ANNEX 8 - Baseline Fuel Consumption Analysis[1]

Baseline Information:

PROJECT DESIGN DOCUMENT FORM (CDM-SSC-PDD) - Version 03

The objective of this project activity is to make available complete heating system solutions to facilitate the transition to clean indoor and outdoor environments, while also improving livelihoods and energy access to the poor. The PoA project boundary is Mongolia and the target population are households, commercial buildings, and institutional buildings. The clean energy products (CEPs) distributed under this PoA include efficiency improvements in coal fired cooking and heating stoves and boilers, improved building efficiency through ger insulation blankets and foam spray.

BASELINE DESCRIPTION

A summary of baseline information for Mongolia is provided here in Annex 3 and detailed in the 2011 Millennium Challenge Account (MCA) - Mongolia Household Survey Report and the World Bank's Asia Sustainable and Alternative Energy Program (ASTAE) 2009 report titled, "Mongolia Heating in Poor, Peri-urban Ger Areas of Ulaanbaatar." Because it includes the most recent data, information from the 2011 MCA-Mongolia report is used to quantitatively determine baseline coal consumption ($C_{y,old}$), while the ASTAE report is used as support to further describe the baseline scenario. Regression analysis was applied to the 2011 MCA data to develop a quantitative model for determining fuel consumption in ger area homes. The independent variables identified in the model will be monitored on-going to adjust baseline values.

1. AMS-II.E ¶1 states that the relevant technology category *comprises any energy efficiency and fuel switching measure implemented at a single building, such as a commercial, institutional or residential building, or group of similar buildings, such as a school, district or university.*

    Target Group: The target group for this project activity are ger area households and buildings. As of 2009, the Ulaanbaatar (UB) city statistical office reported a total of 256,600 households living in the six central districts of Ulaanbaatar, of which approximately 156,600 households are located in the ger area.[2] The MCA- Mongolia report confirms that about 43.2 percent of households in ger areas are currently living in actual gers, and slightly more than half (56.8 percent) of the households are living in rudimentary houses.[3]

    A "ger" is a traditional tent commonly made of felt and wood structures by Mongolian herders. Ger areas of Ulaanbaatar consist of gers as well as constructed traditional wooden and brick houses. The project boundary is the physical, geographical site of the household and buildings located in Ulaanbaatar, Mongolia. According to the 2009 World Bank report, "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

[1] ANNEX 8 – Baseline Fuel Consumption Analysis is an excerpt from CDM 8142 PoA-DD, Appendix 3.
[2] MCA-MONGOLIA-Mongolia. 2011, "Household Survey Draft Report", pg. 15.
[3] MCA-MONGOLIA-Mongolia. 2011; pg. 15.

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".[4]
According to the 2011 MCA-Mongolia report, the majority of households within ger areas consist of 4 to 6 members, and average monthly household income is 599,327 tugrig.[5]

2. AMS-II.E ¶5 states *The energy baseline consists of the energy use of the existing equipment that is replaced in the case of retrofit measures and of the facility that would otherwise be built in the case of a new facility.*

Existing Baseline Fuel: In Ulaanbaatar, the primary baseline fuel used in the absence of the project activity is fossil fuel coal, and woodfuel biomass. Collectively, these solid fuels are used year-round for cooking and heating in ger area households and buildings. 98.7% of the households included in the 2011 MCA-Mongolia survey used coal and/or firewood for cooking and heating. This is in line with the 2007 ASTAE/World Bank report which found that roughly 95% of ger area households use coal and firewood for heating.[6] Firewood is used to start fires and at times to supplement coal, but the vast majority of homes rely on raw coal for heating. As a conservative approach, this analysis will only include coal consumption in the baseline scenario.

The demand for raw coal is relatively inelastic, meaning that there are few alternatives to coal for heating and as the ASTAE/World Bank P.50 states: *the alternative [to coal] is to not survive the severe winter.* Based on 2011 MCA-Mongolia data, the weighted average for the primary types of dwellings within the ger area is 5.20 tons (see Figure 1 below) during the heating months.[7] Other studies estimate coal consumed per household for home heating at 5.45 tons.[8] The project conservatively adopts a modelled value of 5.14 tons coal (see regression model below in next section) as the baseline in the project boundary for ex-ante estimates, but will update the value based on the independent variables monitored during the project activity.

Figure 1. Average Annual Household Coal Consumption in Ger Areas during the Heating Months

HH Type	**Coal (tons)**	**Population (HH)**
Ger HH	4.67	66,300
House HH	5.60	87,200
All HH	5.13	153,500
Weighted All HH	**5.20**	

[4] World Bank Group, 2009. "Mongolia: Heating in Poor, Per-urban Ger Areas of Ulaanbaatar," pg. 6.
[5] MCA-Mongolia. 2011,Table 1-7, pg. 32 (household members) and pg. 52 (monthly income).
[6] World Bank, 2009. Table 4.1, pg. 34.
[7] Average coal consumption was weighted based on 2009 UB city statistical office data: Within ger areas, 56.8% of households live in "simple separate houses" and 43.2% live in gers. Source: MCA-MONGOLIA, 2011; pg. 15.
[8] Iyer, Maithili et al. *Strategies for Reducing Particulate Emissions from Space Heating in the Ger District of Ulaanbaatar, Mongolia.* Earnest Orlando Lawrence Berkeley National Laboratory Report. November 2010. Page 6.

Figure 2. *Baseline coal consumption $C_{y,old}$*

Parameter PDD	*Value*	*Description*
C_{y_old}	*5.14 tons coal*	Quantity of coal used per ger area building in the baseline scenario during the heating season in tonnes.

Existing Baseline Insulation and Housing Structure: The two primary types of dwellings in the baseline consist of detached houses (56.8%) and Gers (43.2%). Amongst ger households, 64% are constructed with 5-walls and 26.6% with four walls.[9] Nearly 74 % of baseline gers are insulated with 2-layers of felt, and 17 % have only a single layer of insulation for the walls and the roof.[10] The majority of both gers and detached homes do not have access to district heating, running water, and sewage services.[11]

Existing Baseline Stove: The MCA-Mongolia report estimates 87.6% of ger area households use a traditional stove for cooking and heating, 0.6% use improved stoves, and 11.5% use small low pressure boilers.[12] The 2009 World Bank report states, *"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".*[13] Most homes have more than one stove but nearly all homes use only one stove for cooking and heating, which is due mostly to small house sizes and the desire to centralize and economize on fuel consumption.

Seasonality: The heating season last about 8 months and ranges from September to April. Fuel consumption peaks in the extreme cold winter months of November to February when temperatures typically remain below 20 degrees Fahrenheit, and is flanked by the cold months of Fall and Spring.[14] The same stove and fuel are used throughout the entire heating season.

3. AMS-II.E ¶6 states the following: *Each energy form in the emission baseline is multiplied by an emission coefficient. For the electricity displaced, the emission coefficient is calculated in accordance with provisions under category I.D. For fossil fuels, the IPCC default values for emission coefficients may be used.*

The emission coefficient for baseline coal uses IPCC default values:

- Subbitumous: 18.9TJ/Gg * 96,100 Emission Factor CO2 = 1,816,290

4. PoA-DD, part II, Section B.7.2 describes the monitoring methodology and approaches used to determine emission reductions.

   Regression analysis was applied to the MCA data and the independent variables within the regression models will be used as inputs for the calculation of $C_{y\_old,CEPi}$, described in PoA-DD, Part II, Section B.7.1.

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[9] MCA -Mongolia. 2011. Table 2-5, pg. 40.
[10] Ibid. pg. 40.
[11] The World Bank Group, 2009; pg.14.
[12] MCA-Mongolia. 2011; pg. 79.
[13] The World Bank Group, 2009; pg. 17.
[14] The World Bank Group, 2009; pg. 36.

To define a model for baseline coal, wood, and other fuel consumption we utilized data collected in MCA 2011 study in Ulaanbaatar's ger districts. In the survey, 1047 households were interviewed about household characteristics such as the number of occupants, income, age, type of dwelling, type of heating technology, type of fuel use, total seasonal fuel use, location of residence, and opinions about upgrading stoves and other technology. A full review of all data collected can be found elsewhere, this statistical analysis is limited to discussion of variables that impact fuel consumption.

Data description

There were 1047 households in our database. We collected data on house characteristics and location. Basic characteristics by district are shown below:

	Ger	Separate house	Ger and separate house	Total	%Total
Bayanzurkh	143	144	2	289	28%
Bayangol	37	39	0	76	7%
Khan-Uul	53	68	1	122	12%
Chingeltei	99	71	1	171	16%
Sukhbaatar	58	72	0	130	12%
Songinokhairkhan	122	137	0	259	25%
Total	512	531	4	1047	100%
% Total	50%	50%	0%	100%	

The survey also collected information on the number of occupants in each household. There was a wide range of household sizes, but the majority of the households had 2-5 members with a mean of 4 members. The distribution of the number of occupants by age is:

Occupant age	Range
under 5 years old	0 - 5
6-17 years old	0 - 5
18-25 years old	0 - 6
26-35 years old	0 - 6
36-45 years old	0 - 4
46-55 years old	0 - 3
56-60 years old	0 - 2
61 years old and over	0 - 2
Total	1 - 15

Seasonal (3-month) fuel consumption was described separately for coal, wood, and other (low pressure gas (LPG) and electricity). There were 1026 households that used any coal, 996 that used any wood, and 4 that used other.

There were 4 seasons, defined as follows:
- Winter – November, December, January
- Spring – February, March, April
- Summer – May, June, July
- Autumn – August, September, October

We obtained daily temperature and wind speed records for Ulaanbaatar from the (US) National Climatic Data Center Climatic Service Branch of the National Oceanic and Atmospheric Administration via geodata.us. These data were collected at Air Force Datsav3 station number (USAF) 442920, located at School Number 56, less than 2 km from the Khairkahn District Statue. Temperature and wind speed are assumed to be regional by nature. In addition to including temperature and wind speed information in our dataset, we also calculated the number of heating degree days (HDD) in each season. The calculations of HDD (Dh) use base temperature (Tbase) of 15.5 oC, maximum temperature (Tmax), and minimum daily temperature (Tmin) in 4 different formulas, based on the relationship between them:

Condition	Formula used
$T_{min}>T_{base}$	$D_h=0$
$(T_{max}+T_{min})/2>T_{base}$	$D_h=(T_{base}-T_{min})/4$
$T_{max}>=T_{base}$	$D_h=(T_{base}-T_{min})/2-(T_{max}-T_{base})/4$
$T_{max}<T_{base}$	$D_h=T_{base}-(T_{max}+T_{min})/2$

The daily value (Dh) was summed for each season. The distribution of mean coal consumption, wood consumption, seasonal temperature, wind speed, and sum of HDD for 2011 was:

	Coal consumption (tons)	Wood consumption (m^3)	Temperature (°C)	Wind Speed (knots)	HDD
Winter	3.56	2.73	-22.39	2.58	3411
Spring	0.78	1.13	-9.13	5.60	2060
Summer	0.01	0.13	13.50	7.14	493
Fall	0.70	1.10	8.59	5.37	888
Heating season (fall, winter, and spring)	5.14	5.20	-7.63	4.50	6359
Dwelling type:					
Ger	1.17	1.14	-	-	-
House	1.40	1.10	-	-	-
Education level of head of household:					
No formal education	0.91	1.60	-	-	-
Primary	1.15	1.62	-	-	-
Partial secondary	1.26	1.34	-	-	-
Completed secondary	1.31	1.14	-	-	-
Vocational	1.28	1.04	-	-	-
Tertiary	1.29	1.08	-	-	-

Models for Coal and Wood Consumption

We used a linear regression model to model coal and wood consumption, despite the repeated measures (i.e. 4 individual season records per household). Because of the large number of households and the relatively small number of repeated observations, this is not a serious violation of the

assumption of independence between observations. We did not model other fuel consumption because there were too few households using other fuels.

Coal consumption

When seasonal coal is calculated there are 4188 observations, with a mean of 1.0 tons and a range from 0 to 24 tons. The dataset was reduced to 4155 observations because we removed were 33 observations that were greater than the 99th% value of 8.0 tons. These high values were removed because they were too influential. Prior to multivariate modeling, univariate models for variables of interest were run. As the table below shows, there were 6 variables with a significant relationship (alpha=0.05) to seasonal coal consumption: seasonal mean daily temperature, seasonal mean daily wind speed, seasonal total HDD, living in the Bayangol district, living in the Songinokhairkhan district, living in a ger, and living in a household.

Covariate in univariate model with seasonal (3-month) coal consumption	Parameter estimate	p-value	R^2
Mean daily temperature (°C)	-0.07862	<0.0001*	0.52
Mean daily wind speed (knots)	-0.75757	<0.0001*	0.64
Total HDD	0.00104	<0.0001*	0.57
Household is in Bayanzurkh	-0.07880	0.1425	0.0005
Household is in Bayangol	-0.36293	<0.0001*	0.0037
Household is in Khan-Uul	0.12290	0.1003	0.0007
Household is in Chingeltei	-0.08088	0.2122	0.0004
Household is in Sukhbaatar	0.10236	0.1608	0.0005
Household is in Songinokhairkhan	0.14905	0.0074*	0.0017
# occupants under 5 years old	0.05124	0.1170	0.0006
# occupants 6-17 years old	0.02131	0.4139	0.0002
# occupants 18-25 years old	0.01328	0.5784	0.0001
# occupants 26-35 years old	0.00443	0.8642	0.0000
# occupants 36-45 years old	0.04041	0.1626	0.0005
# occupants 46-55 years old	0.00219	0.9441	0.0000
# occupants 56-60 years old	-0.05896	0.3814	0.0002
# occupants 61+ years old	-0.02270	0.6614	0.0000
Total # occupants	0.02488	0.0637	0.0008
Type of dwelling is ger	-0.13069	0.0065*	0.0018
Type of dwelling is house	0.13242	0.0058*	0.0018
Total household income	1.11×10^{-7}	0.1293	0.0006
Head of household education to either vocational or tertiary level	0.03259	0.5167	0.0001
Type of dwelling is a small house (less than 30 sq meters)	0.00769	0.9236	0.0000
Type of dwelling is a single-wall ger	-0.03499	0.6524	0.0001
Type of dwelling is a 4-sided ger	0.05465	0.2669	0.0003

*univariate model is significant at alpha=0.05.

The next step was the run the SAS 9.2 algorithm for stepwise regression, using an alpha level of 0.05 to enter the model and an alpha of 0.05 to stay in the model. Following determination by SAS, the model covariates were tested for collinearity. This was done by requiring that the variance inflation factor was less than 5 for all covariates. The multivariate linear regression model was selected from the set of 6 variables that were statistically significant in the univariate analysis. The model that best fit that data for seasonal (3-month) coal consumption used 5 of these variables and had an overall R2 of 0.65. Details of the model are shown in the table below:

Model for seasonal coal consumption	Parameter estimate	Standard error	P-value
Intercept	4.57681	0.099	<.0001
Mean daily wind speed	-0.67248	0.018	<.0001
Mean daily temperature	-0.01124	0.002	<.0001
Dwelling is a house	0.14638	0.028	<.0001
Household is in Songinokhairkhan district	0.11988	0.033	0.0003
Household is in Bayangol district	-0.34805	0.055	<.0001

$$C_{\text{y\_old,CEPi}} = 4.57681 - \left(0.67248 \sum \text{WS}_{\text{y,s}}\right) - \left(0.01124 \sum \text{T}_{\text{y,s}}\right) + 0.14638\text{DW}_{\text{y,house}} + 0.11988\text{D}_{\text{y,Songinokhairkhan}} - 0.36234\text{D}_{\text{y,Bayangol}}$$

Where:

$C_{\text{y\_old,CEPi}}$ = Mean coal consumption during the heating season (Fall, Winter, Spring)\

$T_{y,s}$ = Mean temperature in Celsius for year y and season s (Fall, Winter, Spring, Summer)

$WS_{y,s}$ = Mean wind speed in Knots for year y and season s (Fall, Winter, Spring, Summer)

$D_{y,Songinokhairkhan}$ = *District location is Songinokhairkhan district (dummy variable 1=yes, 0=no)*

$D_{y,Bayangol}$ = *District location is Bayangol district (dummy variable 1=yes, 0=no)*

$DW_{y,house}$ = *Dwelling is a house (dummy variable 1=house, 0=ger)*

Wood consumption

When seasonal wood is calculated there are 4188 observations, with a mean of 1.26 m3 and a range from 0 to 40 m3. The dataset was reduced to 4155 observations because we removed were 29 observations that were greater than the 99th% value of 12.0 m3. As in modeling coal consumption, these very high values were removed because they were too influential. Prior to multivariate modeling, univariate models for variables of interest were run. As the table below shows, there were 11 variables with a significant relationship (alpha=0.05) to seasonal wood consumption:

Covariate in univariate model with seasonal (3-month) coal consumption	Parameter estimate	p-value	R^2
Mean daily temperature (°C)	-0.05385	<0.0001*	0.2156
Mean daily wind speed (knots)	-0.51779	<0.0001*	0.2631
Total HDD	0.00070147	<0.0001*	0.2311
Household is in Bayanzurkh	-0.02324	0.6867	0.0000
Household is in Bayangol	-0.48452	<0.0001*	0.0058
Household is in Khan-Uul	-0.20446	0.0105*	0.0016

Household is in Chingeltei	-0.27232	<0.0001*	0.0037
Household is in Sukhbaatar	-0.17967	0.0208*	0.0013
Household is in Songinokhairkhan	0.62422	<0.0001*	0.0263
# occupants under 5 years old	0.06135	0.0801	0.0007
# occupants 6-17 years old	0.07330	0.0086*	0.0017
# occupants 18-25 years old	0.00916	0.7204	0.0000
# occupants 26-35 years old	0.09706	0.0004*	0.0030
# occupants 36-45 years old	0.01722	0.5783	0.0001
# occupants 46-55 years old	-0.01872	0.5762	0.0001
# occupants 56-60 years old	-0.00894	0.9024	0.0000
# occupants 61+ years old	0.06945	0.2099	0.0004
Total # occupants	0.06330	<0.0001*	0.0047
Type of dwelling is ger	0.01483	0.7731	0.0000
Type of dwelling is house	-0.01844	0.7199	0.0000
Total household income	5.26×10^{-8}	0.5012	0.0001
Head of household education to either vocational or tertiary level	-0.09160	0.0626	0.0009
Type of dwelling is a small house (less than 30 sq meters)	**-0.02731**	**0.7336**	**0.0000**
Type of dwelling is a single-wall ger	0.14604	0.0552	0.0010
Type of dwelling is a 4-sided ger	**-0.06484**	**0.1802**	**0.0005**

*univariate model is significant at alpha=0.05.

The next step was the run the SAS 9.2 algorithm for stepwise regression, using an alpha level of 0.05 to enter the model and an alpha of 0.05 to stay in the model. Following determination by SAS, the model covariates were tested for collinearity. This was done by requiring that the variance inflation factor was less than 5 for all covariates. The multivariate linear regression model was selected from the 11 variables from the univariate analysis that were statistically significant. The model that best fit that data for seasonal (3-month) wood consumption used 5 of these variables and had an overall R2 of 0.30. Details of the model are shown in the table below:

Model for seasonal wood consumption	Parameter estimate	Standard error	P-value
Intercept	3.42434	0.15039	<.0001
Mean daily wind speed	-0.46183	0.02723	<.0001
Mean daily temperature	-0.00748	0.00313	<.0001
Household is in Songinokhairkhan district	0.57023	0.05293	<.0001
Household is in Bayangol district	-0.36234	0.08537	0.0003
Household is in Chingeltei district	-0.14078	0.06116	<.0001

$$B_{\mathrm{y\_old,CEPi}} = 3.42434 - \left(0.46183 \sum \mathrm{WS}_{y,s}\right) - \left(0.00748 \sum \mathrm{T}_{y,s}\right) + 0.57023\mathrm{D}_{y,\mathrm{Songinokhairkhan}} - 0.36234\mathrm{D}_{y,\mathrm{Bayangol}} - 0.14078\mathrm{D}_{y,\mathrm{Chingeltei}}$$

Where:

$B_{y\_old,CEPi}$ = Mean biomass consumption during the heating season (Fall, Winter, Spring)

$T_{y,s}$ = Mean temperature in Celsius for year y and season s (Fall, Winter, Spring, Summer)

$WS_{y,s}$ = Mean wind speed in Knots for year y and season s (Fall, Winter, Spring, Summer)

$D_{y,Songinokhairkhan}$ = *District location is Songinokhairkhan district (dummy variable 1=yes, 0=no)*

$D_{y,Bayangol}$ = *District location is Bayangol district (dummy variable 1=yes, 0=no)*

$D_{y,Chingeltei}$ = *District location is Chingeltei district (dummy variable 1=yes, 0=no)*

In conclusion, we built two models for seasonal fuel consumption in the Ulaanbaatar's ger districts. These models, one for coal and one for wood, provide the main explanatory variables for seasonal (3-month) consumption of fuel. Both models were relatively small models, where the covariates with the major explanatory power were meteorological variables. The model for coal explains a high degree of the variability in the data (R2=0.65), whereas the model for wood consumption is less explanatory (R2=0.30). The seasonal distribution of wood consumption is also less variable overall than that for coal consumption, indicating that wood consumption is more uniform throughout the ger districts surveyed. This conforms with the household pattern of using wood as a lighting fuel, and coal as the primary heating fuel. The task of lighting a fire is fairly uniform, whereas the consumption of coal fuel for ambient room temperatures are more variable. Both models can be used directly to calculate total fuel consumption for populations within these ger districts or fuel consumption during any individual month.

Future comparisons

The models outlined above can be used to calculate total annual fuel consumption or individual seasonal fuel consumption. In order to compare future populations to this baseline consumption rate, there are different approaches to be followed depending on the available resources. The basic approaches are:

- Controlled before-and-after study
- Interrupted time-series design

In a controlled before- and after-study, a control group (or non-treatment group who did not receive the intervention) is compared with the treatment group. In this approach, the treatment and control groups are designed to be as similar as possible so that any overall trends in the general population can be observed and accounted for by comparing the populations. One possibility with a controlled before- and after-study is to compare the treatment group to an historic population who did not receive the intervention as the control group. This option is not possible since it is unethical to bar households from obtaining clean energy technologies that will save money and improve health.

Instead, the project will employ an interrupted time-series design which is a study design that uses a single population as both the control group (prior to the intervention) and the treatment group (after the intervention). Observations on this group are repeated so as to capture any overall trends and account for them in the comparison of the "groups". For the data described in this document, either a controlled before-and-after study with a comparable control population or using a historically controlled population could be an effective way to evaluate changes to fuel consumption. Assuming that the distribution of the population sampled matched or had substantial overlap with the distribution of a future population that has been intervened upon, the data presented here represents the historic control population for future interventions affecting fuel consumption. Matching populations, either a current "after" group to an historic "before" group, or between current control

and treatment groups should be done by selecting groups that overlap substantially in key demographics or other variables (e.g. type of dwelling). Another way to create a control group is through propensity scores, a method that exploits the counterfactual framework to create a counterfactual group that theoretically controls selection bias better than simple matching can. Once a control group is selected, the comparison of fuel consumption between the control group and the treatment group can be carried out using a T-test.

Sample size determination for comparisons of baseline and current fuel consumption

When comparing a future level of fuel consumption for a population to the baseline fuel consumption, one can use a t-test to determine if the mean fuel consumption is different between groups. To determine 20% decrease from the current level of coal consumption during the heating season (fall, winter, spring) in a random population with alpha=0.05 and power=0.80, one would need approximately 66 households. To observe a 5% decrease would require a survey of 1065 households. To determine 20% decrease from the current level of wood consumption during the heating season (fall, winter, spring) in a random population with alpha=0.05 and power=0.80, one would need approximately 290 households. To observe a 5% decrease in wood consumption would require a survey of 4840 households. The reason that a greater number of households would be needed to observe changes in wood consumption is that the variability in wood consumption during the heating season is higher than that for coal consumption.