# Pilot Study of Fuel and Stove Use Behavior of Mongolian Ger Households

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**Abstract**

To reduce levels of outdoor air pollution, new energy-efficient solid fuel stoves have been offered for sale in the ger regions of Ulaanbaatar, the capital city of Mongolia. These energy-efficient stoves ideally use less fuel than the traditional stove and emit a tenth of the pollutant emissions. However, because the stoves were only broadly introduced in August 2011, limited documented information exists of actual household fuel and stove use behaviors or the impact of those behaviors on emissions. During the 2011-2012 heating season (October–March), we evaluated stove use behavior in a small subset of ger households with either a traditional or an energy-efficient stove. Relying on a combination of in-person interviews and stove use monitor (SUM) technology, we observe that stove use behavior can vary substantially between households and identify three main burn cycles related to the use of the energy-efficient stove, which may impact the degree to which particulate matter (PM) emissions can be mitigated. We analyze the temperature data recorded by the SUMs from a convenience sample of 13 ger households with small Turkish (Ulzi) stoves and 4 households with traditional Mongolian stoves. We show that SUMs can potentially play a key role in identifying the frequency of ignition and refueling events and thus the impact user behavior can have on stove emissions. Our analysis reveals that household using small-Turkish stoves in our cohort use their stoves on average 2.5 times per day during the heating season (December 2011-February 2012). But, in a subset of these ger households, the small-Turkish stove use frequency can be as high as four stove use events per day, suggesting the occurrence of refueling events that may lead to increased PM emissions.

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# 1. Introduction

More than 1 million people reside in Ulaanbaatar (UB), the capital city of Mongolia (CIA, 2012). Approximately 60% of the population, or 170,000 households, live in the peri-urban ger regions of the city (Herro et al., 2003). Between 2000 and 2008, the population of ger households in Ulaanbaatar increased at an annual rate of approximately 5% (World Bank, 2011). Roughly half of all households living in the peri-urban region of UB live in a traditional ger home, which consists of a one-room tent structure. Gers can have four, five, or in some cases six walls and typically have indoor floor areas ranging between 20 $m^2$ (a small four-wall ger) to 30 $m^2$ (a large five-wall ger). In the center of the ger is the stove, which is used both for both heating and cooking. A typical traditional Mongolian stove is shown in **Figure 1**. Because average annual temperatures make UB the coldest capital in the world, the traditional ger stove is typically run throughout the winter months from October to March; it is common for temperatures to dip to -40°C during the night. It has been estimated that ger households with traditional stoves consume on average 4.18 tons of coal and 3.18 tons of wood each year to meet their heating and cooking needs[1]. Together across all households this amounts to the consumption of nearly 550,000 tons of coal and more than 400,000 tons of wood during the heating season (World Bank, 2009).

**Figure 1.** A traditional Mongolian Stove located in the center of a ger.

## 1.1 Air Pollution Levels in Ulaanbaatar

Owing primarily to the use of the traditional stove, atmospheric levels of particulate matter (PM) in the ger regions of UB are quite high during the heating season. For example, 24-hr PM10 concentrations have been measured in the winter that exceeded 3,000 μg/$m^3$, and monthly

[1] Based on a questionnaire study by the World Bank, and valid for the 2006/7 heating season. (World Bank, 2008. *Small boiler improvement in Ulaanbaatar*. Part of the UB Clean Air Program mission related to the Clean Air Action Plan for Ulaanbaatar, Mongolia. Wold Bank Consultant Mission Report. As cited in AMHIB, 2010).

average PM2.5 and PM10 concentrations during the 2008-2009 heating season exceeding 1,500 and 1,800 μg/m$^3$, respectively, have been recorded (World Bank, 2011). These measured PM concentrations are striking, and appear to exceed those experienced during the Great London Smog Disaster of 1952, when average PM levels reached approximately 800 μg/m$^3$ (a highest daily average of approximately 970 μg/m$^3$) and contributed to upwards of 12,000 deaths [2] (Bell and Davis, 2001; Lippman, 2010).

At some monitoring stations in the ger regions, the annual average PM2.5 and PM10 concentrations could exceed 300 μg/m$^3$ and 600 μg/m (World Bank, 2011), which are nearly a factor of 10 higher than the World Health Organization (WHO) Interim Targets[3] of 35 μg/m$^3$ PM2.5 and 70 μg/m$^3$ PM10.

## 1.2 Energy-Efficient Solid Fuel Stoves

To address the PM air pollution in Ulaanbaatar, the U.S.-based Millennium Challenge Corporation (MCC) has implemented the Millennium Challenge Energy Efficiency Innovation Facility as part of the Energy and Environment Project (EEP, 2011). As part of the EEP, over 70,000 project-subsidized stoves are planned for distribution during the 2011-2012 heating season, across five of the nine districts of UB including: Chingeltei, Bayangol, Sukhbaatar, Songinokhairkhan, Khan Uul and Bayanzurkh districts. (The six districts are underlined in **Figure 3**.)

Following a series of laboratory and field tests on a variety of improved stoves, the EEP selected four energy-efficient stoves for distribution. During the 2011-2012 heating season, the most widely available of the EEP-subsidized stoves was being manufactured in Turkey and is referred to as the Silver-Mini (Ulzi) model or the small-Turkish stove (**Figure 2**). When operated under manufacturer's recommended operating instructions, the small-Turkish stove uses less fuel than the traditional stove and has PM emissions that are roughly a tenth of the traditional stove. The Silver-Mini is a top-lit updraft design (TLUD). For efficient combustion, the manufacturer specifies that the stove should be cold when loaded with coal and filled two-thirds of the way to the top and then lit from the top using wood and paper. Based on this procedure, the stove will be started no more than twice in a 24-hour period. However, if operated improperly- such as refueled with wood or coal while the stove is burning, the PM emissions may increase dramatically.

[2] The toxic air pollution due to coal combustion, high humidity, and an inversion layer led to roughly 3,000 additional deaths during the first three weeks of December 1952 and estimates of upwards of 12,000 deaths between December 1952 and April 1953 (Bell and Davis, 2001).

[3] Because Mongolia is a transitional economy, the WHO Interim Target-3 guidelines are cited here. These Interim Targets are intended as goals for developing countries where it is unlikely that the WHO Air Quality Guideline can be met in the short term.

The combined EEP subsidy (upwards of 65% of the stove price) coupled with the lower fuel consumption, higher heating efficiency of the small-Turkish stoves and attractive design features, provides a substantial incentive for ger households to purchase a new stove. However, as of the start of the 2011-2012 heating season, limited information documenting the actual fuel and stove use by households with these new stoves existed. The results of our study are focused primarily on introducing and presenting the first set of results to characterize variations in household stove use behavior relying on a combination of household questionnaires and stove use monitoring technology. We refer to another larger field study which included pollutant emissions measurements, conducted by Social Impact, Inc. between January 2012-March 2012 [4], and a forthcoming study during the 2012-2013 heating season, for a more detailed analysis of fuel and stove use behavior in households with traditional and project-subsidized stoves.

**Figure 2.** Small Turkish Stove (Ulzi) in the center of a ger.

[4] Social Impact, Inc. conducted a study of nearly 250 small Turkish and traditional stove ger households to assess household fuel and stove use behavior between January-March 2012. Pollutant emissions ($PM_{2.5}$, CO, $CH_4$, and $CO_2$) were also measured in a subset of 21 HHs during a 14-hour period. A larger scale field study is planned for the 2012-2013 heating season.

## 1.3 Pilot Field Study of Household Fuel and Stove Use

We were requested to conduct an assessment of how ger households view and use their new energy-efficient small-Turkish stoves, specifically characterizing the fuel consumption and number of ignition and refueling events, relative to typical traditional stove behaviors.

Our study region is confined to the Chingeltei District of UB, including 18 khoroos or sub-districts and approximately 32,000 households and 140,000 people. This district was the first to be provided with the option to purchase a project-subsidized stove and currently, almost half of the households in Chingeltei now have project-subsidized stoves. The majority of these approved stoves were the small-Turkish stove.

Using a combination of in-person interviews and stove use monitoring technology, we collected collect data on the variation in fuel and stove use patterns of a convenience sample of 21 households within 12th khoroo of the Chingeltei district (Chingeltei-12). Included in this convenience sample of households were 15 (4 traditional and 11 small-Turkish) ger households that participated in the longer-term stove use follow-up questionnaire and stove use monitoring during the 2011-2012 heating season (October, 2011- February, 2012)[5].

Following initial household visits in September 2011, 18 households agreed to monthly follow-up visits by a local technician throughout the 2011-2012 heating season (October 1st - March 3rd). Based on data collected during these visits, we summarize fuel consumption and stove use behaviors and patterns of 13 small-Turkish and 4 traditional stove ger households, across the heating season; we identify three main fuel and stove use combinations, or stove use events associated with the small-Turkish stoves and measure emissions in the laboratory associated with these events.

[5] In addition, two ger households participated in the initial questionnaire/survey but did not have the SUM installed, and one small-Turkish stove household moved in November and another moved to the countryside in January. One traditional stove household dropped out in October. A house with a big Turkish stove also participated and provided stove use monitoring data between October 2011- March 2012.

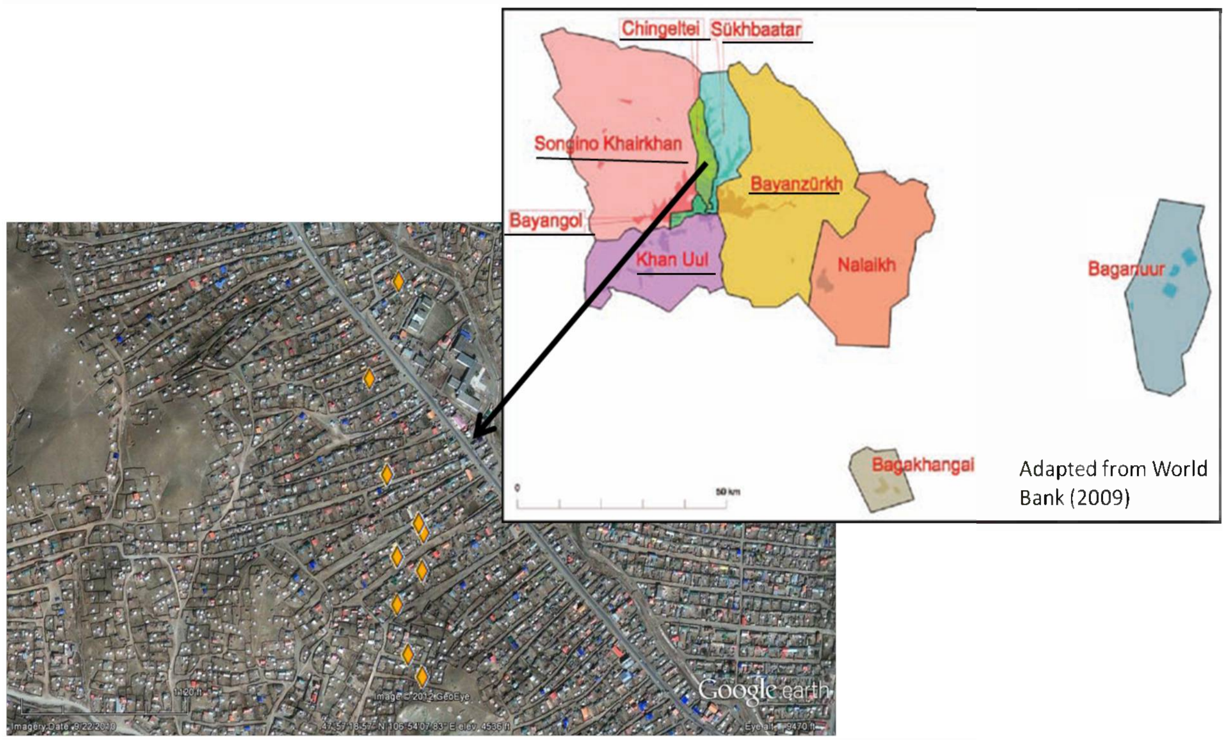


**Figure 3.** The nine districts of Ulaanbaatar, and a map of the Chingeltei-12 ger households (yellow diamonds) that participated in the longer-term monitoring of this study. The energy-efficient stoves/products are planned for deployment in khoroos located in the six underlined districts.

## 2. Background

Here we summarize previously conducted field and lab studies of stoves selected for the EEP and describe useful technology for obtaining data of household-level stove use behavior.

### 2.1 Previously Conducted Field and Lab Studies of the EEP

Prior to selecting stoves for the EEP, a series of laboratory and field tests conducted by Pemberton-Pigott (2011), the UB City Air Quality Office, and the Mongolian University of Science and Technology (MUST), under contract MCA-Mongolia, were conducted to measure pollutant emissions of improved stoves relative to emissions from the traditional stoves. As a result of these tests, four stoves were selected for inclusion in the EEP, including the: Ulzi (Silver-Mini or small-Turkish), Khas (Large Turkish), Dul (Royal Single), and Golomt (Royal Double) stoves. Although the conditions of these laboratory and field tests varied, the Silver-

Mini consistently has the lowest PM emissions of any of these stoves on a mass-coal burned basis[6].

MUST's 24-h average PM emission measurements using a DustTrak (BEECS, 2011), which are summarized in **Table 1**, indicate that the Silver-Mini provides a 10-fold reduction in PM emissions relative to the traditional stove.

**Table 1.** Emission factors (g pollutant per kg MAF coal) measured from 24-hour field testing in gers using a DustTrak, during the 2011 heating season (BEECS, 2011).

| Stove | PM (g/Kg of MAF coal) |
|---|---|
| Traditional stove | 11.6 |
| Anard large stove | 9.32 |
| GTZ-7 stove | 8.02 |
| **Silver Mini** | **1.66** |
| Silver Turbo | 3.81 |
| Royal Single | 2.43 |
| Royal Double | 1.85 |

MAF: moisture and ash free

Because of its large combustion chamber, the MUST (MUST-BEEC, 2011) also found that the Silver-Mini "greatly reduces the need for refueling" to twice per day, which led to the least amount of coal consumed by any EEP stoves ( 1,852 kg coal and 365 kg dried wood during the heating season). However, the Silver–Mini must be "loaded with a full load of fuel because less than a full load allows for inadequate combustion air inlet regulation, in effect, allowing for too much air into the combustion chamber making ignition more difficult" (MUST-BEEC, 2011).

## 2.2 Stove Use Monitors

Stove Use Monitors (SUMs) are sensors that can be used to assess the frequency of stove use. Each SUM is roughly the size of a U.S. penny and can provide continuous time-series data on stove temperature, which is a surrogate for the number of stove ignition and refueling events. The SUMs rely on the Maxim iButtons technology, and temperatures can be downloaded to any laptop/netbook via probe and USB adapter.

The limited set of published studies that have used SUMs to discern household cookstove use patterns have found SUMs to be a low-cost and efficient method to collect data on stove use systematically across a sample of households. For example, Ruiz-Mercado et al (2008) have used

[6] Laboratory tests by Pemberton-Pigott (2011) have shown that PM2.5 emissions reductions associated with the Silver mini (or small-Turkish stove) is over 99% of the PM2.5 emissions associated with Traditional Mongolian Stove, using coal on an as-received (AR) basis.

SUMs to assess the use patterns, including the pace of adoption, of improved cookstoves disseminated in the Guatamalean Highlands.

As described below, SUMs play an integral role in our study, both to assess the use frequency of both the traditional and small-Turkish stoves, as well as a survey tool which helps households recall fuel use and fueling procedure associated with prior stove use events.

## 3. Methods

Our pilot study aims to document fuel and stove use in traditional stove and small-Turkish stove Mongolian ger households. The specific aims include:

1. define the principal stove use events associated with the Small Turkish stoves;
2. estimate the frequency of traditional and small-Turkish stove use events from SUMs temperature profiles; and
3. link defined small-Turkish stove use events to PM emissions.

To achieve these aims, we use a combination of in-person interviews with household members and collect temperature data using SUMs as a surrogate for stove use. In addition, we conduct laboratory tests to validate the use of SUM technology to identify burn cycles, and we measure PM emissions in the laboratory associated with the defined small-Turkish stove use events.

**Table 2** presents the timeline of our field and laboratory activities that were part of the pilot behavior study, including the use of in-person surveys and SUMs.

In the following sections we provide more detail on the activities shown in **Table 2,** as well as on the analytical methods employed to quantify the frequency and the emissions from principal burn cycles. The household visits and SUM temperature data we collected allowed us to characterize typical burn cycles employed by the traditional and small-Turkish households and to make qualitative and quantitative distinctions between the frequency of stove use.

**Table 2.** Timeline of field and laboratory activities conducted during the 2011-2012 heating season as part of the pilot fuel and stove use behavior study.

| Date | Reason/ Objective | Data or Information Collected |
|---|---|---|
| September 25-September 30, 2011 | -recruit ger households<br>-administer initial questionnaire<br>-install SUMs | -household characteristics<br>-fuel use rates<br>-household opinions on stoves |
| October 8-11 and 22-23, 2011 | -follow-up questionnaire<br>-recruit additional ger households<br>-download SUMs data | - temperature profiles<br>- fuel and stove use during previous 24-h day |
| November 12-14, 2011 | -follow-up questionnaire<br>-download SUMs data | - temperature profiles<br>- fuel and stove use during previous 24-h day |
| December 9-11, 2011 | LBNL visit to administer the follow up questionnaire relying on the review of the SUM temperature profile with adult household member | targeted questionnaire to collect data on the household`s previous 1-2 day fuel and stove use based on their SUM temperature profile. annotated SUM temperature profile. |
| January 7-8, February 4-5, and March 3, 2012 | -follow up questionnaire<br>-download SUMs data<br>-install additional SUMs | - temperature profiles<br>- fuel and stove use during previous 24-h day |
| March 16-20 | -installed SUMs in two small-Turkish stove ger households<br>-reviewed temperature profile | technician administered targeted questionnaire relating to the household`s SUM temperature profile. Annotated SUM temperature profiles. |
| Spring 2012 | lab tests conducted at LBNL to:<br>- characterize emissions from various burn cycles<br>-evaluate SUM T profiles | -quantify the PM emissions associated with a cold start and refuel.<br>-evaluate the SUM`s response to a cold start and late refuel. |

## 3.1 Household Visits

As seen in **Table 2,** several follow-up visits were made to the participating ger households during the 2011-2012 heating season following the recruitment and an initial household visit at the end of September 2011. In the following sub-sections, we briefly expand on the activities conducted during the initial household visits and monthly-follow up visits.

The household recruitment procedure, consent forms, and survey protocols used in this study were all approved by the Lawrence Berkeley National Laboratory (LBNL) Institutional Review Board (IRB), Human Subjects Committee.

### 3.1.1 Initial Household Visit

At our initial household visit in September 2011, we administered a questionnaire (provided in the Appendix) to 19 ger households and 1 household living in a 2-room house. This questionnaire allowed us to make inferences on the degree to which our cohort is representative of ger households living in the peri-urban region of UB. During the initial in-person interviews in September, we collected data useful for assessing the representativeness of our cohort based on household characteristics that may affect or influence fuel and stove use behavior, such as:

- size of gers including radius, height at center of ger, door height;
- ger insulation, including the number of current layers, and whether project-subsidized layers are installed;
- renter/owner status of ger, land, and stove;
- presence of a vestibule;
- number and age of household occupants;
- fueling procedure and type of coal and wood used; and
- amount of wood and coal used yesterday, over the course of the previous week, and in the current month (September), as well as in a day last January and in the entire month of January last year.

During the initial visit, we also installed the SUM model DS1922T ("model-T") in a total of 17 of these gers[7]-7 gers with a traditional stove and 10 gers and one house (no heating wall) with a project-subsidized stove (all small-Turkish). One of the traditional stove ger households had a vestibule, as did one of the small-Turkish stove households.

The "model-T" SUMS can record temperatures within the range of $0^{o}C$ to $125^{o}C$, at programmable intervals. The SUMs in our study were set to record temperatures at 5-minute intervals, allowing them to continuously record temperatures over a 4 week period. They were installed in up to four locations within a ger (codes for these SUMs locations are provided in parentheses):

1. on the leg of the stove (SUM1);
2. on a pole about 3 feet from the stove and 6 ft from the ground (SUM2);
3. on the wall of the ger opposite the door (SUM3); and
4. placed loosely on the ground under the stove with the sensor facing up (SUM4)[8].

[7] One ger household declined the SUMs (due to shaman belief of sacred indoor space). Another ger household was moving soon and so could not participate in the follow-up during the heating season.

[8] An additional seven small-Turkish stoves had a SUM placed underneath the stove during the January follow-up visits. This allowed us to compare the temperature recorded by the SUM taped to the leg of the stove (conductive heat transfer) with those recorded by the SUM under the stove (radiative heat transfer).

### 3.1.2 Monthly Follow-up Visits

At each monthly follow-up visit between October 2011 and March 3, 2012 the SUMs temperature profiles were downloaded and a short questionnaire (see Appendix) was administered, which focused on the amount of coal and wood used in the previous week and the time and frequency of ignition and refueling events over the previous 24 hours.

In addition, an LBNL team member (Agnes Lobscheid) returned to UB in December 2011 to evaluate the SUM data collection and administer a revised survey, which involved reviewing the household SUM Temperature profile with an adult household member.

Using the SUM graphing software, we were able to download a household's temperature profile, the peaks and troughs of which indicate start and stop times of the ger household stoves **(Figure 4)**. The chart acted as a guide for households to provide more accurate answers to our survey questions about stove ignition and refueling practices, including the presence or absence of hot coal in the stove prior to adding additional fuel and whether the fuel was ignited from the bottom or top of the stove. The December survey instrument (a copy is provided in the Appendix) was designed to collect data on the prevalence of three general types of stove use behaviors: a cold start, a warm start, and a refuel. These three general behaviors were formulated from the initial interviews in September as well as through discussions with our National University Mongolia collaborator. Therefore, one of the key objectives of the follow-up visit in December was to more precisely define these burn cycles and determine their frequency using the SUM temperature profiles.

As can be seen in the December follow-up questionnaire (Appendix), the questions asked of households relate directly to the type and amount of fuel used, ash removal rates, and the presence of smoldering or hot coal in the stove prior to a fueling event.

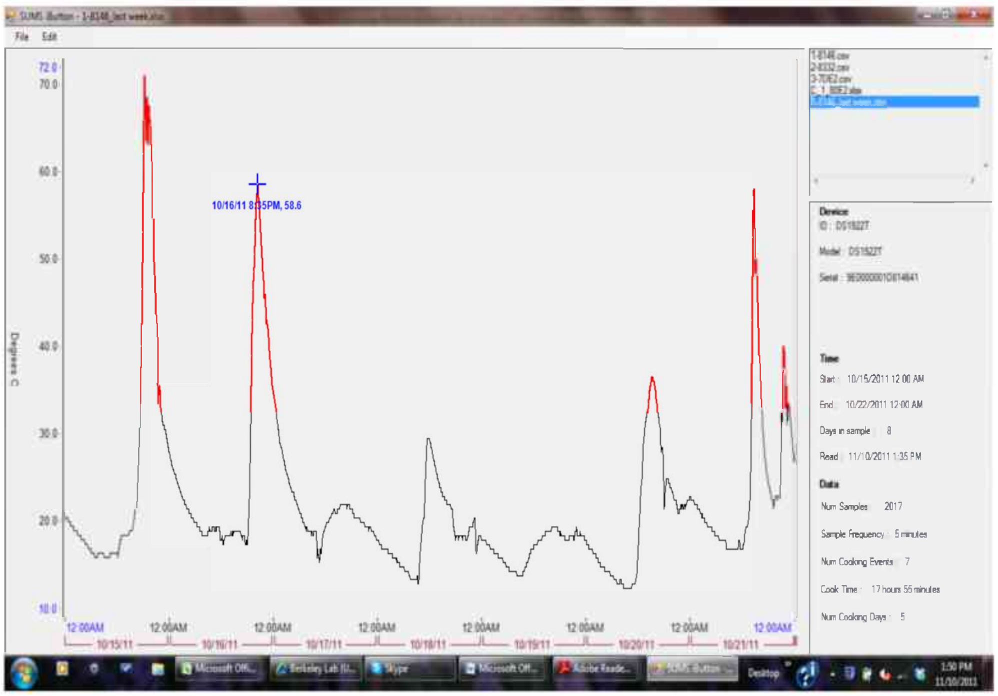


**Figure 4.** an example of a ger household's SUM Temperature profile.

In addition, our technician made a final return visit to two small-Turkish stove ger households in March to conduct a similar interview to provide additional evaluation of the revised survey methodology initiated in December.

## 3.2 Identifying and Quantifying Stove Use Events

We use the interviews to define principal fuel and stove use events[9] of the traditional and small-Turkish stoves, and used SUMs to quantify the frequency of these events across our ger cohort (Section 4.3). The household interviews provided details on the type and amount of fuel used and the fueling procedure associated with a given stove use event.

In order to quantify the frequency of stove use events, such as stove ignition and refueling, we developed an algorithm to process the temperature profiles[10]. Our approach relies on distinguishing temperature swings in the SUM profile. In order to do this, we need to distinguish between random noise and fueling events.

We call our application the "sliding window method." For a minimum temperature to count as a refueling event, we require that it be the smallest value within a fixed span of time to either side. To illustrate, a five-hour sliding window is applied to one of our ger temperature profiles over

[9] Stove use events are also known as burn cycles in the cookstove literature.

[10] The algorithms included in the SUMs processing software do not capture the stove use events, as they are more applicable to traditional cookstoves, as opposed to stoves used both for cooking and heating purposes.

the course of a day **(Figure 5**). We can see that this identifies four major events, and eliminates many minor events (such as the one at 21:30, which is not the smallest value within the sliding window).

The width of the sliding window governs the number of identified events and the increase in the number of events as the window narrows gives an indication of how variable the temperature record is. A smooth temperature record (from an "ideal household" that refuels regularly twice a day) yields almost no increase in the number of events as the window narrows, while a highly irregular record yields a large increase. Following this method, we find that a four-hour window will accurately assess the frequency of stove starts and refueling assuming:

- The interval between fueling events exceeds four hours.
- Stoves are refueled as the household temperature is dropping, and the temperature increases again soon after the coal is added. Thus a stove event (start or refueling) is characterized by a minimum in the temperature record.
- Some minima, particularly those associated with small temperature variations, might be due to other causes -- collapse of the coal bed, opening the door of the ger, etc.
- Large sustained variations in temperature are associated with fueling events, while small, sudden variations in temperature are caused by something other than fueling events.

More information on this method can be found in the Appendix.

We applied a four hour "sliding window" to our SUM temperature data in order to quantify the frequency of stove use events in December, January, and February across the small-Turkish stoves households in our pilot Chingeltei-12 ger cohort. The results of this exercise are presented in the results section of the report.

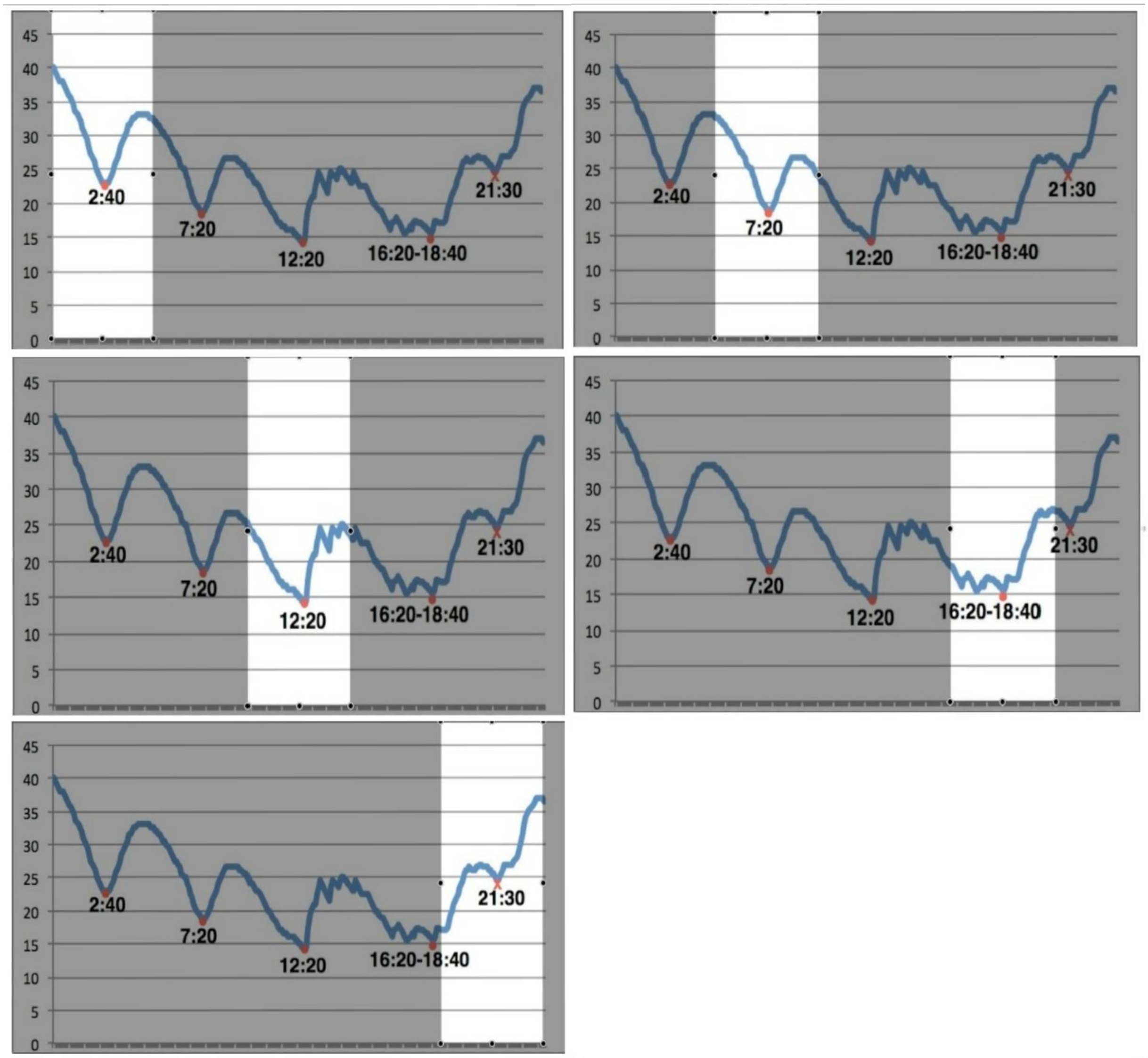


**Figure 5.** Demonstration of the "sliding window method" to assess stove use by ger households. A five-hour sliding window is shown.

## 3.3 Laboratory Tests

We constructed and used the LBNL Stove Test facility (**Figure 6**) to perform tests designed specifically to identify differences in pollutant emissions that are associated with the stove use events we identified in our small-Turkish ger cohort. In addition, we also installed SUMs around the small-Turkish stove during these tests in order to validate the SUMs' performance and reliability.

Our specific aims here were to confirm that the SUMs temperature profiles correspond with the principal fuel and stove use behaviors we identified in the small-Turkish cohort and to determine the pollutant emissions from our behavioral study.

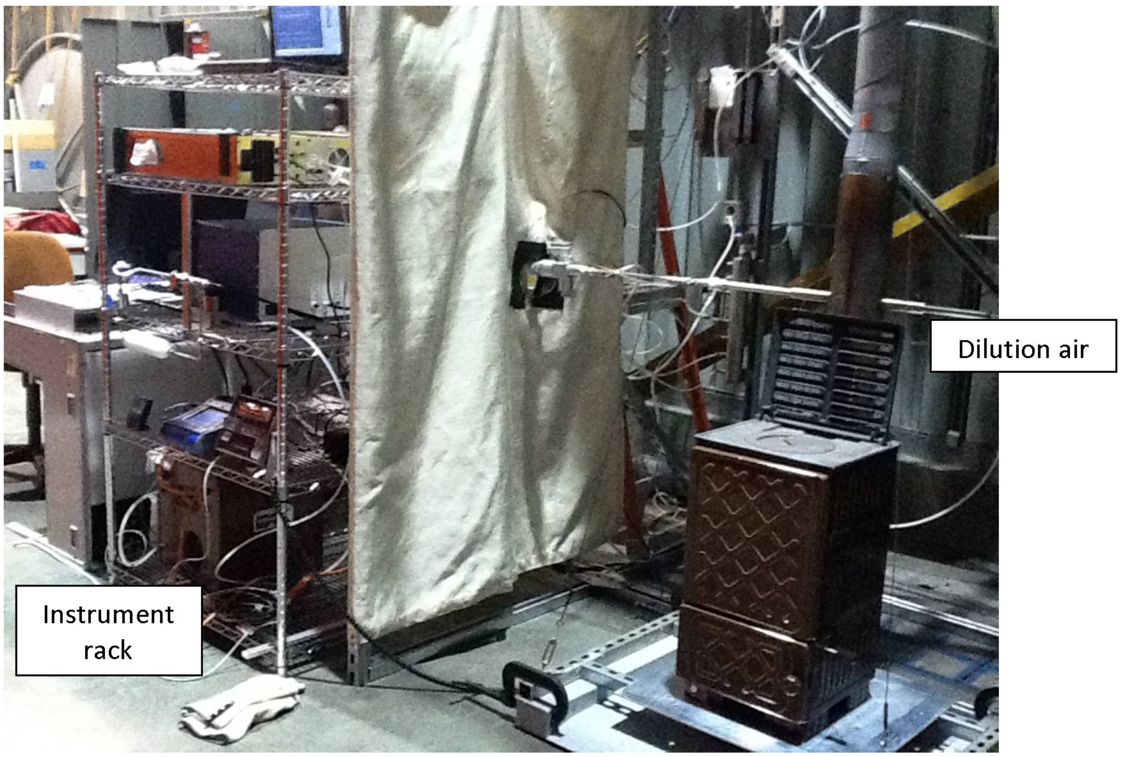


**Figure 6.** Configuration of the LBNL Stove Test facility. A small-Turkish stove is being tested.

### 3.3.1 SUMs validation

We conducted a series of laboratory tests to assess the reliability of the SUMs in response to cold start and refueling events. **Figure 7** displays a schematic of the laboratory set up and SUM placement configuration.

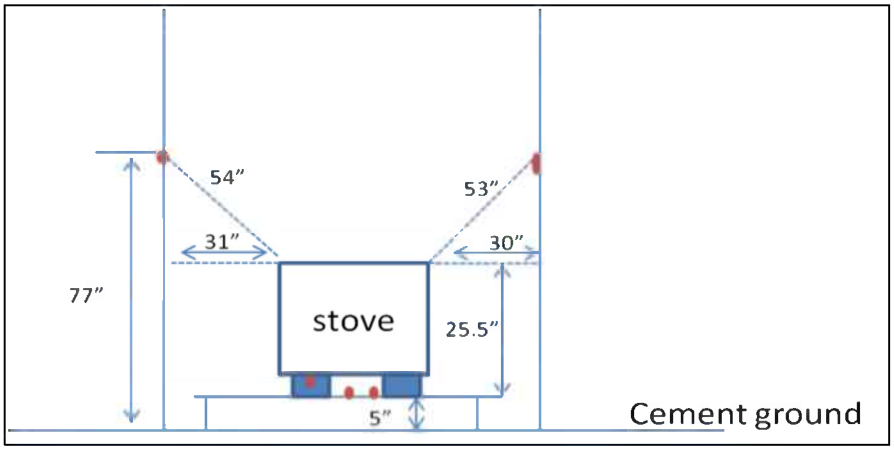


**Figure** 7. Schematic representing the placement of five SUMs in the laboratory validation tests.

In these validation tests, we placed five SUMs around the stove (red dots shown in **Figure** 7), corresponding to locations within the ger, including:

- 1 SUM taped on the leg of the stove, with the sensor side up. This position corresponds to SUM1.
- 2 SUMs placed on the truss to the right and the left of the stove. This position is intended to replicate the SUM placed on the pole located in the center of the ger (=SUM2).
- 2 SUMs placed loosely under the stove (sensor side up). This placement corresponds to the SUM 4 in the gers.

In addition to these five locations, a SUM was placed on each of four wires[11] that surrounds the stove and secures the platform the stove is set upon. These SUMs were installed as an extra validation step to relate the temperature readings or response of the SUM to the fueling events. Photos of the SUMs on a wire, as well as of the SUMs on the truss and additional locations to test alternate SUMs locations, are provided in the Appendix.

In some of the laboratory tests, the area around the stove was enclosed with a plastic tarp (welding curtain), creating a semi-circle around the front of the stove about 6 feet-7 feet from the stove with walls that were 6 feet high), which acts to simulate the ger walls. However, it was not possible to secure a SUM to the tarp, corresponding to SUM3 in the gers.

## 4. Results

From the combination of household interviews and stove use monitoring data, and laboratory tests, we characterize the fuel and stove use patterns of the participating traditional and small-Turkish ger households. In the following sections, we summarize the characteristics and representativeness of the ger household cohort. We then evaluate the stove use patterns and

[11] These SUMs were at various distances from the top corners of the stove (diagonal distances b/w 23-32”; one is level at approximately 8” from the top left of the stove).

frequency of stove use among the cohort, first for the traditional stove households and then for the small-Turkish stove households. Based on the household interviews at which the SUMs temperature profile was reviewed with the households, we define three principal small-Turkish stove fueling behaviors and assess their frequency. Finally, based on laboratory tests, we validate the reliability of the SUMs and provide emissions estimates from small-Turkish stove ger households, based on measured emissions factors and archetypal small-Turkish stove use frequency.

## 4.1 Characteristics of the Chingeltei-12 ger household cohort

A total of 21 households participated during our pilot study, which lasted from September 24, 2011- March 3, 2012. This group included 4 traditional stove and 13 small-Turkish stove ger households that provided SUM temperature data through most or all of the 2011-2012 heating season (October 1, 2011-March 3, 2012). **Table 3** summarizes the characteristics of the pilot ger cohort, including size of ger (number of walls), number of occupants and insulation layers, presence of electric wok or stove, and coal use during the current and previous (2010-2011) heating season.