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Asia Sustainable and
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Mongolia

Heating in Poor, Peri-urban Ger Areas of Ulaanbaatar

October 2009

ASTAE

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Foreword

Ulaanbaatar, Mongolia's capital city, is extremely polluted in the wintertime. Coal and wood burning in traditional stoves is a major cause of the city's severe air pollution. Ulaanbaatar is already the coldest capital of the world, but it need not be its most polluted. Our government is acting to solve wintertime air pollution through a series of measures, including fuel switching, stove replacement, and public awareness. This study provides market information about affordability, attitudes, fuel consumption, and the market for fuels and stoves. It provides valuable insights for solutions to the important challenges facing our government in providing cleaner, affordable heating in poor, peri-urban ger areas of Ulaanbaatar.

There is considerable debate about the right pollution abatement options for wintertime air pollution. This report incorporates lessons learned from previous clean heating programs in Ulaanbaatar. It addresses—in a systematic and analytic way—practical issues in subsidy design, product development, and public awareness. This is a useful reference document that can be used to review issues in clean heating system development and promotion. Nevertheless, significant efforts are still needed to disseminate information on effective pollution abatement measures so that we can build partnerships among government, external partners, and Ulaanbaatar's citizens to sustainably reduce air pollution in our capital city as quickly as possible. I would like to encourage readers to provide their suggestions, ideas, and support to join us in this effort.

Zorigt Dashdorj
Minister of Mineral Resources and Energy
Chairman, 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)
Mongolia

Abbreviations and Acronyms

AQD	Air Quality Division (of 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
CLEM	Central Laboratory of Environmental Monitoring
CO	carbon monoxide
CO_2	carbon dioxide
DH	district heating
EBRD	European Bank for Reconstruction and Development
GTZ	Gesellschaft für Technologische Zusammenarbeit
HVAC	heating, ventilating, and air conditioning
kg	kilogram(s)
kWh	kilowatt hour
LPB	low-pressure boiler
MJ	megajoule
MMCG	Mongolian Marketing Consulting Group
MNE	Ministry of Nature and Environment
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
Tog	Mongolian togrog (unit of currency)
TSP	total suspended particulates
UBCAP	Ulaanbaatar Clean Air Project
UBMG	Ulaanbaatar municipal government

Currency

US$1 = Tog 1,200 (over the period 2007–08)

Acknowledgments

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 Poor, Peri-Urban Areas of Ulaanbaatar. The project 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 the 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), and the Republic of 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 Ulaanbaatar 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 the Asian Development Bank, the European Bank for Reconstruction and Development, Gesellschaft für Technologische Zusammenarbeit, Japan International Cooperation Agency, and many other partners.

This ASTAE activity greatly benefited from the 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 and vice-chaired by the General Manager of Ulaanbaatar City Administration; Ulaanbaatar Municipality (Department of Urban Development and Ulaanbaatar Environmental Protection Bureau); the Ministry of Mineral Resources and Energy; the 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; a full report will be published in the near future. There are numerous other stakeholders from universities and institutes and air pollution experts who contributed their time and comments to these activities, for which the authors are most grateful.

The report 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 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 assessment for testing, and testing protocol, and provided training to stove manufacturers. Mr. Helmut Vierrath contributed to assessments of various semi-coked coal production proposals and technical advisory support on gasification. Mr. Jostein Nygard, World Bank Senior Environmental Specialist and comanager 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, Senior 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[1] of Ulaanbaatar is a large contributor to overall air pollution in the city. The use of coal in simple heating stoves releases high levels of particulate matter (PM)[2] into the air. Updated estimations of these air pollution levels have recently been made[3] and will be published shortly. These estimates show that ger area household heating contributes about 45–70 percent 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 area heating systems burn continuously during the winter season and their contribution to the overall air pollution level then reaches 70 percent and more in the ger areas and up to 60 percent 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 air pollution and associated health problems in Ulaanbaatar. Heating expenses surveyed for this report constitute about 21 percent of the annual income of the poorest fifth of the ger population and 15 percent for the next fifth. However, during winter months heating expenditure represents 42 percent of monthly income for the poorest and almost 26 percent 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 World Bank's Asia Sustainable and Alternative Energy Program (ASTAE) 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 rollout. 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 nonmarket-based approaches 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 include improved insulation for gers and 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 in the six closest ger districts—affordability, fuel consumption, perceptions of various pollution abatement measures—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 and an enforcement mechanism to address noncompliant products and manufacturers;
    - a targeted subsidy program with an 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;
    - a monitoring and evaluation system generating feedback to perfect systems;
    - a public awareness program through mass media; and
    - use of grassroots public participation approaches to encourage participation of the ger area residents in pollution abatement programs.

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

2. The term "particulates" includes a large number of condensed liquid droplets, not only particles of "dust." PM^{10}, the fraction of particles less than 10 microns in diameter, is considered the threshold for major health consequences, even more so the fraction of finer particles, $PM^{2.5}$, less than 2.5 microns in diameter.

3. Norwegian Institute of Air Research, under contract with the World Bank; Draft Updated Urban Air Pollution Analysis for Ulaanbaatar, NILU/World Bank, June 2009.

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

This study focuses only on stove-fuel issues, and although medium-term options, such as moving residents into apartments, electrical heating, heat pumps, and district heating, are briefly addressed in this report, they fall outside the scope of this study.

Much debate has occurred about 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 all have yielded limited success. 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 because it is the major cause of health problems for the population of Ulaanbaatar. Indoor air pollution is not the focus of this study because the high outdoor air pollution level is considered the primary cause of indoor air pollution, provided stoves and chimneys work well.[4]

Key Findings

The following are key findings of the ASTAE activities[5] carried out during the 2007–08 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 (fuel, appliance, insulation of the dwelling, and so forth). The cleanliness of the heating system depends on both fuel efficiency (amount of fuel used to produce a certain heat) and combustion efficiency (amount of emissions per quantity of fuel used). Characteristics of both the stove and the fuel affect cleanliness.
- *A market-based approach for reducing air pollution from ger area heating systems is the sustainable strategy for switching fuels and stoves.* However, based on best available data, technical solutions to reduce emissions from coal-fired ger area heating systems are possible, but are not available on the market. Although technical designs exist that could combust raw lignite much more cleanly than do current heating systems, they are not commercially present in Mongolia.[6] There is also an insufficient supply of reliable alternative fuels. However, based on previous experience, no single solution or abatement measure has been shown to have a major impact alone—a large impact will require a combination of pollution abatement measures. Not all abatement measures need to be identified to get started, but systems should be designed to ensure success.
- *A 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 with raw coal in traditional stoves.* No fuel-stove combination currently available in Ulaanbaatar has been shown to meet prevailing emissions standards.
- *When developing a package of pollution abatement measures, the package's 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 because of a lack of laboratory equipment and experience with testing protocols, very few good results are available. Such

4. ESMAP: Impact of Improved Stoves on Indoor Air Quality in Ulaanbaatar, Mongolia, Report 313/05, 2005.

5. A total of six activities were carried out: (i) 1,000-household ger area survey (December 2007 through February 2008) to establish a baseline and learn about household perceptions and attitudes; (ii) 60-household consumption test (January through March 2008) to measure consumption and user feedback for different fuels in different stoves under real-life conditions; (iii) laboratory assessments and development of a standard testing methodology (December 2007); (iv) capacity building for better stoves among stove designers and stove producers (February 2008); (v) stakeholder project design and structured brainstorming workshop (October 2007); and (vi) interviews with World Bank team experts during missions.

6. Recently, some prototypes have surfaced in Ulaanbaatar.

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 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 some quantity of new heating walls are installed; the estimated value was more than Tog 2 billion in the 2007–08 heating season. Based on the results of the household survey, total fuel consumption in the six ger areas in Ulaanbaatar was estimated at 546,000 tons of coal for the 2006–07 heating season with a value of about Tog 19.2 billion. In addition, a total of 611,000 cubic meters (or about 415,000 tons) of wood were used, with a value of about Tog 36 billion. Some limited regulatory tools, such as technical standards for stoves and fuels, exist, but are not enforced; however, it is not even possible to measure compliance because adequate laboratory capacity is not available.
- 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 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 changing rapidly, in line with housing preferences, resulting in increased 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 percent of surveyed households use LPBs, consuming on average 6.2 tons of coal per season, as compared with 3.5 tons per season for individual traditional ger stoves (resulting in 77 percent higher fuel consumption). The relative increase in emissions from these devices is unknown. The use of heating walls is important, too. Almost as many households living in detached houses have heating walls as live in gers; heating walls consume 4.5 tons of coal per season and provide more comfort than individual stoves (30 percent higher fuel consumption than a ger stove). Only 16 percent of households living in detached houses do not have heating walls or LPBs. The testing protocols that determine emissions factors for fuel-stove combinations will need to be adjusted to the actual fueling practices of these appliances, which are different than those for 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. For example, compared with raw coal, certain briquettes require that larger volumes of ash be disposed of, or other briquettes take much longer to ignite because of the low content of volatiles in the fuel. Factors to consider are, therefore,
  - cost of fuel and appliance;
  - convenience level, including (i) amount of ash and ash disposal system; (ii) ease of cold start up and frequency of refueling; (iii) heating power and controllability of the heat output; (iv) fuel durability and storage; and (v) indoor smell;
  - cooking utility and appearance; and
  - release of smoke through the chimney (contribution to air pollution).
- *Market-based approaches to disseminate cleaner heating systems are preferred over nonmarket-based approaches* such as stove giveaways. The latter are risky and have already resulted in failure when used earlier in Ulaanbaatar. Command and control approaches, such as banning raw coal, could be considered as complements to market-based approaches, but should be carefully examined for 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, the following factors should be considered:
  - *Artisanal manufacturing is not going to have sufficient capacity* to design and supply the market quickly to produce at sufficient scale to bring down unit costs. Different solutions may be required, such as collaboration with foreign manufacturers and substantial technical and financial assistance to present manufacturers.
  - *Subsidies are very likely to be required because of 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 systems they prefer. Subsidy vouchers would be offered to households for the purchase of appliances that comply with low emissions standards. If practical to implement, higher voucher values could be applied for lower-emissions heating systems. This is considered to be an *output-based aid* approach. Reduced coal consumption would also reduce carbon dioxide emissions, for which global mechanisms exist to capture the value.

- *Mechanisms and incentives for the removal of existing heating appliances* should be developed to ensure that they are taken off the market. As an example, incentives could be provided to households to dispose of their old systems when switching to new ones.
- *Calibrating the amount of subsidy will depend also on the endpoints and objectives of the policy.* If reduction in health impacts of air pollution is an endpoint, determining the share of air pollution that comes from ger heating systems will be important to help determine the amount of resources justified for the desired effect. Current estimates of annual average concentrations of air pollution from the ger area vary but appear high. Such measurement is beyond the scope of this ASTAE activity but is being undertaken in cooperation with the Ministry of Nature and Environment/National Agency for Meteorology, Hydrology and Environment Monitoring, 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 for Ulaanbaatar. The program can be supported by three recommended policy options:

- The first policy recommendation is to develop and enforce technical standards for fuel-stove combinations specifically for use in ger areas, perhaps first by setting interim targets and testing new enforcement mechanisms. Complementary fuel substitution policies could be considered; although not specifically addressed in this report, they are currently being studied as part of the EBRD technical assistance project, the Ulaanbaatar Clean Air Initiative.[7] Providing assistance to Mongolian stove producers for the production of better heating systems and possibly linking them with international counterparts should be part of the program. This will first require setting up emissions testing capacity, which does not exist yet in Ulaanbaatar.
- The second policy recommendation is to actively encourage households to switch to better fuel-stove combinations—once these combinations have been identified. Switching could be encouraged by a large-scale publicity and awareness campaign, and putting into place a support mechanism to assist poor households to quickly adopt the measures to clean up the air they breathe. This report suggests using a subsidy voucher system based on the earlier OBA approach that linked producer outputs to subsidies, which showed promising results in Ulaanbaatar.
- The third policy recommendation is to select abatement measures based on an analytical framework that allows policy makers to estimate the overall effect of pollution reduction measures on air pollution. While data problems can cause estimates to vary significantly, the discipline of comparing measures and results will help to get programs started, provide feedback, manage expectations, and continuously improve an air pollution abatement program. As a result of the complexities of Ulaanbaatar's air pollution problems, reducing its air pollution will unavoidably be a multiyear effort involving experimentation, mechanisms for continuous improvement, financing, and sustained support from all citizens of Ulaanbaatar.

7. A report will be issued shortly on the preliminary results of testing different fuels in a traditional stove and one improved stove.

1

Background and Introduction

Air quality in Ulaanbaatar is deteriorating rapidly. During the past few years, complaints about air pollution in the city have increased dramatically, especially during the winter months. Heating season in Mongolia lasts about eight months, starting in September and ending in April of the following year. 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 power plants but also in the ger areas, where households rely on small stoves to keep warm during the winter months. Consensus points to the use of raw coal for heating by ger area residents as one of the main culprits behind the city's rising air pollution.

Ulaanbaatar is surrounded by mountains, which makes air pollution problems in the city more acute. The city consists of two main areas: the city center, with high-rise office and apartment buildings, and the surrounding ger areas, with mainly low-rise—one story—detached houses and gers. Ger areas have grown rapidly in both size and population, mainly as a result of poor rural economic conditions resulting in a rural exodus. Currently, 60 percent of Ulaanbaatar's population lives in the ger areas, and the proportion is growing. Because 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 because these are the cheapest available sources of heating energy. Their heating stoves are inefficient in both fuel use and combustion efficiency.

As a result of the growing ger area population, the use of coal has increased as has the severity of the air pollution. Several proposals to reduce air pollution in the city have been discussed, including imposing a ban on the use of raw coal, introducing cleaner-burning briquettes, introducing semi-coked coal, replacing existing inefficient

heating stoves with fuel-efficient stoves,[8] and resettling ger area households into apartment buildings. However, to date there has been very limited information—the bulk of it 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 gaps in the information needed to formulate appropriate policies and actions aimed at promoting improved heating appliances and fuels.

Exposure to airborne pollutants, primarily fine particulates such as $PM^{2.5}$ and PM^{10} (particulate matter less than 2.5 microns and less than 10 microns, respectively, in diameter), is a serious health hazard for all city residents, not just those in the ger area. 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.

8. Several other proposed solutions are being discussed and debated, such as providing subsidized electricity for ger heating. However, the full analysis of potential longer term alternatives is beyond the scope of this study.

1.1 Structure of the Activities and Report

Between October 2007 and June 2008 a series of activities was launched by the World Bank, with generous support from the Asia Sustainable and Alternative Energy Program (ASTAE), to develop baseline information to design a large-scale program to introduce cleaner heating systems. Results of consumption tests could not have been made possible without financial and expert support from the Ulaanbaatar City Administration.[9] Further essential assistance and collaboration was obtained from GTZ, JinSun Energy Co., and World Vision.

This report is designed to provide background information for those who are interested in either market- or non-market-based approaches 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 and 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, which was in the middle of 2007–08 heating season. To collect complete information on fuel consumption and expenditure, interviewers asked respondents about fuel consumption and expenditure from the previous heating season, which was September 2006 through April 2007. In addition, interviewers collected information on prices and types of fuels and stoves used by the households at the time of the interview for comparison purposes. The survey was designed to collect data from a representative sample of households living in the ger areas surrounding the city center. Ulaanbaatar districts located outside the city (for example, Baganuur) or far from the city center were excluded from this study, because the use of raw coal by residents in those districts has little or no direct impact on air pollution in the city itself.
- Consumer consumption tests carried out January–March 2008. A sample of households used different stoves and different fuels. Four groups of 15 households participated (60 in total), using four different stoves and five different fuels mostly over two-week periods for each different stove-fuel combination (10 weeks in total).
- Laboratory assessments of the same fuel-stove combinations, to determine the relationship between fuel consumption and emissions.
- Technical stove design assessment capacity building among stove designers and stove producers, to promote stove designs for better fuel consumption and emissions reduction.
- A stakeholder project design and structured brainstorming workshop on improved stoves with selected participants.
- Interviews with Bank team experts during missions, in particular with clean coal experts,[10] a gasification expert,[11] and environmental experts.[12]

The Mongolian Marketing Consulting Group carried out the household survey in January 2008 and the Building Energy Efficiency Center (BEEC) of the Mongolian University of Science and Technology supervised the consumption tests. The other activities were carried out by individual international consultants.

1.1.1 Household Survey

Data from the household survey in the ger areas of Ulaanbaatar allow the following: (i) estimating the total number of traditional heating stoves currently used by households living in the in ger areas; (ii) establishing a baseline of heating fuels used by households with traditional heating stoves; (iii) gaining more understanding of households' perceptions and attitudes toward existing traditional heating stoves, improved stoves, and alternative heating fuels; (iv) assessing households' ability and willingness to switch from traditional stove heating to improved stoves; and (v) identifying barriers that may inhibit households from switching to improved stoves. An up-to-date list of all households from all ger area khoroos[13] was used to identify 1,000 households using

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

10. Masaki Takahashi, World Bank power/boiler specialist; J-Coal consultants, World Bank consultants.

11. Helmut Vierrath, coal gasification expert, World Bank consultant.

12. Jostein Nygard, Jitu Shah, World Bank air pollution specialists; Tony Whitten, World Bank biodiversity expert; and Steinar Larssen, air pollution expert, World Bank consultant.

13. A khoroo is a subdistrict of Ulaanbaatar, the capital of Mongolia. Each düüreg—district—consists of a number of khoroos.

simple random sampling, providing a maximum sampling error of 3 percent. Table 1.1 presents the sample size for each district.

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 to test both the questionnaire and the surveyors. A public feedback meeting was held at the Ulaanbaatar Municipal Government (UBMG) building to discuss the questionnaire with interested organizations and individuals before it was field tested. The survey was carried out by the survey 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. Appendix A provides important information on statistical methods used.

Coal consumption and expenditure in the survey are based on responding households' recollection of the heating season previous to the survey—that is, coal consumption and expenditure from September 2006 through April 2007. The estimated weight of coal per bag and volume of firewood per bag are based on the assumptions that one bag of raw coal equals 17 kilograms and 20 bags of firewood equal one cubic meter. Because the responses were based on recollection of the previous heating season, it was not possible for interviewers to weigh fuels during the interviews. Furthermore, raw coal, compressed coal, coal briquettes (except Korean briquettes) bought and sold in the market are based on estimated weight, and firewood on estimated size in cubic meters.

Large truckloads (often on Russian-made trucks) measure about five tons for coal or five cubic meters for firewood. Smaller truckloads (often on Chinese-made trucks) measure about two or three tons for coal or about two to three cubic meters for firewood. Consumers are usually informed about the weight in tons when buying raw coal by the truckload but the weight is not otherwise verified. Raw coal or firewood bought and sold in small bags can be weighed by the user, but usually is not. Consumers who purchase raw coal or firewood by the bag generally 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 fill approximately 60 bags. As a result, the survey assumes that one bag of raw coal weighs about 16.7 kilograms. Similarly, to sell firewood in bags, fuel traders usually divide one cubic meter of firewood into 20 bags, so the survey assumes that 20 bags of firewood equal one cubic meter.

TABLE 1.1: HOUSEHOLD SURVEY SAMPLING DETAILS

District	Sample size	Number of households represented
Bayangol	73	7,369
Bayanzurkh	250	25,235
Songinokhairhan	231	23,317
Sukhbaatar	173	17,463
Chingeltei	193	19,482
Khan-Uul	80	8,075
Total	1,000	100,941

Source: Mongolia Marketing Consulting Group.

1.1.2 Consumption Test

The consumption test in the ger areas of Ulaanbaatar (December 2007–March 2008) allows the following: (i) estimating ger area household consumption levels for different fuel-stove combinations and determining heating costs; (ii) determining the relative fuel consumption for each fuel type compared with 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 of households' perceptions and attitudes toward their existing traditional heating stove, improved stoves, and cleaner heating fuels. These data help to establish the baseline for heating fuels and stoves used by households 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 the data, and wrote a report. A committee consisting of UBMG, World Vision, and Bank staff selected 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 two weeks. The other three groups each had a different stove and participated for eight weeks. Traditional stoves (that participating households already owned),

TABLE 1.2: FUEL AND STOVE COMBINATIONS APPLIED

	Fuel type and period				
Stove type (15 each)	First 2 weeks	Second 2 weeks	Third 2 weeks	Fourth 2 weeks	Fifth 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	n.a.	n.a.	n.a.	n.a.

Source: BEEC.
Note: n.a. = Not applicable. Nalaikh means coal from the Nalaikh mines. hh = Household; SCC = Semi-coked coal.

TT-03 stoves newly purchased from the market, and GTZ improved stoves (donated by GTZ) were used in the tests to reflect the common stoves and the best improved stoves currently available. The 45 households used raw coal for their first two-week period, sawdust briquettes during the second period, coal briquettes during the third period, and a variety of fuels during the fourth period (see table 1.2).[14] Enumerators visited each household every day to check 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.

1.1.3 Laboratory Test

The laboratory test (March 2008) of the same stove-fuel combinations as in the consumption test could be only partly completed. The idea was that standardized laboratory tests of stove-fuel combinations would yield both fuel consumption data and emission data (combustion efficiency, carbon monoxide [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 was lacking.

Although a standard methodology was developed by the ASTAE consultant and generally accepted by the main laboratories in Ulaanbaatar, lack of equipment and trained personnel prevented the tests from being 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 appendix B for the testing protocol.)

1.1.4 Training of Stove Designers and Producers

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 as cleanly as a simple, locally built reference burner.[15] The main difference between

14. Fuels tested during this last period were raw coal from the neighborhood sales points; Yontan coal briquettes manufactured by Sunjin Energy Co., Ltd; coal briquettes manufactured by Burhany Gal Co., Ltd; sawdust briquette "Talst" manufactured by Ulziit Tuv Co., Ltd; raw coal sprinkled with "Clean Coal" liquid; coal briquettes manufactured by Tanu Fuel Co., Ltd; semi-coked briquettes manufactured by MAK Co., Ltd; and semi-coked coal manufactured by MAK Co., Ltd. Fuel choice was agreed upon with UBMG, and all briquettes had to comply with the National Standard for solid fuel, MNS 5679: 2006.

15. A reference burner is a combustor that is not designed to maximize heat output to the room but simply to show the quality of

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 downdraft model, exhaust gases 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. These principles were shared with the stove community in Ulaanbaatar in two steps: (i) discussing and agreeing on the methodology for testing fuel consumption and emissions with the laboratories interested in this type of work; and (ii) organizing a two-day training workshop with follow-up factory visits for interested individuals and firms to demonstrate downdraft principles and discuss how these could be applied to normal heating stoves.

The practical testing that took place in the laboratory demonstrated that conditioning of the coal could also yield substantial benefits. Breaking up the coal lumps into smaller pieces of two to three centimeters improves combustion efficiency because 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 by conditioning it), 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 put 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.

combustion. It can easily be redesigned into a stove when fitted with a heat exchanger so that the combustion gases leave their heat content in the room. The reference burner demonstrated a reduction in PM and CO emissions of more than 90 percent compared with traditional and currently available "improved" stoves.

1.1.5. Brainstorming Workshop

A structured brainstorming workshop took place to discuss the 360-degree experience of all stakeholder groups with promoting improved heating stoves (October 2007). A number of khoroo chairmen, the stove NGO association, stove producers, households, the Ministry of Nature and Environment, UBMG, the stove project implementation unit, and some nongovernmental organizations participated in the workshop. The objective was to obtain feedback on the effectiveness of the previous improved stoves program and obtain guidance for restructuring. (See appendix C for more details and results of the structured brainstorming workshop.)

Finally, many discussions in person and by email took place to review findings and brainstorm about alternative approaches; this contributed to shaping the current report and the results are incorporated throughout the report.

The European Bank for Reconstruction and Development's (EBRD's) technical assistance 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. These were important first tests that could kick-start needed development of appropriate fuel-stove combinations. 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 by the EBRD project 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.[16] 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.

16. University of Johannesburg's SeTAR Centre.

1.2 Summary Results

The following summarizes the data collection effort in three parts: (i) data about the market for stoves and fuels; (ii) data about the perceptions and attitudes of ger area residents about fuels and stoves; and (iii) results of the tests of the different stove-fuel combinations.

1.2.1 Market Data

The 1,000-household survey in Ulaanbaatar's closest six khoroos provides a better understanding of, and statistical data on, 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 and type and size of dwelling unit:

- households living in gers and using heating stoves with chimneys;
- households living in small detached houses and using heating stoves with chimneys to directly heat their homes;
- households living in medium-size detached houses and using stoves attached to a heating wall; and
- households living in larger detached houses and using low-pressure boilers attached to systems with circulating water and radiators.

Comparison of fuel consumption and expenditure among these groups of households shows that both are positively correlated with the heating system and the type and size of home. As expected, households living in gers spend and use the least amount of heating fuel and households living in detached houses 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 of September 2006 through April 2007, households consumed on average about 4.2 tons of raw coal and about 4.7 cubic meters of firewood. The estimated total expenditure per household during the heating season was Tog 175,200 for raw coal and Tog 84,000 for firewood. The survey also shows that lower-income households in the ger areas spend a significant amount of money to heat their ger homes, with an extremely high financial burden for households in the bottom income quintile, which spend as much as 40 percent of their monthly winter incomes on heating fuel. Households in the top income quintile spend only 9 percent of their monthly incomes on heating fuel.

The number of briquette users from the survey was very low, with only 1.6 percent of households in the six surveyed ger areas reporting that they use briquettes all the time, although another 3.6 percent are occasional users. In all, about 5,000 households used briquettes at any time during the heating season covered by the survey. The number of households exposed to or that used briquettes doubled from the 2006–07 heating season. Briquette use appears to be gaining popularity quickly. However, the pattern of briquette usage since the 2006–07 heating season seems to suggest that households are either still testing these new products or could not find a steady supply.

An estimated 104,000 stoves were 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 five years through 2007, an estimated 11,500 stoves were added each year. No systematic disposal of old or unused stoves occurred. Based on the survey, about 24,000 households still possess their old stoves. Although these old stoves are not in working condition, it is not known how many of them 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; perhaps they should be collected and crushed to take them out of service.

1.2.2 Perceptions and Attitudes

The majority of households in the six surveyed ger areas appear to be satisfied with their existing stoves or heating systems. However, when asked if they would be interested in changing their current stove, 52 percent of the households in the surveyed areas responded affirmatively and of those, 56 percent were interested in changing to an improved stove. The main reasons for willingness to change stoves were the desire to reduce heating bills and high expectations 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 and is harmful to their health. Households also show willingness to reduce raw coal consumption and to adopt alternative heating stoves or fuels. The general attitude toward improved stoves is positive. There is no apparent negative opinion toward improved stoves. The majority of households have very little information about briquettes. However, a significant portion of households indicated their willingness to try briquettes; 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 knowledge of costs and benefits and they also have no knowledge about the impact of the proposed solutions or actions. For example, the survey finds that about 60 percent of the households agree with the statement indicating that he or she would really like to only use electricity to heat his or her home or ger; a small number (fewer than 50 percent) think that it is cheaper to use electricity to heat a home or ger than to use 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.

1.2.3 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 megajoules per day[17] compared with 425 megajoules per day for a traditional stove. It was also shown that the energy consumption of a particular type of coal briquettes was 15 percent higher than raw coal in a traditional stove but only 5 percent 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 because of 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 carbon monoxide, hydrogen sulfide, total suspended particulate matter, PM^{10}, and $PM^{2.5}$. A standard testing protocol was discussed with the laboratories that are interested in this type of work. Although emissions tests have been conducted in the past, 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.

17. Across all fuels and all households in the sample.

2

Demographic, Housing, and Socioeconomic 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.[18] Ulaanbaatar can be divided into two main areas, the city center area and the ger areas. The city center comprises mainly high-rise office and apartment buildings while the ger area consists primarily of one-story detached houses and gers. Ger areas spread into a wide region stretching from around the city center to the outskirts and the suburbs of the city. The 2003 population census reveals that there are about 124,000 households in the ger areas. The main ger areas surrounding the center city encompass about six districts and 74 khoroo.[19] The Asia Sustainable and Alternative Energy Program (ASTAE) survey focuses on these main ger areas because of their direct impact on air quality in the city. *The survey data differ from consensus knowledge, which is that the actual population is larger;* however, the sampling frame for the survey used up-to-date khoroo registration lists that may exclude the newest as yet unregistered immigrants and excluded ger areas farther away from the city center.

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

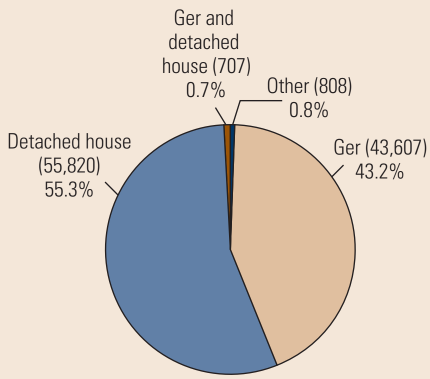
2.1 General Characteristics of Ger Areas

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

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

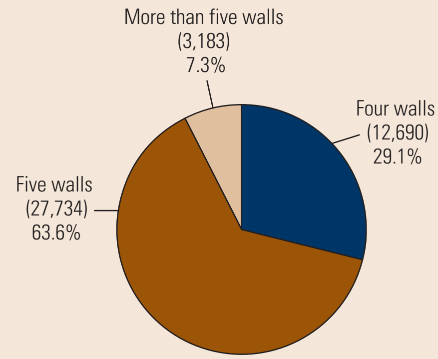
19. There are a few districts located farther away from the city center. These districts are excluded from this study because the use of heating stoves by households in these districts has a limited impact on air pollution problems in the city.

FIGURE 2.1: TYPES OF DWELLINGS



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

FIGURE 2.2: SIZE OF GER



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

2.2 Total Number of Households and Types of Dwellings

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 a one-story wooden house or a felt tent (ger), or both a wooden structure and a ger, 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 indoor running water and sewage services and have to rely on communal standpipes and individual outhouses. The survey confirms that about 43 percent of households in ger areas are currently living in actual gers, and slightly more than half (55 percent) of the households are living in houses (figure 2.1). Recently settled households live in gers, but over the course of several years they start building fixed houses because houses are more spacious and comfortable. Slightly less than one percent (0.7 percent) of the households in ger areas occupy both a ger and a house, that is, a ger with some form of passage connecting to another ger or fixed structure.

2.2.1 Characteristics of Ger Households

The survey results reveal that about 43,607 households currently live in a ger or use a ger as the main dwelling during the winter months. Almost all of the households (93 percent) that live in a ger own the ger and about 5 percent rent. The remaining small number of households that live in gers receive some type of assistance or are allowed to use the ger for free. As depicted in figure 2.2, the majority (64 percent) of gers have five walls, and 29 percent have four walls. Only about 5.5 percent have six walls. The total area for a five-wall ger is estimated to be 28 square meters.[20]

Two-thirds of gers have a double-layer felt cover for both the walls and the roof. Close to 13 percent have a double layer of felt on either the walls or the roof. About one-fifth have only one layer of felt for both wall and roof (see figure 2.3), 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.[21] Felt covers have a limited lifetime and need to be replaced regularly as a result of deterioration from accumulated moisture. Almost all (92 percent) gers have some type of cover for the skylight to retain heat. The majority of gers (82 percent) have a wooden floor, almost 16 percent have an earthen floor, and the remainder use a concrete or cement slab for flooring.

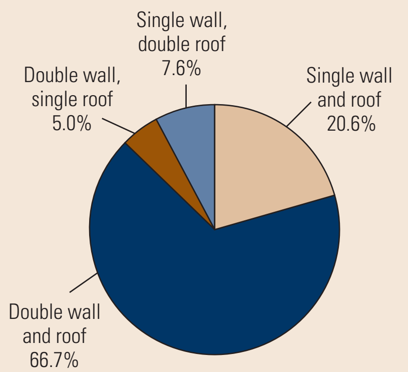
2.2.2 Characteristics of Detached Houses

About 56 percent of households in the six surveyed ger areas live in detached, single-family houses (commonly called a "separate home" using the direct Mongolian to English translation), which amounts to about 56,528 detached houses in the six surveyed ger areas. A detached house in the ger areas is relatively small. The average number of rooms excluding kitchen and toilet

20. The diameter for a typical five-wall ger is about 5.6 to 6 meters, depending on the erected height of the ger.

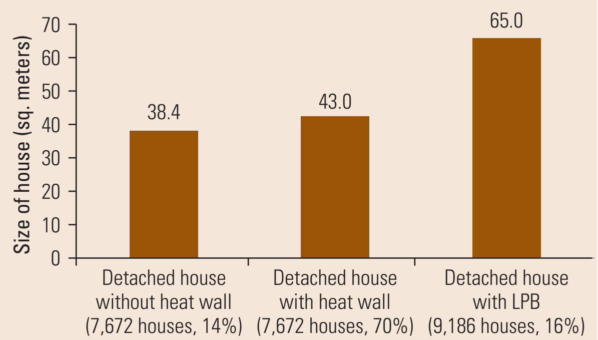
21. The survey did not collect information about the quality and thickness of the felt used to cover walls and roofs, or about the tightness of the coverings, which may prevent heat loss by preventing cold air from blowing into the ger.

FIGURE 2.3: INSULATING FELT COVERAGE OF GERS



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

FIGURE 2.4: SIZE OF DETACHED HOUSES



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

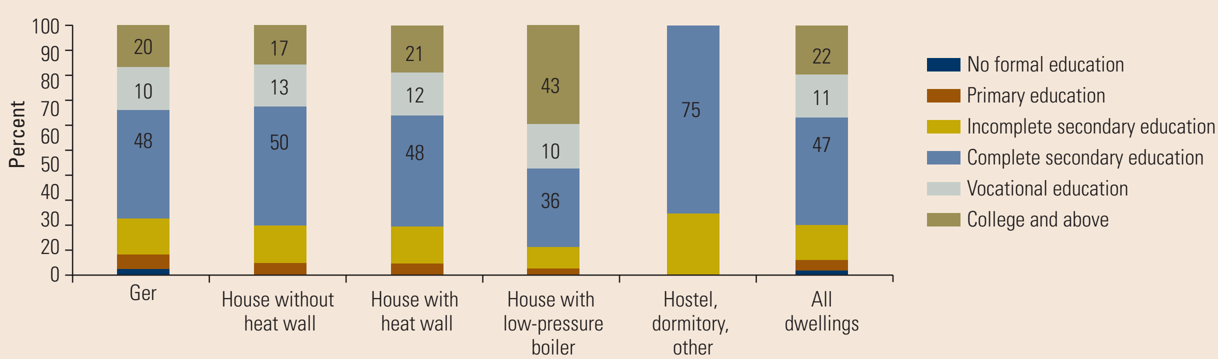
Note: Size of house in square meters excludes kitchen and bathroom.

is about two. Some 80 percent of all houses in the ger areas have only one or two rooms. The average total living space, excluding kitchen and toilet, is only 46 square meters or 495 square feet. Almost all houses have one floor; only 7 percent have a second story. Similar to the gers, almost all houses in the ger areas are owner occupied. About 95 percent are owned by the households and 3 percent are rented. The remaining 2 percent of households are living rent free or receiving some type of assistance that allows them to live for free. All but three respondents interviewed consider their houses to be winterized. Those three respondents indicated that the homes they live in during the winter months are summer homes (that is, not winterized).

The 56,528 detached houses in six surveyed areas can be divided into three groups based on the size of the house and the type of heating system. Detached houses are equipped with stoves that may have heating walls,[22] or with low-pressure boilers (LPB). The largest group, 70 percent of the detached houses, use heating walls and have floor space of about 42 square meters; 14 percent of detached houses have no heating wall and floor space averages 38 square meters, indicating that income is a

22. A hollow interior heat-retaining wall through which flue gases from the stove escape into the atmosphere; this is used to heat the house. The heating wall is a typical extension of stoves in Mongolia. It is a wall made of bricks, in which the hot fumes from the attached stove are led through ducts in the masonry to heat up the whole wall. Because the bricks retain this heat, and pass it slowly to the surrounding environment, the wall makes the stove more effective by providing a large emitter surface for energy absorbed from the smoke, which would otherwise be lost.

FIGURE 2.5: EDUCATIONAL ATTAINMENT OF HEAD OF HOUSEHOLD



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

TABLE 2.1: SOCIOECONOMIC INFORMATION OF HOUSEHOLDS IN THE GER AREAS

	Ger	Detached house without heating wall	Detached house with heating wall	Detached house with low-pressure boiler	Dormitory, hostel, other	Total
Total number of households	43,607	7,672	39,670	9,186	808	100,941
Household income (Tog/month)	206,519	240,836	261,005	341,842	198,248	242,788
Family size (persons)	4.4	4.3	4.4	4.5	3.8	4.4
Female head of household (percent)	24	28	15	10	13	19

Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.
Note: US$1 = Tog 1,200.

factor that determines whether a household can afford a heating wall. Some 16 percent of households in detached houses have low-pressure boilers and average 65 square meters of floor space. (See figure 2.4.)

2.3 Characteristics of Households in the Ger Areas

The average household size in the surveyed areas is slightly more than four persons (table 2.1). The average total household monthly income is estimated at Tog 242,788 per month). About a fifth of the households are headed by a female. The highest educational levels of household heads living in gers and in detached houses using stoves, both with and without heating walls, are quite similar. However, a larger portion of household heads living in detached houses with LPBs have higher levels of education. Overall, households living in detached houses and using LPBs are distinctly richer and household heads are better educated than in other households. The small number of households that live in dormitories, hostels, and other unspecified housing are the poorest (financially) and have the least-educated heads. However, the largest number of households live in gers and are generally the poorest as well. Households living in gers or in detached houses using stoves without heating walls are disproportionately female headed. More than 12,000 households among these two groups are female-headed.

2.4 Conclusion

Analysis of the socioeconomic 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 gers, not in detached houses. 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 rooftop, 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 houses. Among households living in detached houses, the poorest use heating stoves without heating walls. Households that live in detached houses and use heating stoves without heating walls have slightly higher income than households that live in gers. The two remaining financially better-off groups of households live in bigger homes and use heating stoves with heating walls, 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 1 percent of all households in the ger areas; they have the lowest income and education levels, and live in hostels, dormitories, or other unspecified types of dwellings.

Heating Stove Ownership and Preferences

Apartment buildings, stores, and businesses in the city center are heated through a district heating system; water is heated at a central location (combined heat and power plants) and distributed through a system of pipes. Stoves[23] are the primary heating devices 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 in the Russian Federation; they consist of a double wall through which flue gases escape and exchange heat before exiting the chimney. Heating stoves are also used to boil or heat water and to 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 (LPB). This chapter includes photographs of these stoves (see photographs 3.1 through 3.5).

Heating stoves have always been used in Mongolia to survive the harsh winters. During the past seven or eight years a few new models of heating stoves were introduced, commonly known as improved stoves,[24] designed to reduce fuel consumption and CO_2 emissions. Stoves used before the introduction of the new models are typically called traditional stoves.[25] Only very recently, beginning in 2008, have improved stoves been discussed as a tool to reduce air pollution. Not only can improved stoves lower fuel consumption (for higher fuel efficiency), they also can provide better combustion efficiency 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 or 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

23. Broadly defined to include individual stoves, stoves with heating walls, and low-pressure boilers (LPBs).

24. The Ministry of Nature and Environment introduced, through a GEF-supported project, four different improved stove models that had been identified through a competition among stove manufacturers; all four models were found in the sample survey. GTZ recently introduced a new model of 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 the Republic of Korea; this stove was found in the sample.

25. Typical stoves, whether traditional or improved, are primarily made of either cast iron, metal sheet, or both. Some heating stoves are metal shells lined with bricks; these have been classified as traditional stoves. However, some consumers identify traditional stoves with brick linings as the "brick stove."

TT-03 Stove in Market

Stove with Heating Wall

Back Side of Heating Wall

Low-Pressure Boiler Showing Water Pipes

is not always easy to start the fire, but once it is going it will burn for a long time—longer than a wood fire.

This chapter provides the estimated number and types of stoves that are currently being used in the six surveyed ger areas. It also provides a descriptive analysis of the profiles and characteristics of stove users, types of stoves, and how stoves are used to heat the ger or detached house. The last section discusses households' perceptions of the performance of their existing stoves, households' knowledge and perceptions of improved stoves, and their willingness or tendency to switch to improved stoves.

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 ger or house during the winter months. Another 2,120 heating stoves are used by the households to heat home businesses, kiosks, or garages. The remaining 909 stoves are owned by the households as a second stove. These 909 stoves are in working condition, but they are not being used. As shown in table 3.1, traditional stoves account for 88 percent of all stoves that are either being used or are owned by the households living in the surveyed areas.

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 percent of the households that use a traditional stove) have been using the same stove for more than 10 years (table 3.2); and another 11,500 stoves are about 7 to 10 years old. About 25 percent 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 (figure 3.1), the median age is only four years. This means that about 44,300 stoves are less than four years old—quite new. It is estimated that during the five-year period 2003 to

TABLE 3.1: ESTIMATED TOTAL NUMBER OF STOVES IN THE GER AREAS AROUND THE CITY CENTER

Stove type	Number of stoves heating house or ger	Number of stoves heating home business, kiosk, or garage	Second stove owned by the household	Total number of stoves in the six ger areas	Percent
Traditional stove					
Metal or 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	0	0	3,937	3.8
Total	*88,627*	*606*	*1,817*	*91,050*	*87.6*
Improved stove					
TT-03	1,110	101	0	1,211	1.2
G2-2000	707	0	0	707	0.7
EB-1	101	0	0	101	0.1
BONA-2	101	0	0	101	0.1
Total	*2,015*	*101*		*2,120*	*2.1*
Korean stove	1,110	101	0	1,211	1.2
Small LPB					
Made locally	7,268	0	202	7,470	7.2
Imported	1,918	101	101	2,120	2.0
Total	**100,941**	**909**	**2,120**	**103,971**	**100**

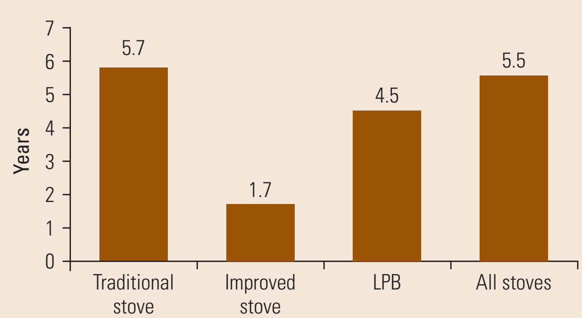
Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

2007, an average of about 11,500 traditional stoves were added each year to provide heat for the residents in the surveyed areas (figure 3.2). The survey did not collect information that would separate the approximate portion of these new stoves bought for replacement from those bought for new households. However, 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 percent of the new stoves added in the year before the survey are used in new households, new gers or houses, or in newly occupied gers or houses.

The second most popular type of stove is a small LPB (that is, a small furnace connected to a low-pressure hot water distribution system including radiators). Typically, an LPB uses a traditional coal-fired stove as the boiler to which a hot water distribution system with pipes and radiators is added. Almost all LPBs are built locally although a small number are imported from China. LPB systems provide the highest level of comfort for ger area homes: not only do LPBs provide the most evenly distributed heat throughout the house, they also operate around the clock to prevent pipe bursts.

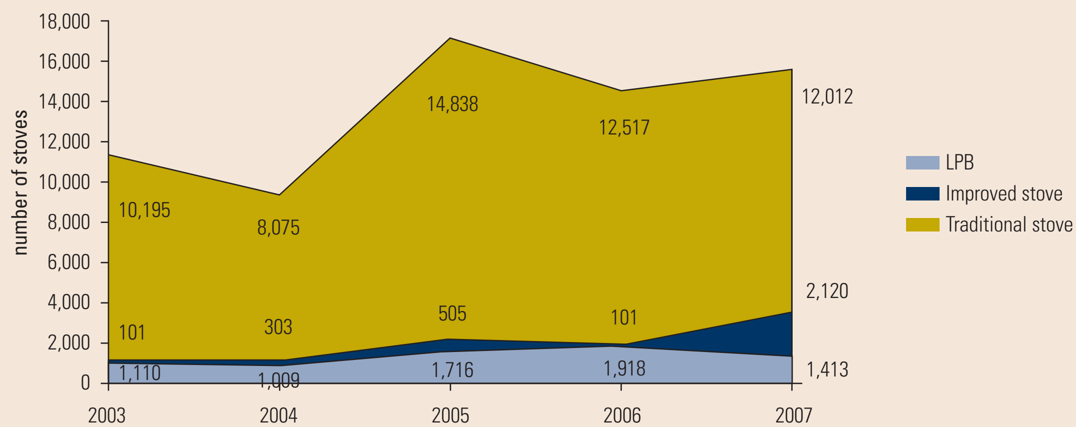
About 9,590 homes in the surveyed areas have LPBs for heating. Stoves with LPBs account for 11 percent of all heating stoves. Most LPBs are relatively new. The survey reveals that about three-quarters of LPBs (or about

FIGURE 3.1: AVERAGE NUMBER OF YEARS HOUSEHOLD HAS USED CURRENT STOVE



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

FIGURE 3.2: ANNUAL INCREASE IN NUMBER OF STOVES, 2003–07



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

7,165 LPB systems) were installed during the five-year period 2003–07. Because of their popularity and the fact that only 16 percent of households living in detached houses already have LPBs, it is expected that the use of LPBs will increase significantly in the near future.

The survey also reveals a relatively small number of improved heating stoves, despite the fact that they have been on the market for several years. The average age of improved stoves is slightly less than two years; about 67 percent of improved stoves are only one year old or less. This suggests that after several years of promotion, improved stoves may have just begun to gain some support from consumers. An improved stove model from Korea was introduced to the market in the 2006–07 heating season and gained some acceptance among ger area households. The survey reveals that about 1,200 households are using this Korean stove, which is designed to use a specific size of honeycomb coal briquette and cannot burn other fuels.

Although heating stoves last a long time, the issue of disposing of or recycling old 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 they are not withdrawn from the stock of stoves and continue to pollute the air. The survey reveals that about 23,822 households (24 percent) in the surveyed areas kept their old stoves, even though they use new ones. These old stoves are not in good working condition, but 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 percent) reported that they gave away or sold their old stove for reuse. This implies that up to 17 percent of stoves in the six ger areas are used or secondhand stoves. Almost an equal number of old unused stoves (15,949) end up in the dump or in the trash pile and only 4 percent 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.

3.3 Types of Heating Stoves and the Households That Use Heating Stoves

In general, how heating stoves are used is closely associated with the type and size of the dwelling. Based on the survey, types of homes and stoves can be classified into four major categories (see figure 3.3).

3.3.1 Heating Stoves Used in Gers

All of the 43,607 households currently living in gers use heating stoves to cope with the cold winters. About 88 percent of ger households use traditional heating stoves made of metal sheet or cast iron. The second most popular stove among ger households is the sawdust stove. Sawdust stoves are a variation of traditional stoves, still made of metal sheet or cast iron, but the primary fuel is sawdust. It is estimated that about of 8 percent of the households living in gers use sawdust stoves. The

TABLE 3.2: AGE OF STOVES

Age (years)	Traditional stove (number) (percent)	Improved stove (number) (percent)	LPB (number) (percent)	Total (number) (percent)
One	12,012	2,120[a]	1,413	15,545
	13.6	67.7	15.4	15.4
Two	12,517	101	1,918	14,536
	14.1	3.2	20.9	14.4
Three	14,838	505	1,716	17,059
	16.7	16.1	18.7	16.9
Four	8,075	303	1,009	9,387
	9.1	9.7	11.0	9.3
Five	10,195	101	1,110	11,406
	11.5	3.2	12.1	11.3
Six	5,148	0	303	5,451
	5.8	0.0	3.3	5.4
Seven	4,139	0	404	4,543
	4.7	0.0	4.4	4.5
Eight	3,634	0	202	3,836
	4.1	0.0	2.2	3.8
Nine	505	0	101	606
	0.6	0.0	1.1	0.6
Ten	7,369	0	202	7,571
	8.3	0.0	2.2	7.5
More than ten	10,195	0	808	11,003
	11.5	0.0	8.8	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:
a. This figure includes 1,110 Korean stoves.

remaining 4 percent use brick stoves, the recently introduced Korean stove, and improved stoves such as TT-03, G2-2000, and EB-1. The newly introduced Korean stove appears to have gained acceptance among the households living in the ger areas. Based on the survey, over 900 (or about 2 percent) of the households that live in gers currently use Korean stoves.

3.3.2 Heating Stoves Used in Detached Houses

Of the 56,528 households living in detached houses in the surveyed areas, 65 percent (or about 36,944 households) use traditional heating stoves made of metal sheet or cast iron, and 15 percent (or 8,378 households) use traditional stoves lined with brick. Households using LPBs account for another 16 percent (or 9,185 households). The remaining 4 percent (or 2,020 households) use improved stoves. The number of sawdust stove users that live in detached houses is very small. (See figure 3.4.)

The survey also finds that most households living in detached houses have heating walls attached to the stoves for more efficient heating of the home. Households in detached houses have more flexibility in installing and using home heating equipment but they mostly use traditional or improved stoves. For example, a large number of households use traditional stoves with heating

TABLE 3.3: WHAT HOUSEHOLDS DID WITH PREVIOUS STOVES

Disposition	Number of stoves (percent in parentheses)
Sold as scrap metal	4,240 (4.2)
Threw away	15,949 (15.8)
Gave to relative or friend	12,315 (12.2)
Sold to another household or person	4,441 (4.4)
Still using old stove	38,963 (38.6)
Still have the old stove but do not use it	23,822 (23.6)
Other	1,211 (1.2)

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

walls or LPBs. As shown in figure 3.4, about 70 percent of the households that live in detached houses use traditional or improved stoves with heating walls, and another 16 percent use LPBs. The remaining 7,369 households use stoves to directly heat their homes (that is, without heating walls).

The differences between households that use stoves with and without heating walls are quite clear. Data collected from the survey suggest that households that use stoves with heating walls tend to live in bigger homes and are financially better off than households that use stoves without heating walls. Households that use stoves directly for space heating tend to live in one-room houses. Of households that have only one room, about 37 percent have a heating wall and 63 percent do not. The average size of a house with a heating wall is about 43 square meters, whereas the average size of a house 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 that of households that use stoves with heating walls. In addition, about 28 percent of households that use heating stoves without heating walls are headed by single females. (See table 3.4.)

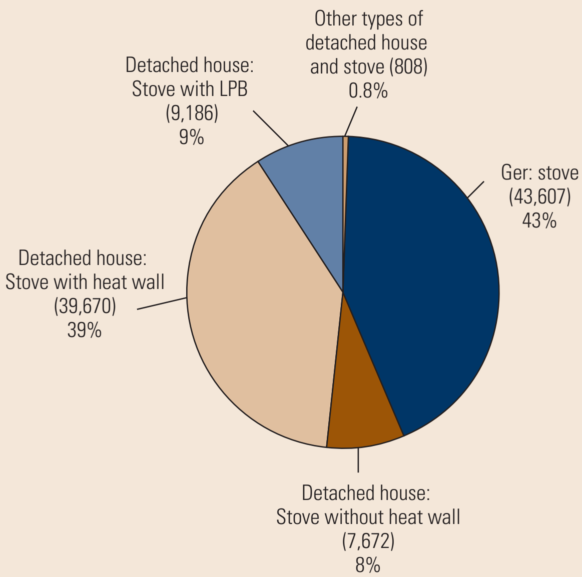
Households with LPBs live in larger homes than households with or without heating walls and are financially better off than the rest (see table 3.4). This finding is not unexpected because an LPB is a better and more convenient system, compared with a stand-alone stove or stove with a heating wall, for distributing heat in a larger home and is more expensive than other types of heating systems. Although traditional stoves have been part of the Mongolian lifestyle for a long time and are appropriate for heating a ger or a small house, lifestyles and living arrangements are beginning to change: close to 60 percent of the households in the surveyed areas no longer live in a ger but in a detached house. Furthermore, with increasing economic prosperity, many households expanded, rebuilt, or constructed larger houses. As a result, typical traditional stoves are no longer appropriate for them and they are looking for alternatives, which they

TABLE 3.4: HOUSEHOLD STATISTICS

	Ger	Detached house using stove without heating wall	Detached house using stove with heating wall	Detached house using LPB	Total
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 (Tog/month)	206,519	240,836	261,005	341,842	243,147[a]
Size of home (square meter)	5 walls	38.4	43.0	65.0	45.9[a]
Total households	43,607	7,672	39,670	9,186	100,134

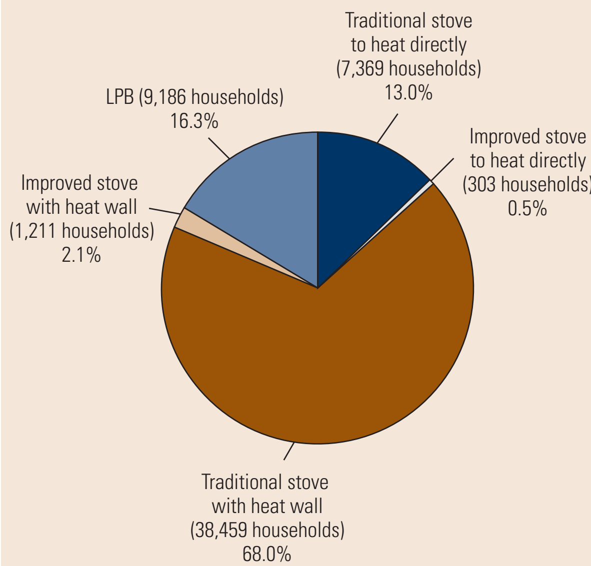
Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.
Note: US$1 = Tog 1,200.
a. Weighted average values.

FIGURE 3.3: TYPES OF DWELLING UNITS AND HEATING SYSTEMS



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

FIGURE 3.4: TYPES OF HEATING SYSTEMS IN DETACHED HOUSES



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

found in heating walls or LPBs. However, not everyone will be able to move into bigger homes in the immediate future; the transition may take some time. In addition, almost all of the heating systems that use LPBs or heating walls still use traditional stoves to heat or boil the water.

3.4 Households' Perceptions of the Performance of Existing Stoves

The survey reveals that, by and large, *the majority of households are satisfied with the performance of their current, generally traditional, stoves.* The survey identifies seven aspects of stove performance: (i) fuel usage, (ii) smoke and soot release from stove, (iii) amount of ash left from fuel burning, (iv) frequency of cleaning soot from the chimney, (v) difficulty in starting the fire, (vi) ability of stove to retain heat for a long time, and (vii) availability of spare parts or repairs.[26] Given these seven aspects of stove performance, the survey finds that only about one-third to one-half of households think that their stoves' performance on each of these points is in the middle range, that is, acceptable. (See figure 3.5.)

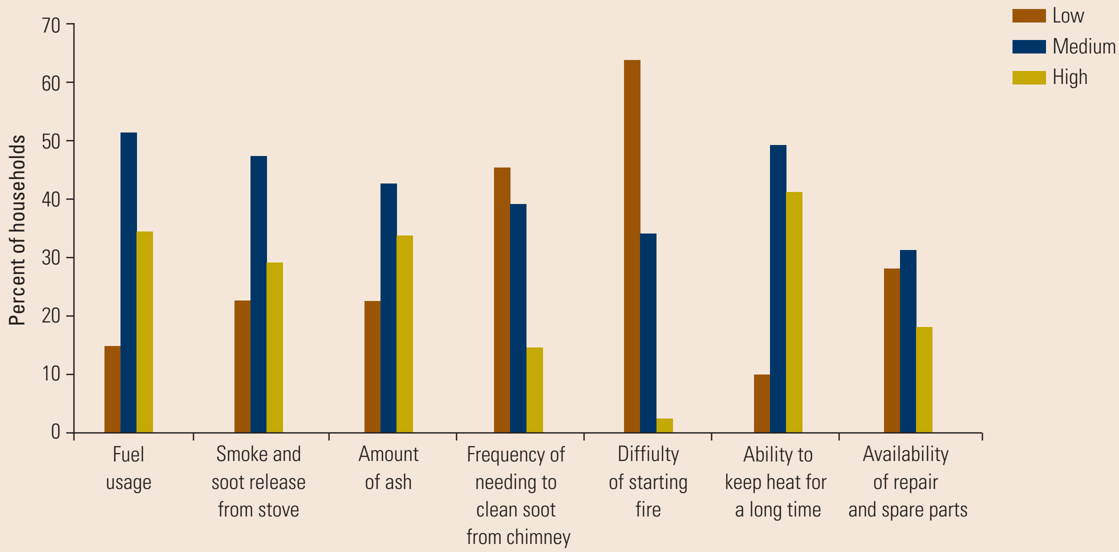
Out of the seven aspects of stove performance, starting the fire is the least concern; about 95 percent of the households believe that it is not difficult to start the fire for their stoves. With respect to fuel usage, smoke and soot, and ash left in the stove, only a third—ranging from 29 percent to 34 percent—of the households believe that their stoves use too much fuel, release a lot of smoke and soot, or leave behind a lot of ash. On the contrary, only 16 percent to 23 percent of the households believe that their stoves have low fuel use, release low levels of soot and smoke, or leave behind low levels of ash.

In all, about 65 percent to 70 percent of the households believe that their stoves use a low to medium level of fuel, emit a low to medium level of soot and smoke, and produce low to medium levels of ash.[27] 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 stoves. Perhaps one of the key findings regarding stove performances is that about 40

26. A significant number of surveyed households—22 percent—answered "do not know" to the question regarding availability of spare parts or repairs. This finding could be interpreted to mean that at least 22 percent of households have not faced any problems requiring spare parts and repair.

27. When combining (i) 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 (ii) households reporting medium levels for each of the three aspects of stove performance.

FIGURE 3.5: HOUSEHOLD OPINION OF THE PERFORMANCE OF THE HEATING STOVE



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

percent of the households believe that their stoves can retain heat for a long time, whereas only 11 percent of the households believe that their stoves cannot retain heat for a long time.

The following subsections compare (i) perceptions of the performance of stoves among households with traditional, improved, or Korean stoves, and households that use LPBs; (ii) perceptions of the performance of traditional stoves among users who live in gers, and in detached houses that use stoves with and without heating walls; (iii) perceptions of fuel consumption among stove owners in different income quintiles. A comparison of the perceptions of stove performance for traditional and improved stove users must be made with caution because the number of improved stove observations in the sample is too small to provide meaningful and statistically significant results.

3.4.1 Perceptions of the Performance of Stoves among Different Types of Stove Users

A comparison of perceptions of stove performance between households that use stoves and households that use LPBs reveals significant differences. A large number of households using LPBs believe that their stoves use a lot of fuel (57 percent) but can retain heat for a long time (63 percent), while only a third of households with traditional stoves think so (32 percent for fuel usage and 38 percent for heat retention). See table 3.5. This is to be expected because households that use LPBs live in larger homes than do those with traditional stoves. As a result, LPB users do, in fact, use more fuel than traditional stove users. Moreover, typical LPBs distribute heat more evenly and retain heat for longer periods through the hot water pipes and radiators.

The perceptions of households with LPBs about smoke and soot released and chimney-cleaning frequency appear to be contradictory. About 44 percent of households using LPBs believe that their stoves release a lot of smoke and soot, but only 4 percent believe that they have to clean their chimneys very often. Possible explanations for this apparent contradiction include the following: LPB users may expect a lot from their rather expensive heating systems, most LPBs are still relatively new and do not emit much soot, or the design of the flue or vent in the LPB systems actually does result in an inordinate amount of cleaning.

Improved stove users' perceptions of fuel usage and heat retention appear to be distinctly different from those of all other stove users. More than half (55 percent) of the improved stove users perceive that fuel usage is low, while a third perceive that the improved stove has a low capacity to retain heat for a long time. Perceptions of improved stove users on heat retention suggest that improved stoves do not perform better than traditional stoves in this regard.

TABLE 3.5: PERCEPTIONS OF THE PERFORMANCE OF STOVES (PERCENT)

Performance indicator	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	63	27
Do not know	0.5	0	0	0
Smoke and soot released 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 of needing to clean 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
Total number of households	**88,626**	**2,019**	**9,186**	**1,111**

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

Survey results show that 70 percent of improved stove users think that the improved stove has medium to high capacity to retain heat, while about 90 percent of traditional, LPB, and Korean stove users think that their stoves have that capacity. Although survey results seem to suggest that improved stoves do not retain heat very well, this finding must be taken with caution because a stove's heat retention time depends on several factors external to the stove, such as size of home, insulation, and the temperature of the home relative to outdoors. Moreover, because of the very small sample size of improved stove users, it is not possible to control for all other factors when comparing users' perceptions of this issue. With respect to smoke and soot released and ash accumulation, households think that improved stoves perform better than traditional stoves and LPBs, but Korean stoves gain the most approval from users.

These findings suggest that a campaign targeting smaller market segments, such as LPB users, will be more effective if it focuses on a boiler or stove that uses less fuel and emits low levels of soot and smoke. However, a campaign targeting traditional stove users will be more effective if it focuses 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 a stove's heat retention capacity also depends on many other factors.

3.4.2 Perceptions of Performance among Traditional Stove Users

The survey finds no significant difference in perceptions about fuel usage between households in gers with traditional stoves and households in detached houses with traditional stoves with or without heating walls. This makes sense because the stoves are essentially the same. With regard to the issue of smoke and soot, the survey finds that about the same proportion of households—27 percent to 29 percent—in all three groups believe that smoke and soot from their stoves is high. Similarly, about 22 percent to 24 percent of households in all three groups believe that smoke and soot released from their stoves is low. However, only 9 percent 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 LPB users. The low frequency with which chimneys need to be cleaned of soot could be a result of the design of the flue and vent of the heating wall system.

However, one of the important findings is the perception of households about the ability of stoves to retain heat for a long time. The survey shows that 35 percent of the households living in gers and only 26 percent of the households in detached houses without heating walls believe that their stoves can retain heat for a long time. By contrast, about 43 percent of the households that use stoves with heating walls believe that their stoves can retain heat for a very long time. This finding implies that detached houses without heating walls may require heating systems to help distribute heat more evenly throughout the home. This is so because about 37 percent of homes without heating walls have more than one room and more than half of these homes are 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 a house.

Therefore, any marketing campaign targeting the smaller market segment of detached houses without heating walls should emphasize stoves with greater capacity to

TABLE 3.6: TRADITIONAL STOVE USERS' PERCEPTIONS OF PERFORMANCE (PERCENT)

Performance indicator	Ger	Detached house with traditional stove but without heating wall	Detached house with traditional stove and 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 released from stove			
Low	24	22	24
Medium	45	49	49
High	29	28	27
Do not know	1.6	1.3	0.8
Frequency of needing to clean soot from chimney			
Low	31	45	56
Medium	45	30	34
High	23	25	9
Do not know	0.9	0	0.8
Total number of households	**43,607**	**7,672**	**39,670**

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

distribute heat evenly. Furthermore, improved stoves in combination with energy-efficient heating walls should be explored and introduced.

3.4.3 Perceptions of the Performance of Stoves, by Income Quintile

As mentioned earlier, households from different income classes bear the burden of heating expenditures disproportionately. This is reflected in the perception of households that are financially worse off versus financially better off. As shown in table 3.7, about 43 percent and 45 percent of households in the bottom income quintile believe that their stoves use a medium or high level of fuel, compared with 54 percent and 28 percent of households in the top income quintile. This finding confirms that any campaign to promote fuel-saving stoves will be more effective among lower-income households than higher-income households.

3.5 Households' Preferences and Willingness to Change Type of Stove

Although the majority (about 65 percent to 70 percent) of the households in the survey areas appear to be satisfied with the overall performance of their stoves, slightly more than half are nevertheless interested in changing (table 3.8). A total of 52,287 households in the surveyed areas indicate that they are interested in changing their stoves and 71 percent 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 reasons for willingness to change stoves appear to be a desire to reduce the heating bill and high expectations for the performance of improved stoves. The survey shows that the average monthly income of households that are interested in changing stoves 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 3.7: PERCEPTION OF FUEL USAGE OF EXISTING STOVE (PERCENTAGE OF HOUSEHOLDS)

	Income quintile (Tog/month)					
Perception	Less than 111,331	111,331 to 172,660	172,661 to 233,990	233,991 to 325,860	More than 325,860	Total
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	0.5	0	0	0.2

Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.
Note: US$1 = Tog 1,200.

TABLE 3.8: NUMBER OF HOUSEHOLDS INTERESTED IN CHANGING CURRENT STOVE

	Interested in changing current stove			
Indicator	Yes	No	Have not thought about it	Total
Number of households	52,287	47,039	1,615	100,941
Percent	51.8	46.6	1.6	100
Household income (Tog/month)	234,585	251,669	249,704	242,788
Expenditure on raw coal (Tog; 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.
Note: US$1 = Tog 1,200.

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

Households that are or are not interested in changing stoves do not differ much in type and size of homes, or in current heating system. For example, 42 percent and 43 percent of households that are interested in changing stoves live in gers or detached houses using stoves with heating walls, respectively, compared with 45 percent and 35 percent of households that are not interested in changing stoves (see table 3.9).

However, households interested in changing stoves have slightly lower incomes than households that are not interested in changing stoves, maybe because households that are interested in changing stoves spend more on raw coal than do households that are not interested

TABLE 3.9: NUMBER OF HOUSEHOLDS INTERESTED IN CHANGING CURRENT STOVE, BY TYPE OF DWELLING, AS PERCENTAGE OF RESPONSE

Type of dwelling	Yes (percentage of "yes" respondents)	No (percentage of "no" respondents)	Have not thought about it (percentage of "have not thought about it" respondents)	Total number
Ger	42.3	44.6	31.3	43,607
House without heating wall	8.9	6.2	6.3	7,671
House with heating wall	42.9	35.0	50.0	39,690
House with LPB	5.4	13.1	12.5	9,185
Hostel, dormitory, other	0.6	1.1	0	808
All types of dwellings	100	100	100	n.a.
Total households	52,287	47,039	1,615	100,941

Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.
Note: n.a. = Not applicable.

TABLE 3.10: NUMBER OF HOUSEHOLDS INTERESTED IN CHANGING CURRENT STOVE, BY TYPE OF DWELLING, AS PERCENTAGE OF DWELLING TYPE

Type of dwelling	Yes (percentage of dwelling type)	No (percentage of dwelling type)	Have not thought about it (percentage of dwelling type)	Total
Ger	50.7	48.1	1.2	100
House without heating wall	60.5	38.2	1.3	100
House with heating wall	56.5	41.5	2.0	100
House with LPB	30.8	67.0	2.2	100
Hostel, dormitory, other	37.5	62.5	0	100
All types of dwellings	51.8	46.6	1.6	100
Total households	52,287	47,039	1,615	100,941

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

TABLE 3.11: TYPE OF STOVE PREFERRED BY HOUSEHOLDS INTERESTED IN CHANGING STOVE

Stove type	Ger	House without heating wall	House with heating wall	House with LPB	Hostel, dormitory, other	All types of dwelling
Traditional stove	1,413	404	1,110	0	0	2,927
Percent	6.4	8.7	5.0	0	0	5.6
Improved stove	15,545	2,221	9,388	1,918	303	29,375
Percent	70.3	47.8	41.9	67.8	100.0	56.2
Briquette stove or Korean stove	3,129	404	1,413	101	0	5,047
Percent	14.2	8.7	6.3	3.6	0	9.7
Sawdust stove	1,817	0	707	0	0	2,524
Percent	8.2	0	3.2	0	0	4.8
LPB	202	1,615	9,791	808	0	12,416
Percent	0.9	34.8	43.7	28.6	0	23.7
Total	22,106	4,644	22,409	2,827	303	52,289
Percent	100	100	100	100	100	100

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

in changing stoves (Tog 178,000 versus Tog 170,000, respectively; see table 3.8). The survey finds no differences in age and education of the heads of households between these two groups.

Further comparison reveals that households living in detached houses without heating walls are more likely to be interested in changing stoves than are households that live in other types of homes and use different types of heating systems. The odds that households living in a detached house without heating walls answer "yes" are 0.6, whereas the odds that households with heating walls and households living in gers answer "yes" are 0.56 and 0.51, respectively (see table 3.10). Although indicating interest does not always translate into action, the finding provides an estimate of the total number of potential households that could be targeted first for any improved stove promotion program or project.

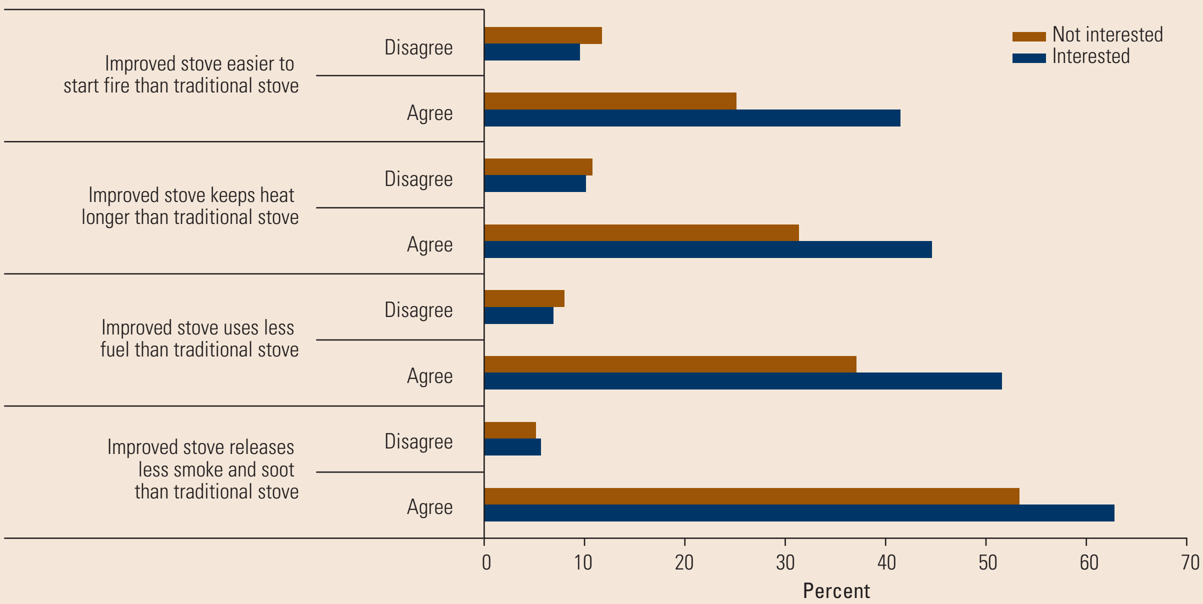
The survey also finds that interest in improved stoves among households that are interested in changing stoves is quite high and spreads across the board (see table 3.11). About 56 percent of households that are interested in changing would choose an improved stove. The proportion of households interested in improved stoves is as high as 70 percent among households living in gers and as low as 42 percent among households living in detached houses with heating walls. LPBs received the second most interest.

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

As shown in figures 3.6 and 3.7, a larger portion of households interested in changing stoves have a more favorable opinion of the performance of improved stoves and are more knowledgeable about improved stoves. For example, 52 percent of households that are interested in changing stoves believe that improved stoves use less fuel than traditional stoves; meanwhile only 37 percent of households that are not interested in changing stoves believe that improved stoves use less fuel. Close to half of all households interested in changing stoves believe that improved stoves are very expensive, while only a third of their uninterested counterparts believe the same.

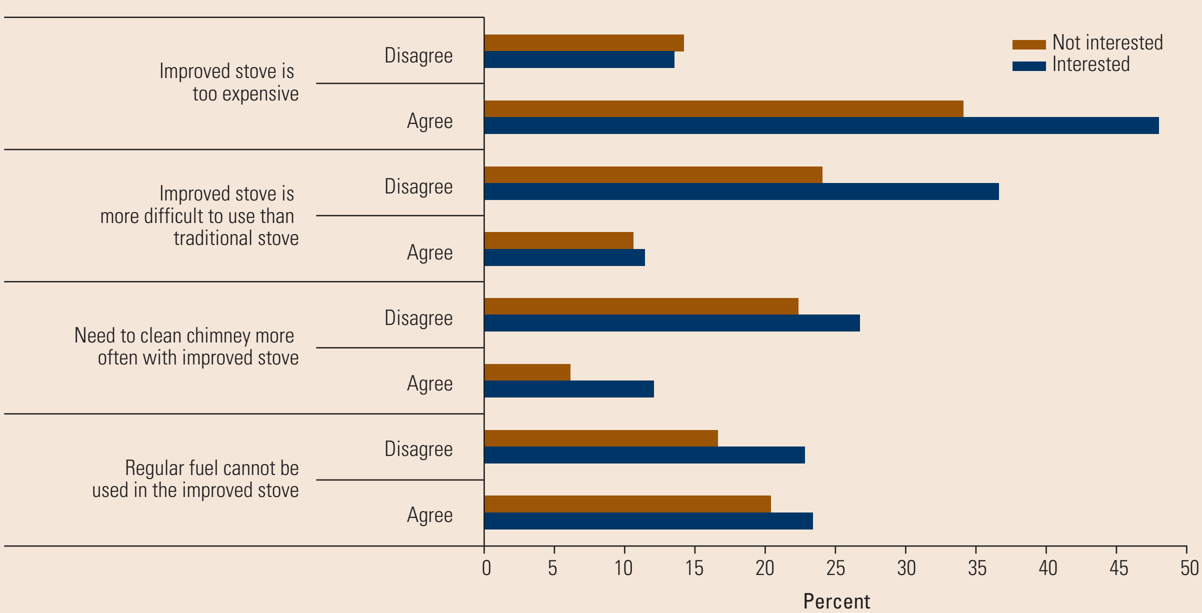
Regarding the time frame for changing to a new stove, about 71 percent would like to change in the near future. A closer look at the households interested in changing stoves in the near future reveals that these households had very high expenditures on raw coal during the surveyed heating season (table 3.12). In fact, their expenditure on raw coal was significantly higher than average. As a result, when combined with their faith in the

FIGURE 3.6: OPINIONS OF IMPROVED STOVES, POSITIVE ATTRIBUTES, HOUSEHOLDS INTERESTED AND NOT INTERESTED IN CHANGING STOVES



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

FIGURE 3.7: OPINIONS OF IMPROVED STOVES, NEGATIVE ATTRIBUTES, HOUSEHOLDS INTERESTED AND NOT INTERESTED IN CHANGING STOVES



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

TABLE 3.12: INCOME AND RAW COAL EXPENDITURE OF HOUSEHOLDS INTERESTED IN CHANGING STOVES IN THE SHORT AND LONG TERM

Indicator	Household income (Tog/month)	Average expenditure on raw coal, Sept 06–Apr 07 (Tog)
Short-term interest	237,298.34	184,525.77
No. of households	37,146	36,238
Long-term interest	227,929.47	162,509.72
No. of households	15,141	14,536
Short and 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.
Note: US$1 = Tog 1,200.

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 a better financial position than those with longer term plans for replacing their stoves. The results suggest that should credible information on effective heating systems be effectively communicated to households, there would be a willingness to consider switching to improved systems.

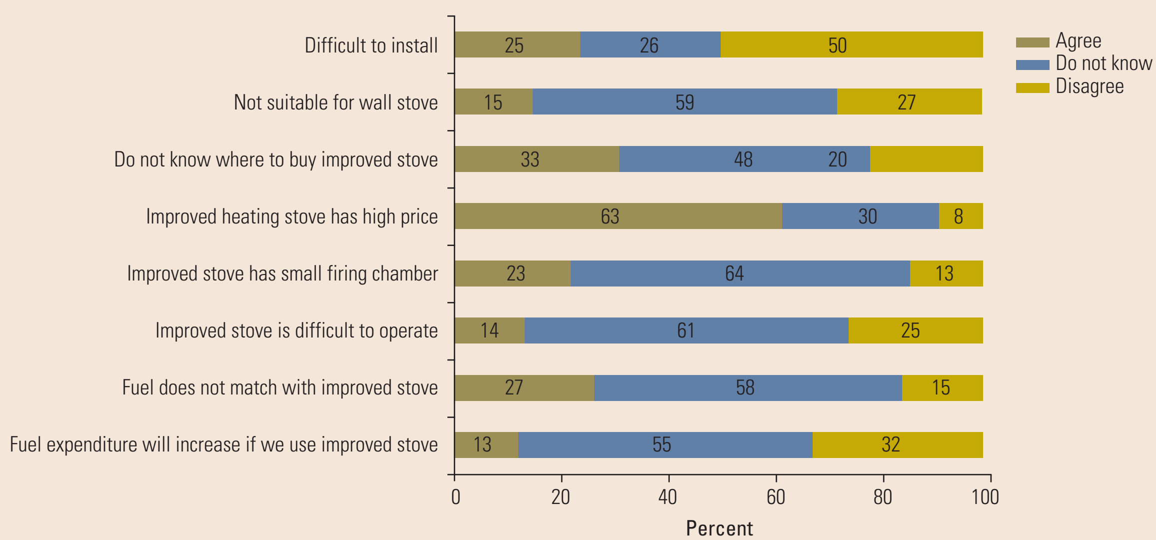
3.5.1 Perceived Obstacles to Replacing Stoves

General perceptions of the public at large about obstacles to changing to improved stoves are perceived high prices and a lack of information on where to purchase them (figure 3.8). However, the biggest problem is the lack of accurate 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 preventing or inhibiting households from changing to improved stoves. The large number of households that answered "do not know" suggests that these households are either indifferent to changing to improved stoves or have very limited information. In general, about 28 percent of households have never before heard of improved stoves.

3.6 Sources of Information about Improved Stoves

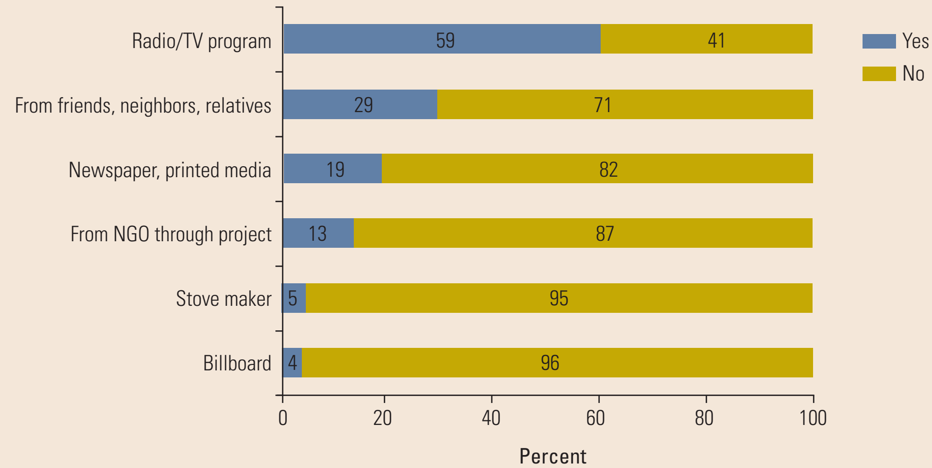
As expected, radio and television are the most effective means for disseminating information about improved stoves. As shown in figure 3.9, most households in the six surveyed districts heard about improved stoves from radio or television or both. Word of mouth from friends, relatives, and neighbors is the second most important

FIGURE 3.8: PERCEIVED OBSTACLES TO CHANGING STOVES



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

FIGURE 3.9: SOURCES OF INFORMATION ABOUT IMPROVED STOVES



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

source of information for households in the ger areas. Because the majority of households still have 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 and where to obtain them.

3.7 Conclusion

About 100,941 stoves are currently used by the households in the six surveyed ger areas to heat their homes; 909 stoves are used to heat home businesses, kiosks, or garages; and another 2,100 stoves are owned but used only occasionally. During the period 2003–07, about 11,500 stoves were added each year, but with no systematic disposal of old or unused stoves. Based on the survey, an estimated 23,822 households still have their old stoves. Although these old stoves are not in working condition, it is not known whether or 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 secondhand or used stove market exists. 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 that needed to be preserved.

Survey results also confirm that stove type and type and size of dwelling are closely related. Households living in gers or in small, one-room detached houses use heating stoves to directly heat their homes. Households living in larger houses tend to use heating stoves with heating walls. The largest and more modern detached houses are equipped with LPBs. *Survey data also suggest that although the majority of the households in the six surveyed ger areas appear to be satisfied with their existing stoves or heating systems, they are also interested in changing in the future.* Maybe they are waiting for much better stove models to appear?

Although the penetration of improved stoves in ger area households is still low, the majority of households interested in changing stoves are interested in changing to improved stove models. *The main reasons for willingness to change stoves are the desire to reduce heating bills and high expectations for the performance of improved stoves.* The results appear to indicate that reliable 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 hearsay information and results from poorly performed tests are in circulation and given more authority than the results of the few existing trustworthy tests would indicate they deserve. As explained in chapter 5, the current state of laboratory testing capability makes it difficult to determine which stove and fuel combination will have the highest impact on air quality in Ulaanbaatar, and households are wise to wait to change stoves until better models are available.

4

Heating Fuel Consumption and Expenditure

The main fuel used to heat dwellings in the six surveyed ger areas is raw coal. Firewood is also used, but primarily to start the fire; some households do use it to supplement coal. In addition to coal, a small number of households use sawdust, coal briquettes, and animal dung. This chapter provides an analysis of the fuels—coal, firewood, sawdust, and briquette—used by households in the surveyed areas. An analysis of household consumption and corresponding expenditures for heating fuels is given as well. Table 4.13 shows that households spend on average about 20 percent of their reported income on heating fuels; for the poorest quintile expenditures are about 40 percent of income, which clearly demonstrates the severity of the winter and that households have no choice but to heat their homes. The analysis also includes households' perceptions of different types of briquettes. The chapter begins with a short introduction to 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 result of fuel efficiency (quantity of fuel used to heat the house) and combustion efficiency (quantity of emissions per unit of fuel used). Previous programs only tested fuel efficiency. Laboratory capacity will need to be improved to perform robust tests of combustion efficiency, including measuring emissions of carbon monoxide, nitrogen oxides, hydrogen sulfide, and particulate matter.

Traditional stoves lack the proper air control mechanism to improve combustion efficiency; as a result, exhaust gases will remain quite dirty. And the designs of the currently available "improved" stove models are not adequate to significantly reduce Ulaanbaatar's air pollution. An essentially different stove design, such as based on the reference burner, is needed to effectively clean up the air. Such improvements to stoves' combustion efficiency have not been made because the absence of appropriate equipment made it impossible to conduct definitive lab tests. Moreover, as became obvious during the consumption tests, fuel consumption and emissions depend on both the stove and the fuel. It remains necessary to test the performance of different stove and fuel combinations.

The following sections provide feedback from the surveys on the quantities of fuels used by type of stove, type of fuel, type of house, and characteristics of the households.

TABLE 4.1: HEATING FUELS USED BY HOUSEHOLDS

Households	Coal	Firewood	Sawdust	Briquette	Dung	Anything that burns	Total
Number	95,793	95,995	5,249	1,817	4,542	202	100,941
Percent	94.9	95.1	5.2	1.8	4.5	0.2	100

Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.
Note: Rows do not sum to totals because individual households may use more than one fuel.

4.2 Type of Fuels Used by Households

The survey confirms that raw coal and firewood are the main fuels used to keep ger area residents warm. As shown in table 4.1, raw coal is the most popular heating fuel among households living in the surveyed areas. Firewood is used to start fires 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 percent, that use anything that can burn, primarily to supplement raw coal; one of these households has a very low income.[28] Because only two 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 socioeconomic status of the estimated 202 households out of the total in Ulaanbaatar is similar to the status of those two. 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.

Coal from Nalaikh appears to be the most popular among households in the six surveyed areas. The second and third most popular types of raw coal are from Baganuur and Alagtolgoi, respectively. As depicted in table 4.2, ger area households rely on coal from several sources throughout the heating season. Typically households will use raw coal from various sources, especially when they buy bagged coal. However, those who purchase coal in large enough quantities to last the whole heating season undoubtedly use coal from only one source.

In the winter, 95 percent of ger area households use coal and firewood for heating and cooking; 5 percent use sawdust, dung, or paper; 2 percent briquettes; and some 0.2 percent burn anything they can obtain, which may range from paper and 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.

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 very low (above –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. As the use of semi-coked coal, which is difficult to light, increases, the use of firewood and starter fluids is likely to increase. The main types of wood used are larch (76.8 percent) and pine (51.0 percent). Some 4.6 percent of households report that they use construction or packaging wood (pallets) and 2.4 percent use 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 vary depending on its source. Most coal comes from the Nalaikh mines some 25–30 km from the city center. Officially these mines are closed but some 76 percent of households indicate they use Nalaikh coal. Another 15.3 percent indicate they use higher quality coal from Alagtolgoi,[29] 25.3 percent use coal from Baganuur (the city's combined heat and power plants use Baganuur coal), and 2.8 percent from Sharyn gol. Table 4.2 shows the characteristics of a few fuels used in Ulaanbaatar for heating. The price of raw coal from Baganuur tends to be the lowest because

28. Based on the sampling design, one sampled household represents 101 households.

29. "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, and its sulfur or other contaminant content.

TABLE 4.2: SOURCES OF COAL USED BY HOUSEHOLDS

Origin	Number (percent) of households	Estimated heating value (kcal/kg)	MJ/kg	Moisture content (%)
Nalaikh	72,778 (76.0)	3,508	14.7	27.0
Alagtolgoi	14,636 (15.3)	6,186	25.9	10.7
Sharyn gol	2,725 (2.8)	3,510[a]	14.7	—
Baganuur	24,226 (25.3)	3,524	14.7	33.0
Total	**95,793**	**n.a.**	**n.a.**	**n.a.**

Source*:* ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.
Note: kcal/kg = kilocalories per kilogram; MJ/kg = Megajoules per kilogram; — = Not available; n.a. = Not applicable. Households may use more than one type of coal. Calorific values were measured by the Building Energy Efficiency Center (BEEC) of the Mongolian University of Science and Technology as part of the ASTAE consumption tests.
a. Coal from Sharyn gol was not found during consumption testing performed by BEEC and therefore not tested; this is a subbituminous coal with calorific value similar to Baganuur and Nalaikh coal.

it has the lowest heating value, ranging around 3,300-3,800 kilocalories per kilogram. Baganuur is about 120 km from Ulaanbaatar and most of the coal is brought in by train. The most expensive coal is from Alagtolgoi, not only because it has the highest heating value, but also because it comes the longest distance. Because of its price and quality, raw coal from Alagtolgoi is preferred among higher-income households. About 12 percent of the top income quintile and 10 percent of the next income quintile use raw coal from Alagtolgoi more often than households in other income classes. However, only 4 percent and 6 percent of households in the bottom and next-lowest income quintile, respectively, use Alagtolgoi coal more often than households in other income classes.

Coal from Nalaikh during the 2006–07 heating season cost about Tog 35,000 per ton delivered at the household. During the 2007–08 season, the price ranged from Tog 50,000 per ton at the onset of the season to Tog 65,000 per ton at the height of the winter (in February). Poorer households cannot afford to buy a truckload 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 Tog 1,200, increasing to Tog 1,800 in February. (During the 2006–07 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 Tog 1,000 in December, Tog 1,200 in January, and Tog 1,500 in February.

At the start of the 2007–08 heating season, the cost of coal was 2.6 Tog/MJ purchased per truckload and 3.5 Tog/MJ purchased by the bag; the cost of wood was 7.8 Tog/MJ.[30]

4.3 Fuel and 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 with a small wheelbarrow to buy bags of coal. Typically households buy one bag per day during the early and late season and two bags during the peak of winter. Coal can also be bought from wholesalers who use Chinese trucks with a carrying capacity of about 2.5 tons of bulk coal or Russian trucks with a 5-ton capacity. 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 trucks in Ulaanbaatar. Loaded mainly with Nalaikh coal, trucks line the road waiting for customers,

30. Calculated using 14.7 MJ/kg for coal and 15.5 MJ/kg for wood, both air dry.

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. No statistics are available on the number of actors in the supply chain, but there are hundreds of truck owners, hundreds of wholesalers, plus 5–10 retailers per khoroo.[31] Coal lumps loaded on the trucks are generally too large to be used directly in the stove so need to be broken up, which will done by the distributor before bagging the coal in the khoroo or by the household at home.

4.3.2 Stoves

Stoves are purchased mainly at the central market (Narantuul) and to a lesser extent from stove manufacturers, and recently from the Ger Stove Association, a group of middlemen associated with certain stove manufacturers. There are about 40 stove manufacturers, most of which operate as family businesses that also produce other steel products and whose main outlets are at the central market. About 150,000 ger area household stoves are in use, of which about 49 percent are stand alone, 42 include a heating wall, and 9 percent have a low-pressure boiler (LPB). The combined replacement value of these stoves could be as much as Tog 24 billion. The reported combined production capacity for all producers is about 6,000–10,000 winter stoves per year, including both traditional and improved stoves. The same manufacturers that make traditional stoves also make improved stoves. Stoves are sold mainly just before the winter season starts, during a period beginning in late August, although they are available throughout the year. In early September, hundreds can be found at any time at the central market; during the remainder of the year only a few dozen are available.

Of the six improved stove models available on the market today, three are made by a number of producers as open source models (TT-03, G2-2000, and the GTZ improved stove) and three are more proprietary models, mainly produced by the inventor-manufacturer of the stove (Bona-2, EB-1, and MG203). Low-pressure boilers are not kept in inventory; it is expected that consumers contact a shop specializing in such equipment that assembles the parts and designs a custom-made system for the client.

In 2007, traditional stoves were sold for about Tog 30,000–35,000 and improved stoves for Tog 60,000–100,000. The consumer has to transport the stove home—not an easy task because some of the stoves can approach 100 kg. Prices in 2008 rose considerably as a result of the worldwide increase in steel prices.

In addition to the stove, most consumers also need to buy a stovepipe or chimney—about three meters long for use in a ger—which can be purchased from the stove manufacturer or from a supplier located next door at the market. Depending on the thickness of the chimney, households pay Tog 8,000–10,000. Most chimneys have two or three 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 repair stoves, so have contracted with the association to perform these services on their behalf. The association tries to convince households to buy improved stoves or to install heating walls. Given that a heating wall is a temporary solution and many households will adopt LPBs in the future, consumer households may be persuaded to leapfrog to LPBs, skipping heating walls altogether. A heating wall increases fuel consumption and does not improve the combustion efficiency of the stove.

4.4 Heating Habits

The heating season in Mongolia consists of the cold months in the fall and in the spring and the very cold months during the winter. The cold months in the fall usually begin in mid-September and last through the middle or the end of October, and the cold months in the spring are March and April. The very cold months in the winter usually extend from November to the end of February, when the temperature rarely exceeds –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 what the household can afford. Table 4.3 shows the average number of times households added fuel during a 24-hour period in the fall and spring (the cold months), and during the winter (the very cold months): households added fuel for heating during the fall and spring an average of 2.3 times during a 24-hour period, and double that number of times during the winter months. The survey

31. There are 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.

TABLE 4.3: AVERAGE NUMBER OF TIMES HOUSEHOLDS ADD FUEL DURING 24-HOUR PERIOD

Time of day	Fall and spring	Winter
6:00 am to 4:00 pm	0.97	1.74
4:00 pm to 10:00 pm	0.71	1.60
10:00 pm to 6:00 am	0.63	1.26
Total for 24 hours	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 4.4: HOUSEHOLDS USING SUPPLEMENTAL HEATING

Supplemental heating device	Number (percentage) of households
Heat pump	505 (0.5)
Gas space heater	1,211 (1.2)
Electric space heater	5,148 (5.1)
Total households	**100,941**

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

finds no relationship between the number of times households add fuel and household income, or between the number of times and the number of persons in the household. The number of times households add fuel is the same for all income classes. This finding implies that households add fuel only when really needed. The survey did not collect or measure average temperature inside gers or houses. Therefore, it is unclear whether households add fuel only when needed so as to prevent excessive heat inside the dwelling, or simply to maintain a minimum level of comfort.

Although the weather, especially during the winter, is very cold, it appears that households in the surveyed areas rely primarily on raw coal, the traditional heating fuel. The survey finds that a very small number of households, about 7 percent, use other devices to provide supplemental heat (table 4.4). As expected, the most popular supplemental heating device is an electric space heater. Some households also reported using gas space heaters and a small minority, perhaps well-off households, reported using heat pumps.

4.5 Estimated Raw Coal Consumption and Expenditure

As noted previously, the vast majority of households in the surveyed areas use raw coal and firewood as the main fuel for heating. On average, households used about 4.19 tons of raw coal and spent about Tog 174,767 from September 2006 through April 2007 (table 4.5). The survey estimates the raw coal consumption during that period for all households living in the surveyed areas to be about 399,601 tons.

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

Although the poor spend less on raw coal to heat their homes, the amount they spend accounts for a larger portion of their income than it does for the rich. The disproportionate financial burden of the heating bill exists not only between the rich and poor in the ger areas, but also between households that live in the ger areas and those that live in the central part of Ulaanbaatar. Heating bills for district heating are much lower than for those who must use coal in individual stoves to stay warm. In Mongolia, as in many other countries, those with the poorest service (ger area households) pay the most.

4.5.1 Comparison of Raw Coal Usage between Households Living in Different Types of Dwellings

Typically, household demand for raw coal depends on several factors, including household income, price of coal, type and size of home, 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.

TABLE 4.5: HOUSEHOLD COAL USAGE AND EXPENDITURE, BY INCOME QUINTILE, SEPTEMBER 2006 THROUGH APRIL 2007

Income quintile (Tog/month)	Average expenditure per household (Tog)	Average consumption per household (tons)	Total consumption by all households (tons)
≤111,330	153,275	3.29	61,117
Valid N	18,371	18,573	18,573
111,331–172,660	168,993	3.76	71,350
Valid N	18,977	18,977	18,977
172,661–233,990	170,912	4.12	76,122
Valid N	18,371	18,472	18,472
233,991–325,860	182,726	4.81	95,659
Valid N	19,885	19,885	19,885
More than 325,860	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 expenditure or consumption. US$1 = Tog 1,200.

Incidentally, these five groups are also positively correlated with household income. Consumption of raw coal and associated expenditures as well as household monthly income among the five groups are significantly different. As shown in tables 4.6 and 4.7, coal usage and expenditure both appear to form linear trends against income quintile and against type of dwelling. The lowest consumption is exhibited by ger households, which

TABLE 4.6: COAL USAGE AND EXPENDITURE, BY TYPE OF DWELLING AND HEATING SYSTEM, SEPTEMBER 2006 THROUGH APRIL 2007

Type of dwelling and heating system	Average household monthly income (Tog)	Total expenditure for coal (Tog)	Average raw coal used per household (tons)	Total coal used by all households (tons)
Ger	206,519	162,087	3.49	137,211
Valid N	43,607	39,266	39,367	39,367
House without heating wall	240,836	176,073	3.90	27,939
Valid N	7,672	7,167	7,167	7,167
House with heating wall	261,005	176,870	4.49	175,122
Valid N	39,670	38,862	38,963	38,963
House with LPB	341,842	219,385	6.17	55,435
Valid N	9,186	8,984	8,984	8,984
Hostel, dormitory, other	198,248	182,125	4.82	3,895
Valid N	808	808	808	808
Total	242,788	174,767	4.19	399,601
Valid N	100,941	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 income, expenditure, or consumption. US$1 = Tog 1,200.

BOX 4.1: RELATIONSHIP BETWEEN COAL CONSUMPTION AND TYPE OF DWELLING AND HEATING SYSTEM

Analysis of variance reveals that the differences in coal consumption among households by type of dwelling and heating systems are statistically significant, F-stats = 47.36. An orthogonal contrast of coal consumption between households living in gers and in detached houses without heating walls is statistically significant at 0.11, t-stats = 1.58.

used 3.49 tons of raw coal from September 2006 through April 2007. Households in small dwellings—typically one- to two-room detached houses with traditional stoves—show a consumption level of about 3.90 tons for the same period. Households that live in larger detached houses and use stoves with heating walls consume, on average, 4.49 tons of raw coal. Finally, raw coal consumption for households that live in the largest detached houses and use LPBs jumps to about 6.17 tons per household. These findings appear to confirm the strong relationship between coal consumption and the type and size of home and the type of heating system attached to the stove.

Although households living in gers had the lowest average coal consumption, the total coal consumption by all 40,000 households in this group accounted for 137,211 tons, or the second largest of any group. As a group, households living in detached houses with heating walls consumed the most raw coal, at an estimated 174,122 tons 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 aimed at reducing air pollution caused by raw coal usage must target these two groups of households to have the largest impact. Long-term actions should also consider households adopting LPB (low-pressure boilers) because this is the most comfortable heating solution for ger area households.*

BOX 4.2: RELATIONSHIP BETWEEN COAL CONSUMPTION AND TYPE OF HEATING SYSTEM

Analysis of variance shows that the differences in raw coal usage among traditional stoves, improved stoves, and LPBs are statistically significant, F-stats = 45.08. However, an orthogonal contrast comparing raw coal consumption between households that use traditional or improved stoves shows that the differences are not statistically 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, that may also influence coal consumption. Furthermore, the number of cases representing households that use improved stoves is very small, only 2 percent of the entire sample. As a result, it is not possible to divide households with improved stoves into smaller subgroups to control for other determinant factors that may influence coal consumption.

TABLE 4.7: COAL USAGE AND EXPENDITURE, BY TYPE OF HEATING SYSTEM, SEPTEMBER 2006 THROUGH APRIL 2007

Heating system	Average household monthly income (Tog)	Total expenditure for coal (Tog)	Average raw coal used per household (tons)	Total coal used by all households (tons)
Traditional stove	229,355	169,587	3.97	335,460
Valid N	89,737	84,286	84,488	84,488
Improved stove	389,186	194,444	4.79	8,706
Valid N	2,019	1,817	1,817	1,817
LPB	341,842	219,385	6.17	55,435
Valid N	9,186	8,984	8,984	8,984
All stoves	242,788	174,767	4.19	399,601
Valid N	100,941	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 income, expenditure, or consumption. US$1 = Tog 1,200.

4.5.2 Comparison of Raw Coal Usage among Different Types of Stoves

In addition to type and size of home and household income level, the type of stove is also a main determinant of the level of raw coal consumption. The previous section provides an extensive discussion of raw coal usage among households living in different types and sizes of dwelling and using different types of heating systems. This section provides a direct comparison of raw coal usage by households that use traditional stoves, improved stoves, and LPBs.[32] A separate study comparing fuel usage by traditional and improved stoves is being carried out parallel to this study. The Korean stove is considered an improved stove, but is designed for use with one specific size of honeycomb-shaped coal briquette, so is not included in this section.

A comparison of raw coal consumption between households that use traditional stoves, improved stoves, or LPBs shows that users of improved stoves consume considerably more raw coal than do users of traditional stoves but less than households with LPBs. This finding contradicts the conventional notion that improved stoves save fuel compared with traditional stoves. However, as pointed out, stove type is only one of many factors that influence the amount of fuel used to heat a home. Other important factors that must be taken into account include income of the household, type and size of dwelling, how stoves are used (with or without heating wall), and preferred level of comfort. As shown in table 4.7, it appears that *improved stove users are financially better off than households with traditional stoves* and this may well explain why their consumption is higher. As discussed above, raw coal usage is positively correlated with income; 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 percent of improved stove users are in the top two income quintiles, most improved stove users live in larger houses, which also tends to lead to higher fuel consumption. About 60 percent of improved stove users live in detached houses with heating walls and about 35 percent of improved stove users live in gers—which use the least amount of fuel among the three types of dwellings.

32. The comparison is made without controlling all other factors that are known to influence consumption. Detailed analysis within the group of improved stove users must be made with caution because the number of sample households that use an improved stove is too small to provide meaningful statistical results. Nevertheless, this section is undertaken in the interests of providing full information on the survey results.

4.6 Estimated Firewood Consumption and Expenditure

On average, households used about 4.68 cubic meters (m^3) of firewood and spent about Tog 84,853 for firewood during the heating season of September 2006 through April 2007. Firewood usage per household ranged from 4.3 to 5.0 m^3 and spending ranged from about Tog 80,000 to Tog 90,000 for the entire seven-month period. Overall, 441,147 m^3 of firewood was used by all households in the six surveyed ger areas during these months.

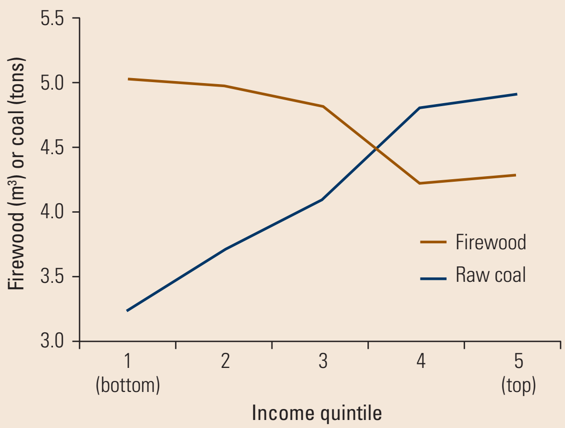
As discussed above, raw coal is the primary heating fuel for households in the ger area, and firewood is generally used just to start the fire. However, some households also use firewood to supplement raw coal, particularly at the beginning and the end of the heating season, or for cooking. Typically, firewood sold in bags is used specifically to start the fire. However, some households purchase wood as logs or other large pieces; they can either use the wood to provide heat or split it into 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 simply 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 suggests that firewood is used to complement the use of raw coal.

A comparison of firewood consumption and expenditure by income quintile (table 4.8) reveals that firewood usage varies only slightly. However, firewood usage is negatively correlated with income; households in the lower income quintiles use more firewood than households in the higher income quintiles (figure 4.1). The average volume of firewood consumed per household from September 2006 through April 2007 ranged from a high of 5 m^3 in the bottom income quintile to 4.3 m^3 in the top quintile. Very small variations of firewood usage among different income quintiles suggest that demand for firewood is income-inelastic.

Firewood consumption is negatively correlated with type and size of home as well as with heating system (figure 4.2). Households living in gers and households living in detached houses without heating walls use more firewood than do households living in detached houses using stoves with heating walls and households living in the larger detached houses using LPBs (table 4.9).

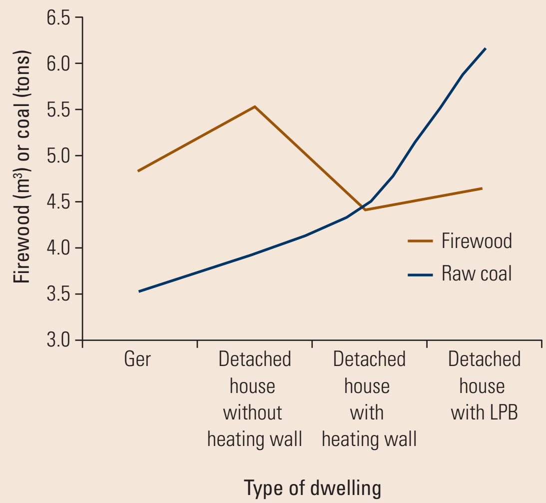
The negative correlation between firewood usage and income, and between firewood usage and type and

FIGURE 4.1: COMPARISON OF FIREWOOD AND RAW COAL USAGE PER HOUSEHOLD, BY INCOME QUINTILE, SEPTEMBER 2006 THROUGH APRIL 2007



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

FIGURE 4.2: COMPARISON OF FIREWOOD AND RAW COAL USAGE PER HOUSEHOLD, BY TYPE AND SIZE OF HOME AND HEATING SYSTEM, SEPTEMBER 2006 THROUGH APRIL 2007



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

size of home and heating system, is in contrast with raw coal usage, which shows a positive correlation with income as well as with type and size of home and heating system. These consumption patterns might lead to the conclusion that these two complementary 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

TABLE 4.8: HOUSEHOLD FIREWOOD USAGE AND EXPENDITURE, BY INCOME QUINTILE, SEPTEMBER 2006 THROUGH APRIL 2007

Income quintile (Tog/month)	Total expenditure on firewood (Tog)	Average firewood used per household (m³)	Total firewood used by all households (m³)
Less than 111,331	88,098.38	5.05	95,369
Valid N	18,674	18,876	18,876
111,331–172,660	90,815.11	4.96	91,669.57
Valid N	18,371	18,472	18,472
172,661–233,990	85,174.44	4.84	89,004.73
Valid N	18,169	18,371	18,371
233,991–325,860	78,761.72	4.27	82,362.81
Valid N	18,775	19,280	19,280
More than 325,860	81,639.47	4.31	82,741.34
Valid N	19,179	19,179	19,179
Total	84,852.80	4.68	441,147.50
	93,169	94,178	94,178

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 income or consumption of firewood. US$1 = Tog 1,200.

TABLE 4.9: HOUSEHOLD FIREWOOD USAGE AND EXPENDITURE, BY TYPE OF DWELLING, SEPTEMBER 2006 THROUGH APRIL 2007

Dwelling type	Total expenditure (Tog)	Average firewood used per household (m^3)	Total firewood used by all households (m^3)
Ger	85,070.18	4.82	186,947.78
Valid N	38,257	38,761	38,761
Detached house without heating wall	103,623.66	5.53	40,154.33
Valid N	7,167	7,268	7,268
Home with heating wall	80,842.53	4.40	168,465.48
Valid N	37,853	38,257	38,257
Home with LPB	86,065.56	4.61	41,875.37
Valid N	9,085	9,085	9,085
Hostel, dormitory, other	82,300.00	4.59	3,704.53
Valid N	808	808	808
Total	84,852.80	4.68	441147.5
Valid N	93,169	94,178	94,178

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 expenditure on or consumption of firewood. US$1 = Tog 1,200.

keep the fire in the stove alive longer, thus would need to start a new fire less often. However, households that use less raw coal will allow the fire to die down more often and, therefore, would need to start a new fire more frequently, which means using more firewood.

4.7 Estimated Briquette Consumption and Expenditure

The estimated number of briquette users is very low; only 1.6 percent of households in the surveyed areas reported that they use briquettes all the time, and another 3.6 percent are occasional users (table 4.10). In all, about 5,249 households have used or are using briquettes at any time during the 2007–08 heating season. The number of households that have been exposed to or have used briquettes has doubled from the 2006–07 heating season. Briquettes appear to be gaining popularity quickly. However the pattern of briquette usage since the 2006–07 heating season seems to suggest that households are either still testing these new products or could not find a steady supply.

The number of households that used any type of briquette during the heating season covered by the survey is estimated at 2,624 households, of which 2,200 used a small quantity. The total spending for briquettes for the period ranged from only Tog 1,200 to Tog 20,000. The small amount of money spent on briquettes during the 2007–08 heating season may be a result of households simply testing a new product.

4.8 Perceptions of Performance by Briquette Users

The number of briquette users is very low and not all of the households that used briquettes gave their opinions.[33] Therefore, the results are based on a very small subset of the data and must be used with caution because of the very large sampling error.

As a result, no inferences should be made about the general population. However, responses from the small number of briquette users may shed some light on user acceptance of these new products and their performance.[34] Results from the survey aim to evaluate users'

33. This section covers users who ever used briquettes during the surveyed heating season. The vast majority of users in the sample are those who used them once or more. Only two households in the sample used briquettes for the entire heating season.
34. A separate study focuses on the performance of briquettes and perception of users. 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. Several types are already available on the market, some of which are produced on a small scale in Ulaanbaatar. Laboratories from both the Energy Research and Development Center and the Academy of Sciences have tested some of these briquettes for their composition but standardized combustion tests have not been carried out. The three generic types follow:

- Densified coal powder briquettes. These are made of pulverized coal mixed with chemical additives to improve combustion characteristics, and a binder is added; for some briquettes the binder is clay. Two forms are generally used: pillow-shaped, like the charcoal briquettes used in the West for barbequing, and cylindrical with vertical holes, which are often used in Northern China and other Asian countries for heating. The coal can come from any source. It is best to compact it at the mine because briquette density is higher than that of the raw coal, which decreases transportation costs. A joint Mongolian-Korean company has developed (with assistance from the Republic of Korea) a production line for Yontan briquettes with a 120,000 ton/year capacity, mixing coal residue with 30 percent clay. The user needs a special stove to burn these briquettes and the ash residue is considerable; the briquette burns without smoke. This fuel 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 seven members.

- Semi-coked coal (SCC) has been produced in a pilot program 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 was converted at a professional coking plant in Russia with good results, producing a clean burning light fuel with a high calorific value as tested by the ERDC. However, SCC briquettes are difficult to ignite in a traditional stove. The investment costs for a 150,000 ton/year coking and briquetting company have been estimated at Tog 37.8 billion. At least three companies are considering the production of SCC for the 2008/09 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 may be 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 2,000 ton/year 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. More sustainable options to provide a steady flow of wood for the production of briquettes in the longer term are the community-managed forests and 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 two to three centimeters in 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 emissions tests following the standard testing protocol. Limited testing shows that the stove technology is a critical factor in controlling emissions; thus, focusing only on the composition of the fuel would limit large potential emissions reductions.

TABLE 4.10: ESTIMATED NUMBER OF HOUSEHOLDS USING BRIQUETTES, FALL 2007 AND WINTER 2008

Usage	Compressed coal	Sawdust briquette	Korean briquette	All types of briquettes
Households using all the time	606	--	1,009	1,615
Percent	0.6		1.0	1.6
Households using some of the time	--	303	303	606
Percent		0.3	0.3	0.6
Households rarely using	1,716	202	1,110	3,028
Percent	1.7	0.2	1.1	3.0
All households	100,941	100,941	100,941	100,941

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

perceptions of the cost, availability, and performance—burning time, heat emitted, emissions of particulates—of briquettes.

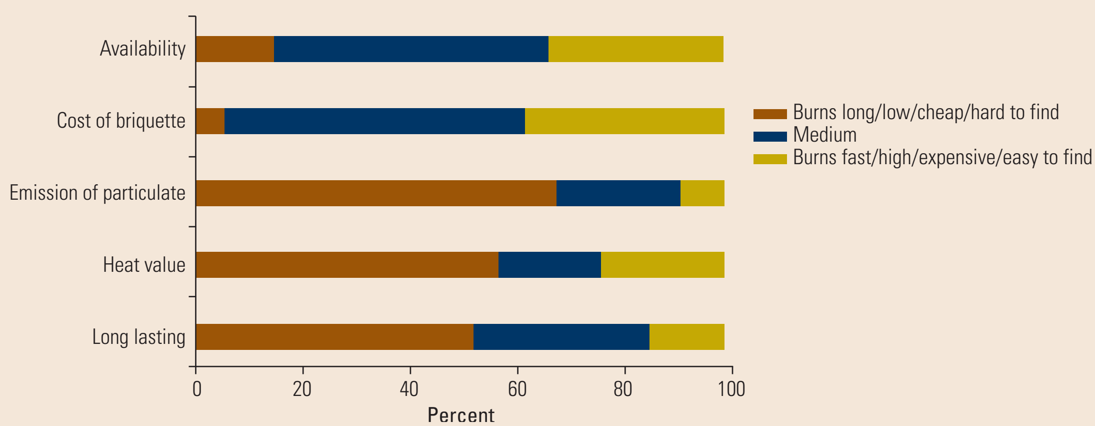
4.8.1 Compressed Coal Briquettes

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 fewer particulates. 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. Most compressed coal users think it is not difficult to find. (See figure 4.3.)

4.8.2 Sawdust Briquettes

Sawdust briquette users have slightly different perceptions. It appears that when compared with raw coal, about 40 percent of sawdust briquette users think that sawdust briquettes last a long time, close to two-thirds think that sawdust briquettes have low heating value, and the vast majority think that they have medium levels of emission of particulates. Half of sawdust briquette users think that they are 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 percent of those who have used sawdust briquettes think it is difficult to find sawdust briquettes in the market. (See figure 4.4.)

FIGURE 4.3: PERCEPTIONS OF COMPRESSED COAL USERS



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

BOX 4.4: SAWDUST BRIQUETTES

Sawdust is a source of energy that is available in large quantities from sawmills; it can be converted into briquettes that were 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. According to the FAO, the Northern forests could supply a large quantity of the ger area's heating fuel requirement on a sustainable basis through a commercial venture in which the communities that manage the forests convert residues into briquettes.[a] As with any other fuel used in Ulaanbaatar, emissions testing has not been carried out.

a. Food and Agriculture Organization, Mongolia: Capacity Building and Institutional Development for Participatory Natural Resource Management and Conservation in Forest Areas in Mongolia. GTZ: Program Conservation and Sustainable Development.

TABLE 4.11: ESTIMATED NUMBER OF HOUSEHOLDS USING BRIQUETTES, SEPTEMBER 2006 THROUGH APRIL 2007

Type of briquettes	Number (percent) of households
Compressed coal	1,110 (1.1)
Sawdust briquette	505 (0.5)
Korean briquette	1,009 (1.0)
All briquettes	2,624

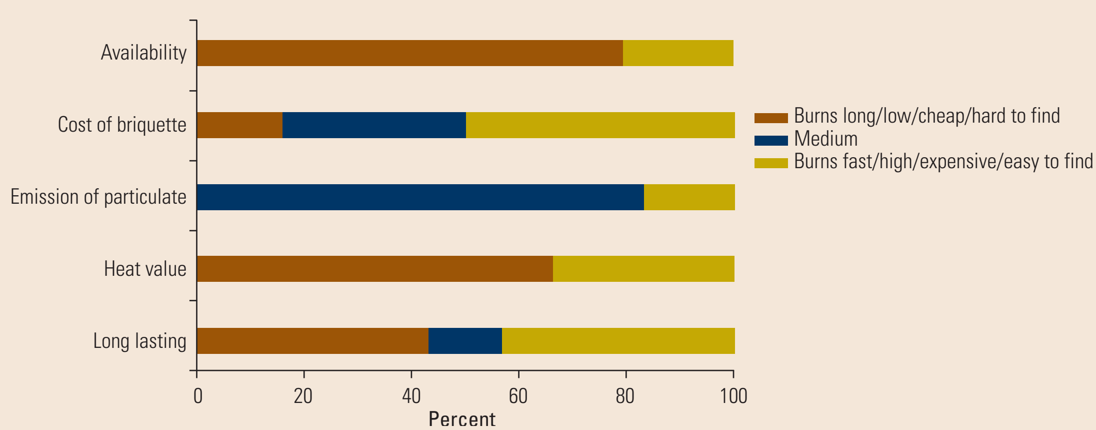
Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

4.8.3 Korean Briquettes

Users' perceptions of the Korean briquette's length of burning is similar to the two previous types. However, users' perceptions of the heating value of Korean briquettes 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 briquettes are cheap and about 60 percent think that the price is competitive with raw coal and not difficult to find in the market. (See figure 4.5.)

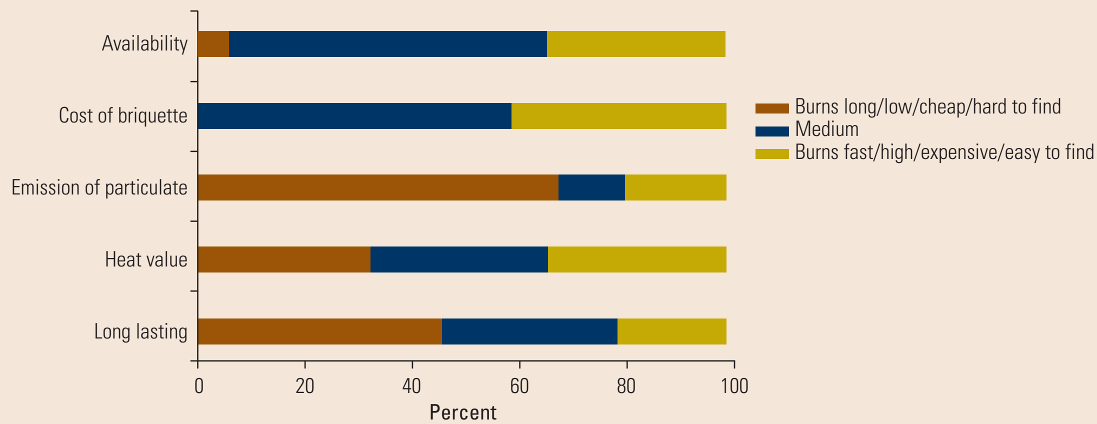
When comparing user perceptions of sawdust with perceptions of other briquettes, it appears that households with sawdust briquettes are not very positive about two key desirable fuel characteristics: capacity to burn for a long time, and heating value. The majority of sawdust briquette users think the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

FIGURE 4.4: PERCEPTIONS OF COMPRESSED SAWDUST BRIQUETTES



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

FIGURE 4.5: PERCEPTIONS OF COMPRESSED KOREAN BRIQUETTE



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

4.9 Quantitative and Qualitative Results of Consumption Tests

Consumption tests were carried out by households and showed considerable performance differences between traditional and selected 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 stoves are generally more fuel efficient than the traditional stove, although the savings level varies with 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 satisfaction. The consumption tests did not address 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 percent 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. Through the present, such testing has not been carried out for lack of proper testing equipment, and it will be difficult to pronounce which stove has lower emissions.

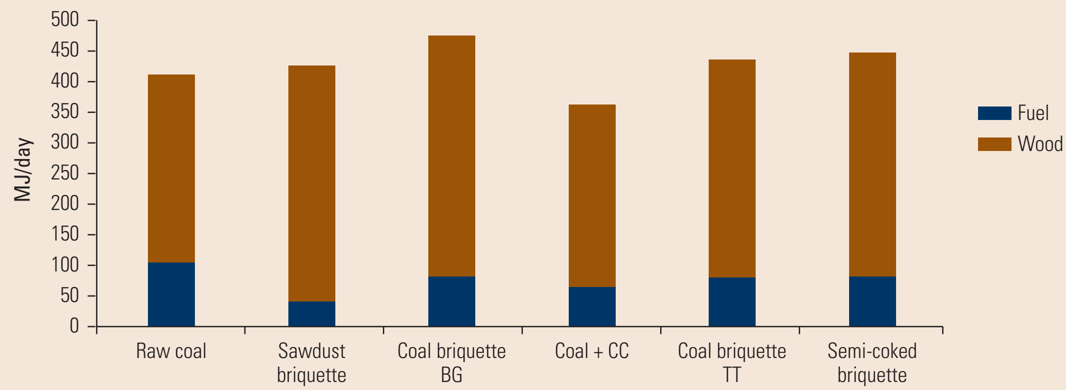
Table 4.12 shows the relative fuel consumption compared with the traditional stove, normalized for a temperature difference of 40 degrees Celsius.[35] The table shows that it matters quite a bit which fuel is used in which stove. A full report on the consumption tests is available from ASTAE.

The TT-03 and the GTZ stoves are slightly more fuel efficient than the traditional stove, with a range of 4–17 percent fuel savings and 5–34 percent wood savings depending on the type of main heating fuel used. Nevertheless, an increase in 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 4.6 shows the energy consumption in a traditional stove, with the lower part of each bar representing the

35. The average fuel consumption over 14 days for users with TT-03 or GTZ stoves is compared with the average consumption for users with traditional stoves, for a particular fuel, and measured during the same time period. The data are corrected for temperature variations (an average temperature difference of 40 degrees Celsius between outside and inside temperature is used).

FIGURE 4.6: ENERGY USE IN A TRADITIONAL STOVE (MJ/DAY)



Source: BEEC 2008.

energy contained in the wood (for starting the fire) and the upper part of each bar is the energy contained in the fuel. As in table 4.12, the energy use is normalized for a standard comfort level. Compared with raw coal, only coal sprayed with 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 with raw coal.

Figure 4.7 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 percent lower consumption than for the traditional stove, but with differences for each fuel-stove combination. For example, the semi-coked coal briquette consumed more energy than did raw coal in the traditional stove, but less 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:

- It is important to test the stove-fuel combinations.
- Households' knowledge of how to use fuels most efficiently in their appliances can have an impact on fuel use.

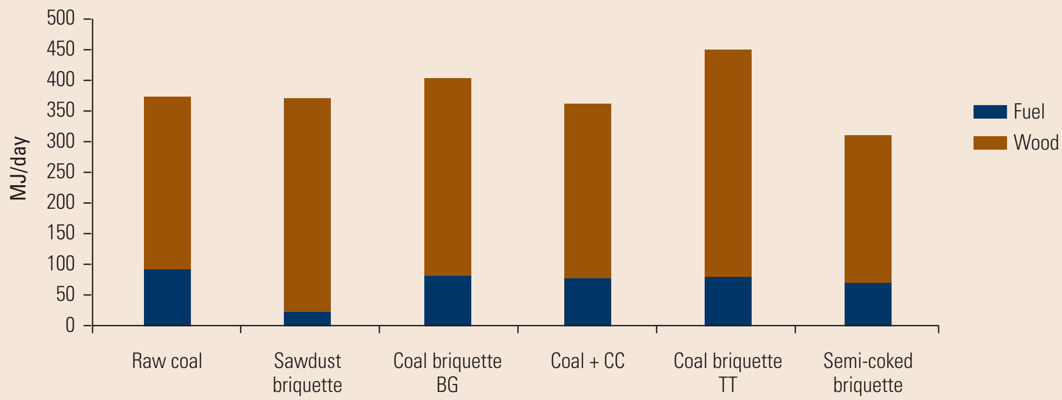
It must be noted that there were too few observations for semi-coked coal due to a lack of availability of the fuel. However, there were sufficient observations for other fuels.[36] Eight households tested briquettes of semi-coked coal mixed with yellow clay and clean coal liquid, experimentally produced in China by a Mongolian company that wants to promote semi-coked coal. About 30 percent of those briquettes had crumbled completely before they

TABLE 4.12: FUEL CONSUMPTION RELATIVE TO THE TRADITIONAL STOVE

	Stove fuel used (percent)	Firewood used (percent)
Raw coal		
TT-03	-8	-7
GTZ	-4	-5
Sawdust briquette		
TT-03	-11	-34
GTZ	-4	+23
Coal briquette company A		
TT-03	-17	-5
GTZ	-13	-18
Coal+ sprayed Clean Coal liquid		
TT-03	-4	+21
GTZ	-8	+52
Coal briquette company B		
TT-03	+4	-5
GTZ	-7	+5

Source: BEEC 2008.

FIGURE 4.7: ENERGY USE IN A TT-03 STOVE (MJ/DAY)



Source: BEEC 2008.

could be used. Upon discussion with the company, two households further tested lumped semi-coked coal (not in briquette form). The semi-coked 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-coked coal is better when 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 because of 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, longer heat retention, and no air pollution. Households liked this fuel,[37] as indeed it ignited easily with little wood, but they also noted that it burned out relatively quickly (but gave off much heat). Some households talked to the manufacturer after the tests and requested more sawdust briquettes against payment, that is, for the same price.

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—manufacturer B's briquettes were well compressed and hard, but manufacturer A's briquettes easily collapsed. To improve 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 of both manufacturers' coal briquettes, and that it takes time and effort to learn how to use these 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 that these briquettes would not ignite easily and have a high level of ash. Many users also complained that the ash smelled strongly.

One can conclude that

- *The combination of stove and fuel is important;* the consumption levels are quite different for different stove-fuel combinations.
- Even more important, *the tested improved stoves and improved fuels are not adequate solutions to clean up the air in Ulaanbaatar;* the resulting relative fuel consumption is not much different from the consumption of a traditional stove. Even if all households were to use the improved stoves on the market today, a 10 percent 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 percent reduction in fuel use means a 10 percent reduction in particulate emissions. A significantly more efficient and clean fuel (resulting in reduced emissions) and a significantly more efficient improved stove (resulting in reduced fuel consumption) will be needed if stoves or fuels are to be considered a solution for air pollution control.

37. A survey was held at the end of the testing period.

TABLE 4.13: TOTAL HOUSEHOLD EXPENDITURE FOR ALL FUELS (RAW COAL, FIREWOOD, AND BRIQUETTES), SEPTEMBER 2006 THROUGH APRIL 2007

Monthly income quintile (Tog)	Total expenditure for heating fuels (Tog)	Total expenditure per heating month (Tog)	Heating expenditure as % of monthly income
≤111,330	241,101.67	34,443.10	42.3
111,331–72,660	256,806.72	36,686.67	25.8
172,661–233,990	254,388.95	36,341.28	17.6
233,991–325,860	257,259.80	36,751.40	12.9
More than 325,860	277,121.09	39,588.73	8.7
Total	257,581.39	36,797.34	20.7
Households	94,481	94,481	94,481

Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.
Note: US$1 = Tog 1,200.

4.10 Household Total Expenditure for Heating Fuels

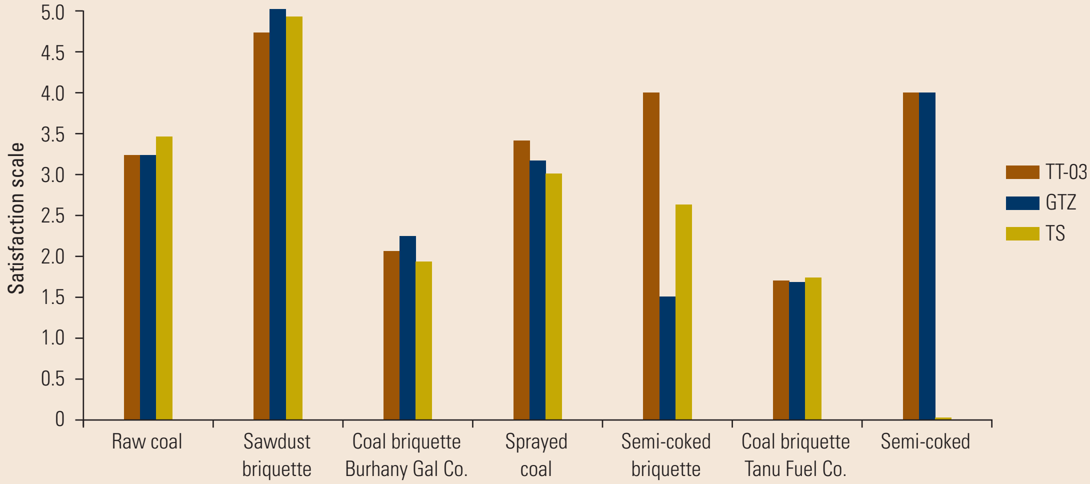
As shown in this chapter, the overwhelming majority of households in the six surveyed districts used raw coal as their main heating fuel and spent a significant amount of money on raw coal.[38] In addition, they also incurred expenditures for firewood, mainly for starting the fire. A few households have also tried some types of briquettes. As shown in table 4.13, the poorest households spend an extraordinary percentage of their reported income on heating fuels. It is estimated that from September 2006 through April 2007, each household spent a total of Tog 257,582 for all fuels to heat the dwelling. About 67 percent of this amount was spent for raw coal and the remaining 32 percent was spent on firewood. The quantity of briquettes used was small, thus, expenditures for briquettes were insignificant when compared with those for raw coal and firewood.

As shown in table 4.13, the total amount of household expenditures for heating fuels—raw coal, firewood, and briquettes—from September 2007 through April 2008 amount to about Tog 36,797 per heating month per household. Based on the reported cash income collected from the survey, household monthly expenditure for heating fuels from September 2007 through April 2007 accounts for 20.7 percent 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 spent more than 40 percent of their monthly income for heating fuels during the seven-month heating period. The situation is significantly better for households in the second lowest income quintile. However, household heating fuel expenditure for the richest income quintile and second highest income quintile accounts for slightly less than 9 percent and 13 percent of their monthly income, respectively.

Any increase in heating fuels resulting from 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, none of which are acceptable anyway. For example, households may reduce heating fuel consumption in response to price increase. Unfortunately, poor households have already reduced heating fuel usage 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 ladder or find some other coping strategies, including using unconventional approaches such as burning trash, old tires, and the like to keep warm. Luckily, the survey shows (see above) that not many households (0.2 percent) report using such alternatives thus far.

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

FIGURE 4.8: OVERALL SATISFACTION WITH FUELS



Source: BEEC 2008.

4.11 Conclusion

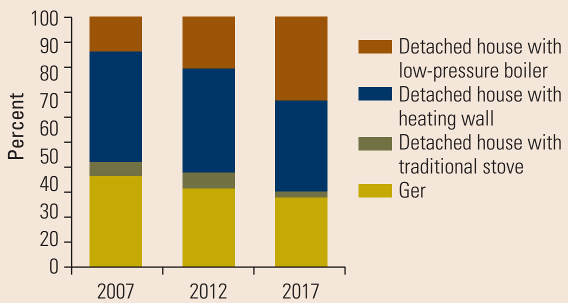
The survey confirms that just about every household in the six surveyed ger areas uses raw coal as the main heating fuel. It is estimated that about 399,601 tons of raw coal were used by all households in the surveyed areas during the 2006–07 heating season. On average, households consumed about 3.9 tons of raw coal and spent about Tog 174,767 during that heating season. As expected, coal from Nalaikh is the most popular, with coal from Baganuur ranking a distant second. The survey also reveals that *demand for raw coal is positively related to income and type and size of home*. However, coal usage varies only slightly between poor households living in gers or small detached houses and rich households living in larger detached houses. This pattern of raw coal consumption implies that *demand for raw coal is rather inelastic*. This can easily be understood because one simply has no choice but to heat the dwelling; the alternative is to not survive the severe winter.

Firewood is also used by just about every household living in the surveyed areas, mainly to start the fire. It is estimated that about 441,147 m^3 of firewood were used by all households in the surveyed areas during the surveyed heating season. During this period, each household used about 4.68 m^3 of firewood, for which it spent about Tog 84,853. *In contrast to raw coal, firewood is negatively correlated with income and type and size of home*. As a result of these consumption patterns, we may conclude that these two complementary 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 alive more often, thus needing to start a new fire less often. Conversely, households that use less raw coal allow the fire to die down more often; consequently, these households need to start the 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 surveyed heating season, only a handful used briquettes as their only heating fuel. Judging from the reported quantity of briquette used and the amount of money spent on it, it appears that the vast majority of households that used briquettes during the surveyed heating season were either testing the briquettes or could not find a steady supply of briquettes to continue using that fuel. However, households that used sawdust briquettes reported perceptions suggesting that this fuel burns fast and has a low heating value.

Figure 4.8 shows the overall satisfaction with the fuels for each of the different stoves as expressed by the households at the end of the consumption tests. Raw coal and sprayed coal score about equally, with minor differences

FIGURE 4.9: FUEL CONSUMPTION BY HEATING TYPE



Source: BEEC 2008.

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 because 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 a more than significant amount of money to heat their gers or houses.* Households in the bottom income quintile have an extremely high financial burden: during the period September 2007 through April 2008, households in the bottom income quintile spent about 40 percent of their monthly income for heating fuels, including raw coal and firewood. In contrast, households in the top income quintile spent only 9 percent of their income each month for heating fuels.

This information is particularly important for indicative estimates of subsidy programs. Fuel subsidies currently contemplated[39] involve provision of subsidized raw lignite for processing into semi-coked coal. However, this subsidy would benefit richer households more because 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 Tog 3.8 billion per year, covering 15 percent of total raw coal consumption for ger area household heating.[40] Stove subsidies involve a one-time capital grant that could cost approximately Tog 8.1 billion if low-emission stoves cost about twice the current market price for traditional stoves.[41] Targeting mechanisms are especially difficult for fuel subsidies in other countries and usually involve a number of administrative measures and assessments of taxes on polluting fuels. Chapter 8 discusses issues and options on moving forward with a program to support cleaner, affordable heating.

Finally, a trend to be highlighted is the move toward more fuel-consuming heating appliances that provide more comfort, particularly low-pressure boilers. Larger LPB-fitted homes consume more than twice what ger households use to heat their gers. Combined with another trend—moving out of gers and constructing detached houses —implies that the importance of the different heating appliances will evolve over time. (See figure 4.9 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 LPBs or traditional stoves contribute very little to overall fuel consumption, in the future, consumption from LPBs will grow the fastest to become more important than both ger households and nonheating wall households combined. It is therefore necessary to focus on LPBs and ensure that these are low emission and high efficiency. The proposed standards should certainly take this into account.

39. Based on interviews with government officials.

40. Assuming that briquettes are equally priced as raw coal (2007–08 price data), at Tog 60,000 (US$50) per ton.

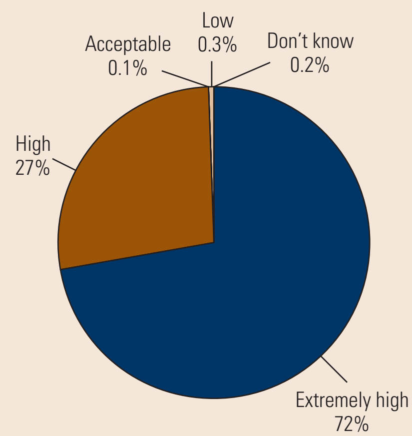
41. Assuming all stoves costing Tog 60,000 (US$50) to be replaced (135,000) at 50 percent subsidy.

5

Attitudes about Air Pollution, Alternative Fuels, and Stoves

Virtually all households in the six surveyed ger areas think that air pollution in Ulaanbaatar is high. In fact, about 72 percent of the households think that air pollution in Ulaanbaatar is extremely high and another 27 percent think that air pollution is high (figure 5.1). Everyone also agrees that because of the pollution problem in the city, it is very difficult to breathe in the morning during the winter. Furthermore, everyone agrees that air pollution in the city creates health problems for family members (figure 5.2).

FIGURE 5.1: OPINION OF AIR POLLUTION PROBLEM



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

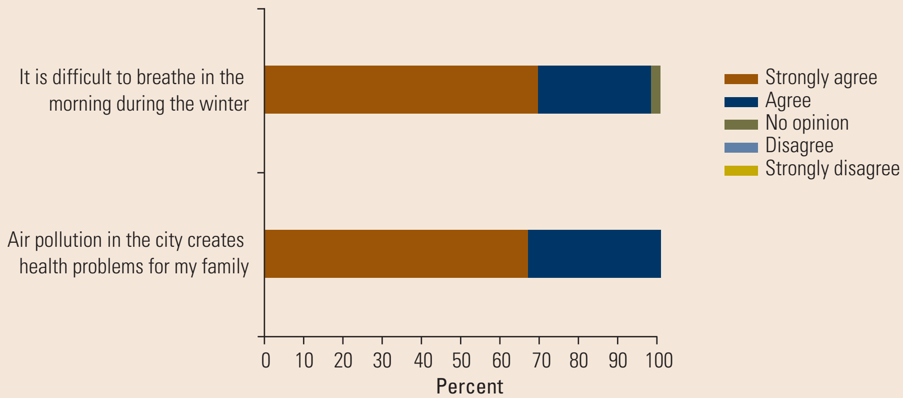
5.1 Perceptions of the Causes of Air Pollution

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 5.3, households believe that the contribution of stoves to air pollution is very high. About 85 percent of the households believe that the use of raw coal and heating stoves by ger area households has a very high contribution to air pollution and another 14 percent believe that it has high contribution, but only 1 percent think that it has a medium contribution.

In addition to the use of raw coal and heating stoves, the vast majority of households also find that motor vehicles, power plants, undisposed-of solid waste, industry, and dust also contribute to the air pollution problem in the city. However, only about 10 to 20 percent of the surveyed households think that these causes have a very high contribution to air pollution.

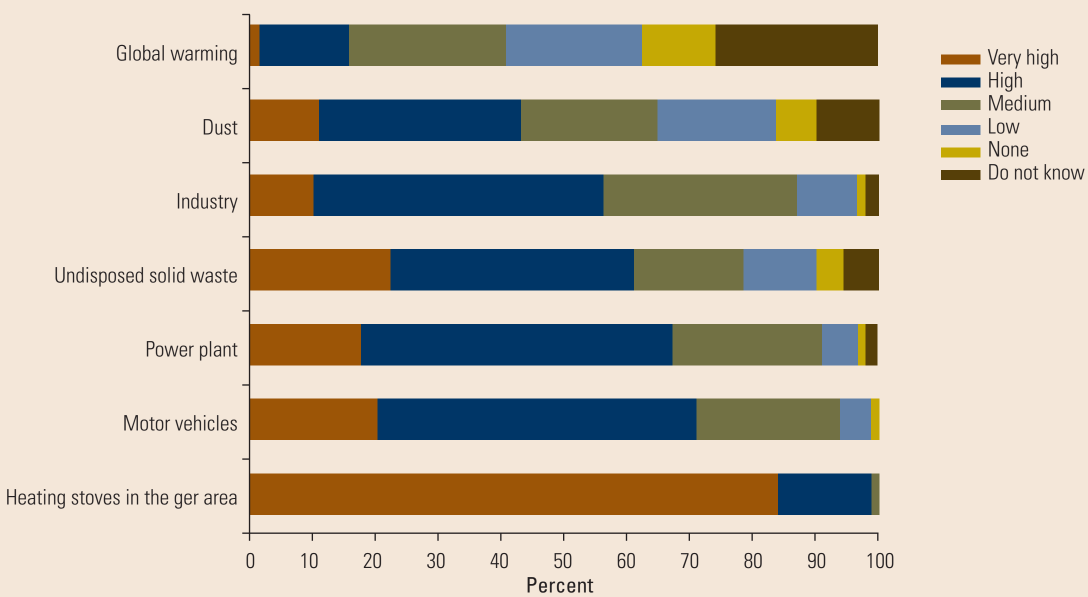
The survey gauges households' opinions of several different courses of action that may reduce air pollution in the city (figure 5.4) and finds that almost everyone (96 percent) thinks that moving ger residents to live in apartments is the suitable action for this purpose. Other courses of action that the majority of surveyed households (ranging from 60 to 85 percent) believe to be very suitable are (i) reduce raw coal consumption, (ii) ger area residents use electricity to heat their homes, (iii) use

FIGURE 5.2: OPINION OF EFFECTS OF AIR POLLUTION PROBLEM



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

FIGURE 5.3: OPINION OF SOURCES CONTRIBUTING TO AIR POLLUTION

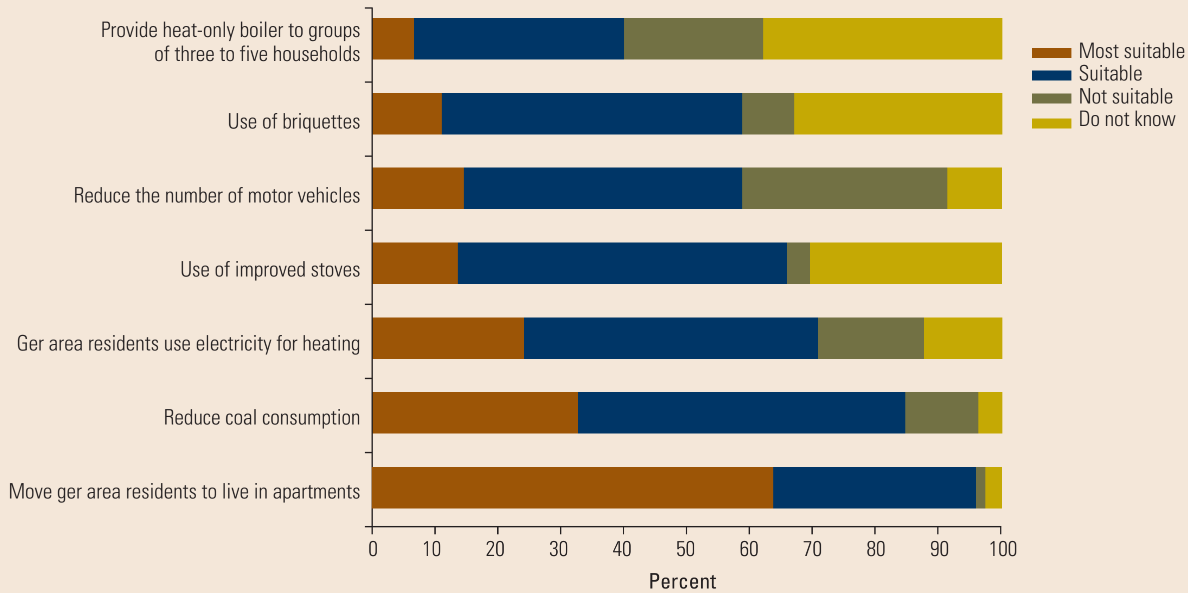


Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

improved stoves, (iv) reduce number of motor vehicles, and (v) use briquettes instead of raw coal.

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

FIGURE 5.4: OPINIONS OF COURSES OF ACTION TO REDUCE AIR POLLUTION



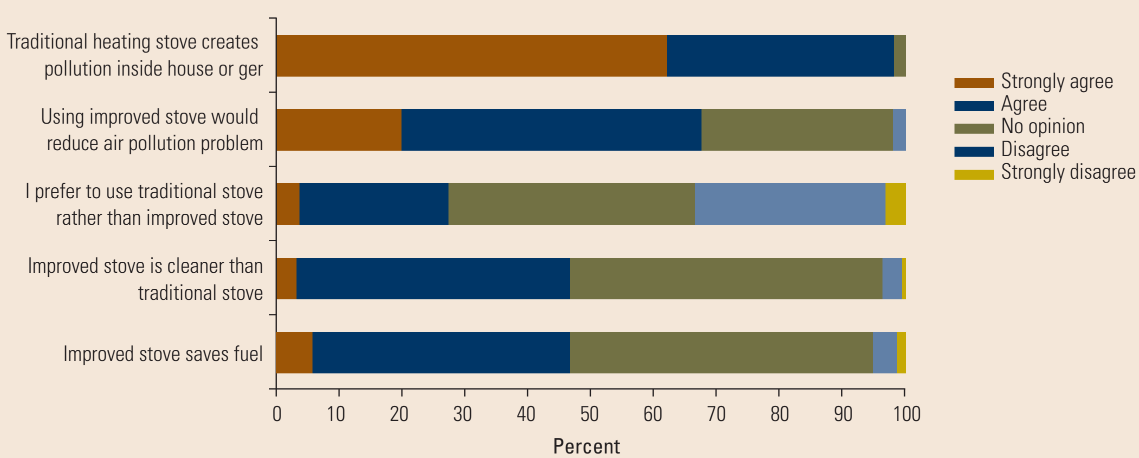
Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

5.2 Attitudes toward Heating Stoves

Households' attitudes toward the use of heating stoves and raw coal provide further evidence that households know of the health risks they are facing. They are also well informed about the pollution problem and about the public discussion on pollution issues. The survey finds that just about everyone agrees—more than 60 percent strongly agree and 30 percent agree—that traditional stoves create air pollution inside the ger or detached house.

However, survey data also seem to indicate that less than half of the households have confidence in the performance of improved stoves. As shown in figure 5.5, slightly less

FIGURE 5.5: ATTITUDES TOWARD HEATING STOVES



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

than half of the households agree that improved stoves save fuel or are cleaner than traditional stoves.

Although only close to half of the households have confidence in the performance of improved stoves, about 70 percent of the households agree with 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 attitudes toward using traditional stoves also implies that households may believe that improved stoves are a better alternative for reducing air pollution than continuing to use traditional stoves—only a third of the households agree with the statement suggesting that the respondent prefers to use a traditional stove compared with an improved stove (figure 5.5).

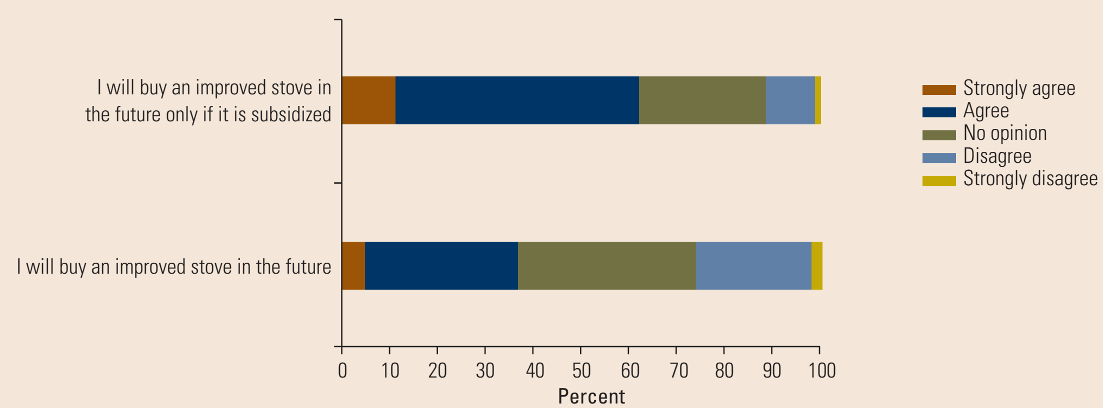
A significant portion of households, including the half of all households that expressed "no opinion" and the small portion of households who disagreed, must be convinced in the future that improved stoves save fuel, are cleaner burning than traditional stoves, and would help reduce air pollution in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

With respect to the readiness to change to improved stoves, the survey finds positive responses regarding willingness to change for the better and close to 40 percent agree with the statement indicating that the respondent would like to buy an improved stove in the future (figure 5.6). In addition, a larger portion (more than 60 percent) agree with the statement indicating that he or she will buy an improved stove in the future only if it is subsidized.

5.3 Attitudes toward Raw Coal, Briquettes, and Using Electricity for Heating

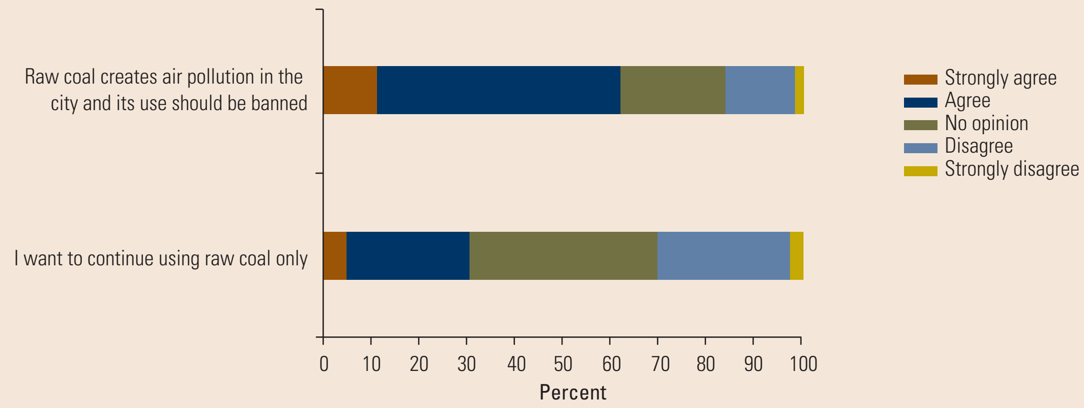
Attitudes toward raw coal seem to reflect that households are well informed about the health threat from using raw coal (figure 5.7). The majority of surveyed households (60 percent) agree with the statement indicating that raw coal creates air pollution in the city and its use should be banned. Such a call indicates a lack of awareness of the several alternatives to consider, including that perhaps the stove, not the fuel, creates the pollution by burning fuel badly. However, at present households do not feel they have many alternatives. Almost no one has seen a clean-burning stove. The majority of the households do not know anything about the performances of briquettes, which could be the best potential alternative to raw coal. The household survey in the six ger areas reveals that the majority of households—50 to 70 percent (see figure 5.8)—have no opinion about the performance or quality of any type of briquette (coal or sawdust). However, on

FIGURE 5.6: ATTITUDES TOWARD CHANGING TO IMPROVED STOVE



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

FIGURE 5.7: ATTITUDES TOWARD RAW COAL

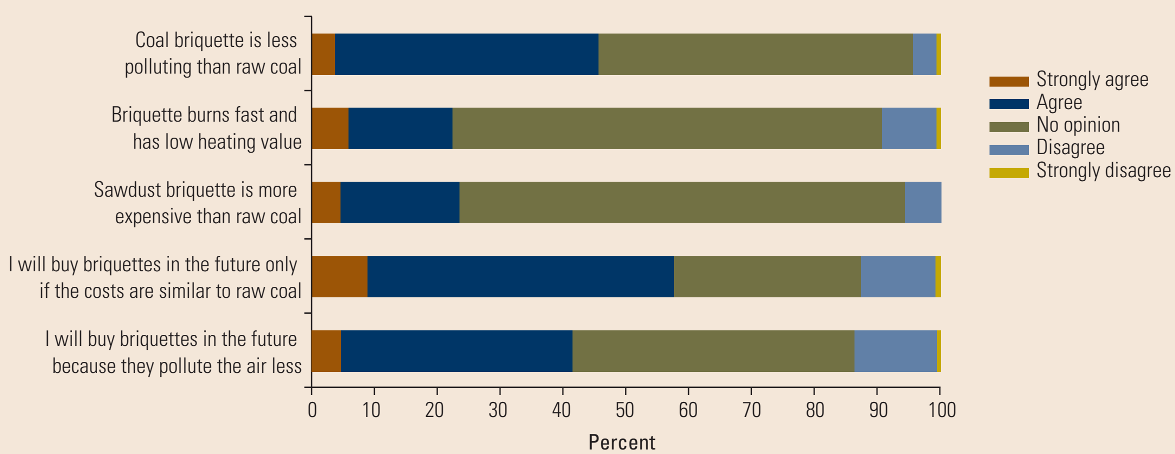


Source: ASTAE/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.

a positive note, only a small portion of households, ranging from 5 to 9 percent, disagree with the statements indicating that coal briquettes are less polluting than raw coal, briquettes burn fast and have low heating value, and sawdust briquette is more expensive than raw coal.

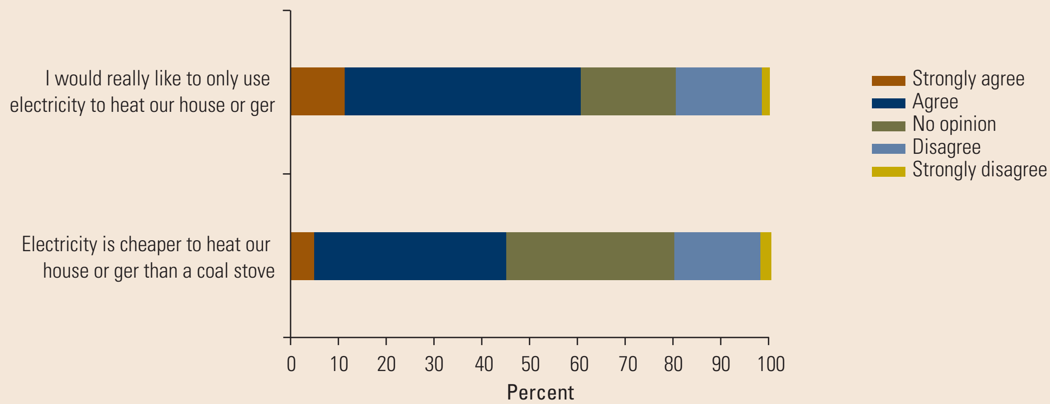
This finding confirms that briquette products are very new and are not yet widely available in the market. As a result, very few households have had exposure to the new products. As is typical with new products and market acceptance, it is important to prevent any initial bad impression of briquettes 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 consumers' initial bad impressions of any new products. So far, about 40 percent 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 they are less polluting. In addition, more households agree with the statement

FIGURE 5.8: ATTITUDES TOWARD BRIQUETTES



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

FIGURE 5.9: ATTITUDES TOWARD ELECTRICITY FOR HEATING



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

indicating that they will buy briquettes if the price of briquette is on par with raw coal. These findings are promising for briquette producers and others who would like to promote briquettes.

Figure 5.8 provides feedback on briquettes from the household survey; opinions of those households who have not necessarily used briquettes before are included, unlike the households participating in the consumption tests. Some households think that briquettes burn more slowly and are less expensive than coal, and they are more likely to use briquettes if they are cheaper than coal; they also think that briquettes are equally as polluting as coal. This means that the real features of briquettes—level of pollution, duration of the burn, and costs—will need to be advertised, once the test results are fully known.

Electricity is not currently used by many ger area households for heating and only a small number of households use electric space heaters as a supplemental heating source. The survey finds that about 60 percent of the households agree with the statement indicating that the respondent would really like to only use electricity to heat his or her ger or house; a small number (less than 50 percent) think that it is cheaper to use electricity to heat the house or ger than to use raw coal (figure 5.9). The question should be raised about 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 the current costs of using raw coal and traditional stoves. (See box 5.1.)

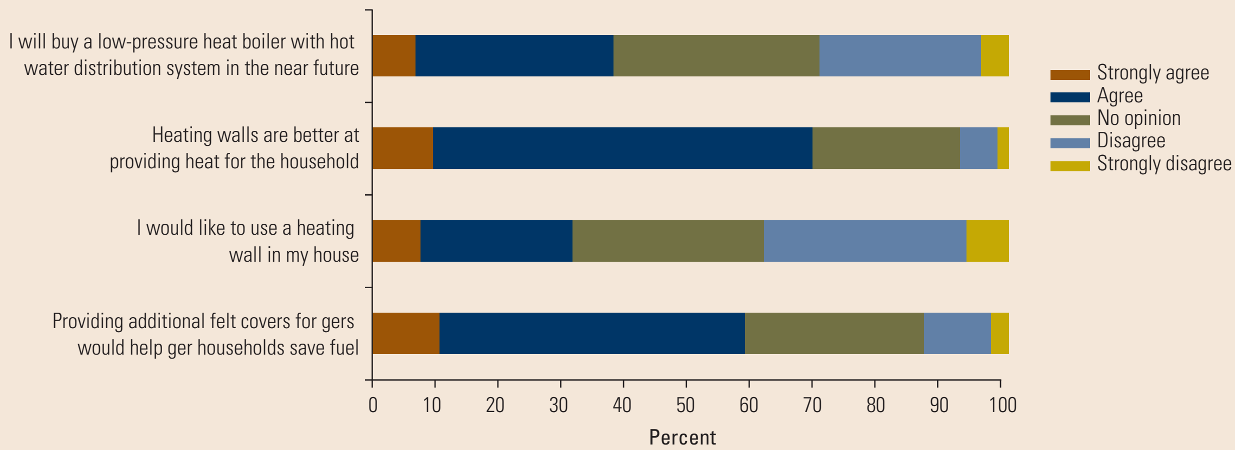
BOX 5.1: FACTS ABOUT THE ELECTRICITY ALTERNATIVE

Electricity has been mentioned as the preferred alternative for ger area heating. (See appendix 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 Tog 1.68 trillion; and (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 Tog 64.8 billion per heating season.

5.4 Other Attitudes

Other findings on household attitudes confirm that a significant number of households are interested in alternative heating devices or systems that would provide more comfort and better living conditions (figure 5.10). Aside from using electricity to heat a significant number

FIGURE 5.10: OTHER ATTITUDES



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

of households, close to 40 percent are also interested in buying low-pressure boilers with hot water distribution systems. About 70 percent of the households think (that is, agree with the statement) that heating walls are better at providing heat for the household than stand-alone stoves but only a third would like to use heating walls in their homes. This contradiction may have come about because heating walls are not appropriate 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.

6

Knowledge of Air Pollution Caused by Stoves and Fuels

6.1 Laboratory Tests

One of the tools planned to be used to further quantify air pollution measures was *laboratory testing* of the same stove-fuel combinations as examined in the consumption tests carried out in March 2008. Laboratory testing would have quantified emissions by type of pollutant as a function of fuel consumption. The idea is that standardized laboratory tests on stove-fuel combinations would yield both fuel consumption data and emissions data (combustion efficiency, carbon monoxide [CO], particulate matter [PM]). With these data it would be possible to correlate emissions with fuel consumption, which is essential for assessing different corrective measures for air pollution. 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 emissions 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 were not available.

Although a standard methodology was developed by the ASTAE consultant and agreed on with the main laboratories in Ulaanbaatar, the lack of equipment and qualified personnel prevented the tests from being carried out systematically. Nevertheless, Ulaanbaatar municipal government (UBMG) staff (Air Pollution Division) carried out some tests with different fuels in the traditional stove. The results, although indicative only, suggested an important conclusion.

When considering emissions reductions, it is risky to dissociate the fuel from the stove; the two should be looked at simultaneously rather than focusing 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 a standard testing methodology, and quantified for possible fuel-stove combinations to identify the optimal solutions for air pollution reduction.

So far, stoves have been tested 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 cubic meter (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 or about the total emissions. As an example, if stove A's emissions were Xg/m^3 and stove B's emissions were 0.75Xg/m^3, the conclusion was that stove B would be the cleaner stove; however, this conclusion 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 to produce these emissions. This was not done in earlier tests, and as a result, previous emissions measurements cannot be used to compare emissions output from different stoves.

For large-scale applications such as power plants, a furnace would normally be designed and optimized for a fuel with specific characteristics, but for simple household stoves costing less than Tog 60,000 per unit, such optimization is usually not done. Heating stoves should be treated exactly like other appliances, with enforced standards achieving expected emission and performance outcomes. The important parameter is the emissions factor, which is the rate of emissions per unit of fuel consumed (grams of pollutant per m^3/second emitted in the stovepipe per grams of fuel used per second); this parameter needs to be established for all stove and fuel combinations so that the environmental performance of the different options can be assessed.

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 the oxygen level (from which the CO_2 can be inferred). As a result, nothing can be deduced from those particular tests about combustion efficiency or stovepipe losses (which can be calculated from a combination of stovepipe temperature and excess air level). CO can be taken as a rough proxy for PM emissions until equipment arrives to carry out real-time measurement of PM emissions from the stovepipe exhaust gases.[42]

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 appendix B and the necessary lab equipment in appendix E.

The reporting of CO levels without the dilution factor must be discontinued; not only is it misleading, the wrong conclusions can even be drawn. Particulate emissions must be cooled and diluted before they are measured. This means samples have to be drawn from the stovepipe, 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 must be sampled for particulates based on a gas flow rate, and the quantity in the original sample must be calculated.
- The alternative is to do gravimetric (mass measurement) samples in which 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 two or three filters, at least the 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 the National University of Mongolia can do gravimetric measurements but does not have equipment to dilute stovepipe 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.
- The Central Laboratory of Environmental Monitoring (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 recently had not been available. CLEM can also do total suspended particulates (TSP) tests at the same time; such tests take 20 minutes to complete, so with one test per hour during a four-to-five-hour test period, this testing 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 Air Quality Division (AQD) could carry out the same tests using their newly acquired Dust-Trak, which can measure one PM fraction at a 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 general relationship between the CLEM TSP measurement and the real-time $PM^{2.5}$ levels.

42. Stoves with low CO emissions will also have low PM emissions.

- The National University of Mongolia can enable its diluted gravimetric PM measurements and collaborate with UBMG or CLEM to establish the general relationship between the real-time $PM^{2.5}$ and the gravimetric $PM_{2.5}$ per m^3 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 that the tests were for just two hours. Because fuel use was not recorded, a correction was calculated based on the assumption that all heat generated in the fire came from carbon.[43] The resulting CO/CO_2 ratios are given in figure 6.1.

Figure 6.1 is dense, but the lesson is simple: emissions from fuels tested far exceed the current standard, although for one or two stove models the emissions level is only a factor of 10 higher. A few further observations can be made from figure 6.1. First, a full test should last about four to five hours, until the fuel is fully combusted; both the household survey and the consumption tests indicated that stoves are normally refueled after four to six hours. Only the first two hours of testing are shown in figure 6.1, which is likely why the ratio for some of the fuels continues to increase.[44] Figure 6.2 shows the accumulated total emissions over the two-hour testing period. Accumulated emissions 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 was still increasing toward the end of the two-hour measuring period).

Second, the horizontal line at 2 percent 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 percent for wood and 0.5 percent for anthracite. None of the fuels comes close, which means that under actual conditions, all fuels exceed the legal emissions limit. Raw coal from Nalaikh appears to be a relatively clean fuel, on par with the Yontan briquette, at least compared with 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 semi-coked coal (SCC) briquettes, but their CO/CO_2 ratios are still 20 times 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.

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

- 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 rates should peak and then die down (when all of the fuel is spent). The fuels that behave like this are the Yontan briquette and Nalaikh raw coal.
- constant emissions for an extended period, after a gradual build-up of 10–20 minutes. However, the levels for sawdust briquettes and SCC briquettes are at least 20 times the permissible standard.
- all other fuels show increasing emission values from the start, with 40–60 times the permissible levels some two hours after start-up. Eventually emissions levels should peak; this behavior is observed for all other coal and briquettes: coal + cow-dung mixture, coal + 30 percent clay mixture, 45 percent coal + 45 percent coke + 10 percent clay mixture.

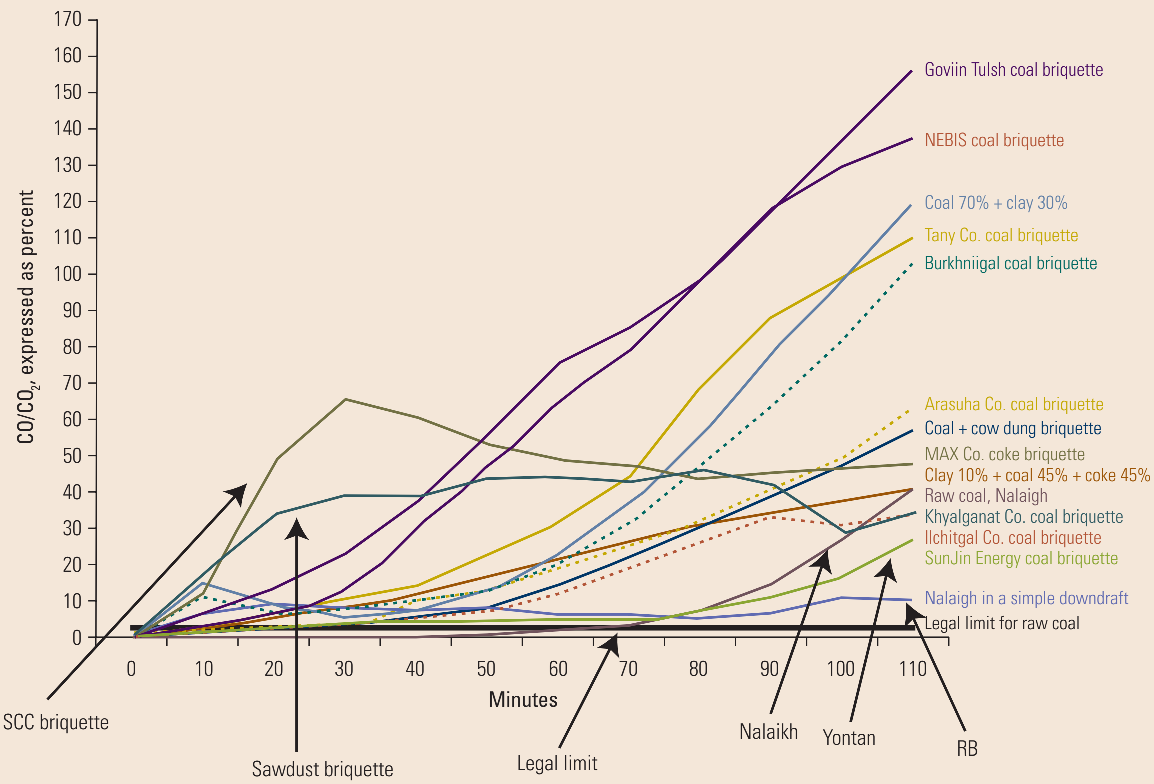
The data presented here should be interpreted with much care until more detailed systematic tests are completed. The preliminary conclusions are two-fold: (i) it appears possible to burn Nalaikh coal in simple stoves with reasonable emissions as presented in the legal emission limits; (ii) most "improved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

Another reason for quickly retesting these fuels and stoves is that the 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 the hydrogen to ignite and burn immediately, but this apparently was not the case. Another observation is that the stovepipe temperature is too low (below 100

43. 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 if the carbon content of the coal is known.

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

FIGURE 6.1: CO/CO_2 RATIOS FOR DIFFERENT FUELS



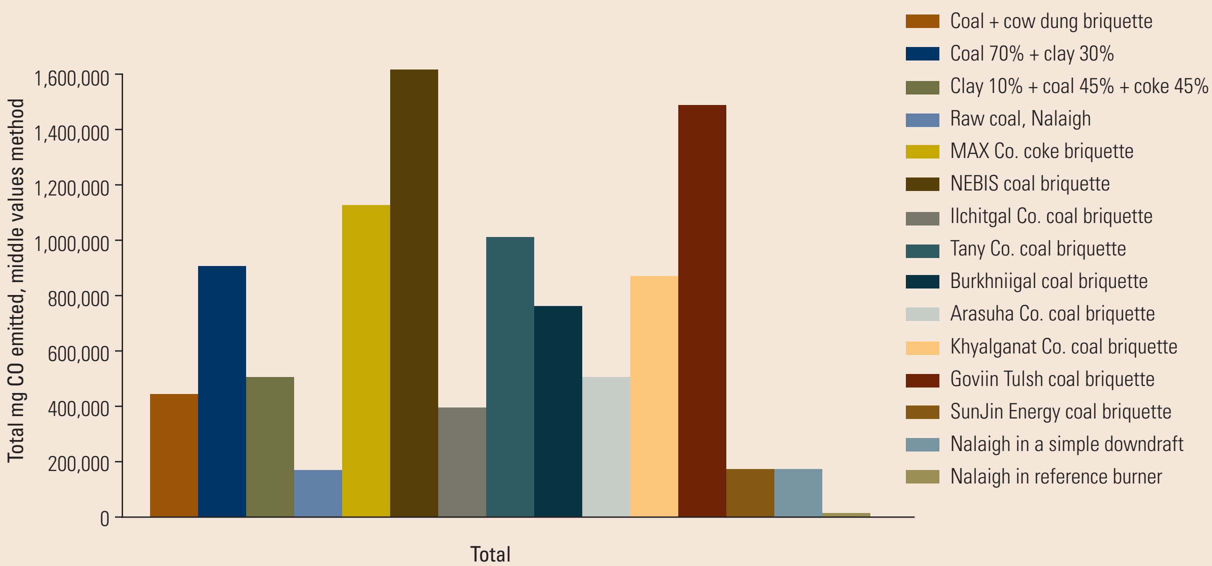
Source: UBMG.
Note: Carbon-monoxide divided by carbon-dioxide for 12 fuels tested in a TT-03 stove, one in a sunjin, and one in a downdraft stove.

degrees C) for at least two improved stove models. With such low temperatures, exhaust gases will condense and drip down into the stove, creating problems of corrosion, further emissions, and so forth. 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 large-scale marketing of the fuel.

It is thus urgent that these tests be repeated in a regular laboratory, with strict adherence to the testing protocol and use of the appropriate equipment. The conclusions are far-reaching, seemingly suggesting that the current research into new fuels may not be an efficient use of funds. Further research into higher performance stove-fuel combinations also seems to be warranted because it should be possible to beat the 2 percent CO/CO_2 legal limit.

This report did not address indoor air pollution although the stove igniting phase produces smoke. 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. First, all exhaust gases must definitely escape into the ambient air, so the chimney needs to closely fit the stove and should not leak. Second, the stove itself must be well made; MNS 5216: 2002 sets the quality standards for domestic burners of solid fuels, including a fuel efficiency standard. However, in practice the chimney often leaks or the stove is not well made and gases may leak into the indoor atmosphere. Therefore, emissions may indeed pollute the indoor air directly, which is particularly

FIGURE 6.2: TOTAL CO EMISSIONS OVER THE TWO-HOUR MEASURING PERIOD



Source: UBMG.
Note: Twelve fuels tested in a TT-03 stove, one in a Sunjin, one in a downdraft stove, one in reference burner.

worrisome because 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 than cleaning up the indoor air—in fact, indoor air automatically becomes cleaner when better stoves and fuels are used.

A common mistake of stove developers is to include a damper at the stovepipe to slow the burning rate of the fuel; however, exhaust gases then are unable to escape and are vented into the room and the choked fire produces more CO than normal. Elevated levels of CO are dangerous, 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 air needed for combustion 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 for Stove Manufacturers

A two-day training session for stove designers and producers took place in March 2008 to demonstrate to them that traditional and currently available improved stove models do not burn raw coal as cleanly as 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 downdraft mode, exhaust gases 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 great interest in learning more about the principles behind them.

These principles were shared 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 downdraft principles and discuss how they could be applied to heating stoves.

One segment of the practical testing that took place in the laboratory demonstrated that conditioning of the coal could also yield substantial benefits. Breaking up the coal lumps into smaller pieces of two to three centimeters improves combustion efficiency because air flow is better regulated and more complete combustion takes place. Conditioning only works in a properly designed stove: air leaks as result of holes in the stove body will negate the benefits.

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. The private sector is responsible for developing such stove models and although a few models did surface in 2008 and again when the European Bank for Reconstruction and Development's (EBRD's) March–April 2009 tests took place, the quality of the stoves was highly variable and they have not been put 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 from the EBRD's work 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 emissions were high during the start-up phase because lighting the fuel was difficult, requiring larger amounts of wood over a longer period of time than for raw coal. The resulting net emissions reduction, therefore, is not yet convincing and needs more testing to understand this 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.

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

- Continued testing is required, particularly for new fuels, which need to be tested in different stoves. It is 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 included (not done currently). Such briquettes are appealing and look more modern than the densified clay briquettes that have been for sale for a few years 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.
- Any tests performed should reflect how stoves are actually used by consumers. Tests should be seen as the starting point of a more systematic effort to address emissions from individual household heating systems in ger areas. Improvement of household heating systems is actually more complicated 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 occur. These factors make designing a stove that performs well under this wide range of operating conditions a complex task.
- The government should insist on use of a standard protocol designed for small household heating stoves and behaviors for the tests. A testing protocol, presented in appendix B, has been designed for consideration. This protocol reflects the heating cycle as practiced by households: start-up, rapid heating up, slowly cooling down, and then refueling and letting the fire burn until it dies. A complete

cycle may take more than five hours. Emissions should be measured during all phases of the test to determine the accumulated level of emissions (the Emission Factor, or EF); this can be represented for the heat delivered, for the quantity of fuel used, or for the energy content of the quantity of fuel used. As a result of testing under a standard protocol, EFs can be compared for different stoves and different fuels to determine the fuel-stove combination that yields the lowest emissions.

- The protocol for testing stoves connected to a heating wall and for low-pressure boilers should also be established now.
- All testing should be carried out in a properly equipped laboratory, available to those willing to test new fuels or new stoves. If a laboratory is not made available, a solution to the air pollution problem will depend on the willingness of experts outside Mongolia to carry out tests, which will always be a second-best solution.
- A testing protocol such as the one proposed in appendix B could be used systematically to make test data consistent and comparable.
- Sufficient time must be provided to test complete cycles of fueling and refueling (more than five hours per test) because emission characteristics differ during the burning cycle: visual and tested indications show that the largest emissions appear during start-up of the stove and during refueling; it appears that for traditional stoves, start-up emissions are high and emissions continue to increase during normal steady-state conditions.
- Emissions levels should be tested for both 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 for it. This would be a zero-cost solution to immediately reduce emissions from ger heating stoves Back lighting most likely results in cleaner combustion for all stoves and all fuels. Although back lighting might be somewhat difficult for the household to get used to, 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 will result in an increase in fuel efficiency as the ignition period is extended. This phenomenon occurs because a fire started at the back end of the stove and the fuel pile, near the chimney, causes the flame front to travel through the pile of fuel toward the door at the front of the stove. All combustion gases have to travel through the hot combustion zone where much of the PM can be destroyed.

6.4 Conclusion

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

The missing link is scientific confirmation of the impact of the different stoves and fuels on air pollution reduction. A thorough analysis will need to be undertaken as soon as possible, and it is recommended that fuels and stoves be fully characterized before they are allowed to hit the market. The tests that were recently carried out by the EBRD confirm this conclusion.

7

Combustion Efficiency and 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 have 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 to 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, light, or both, 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:

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O + \text{heat},$$

or methane and oxygen react to yield carbon dioxide, water (usually water vapor), and heat.

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

Combustion efficiency expresses how clean the burn of the fuel was. The less clean, the greater will be the presence of complex compounds of NO_x, SO_x, H_2S, and particulate matter (PM). 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 for different fuels and for different stoves.

Coal in Mongolia is typically composed of carbon, moisture (30 percent), ash (5 percent for Alagtolgoi, 10 percent for Nalaikh), sulfur (0.4 percent), volatiles (40–45 percent), and other substances or compounds. The level of moisture is important: the moisture needs to be evaporated before the coal can burn well, and evaporation 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, because ash does not burn and so does not contribute to heat output. Briquettes normally have a high ash level (20–40 percent). 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 it over time: heat retention may be higher than in fuels with lower ash content. The volatiles will burn off immediately and determine, to a certain extent, the ease with which the coal fire can be ignited; a high-volatile coal can normally be easily ignited.

Coal briquettes typically have a high ash content because clay is mixed into a coal slurry to form briquettes. At the same time, some additives, such as calcium-rich compounds, can be mixed in to contain the sulfur when combustion takes place, reducing the SOx emissions. When these briquettes are burned, the original shape of the briquette may still be present in the stove as a result of the high ash content. Sawdust briquettes will have very low ash content and high volatiles content: they burn quickly without leaving a lot of ashes. Semi-coked coal is coal that is heated so that the moisture and volatiles are removed (box 7.1). 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 is not enough oxygen to allow the fuel to react completely with the oxygen to produce CO^2 and H_2O, or 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 downdraft stove design is likely to produce a cleaner burn than an updraft design. In a downdraft, 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 emissions standards. In the United States and Europe, emissions standards are enforced for household heating appliances, too.

Large-scale production of sawdust briquettes in Mongolia is a real possibility. Although there are vast areas without a single tree, the northern parts of the country 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 burned on site. Rather than being burned, these resources could be transformed into energy. In addition, large quantities of sawdust are available that could be transformed into briquettes. The technology is not in question, but the economics of production and transportation need to be proven before launching such a venture. (See appendix G for more details.)

BOX 7.1: SEMI-COKED COAL PRODUCTION

Lump (20–100 mm), bituminous coal (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 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 (hydrogen cyanide), sulfur compounds, phenols, and other organic—mostly toxic—matter as well as coal dust is collected in a tank. The environmental implications of waste-water disposal are of great concern.

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

7.2 Standards

Standards are in force for most durable consumer goods, whether cars, thermometers, or electric heaters. Such standards are in place and enforced in the West for cooking and heating stoves—for safety aspects and sometimes also for environmental reasons—but not in many emerging economies. Even if there are standards, they are often not enforced. In a few countries, including Mongolia, standards for stoves and fuels exist but are generally not enforced. However, it would make sense to start enforcing reasonable standards in an effort to clean up the air around Ulaanbaatar. This section discusses the existing situation with regard to standards, 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 (i) MNS 5216: 2002 that deals with household stoves, (ii) MNS 5041: 2001 that deals with domestic boilers and furnaces below 100 kW, and (iii) 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 Urban Centers project that was implemented by the Ministry of Nature and Environment in conjunction with the Ulaanbaatar municipal government and financed by the Global Environment Facility. 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 project implementation unit 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 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, factories, and the like. 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 of CO to CO^2 cannot be greater than 0.5 percent for anthracite burners, 2 percent for coal burners, and 4 percent for wood burners.

Assessment of standards. Although the household stove standard (MNS 5216: 2002) is a good start, it could be improved to incorporate the fact that stoves and fuels cannot be dissociated: the two critical measures to determine the level of emissions are (i) fuel consumption for a standard heating task (thermal efficiency), and (ii) emissions factors, or emissions per megajoule of fuel used (combustion efficiency) during the same heating task. The standards could also address a cooking task, although coal consumption for cooking will be much lower than for space heating and thus less important. The standard heating task should be defined as keeping a standard room warm at 20 degrees C during 24 hours with an average outdoor temperature of minus 20 degrees C. Emissions to consider are CO, SO_2, H_2S, total suspended particulates in the stack emissions, PM_{10}, and $PM_{2.5}$. The fuel consumption during the 24-hour testing period should be measured, as should the emissions from the chimney. It is recommended that such new standards be developed and approved.

Regarding indoor air quality, the main danger observed with current stoves (traditional as well as improved) is the CO level in the home—even 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 chokes 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 intake and controls the power output, (ii) no chimney damper, and (iii) better construction quality with no holes in the stove or the weldings. These design features ensure that the stove is under negative air pressure, so that air only leaks in, 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 to their families.

The 100 kW boiler and furnace standard (MNS 5041: 2001) is meant for community applications such as schools, apartment buildings, and other large structures, and is not really meant to include household stoves and boilers, which normally have a capacity of 6–20 kW. It is recommended that two separate standards be developed, 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. Stoves should only be certified for certain stated fuels, in line with their performance as described above. The two new standards would render the standard for solid fuel combustion (MNS 5679: 2006) obsolete. (See table 7.1 for a summary of recommendations for new standards.)

At the moment, none of the tested household stoves complies with MNS 5679: 2006. Moreover, heating wall stoves and low-pressure boilers have not been subjected 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 meet this standard. It is recommended that an effort be carried out to develop stove models in Mongolia, or identify another source outside the country, that would comply with the new standards and therefore emit much lower harmful emissions.

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 box 7.2 for the experience in South Africa on standards for kerosene stoves. In Mongolia, standards that exist are not enforced and will be difficult to begin to enforce. Instead, it is recommended that verification of the standard at entry takes place, that is, before equipment enters the market; this system is the easiest to put into action and will ensure that, at a minimum, all new equipment complies. This method would require (i) the government to set the standards, (ii) a certifying agency to check for compliance with the standards and to certify appliances before they are allowed to enter the market, and (iii) 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 is charged with the development of appropriate standards. It has the right to develop a standard on its own initiative, but an outside agency can also request that it develop a new standard. 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 technical committees. The JTC may form an informal working group of experts to advise and draft parts or all of the standard; however, the draft would be voted on and accepted by the JTC.

The State Specialized Inspection Agency (SSIA) is charged with verification of compliance with 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 nongovernmental organization (NGO) is another way to enforce the standard, through automatic regulation. This association sells and promotes only stoves that comply with the standard. It also actively promotes the use of heating walls, for which no standard exists, and tries to avoid the production of unimproved traditional stoves through education and raising awareness. It will take quite an effort to enlarge this

TABLE 7.1: 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 setting fire to the room
Combustion	Gives maximum fuel consumption rate	Should still give maximum fuel consumption rate, but should be related to a normalized temperature and to the type of fuel used
Emissions	Gives some emissions rates, but these are not correctly defined	Give properly defined emissions factors that cannot be exceeded

Source: Authors' compilation.

self-regulation capacity to cover the whole stove market within a reasonable time.

Verification capacity. The SSIA is charged with verifying compliance with approved standards, but it lacks the capacity to do so for household heating systems. As mentioned above, first, better standards need to be set and publicized, and feedback needs to be solicited from interested industries, then analyzed. The International Organization for Standardization has 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 emissions testing. An essential element of these tests is the ability to measure the power output of a stove during the whole testing period. Stoves (sometimes weighing more than 100 kg) plus fuel and testing apparatus need to be placed on a scale and the weight checked every few minutes. Emissions factors need to be determined, which requires simultaneous measuring of (i) fuel consumption, (ii) excess air flow in the chimney, and (iii) 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 certification could also be carried out by other qualified laboratories. However, certification tests for compliance should only be done at a laboratory that is itself certified as competent to do so. In practical terms, stove manufacturers would submit their appliances to a certifying laboratory that 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 enforcement mechanism needs to be developed. At the moment it is possible to measure within a 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 the source, assuming that these stoves continue to comply with the standard over time and that noncertified stoves no longer be sold. For this to happen, a combination of scheduled tests and self-regulation is needed.

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 that are in compliance with 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 model.

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 noncompliant product loses its certification.

Self-regulation is needed so that stove makers no longer manufacture uncertified models. Making a subsidy available only for certified models could help tremendously. Awareness among consumers should also be raised so that they no longer want to buy traditional and noncertified stoves and will report producers to the inspectorate. Some promotional and controlling activities may need to be put in place for some time at popular stove selling spots, such as at the Narantuul market.

7.3 Implementation Strategy

Irrespective of whether a ger area heating project will be implemented, it is recommended that standards for ger area heating systems be improved and enforced, and that the existing institutional capacity to realize this be reinforced. This capacity includes the agencies for 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, particularly the regulating authorities such as the Agency for Standardization and Metrology and the SSIA, and industrial partners. Usually a compulsory standard is preceded by having the proposed standard made voluntary for a specified time (one or two 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 will be examined to see if the testers get the same results as the developers. Agreements to edit the testing can be made if necessary, which prevents lawsuits over poor wordcraft. After the voluntary period, an enforcement agent is appointed. Instead of being made completely compulsory, the standard could be 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 might not. No product may be sold or imported that does not meet those relevant sections of the standard that are now law (that is, compulsory). A certificate of compliance (obtained after testing) must be accessible to anyone who asks, usually at the vendor's site; 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 becomes illegal to sell noncompliant products, compliance certificates should be available, routine testing is in place, and designs can be certified for replication, and the like. Because there are still many unresolved problems associated with stoves, low-pressure boilers, and heating walls, time must be allowed for implementing agents to ensure products are available if and when enforcement begins. 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 the situation seriously and develop new stove models.

Stove industries are likely not capable of developing better stoves without significant technical assistance. The Improved Household Stoves in Urban Areas project showed that the industries had developed models that saved fuel but did not reduce emissions. There are some 40 stove-producing firms that mainly sell through the central market. A few larger steel-processing companies could manufacture stoves on a large scale, but they cannot develop new stove models. It is recommended that a tailored program be launched to develop low-emissions stoves for different fuels currently on the market 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 significant research capacity exists. The climate in Johannesburg, for example, is such that households need stoves for heating but use 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.[45]

In addition, stoves that would comply with the standard, or even stricter air pollution standards, such as in California, exist (see appendix H). Solid fuel stoves are available not only in the United States but also in Germany, the United Kingdom, China, the Czech Republic, and the Republic of Korea that would meet the Mongolian criteria. The main issue is that these stoves are made for a richer client who often uses it as a back-up heater, and 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 in Mongolia. After all, supplying 150,000 stoves in a relatively short period is quite a large market opportunity for which scale economies might be possible.

In the past, the government played a role in convincing households to switch equipment, 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 one to three years old, much newer than when the distribution took place. The method followed just before the Improved Household Stoves project closed down—output based-aid—was more successful in delivering some 2,000 stoves in a relatively short period. It is now time to combine enforcement of better stove standards with mechanisms providing incentives to households to switch stoves.

45. 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.

7.4 Conclusions

The recommendations emanating from this project follow:

- Develop new standards for ger area household heating systems, anticipating continuation of observed trends of 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 and estimated costs in appendix E).
- Test equipment using 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.[46] 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 noncompliant appliances and suppliers.

46. Central Laboratory of Environmental Monitoring; nuclear physics laboratory at the National University of Mongolia; UBMG/AQD.

8

Discussion, Conclusions, and Recommendations

Winter air pollution levels in Ulaanbaatar are high, affecting general health conditions at great economic cost, and therefore urgently need to be addressed. Some 99 percent 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 contributes considerably to this problem. More than 95 percent of households say that the contribution of ger stoves to air pollution is very high or high. In fact, 40–70 percent of emissions of particulate matter of 2.5 microns or less ($PM^{2.5}$) 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 chimneys are leaky, combustion gases can enter into the room and indoor air can become polluted, too. However, poor quality outdoor air also trickles into the home through the door, vents, and holes in the walls.[47] The priority, therefore, is to improve outdoor air quality because it affects ger area residents as well as all other residents in Ulaanbaatar. Improving indoor air quality is intrinsic to the solutions pursued.

The solutions to the air pollution problem are to use better stoves, cleaner fuels, or both. Households generally feel that they can and should contribute toward solutions, but for the poorest a support mechanism will be needed. Some 75 percent of the households state that they think that improved stoves would contribute to cleaner air and 60 percent state that briquettes would do the same. For both options, 40 percent of the households indicate that they will use these in the future—60 percent will 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 officials do prefer that fuels be switched because it provides a ubiquitous solution—better fuels can be placed in any equipment without switching the equipment. While fuel-switching may have some effect, ignoring the equipment in which it is burned will significantly limit potential emissions reductions. This study concludes that there is no evidence available at this time that suggests any one solution will meet the "smokeless" objective.

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

It is not now possible to verifiably quantify emissions from stove-fuel combinations because 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 separated one from the other when evaluating emissions reduction potential: a stove is needed to burn fuel, and emissions stem from a combination of the two and need to be as low as realistically possible.

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

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

Preliminary emissions testing of improved stoves suggests that current models available in Ulaanbaatar may not have the capacity to sufficiently reduce air pollution and emissions; even fuel savings of 10–30 percent, if obtained, may not be enough to substantially reduce the city's air pollution. In fact, it is unlikely that air pollution problems can be solved with any currently available combinations of stoves and fuels. Different kinds of solutions will therefore be needed, both long-term and short-term. Several interventions are discussed in the remainder of this chapter.

BOX 8.1: CHALLENGES TO DISTRICT HEATING, ELECTRICITY, AND LPG IN GER AREAS

- **Connection to DH for ger area households.** The additional infrastructure needed for connecting all ger area households to the DH system will be high. Losses will also be high because the distribution lines from house to house will be outside (as opposed to running inside an apartment building), and metering will be difficult. Management of the DH system is already complicated and these additional challenges are not 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 (heating, ventilating, and air conditioning) systems (for example, apartment buildings), or incomes rise very quickly.

- **Use of electricity for heating by ger area households.** The additional load for heating ger area households has been estimated at roughly 600 megawatts, or double the existing generation capacity in the whole country.[a] Investments for developing this infrastructure would amount to more than Tog 1.68 trillion, which would be an unbearable burden on the government. In addition, the cost to households for heating with electricity will be much higher than with coal: ger area households pay roughly Tog 250,000 per year for heating with coal;[b] with electricity, the monthly heating bill would be Tog 82,000, or almost double the expense of coal—even at the cheaper nighttime tariff. They also will need to buy electric heating stoves. Ger area households rated access to electricity for heating very high in the survey. The survey also found that 5 percent of households already use low-cost electric stoves to supplement heat from their coal stoves.

- **LPG.** The main uses of LPG are to fuel taxis and limited household cooking. LPG was just recently introduced for taxis and the market is still small. Scale economies are an important factor for determining the final price of LPG; LPG is imported from Russia at relatively high costs. In fact, it is more expensive to cook and heat with LPG than it is with electricity, which will limit the potential use of LPG for space heating. (See table 8.1 for an overview of the different fuels and their costs if used for heating.)

a. See appendix D, Case Study on Electric Heating in Beijing.
b. The household survey found Tog 174,000 for the 2006–07 heating season. Corrected for the coal price increase, for the 2007–08 heating season, the average heating costs would be roughly Tog 250,000.

TABLE 8.1: HEATING FUEL PRICES AND COSTS, 2007–08 SEASON

Fuel and unit	Tog/unit	kg/unit	MJ/kg	Tog/MJ	Heating cost/MJ[a]
Coal, truck (kg)	130,000	2,500	14.7	3.5	5.1
Coal, bag (kg)	1,200	18	14.7	4.5	6.5
Firewood (m^3)	1,200	8	15.5	9.7	13.8
Briquettes, sawdust (kg)	1,200	18	20.3	3.3	4.7
Coal briquettes, burkh. (kg)	1,200	18	17.0	3.9	5.6
Coal briquettes, yontan (kg)	200	3	17.6	3.8	5.4
Semi-coked coal briquettes (kg)	1,200	14	25.8	3.3	4.7
LPG (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/World Bank: Baseline Fuel Consumption, Heating Stove, and Household Perception Survey, December 2007.
Note: US$1 = Tog 1,200.
a. The efficiency of the stove is incorporated; for solid fuel, 75 percent; for gaseous, liquid, and electric fuel, 85 percent.

8.1 Possible Interventions

8.1.1 Long Term

Resettling ger area residents into apartments connected to district heating (DH) is among the potential long-term air pollution solutions frequently discussed. The residents would then use DH instead of coal stoves. This ultimate long-term solution is included in the government's air pollution reduction measures Resolution 218. As a result of this resolution, construction of several large-scale apartment buildings is now underway. Nevertheless, the realization of this solution is likely to take a long time, and much investment will be required before all ger area households live in apartments. The survey respondents concur with this solution—97 percent agreed or strongly 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 nonsolid fuels such as liquefied petroleum gas (LPG), kerosene, or electricity, or extending the DH 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, as has already been observed with the increased use of heating walls and low-pressure boilers (LPBs). Nonsolid fuels have higher energy content per unit weight than unprocessed coal and are typically used in mass-produced energy-efficient stoves. Some 70 percent of the survey respondents say that electricity would be a good heating energy source. However, 40 percent also say that electricity is cheaper to use than coal, which is currently not true. 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. (See table 8.1 for a summary of the prices and costs of a variety of fuels.)

Fuel switching will not be easy to achieve because the cost of heating with raw coal is low compared with modern fuels (see table 8.1); 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 DH costs[48] whereas the poorest households living in ger areas have to pay the full cost of individual heating. Ger area households have

48. Tog 256 (US$0.21) per square meter of floor space and Tog 1,000 (US$0.83) per person. For a 100 square meter apartment, a typical payment would be less than Tog 30,000 (US$25) per month; the average expenditure for ger area households is about Tog 37,000 (US$31) per month.

low-quality heating, and residents have to get up several times a night to maintain the fire, while apartment dwellers enjoy high quality heating for which they pay less.

Ger area households tend to improve their own living conditions by constructing one- or two-story wooden or brick homes, sometimes over the course of several years. As of the time of the survey, only some 43 percent of ger area households still lived in gers as their main residences. More than half have constructed a more durable single-family detached house. 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 percent currently use stoves, 69 percent use heating walls, and 16 percent use LPBs. Some 70 percent of all respondents agree that heating walls are a good solution and 30 percent want to construct one in the future; 40 percent want to install an LPB. Households are looking to improve their situations rather than to move into apartments in the near future. The impact will be more air pollution—clean-burning heating wall stoves and LPBs currently do not exist and fuel consumption per household will increase. Heating wall stoves consume, on average, 30 percent more fuel than stoves without heating walls, and LPBs as much as 70 percent more, mainly because they are used in larger homes. Something clearly needs to be done on the stove side to ensure that cleaner-burning devices become available.

8.1.2 Short Term

Until these more long-term solutions fall into place, short-term options need to be actively pursued. Certain immediate solutions 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 to quickly reduce fuel consumption and emissions levels under certain conditions. This course is fundamentally different from what was done under the Improved Heating Stoves in Urban Centers 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 gers in traditional ways for thousands of years. Without substantial incentives to promote behavioral changes, entrenched customs tend to persist, and in Ulaanbaatar have led to severe air pollution. Subsidies may offer a major incentive, as they earlier did in the Improved Heating Stoves project. Another incentive could be users' recognition that switching to improved heating systems carries a high value in assisting the community to clean up the air.

Why, then, do many households fail to perceive this community-assistance 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 results of a study looking into more details are forthcoming. Another reason is that optimal designs may not automatically be appreciated by users: a new model that resolves one problem sometimes creates other difficulties for the user. For example, an 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 new heating systems. Design trade-offs such as usability, ease of heating and cooking, lighting speed, costs, and end-use efficiency must be addressed in an integrated way to develop viable markets for improved stoves.

The government has an interest in promoting cleaner fuels produced by private suppliers. These fuels could include semi-coked coal and other kinds of coal briquettes. Because no regular supply of these briquettes is available 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 the technical design of coal stoves will need to be solved. First, traditional stoves are designed to use firewood, not coal, resulting in higher than necessary fuel consumption and emissions. In addition, stoves take warm air from inside the home for combustion instead of cold air from outside, which unnecessarily increases heating requirements. Quality problems also result from air leaks in stoves, a lack of regulating valves, and the fact that some stoves are too large for the task at hand. Some chimneys are poorly attached to the stove or leak, and have close-off valves to smother the fire. A number of these issues might cause outright safety problems, such as CO (carbon monoxide) entering into the room with possibly lethal consequences. Although the currently available improved stoves have been user tested and were well liked during the tests, sales have not taken off and only a small percentage of the population actually uses these stoves. The survey showed that 3 percent of the respondents have an improved stove. However, these stoves have not been sufficiently laboratory tested to know if they reduce particulate emissions; fuel efficiency tests were carried out, but emissions testing could not be done because of 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 buy stoves made from second-hand steel to save money, minimum quality standards need to be set. Standards need to be verified too, which should be an ongoing process. It should be possible for end users to manage heat output through a control mechanism that allows the heat to be turned down without risk of CO poisoning. Households would prefer to have stoves that burn longer, but a stove with a simple fuel hopper does not exist.[49] It should be possible to put customary cooking vessels on top of the stove.

A stove's fuel consumption is easy to verify, but emissions are more important for air pollution reduction and should be measured. Both fuel consumption and emissions depend on the stove design and the type of fuel used, and tests of various fuel-stove combinations should be carried out before new stove models are put on the market. Three factors will play roles in the successful production and introduction of such stoves: (i) more interaction is needed among users, manufacturers, and designers to develop stoves that satisfy households and that also perform well; (ii) it will be important to provide data from ongoing monitoring and evaluation to manufacturers and designers for fine-tuning, as well as to politicians to elicit their continuing support; and (iii) technical design and infrastructure must make use of resources consisting of laboratories, universities, foreign specialists, Ulaanbaatar municipal government (UBMG), 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 finalize and stylize the design, and finally reduce the manufacturing costs.

Promotion and market development. Stove promotion and market development will need to take place to ensure that households understand what to buy, where to buy, 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.[50] 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, providing credit facilities for stove makers, facilitating the availability of raw materials and manufactured parts, and offering promotional support. Close collaboration between manufacturers and the UBMG is required, not only for the promotional campaigns but also for the quality control aspects and the subsidy mechanism.

International experience shows that well-targeted subsidies and equitable pricing are integral parts 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 programs 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 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.

Institutional support. Cooperation among different organizations is required. It does not make sense for each institution to pursue only 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.

49. A hopper is a simple device to continuously feed the stove with new fuel. The simplest hoppers are gravity fed; more complex ones use electric motors. Hoppers work best if the coal size is small compared with the feeding hole in the stove.

50. Barnes, Douglas, Priti Kumar, and Keith Openshaw. 2008. "Cleaner Hearths, Better Homes: Improved Stoves for India and the Developing World." ESMAP Draft Report, World Bank, Washington, DC.

In addition, the laboratories and the institutions working on design, verification, and enforcement of standards should all participate, as should the private-sector actors that will need to commercially produce briquettes and stoves.

Most successful improved stove programs around 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.[51] In addition, significant international evidence suggests that improved stove programs should target regions with the greatest need, which in Mongolia is clearly Ulaanbaatar. Finally, effective programs must disseminate reliable, durable solutions.

Integration into broader initiatives. 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, 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 Tog 60,000–120,000, this new model has become a popular use of the fund. In addition, local nongovernmental organizations 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 Mongolian 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 the UBMG, 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.

51. Cecelski 2000; Shailaja 2000.

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.

Quality. 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.

8.1.3 Overview of the Options

Table 8.2 shows the merits of the different options, also showing, however, 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 emissions levels.

8.1.4 Economic Considerations

For the government to be involved in promoting more efficient heating systems, considerable economic and social benefits will need to come out of any program to replace stoves with more fuel-efficient, emissions-reducing models—with or without the use of cleaner fuels. A reduction in the consumption of coal will

- reduce the household heating bill—a positive socioeconomic benefit;
- reduce the emissions of CO_2—a positive global environmental benefit; and
- reduce the emissions of CO, H_2S, and PM—for immediate and long-term health benefits that will also extend the length of life.

A stylized example of the potential economic benefits, presented in box 8.2, gives a clear justification for relatively large subsidies. From the household perspective,

TABLE 8.2: OVERVIEW OF POSSIBLE OPTIONS

Option	Time period	Pros	Cons
Move ger area households into apartments	Long term	Ultimate solution, providing the largest benefits with regard to living conditions; lower operational heating costs for households	Expensive; public construction investments are high Some households may not want to move
Use of nonsolid fuels, LPG, and electricity	Long term	Provide better heating solutions without moving households	Expensive fuels result in high operational costs for households Public infrastructure for electricity generation and distribution is expensive
Connect to district heating system	Long term	Good heating solution at possibly relatively low public investment	Very high technical losses because of the multitude of small customers
Semi-coked coal briquettes	Short to medium term	Could provide high-heating-content fuel, from the private sector Appears to provide "smokeless" heat, but after ignition	Medium to high investment costs and operational costs Stove design may need to be adapted; needs emissions verification If subsidized fuel provided, prevention of leakage to nontargeted 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 by households Already in production by the private sector	Fuel cannot be produced in Ulaanbaatar, only near the forests or sawmills Stove design may need to be adapted; needs emissions verification
Conditioned coal (dried, small pieces)	Short term	Low cost Immediate solution available from the private sector	Stove design may need to be adapted; needs emissions verification
Compressed coal briquettes	Short term	Low cost (but somewhat higher investment than conditioned coal) Immediate solution available from the private sector	Stove design may need to be adapted; needs emissions verification
Different stoves	Short term	Could satisfy households, particularly if designed in participatory way Private sector solution	Needs emissions verification in combination with fuel

Source: Authors.

investing in an improved stove makes sense, and the financial rate of return for investing in an improved stove is positive. There are a few caveats regarding this analysis, particularly regarding the data used, because there are three independent surveys and tests, each with different results. Fuel consumption, as emphasized throughout this report, is a function of the type of stove used, fuel used, household practices in keeping the home warm, and actual climatic conditions, making it somewhat difficult to compare the results directly. The first analysis consisted of laboratory tests followed by household consumption tests performed a few years

BOX 8.2: STYLIZED EXAMPLE OF POTENTIAL ECONOMIC BENEFITS

The total coal consumption for the six surveyed ger areas was 546,000 tons of coal at Tog 60,000 per ton. If the switch-out program is fully completed, the result would be a fuel savings of 35 percent and a reduction in emissions of 80 percent. The annual economic benefit would amount to Tog 11.4 billion for the 191,000-ton reduction in coal use. This benefit would mainly be felt by households, particularly lower-income households. In addition, a global economic benefit of Tog 5.04 billion would be realized for a 285,000-ton reduction in CO_2 emissions. Benefits for the health implications are more difficult to estimate, but if it can be assumed that a Tog 30,000 annual reduction per household for doctors' visits can be obtained, the total benefits would be around Tog 9 billion. The total benefits for these three benefits combined would be about Tog 25.4 billion per year. Thus, a relatively large subsidy to accelerate the switch-out of stoves and the introduction of cleaner fuels is fully justified.

ago by the project implementation unit of the Improved Heating Stoves project. This test found that households cut their fuel consumption by 40 percent and reduced their consumption to three tons of coal per year, from a starting point of five tons of coal per year. The household consumption tests were consistent with the laboratory tests. The second analysis, the 1,000-sample household survey conducted in 2008, found that households with improved stoves are generally richer than households with traditional stoves and also consumed more fuel. However, the sample was not large enough to correct for the income dependence. Finally, the 2008 household consumption tests found that households with improved stoves reduced their energy consumption by some 8–15 percent, depending on the exact type of stove and type of fuel used.

Moreover, the savings depend on the stove and the fuel—some fuels result in increased consumption for particular types of stoves. The incremental cost of buying an improved stove (the purchase price of an improved stove minus the purchase price of a traditional stove) is roughly equal to the fuel savings accumulated over two years (the fuel costs of a traditional stove minus the fuel costs of an improved stove) at the consumption rate observed during the consumption tests. The rate of return, assuming a six-year lifetime for an improved stove, would be about 37 percent. If the 40 percent savings rate found in the previous Improved Heating Stoves project were confirmed, the payback time would be less than half a year. Additional uncertainties in this assessment include (i) the price of the stove (whether traditional or improved), which was subject to large variations over time, and (ii) the statistical validity of the absolute fuel savings, as discussed before. This analysis considers two separate cases. The first just compares traditional stoves and improved stoves for coal and wood consumption (improved stoves used 7 percent less coal and 8 percent less wood than did traditional stoves during the consumption tests). The second case uses the average reduction of heating energy used for all different fuels combined during the consumption test and for wood, between traditional stoves and improved stoves (improved stoves used 11 percent less heating energy for all fuels combined, and 7 percent less heating energy for wood, than did traditional stoves).

Despite this level of uncertainty, improved stoves remain an interesting option to pursue for a number of reasons: if a fuel savings of only 10 percent results in a two-year payback time, the prospects for promoting a more-energy efficient stove are good—10 percent savings is not a lot to try to achieve. In addition, fuel prices increased some 30 percent between the 2006–07 and the 2007–08 heating seasons, further decreasing the financial payback time. A 10 percent savings for the whole stove population would mean a reduction in coal consumption of about 40,000 tons per year, with a value of about Tog 1.8 billion.

8.2 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 interventions become 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 or fuels or both 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 well-constructed, acceptable to clients, have good thermal performance, and produce low emissions. Solutions need to be developed for simple ger or house heating, heating walls, and LPBs. The two related options are promoting (i) better stoves for use with raw coal, or (ii) better fuels—the exact types still to be determined—in combination with a better stove. The following should be kept in mind:

- Because fuels have to be matched with specific heating appliances to achieve the lowest possible emissions, verification tests are required.
- Existing stove models—both traditional and improved—do not comply with current emissions standards and are in need of improvement. Moreover, no efficient alternatives are available for LPBs, the fastest growing market segment for stoves. LPBs 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.
- At least three different private and semi-public firms are interested in producing briquettes or semi-coked coal briquettes. So far, they have not identified a stove in which to burn these new fuels efficiently and cleanly. A high priority should be placed on developing such a stove before these producers are allowed to introduce their fuels to the market. The risk is that these fuels will emit more pollution because current stoves are ill-adapted for their use.
- A user who switches from a solid fuel to a gaseous fuel automatically assumes that a new stove is needed. If the same user switches from one solid fuel to another solid fuel, no thought is given to changing stoves, but that should be part of the decision.
- If a stove that uses raw coal meets the emissions standard, it should be eligible for use in ger areas. There is no inherent reason to abandon the use of raw coal. Any combination of stove and fuel meeting the standard should be permitted.
- Conditioning of raw coal—drying it and breaking it up into small standard-size pieces—should also be pursued. Conditioned coal results in a cleaner burn at a fraction of the cost of producing briquettes, and would facilitate the use of a small hopper that will allow the heating system to be operated for much longer without feeding.

- The government should *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) a unified certification system with standards that can deliver desired air pollution reduction results, (ii) administrative measures to realistically enforce the standards, and (iii) incentives to create sufficient demand for new stoves to both justify commercial financing for small business owners and create business justification for larger manufacturers outside and inside Mongolia. The current standard should be modified to include better fuel efficiency and combustion efficiency of both household stoves and LPBs.
  - 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 PM emissions testing in particular cannot be carried out. This situation urgently needs correction because PM emissions are the main air pollution culprits.
  - From now on, only fuels and stoves that result in low emissions factors should be allowed on the market. To promote this objective, the new standards should be developed in collaboration with stove manufacturers. Existing institutional capacity at the Agency for Standardization and Metrology (ASM) and the State Specialized Inspection Agency should be expanded to allow these agencies to enforce standards for household heating systems. Enforcement will not be easy—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, and verify compliance of equipment.

- The government should adopt a policy to promote and support a *mechanism to facilitate rapid dissemination of low-emissions 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 they want and can afford in the market. The output-based aid (OBA) 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 emissions reduction obtained with the new equipment and fuel. (See appendix F for more details.)
  - Base the subsidy 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 the economic benefits

of the reduction 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-emissions stoves.
    - Jointly with civil society organizations, design a systematic and sustained grassroots awareness-raising scheme 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) persuasion to buy only certified stoves in the future, and (iii) the need to remove old stoves from the market.
    - Evaluate the use of negative incentives. If negative incentives, too, are to be introduced, a polluter tax—reversely proportional to the obtained emissions factors—to assist with the introduction and dissemination of cleaner alternatives would be preferred over an outright ban on the use of raw coal.

- *Manage expectations* by starting with a *large-scale pilot* to promote better heating systems, concentrated in one area or district before citywide rollout. The proposed implementation strategy follows:
    - Short term
        - scale up fuel-stove tests using emissions-measuring equipment but with well-adapted, robust methodology;
        - purchase laboratory equipment and implement lab testing in a qualified lab, using unified protocol, supervised by UBMG together with ASM;
        - assist stove designers in developing better stoves and assist briquette producers in beginning to produce good quality briquettes with low emissions; link these producers to international players;
        - implement a large-scale OBA pilot in one ger area;
        - monitor emissions and consumer and producer behavior.
    - Medium term
        - revise and adopt new standards;
        - establish a permanent, qualified, laboratory-based certification system;
        - scale up subsidy program to promote purchase of new equipment and hand in old equipment.

Concluding Remarks

The survey 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, cleaner fuels, or both. More than half of the ger area population live in detached single family-houses and are likely to be capable of investing in such solutions if these were available and known to them, but such solutions are not available in Ulaanbaatar. The poorest households, particularly those living in gers, would likely not be able to adopt these solutions without financial assistance.

Households in gers and households in detached houses without heating walls or LPBs spent more than 20 percent, a very high proportion, of their disposable income on heating fuel. They are not likely to invest in any proposed solutions without some financial assistance. Some 60 percent of households said that they want to buy improved stoves but only if the purchase is subsidized. Close to 60 percent of households indicated that they will buy briquettes but only if not more expensive than raw coal. Households also expressed an 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 lately has increased as a result of two recently observed trends: (i) construction of more detached houses and (ii) upgrading from traditional heating stoves plus chimneys to heating walls or to LPBs with hot water circulation systems. Both trends increase the household comfort level but also increase fuel consumption. No good, clean heating systems are now available to households, even if they wanted to buy one.

In addition, no overview is available of the combustion performance of different stoves and fuels, including heating walls and LPBs. This makes it difficult, if not impossible, for buyers to determine the heating system with the lowest emissions. The first step, therefore, is to describe the performance of the individual heating systems available on the market now, which will require the laboratory capacity to be upgraded and equipped with adequate measurement equipment. Once the performance of all heating systems is known, standards should be adopted and enforced. It is highly likely that better stoves and cleaner fuels can be identified, originating either outside or inside 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 the combustion performance of these new products can be tested and characterized.

One immediate solution appears to exist that could quickly reduce air pollution without any user investment other than a willingness to adopt different fire-tending practices. This solution needs to be verified and its savings quantified before it is pursued on a large scale. Recent testing showed that a large part of the pollution stems from the fire start-up and restarting phases. The technique of back lighting is expected to significantly reduce emissions levels 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 need to be put in place. The first is the creation of capacity to design, build, and verify the quality of low-emissions heating systems. The second is to assist the poorest households to adopt better heating systems and convince more well-to-do households to replace their current heating systems with better ones. Such heating systems, when made available through a support mechanism, could be adopted rapidly and become part of the solution to significantly cleaning 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 the give-away program raised expectations that future stoves would be free. Limited competition at the production level for improved stoves has kept prices artificially high and has not yielded any substantially better stoves than those available now.[52] Nevertheless, the foundations for a professional stove distribution supply chain have been laid, including a valued after-sales service, by previous projects. Additionally, the government tested, with the support of the Global Environment Fund and later the Asian Development Bank, the OBA approach, providing subsidies to manufacturers and distributors only upon verified installation of their improved stoves. This provided the largest impetus to the commercialization of improved stoves.

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

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

A failure to respond to the air pollution contribution from heating in the poorest parts of Ulaanbaatar not only would directly put at risk the 57 percent or so of Ulaanbaatar's population that live in the ger areas, it would also put at risk the general health of all other residents. Measures exist to address the problems relatively rapidly, and they are too important to be ignored.

52. For example, no downdraft stoves, gasifier stoves, or fan-assisted stoves have appeared so far.

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