various other compounds such as H_2S, NO_x and PM.

The quality of combustion can be improved by changing the internal design of the stoves and boilers. A down-draft stove design is likely to burn more cleanly than an updraft design. In a down draft, the hot combustion air flows through the hot combustion zone on the grate before exiting through the chimney. Further improvements are achievable by catalytic after-burning devices (such as catalytic converters) or by the simple partial return of the exhaust gases into the combustion process or feeding fresh oxygen after the combustion zone (secondary combustion). Such devices are required by environmental legislation for cars in most countries, and in large combustion devices, such as thermal power plants, to reach legal emission standards. In the USA and Europe emissions standards are enforced for household heating stoves too.

Box 7.1 Semi-Coked Coal Production

Lump (20-100mm), bituminous coal and not lignite as used in Ulaanbaatar should be ground to 3 mm, then coked at 750°C in a vertical coker with direct heating using the pyrolysis gas and cleaned with scrubbers. Excess gas should be flared or used for a different thermal application.

The condensed hydrocarbons and water are collected in a tar/ammonia water separator and water is recycled to the scrubber; the tar/oil/water mixture containing ammonia, HCN, sulfur compounds, phenols and other organic – mostly toxic - matter as well as coal dust are collected in a tank. The environmental implications of waste water disposal is of great concern.

Briquettes should be prepared on a roller press using either imported starch or clay (22%) as binder, about doubling the ash content to about 50%, depending on coal ash content. The resulting fuel should be tested in a stove to determine the fuel efficiency and the emissions.

There is a real possibility to produce sawdust briquettes in Mongolia at a large scale. This may sound strange, since there are vast areas without a single tree, but the Northern parts are well forested. In fact, for optimum growth of these forests and for fire protection, these forests need yearly maintenance cuts which at the moment are all burnt *in situ*. Rather than burning, these resources could also be transformed into energy. In addition, there are large quantities of sawdust that could be transformed into briquettes. The technology is not in question, the economics of the production and transportation need to be proven prior to launching such a venture. See Annex G for more details.

7.2 Standards

Standards are in force for most durable consumer goods, whether these are cars, thermometers, or electric heaters. Such standards are in place and enforced in the Western world for cooking and heating stoves, for safety aspects and sometimes also for environmental reasons, but this is not the case in many emerging economies. Even if there are standards, often they are not enforced. In a few countries including Mongolia standards regarding stoves and fuels exist but are generally not enforced. However, it would make sense to start enforcing sensible standards in an effort to cleanup the air around UB. In this section, standards are discussed, first the existing situation, then how standards could be used as a tool for air pollution reduction.

7.2.1 Stove Standards

Existing standards.

The three main standards dealing with coal and boilers are: (a) MNS 5216 2002 that deals with household stoves, (b) MNS 5041: 2001 that deals with domestic boilers and furnaces below 100 kW, and (c) MNS 5679: 2006 that deals with solid fuels in domestic boilers. The household stove standard is the result of the project ***Improved household stoves in Mongolian urban centers*** that was implemented by MNE in conjunction with UBMG and financed by GEF. A competitive method was used to identify appropriate fuel efficient stoves. Four stove models were accepted and after laboratory tests were subjected to marketing tests. Based on these data, the PIU for the project proposed a standard for new heating stoves that was accepted by the Agency for Standardization and Metrology. This standard addresses the quality of the stove construction, maximum fuel consumption, and maximum soot emissions. The second standard deals with larger boilers using solid fuels such as Heat only Boilers for schools and other institutions, and factories, etc. The standard assumes regular inspections of the equipment. There is no lower limit to the capacity mentioned in this standard and technically household stoves would have to meet the minimum standards it contains. The third standard deals with combustion of solid fuels and provides the upper limit for carbon monoxide (CO) emissions. It distinguishes between bituminous coal, anthracite, and wood: the ratio CO to CO_2 cannot be greater than 0.5% for Anthracite burners, 2% for coal burners, and 4% for wood burners.

Assessment of standards.

Although the household stove standard is a good start, it could be improved to incorporate the fact that stove and fuels used cannot be dissociated: the two critical measures to determine the level of emissions are: (a) fuel consumption for a standard heating task (thermal efficiency), and (b) emission factors, or emissions per MJ of fuel used (combustion efficiency) during the same heating task. They may also set a cooking task, although in terms of energy consumption coal consumption for cooking will be much lower than space heating and thus less important. The standard heating task should be defined as to keep a standard room warm at 20 C during 24 hours with an average outdoor temperature of – 20 C. Emissions to consider are CO, SO_2, H_2S, TSP[53], PM_{10} and $PM_{2.5}$. The fuel consumption during the 24 hour testing period should be measured as well as the emissions from the chimney. It is recommended that such new standard is developed and approved.

53 Total Suspended Particulates in the stack emissions

Regarding indoor air quality, the main danger observed with current stoves (traditional as well as improved!) is the CO level in the home. A modest CO level is deadly: to regulate the heat output of stoves, a damper is normally placed at the foot of the chimney. This would choke the outgoing gases with the intent of lowering the combustion rate by not drawing as much fresh air into the stove. The result is usually poor combustion and the generation of much CO that cannot escape through the chimney because it is partially or completely closed. The CO therefore escapes into the room through numerous small holes in the metalwork. It is recommended that in the future new stoves have (i) a mechanism that regulates the air-inlet and control the power output; (ii) no chimney damper; and (iii) a better construction quality with no holes present in the stove or the weldings. This places the stove under negative air pressure, ensuring that air leaks in and not out. None of the traditional - or improved - stoves operate in this manner. If there is a damper in the chimney, households will need to be informed through an awareness campaign about the dangers for their family.

The 100 kW boiler and furnace standard is meant for community applications such as schools, apartment buildings, etc. and is not really meant to include household stoves and boilers that normally have a capacity of 6-20 kW. It is recommended to develop two separate standards, one for household heating systems and one for larger community organization heating systems. The household standard should include separate provisions for ger stoves, heating wall stoves, and low pressure boilers. It is recommended that a stove will only be certified for certain stated fuels in line with their performance as described above. With the two new Standards as described, the Standard for solid fuel combustion will be rendered obsolete.

At the moment, none of the tested household stoves complies with the MNS 5679: 2006 standard. Moreover, heating wall stoves and low pressure boilers have not been subject to tests at all. Unfortunately, no stove models have been identified so far that would comply with even this standard, although the reference burner showed that it is technically feasible to do so. It is recommended that an effort is carried out to develop stove models in Mongolia - or identify these from elsewhere - that would comply with the new standards and therefore emit much less harmful emissions.

Table 29: Existing and Revised Standards

	Existing standard	**New standard**
Quality	Deals with construction strength and quality	Should deal with safety: no CO emissions, therefore no damper in the chimney and no holes in stove to allow leaks, but air control in the stove itself; touch open fire could result in burns or even fire setting to the room
Combustion	Gives maximum fuel consumption rate	Ibid, but it should be related to a normalized temperature and also to the type of fuel used
Emissions	Gives some emission rates, but these are not correctly defined.	Give properly defined emission factors that can't be exceeded

7.2.2 Enforcement of standards

Standards are only useful if they are enforceable and enforced. It helps if the involved industries assist in drafting the new standard, see also Box 6.2 for the experience in South Africa on standards for kerosene stoves. At the moment, standards that exist are not enforced and it will be difficult to enforce now. Instead, it is recommended that verification of the standard at entry takes place, i.e., before equipment enters the market place; this is the easiest to realize and will make sure that, at a minimum, all new equipment complies. This would require (a) the government to set the standards; (b) a certifying agency to check for compliance with the standard and to certify appliances before they are allowed to enter the market; and (c) certain planned and random verification tests to be conducted over time by another independent agency.

Current responsibilities for enforcement.

The Agency for Standardization and Metrology (ASM) is charged with the development of appropriate standards. It has the right to develop a standard on its own initiative, but it can also be requested to develop a new standard by an outside agency. It is proposed that a Joint Technical Committee (JTC) be formed from those permanent Technical Committees representing fuels, energy, science and possibly housing because the subject of stoves is of interest to several of the about 40 existing TC's. The JTC may form an informal 'Working Group' of experts to advise and draft parts or all of the Standard, however the draft will be voted on and accepted by the JTC.

Box 7.2: Standard for Kerosene Stoves, South Africa.

Many deaths occur in South Africa as a result of the use of poorly designed kerosene stoves. The Government asked stove producers to voluntarily develop better stoves, particularly ones that stop burning when tipped over and ones that have lower emissions. These were developed only after better standards were developed (in conjunction with the producers) and officially adopted, and after the Government conveyed the message that it would in fact enforce these standards after a certain grace period. As a result, there are now a few better stove models available, complying withy the new standards, and many households bought new stoves. The interesting fact is that many households opted for a safer, better looking and somewhat more expensive stove rather than the cheapest option.

The State Specialized Inspection Agency is charged with verification of compliance of the various standards. It is obvious that the household stove standard is not being enforced now, nor is it enforceable without a special mechanism and additional, suitably trained staff.

The existing Stove NGO is another way to enforce the standard: Auto regulation. This association only sells and promotes stoves that comply with the standard. It also actively promotes the use of heating walls, for which no standard exists, and it tries to avoid the production of unimproved traditional stoves through education and raising awareness. It will take quite an effort to enlarge this self regulation capacity to cover the whole stove market within a reasonable time.

Verification capacity.

The State Specialized Inspection Agency (SSIA) is charged with verifying the compliance with approved standards, but it lacks the capacity to do so in case of household heating systems. As mentioned above, first better standards need to be set, publicized and feedback solicited from interested industries, and analyzed. There are ILO guidelines for how this is done. Then, a certified laboratory is required to verify, on behalf of the SSIA that the standards are appropriate and applicable. At the moment, this testing and verification capacity does not exist, particularly with respect to emission testing. An essential element of these tests is the ability to measure the power output of a stove during the whole testing period. Stoves[54] plus fuel and testing apparatus need to be placed on a scale with their weight checked every few minutes. Emission factors need to be determined, which requires simultaneous measuring of (i) the fuel consumption; (ii) excess air flow in the chimney; (iii) and selected emissions. These emissions measurements cannot currently be carried out in Ulaanbaatar laboratories.

The same laboratory that tests the standards could also certify equipment for compliance with the standard, although this could also be carried out by another qualified laboratory or laboratories. However, certification tests for compliance should only be done at a laboratory which is itself certified as competent to do so. In practical terms, stove manufacturers would submit their appliances to a certifying laboratory which will test them for compliance with the relevant standard and certify the product on behalf of the certifying agency. The stove manufacturer may then sell certified and suitably marked designs, components or stoves.

Enforcement capacity.

A practical mechanism needs to be developed; at the moment it is possible to measure within reasonable time the performance of a few hundred low pressure boilers of which the locations are known, but it is impossible to do the same for all estimated 150,000 household heating systems currently in use in ger areas. It is much more practical if new stoves are certified at source, assuming that these stoves continue to comply with the standard over time, and that non-certified stoves are no longer sold. For this to happen, a combination of scheduled tests and self-regulation is needed.

For regular verification of the already certified models, a dedicated laboratory needs to carry out random and scheduled tests. Once a year inspectors would randomly select from any manufacturer a limited sample of certified stoves for compliance testing. Alternatively, if complaints about certain stove models surface, the dedicated laboratory may carry out additional tests as and when they deem appropriate. The Standard should contain details on how a non-compliant product loses its certification.

Self regulation is needed so that stove makers do not manufacture uncertified models any more. The fact that a subsidy could be available only for certified models may help tremendously. Awareness among consumers should also be raised, so that they don’t want to buy traditional and non-certified stoves any longer and will report producers to the inspectorate. Some promotional and controlling activities may need to be realized at popular stove selling spots for some time, such as Narantuul market.

7.3 Implementation Strategy

Irrespective if a ger area heating project will be implemented or not, it is recommended that standards for ger area heating systems will be improved and enforced, and that the existing institutional capacity to realize this will be reinforced. This capacity includes the agencies for

[54] Sometimes more than 100 kg.

development and enforcement of standards as well as the industries to produce equipment compliant with these standards.

In principle, there are two types of standards: *Voluntary Standards* that can be implemented and monitored by the Stove NGO (for example) and other involved industrial partners, and *Compulsory Standards* that involve everyone and particularly the regulating authorities such as ASM and SSIA, and industrial partners. Usually a compulsory standard is initially preceded by having the proposed standard made voluntary for a specified time (1 or 2 years) during which time the manufacturers try to develop and market compliant products – so-called interim targets. During this development time products will come in for testing and the test method is examined to see if the testers get the same results as the developers, and agreement to edit the testing is made if need be; this avoids law suits over poor word craft. After the voluntary time, an enforcement agent is appointed. The Standard could be, instead of being entirely made compulsory, broken into sections that will and will not be declared law. For example, the emissions target can be made compulsory, while the durability and thermal efficiency sections are not. No product may be sold or imported that does not meet those relevant sections of the Standard that are now law (compulsory). A certificate of compliance (obtained after testing) must be accessible to anyone who asks, usually at the vendors place; products can be marked and promoted as compliant; fraud can be detected; reporting procedures are publicized.

After a standard or a portion of a standard is made compulsory, it will be illegal to sell non-compliant products, compliance certificates should be available, routine testing is in place, and designs can be certified for replication, etc. As there are still many unresolved problems associated with stoves, radiant hot water boilers and heating walls, time must be allowed for an implementing agent(s) to ensure there are products available if and when 'the curtain comes down'. An unenforceable standard is no different from a standard that rules out all existing products. It will simply be ignored. The example of standards for kerosene cooking stoves in South Africa shows that once appropriate standards are about to be enforced, industries will take it seriously and develop new stove models.

Stove industries are likely not capable of developing better stoves without significant technical assistance. The Improved Household Heating Stove project showed that the industries had developed models that saved fuel but not reduced emissions. There are some 40 stove producing firms at the moment that mainly sell through the central market. There are a few larger steel-processing companies that could manufacture stoves on a large-scale, but they cannot develop new stove models. It is recommended that a tailored program is launched to develop low-emission stoves for different fuels that are on the market at the moment or that will be on the market soon, such as semi-coked coal or briquettes. Interaction between stove producers and international stove parties should be encouraged strongly, particularly focusing on South Africa where a lot of research capacity exists. The climate in e.g. Johannesburg is such that households need stoves for heating and they do so with poorly performing bituminous coal burning stoves, polluting the air to similar magnitudes as found in Ulaanbaatar. A research and testing center has been established to address these issues.[55]

[55] The Sustainable Energy Technology Testing and Research (SeTAR) Center, Faculty of Art, Design and Architecture, Bunting Road Campus, University of Johannesburg, has a program to develop low-cost, low-emissions coal stoves for the marginalized communities in the Vaal Triangle highveld areas.

In addition, stoves that would comply with the standard or indeed even stricter air pollution standards such as in California exist (See Annex H). There are solid fuel stoves not only in the USA but also in Germany, in the UK, in China, the Czech Republic, and Korea that would meet the Mongolian criteria. The main issue is that these stoves are made for a richer type of client who often uses it as his back up heater: prices are high. Nevertheless, it is recommended that an effort be launched to see how stove producers in these countries could be invited to become active here in Mongolia. After all, supplying 150,000 stoves in a relatively short period is quite a large market for which scale economies might be possible.

In the past, the Government in played a role in convincing households to realize an equipment switch, but the household survey showed that this was not very successful. Free stoves were handed out but cannot be traced any more: the household survey shows that the majority of improved stoves are 1-3 years old, much newer than when the hand-out took place; the method followed just before the Improved Household Stove project closed down, Output Based-Aid (OBA), was more successful in delivering some 2000 stoves in a relatively short period. It is now time to combine enforcement of better stove standards with mechanisms providing incentives to households to encourage switching of stoves.

7.4 Conclusions

It is recommended that:

- New standards are developed for ger area household heating systems, anticipating continuation of observed trends whereby households installing heating walls and low pressure boiler systems, and using new fuels such as briquettes of compressed coal or semi-coked coal. The new standards should focus on safety and on emissions, and to a lesser extent on fuel consumption.
- Procure laboratory equipment to enable regular testing and certification of heating systems (See equipment list & estimated costs in Annex E).
- Test equipment with a unified and approved protocol, which could be based on the protocol developed by the consultant in March 2008 and discussed with the key laboratories in Ulaanbaatar[56]. Sufficient training and supervision should be provided. Once the protocol is in place, different stove models can be certified.
- Assist producers and manufacturers to develop compliant stove models, for ger heating systems, for heating wall systems, and for low pressure boiler systems.
- Set up a unified certification system, including (i) qualified laboratories with sufficient skills and equipment to carry out testing and certification of heating systems; (ii) an enforceable certification program that creates incentives for suppliers to participate (rather than avoid); and (iii) administrative controls for non-compliant appliances and suppliers.

[56] CLEM; Nuclear physics laboratory at NUM, UBMG/AQD.

8. Discussion, Conclusions and Recommendations

8.1 Conclusions

Winter air pollution levels in Ulaanbaatar are very high, affecting general health conditions at great economic costs, and therefore urgently need to be addressed. Some 99% of all households in ger areas find that air pollution in Ulaanbaatar is very high or high. There is also no doubt among ger area households that heating of their own homes considerably contributes to this problem. More than 95% of households say that the contribution of ger stoves to air pollution is very high or high. In fact, 40-70% of the $PM_{2.5}$ emissions in town are attributed to the use of coal stoves in ger areas. Most stoves are of low quality and burn poorly with the result that they pollute the air.

Most combustion gases from the burning coal escape into the atmosphere through the attached chimney; virtually all stoves have a chimney. If stoves, or the attached chimney, are leaky, combustion gases can enter into the room and indoor air could become polluted too. However, since the outdoor air is of such poor quality, this trickles into the homes through the door, vents and/or holes in the walls[57]. The priority therefore is to improve outdoor air quality, as this affects ger area residents as well as all other residents in Ulaanbaatar. Improving indoor air quality is almost intrinsic in the solutions pursued.

The solutions to this are using better stoves, cleaner fuels, or both. Household generally feel that they can and should contribute towards solutions, but for the poorest a support mechanism will be needed. Some 75% of the households state that they think that improved stoves would contribute to a cleaner air and 60% that briquettes would do the same. For both options, 40% of the households indicate that they will use these in the future and 60% if subsidies are involved. Households do not have a clear preference for stoves or for briquettes, but they certainly would like their heating costs to remain at the same level or to decrease. Many official counterparts do have a preference to switch fuels because it is an ubiquitous solution – it can be placed in any equipment without switching the equipment. While the fuel may have some effect, ignoring the equipment in which it is burned will significantly limit potential emission reductions. This study concludes that there is no evidence available at the writing of this report that suggests any one solution will meet the "smokeless" objective.

At the moment it is not possible to verify emissions from stove-fuel combinations as the technical capacity does not exist: the necessary equipment is not available in Mongolia. Some tests have recently been conducted but a more systematic approach would help build confidence in proposed solutions. This report finds that fuels and stoves cannot be detached one from the other when evaluating emissions reduction potential: a stove is needed to burn fuel, and emissions stem from combination of the two and need to be as low as realistically possible.

Somewhat better stoves - improved stoves that reduce the fuel consumption - are available on the market but very few people use them (about 3%). Improved stoves that reduce the fuel consumption do not necessarily reduce emissions too, although it is likely due to the reduced consumption. However, cleaner burning stoves are not available on the market and people have no choice but to use polluting stoves.

[57] Air needed for combustion is drawn from the room; this air is replaced by cold and polluted air from outside.

Heating is necessary for sheer survival, for 5-6 months out of the year when the temperatures may drop to below -30 C. Average heating costs approach 20% of disposable income, which is high for most ger area households and may approach 40% for the poorest households, which is extremely high by almost any standard. Therefore, it is unrealistic to think that the poorest households can buy a new stove or switch fuels without some form of financial assistance.

Preliminary emission testing of improved stoves suggests that current models available in Ulaanbaatar may not have the capacity to sufficiently reduce air pollution and emissions; even if fuel savings of 10-30% can be obtained, this may not be enough to substantially reduce the air pollution. In fact, it is unlikely that air pollution problems can be solved with the currently available combinations of stoves and fuels. Different kind of solutions will therefore be needed, both long-term and short term. In what follows, several ways to intervene are discussed.

8.2 Possible Interventions

8.2.1 Long term

Resettling of ger area residents into apartments connected to district heating is among the potential long-term air pollution solutions that are frequently discussed. They would then refrain from using coal stoves and instead use the district heating system. This ultimate long-term solution is included in Government's air pollution reduction measures Resolution 218. As a result of this Resolution construction of several large-scale apartment buildings is now under way. Nevertheless, the realization of this solution is likely to take a long time and much budget will be required before all ger area households effectively live in apartments. The survey respondents concur with this solution as 97% agreed or highly agreed that moving ger area residents into apartments is a good course of action; nevertheless, it falls outside the scope of the present work.

Other possible long-term solutions include the use of non-solid fuel such as LPG, kerosene, electricity, or extending the district heating system to include individual houses in ger areas. See Box 8.1 for more details about these options. As and when incomes rise, households are likely to start looking for more modern and convenient sources of energy. In a way this has already been observed with the increased use of heating walls and low pressure boilers. Non-solid fuels have higher energy content per unit weight than unprocessed coal and are typically used in mass produced energy-efficient stoves. Some 70% of the survey respondents say that electricity would be a good heating energy source. However, some 40% also says that electricity is cheaper to use than coal, which is currently not the case. They may refer to the cheap night tariff, even though this is slightly more expensive than coal on a heat provided basis, or they may or intend to have an unmetered electrical connection.

Table 30: Heating fuel details – Prices and Costs

Fuel prices in 2007/2008 season	TG/unit	kg/unit	MJ/kg	TG/MJ	Heating cost/MJ [58]
coal, truck (kg)	130000	2500	14.7	3.5	5.1
coal, bag (kg)	1200	18	14.7	4.5	6.5
Wood	1200	8	15.5	9.7	13.8
briquettes - sawdust (kg)	1200	18	20.3	3.3	4.7
coal briquettes burkh. (kg)	1200	18	17.0	3.9	5.6
coal briquettes yontan (kg)	200	3	17.6	3.8	5.4
semi-coked coal briquettes (kg)	1200	14	25.8	3.3	4.7

[58] The efficiency of the stove is incorporated; for solid fuel: 75%, of gaseous, liquid and electric fuel 85%

LPG (per liter)	900	45	20.0	26.7
Kerosene (liter)	650	35	18.6	24.8
electricity (/kWh)	50	3.6	13.9	16.3
electricity (/kWh) night time	22	3.6	6.1	7.2

Source: ASTAE survey

Fuel switching will not be easy to achieve as the cost of heating with raw coal is low compared to modern fuels (see Table 30) all alternatives are more expensive. 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. In addition, an important social equity issue also plays a role: households comfortably living in apartments pay a low monthly fee to cover district heating costs[59] whereas the poorest households living in ger areas have to pay the full cost of individual heating. Ger area households have low quality heating, they have to get up several times per night to maintain the fire, while apartments enjoy high quality heating and pay less for this.

Box 8.1: Challenges to DH, Electricity and LPG in Ger Areas

- Connection to DH for ger area households: The additional infrastructure needed for connecting all ger households to the DH system will be high; losses will also be high because the distribution lines from house to house will be outside (in an apartment building these are inside); metering will be difficult; management of the DH system is already complicated and these additional challenges are not really welcome; it is therefore not realistic to think that the heating company is ready to connect ger area households to the DH grid, unless the built up area requires HVAC systems (eg. apartment buildings, or incomes rise very quickly).
- Use of electricity for heating by ger area households: The additional load for heating ger households has been roughly estimated at 600 MW[60], or a doubling of the existing generation capacity in the whole country. Investments for developing this infrastructure would amount to more than $1.4 billion and this would be an unbearable burden on the government. Also for households the cost of heating with electricity will be much higher than with coal: ger area households pay roughly 250k Tg/yr for heating with coal[61]; with electricity the monthly heating bill would be MNT 82,000 or almost double compared to coal – and this includes using the cheaper night time tariff. They also will need to buy an electric heating stove. The cost of a MJ delivered to the room is 5.1 TG/MJ for coal purchased by truck once a year, 6.6 TG/MJ for coal purchased in bags, and 13.2 TG/MJ for electricity, see Table 14 below. Ger households rated access to electricity for heating very high in the survey; the survey also found that 5% has the equipment to supplement heat from their coal stove with a low-cost electric stove.
- LPG: taxies and some limited household cooking are the main uses of LPG; gas has been introduced not so long ago for taxies and the market is still small. Scale economies are an important factor for determining the final price of LPG; LPG needs to be imported from Russia at relatively high costs. In fact, it is more expensive to cook/heat with LPG than it is with electricity and this will limit the potential use of LPG for space heating. See Table 30 for an overview of the

[59] MNT 256 per m^2 of floor space and MNT 1000 per person. For a 100 m2 apartment, a typical payment would be less than MNT 30,000, where as average expenditures for ger district households are around MNT37,000 per month.
[60] See Annex D Case Study on Electrict Heating in Beijing.
[61] The household survey found MNT 174,000 for the 2006/7 heating season. Corrected for the coal price increase, for the 2007/8 heating season the average heating costs would be roughly MNT 250,000.

different fuels and their costs if used for heating.

Observations show the tendency for ger area households to improve their own living conditions by constructing one or two story wooden or brick homes, sometimes over the course of several years. Today only some 43% of ger area households still live in a ger as their main residence and more than half have constructed a more durable single family detached building. The relative number of gers has decreased over time and that of more permanent structures continues to increase: Ger area households appear to be settling into a more comfortable life. Of the non-ger households, 14% currently use a stove, 69% use a heating wall, and 16% use a low pressure boiler. Some 70% of all respondents agree that heating walls are a good solution and 30% wants to construct one in the future while 40% wants to install a low pressure boiler. In other words, households are looking for improving their situation rather than moving into apartments in the near future. The impact will be more air pollution, as heating wall stoves or low pressure boilers that burn cleanly currently do not exist and per household fuel consumption per household will increase. Heating wall stoves consume on average 30% more fuel than ger stoves and low pressure boilers as much as 70% more mainly because they are placed in larger homes. It is clear that something needs to be done on the stove side to ensure that cleaner burning devices become available.

8.2.2 Short term

Until these more long-term solutions fall into place, it is recommended to actively pursue short-term options. These would provide interim or even immediate solutions that could remain in place for a relatively long period. Such solutions include the promotion and adoption of improved heating systems as a relatively simple and low-cost measure that can quickly reduce fuel consumption and emission levels under certain conditions. This is essentially different from what was done under the Improved Heating Stoves project, where the focus was mainly on the thermal efficiency of stoves and the reduction of fuel consumption.

One might rightly ask whether the government should be involved in promoting improved heating systems. After all, as previously indicated, households have heated their ger in traditional ways for thousands of years. Without substantial incentives to promote behavioral changes, entrenched customs tend to persist, and in the case of Ulaanbaatar these lead to severe air pollution. Subsidies may offer a major incentive, as they earlier did in the Improved Heating Stove project. Another incentive could be users' recognition that switching to improved heating systems carries a high value for them: assist the community to clean up the air.

Why then do many households fail to perceive this value when it comes to improved coal stoves? One possible reason is that the health costs associated with using traditional stoves are either unknown or unproven. The result of a study to look into more details is forthcoming. Another reason is that optimal designs may not automatically be appreciated by users: if a new model resolves one problem it may create other difficulties for the user. For example, emphasis on achieving greater stove combustion efficiency and cleaner burning via the use of a smaller firebox may inadvertently result in the perception that the stove is too small to heat the house or to cook a meal; as a result, the value of the better stove is diminished in the eyes of the consumer. Finally, some households may be too poor to invest in a new heating system. Design trade-offs as usability, ease of heating and cooking, lighting speed, costs and end-use efficiency must be addressed in an integrated way in order to develop viable markets for improved stoves.

The Government has an interest in promoting cleaner fuels that will be produced by private suppliers. These fuels could be in the form of coal-based or upgrade coal briquettes. Since there is no regular supply of these briquettes yet, they should be tested in a laboratory in conjunction with different stoves. An inventory of their capacity to reduce emissions should be made before the new fuels are sold on the market.

Technical design problems with coal stoves will need to be solved. First of all, the traditional stoves are not designed for using coal but for using firewood, and this has an impact on fuel consumption and emissions, which are both higher than necessary. The same is true because stoves take warm air from the inside the home instead of cold air from the outside and this unnecessarily increases the heating requirements. Then there is a quality problem as some stoves leak air, lack a regulating valve, and are too large for the task at hand; some chimneys are poorly attached to the stove or leak, and have a close-off valve to smolder the fire. Some of these might cause outright safety problems, such as CO entering into the room with possible lethal consequences. Although the currently available improved stoves have been user tested and were well liked during the tests, their sales have not taken off and only a small percentage of the population actually uses one. The survey showed that 3% of the respondents have an improved stove. However, these stoves have not been sufficiently tested in the laboratory to know if they reduce particulate emissions: fuel efficiency tests have been carried out, but emission tests have not for a lack of capacity and equipment.

Better and more designs are necessary if stoves are to become part of the short term solution to air pollution problems. Conditions that play a role are safety, comfort, performance and costs. Leaky stoves or chimneys are out of the question and because many households in order to reduce the price buy a stove made from second hand steel, minimum quality standards need to be set. Standards need to be verified too, and this should be an ongoing process. For end-users, it should be possible to manage the heat output through a control mechanism that allows the heat to be turned down without risk of CO poisoning. Households would prefer to have a stove that burns longer, but stoves with a simple fuel hopper[62] do not exist. It should be possible to put customary cooking vessels on top of the stove.

Performance of the stove in terms of fuel consumption is easy to verify, but for air pollution control emission of pollutants is more important and should be measured. Both fuel consumption and emissions depend on the stove design and the type of fuel used, and such tests should be carried out before new stove models are put on the market. Three aspects play a role to realize such stoves: (i) more interaction between users, manufacturers and designers to develop stoves that are appreciated by households and have a high performance; (ii) it will be very important to have data from ongoing monitoring and evaluation fed back to manufacturers and designers for fine-tuning, as well as politicians for continuing support; and (iii) technical design and infrastructure consisting of laboratories, universities, foreign specialists, UBMC government and manufacturers. Stoves should be designed with a particular fuel type in mind, tested and verified in the laboratory, tested by households, and then handed over to market parties to work on finalize and stylize the design, and finally reduce the manufacturing costs.

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[62] A simple device to continuously feed the stove with new fuel; the most simple hoppers are gravity fed; more complex ones use an electric motor. Hoppers work best if the coal size is small compared to the feeding hole in the stove.

Stove promotion and market development will need to take place to ensure that households understand what to buy, where to buy it, and why it is advisable to buy now. Most successful improved stove programs aim to promote the buying and selling of stoves in the retail marketplace[63]. But it is impractical to expect the private sector, usually small entrepreneurs, to bear all the costs of stove development and promotion. The government should therefore support the market development process. The Government and donors could assist in the formulation of policies that provide private-sector operators incentives to produce, distribute, and sell improved stoves. This assistance could be in the form of providing technical standards, credit facilities for stove makers, facilitation of the availability of raw materials and manufactured parts, and promotional support. A close collaboration between manufacturers and the UBMC government is required, not only for the promotional campaigns but also for the quality control aspects as well as for the subsidy mechanism.

International experience shows that *well targeted subsidies and equitable pricing* are an integral part of all improved stove programs. The issue is not whether subsidies are needed but how they are administered. Around the world, donor-funded programs—especially small ones with targeted communities or households—have provided large stove subsidies. But when scaled up to the national level, such programs become less sustainable if no changes are made because of the larger amounts of financing involved. Moreover, when donors and governments are involved in selecting program participants and solutions, programs often go awry. The most successful ones have involved little or no stove subsidies; rather, subsidies have been directed toward technical assistance, quality control, and the broad array of design and testing activities that support market development. In the case of Mongolia, direct financial support will be needed to ensure that the poorest segments of the population will be able to afford the new heating systems too.

Institutional support is required between different organizations. It does not make sense if each institution pursues its own objectives. The Ministry of Fuel and Energy, the Ministry of Environment and Nature, and the UBMG should collaborate to ensure that all viable options can be pursued, using market development as the basic strategy for realizing the options. In addition, the laboratories and the institutions working on design and verification/enforcement of standards should all participate too, as should the private sector that will need to commercially produce briquettes and stoves.

Most successful improved stove programs in the World have had dedicated implementation groups responsive to user needs and preferences; well-defined populations that need the improved stoves; and durable, high-quality models. Whether China's rural energy units or Vietnam's Women's Union, such outreach groups have focused on improving energy services for consumers. As the world's main stove users, women have sometimes succeeded via women's groups—particularly those supported by microfinance agencies—in promoting improved stoves and other programs[64]. In addition, significant international evidence suggests that improved stove programs should target regions with the greatest need, which in the case of Mongolia is clear with a focus on Ulaanbaatar. Finally, effective programs must disseminate reliable, durable solutions.

If *integrated into broader social and health initiatives* that enhance welfare and improve overall cooking or heating practices, improved stove programs are more likely to succeed. In Guatemala,

[63] Barnes, Douglas, Priti Kumar, and Keith Openshaw. 2008. Cleaner Heaths, Better Homes: Improved Stoves for India and the Developing World. ESMAP Draft Report, Washington DC.
[64] Cecelski 2000; Shailaja 2000

for example, where many rural households now use improved stoves, multiple ways have been found to promote the stoves. The primary mechanism has been a government social fund that communities can use for a variety of purposes, including the purchase of a government-approved stove model with proven social acceptance among rural residents; valued at US$ 50–100, this new model has become a popular use of the fund. In addition, local NGOs without access to the social fund, but with strong support from international development agencies, have offered rural consumers a wide variety of stove designs.

To date, the health ministry and related agencies have had little involvement in the improved stove program. They should be at the forefront of such efforts—in cooperation with UBMG government, schools, and health services units—to remove indoor and outdoor pollution and improve household air quality. The focus of an awareness-raising campaign to promote better heating systems could be on causes of respiratory illness. Such efforts could be linked to educating consumers about the need for better ventilation; the role of chimneys in smoke removal; and the importance of keeping children, especially infants, away from smoke-filled environments. Microfinance organizations, notably Grameen Shakti in Bangladesh, have been effective in promoting improved stoves. The participation of such organizations has been beneficial in several ways. First, many of them have women as their main customers. Second, by offering small loans that can be paid off over time, appliances beyond the financial means of poorer households become more affordable; using credit, stoves with a life span of 5–10 years can be paid off well within this period. Third, such organizations have cared about the quality of the appliances offered under their programs and have guaranteed their products for designated time periods.

Ensuring the *quality of improved stoves* and their component parts has been another hallmark of successful programs worldwide. Many countries have achieved better quality control via centralized production of stoves and stove parts. This solution has proven effective in countries with a high degree of urban stove use; all-metal stoves or insulated ceramic stoves with a metal casing, including a door, are produced and sold in the marketplace, along with other consumer goods. The stoves are relatively small and can be purchased off the shelf. With appropriate technical support for correct designs, Mongolia's future programs could adopt such a system.

8.2.3 Overview of the options

The following Table shows the merits of the different options.

Table 31: Overview of possible Options

Type of Option	Time period	Pro	Contra
Move ger area households into apartments	Long-term	Ultimate solution, providing the largest benefits in terms of living conditions; lower operational heating costs for households	Expensive; public construction investments are high, Maybe not every household wants to move.
Use of non-solid fuels, LPG and electricity	Long-term	Provide better heating solutions without moving households	High operational costs for households due to expensive fuel. Public infrastructure for electricity generation and distribution expensive.
Connect to District Heating system	Long-term	Good heating solution at possibly relatively low public investment	Very high technical losses due to multitude of small customers
Semi-coked coal briquettes	Short-medium term	Could provide high-heating content fuel, private sector Appear "smokeless" but after ignition	Medium-High investment costs and operational costs Stove design may need to be adapted – needs emissions verification If subsidized fuel provided, prevention of leakage to non targeted households will be needed Fuel takes longer to light, so more wood or another quicker lighting technique is needed
Sawdust Briquettes	Medium to Short-term	Well liked fuel by households, is already in production, private sector	Fuel cannot be produced in Ulaanbaatar but near the forests or sawmills. Stove design may need to be adapted – needs emissions verification
Conditioned coal (dried, small pieces)	Short-term	Low cost, private sector, immediate solution	Stove design may need to be adapted – needs emissions verification
Compressed coal briquettes	Short-term	Low but somewhat higher investments than conditioned	Stove design may need to be adapted – needs emissions

		coal, private sector, immediate solution	verification
Different stoves	Short-term	Could be appreciated by households, particularly if designed in participatory way, private sector.	Needs emissions verification in combination with fuel used.

From Table 31 it is clear that: (i) there is not one solution but several simultaneous partial-solutions; and (ii) before any of the short-term partial solutions can be promoted, tests need to be carried out to verify emission levels.

8.2.4 Economic considerations

For the Government to be involved in promoting more efficient heating systems, there will have to be considerable economic and social benefits coming out of a program to replace stoves for more fuel efficient models that emit less CO, CO_2, H_2S and PM emissions with or without the use of cleaner fuels. A reduction in the consumption of coal will:

- reduce the household heating bill; this has a positive socio-economic benefit;
- reduce the emissions of CO_2; this has a positive global environmental benefit;
- reduce the emissions of CO, H_2S and PM; this has immediate and long-term health benefits and will extend the length of life.

A stylized example of the potential economic benefits presented in Box 8.2 gives a clear justification for relative large subsidies. From the household perspective, investing in an improved stove makes sense too and the Financial Rate of Return for investing in an improved stove is positive. There are a few caveats regarding this analysis and particularly regarding the data used as there are three independent surveys and tests, each with different results. As a reminder, please note that the fuel consumption is a function of the stove type used, type of fuel used, practices of the household in keeping the home warm, and the actual climatic conditions, making it somewhat difficult to compare the results directly: (i) laboratory tests followed up by household consumption tests done a few years ago by the PIU of the Improved Heating Stoves Project; this test found that households saved about 40% of their fuel consumption and reduce their consumption from 5 to 3 t of coal per year; the results concurred with laboratory tests; (ii) the 1000 sample household survey (2008) that found that households with an improved stove are generally richer than households with a traditional stove and consumed more fuel – however, the sample was not large enough to correct for the income dependence; and (iii) the 2008 household consumption tests that found that households with an improved stove reduced their energy consumption by some 8-15%, depending on the exact type of stove and type of fuel used.

Box 8.2 Stylized Example of Potential Economic Benefits

The total coal consumption for the six ger areas of 546,000 t of coal at $50/t, a fuel saving of 35% if the switch-out program is fully completed, and a reduction in emissions of 80%, the annual economic benefits would amount to $9.5m for a 191,000 t reduction of coal use (i); this would mainly be felt by households and particularly lower income households; $4.2m for 285,000 t reduction of CO_2 emissions (ii), which is a global economic benefit. Benefits for the health implications are more difficult to estimate, but assume that a $25 reduction per household for annual doctor's visits can be obtained, the total benefits would be around $7.5 m. The total benefits for these three benefits combined would be about $21.2m per year. It is clear that a relatively large subsidy to accelerate the switch-out of stoves and the introduction of cleaner fuels is fully justified.

Moreover, the savings depend on the stove and the fuel, and some fuels resulted in an increased consumption for a particular stove type. The incremental costs of buying an improved stove (IS, purchase price of IS minus purchase price traditional stove, TS) is roughly equal to the savings accumulated over 2 years (fuel costs TS minus fuel costs IS) at a consumption rate as observed during the consumption tests. The rate of return, assuming a 6 year lifetime, would be around 37%. If the earlier found 40% savings rate were confirmed, the payback time would be less than half a year. Further uncertainties in this assessment were: first of all the price of the stove, which was subject to large variations over time; second, statistical validity of the absolute fuel savings remains an issue, as discussed before. In this analysis two separate cases were reviewed: one just comparing TS and IS for coal and wood consumption (resp. 7% and 8% savings during the consumption tests), and the second using the average reduction of heating energy for all different fuels combined during the consumption test and for wood (11% and 7%) between TS and IS.

Despite this level of uncertainty, improved stoves remain an interesting option to pursue for a number of reasons: if a fuel saving of only 10% already results in a 2 year payback time, the prospects for promoting a higher energy efficient stove are good, as 10% savings is not a whole lot. In addition, fuel prices increased some 30% between the 2006/7 and 2007/2008 heating seasons, further increasing the financial payback time. A 10% saving for the whole stove population would mean a coal consumption reduction of about 40,000 t per year, with a value of about 1.5 million US$. Now this idea should be taken from the design tables into the streets!

8.3 Recommendations

Based on the results drawn from the various tools used during the ASTAE activity, the following short-term recommendations can be made:

- As a matter of policy, the Government should actively encourage the use of *cleaner heating systems* in ger areas. Until longer term intervention becomes effective, such as moving ger area households into apartments, coal will be used in stand-alone stoves for households, businesses and institutions. Unless better stoves and/or fuels are used by as many households, businesses and institutions as possible, air pollution will prevail. The focus should therefore be on developing fuel/stove combinations that are of good construction quality, acceptable to clients, have good thermal performance and show low emissions when burning a particular type of fuel. It is necessary to develop solutions for simple ger or house heating, heating walls, and low pressure boilers. The two related options are promoting (i) better stoves in combination with raw coal, or (ii) a better fuels – to be determined - in combination with a better stove. The following should be kept in mind:

- Since it is necessary to match the preferred fuel with a specific heating appliance for lowest possible emissions performance, tests are required to verify this.
- Existing stove models – traditional and improved – appear not good enough to even comply with the current emission standards and are in need of improvement. Moreover, for the fastest growing market segment for stoves, low pressure boilers there are no efficient alternatives available; low pressure boilers are also the long-term preferred solution for most ger area households living in detached houses and consume the largest quantity of coal of all stoves.
- There are at least 3 different private and semi-public firms interested to start producing briquettes or semi-coke coal briquettes. So far, they have not identified a good stove in which to burn these new fuels efficiently and cleanly; this should be done as a priority before they are allowed to introduce their fuel on the market. The risk is that these fuels will emit more pollution because the stove is not adapted to this fuel.
- When a user switches from a solid fuel to a gaseous fuel, (s)he automatically assumes that a new stove is needed. If the same user switches from one solid fuel to another solid fuel, he does not reflect on changing stoves, but in fact (s)he should.
- If a raw coal stove meets the emission standard, it should be eligible for use in ger areas. There is no reason *per se* to abandon the use of raw coal. Any combination of stove and fuel meeting the standard should be permitted.
- Conditioning of raw coal should be pursued also, drying and breaking up in small standard pieces as in general this results in a cleaner burn at a fraction of the costs of producing briquettes, and it would facilitate the use of a small hopper that will allow the heating system to be operated for a much longer period without feeding.

- The Government should adopt the policy *to set and enforce standards for new stoves and fuels*. However, the Government should allow the *market to pick and distribute winners*. This market-based approach requires a three-pronged strategy: (i) unified certification system with standards that can deliver desired air pollution reduction results; (ii) incentives to create sufficient demand for new stoves to (a) justify commercial financing for small business owners; (b) create business justification for larger manufacturers outside and inside Mongolia; and (iii) administrative measures to realistically enforce the standards. The current standard should be modified to include better fuel efficiency and combustion efficiency of both household stoves and low pressure boilers.
    - Ensure that enforcement and verification procedures exist and are clear and transparent. Laboratory capacity needs to be created for emissions performance testing of new and different stove-fuel combinations. At the moment this capacity is not available, and particularly PM emission testing can not be carried out. This needs urgently correction, as PM emissions are the main air pollution culprits.

- From now on, only fuels and stoves that result in low emission factors should be allowed on the market. For this to happen, the new standards should be developed in collaboration with stove manufacturers. Existing institutional capacity of ASM and SSIA should be expanded to allow enforcing of standards for household heating systems. It should be kept in mind that this will not be easy, as the current standards are not enforced and will be enforceable only after a participatory awareness and capacity building effort to develop better standards, develop better equipment, verify compliance of equipment.

- Finally, the Government should adopt a policy to promote and support a *mechanism to facilitate rapid dissemination of low-emission heating systems* in the ger areas for all households including the poorest.
    - Design a subsidy scheme to address affordability, but allow households to choose which certified stove it wants and can afford in the market. The Output-based Aid approach is a subsidy scheme that was shown to produce results in Mongolia. It gives people the choice to purchase qualified equipment with a partial subsidy. The report envisions a voucher system distributed to all households whereby the value of the voucher depends on the ultimate emission reduction obtained with the new equipment and fuel. See also Annex F for more details.
    - The subsidy should be based on a clear cost-benefit justification. Calculate by how much raw coal burning traditional stoves should reduce emissions to achieve a meaningful reduction in their contribution to air pollution, based on available technologies and calculate economic benefits to value the subsidy. These calculations should be carried out as soon as PM measurements are possible in Ulaanbaatar;
    - Focus on building capacity of artisanal stove manufacturers but allow for inclusion of larger players, including importers of low-emission stoves;
    - Design a systematic and sustained grassroots awareness raising scheme, jointly with civil society organizations, to deliver key messages about the justification of the program and to stimulate buy-in, even among the lowest income households;
    - Develop a marketing campaign, focusing on (i) the need to replace old stoves; (ii) to buy only certified stoves in the future; and (iii) to remove old stoves from the market.
    - If negative incentives are to be introduced as well, a polluter tax to assist with the introduction and dissemination of cleaner alternatives that is reverse proportional to the obtained emission factors would be preferred over an outright ban on the use of raw coal.

- *Manage expectations*. This can be done by starting with *large-scale pilot* to promote better heating systems, concentrated in one area or district before rolling out city-wide. The proposed implementation strategy is the following:
    - Short term:
        - Scale-up fuel-stove tests using emission measuring equipment but with well adapted, robust methodology;

- Purchase laboratory equipment and implement lab testing in qualified lab, using unified protocol, supervised by Ulaanbaatar municipality together with Standards Bureau;
- Assist stove designers to develop better stoves and assist briquette producers to start producing good quality briquettes with low emissions; link these producers to international players;
- Implement large scale OBA pilot in one ger area
- Monitor emissions, behavior

- Medium Term:
  - Revise and adopt new standards
  - Establish permanent qualified laboratory-based certification system
  - Scale up subsidy program, to promote purchase of new equipment as well as hand in old equipment

8.4 Concluding Remarks

The surveys showed that ger area households realize they are part of the air pollution problem in Ulaanbaatar and that they want to be part of the solution too. Such solutions could include using cleaner heating systems which may involve better stoves and/or cleaner fuels. More than half of the ger area population live in a detached single family house and are likely to be capable of investing in such solutions if these were available and known to them – which they are not at the moment as such solutions are not available in Ulaanbaatar. The poorest households, particularly those living in a ger, would likely not be able to adopt these solutions without financial assistance.

Households in gers and households in detached single family houses without heating wall or LPB spent more than 20% of their disposable income on heating fuel. This is very high and they are not likely to invest much in said solutions unless some financial assistance is provided. Some 60% of households said that they want to buy an improved stove but only if it is subsidized. Close to 60% of households indicated that they will buy briquettes but only if these are not more expensive than raw coal. Households also expressed their interest in electrical heating and moving into apartments, naturally more convenient but significantly more expensive options.

Air pollution generally keeps pace with the growing population of the city but in addition it also increases as a result of two recently observed trends: (i) constructing more detached single family houses; and (ii) upgrading from a ger heating stove plus chimney to a heating wall or to a low pressure boiler with hot water circulation system. Both trends increase the household comfort level but also increase the fuel consumption. At the moment there are no good and clean heating systems available to households, even if they wanted to buy one.

In fact, there is no overview of the combustion performance of different stoves and fuels, including heating walls and LPBs. This makes it very difficult - if not impossible – for buyers to determine what the lowest emission heating system is. The first step therefore is to describe the performance of the individual heating systems that are available on the market now. For this to happen first the laboratory capacity needs to be upgraded and equipped with adequate measurement equipment that is available elsewhere. Once the performance of all heating systems is known, standards should be adapted and enforced. It is highly likely that better stoves and cleaner fuels can be identified from outside or inside of Mongolia. Given that a few new stove designs have surfaced and several companies are working on cleaner fuels, it is a matter of time before these can be tested and characterized in terms of combustion performance.

In addition, it appears that one immediate solution exist that could immediately reduce air pollution without investments for the user other than willing to accept a different practice of tending the fire. This however, needs to be verified and savings quantified before pursued on a large scale. The recent testing showed that a proportionally large part of the pollution stems from the start-up phase and the restarting phase of the fire. A different firing technique is expected to significantly reduce the level of emissions by leading the smoke through the hot firing zone of the stove.

Should the Government decide to focus on short and medium term solutions involving upgrading or replacing existing low cost heating systems, two support mechanisms are needed: One to create capacity to design, build, and verify the quality of low-emission heating systems. The second is to assist the poorest households to adopt a better heating system and convince more well-to-do households to replace their current heating system with a better one. Such heating systems, once available through a support mechanism, could be adopted rapidly and become part of the solution to significantly clean up the air in Ulaanbaatar while more long-term solutions take hold.

Several mechanisms to disseminate improved stoves have been researched and tested in Ulaanbaatar and have yielded valuable lessons. Programs in Ulaanbaatar that gave away stoves failed; transitioning to a market based approach required a long time because a give-away program had raised expectations for future free stoves. Not enough competition at the production level for improved stoves has kept prices artificially high and did not yield any substantially better stoves than available now[65]. Nevertheless, the foundations for a professional stove distribution supply chain have now been laid, including a well-appreciated after-sales service, by previous projects. Additionally, the Government tested, with the support of the GEF and later Asian Development Bank, the Output Based Aid (OBA) approach, providing subsidies to manufacturers/distributors only on the verified installation of their improved stoves. This provided the largest push to the commercialization of improved stoves.

Based on lessons learned, the OBA approach should be continued, but adapted to the main problems that (i) available improved stoves are not good enough to constitute a realistic solution for air pollution mitigation, and (ii) better heating walls and low pressure boilers do not exist at the moment. In addition, the OBA approach could easily be further refined to provide proportional incentives with the reduction in emission levels: heating systems with larger emission reductions should obtain more financial support.

Calibrating the level of Government support will depend on the end-points and objectives of the pollution abatement policy. If reduction in health impacts of air pollution is an end point, it will be important to determine the share of air pollution that comes from point sources, including ger heating systems. This is beyond the scope of this ASTAE activity but is being undertaken in cooperation with Ministry of Nature and Environment / NAMHEM and the World Bank in a separate activity of the Ulaanbaatar Clean Air Program.

Not responding to the air pollution contribution from heating in the poorest parts of Ulaanbaatar not only would directly put at risk 57% or so of population that live in the ger areas, it would also

[65] E.g., no down draft stoves, gasifier stoves, fan-assisted stoved appeared so far.

put at risk the general health of all other residents. Since measures exist to address the problems relatively rapidly, it is too important to be ignored.

ANNEX A: SURVEY METHODOLOGY AND DATA

The Baseline Fuel Consumption, Heating Stove, and Household Perception Survey conducted in the ger areas in Ulaanbaatar, which was carried out in December 2007 was one of the first comprehensive household survey designed to assess household heating fuels consumption, heating stove ownership and usage, and household perception toward stoves, heating fuels, and air pollution in the city.

The survey was designed to fulfill the following specific objectives:

(1) Assess and provide baseline information regarding heating fuels consumption and expenditure of households living in the ger areas.
(2) Provide the baseline information on the estimated numbers and types of heating stoves used by the households in the ger area.
(3) Analysis of the types of heating fuels used by the households as well as their perception and preferences toward heating fuel being used and alternative heating fuels.
(4) Analysis of the types of heating stove used by the households as well as their perception and preferences toward heating stove being used and alternative heating stove especially, improved stove.
(5) Assessment of households' knowledge, perception and attitude toward air pollution situation and causes of air pollution problem in the city as well as households' willingness to help solving air pollution problem in the city.

The field survey was conducted in December 2007 by local market research firm. Pre-designed questionnaire was used to interview head of the household. However, if head of the households was not available, the spouse or responsible adults who is knowledgeable about heating fuels and stove will be interviewed

Sampling Frame and Sampling Design

Due to specific hypothesis regarding the relationship between the uses of raw coal for heating among households living in the ger area and air pollution in the city, the sampling method was designed to focus on ger areas that are located around the city center. It was determined the uses of raw coal for heating among households that live in the ger areas further away from the city center will have minimal impact on air pollution problem in the city. Moreover, the decision to exclude ger areas that are located further away from the city center were also based on the time constraint which required the field survey and analysis to be completed within a very short time span. As a result, the survey only concentrated in the six ger areas which are located near the city center in Ulaanbaatar. The remaining districts that are located further away from the city were excluded from survey.

Administrative record containing list the most up-to-date list of households living in each Khoroo is used to develop the sampling frame. Based on the compiled list of household from every Khoroo in the six ger area, there are a total 100,941 households that are currently living in 74

Khoroos covering six districts in the sampling frame. A total of 1,000 households were systematically selected from the sampling frame for interview.

Administratively, Ulaanbaatar Municipality consists of nine districts, which are divided into 121 Khoroo. In general, the city is divided into two main areas namely, city center area and the ger area (commonly referred to as the ger areas). Base on the most recent estimate there are about 215,727 households that are currently living in Ulaanbaatar. However, based on the administrative records compiled for this project, it is estimated that about 111,533 households are currently living in the ger area covering six districts and 82 Khoroos of the city.

	Bayangol District		
No	**Khoroo no.**	**Total households number**	**Surveyed household number**
1	9th Khoroo	1583	15
2	10th Khoroo	1560	18
3	11th Khoroo	2053	32
4	16th Khoroo	622	6
5	20th Khoroo	269	4
	Total	**6087**	**75**

	Sukhbaatar district		
No	**Khoroo no.**	**Total households number**	**Surveyed household number**
1	12- Khoroo	1554	17
2	15- Khoroo	1468	14
	Total	**3022**	**31**

	Chingeltei		
No	**Khoroo no.**	**Total households number**	**Surveyed household number**
1	7 th Khoroo	1921	19
2	8th Khoroo	1850	13
3	9th Khoroo	1447	12
4	10th Khoroo	1275	12
5	11th Khoroo	1094	13
6	12th Khoroo	1275	17
7	13th Khoroo	1094	15
8	14th Khoroo	1180	14
9	15th Khoroo	1420	15
10	16th Khoroo	1658	16
11	17th Khoroo	1404	12
12	18th Khoroo	1700	16
13	19th Khoroo	1921	19
	Total	**19239**	**193**

	Khan-Uul district		
No	Khoroo no.	Total households number	Surveyed household number
1	4th Khoroo	1005	10
2	5th Khoroo	745	7
3	6th Khoroo	993	13
4	7th Khoroo	726	6
5	8th Khoroo	1831	18
6	9th Khoroo	1750	16
7	10th Khoroo	566	6
8	11th Khoroo	157	4
	Total	**7682**	**80**

	Bayanzurkh district		
No	Khoroo no.	Total households number	Surveyed household number
1	2- th Khoroo	3353	32
2	5- th Khoroo	1418	14
3	6- th Khoroo	1163	6
4	8- th Khoroo	2249	16
5	9- th Khoroo	1834	18
6	12- th Khoroo	1774	7
7	13- th Khoroo	1130	12
8	14- th Khoroo	2023	24
9	16- th Khoroo	2434	13
10	17- th Khoroo	1500	14
11	19- th Khoroo	722	7
12	21- th Khoroo	1025	11
13	22- th Khoroo	1818	14
14	23- th Khoroo	912	11
15	24- th Khoroo	1815	25
	Total	**24875**	**224**

	Sukhbaatar district		
No	Khoroo no.	Total households number	Surveyed household number
1	1- th Khoroo	1405	13
2	2- th Khoroo	651	5
3	3- th Khoroo	1998	19
4	4- th Khoroo	1976	22
5	5- th Khoroo	1531	14
6	6- th Khoroo	1273	12
7	7- th Khoroo	2128	19
8	8- th Khoroo	1167	15
9	9- th Khoroo	1056	14
10	10- th Khoroo	2153	23
11	11- th Khoroo	1342	16
12	13- th Khoroo	129	1
13	14- th Khoroo	1562	15
14	15- th Khoroo	216	2
15	16- th Khoroo	232	2

16	19- th Khoroo	113	0
17	20- th Khoroo	640	4
18	22- th Khoroo	177	1
19	23- th Khoroo	1529	15
20	24- th Khoroo	995	10
21	25- th Khoroo	1529	10
Total		**23802**	**232**

	Sukhbaatar district		
No	**Khoroo no.**	**Total households number**	**Surveyed household number**
1	9th Khoroo	2050	22
2	11th Khoroo	3071	32
3	12th Khoroo	*1600*	17
4	13th Khoroo	1592	13
5	14th Khoroo	1558	14
6	15th Khoroo	*1300*	14
7	16th Khoroo	1700	18
8	17th Khoroo	1540	17
10	18th Khoroo	1724	23
Total		16035	170

Estimate of Sampling Errors

The main errors which occur in the survey can be divided into two types namely, non-sampling errors and sampling errors. Non sampling errors usually arises from a several of situations including interviewing errors, unclear wording in the questionnaire, mistakes made by interviewers and/or respondents, data entry errors, measurement errors, and assumption used in the data collection process such as, average weight and/or size of specific fuels. All attempts were made in all stages of survey data collection process and analysis to minimize non-sampling errors. This is because it is not possible to provide any estimate of non-sampling errors. However, it is very important to recognize the problems of non-sampling errors associated with survey.

Non Sampling Errors

Although it is not possible to measure non sampling errors, it is very important to recognize that some variables collected from the survey are more likely to be subjected to higher non sampling errors than others. These variables include questions which are based on respondents' recollection of heating fuels purchased and used during the last heating seasons. Since the questions are based on recollection from previous heating season, it is not possible for interviewers to weight fuels usage during the interview. Furthermore, raw coal, firewood, compress coal, and coal briquettes (except Korean briquette) bought and sold in the market are based on estimated weight and estimated size in cubic meters in the case of firewood. Raw coal or firewood loaded/piled up on the large truck is considered to weight about 5 ton or 5 cubic meters for firewood, and or raw coal or firewood loaded/piled up in a smaller truck is considered to weight about 2 or 3 tons or about 2-3 cubic meters for firewood. Consumers are usually told about the weight in ton when buying raw coal in large quantity. However, the coal was not weighted for practical reason. Although raw coal or firewood bought and sold in small bag can be weighted, but they are not usually weighted either. Consumers who purchase raw coal or firewood in bag usually rely on traders to tell them the weight. Data collected from field interviews with fuels traders in Ulaanbaatar, indicate that to sell raw coal in bag traders usually divide raw coal into small bags, and one ton of raw coal be divided into approximately 60 bags. As a result, the survey assumes that one bag of raw coal weights about 16.67 Kilogram. Similarly, to sell firewood in bag, fuel traders usually divide one cubic meter of firewood into 20 bags. As a result, the survey assumes that 20 bags of firewood equal to one cubic meter.

The combination of recall questions and estimated weight and size of fuels bought and sold in the market suggests that the estimated amount of fuels used may be subjected to larger non sampling errors than their corresponding expenditures and/or other variables in the survey.

One ideal survey technique that can be employed to overcome the recollection and measurement problems is to divide sample into seven groups. The first group of sample households is interviewed in September, second and subsequent groups are interviewed in October, and the subsequent months. In addition interviewers must use scale to weight fuels. These survey techniques were discussed but were not possible to implement due to a few problems including the need to complete the study in a few months, and funding for this study was not available until early December 2007.

Sampling Errors

Sampling errors occurs in the surveys due to sampling variation. When sampling is used to estimate the population parameter the sample estimates will not be exactly be the same as the population parameter. The sampling errors are the difference between sample estimate and population parameters.

Given the simple random sampling technique with the sample size of 1,000 household, at 95% confidence interval, sampling error for different proportion for each variable of interest could range from +/- 0.019 to 0.30. For example, if the proportion of households with improved stove is close to or around 10%, the sampling error is estimated to be +/- 0.019 or about +/- 2% sampling error at 95% confidence interval. However, if the proportion of Ger dwelling is estimated at close to or around 50% -- highest variance – the sampling error is estimated to be +/- 0.030 or +/- 3 percent sampling error.

Estimate Sampling for Selected Variables

	Value	Number of Cases	Standard Errors (95% C.I.)	Confidence limits (95% C.I.) Lower	Upper
Type of dwelling unit: Ger	43.2%	1000	.0156	40.1%	46.3%
Separate or single family home	55.3%	1000	.0157	52.2%	58.4%
Ger and single family home	0.7%	1000	.0023	0.18%	1.2%
Size of home (winter) in sq. meters	55.9	562	.9780	44.0	47.9
Size of ger (winter): average # walls	4.8	437	.0326	4.7	4.9
Average household income/month	242,788	1000	6046.47	230,923	254,653
Type of stove owned					
Traditional stove	.878	1000	0103549	.8576802	.8983198
Improved stove	.02	1000	.0044294	.011308	.028692
Korean stove	011	1000	.0033	.0045243	.0174757
Small LPB	.091	1000	.0090995	.0731436	.1088564
Years household using existing heating stove	5.5	1000	.1641	5.2	5.8
Total numbers of stove owned and are using to heat home (include 2nd stove and exclude stoves used in home business/kiosk)	103,061	1000	457.9	102,162	103,959
Household think about performance of his/her heating stove					
Fuel Usage:					
Low	15.9%	1000	.0116	13.6%	18.2%
Medium	49.9%	1000	.0158	46.8%	53.0%
High	34.0%	1000	.0014	31.0%	36.9%
Smoke &soot release from stove					
Low	23.2%	1000	.0133	20.6%	25.8%
Medium	43.6%	1000	.0158	43.2%	49.4%
High	29.4%	1000	.0144	26.6%	32.2%
Ability to keep heat for long time					
Low	11.4%	1000	.0100	9.4%	13.4%
Medium	47.9%	1000	.0158	44.8%	51.0%
High	40.3%	1000	.0155	37.2%	43.3%
Freq. to clean soot from chimney					
Low	44.4%	1000	.0157	41.3%	47.5%
Medium	39.0%	1000	.0154	35.9%	42.0%
High	15.8%	1000	.0115	13.5%	18.1%
Difficult to start fire					
Low	61.8%	1000	.0154	58.8%	64.8%
Medium	33.5%	1000	.0149	30.5%	36.4%
High	4.2%	1000	.0034	0.5%	1.9%
Amount of ash					
Low	23.3%	1000	.0134	20.7%	25.9%
Medium	41.9%	1000	.0156	38.8%	44.9%
High	33.6%	1000	.0149	30.7%	36.5%

	Value	Number of Cases	Standard Errors (95% C.I.)	Confidence limits (95% C.I.) Lower	Upper
Household interested in changing stove	51.8%	1000	.0158	48.7%	54.9%
Not interested in changing stove	46.6%	1000	.0157	43.5%	49.7%
Household opinion about improved stove					
Improved stove is easier to start fire than traditional stove					
Agree	33.7%	1000	.0149	30.7%	36.6%
Disagree	10.4%	1000	.0096	8.5%	12.3%
Do not know	55.9%	1000	.0157	52.8%	58.9%
Improved stove releases less smoke than traditional stove					
Agree	58.2%	1000	.0156	55.1%	61.3%
Disagree	5.1%	1000	.0069	3.7%	6.5%
Do not know	36.7%	1000	.0152	33.7%	39.7%
Improved stove keeps heat longer than traditional stove					
Agree	38.1%	1000	.0154	35.1%	41.1%
Disagree	10.1%	1000	.0095	8.2%	12.0%
Do not know	51.8%	1000	.0158	48.7%	54.9%
Improved stove uses less fuel than traditional stove					
Agree	44.8%	1000	.0157	41.7%	47.9%
Disagree	7.3%	1000	.0082	5.7%	8.9%
Do not know	47.9%	1000	.0158	44.8%	51.0%
Improved stove is more difficult to use than traditional stove					
Agree	10.6%	1000	.0097	8.7%	12.5%
Disagree	30.0%	1000	.0144	27.1%	32.8%
Do not know	59.4%	1000	.0155	56.3%	62.4%
Improved stove needs to have chimney cleaned more often use than traditional stove					
Agree	8.8%	1000	.0089	7.0%	10.6%
Disagree	24.1%	1000	.0135	21.4%	26.7%
Do not know	67.1%	1000	.0148	64.1%	70.0%
Improved stove is too expensive					
Agree	41.1%	1000	.0155	38.0%	44.1%
Disagree	13.5%	1000	.0108	11.4%	15.6%
Do not know	45.4%	1000	.0157	42.3%	48.5%

	Value	Number of Cases	Standard Errors (95% C.I.)	Confidence limits (95% C.I.) Lower	Upper
Household have heard about improved stove from:					
Friends/neighbors/relatives					
Yes	29.3%	1000	.0144	26.5%	32.1%
No	70.7%	1000	.0144	67.9%	73.5%
Radio/TV program					
Yes	59.3%	1000	.0155	56.2%	62.3%
No	40.7%	1000	.0155	37.6%	43.7%
Newspaper/printed media					
Yes	18.5%	1000	.0122	16.1%	20.9%
No	81.5%	1000	.0122	79.1%	83.9%
NGO through project					
Yes	13.4%	1000	.0108	11.2%	15.5%
No	86.6%	1000	.0108	84.4%	88.7%
Stove maker					
Yes	4.7%	1000	.0067	3.4%	6.0%
No	95.3%	1000	.0067	93.9%	96.7%
Billboard					
Yes	3.7%	1000	.0059	2.5%	4.9%
No	96.3%	1000	.0059	95.1%	97.5%
What household think if we buy current stove and give back improved and fuel efficient stove at low cost:					
Agree	37.0%	1000	.0153	34.0%	40.0%
Need to think about it	43.5%	1000	.0157	40.4%	46.6%
Number of times add fuels during 24 hrs period (Sept, Oct 07 and Mar, Apr 08)	2.30	797	.0421	2.23	2.40
Number of times add fuels during 24 hrs period (Nov, Dec 07 and Jan, Feb 08)	4.48	797	.0765	4.34	4.64
Average raw coal consumption per household (Sept 07 to Apr 08) in ton	4.18	941	.0709	4.04	4.32
Average expenditure on raw coal per household (Sept 07 to Apr 08) in Tg./	174,357	941	2607.58	169,240	179,474
Average firewood consumption per household (Sept 07 to Apr 08) in M^3	4.69	922	.0939	4.50	4.87
Average expenditure on firewood per household (Sept 07 to Apr 08) in M^3	84,626	922	1698.22	81,293	87,959
Household thinks air pollution problem in Ulaanbaatar is extremely high	72.4%	1000	.0141	69.6%	75.2%
Household thinks air pollution problem in Ulaanbaatar is high	27.0%	1000	.0140	24.2%	29.7%

	Value	Number of Cases	Standard Errors (95% C.I.)	Confidence limits (95% C.I.) Lower	Upper
Households think source of air pollution in the city					
Motor vehicle					
Very high	19.7%	1000	.0125	17.2%	22.2%
High	52.0%	1000	.0158	48.9%	55.1%
Industry					
Very high	10.3%	1000	.0096	8.4%	12.2%
High	46.1%	1000	.0158	43.0%	49.2%
Power plant					
Very high	17.9%	1000	.0121	15.5%	20.2%
High	50.1%	1000	.0158	47.0%	53.2%
Heating stove from ger areas					
Very high	83.9%	1000	.0116	81.6%	86.2%
High	14.3%	1000	.0110	12.1%	16.5%
Household thinks best way to reduce air pollution in the city					
Reduce coal consumption					
Most suitable	33.2%	1000	.0148	30.3%	36.1%
Suitable	52.1%	1000	.0158	49.0%	55.2%
Consumption of briquette					
Most suitable	11.7%	1000	.0101	9.7%	13.7%
Suitable	47.5%	1000	.0158	44.4%	50.6%
Use improved stove					
Most suitable	13.9%	1000	.0109	11.7%	16.0%
Suitable	52.0%	1000	.0158	49.0%	55.1%

ANNEX B: TESTING PROTOCOL

The testing protocol was discussed and approved by all laboratories that have an interest in air pollution control. The purpose of the protocol is to determine emission factors for a domestic space heating and cooking stove using a particular fuel. This is done by measuring and recording during the whole test the following aspects:

a.	Rate of fuel burned	kg/sec
b.	Fuel moisture content	% WWB (measured only at the beginning of the test)
c.	Dilution factor (excess air)	O_2 % (EA)
d.	Carbon-monoxide	CO ppm (stack and ambient)
e.	Carbon-dioxide	CO_2 % (stack and ambient)
f.	Sulphur-dioxide	SO_2 ppm "
g.	Nitrogen-oxides	NO_x ppm "
h.	Total suspended particulate matter	TSP micrograms per cubic meter $\mu g/m^3$
i.	10 micrometer particulates	PM_{10} $\mu g/m^3$
j.	2.5 micrometer particulate	$PM_{2.5}$ $\mu g/m^3$
k.	Volatile Organic Compounds	VOC $\mu g/m^3$
l.	Polycyclic aromatic hydrocarbons	PAH $\mu g/m^3$
m.	Hydrogen	H_2 ppm
n.	Relative humidity ambient	% RH
o.	Relative humidity in the stack	% RH

Based on the above observations, emission factors can be calculated for:

q.	CO	g/MJ and g/kg
r.	CO_2	g/MJ and g/kg
s.	SO_2	g/MJ and g/kg
t.	PM_{10}	$\mu g/MJ$ and $\mu g/m^3$ and $\mu g/g$
u.	$PM_{2.5}$	$\mu g/MJ$ and $\mu g/m^3$ and $\mu g/g$
v.	TSP	$\mu g/MJ$ and $\mu g/m^3$ and $\mu g/g$
w.	VOC	$\mu g/MJ$ and $\mu g/m^3$
x.	PAH	$\mu g/MJ$ and $\mu g/m^3$
y.	Hydrogen	$\mu g/MJ$ and $\mu g/m^3$

A quality check of the obtained data can be determined by comparing the following results with recorded data:

z.	O_2	%, calculated from gases detected in the stack
aa.	Carbon balance:	CO_2+CO+HC x stack flow rate = fuel burned

The procedure is based on the SeTAR Center protocol 01-1.04.2009:

Determine the composition of the fuel. Cold start fire in stove with a suitable load of coal (3 kg) and some wood and newspaper; add 1 kg fuel after 2 hours and then do not add anymore. Continue to measure at 10 minute intervals until all fuel is spent and there is no flue gas anymore; this may last up to 4-5 hours. Carry out the procedure 3 times with each fuel used, whether raw coal, semi-coked coal, briquettes, etc.

Equipment to be used: an accurate scale capable of holding the whole stove and fuel (150 kg platform scale accurate to 5 grams or failing that, 10 grams), plus a gas collection and dilution system to quantify the particulate emissions. A facility will have to be constructed with, for example, a concrete scale base and suitable ventilation, a collection hood (to be fabricated locally) to collect emissions, dilute them with dry air, and measure the particulate quantity in real time. The hood can only be installed in a laboratory setting that is permanent. Except for gas analysis, there is no equipment available for testing stoves. The testing capacity available in Ulaanbaatar is focused on the monitoring of power stations and Heat Only Boilers built according to Mongolian National Standard MNS 5216:2002. That standard deals only with combustion efficiency and durability, not particulate emissions, cooking and space heating. For CO, CO_2, SO_2, NO_x emission, a device such as a TESTO 350 or better is needed. A Dusttrak or other similar device such as a Beta absorption detector is needed to measure realtime condensed aerosols and very fine dust in small concentrations.

ANNEX C: STRUCTURED BRAINSTORMING WORKSHOP

A structured brainstorming workshop was organized by the World Bank team jointly with UBMG/AQD team. About 15 people participated, of which Khoroo governors, stove producers, a stove NGO, the old PIU for the MNE stoves program, ministry officials, international NGOs, and households.

A total of 5 questions were discussed during the one-day workshop:

(i) What do you think should be the objective of the stove program?

(ii) What do you think went wrong with the previous improved stove program?

(iii) What do you think is more effective in combating ger area air pollution?: Improved Stove (IS) or Cleaned Fuels (CF) and Why.

(iv) How can a project sell more than 30,000 improved stoves before next winter? How can the future project sell many stoves in a short period?

(v) How should a subsidy for improved stoves be targeted? And why.

The first question, "What do you think should be the objective of the stove program?" gave two main answers: (i) Support stove producers to develop better stoves, that are cheap, good, efficient, and come with a subsidy; and (ii) Air Pollution Reduction in Ulaanbaatar through stoves that do not pollute air, emit less smoke, reduce fuel consumption, are affordable, are of good quality, compact, can burn anything.

The second question, "What do you think went wrong with the previous improved stove program?" gave 8 reasons: (i) Project design should have targeted particular Khoroo and districts; (ii) Policy should have been to prohibit inefficient stoves and should have been better understood and supported by politicians; (iii) Stake holder involvement could have been better: traditional stove producers continued to make traditional stoves and community consultations were weak; (iv) Stove awareness and advertisement did not reach the full population; (v) Market development was weak, no real marketing strategy, lack of understanding by consumers, and uncertain delivery mechanism, where to buy; (vi) High cost of stoves, particularly at the beginning of the project; a minority of the population can obtain credit to buy a stove; (vii) Stove model, design, quality were not appropriate, more models are needed that allow longer refueling periods, emit less smoke, can use different fuels; and (viii) Government: Poor government management (too broad focus, management should have focused on a smaller area); only one government agency involved; no law, no regulation to support; no dedicated government official looking at air pollution issue, neither in national nor municipal government; Government created a parallel program by providing stoves for free; weak cooperation between the Ministery (MNE) and UBMG; More private organizations should be involved

The project has good result, but the government did not support it. Ministries and khoroo should support more consumers. Stove has a good impact: coal saving; heat efficiency, but could not fully disseminate to the market. In comparison to traditional stove, few improved stove were produced and a large number of consumers purchased cheap and inefficient traditional stove.

Responses were discussed and grouped, and then voted on. Participant could give 3 votes, with weight 1, 2, and 3 for the most important aspect on the board; they could vote for the main topics or for the more detailed subject within the topics. The results are as follows:

Stakeholder Involvement:

16 votes: All stakeholders need a shared vision

2 votes Lack of community consultation

Project Design:

15 votes: Select the Khoroos to work in

Marketing

14 votes: There was no marketing strategy

9 votes: Lack of understanding of the consumer

5 votes Poor delivery mechanism (consumers did not know where to buy improved stove)

Stove model, design, quality

11 votes: More and different stove models are needed

4 votes Improved stoves lack practical usage

4 votes Improved stove has high emission especially dust and smoke

3 votes No filter for smoke

Policy:

9 votes No policy and/or regulation prohibiting the uses of inefficient stoves

2 votes Very little understanding and support from politician

Others:

6 votes: Awareness not effective

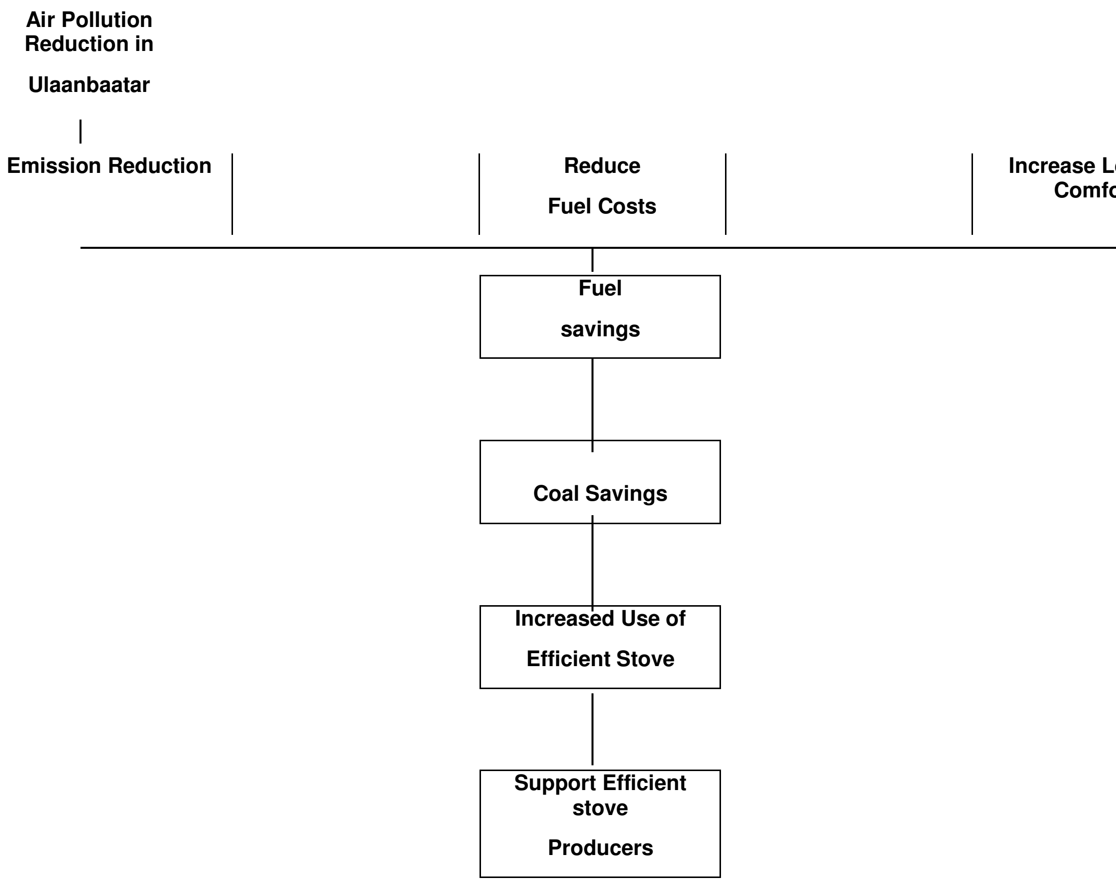
5 votes: More private sector involvement needed

4 votes: Only one government agency was involve in the project

4 votes: Too high costs for stoves

The third question "What do you think is more effective in combating ger area air pollution?: Improved Stove (IS) or Cleaner Fuels (CF) and Why?" gave more importance to improved stoves than to cleaner fuels, although the consensus was that the two are linked:

- IS because at least we have learnt some lessons from IS; we have no idea how to introduce clean fuel. Unless draconian measures approach to ban raw coal.
- IS, it can only take one type of fuel
- IS, clean fuel is next step
- Have to use IS; there is a case of producing air pollution not depending on fuel heating capacity
- IS, people can buy IS only once; they must buy everyday and this is expensive
- IS should become better; it is difficult to control which fuel is used at households
- IS but (i) fuel should be clean; (ii) smoke filter should be used; and (iii) electricity should be used for ger heating



The fourth question "How can a project sell more than 30,000 improved stoves before next winter? How can a future project sell many stoves in a short period?" gave a wide variety of answers, which became much clearer after the voting.

Voting Results:	
Financing:	
20 votes:	Availability of financing such as, providing loan to consumers
11 votes	Khoroo and local bank involvement in financing activity including credit provision related to voucher system
Creating awareness 19 votes	
Marketing:	
8 votes	Establish stove sales kiosk in each district
4 votes	Launch marketing campaign to promote improve stove
Project Design:	
7 votes	Coordination of all administrative units
7 votes	Train consumers (short time).
5 votes	Every household should have access to voucher for improved stove
4 votes	Every household should have opportunity to replace his/her old stove with improved stove
Management:	
5 votes	Ulaanbaatar municipality and government should participate fully to organize awareness, marketing campaign, selling location
4 votes	Government policy must support dissemination of 30,000 improved stoves
3 votes	Make good select of district(s) and/or khoroo(s) and focus on it.

The fifth question "How should a subsidy for improved stoves be targeted? And why?" gave a split result for consumers and producers. A subsidy to consumers would make the discount most visible, but a subsidy to buy down some costs of the supply chain (Manufacturer, distributor and after sales service providers) was also seen as productive: support to producers from the private sector, not through the government, would be win-win for both the producer and the end-user, but any subsidy should be based on sales result. Finally, people also said that both consumers and producers should be supported, 50%-50%.

Disadvantages of the previous stove project as mentioned were:

- Subsidy to producer was provided after the sale, but it would be good instead if some advance were given upfront for raw material purchasing
- All manufacturers should be involved instead of a few and the subsidy should be 50% of production costs; number of producers in program too few to get long lasting effect
- Sales persons needed; subsidy not only for manufacturers: middle man incentives
- Failure to get rid of Traditional Stove completely
- No choice for households
- Too few stove models
- Iron price goes up but subsidy amount did not
- No incentives for manufacturers to reduce the price
- Consumer should also be subsidized through Khoroo by 50%

ANNEX D: CASE STUDY ELECTRIC HEATING[66]

This note has been prepared to review the issues dealing with electric heating for ger areas as a measure for reducing air pollution.

Electric heating in ger area, needs and issues

Ulaanbaatar city is struggling to accommodate almost 1.2 million people with an infrastructure that is originally designed for not more than half a million people. At this moment 60% of population of Ulaanbaatar or some 150,000 households live in ger areas, which are zones made up of informal settlements of gers, nomadic felt tents and small single family wooden or brick houses with own fenced area, hashaas. In general, ger area dwellers are low-income people compared to apartment dwellers because significant part of these families moved to Ulaanbaatar recently to escape rural unemployment problems and obtain better education for their children.

The recent survey has found that in the ger areas of Ulaanbaatar only 32% of the sample population lived on stable income such as salary or pension; and 53% of respondents registered themselves as "unemployed" and 80% of households reported one or more unemployed adult family members. Poverty incidence in Ulaanbaatar's ger areas was 47%, compared to 16% among the capital's apartment dwellers. During 2007 of about 17,000 families who moved into Ulaanbaatar from rural areas only 400 have moved to apartments.

Ulaanbaatar is considered one of the coldest capitals in the world, where air temperatures range between minus 25 to 40 degrees Celcius in the winter. Because of these severe climate conditions, heating is vital for Mongolia and the heating season lasts 8 months, from September 15 to May 15. Electricity is considered one of the cleaner heating options but may not be suitable for low-income households in ger area unless subsidies are provided. The option could be considered if the Government and Ulaanbaatar city municipality are willing to commit necessary investments and subsidies and this note explains some of the implications. This note reviews the data and analyzes what the issues are so that a better founded decision can be taken.

1. Electricity capacity expansion and upgrade for ger area

There are approximately 150,000 households in ger area and average non-heating electricity demand for average family is 0.8-1 kW. The electric capacity needed to satisfy additional heating needs are estimated as follows:

Heating capacity needed to heat up 1 m2		150 W
Average heating area (small house of 5 x 6 m)		30 m2
Total heating capacity needed for the house	(150 x 30 m2 = 4500 W)	4.5 kW
Total heating capacity needed for the ger	(150 x 22 m2 = 3300 W)	3.3 kW

If we assume that average needed capacity for electric heating as 4 kW per family in ger area, there is a need to increase electric capacity of Ulaanbaatar by 600 MW. To compare this to the actual capacity, the peak demand in Ulaanbaatar in January 2008 was 335 MW. It is clear that without additional generation capacity ger area households cannot use electricity for heating. With the increase of needed capacity there is a need to increase capacity of transmission and distribution networks. In fact, the distribution network in Ulaanbaatar is already 30 years old and needs

[66] Written by Liu Feng and Tumentsogt Tsevegmid, World Bank staff, based on data in the first half of 2008.

significant rehabilitation and upgrading. Main feeder transformers of 110 kV at Omnod, Baruun, Umard, Dornod –II and Tuul substations are already overloaded and cannot accommodate additional loads without the risk of shutting down parts of the system.

Additional investments to the power infrastructure are needed before ger districts can start using electricity for heating on a large scale. Such required investments for increased generation, transmission and distribution capacity as well as for the purchase of electric heaters, installation of internal wiring, and special meters, envelope renovation etc. can be estimated as follows:

1.	Generation capacity by 600 MW x $1,5 million	$ 900 million
2.	Transmission system rehabilitation and upgrade	$ 150 million
3.	Upgrade and rehabilitation of MV and LV	$ 150 million
4.	Electric heaters 150,000 x $300	$ 45 million
5.	Internal wiring, special meter, envelope renovation 150,000 x $1000	$ 150 million
Total:		$ 1,395 million

These are very rough estimates based on costs for electric heaters, internal wiring, special meter, envelope renovations as found in a case study of electric heating in Beijing. It is obvious that neither the Government nor Ulaanbaatar city are in a position to finance such investments in near future, even if ger households provide the heaters and pay for the internal wiring costs.

2. Housing plans and the future of ger areas

The Government of Mongolia, Ulaanbaatar city Municipality, and the Ministry of Construction and Urban Development (MCUD) are in the process of implementing a housing program "40,000 apartments units", including the expansion of heating, electricity, water and sanitation networks to potential housing area sites. UBMG announced in 2008 the start of a project to relocated khashaa households closest to the city center area into new apartments.

In fact, this is a long term and relatively expensive option, which has been included in the Master Plan to reduce Air Pollution in Ulaanbaatar considered. However, many issues need to be clarified, such as evaluation of khashaa land value, expansion of public services infrastructure, such as water supply, sanitation, heating and electricity networks, construction cost of new apartments, etc.

3. Efficiency of heating gers using electric heaters

From an energy efficiency point of view, electric heating in gers or wooden single family houses is not realistic. The ger itself does not retain heat efficiently due to poor insulation since it is built of from materials such as felt, wooden carcass and simple fabric. The design of the ger followed the traditional way of life, which suited well for nomadic way of life, greater mobility to follow livestock, easy and light to assemble even by one woman etc, but the ger is inefficient in terms of heat insulation compared, for example, to brick houses. Heat losses due to infiltration of outside air in the ger is "worse" compared to panel building apartment by 20 times and 5 times compared to ordinary brick house.

4. Electric heating using night time special rate for electricity

There are potential options for using time differentiated tariffs for electricity during the day and night time to make use of spare generating capacity. Estimates were made for the Ulaanbaatar electricity distribution network (UBEDN) and using electric heaters in ger areas, see following table below. An average family spends in ger area 10,000-15,000 MNT tugrugs for electricity in addition to using existing conventional coal heating stoves. The table below shows how much such family would pay for electricity if the heating will be provided using electric heaters using the differentiated tariffs during the day and night time.

The estimates show that an average usage of electric heaters for 18 hours a day (9 hours during the night time and 9 hours during the day time) would cost around MNT 110160 tugrugs per month. It means that electricity charges will increase by about 3 times though it assumed that they will not spend money to fuel (coal, firewood, and briquettes) anymore which was roughly 2000 Tugrugs per day during the coldest days in early 2008.

#	Items	Unit	Total
1	Average usage of electric heaters per day	Hours	18
2	Out of which: night time (9.00 pm - 6.00 am)	Hours	9
3	Day time (anytime between 6.00 am – 9.00 pm)	Hours	9
4	Electricity used during night time	kWh	36
5	Electricity used during day time	kWh	36
6	Electricity night tariff	Tug/kWh	34
7	Electricity day tariff	Tug/kWh	68
8	Electricity charges during night time	Tugrug	1224
9	Electricity charges during day time	Tugrug	2448
10	Electricity charges for using electric heater (per day)	Tugrug	3672
11	Electricity charges for using electric heater (per month)	Tugrug	110160

The question thus arises if households can afford to pay for the costs at the current tariff. Even taking into account reduced night-time tariffs, it appears that electric heating is some 40% more expensive than heating with coal. With the current tariff, electric heating would be roughly 110160 tugrugs not including the electricity used for other purposes, such as lighting, refrigerator, TV etc. Compared to heating bills for apartment buildings, these costs appear very high.

Based on the above assumptions, the total subsidy needed for ger area households to use electric heaters at similar costs as coal stoves would be roughly 54 million US$ per heating season.

One of the measures for air pollution reductions in ger areas considered by Ulaanbaatar city Municipality and proposed in the "Ulaanbaatar city Master Plan for Air Pollution Reduction" was the use of electric heaters using the night time tariffs. At the time of conducting the current study, night time tariffs were relatively low at 11.3 Tug/kWh, but the Energy Regulatory Authority increased these from July 15, 2008 to a daytime tariff of 68,0 Tug/kWh (+30%) and a night time tariff to 34,0 tug/kWh (+300%).

Mongolia covers its peak power deficit by imports from Buryatia of the Siberian Energy System (Russia). Based on Mongolia's current generation mix that is based only on coal fired combined heat and power (CHP) plants, the National Dispatch Center (NDC) of the Central Energy System (CES) has limited flexibility of dispatch regulation during the peak and off peak hours. Due to these limited maneuvering capabilities, the CES does not have another choice but to operate at night to ensure availability and to produce heat for the central heating system (there are no other generation mixes, such as hydro and gas). For many years, the Russia didn't pay for night time electricity and recently it allowed to credit or to write-off night time electricity flows to Russia from the amount of electricity sold to Mongolia. For that reason, there were public calls to use the night time electricity for heating purposes instead of letting it flow to Russia. At this moment the National Dispatch Center have managed to find optimal generation dispatch regime, which allows very small fraction of electricity generated during the night time to flow to Russia.

In 2007 the total demand in CES was 3724.13 million kWh, and CES imported from Russian Federation 130,0 million kWh (3.49%), and the electricity, which "flowed" to Russia during the night time is only 13,94 million kWh, or 0.37% of the demand. Out of that amount about 80% has been exported during the night time and average capacity was only 15-20 MW on average. Whereas, if in the high scenario, the 100,000 households will use electric heaters (100,000 x 4 kW = 400 MW; 400 MW x 9 hours = 3600 million kWh), the capacity which exceeds the entire demand for CES is needed to electrify the heaters for ger areas.

It is very clear that at the moment it is not possible for technical and economical reasons both at the state and municipal levels to introduce electric heaters for heating purposes.

Risks

Coal prices increased this heating season from Tg 30,000 per ton in 2007 to some Tg 50,000-60,000 per ton in 2008. If coal prices continue to increase, and electricity prices remain stable (however unrealistically), electric heating becomes cheaper than heating with coal and the risk is that a large number of households may switch to electric heating. The UBDEN is not ready for such an increased load and will experience supply problems, with an impact on the whole city.

Case Study: Beijing's Electric Heating Program

As part of Beijing's air pollution control program, the Municipal Government began studying and demonstrating the use of electric storage heaters to replace coal-fired heating stoves in 2000 in the city's "Historical and Cultural Preservation Zones," where construction of natural gas distribution or district heating networks are prohibited. There are four municipal government agencies involved in the electric heating program, and the principles of the conversion policy were derived from the initial pilots and demonstrations, including:

- Sharing the costs (investment and operation) among the municipal and district governments, the electric utility company, and the households; and
- Using distributed electric storage heaters.

More specifically, the municipal and district government and the electric utility (which is owned by the municipal government) cover the costs of upgrading the distribution network and the special meters, as well as the costs of necessary building envelop improvements (wall insulation and double glazed windows for examples). The government also covers two thirds of the cost of the electric storage heaters eligible for the dwelling (in practice, it is basically one heater for one formal living room or bedroom). The households pay for the cost of internal wiring. Households receiving government living expense support receive 100% cost subsidy for internal wiring and heaters. In addition, the municipal and district governments also pay for two thirds of the off-peak electricity cost, which could amount to 130 million yuan (US$18 million) per year for 140,000 households.

The off-peak electricity price for electric heating is 0.30 yuan/kWh, compared with the 0.48 yuan/kWh for regular residential consumption. The special price last from 10 pm to 6 am and is effective from November 1 to March 31. The households prepay by the price of 0.30 yuan/kWh and get 0.20 yuan/kWh back from the government after the heating season. Thus, the actual out of pocket cost of electricity for off-peak consumption is 0.10 yuan/kWh.

The nominal investment cost (based on officially published figures) of the electric storage heater program is high at about 38,000 yuan per household (about US$5,290/hh), based on 2007 investment figures. About 55% of the investment is said to be used for upgrading distribution networks (including meters).

Concluding remarks

It is clear that electrical heaters will be an extremely expensive option from an economic point of view: the necessary investments are high and there are quite a few technical and financial issues. Even with the established policy for promotion of electric heaters (time differentiated tariffs, sharing the costs) there is a need for continuous commitment for subsidies at Government and local authorities' level.

- Technical issues, such as significant needs in terms of expansion of generation capacity, upgrade of existing transmission, medium and low voltage distribution networks to accommodate possible increase in power demand in ger area needs to be addressed. Very rough estimates show that there is a need to upgrade generation capacity by 600 MW, and upgrade by same capacity the transmission, distribution networks, improve wiring, metering and insulation of gers, houses to get full benefits of electric heating, and the direct investment costs of such measures may vary between 1,0-1,395 billion USD. These estimates do not include possible tariff subsidies because significant part of ger area households are low-income people and without targeted subsidy program this option may not be realized.
- Policy and financial issues need to be clarified. In comparison to case study in Beijing, it is evident that in case of Ulaanbaatar there is no clear policy that has been identified yet for electric heating in terms of responsible agencies, financing sources and mechanisms (including tariff subsidy), technical solutions (electric storage heaters or other appliances, automatic remote regulation of consumption during peak and off-peak hours, etc.), investments to upgrade distribution network, sharing the costs etc. The Central and Ulaanbaatar government have not come up with the thorough and rigorous analysis on how much it would cost to use electrical heating in ger area and commitment to allocate such resources.
- Uncertainty with future planning of ger area. The current Ulaanbaatar city Government has plans to exchange the lands of khashaas closer to the city to housing units. In this case, if the heating using electric heating will be used, it should be clarified which ger areas will remain for some time as ger areas and which areas will be soon transformed into housing areas.

ANNEX E: LABORATORY TEST EQUIPMENT NEEDED

A suitable permanent laboratory needs to be set up and equipped for stove and fuel testing; total costs for equipping the laboratory are estimated to be less than $100,000, including recorders and computers. Tests to be carried out include fuel consumption tests as well as emission tests.

The following equipment is required over an above what is already available:

1. A 150 kg platform scale accurate to 5 grams or failing that, 10 grams. The complete stove and chimney need to be placed on the scale to measure the rate of fuel consumption, from which the power output of the stove can be determined.

2. A source of compressed air, such as from a small compressor that can be obtained from any tool shop, fitted with a moisture condenser and then chemical dryer

3. A flow regulator to control the diluted flow of combustion air to the meters.

4. A collection hood (to be fabricated locally) to collect emissions, dilute them, and measure the quantity in real time. The hood can only be installed in a laboratory setting that is permanent.

5. A lab for testing stoves. It appears that the Municipality will have to locate and make this space available. The available Dusttrak meter can measure the particulates to give an indication of cleanliness of the burn, but the exhaust gases need to be diluted and cooled before they can be measured.

6. Installation of an infrared cell in the Testo 350. At the moment the Testo 350 only calculates the level of CO_2 from the O_2 level but should be able to measure this with an non-dispersive infrared CO_2 cell.

7. Dusstrak DRX Model 8533 or similar for measuring particulate emissions in real time, together with a dilution system to condense particulates prior to measurement. Other suppliers include Ankersmid and Met-One both of which supply Beta particle absorption mass detection of particulates.[67]

[67] The World Bank cites these as examples of the types of equipment that could be purchased but this does not endorse the brand or the model in any way.

ANNEX F: VERIFICATION AND CERTIFICATION SYSTEM

Overview

The objective is to quickly lower emissions of pollutants from coal consumption in UB; this will be realized by replacing heating stoves in most ger area households that use traditional coal stoves for heating their homes over the next 2-3 years. Complementary action will promote the use of cleaner fuels.

The following presents the suggested approach for rapidly disseminating improved heating stoves in ger areas in Ulaanbaatar while also removing inefficient old stoves. It is desirable to create an infrastructure for selling and repairing stoves that is more professional than is now the case. A large information and awareness raising campaign will form the basis for the intervention, targeting all ger area households with messages about the impact of air pollution on their lives and possible solutions.

Calibrated and well targeted subsidies are needed to facilitate the rapid replacement of inefficient old stoves with new and more fuel efficient stoves. It is proposed to provide these subsidies through a voucher system to all ger area households for the purchase of a new and efficient stove. Households are invited to buy a new stove and can partly pay for this with the voucher - if the stove meets or exceed the minimum efficiency standards as laid down in the National Stove Standard. Market development will be promoted as much as possible and the goal is to quickly obtain a number of improved stove models from different stove manufacturers in the formal and informal sector. There should be no regulation of stove prices, which will be set entirely by manufacturers. The focus will be on stoves for use in gers and for use in detached single family houses (with hot water circulation system).

It is proposed to develop and maintain a list of certified stove models and a list of certified producers of stoves that meet the standard; only certified stoves can be paid with the subsidy voucher, and the payment will be done after verification of the stove and its installation. The list of stoves and manufacturers will be publicized during the awareness campaign. Stove manufacturers will be responsible for providing proof that a stove meets the standards. Laboratories will be used to verify performance of the stoves compared to the National Standard.

Previous Experience

The main improved stoves activity has been a GEF funded program implemented by MNE; ADB also provided some funds. Four different stove models have been identified through a competitive procedure, of which two were acceptable to households. Initially orders were given to manufacturers, to pilot test the market. Later an OBA approach was used, whereby producers competed for a subsidy that was announced several times. Some 16 thousand have been disseminated over the past 5-6 years. The production process is not sustainable and there is some doubt that currently produced stoves are of the same quality as the ones produced during the project. There is survey and laboratory evidence that the stoves reduce fuel consumption, but political forces prefer to cite the failure of the activity. The main lessons of the project were: involve all stakeholders in the design of the activity, give people choices, and don’t disseminate stoves for free. There are or have been some other stove activities, the most significant of which are stoves from the JinSun Energy company and the GTZ program.

Proposed project

There are 4 components to the proposed heating stove program:

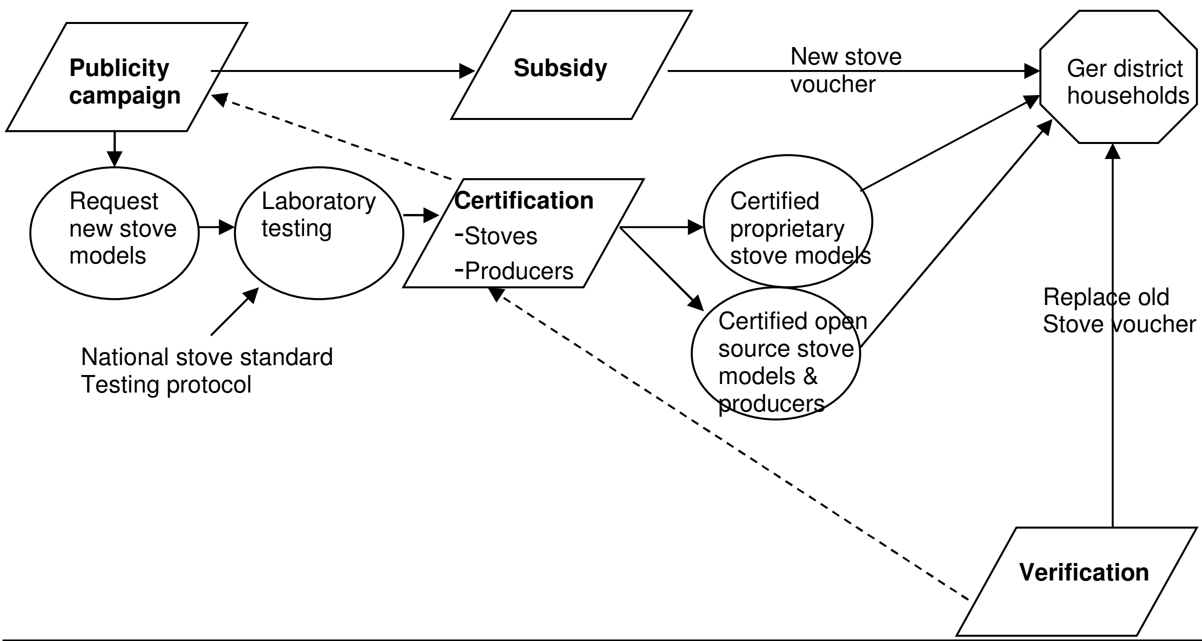
(i) certification

(ii) publicity & promotional campaign

(iii) subsidy vouchers for new stoves and for returning old stoves

(iv) verification of stove quality

A flow diagram is presented below to show the project's activities.



Component 1: Certification.

The program addresses heating stoves for gers and for single households in ger areas, and includes both stand-alone stoves and low-pressure boilers. The UBMG will maintain a list of certified stove producers and a list of certified stoves; anyone who satisfies certain criteria (to be developed) can get registered as a certified stove producer and submit stove models for certification. The stove producer will need to get his stove model tested by an agreed laboratory at his own costs; the certification will be done by UBC after verification that it meets or exceeds the national stove standard as tested by the laboratory. UBC will maintain the lists of certified stove models and certified producers.

It is likely that two types of stoves will be submitted for certification: (i) proprietary stoves (which are unknown at the moment) and (ii) public domain stoves (of which two are known, the G2-2000 and TT03, the GTZ stove, but which will still be subjected to laboratory tests for certification – with the risk that they cannot be certified because they do not meet emission standards). For the first category, it is likely that one or more stove manufacturers submit their stove model(s) for certification; only they will be able to manufacture these stoves unless they allow production under license. For the second category, some stove producers are likely to request to be registered as certified producer; this will be only for the production of certified public domain stove types. Each stove on the list of certified models will be accompanied by a registration number or certificate so that its origins can be traced.

The certification procedures will be developed based on the following:

- Evaluation of the national standard for stoves and combustion of fuels
- Standard testing criteria and testing protocol for household heating stoves
- Capacity for testing and certification by laboratories
- An organization that can do the certification of stoves and stove producers, based on data provided by the laboratory and by the producers; this will yield the two lists of certified products and actors. UBMG could also be this organization, or more precisely, the PIU; an alternative would be the Bureau of Standards.

Component 2: Publicity and promotion

This will be a large part of the project activities, to inform the ger area population that there is a program to replace traditional heating stoves and that there are certified producers and certified stoves for which a subsidy is available to all households. The benefits of such stoves will be made known: cleaner air, fuel savings, longer burning time, etc. In addition, their old stoves have value and can be turned in against a payment under certain conditions.

The list of stoves and list of manufacturers will be publicized by UBMG; it will be widely circulated and posted at market outlets; it will also be regularly updated to incorporate new stove models and new stove producers. In one way or another, certified products will be distinguishable from non-certified products (a certificate, a sticker, etc) and certified producers will benefit from the publicity and promotional campaign (to be worked out). For as long as certified producers make stoves that satisfy the criteria, they'll be able to benefit from the project's infrastructure and support. As soon as this is no longer the case (i.e., make poor quality stoves and are unable/unwilling to correct this soon), they'll be removed from the list.

A subsidy will be available for households to buy a certified stove and also to return old stoves. A voucher system will be used to manage the subsidies. An NGO will verify that certified stoves are actually installed in households and that people know how to use them, and will also collect old stoves.

The publicity and promotional campaign will consist of the following:

- Develop and carry out a promotional campaign to announce that vouchers/subsidies are available for better stoves and for returning old stoves, using all media to effectively bring this message across;
- Inform ger area households why it is recommended to use a stove that reduces emissions and what the options are for realizing this;
- Publicize the list of certified producers and certified products, and keep this list up to date; the list should be available in various places where people might consult it;
- To assist certified producers with the promotion of their certified products

Component 3: Subsidy

There are likely to be two types of certified stoves: those meeting the national stove standard, and those (far) exceeding the national stove standard. The first category stoves should allow improved stoves to be almost equal in price with traditional stoves; the second category stoves are much more efficient and the subsidy level could be higher; details will need to be worked out. A flat subsidy should be used for all certified stove models within each category to reduce production prices and promote competition.

In addition, a second subsidy will be available for households that (i) purchased a certified stove and (ii) installed it, and (iii) handed in their old stove. A mechanism will need to be developed for the collection of old stoves and for the handing out of vouchers. (See also the verification scheme.)

The subsidy scheme will consist of the following activities:

- Identify the subsidy levels for new stoves; this is based on actual costs compared to the cost of traditional stoves as well as average emission savings to be obtained;
- Develop the voucher system to deliver the subsidy; options could be through the Khoroo government, one or more NGOs, or even private companies who might be awarded a concession contract for one or more Khoroo or Districts;
- Identify the subsidy levels for returning of old stoves for households who purchased and installed a new stove; the level should be determined and a mechanism for collection should be developed, possibly in combination with a certification.

Component 4: Verification

Improved stoves should be of good quality and perform at least according to the national standard. To verify this, a mechanism will be put in place. The mechanism consists of three elements, each with its own characteristics:

- random checks;
- verify installation; and
- checks based on feedback.

From time to time, randomly selected certified producers need to submit a stove for verification (details to be developed) for retesting, and also certified stoves will occasionally be randomly purchased from the market to verify compliance with the quality standards. If a certified producer does not comply with the standards, he will need to make corrections or risks being taken off the list of certified producers; this also hold for producers of (open source) certified stove models: if they experience quality problems, this must be fixed or they will no longer be allowed on the list of certified producers.

After a producer sold a stove with subsidy, the beneficiary will be visited to verify the quality of the stove and also that the stove is actually installed in his/her home. Once this is properly verified in the beneficiaries' home, the PIU will obtain the permission to pay the registered producer the counter value of the voucher. At the time of verification, the household will be offered to hand in his old stove, for which (s)he will obtain a further subsidy. The exact mechanism how this will work is still to be developed. This will allow the project to collect old stoves and recycle these to the steelmills in Darkhan. This verification system should be set up in such a way that Khoroo-based organizations are involved; one way would be that they can keep the value of the old stoves.

Consumers are suggested (through the publicity/promotional campaign) to register complaints if and when justified. If a certified producer, or a certified stove model receives a significant number of complaints, a verification check should specifically research this question with a view to rapidly find solutions.

Risks

Three main risks have been identified: (i) political economy: frequent changes in Government posts may lead to alterations or delay in agreed work plans; (ii) there are not enough certified stove models or existing stoves are not good enough for emission reduction purposes. Specific training and capacity building among national stove producers should take place and a mechanism to import stoves that meet the standards should be created. The potential market for such stoves is sufficiently large that foreign stove producers could be interested; (iii) subsidies are not large enough for households to replace their old stove.

ANNEX G: SAWDUST BRIQUETTES

Introduction

This Annex discusses the options for producing a household fuel for heating from other natural resources than coal, and it aims mainly at replacing UB's coal consumption. Sawdust briquettes are particularly considered here as a generic option. Sawdust briquettes can be made of sufficiently high quality to be transported over long distances (if necessary); they are usually appreciated by households because of the combustion characteristics: smokeless, slow burning, no ash remaining, and 50% claimed lower consumption (on a weight basis compared to raw coal). At least two producers exist and one of them carried out limited acceptance tests in Khoroo 50 of Sukhbaatar District: households highly appreciated the briquettes and reportedly even paid 70 Tg/kg as compared to 30 Tg/kg for wholesale delivery of coal (40 Tg/kg for purchase in bags).

For the supply of biomass briquettes to be sustainable, the supply of raw material to produce the briquettes needs to be stable and assured. Biomass, if managed well, is a renewable energy source and can be used in the long-run. In this Annex two cases are considered: (i) wood from natural resources available in Mongolia; and (ii) special cases where a large volume of residues happens to be available.

Resource base and theoretical sustainable production capacity

The forest area in Mongolia is about 17.8 million ha with a standing stock of about 1.36 billion m3 of wood of mainly coniferous trees (Larix, Pinus). The forested area to the North of Ulaanbaatar has about 3 million ha that could annually produce some 3 million m3 of wood products on a sustainable basis. Total recorded consumption of sawn wood in the country is only 0.6 million[68] m3 (NSO 2005) and it is likely that much more is harvested but undocumented: Firewood is a major source of energy in the country but there are no statistics on how much wood is harvested for this purpose. Experts who know this Northern forest area claim that an additional 1 million m3 of wood could easily be harvested without impacting the standing stock (i.e., no deforestation, and also no disturbance of any ongoing harvesting).

Although it is in no way recommended to start harvesting such large volumes of wood, this option is considered just for the sake of determining the boundaries: is it possible to replace the entire Ulaanbaatar ger area coal consumption[69] with sawdust briquettes for use in traditional stoves? Some 0.5 million t/yr of sawdust briquettes are needed[70], requiring the annual harvesting about 0.9 million m3 of wood. It is not necessary to use 1st grade logs but lower quality wood and residues will be good enough. So, at least in theory, the production of wood briquettes to replace the full consumption of coal would certainly be a possible technical option that could be sustainable in the long-run, even if improved stoves are not used. Large-scale use of improved stoves will bring down the demand to some 0.3 million t/yr of briquettes.

The new Forestry Law allows and promotes long-term management of forests by local communities. Communities active in forest management would greatly benefit if they can produce

[68] These are taken out in the form of logs; at some 25% or more of this volume stays in the forest as residue (tops, branches, roots, leaves, etc).

[69] 0.7 million t/yr

[70] This is calculated purely on the basis of calorific value of the fuels; 1.3 t coal replaces 1 t of briquettes; the BEEC consumption tests showed a replacement factor of 1.10 - 1.15 plus a large reduction in the use of wood for kindling.

and sell one or more products, and raw material for the production of high-quality wood-briquettes could be one of these products. The communities would harvest and sell the low-grade wood material to transporters. Briquettes would then be made by a locally based company and transported to the market. Several smaller briquetting plants with a production capacity of several 10s of kt/yr could be set up. The market for briquettes is mainly in UB, Aimag and Soum centers, for the heating use of households and low pressure boilers that now use poor quality brown coal. There are multiple benefits: a high quality heating fuel available for end-users; less air pollution for the community as a whole; employment and income generation for local communities; a profitable operation for the briquetting company; and less CO2 emissions for the global environment.

Alternative short-term supply options

An alternative option to harvesting wood from forests is using locally available residues, whether as a one-off or continuous operation. Sawmill residues often tend to accumulate in large mountains that remain in tact for many years; at the moment there are no statistics on residue composition and availability, and the number of operating and closed-down sawmills in the country.

At a sawmill close to Ulaanbaatar (Tunkhul), sawdust has accumulated for many years with a resulting volume of possibly some 0.3 - 0.5 million m3 [71]. Although the major sawmilling operations ceased long-time ago, small-scale milling continues today and probably a supply of 3-5000 t of fresh sawdust is generated annually. One company established a pilot plant and already sells 2000 t sawdust briquettes per year to the railway company and intends to scale up to some 16,000 t/yr. The director of the company saw a similar plant while in China and invested in the pilot plant. He has now prepared a business plan to expand to a more fully-fledged production facility and is currently looking for financing.

The production of briquettes from sawmill residues - as opposed to from community managed forests - is a lower-cost option but it is normally not sustainable because the residues will be depleted sooner or later. Nevertheless, it would make good business sense to immediately start converting accumulated sawdust into briquettes and simultaneously identify a new supply stream of raw materials to realize a sustainable production level in the medium future.

Potential supply

The potential supply of briquettes from known sources is large: at least 0.6 million t of briquettes from the natural forest closest to Ulaanbaatar in theory, and ; about 0.3-0.5 million t and thereafter a limited quantity of probably 3-5 thousand t/yr from the Tunkul soum. Data for other sawmills are unknown. These quantities suggest that sawdust briquettes are certainly worth pursuing as long as they can be sold for a price that is acceptable to clients. This means that heating costs do not increase for the average ger area household, although a certain number of them may be willing to pay a premium because of the superior burning characteristics of briquettes. Sawdust briquettes should be considered at least as seriously as semi-coked coal briquettes.

Carbon financing could be used to make the production process more viable. Carbon financing at a level of $10/t could reduce the production cost of the briquettes by $19/t.

Market size

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[71] This is a very rough estimate and a better evaluation is needed; sawdust may deteriorate over time and become unusable.

The widespread use of improved stoves would reduce the coal consumption from the current level of some 0.7 million t/yr to about 0.4 million t/yr. Between 0.2 and 0.3 million t/yr of sawdust briquettes[72] are sufficient to provide the same amount of heat. Less briquettes may be needed even if the results of the limited acceptance tests can be generalized.

Forest Residues-based briquette production: description of activities

The sustainable production of sawdust briquettes from forest residues requires the following activities:

(i) forest-based harvesting;

(ii) transformation; and

(iii) commercialization.

The *forest-based* harvesting activities include the extraction of low-quality wood, drying in the sun in a safe place (to prevent forest fires!), and transporting to a collection point. These forest-based activities, including sustainable forest management practices, could be developed either under the proposed WB forestry project or under the ongoing GTZ fire prevention activities[73].

A community group producing 1000 m3 of wood per year requires about 15 people to be employed during the harvesting season (100 days/year); they each would earn a reasonable sum of money for work carried out[74]. An area of about 1000 ha per community is needed for such an operation, which seems not unrealistic. Some 100 community groups would be needed to produce enough wood to produce about 120,000 t of briquettes in this manner.

The forest-based activities can be avoided if sufficient residues are available; this would lower the production costs, at least temporarily.

Transformation includes chipping at the collection point with a mobile chipper and transporting chips to the briquetting plant, further drying (if needed), hammer-milling and briquetting. A screw-press will be used to form briquettes without binder; the high pressure will liquefy lignin in the wood and this will act as a binder. The resulting briquette is of high quality and allows for slow and clean combustion. Some 100-150 people are likely to be involved in this transformation process.

The commercialization involves transport to the end-user and retail marketing, and is likely to require also about 100 persons to be involved. Some 10 trucks per day are needed to transport the briquettes to town. In all, the production of 100-120,000 t of briquettes from natural forest feedstock will employ about 2000 people.

Estimation of the production costs

The following table gives a rough estimation of the production costs; included are investment costs and depreciation, operational costs, and margins for all involved[75], and based on typical investment

[72] If only the heat content is considered, per t of sawdust briquette 1.3 t of coal are replaced and 1.9 t of CO2 are saved.
[73] GTZ confirmed its highly positive interest in this
[74] Here a fee of 4800 Tg/person per day is considered.
[75] A much better analysis will need to be carried out; this is just to give a flavor of the involved costs.

costs as prevail in Europe[76]. In addition, a subsidy for avoiding CO2 emissions from coal and a polluter tax benefit are taken into account. The resulting wholesale price is about Tg 38,600 per t of briquettes which can be compared to Tg 30,000 per t of coal on an equivalent energy content basis. Or if the limited acceptance tests can be validated, the equivalent coal price would be 77,200 per t, in which case household' costs for heating would be reduced if they switch to briquettes. This also means that without carbon financing and without benefits from a polluter tax, the briquettes can be sold at their current price and this will not increase annual heating costs fro households.

Table 1: ESTIMATED PRODUCTION COSTS OF SAWDUST BRIQUETTES

	Tg/t	US$/t
cost of wood extraction & transport to collection point by community	6,000	5
sun drying		
cost of chipping	12,000	10
& transport to the briquetting plant by transporter (50 km)	4,800	4
Drying	12,000	10
Briquetting	18,000	15
transport to UB	18,000	15
	70,800	59
carbon financing	(23,143)	(19.3)
polluter tax benefit	(9,000)	(7.5)
Total	38,657	32.2

Potential project activities

The assistance to develop forestry-based community development activities should be the responsibility of another program and cannot be covered under the Air Pollution Project. However, if a sustainable supply of wood can reasonably be guaranteed, briquetting makes sense, particularly if they first start off finishing accumulated resources. An assessment of how many communities there could be, their locations, and their resource availability will need to be carried out as well as an assessment how many briquetting plants would be optimal for the projected sustainable supply of wood.

The proposed air pollution project could support and enable the transformation and the commercialization of briquettes through a number of private companies. To that end, the market for briquettes could be actively promoted, through acts of publicity and awareness raising, and TA could be provided to potential briquette producers to set up the forest-based chipping capacity and one or more centrally located briquetting plants. In principle, existing transportation companies should be used to transport chips from the forest to the briquetting plant and then briquettes to the consumer. The capacity of the transport sector will need to be assessed. The private firm(s) will need to invest in the briquetting plant(s); the project will neither provide finance for investment nor

[76] Investment costs for a 100kt/yr plant would be $3-4 million, including tractor, forklift, crane, buildings, etc; the local firm proposed a budget of $0.5 million for a similar plant using Chinese equipment (and not quite adhering to the European labor standards).

for the operations; it could possibly provide pre-financing if needed, and mostly TA for starting up the operations. Climate change funds or polluter funds could possibly be available to buy down the production costs of briquettes.

ANNEX H: SOLID FUEL STOVES IN OTHER COUNTRIES

Introduction

Modern coal stoves exist, they may not be easy to find; a few websites that offer such stoves are presented below[77]. In the USA, in the UK, and in Germany and some former Eastern European countries coal is still regularly used by large numbers of customers. Solid fuel stoves appear to be making a comeback in Western countries, mainly because of escalating fuel-oil and gas prices. Wood stoves are the most popular choice, but some interest is gaining in coal stoves. In the USA emissions are strictly regulated by the EPA (Environmental Protection Agency) and most solid fuel stoves need a catalyzer to meet the air quality requirements. Solid fuel stoves are not cheap; although no prices were collected, one can safely assume that they range between $2000 and $5000, including transport and installation.

A quote from a manufacturer: "*If you've been looking, you'll find that coal stoves seem harder to find* (compared to wood burning stoves or stoves using gaseous or liquid fuels). *It's no illusion. Coal as a fuel source for residential heating has waned, and that's very unfortunate. It's unfortunate because anthracite coal is an excellent fuel, an American resource, and has shown remarkable price stability and value in terms of BTU/$. So why has popularity of coal dropped? Like wood, some people feel it's messy, or too much work. Of course, people had the luxury to feel that way during good economic times and low energy prices when turning up the thermostat was a 'no-brainer'. Another concern was that EPA regulations for emissions from wood stoves impacted sales for those consumers that wanted the flexibility of burning both fuels. This had the effect of forcing many consumers to choose a wood stove or a coal stove and not a combination stove. Most chose wood.*

As more people come to realize that a new energy sensitive era is emerging, coal will probably be recognized for its value and availability, and manufacturers will turn to create more coal stove models".

So, two things can be learnt here: unlike what most Mongolian households think, a heating stove designed for wood isn't always good for burning coal, although a properly designed compromise design (hybrid) is available that can burn wood and/or coal relatively efficiently. Second, it is expected that new models coal stoves will come on the market in the near future to cater to the market for people who perceive liquid or gaseous fuels as too expensive. It might be an idea, to accelerate this movement, to write an open invitation to these (and any other) manufacturer of coal stoves with the message that a market of > 100k coal stoves is present in Mongolia, and inform them about the generic heating requirements, quality of different types of coal being used in UB, and the generic air quality and fuel consumption characteristics plus the prices that people now pay for their stoves.

A feature of modern solid fuel stoves is their ease of use; they operate almost like a gas stove. Some are designed for pellets and/or come with a hopper, an automatic feeder mechanism that allows users to feed their stove only once a day or once every two days. This idea hasn't been pursued at all in Mongolia, but would make a lot of sense!

Examples of commercial suppliers of coal stoves, mainly in the USA:

http://www.readingstove.com/
http://www.harmanstoves.com/
http://www.leisurelinestoves.com/

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[77] These are commercial manufacturers that were identified through a Google search; the authors do not endorse any of these manufacturers – they are just presented to demonstrate that there is a choice of manufacturers for coal stoves.

http://www.vermontcastings.com/index.cfm
http://hearth.com/econtent/index.php/articles/coal_stoves/
http://www.prestontradingpost.com/coal_stoves.htm
http://coal-stoves.net/