WINTER MONITORING REPORT 2019-2020

TECHNICAL

DOCUMENT DEVELOPED BY

OTGONZUL Enkhtuvshin, Project Impact Indicator Monitoring and Evaluation Officer-GERES

Marc GLASS, Energy and Housing Project Manager – GERES

Building Energy Efficiency Center (of MUST)

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LIST OF ABBREVIATION

AQI	Air Quality Index
ADB	Asian Development Bank
BEEC	Building Energy Efficiency Center
BNbD	Mongolian Building Norm and Contruction code and standards
CO_2	Carbon Dioxide
DIY	Do It Yourself
EES	Energy Efficient Solution
ERC	Energy Regulatory Commission
EPS	Expanded Polystyrene Insulation
GHG	Greenhouse Gas
GCMC	Ger Community Mapping Center
HDD	Heating Degree Days
HH	Household
IPCC	Intergovernmental Panel on Climate Change
NAMA	Nationally Appropriate Mitigation Actions in the construction sector in Mongolia project
NCV	Net Caloric Value
PPM	Parts per million
RH	Relative Humidity
Temp	Temperature
XPS	Extruded Polystyrene Insulation
LR	Living room
BR	Bedroom

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1. BACKGROUND

The winter monitoring was conducted under activity 1.1.3 ‘Definition of typology and baseline data’ by Geres and BEEC from December 2019 to March 2020.

In this report, 29 houses located in three districts - Songinokhairkhan (SKHD), Sukhbaatar (SBD), and Chingeltei (CHD) were monitored. GCMC found households willing to have tested in their houses and agreed with them about responsibilities, activities to be carried out, and incentives to be given.

According to the Mongolian Government program, most of the houses having stoves started using improved fuel in May 2019 to reduce air pollution. Improved fuel is a mixture of coking coal and additional chemicals, which is considered to have low emission of particulate matter pollution.

1.1. OBJECTIVES AND OUTCOMES

The objective of the previous winter monitoring conducted in 2018-2019 was to identify indoor air quality and energy consumption of the detached houses located at Ger area before implementing any energy-efficient solution.

The objective of this winter monitoring report was the same as the previous monitoring. Following outcomes are expected to be achieved:

- Indoor air quality parameters’ analyses of the houses
- Thermal comfort analyses
- Heating energy consumption of the houses
- GHG emission of the houses

1.2. METHODOLOGY

The indoor air temperature was monitored in the living room and the bedroom of houses if the bedroom was available. Datalogger was installed in the middle of the room, protected from direct sunlight, and distanced from the external envelopes and heating device as specified by a technical expert from Geres.

The outdoor air temperature was measured at locations of the household at Songinokhairkhan and Sukhbaatar districts. Data loggers were installed in a shaded area away from the wall adjacent to the heated room in order to avoid thermal interaction.

Households recorded their fuel usage according to the template by themselves and submitted it to BEEC and Geres team. The testing period was divided into 4 time periods: morning time (6 AM-12 AM), afternoon time (12 AM-6 PM), evening time (6 PM-12 PM), night time (12 PM-6 AM).

Parameters; indoor air CO2 and PM2.5 concentrations as well as air quality index were monitored with laser egg equipment installed in the living room.

1.2.1. MONITORED DATA

Following data were collected from each house:

- Indoor air temperature
- Indoor air relative humidity
- CO_2
- PM2.5
- Air quality index
- Electricity and fuel consumption for heating.

1.2.2. MONITORING DURATION

The measurement started on **31st December 2019 and ended on 20th March 2020.** The testing period varies among households. Parameters such as CO_2, PM2.5, and Air quality index were measured for a duration of 7 days due to equipment availability. After testing one house, the equipment was transferred to the next household.
Parameters such as indoor air temperature and relative humidity were measured for a longer period. The measurement duration varied among households related to the cooperation agreement made between the project team and the households. Indoor temperature and relative humidity were logged every 30 minutes, while CO_2 and PM2.5 have logged every minute automatically.

1.2.3. MONITORING EQUIPMENT

Please see table 1 for technical specification of the equipments used for monitoring.

Table 1 Equipment technical specification

Device model	Kaiterra Laser egg *(indoor air quality)*	Testo H174 *(Indoor air temperature and humidity data logger)*	Testo H175 *(Outdoor air temperature and humidity data logger)*	OWL+USB *(energy monitoring of electric heaters)*
Parameter	• CO_2 • PM2.5 • Temperature • Relative humidity • Air quality index	• Temperature • Relative humidity	• Temperature • Relative humidity • Dew point temperature	• Energy usage

Measurement range	CO_2: 400-5000ppm PM2.5: 0-999µg/m3 Temp: -20 to100^{0}C RH: 0-99% AQI: 1-500	Temp:-20 to 70^{0}C RH: 0-100%	Temp:-20 to +55^{0}C RH: 0-100% Dew: -40 to 50^{0}C	Operating range up to 30m Cables rated up to 71A Temp: 0 °C to 40 °C RH: 25%- 95%
Data storage		16.000	1.000.000	30 days
Battery	Lithium 2200mAh	2X3V button cell	3xAIMn AAA	6 x AA Alkaline Battery
Other	Wi-Fi connection			
More information	www.kaiterra.com	www.testo.com	www.testo.com	https://www.theowl.com/
Photo				

1.2.4. LIMITATIONS

Last year the winter monitoring was conducted on 15 houses. Among them, only 6 houses were insulated. Unfortunately, the number of houses that implemented the EES solution to be used in the energy-saving analysis was reduced to 2 houses because three houses were eliminated from the analysis in the previous report due to unusual low consumption, and one house was taken out of this analysis due to the same reason. This winter monitoring has a small sample size for insulated houses, which is 6.

From the 6 houses of previous winter monitoring, additional 23 houses were monitored during this winter monitoring. Additional houses to be monitored were found by the GCMC team, and signing a cooperation agreement with the new houses took longer than expected. Therefore, depending on the cooperation start date, the monitoring duration varies among households.

Parameters such as CO2, PM2.5, and air quality index were measured for a duration of 7 days in each household due to equipment availability and were circulated among households for measurement. Therefore, indoor air quality parameters between houses were assumed to be analyzable up to some extent but limited as measurements took place at different period.

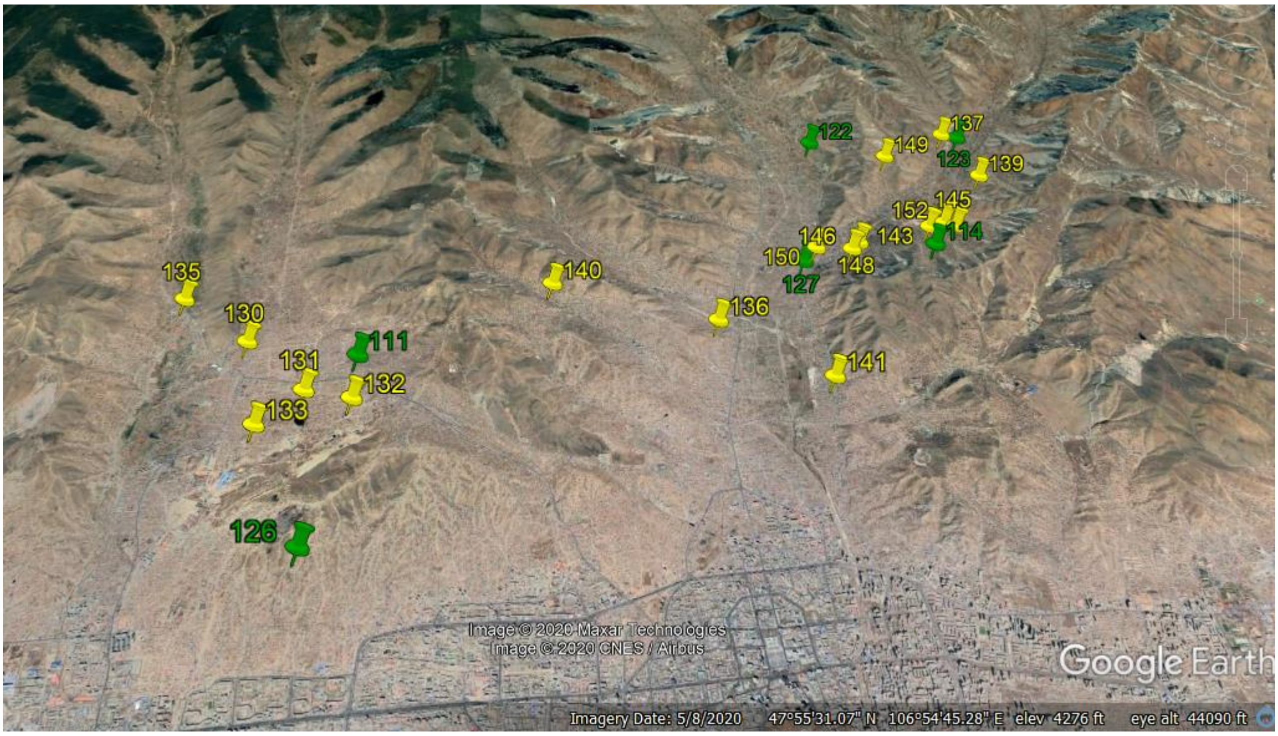
There are 9 air quality monitoring stations in Ulaanbaatar. Among them, some stations monitor a few parameters, and some stations do not regularly work; therefore, available historical data of 2019-2020 winter was limited to only two stations located at the US embassy (AQI) and M.N.B(PM2.5). Stations are located at the outskirt of ger areas or at the near outskirt of ger area, far from winter monitoring houses or target khoroos. Hence, we assume some limits for comparing indoor and outdoor air quality parameters because of differences in locations.

1.3. HOUSEHOLD CHARACTERISTICS

There was a total of 29 houses monitored from December 2019 to March 2020. Figure 1 shows the houses' locations on Google earth, and Table 2 shows general characteristics of the monitored houses.

Among monitored houses, 34.5% are located at the SKH (Songinokhairkhan district), 58.6% are at the SBD (Sukhbaatar district), and 6.9% are at the CHD (Chingeltei district) accordingly.

Figure 1 Locations of the houses (Google Earth)



Out of total houses, with an overlapping number of houses, 31% of the houses are wall insulated, 34.5% are roof insulated, and 20.7% are floor insulated.
The majority of the houses built the external wall with brick. Windows are mainly oriented to the south and double glazed with PVC frames. All the houses' doors are non-insulated metal with subsequent air leakage except for one house's wooden door. The average floor area of the monitored houses is 50 m^2.

When analyzing houses, some houses have shown too much fuel consumption or unusually low temperature. This amounts to 4 houses which are HH126, HH132, HH148, and HH149 (Annex 5.3 included those houses excluded from the analysis). Therefore, monitoring analysis is based on 25 houses. Approximately 24% (6 houses) of that 25 house were using an electric heater.

<u>To make it easy to compare, the houses were classified into five groups by types of energy-efficient solutions (EES) implemented as follows:</u>

- EES 1- Full insulation (6HHs): The houses insulated its' roof, wall, foundation by the project are in this group.
- EES 2- Roof insulation (2HHs): The houses with roof insulation are classified into this group.
- DIY insulation wall + roof (1HHs): This group consists of only one HH (HH 131), which is DIY insulated its' wall and roof by house owners without support from the project.
- DIY insulation wall (2HHs): The two HH who has DIY insulation on the wall without the project's support are included in this group.
- No insulation group (14HHs): The houses, which have not implemented any EES, are included in this group.

EES 1- Full insulation
EES 2- Roof insulation
DIY insulation- Wall+Ro
DIY insulation- Wall
No insulation
Excluded houses

- Excluded houses(4HHs): Those which has shown too much fuel consumption or unusual low temperature: HH126, HH132, HH148, and HH149

ID	General		Structure type									
	District	Floor area, m2	Wall		Roof		Floor / foundation		Window	Door	Ventilation	Heating
			Base	Insulation	Base	Insulation	Base	Insulation				
111	SKHD	47	Brick	EPS 15cm	Wood	Fiber 20cm	-	XPS10	PVC	metal	+	electricity
114	SBD	43	Light concrete	EPS 15cm	Wood	Fiber 20cm	-	XPS10	PVC	metal	+	improved stove
122	SBD	56	Brick	-	Wood	Fiber 20cm	-	-	PVC	metal		improved stove
123	SBD	23	Brick	EPS 15cm	Wood	Fiber 20cm	-	XPS10	PVC	metal	+	electricity
126	SKHD	23	Light concrete	-	Wood	Fiber 20cm	-	-	PVC	metal		improved stove
127	SBD	60	Wood	Fiber 15cm	Wood	Fiber 20cm	-	XPS10	PVC	WOOD	+	trad stove +electricity
130	SKHD	49	Balk	Fiber	Wood	Fiber 20cm	-	XPS10	PVC	metal	+	electricity
131	SKHD	64,2	Brick	EPS 10cm	Wood	Fiber 20cm	-	-	PVC	metal		improved stove
132	SKHD	25	Balk+ Brick	-	wood	Fiber 20cm	-	-	PVC	metal		improved stove
133	SKHD	46,2	Balk	Fiber 15cm	Wood	Fiber 20cm	-	XPS10	PVC	metal	+	traditonal stove
134	SKHD	19,6	Brick	-	Wood	-	-	-	PVC	metal		traditonal stove
135	SKHD	44,2	Wood+ Brick	EPS 5cm	Wood	-	-	-	PVC	metal		improved stove
136	CHD	46,3	Wood+ Brick	-	Wood	-	-	-	PVC	metal		improved stove
137	SBD	49	brick	EPS 5cm	Wood	-	-	-	PVC	metal		improved stove
138	SKHD	43,6	Brick	-	Wood	-	-	-	PVC	metal		improved stove
139	SBD	40,8	Light block	-	Wood	Fiber 20cm	-	-	PVC	metal		improved stove
140	CHD	38	Brick	-	Wood	-	-	-	PVC	metal		improved stove
141	SBD	32.5	Concrete	-	Wood	-	-	-	PVC	metal		improved stove
142	SBD	32,5	Concrete	-	Wood	-	-	-	PVC	metal		improved stove
143	SBD	50,4	Balk	-	Wood	-	-	-	PVC	metal		improved stove
144	SBD	30	Brick	-	Wood	-	-	-	PVC	metal		improved stove
145	SBD	30	Brick	-	Wood	-	-	-	PVC	metal		improved stove
146	SBD	80	Brick	-	Wood	-	-	-	PVC	metal		trad stove+elec tricity
147	SBD	80	Brick	-	Wood	-	-	-	PVC	metal		trad stove+elec tricity
148	SBD	69	Balk	-	Wood	-	-	-	PVC	metal		improved stove
149	SBD	27,6	-	-	Wood	-	-	-	PVC	metal		improved stove
150	SBD	42	-	-	Wood	-	-	-	PVC	metal		improved stove
151	SKHD	25,9	Brick	-	Wood	-	-	-	PVC	metal		traditional stove
152	SBD	50	timber+ Clay	-	Wood	-	-		PVC	metal		improved stove

Table 2 General description of houses

Note: Households with bold ID were monitored in the winter of 2018-2019.

2. ANALYSES AND RESULTS

2.1. OUTDOOR AIR TEMPERATURE

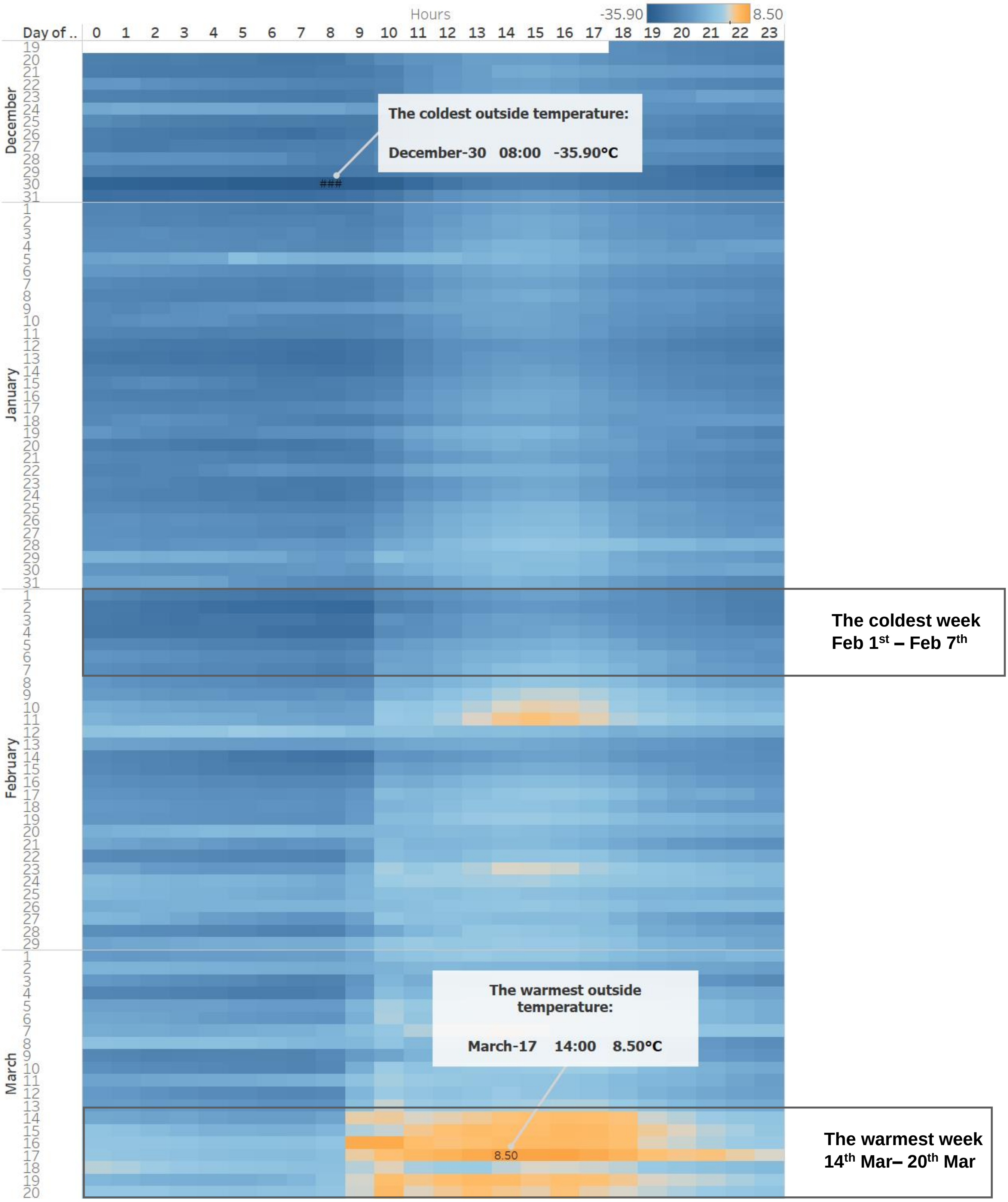


Figure 2 Outdoor air temperature during monitoring period

Two thermometers were placed outside on the north side of two houses to measure proper external temperature data.

The average temperature is calculated on the sum of all data recorded divided by its amount (48 data per day at ½ hour interval). The overall outside average temperature is **-15.5°C**, the lowest temperature throughout the monitoring period is **-35.9°C,** and the highest temperature is **8.5°C**.

The warmest part in the afternoon (-8.8 °C) while the coldest part at night (-14.7 °C).

2.2. INDOOR AIR TEMPERATURE

The indoor air temperature was measured in all the available rooms. Some of the houses have separate bedrooms while most of them have only one room. We called this room a living room (LR). If there is a separate room for sleeping, we named it a bedroom (BR). The indoor air measurement interval was 30 minutes. Indoor air temperature fluctuations are shown in Figure 3. There are 8°C to 50°C temperature differences that occurred for indoor air temperature.

Figure 3 Indoor air temperature fluctuation of the houses

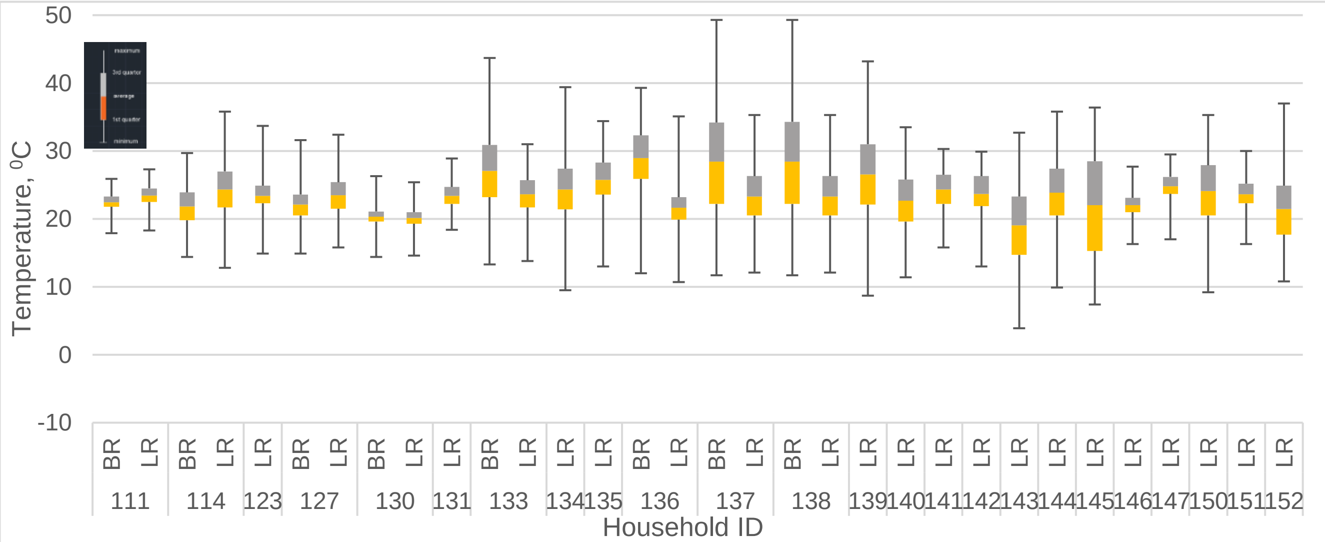


Table 3 The highest and the lowest fluctuations of indoor air temperature

The 5 HHs having the highest temperature fluctuation			The 5 HHs having the lowest temperature fluctuation		
ID	**Heating type**	**Insulation type**	**ID**	**Heating type**	**Insulation type**
HH133	Stove	EES 1	HH111	Electric heater	EES 1
HH134	Stove	No Insulation	HH130	Electric heater	EES 1
HH137	Stove	No Insulation	HH131	Improved stove	DIY insulation- Wall + Roof
HH138	Stove	No Insulation	HH146	Electric heater	No Insulation
HH139	Stove	EES 2	HH147	Electric heater	No Insulation
Total	**5 of 5 Stove**	**3/5 No insulation**	**Total**	**4 of 5 Elelctic heater**	**3/5 EES 1, DIY insulation- Wall + Roof**

When taking an example of five houses with the highest and the lowest temperature fluctuation among 25 HHs, the type of heater shows more impact on temperature fluctuation and can be seen from table 3. However, as the sample size is still few, we cannot be sure whether temperature fluctuation depends on one major factor, which is the type of heater, in fact, it can be both: type of heater and level of insulation.

As the highest and the lowest indoor air temperature fluctuations have been found, hourly temperature distributions were analyzed for the 130th and 137th houses, as shown in Figure 4.

Though outdoor air temperature fluctuates throughout the day, the indoor air temperature was stable throughout the day, and fluctuation was **4.4^{0}C** for the 130th house. This shows that the house's heating behavior is normal since an electric heater was used during the heating season. Indoor temperature is stable for HH130 because of the constant internal thermal regulation of the electric heater.

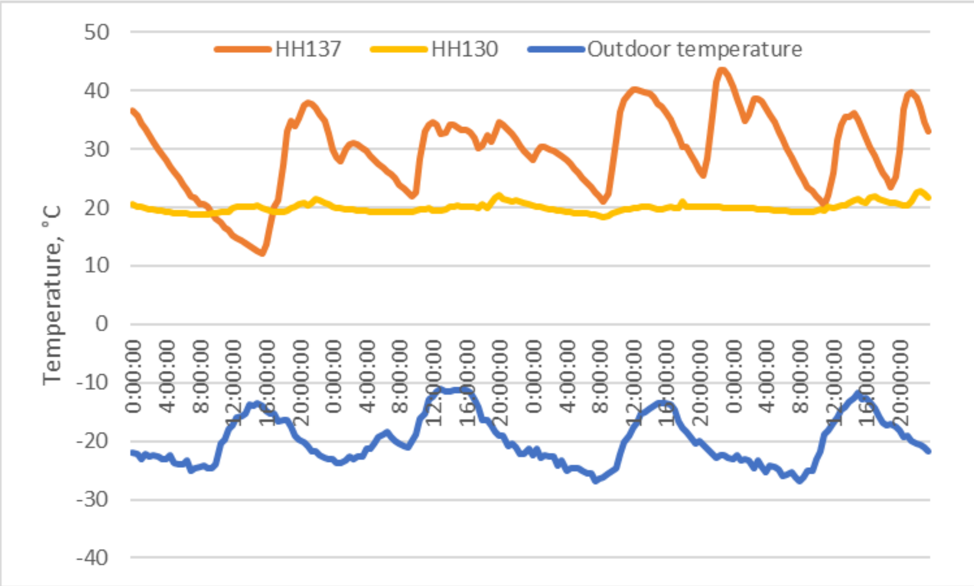
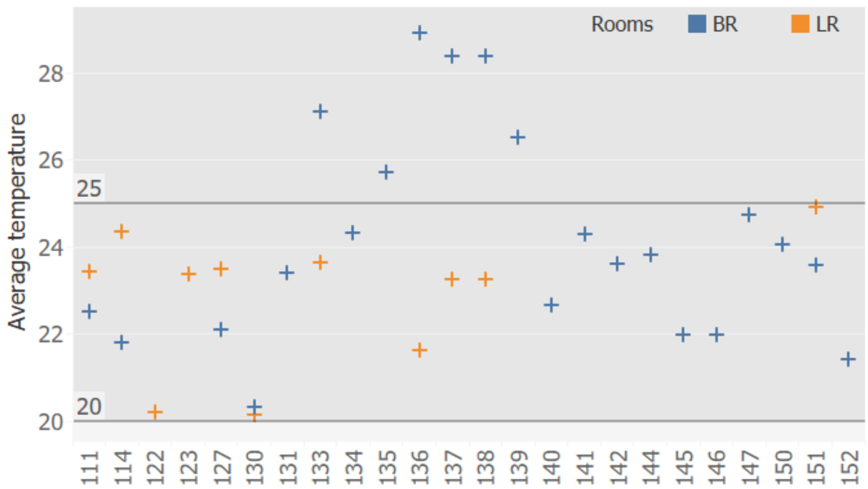


Figure 4 Hourly indoor air temperature of the 130th and 137th household

In contrast, indoor air temperature fluctuation was obviously high for the 137th house. Indoor temperature as high as 40°C is observed due to fueling the stove before mid-night and reached 20°C - 23°C before noon. Houses using stoves usually has high-temperature fluctuation compared to houses with the electric heater. However, it is related to heating device types and the evidence of a significant difference between insulation levels in those houses.

Please see the below figure for mean indoor air temperatures in the houses. The mean indoor temperatures are generally between 20°C and 25°C. Big differences in mean indoor temperatures between rooms in non-insulated houses(HH 136, HH138, and HH 138) are shown while indoor temperatures were uniform in insulated houses(HH 111, HH114, HH127, and HH130). Please see the thermal comfort session for further investigation of the impact of insulation on indoor temperatures: indoor temperature decreases more abruptly and quicker with higher indoor temperature variation between time of the day in non-insulated houses than insulated houses.

Figure 5 Mean indoor air temperatures



Please see Table 4 for indoor air temperature comparison by each session. There was no significant difference found between the time period of the day. Daily hours had been divided into 4 such as morning 06:00-11:30, afternoon 12:00-17:30, evening 18:00-23:30, night 00:00-05:

Table 4 Comparative temperatures

Comparative temperature results															
Average T° C / HH No.	Overall			Morning			Afternoon			Evening			Night		
	LR	BR	Outside	LR	BR	Outside	LR	BR	Outside	LR	BR	Outside	LR	BR	Outside
111	23.4	22.5	-15.5	23.1	22.1	-14.7	23.1	22.3	-10.1	23.7	22.6	-15.4	23.5	22.5	-19.0
114	24.3	21.8	-15.5	24.3	21.0	-14.7	24.3	21.2	-10.1	24.3	21.7	-15.4	24.3	23.5	-19.0
122	20.2		0.0	20.2		0.0	20.1		0.0	20.1		0.0	20.3		0.0
123	23.4		-15.5	22.7		-14.7	23.9		-10.1	23.1		-15.4	23.2		-19.0
127	23.5	22.1	-15.5	22.9	21.6	-14.7	23.9	22.8	-10.1	24.1	22.2	-15.4	22.8	21.8	-19.0
130	20.1	20.3	-15.5	19.2	19.8	-14.7	20.7	20.5	-10.1	20.4	20.6	-15.4	19.9	20.1	-19.0
131		23.4	-15.5		22.1	-14.7		24.0	-10.1		23.6	-15.4		23.4	-19.0
133	23.6	27.1	-15.5	21.2	25.3	-14.7	24.7	28.7	-10.1	24.3	28.6	-15.4	23.3	25.6	-19.0
134		24.3	-12.8		20.4	-13.3		24.7	-7.1		25.1	-13.1		24.8	-17.0
135		25.7	-12.8		22.8	-13.3		27.6	-7.1		25.9	-13.1		25.3	-17.0
136	21.6	28.9	-12.8	19.4	25.1	-13.3	22.0	29.7	-7.1	22.0	28.6	-13.1	22.1	31.4	-17.0
137	23.3	28.4	-12.8	20.4	24.0	-13.3	25.0	30.2	-7.1	23.9	29.8	-13.1	23.1	29.9	-17.0
138	23.3	28.4	-12.8	20.4	24.0	-13.3	25.0	30.3	-7.1	23.9	29.8	-13.1	23.1	30.0	-17.0
139		26.5	-11.9		26.6	-16.2		20.7	-13.8		26.8	-6.3		30.5	-11.6
140		22.7	-10.3		21.9	-14.6		18.6	-11.9		22.8	-4.9		25.7	-10.2
141		24.3	-10.3		23.5	-14.6		22.4	-11.9		25.0	-4.9		25.2	-10.2
142		23.6	-10.3		24.7	-14.6		24.0	-11.9		24.0	-4.9		21.6	-10.2
143		19.0	-10.3		16.8	-14.6		13.7	-11.9		19.4	-4.9		22.7	-10.2
144		23.8	-10.4		22.7	-15.0		19.3	-10.2		24.5	-5.0		26.4	-11.3
145		22.0	-10.4		15.9	-15.0		19.2	-10.2		23.3	-5.0		26.3	-11.3
146		22.0	-10.4		20.8	-15.0		22.0	-5.3		21.7	-7.7		23.0	-13.6
147		24.7	-10.4		23.0	-15.0		25.2	-5.3		24.7	-7.7		25.6	-13.6
150		24.1	-10.4		20.5	-10.2		25.9	-5.2		24.4	-11.3		24.5	-15.0
151	24.9	23.6	-10.4	25.3	23.0	-5.0	25.3	23.8	-10.3	24.4	23.6	-14.6	25.1	23.7	-11.9
152		21.4	-10.4		22.9	-5.0		24.7	-10.3		21.9	-14.6		17.0	-11.9
AVERAGE	**22.9**	**23.9**	**-12.0**	**21.7**	**22.2**	**-13.0**	**23.4**	**23.6**	**-9.0**	**23.1**	**24.4**	**-10.6**	**22.8**	**24.8**	**-14.4**

Overall average temperature for all households throughout the testing period was **23.4℃**.

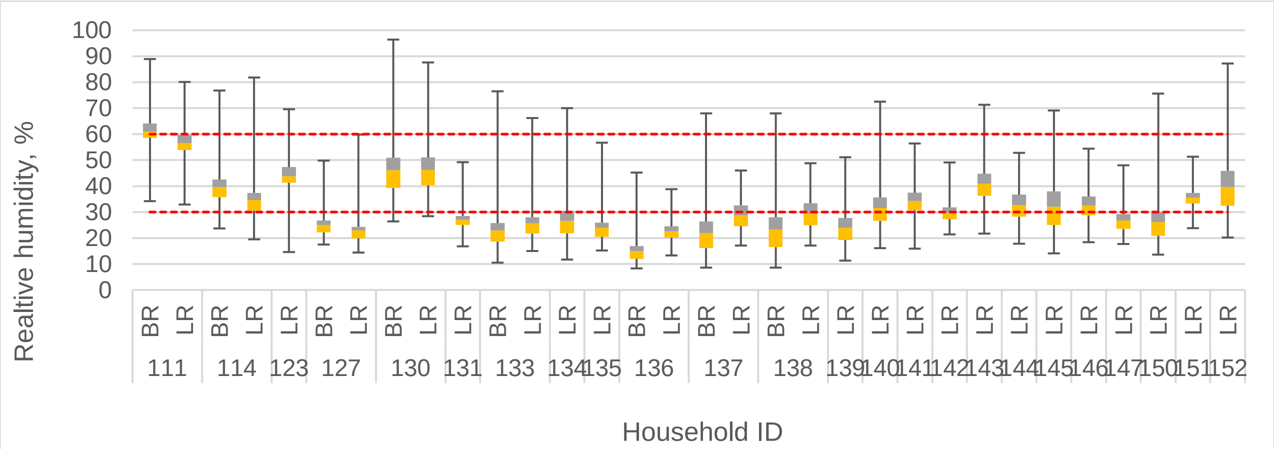
2.3. INDOOR AIR RELATIVE HUMIDITY

Indoor air relative humidity (RH) fluctuations are shown in Figure 6. Forty-eight percent of the measured median RHs are in a comfortable range which is stated in the MNS4585:2016 "Air quality. General technical requirement" standard indicated by a red line in figure 6.

The average relative humidity was highest for the 111th house due to the veranda's construction (pilot project implemented by Geres). Condensation occurred in the veranda wall due to the household was not following the ventilation recommendations given.

HH111, HH114, HH123, HH127, HH130, and HH133 have installed mechanical ventilation, consisting of extractor and supply vents, valve, through-the-wall extractor fan, back draught ducting shutter, duct sound absorber, and filter by the project. However, as shown in Figure 6, there is not much difference found between houses with and without proper ventilation regarding indoor air RH. RH will increase depending on occupant's behavior, such as not ventilating kitchen or rooms immediately after cooking or washing clothes, not ventilating the house long enough, or for houses with the ventilation system, it can be keeping wall vents closed or not operating fans regularly. The majority of non-insulated houses have shown RH, which were lower than comfortable range, stated in the Mongolian standard, related to higher indoor mean temperature or over-ventilating such as keeping windows or door open for a long period.

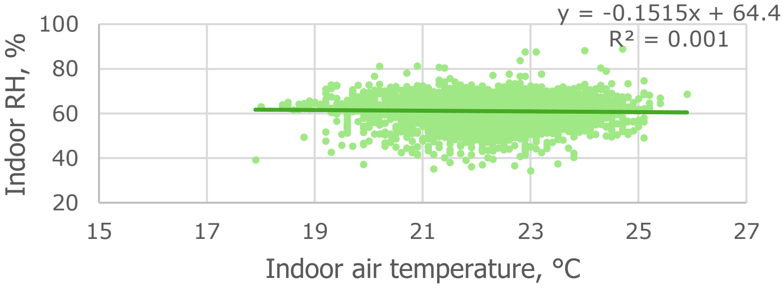
Figure 6 Hourly indoor air relative humidity of the houses



Before and after implementing the veranda, the project team informed the house owners how to use the veranda. The recommendation to open the veranda's windows for a certain time of the day to allow the accumulated moisture to escape out of the veranda was given. However, the project team noticed that veranda HH111 is not following the project team's recommendation, and this assumption is proven to be true, as shown in figure 6.

The relationship between indoor air temperature and relative humidity of the HH111 is shown in Figure 7. The graph shows that there is almost no relation between indoor air temperature and relative humidity for HH111. The condensation and accumulated moisture due to poor ventilation might increase the indoor air relative humidity in HH111.

Figure 7 Relationship between indoor air temperature and relative humidity of the 111th household



2.4. THERMAL COMFORT

Please find the indoor temperature of EES 1 houses with insulation which is done by the project, and reference non-insulated houses in the below figure. The mean indoor air temperatures were averaged by the time period of the day and indicated by different colors, as shown in Figure 8.

Temperature variation was lower for those heated with the electric heater. Houses heated with all types of the stove have higher temperature fluctuation related to the stove feeding behavior. When the fuel is inserted into the stove, temperature increases rapidly, and once the fed fuel is burnt out, the temperature drops accordingly, especially during nighttime or non-occupied times.

The HH111, HH123, HH127, and HH130 are well-insulated houses plus uses electric heater. Therefore, mean temperatures on those houses present stable and smooth lines, while well-insulated houses using the stove as a heater (HH114 and HH133) show higher temperature variance depending on the time period. If we take a closer look at temperature lines corresponding to HH 114, the house stays warmer during the evening and nighttime with little temperature variation for a whole day when for HH133 indoor temperature were warmer during evening and afternoon hours with visible temperature differences between the time period of the day.

Also, non-insulated houses highlighted in a light-grey box are shown as a comparison to insulated houses, and higher temperature fluctuation due to stove as a heater in addition to lack of insulation can be seen in figure 8. Therefore, indoor temperature decreases more abruptly and quicker in these houses than in insulated houses. In this sense, further investigation for HH 133 is required to identify whether high daily temperature variation is due to the heating behavior of the stove or behavior of the house owners, such as over-ventilating.

Figure 8 Average indoor temperature profiles

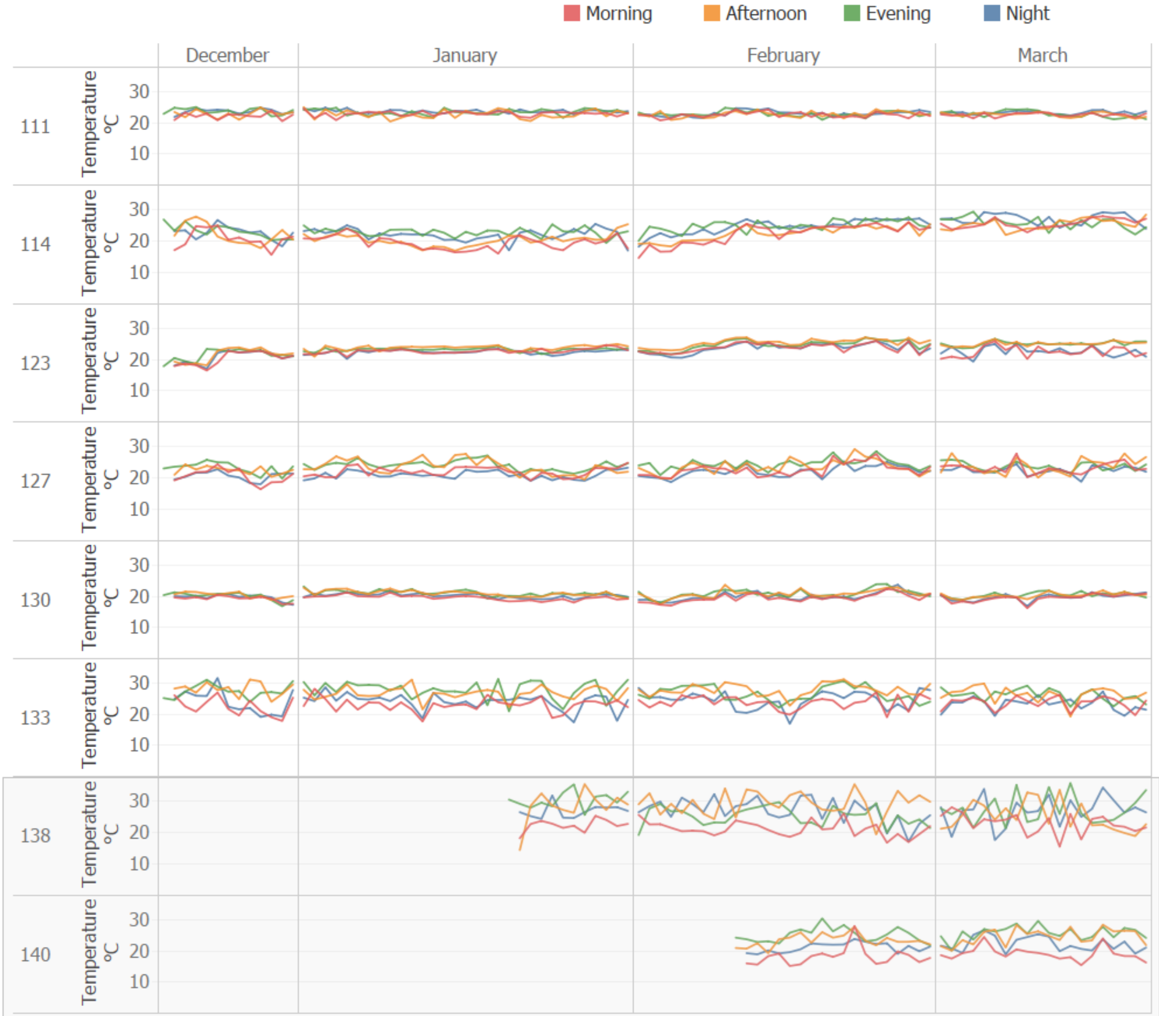


Table 5 Average indoor temperatures and perception of thermal comfort

ID	Indoor temperature								House owner's perception of thermal comfort	
	Morning 06:00-11:59		Afternoon 12:00-17:59		Evening 18:00-23:59		Night 00:00-05:59			
	Before	After	Before	After	Before	After	Before	After	Before	After
111	19.7	22.6	22.6	22.7	22.1	23.2	21.2	23.0	4	1
114	17.7	21.9	26.3	22.4	25.3	23.3	20.1	24.8	4	1
123	23.7	22.7	28.0	23.9	29.6	23.1	23.3	23.2	4	2
127	17	22.2	18.5	23.3	19	23.1	18.5	22.3	4	1
130	-	-	-	-	-	-	-	-	1	3
133	-	-	-	-	-	-	-	-	4	1

Also, 4 of 6 EES1 houses were monitored in previous winter monitoring when the houses were yet done any insulation work by the project. Therefore, average indoor temperatures for the time period of the day corresponding to before and after insulation works are shown in Table 5. Indoor mean temperatures in HH123 and HH127 decreased and increased into more stable temperatures throughout the day.

According to survey results (The Socio-Economic impact report of the SOAP project, 2020), house owners answered that their perception of thermal comfort meet exceptionally through the insulation as shown in Table 5 (Answers were in the range of 1 to 5, where 1 indicates the most comfortable, in contrast, 5 means not comfortable at all). For HH130, the house is heated with a floor electric heater; therefore, the house areas did not get heated uniformly. Thus the answer was 3, which means moderate. Both survey and monitoring results comply with each other.

Temperature decay: The faster the temperature drops down to meet the outside temperature level, the greater the house is uninsulated and has low thermal mass. Thus, how quick temperature decays shows a level of insulation and thermal mass of the building. For example, both HH 131 and HH 140 has improved stove with a difference of insulation in its wall and roof as shown in Table 6.

Table 6 House characteristics of HH 131 and HH 140

ID	Structure type								Ventilation	Heating
	Wall		Roof		Floor / foundation		Window	Door		
	Base	Insulation	Base	Insulation	Base	Insulation				
131	Brick	EPS 10cm	Wood	Fiber 20cm	-	-	PVC	metal		improved stove
140	Brick	-	Wood	-	-	-	PVC	metal		improved stove

The difference in insulation results in a significant difference in temperature decays as well. In Figure 9, it can be seen that temperature decreases down about 5°C in 8 hours (from point 1 to 3) for HH 131 and in 3 hours (point 1 to 2) for HH 140. Once the stove is fueled, for both heating and cooking purposes in the evening, indoor temperature increases and reaches its peak before midnight in both houses. However, the insulated HH 131, indicated by the orange curve, shows slower temperature decay than the uninsulated HH 140, marked by a blue line in Figure 9.

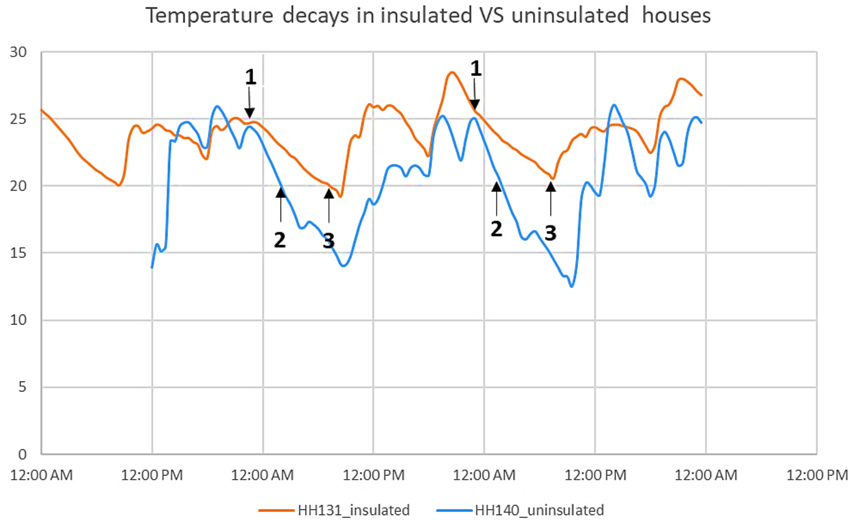


Figure 9 Temperature decays in insulated house and uninsulated house

Temperature decay is **more than 2 times** slower for the insulated house (HH131) even though the outside temperature was much lower when measuring HH 131, as shown in Figure 10.

Note that a significant difference between the two outside temperatures was caused by different dates that measurement took place at. Outside temperature for HH131 was measured around mid-January while it was the 10th of February for HH140 for Figure 10.

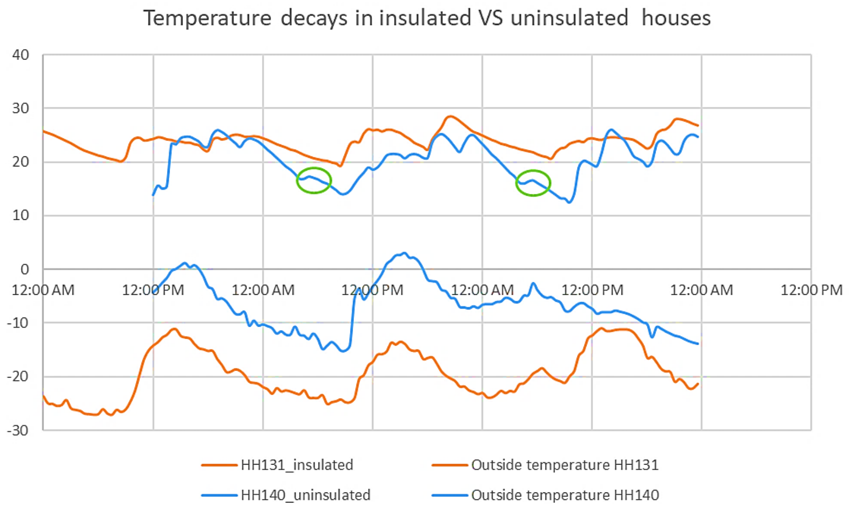


Figure 10 Outside and indoor temperatures in insulated house and uninsulated house

Higher the temperature difference between inside and outside, the quicker the temperature decay will be.

The example of these two houses represents how temperature decay and heat loss differ depending on how well insulated the house is and shows the differences in house owner's daily routines. In the morning, the indoor temperature of the insulated HH 131 still stays in a comfortable range of around 20°C; thus, there is no need to fuel the stove in the morning. In contrast, HH 140 does not meet comfortable indoor temperature; therefore, there is no choice but to fuel it. The green circle shows this behavior in Figure 10.

Figure 9 and Figure 10 show that both HH 131 and HH 140 reach their peak temperature, which is almost 24°C before midnight and reaches its lowest around noon. **Over the course of 12 hours**, the indoor temperature in insulated HH 131 does not decrease below the 18°C besides much lower the outside air temperature compared to HH 140.

Indoor temperature is stable for those insulated houses heated by an electric heater related to the constant operation of the heating device and well insulation, while stove heated non-insulated houses can be uncomfortable for most of the hours of the day due to high-temperature fluctuation.

2.5. INDOOR AIR CO2 CONCENTRATION

The average CO_2 concentration was compared in Figure 11. CO_2 concentration **was within the acceptable limit for most of the houses**. CO_2 during evening and night time is the highest due to house is more occupied and lower air exchange while CO_2 is the lowest during the afternoon due to fewer occupants in the house.

CO_2 level inside the house is affected by stoves and various factors such as the number of occupants present or whether the ventilation system is being properly utilized, or even ambient conditions.

As mentioned before, there were 6 houses with proper insulation and a mechanical ventilation system installed by the project. Among these houses, there were 4 houses which were using electric heater solely. CO_2 concentration was **high for HH111 and HH130 due to occupants' behavior of not properly ventilating (figure 6 and figure 11) even though these houses had the electric heater on top of proper insulation and ventilation system**. In contrast, similar houses with insulation and electric heater (**HH123 and HH127) had lower RH and lower indoor CO_2, which means that these houses were properly utilizing the ventilation system installed by the project.**

The majority of non-insulated houses has shown average CO_2 related to lower RH due to over-ventilating, such as keeping windows or door open for a long period. Non-insulated houses using a combination of stove and electric heater (HH146 and HH147) did not show lower CO_2 concentration than other non-insulated houses.

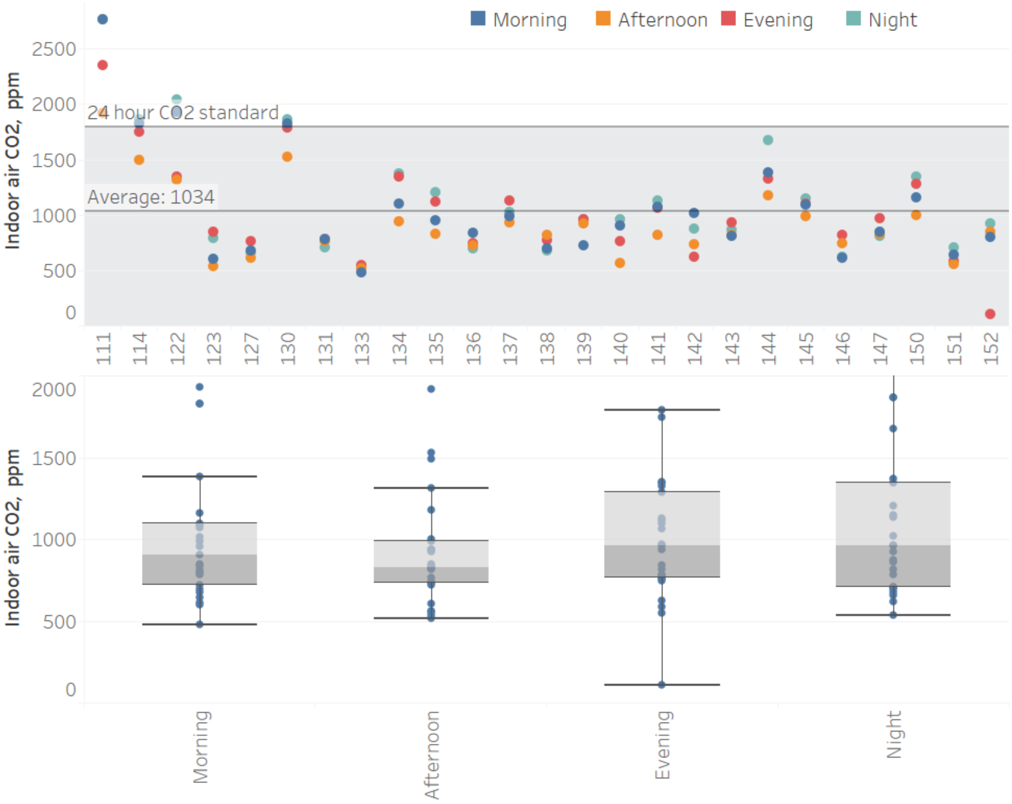


Figure 11 Indoor air CO2 concentration

2.6. PM2.5

As mentioned before, parameters such as PM2.5 and air quality index were measured for the duration of 7 days in each household due to the availability of a measurement device; therefore, the time of each measurement did not happen to overlap at the same time. Measurement data were inherently not possible to compare; therefore, outdoor PM2.5 was attained from air quality monitoring station located at M.N.B, which is an outskirt of ger area (https://aqicn.org/city/ulaanbaatar/mnb/) for a comparison of outdoor and indoor PM2.5.

PM2.5 was higher than the acceptable limit for 72% of the houses according to MNS4585:2016 “Air quality. General technical requirement” standard in which the acceptable limit for 24-hour average PM2.5 is 50 µg/m3.

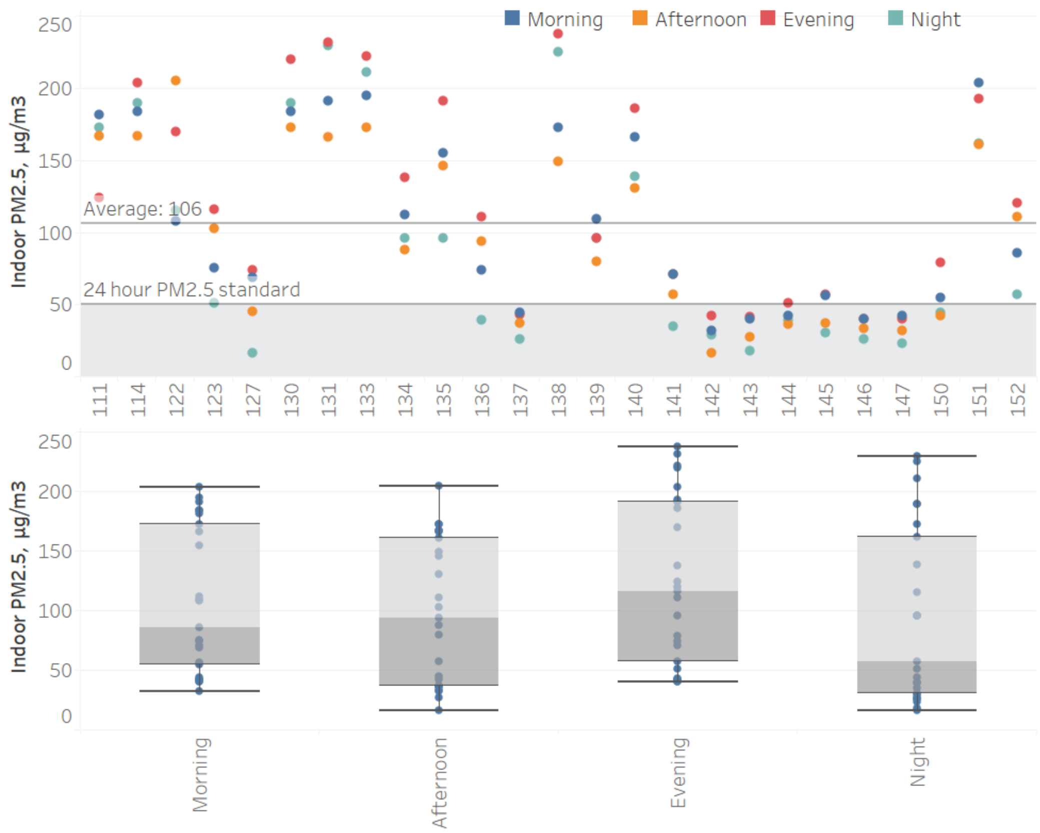


Figure 12 Indoor air PM2.5 concentration

The visible difference in PM2.5 depending on the time of the day can be seen in Figure 12. PM2.5 is the highest during evening hours and being lowest during nighttime. **Comparison of outdoor and indoor**

PM2.5:

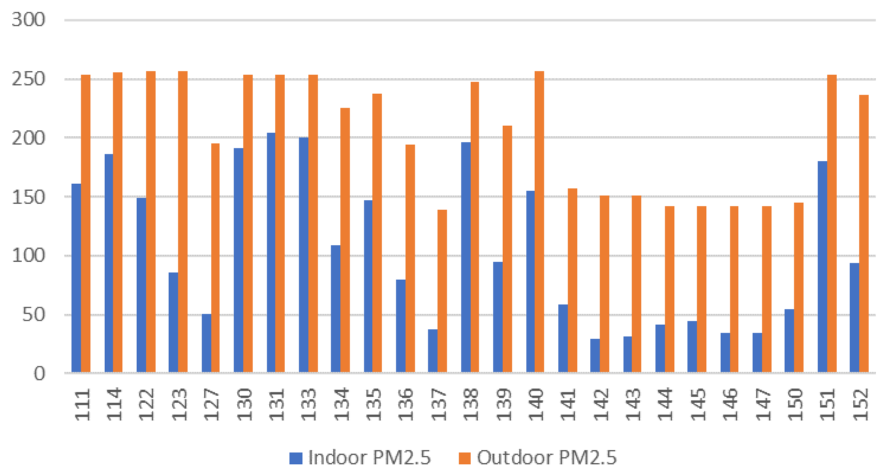


Figure 13 Outdoor and indoor PM2.5

The two houses (HH123 and HH127) show better indoor air quality with 66% and 74% differences in indoor and outdoor PM2.5 because houses were using electric heater instead of stove addition to full insulation and ventilation (with filter) by the project. The houses were ventilating properly as normal RH, and lower carbon dioxide concentration was observed in figure 6 and figure 11. Thus**, the proper insulation and proper ventilation combined with an electric heater can decrease indoor PM2.5 concentration significantly.**

The HH111, HH130 which were insulated by the project and using electric heater had higher carbon dioxide concentration (figure 11), which is caused by the occupant's behavior of not ventilating properly(previously mentioned) showed less difference (around 30%) between the indoor and outdoor concentration of PM2.5 as well. **Even though the house is properly insulated and installed, the ventilation with filter and having electric heater did not necessarily provide a drastic decrease in the indoor concentration of PM2.5 as occupant's behavior of properly ventilating their house is important.** Roof insulated HH122 showed about 42% improvement in indoor PM2.5.

The insulated houses with stoves (HH131 and HH133) show similar improvements in indoor PM2.5, which are less than other insulated houses, due to the use of the stove.

Uninsulated houses (HH137, HH141, HH142, HH143, HH144, HH145, HH146, HH147, HH148, HH149, and HH150) had been measured throughout February and March, which is comparably warmer months of the winter, the outside air temperature was warmer compared to measurement conditions of other houses. Due to warmer weather conditions, these houses might have fired the stove fewer times. With over-ventilation, which can be seen from lower RH and lower carbon dioxide concentration as shown in figure 6 and figure 11, these uninsulated houses showed significantly lower indoor PM2.5 than outdoor PM2.5 durin this period.

2.7. AIR QUALITY INDEX

Air Quality Index (AQI) Values	Levels of Health Concern	Colors
0 to 50	Good	Green
51 to 100	Moderate	Yellow
101 to 150	Unhealthy for Sensitive Groups	Orange
151 to 200	Unhealthy	Red
201 to 300	Very Unhealthy	Purple
301 to 500	Hazardous	Maroon

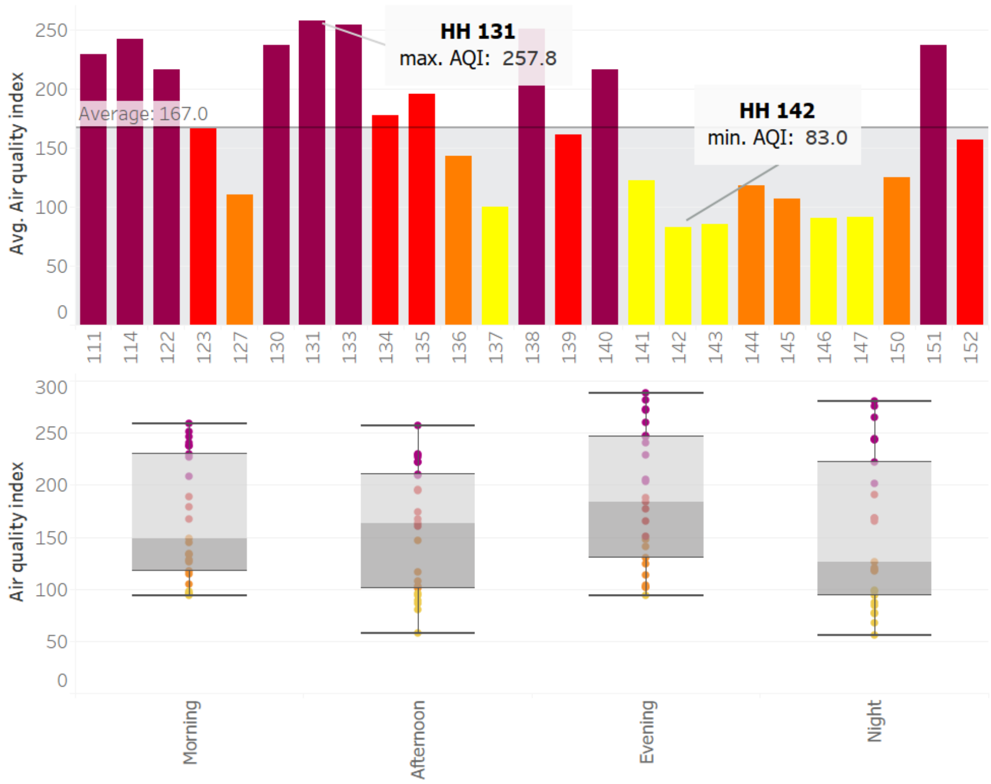
Table 7 Air quality index level (MN)

The daily air quality index for 9 of 29 households was very unhealthy, whereas 10 households were unhealthy. While there were only 6 HHs with moderate air quality, it was unhealthy for sensitive for 5 households. In fact, measurement date had a major impact on the result of the AQI because measurements that took place in January mostly showed the poorest AQI (first third house of the chart, HH151 and HH152) when February measurements had better results with moderate or unhealthy for sensitive groups AQI (from HH141 to HH 150 in the chart).

Depending on the time period of the day, there was a difference in the air quality, where air quality is much better during nighttime and the poorest during the evening due to evening is the peak time of Ulaanbaatar's air pollution. Outside air quality shows more impact on indoor PM2.5 and air quality indexes than the level of insulation of the houses.

Indoor air quality is not only dependent on electric heaters or households' behavior, level of insulation but depends upon outdoor air quality. Hence, outdoor air quality needs to be improved to improve indoor air quality in houses in the ger area.

Figure 14 Daily average air quality index of the houses



Comparison of outdoor and indoor AQI:

Outdoor AQI indexes were obtained from the U.S. Department of State (https://www.stateair.mn/), of which air quality monitoring station is located at the US embassy in Ulaanbaatar. Please note that outdoor AQI could have been most likely higher if it were measured in the midst of the ger area.

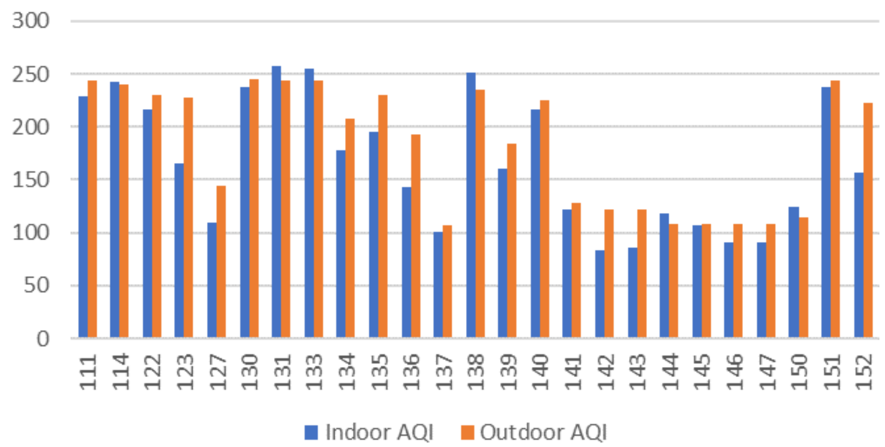


Figure 15 Outdoor and indoor AQIs

As individual house indoor air quality parameter measurements took place at different times, it was hard to compare and to see the impact of insulation or of the electric heater on indoor air quality. Therefore, outdoor AQI corresponding to each house's monitored date was obtained for comparing indoor and outdoor AQIs.

Among 4 of 6 insulated houses, which were using an electric heater, two houses (HH123 and HH127) show better indoor air quality with 27% and 24% differences compared to outdoor air quality because houses were using electric heater instead of stove addition to full insulation and ventilation (with filter) by the project. The houses were ventilating properly as normal RH, and lower carbon dioxide concentration was observed in figure

6 and figure 11. Thus, **the proper insulation and proper ventilation combined with an electric heater can improve indoor air quality more effectively.**

The rest which were insulated by the project and using the electric heater (HH111, HH130), had higher carbon dioxide concentration (figure 11), which is caused by occupant's behavior such as not ventilating the kitchen or rooms immediately after cooking or washing clothes, not ventilating the house long enough or keeping wall vents closed or not operating fans regularly, showed poor indoor air quality as well. **Even though the house is properly insulated and installed the ventilation, and having an electric heater did not necessarily provide better indoor air quality as it also depends on the occupant's behavior of properly ventilating.**

Among uninsulated houses, 6 (HH134, HH135, HH136, HH142, HH143, and HH152) had comparably better AQI, thanks to over-ventilation, which can be seen from lower RH and lower carbon dioxide concentration as shown in figure 6 and figure 11.

Uninsulated houses using combination of stove and electric heater (HH146 and HH147) had similar RH and CO_2 concentration with other uninsulated houses as shown in figure 6 and figure 11, but their indoor AQI is not improving much from outdoor AQI as the house lacks insulation and ventilation with filter.

2.8. FUEL CONSUMPTION AND HEATING DEMAND

Each house's fuel consumption was recorded by the households themselves according to the template provided. Three houses were heated by an electric heater only, three houses were heated by a combination of the stove with an electric heater, and the remaining houses were heated by the stove only.

To estimate total annual fuel consumption, it was necessary to:

- Obtain the total fuel consumption of individual houses within the monitoring period.
- Determine specific daily fuel consumption per degree day for the monitoring period
- Multiply the specific daily fuel consumption with heating degree days for a typical meteorological year with the following equations:

The Heating Degree Day (HDD):

$$HDD_{monitoring} = (t_{in.n} - t_{out.n}) \cdot n$$ ^{o}C*day, where:*

n – duration of monitoring period, day

$t_{in.n}$ – indoor mean air temperature during the monitoring period (^{o}C)

$t_{out.n}$ – outdoor mean air temperature during the monitoring period (^{o}C)

It is a measurement designed to reflect the demand for energy needed to heat a building. It is calculated by counting the missing degrees to reach a comfort temperature. It is usually used for the outdoor temperature to qualify a climate. The comfort temperature at **20°C** is selected as the same as the value used in the energy audit following the Mongolian Building Norm and Construction code and standards.

Specific daily fuel consumption:

$$m_n = \frac{M_n}{A * HDD_{monitoring}}$$ *kg.coal/m^{2o}Cday, where:*

m_n – specific fuel consumption, kg/ ^{o}Cday (if using electric heater kWh/ ^{o}Cday)

M_n – total fuel consumption of testing period, kg (if using electric heater it must be kWh)

A – Area, m²

Table 8 Monthly exterior temperatures for Ulaanbaatar (from October until May)

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Mean
Days	31	30	31	31	28	31	30	**212**
Outdoor air temperature, °C	-0.1	-12.4	-19.6	-23.1	-19	-10.2	1	**-11.8**

Source: BNbD 23-01-09 Climate and geophysical evidence of construction

Annual fuel consumption:

$$M_a = m_n \cdot (t_b - t_{out}) \cdot N * A$$ *kg.coal/a or kWh/a, where:*

M_a- annual fuel consumption, kWh/a or ton.coal/a (lignite)

m_n – specific fuel consumption, kg/ °Cday (if using electric heater kWh/ °Cday)

t_b – base temperature,°C (20 °C)

t_{out} – outdoor mean air temperature for typical year,°C (-11.8 °C)

N - heating period, d/a (212 d/a)

As some houses are using a combination of fuel and electricity for heating, specific daily consumption of each fuel (coal, wood, and electricity for an electric heater) are calculated separately in kWh, and their sum converted into annual fuel consumption with the above equation and into its coal equivalent. To compare fuel savings for retrofitted houses, lignite was taken into account as the fuel type instead of improved fuel. Currently, lignite is still being widely used in other towns and cities except for Ulaanbaatar.

To estimate annual heating demand:

Annual fuel consumption is converted into heating energy demand with a simple conversion, considering stove efficiencies. Stove efficiency was considered the same as the previous winter monitoring report, which is 33% and 50% for the traditional stove and improved stove, respectively.

Annual heating demand for electric heater:

$$E_a = M_a$$ *kWh/a or ton.coal/a*

Annual heating demand for coal or wood:

$$E_a = M_a \cdot NCV \cdot \eta$$ *kWh/a, where:*

NCV – net (low) caloric value of fuel, kWh/kg

η – efficiency of stove

Net calorific value (NCV) of the improved fuel was measured in several laboratories, as the state inspection agency stated; therefore, it is difficult to know the real value. Thus, we considered the improved fuel's NCV value as 6374 kcal/kg (**7.4kWh/kg**) as determined by the laboratory of the « Region Sever Zapad » in Russia. The NCV values of coal (lignite) and wood were taken from the same previous report and considered equal to **4.06kWh/kg** and **5.5kWh/kg** accordingly.

Specific heating energy demand per degree day:

To get a reasonable comparison of heating energy consumption of monitored houses, it is necessary to eliminate the effect from differences in heating area and weather. In this sense, specific heating energy demand per degree day was calculated based on monitoring data as follows:

$\text{Specific heating energy demand per degree day} = m_n * \eta$ kWh/m² °Cday, where:

m_n – specific daily fuel consumption, kWh/ m² °Cday

η – efficiency of stove

Therefore, the mean indoor temperature, area, and fuel consumption for the monitoring period are shown in Table 8.

Table 9 Fuel consumption for monitoring duration

ID	Monitoring			Average air temperatures, °c		Area, m2	Fuel consumption for monitoring duration, kg		Fuel consumption for monitoring duration, kWh		
	Start date	End date	Days	Indoor	Outdoor		Improved fuel	Wood	Improved fuel	Wood	Electricity for heater
111	2019.12.31	2020.03.20	80	23	-14.6	47	0	0	0	0	5200
114	2019.12.31	2020.03.20	80	23.1	-14.6	43	960	80	7104	440	0
122	2019.12.31	2020.03.20	80	20	-14.6	56	2240	0	16576	0	0
123	2019.12.31	2020.03.20	80	23.4	-14.6	32	0	0	0	0	3840
127	2019.12.31	2020.03.20	80	22.8	-14.6	60	2400	80	17760	440	1600
130	2019.12.31	2020.03.20	80	20.2	-14.6	49	0	0	0	0	3680
131	2019.12.31	2020.03.20	80	23.4	-14.6	64.2	2000	80	14800	440	0
133	2019.12.31	2020.03.20	80	25.4	-14.6	46.2	2080	0	15392	0	0
134	2020.01.20	2020.03.20	61	24.3	-12.9	19.6	1281	61	9479	335.5	0
135	2020.01.20	2020.03.20	61	25.7	-12.9	44.2	1830	61	13542	335.5	0
136	2020.01.20	2020.03.20	61	25.3	-12.9	46.3	1525	61	11285	335.5	0
137	2020.01.20	2020.03.20	61	25.9	-12.9	49	2013	244	14896	1342	0
138	2020.01.18	2020.03.20	63	25.9	-13.1	43.6	945	0	6993	0	0
139	2020.01.31	2020.03.20	50	26.5	-12.0	40.8	1000	0	7400	0	0
140	2020.01.31	2020.03.20	50	22.7	-12.0	38	1000	150	7400	825	0
141	2020.02.10	2020.03.20	40	24.3	-10.4	32.5	1400	0	10360	0	0
142	2020.02.10	2020.03.20	40	23.6	-10.4	32.5	1400	0	10360	0	0
143	2020.02.10	2020.03.20	40	19	-10.4	50.4	640	80	4736	440	0
144	2020.02.10	2020.03.20	40	23.8	-10.4	30	800	0	5920	0	0
145	2020.02.10	2020.03.20	40	22	-10.4	30	1120	0	8288	0	0
146	2020.02.10	2020.03.20	40	22	-10.4	40	1000	0	7400	0	840
147	2020.02.10	2020.03.20	40	24.7	-10.4	40	1000	0	7400	0	840
150	2020.02.10	2020.03.20	40	24.1	-10.4	42	1040	0	7696	0	0
151	2020.02.10	2020.03.20	40	24.3	-10.4	25.9	800	0	5920	0	0
152	2020.02.10	2020.03.20	40	21.4	-10.4	50	1200	0	8880	0	0

Specific daily fuel consumption and annual fuel consumption are shown in Figure 16.

Types of fuels being used in the houses are indicated in the chart with different colors. Three houses are using electric heaters solely whereas 2 houses are using a combination of stove and electric heater. Wood is consumed almost negligible compared to improved fuel. The fully insulated HH130 obviously has the lowest specific daily fuel consumption. The annual coal (lignite) consumption of each monitored house is placed inside the bar chart in the figure, and its average value is **8.2 tons**, as shown in Annex.3(not considering excluded house from average).

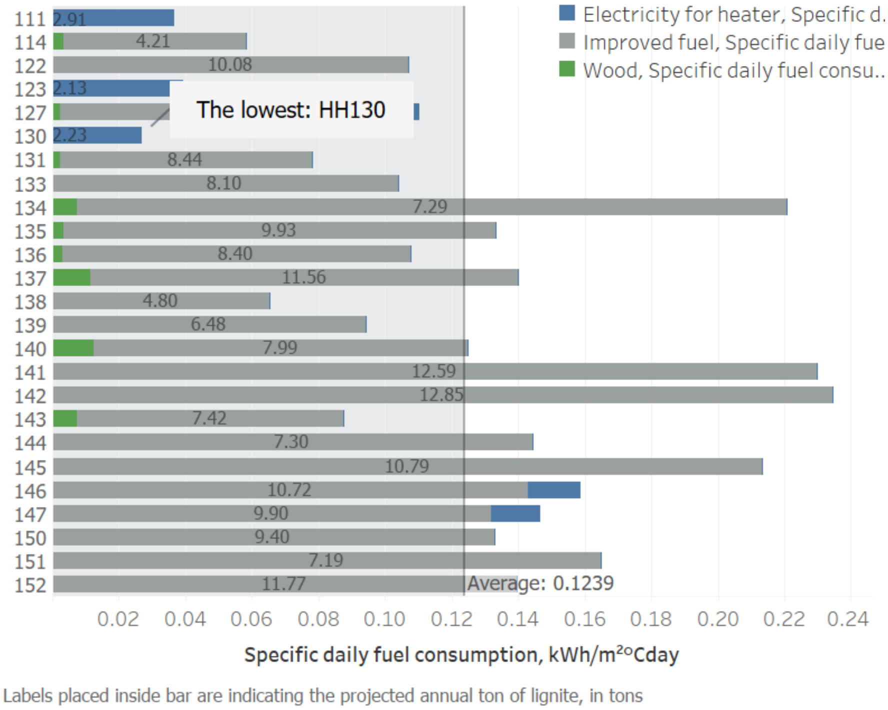


Figure 16 Projected fuel consumptions

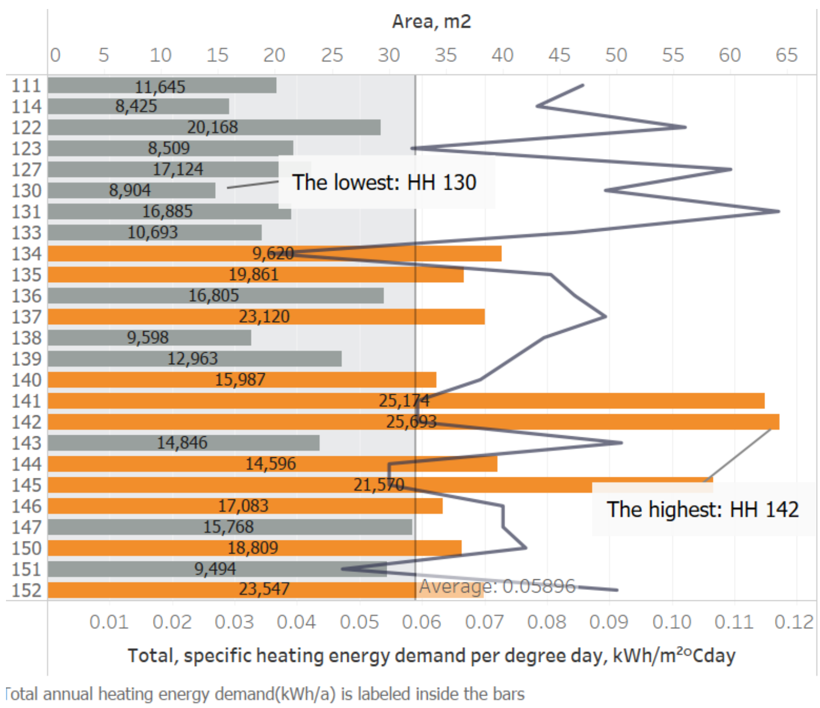


Figure 17 Specific heating energy demand per degree day

The estimated **average specific heating energy demand per degree day is 0.059kWh/m²°Cday** as shown in Figure 17**.** As mentioned before, the differences in weather and heating areas are corrected by estimating specific heating energy demand per degree day. The results show us a reasonable comparison between houses.

HH 130 with full insulation shows the lowest value. Houses indicated by yellow in figure 17 have higher heating energy demand than the average, 0.059 kWh/m²°Cday which would convert into 398 kWh/m² (considering HDD= 6741.6°Cday). Both “yellow” houses are non-insulated houses; thus, the results are normal, showing a tremendous heating energy demand for keeping houses warm.

On the other hand, having lower energy consumption than average does not necessarily mean that these houses actually have low heating energy demand as 0.059 kWh/m²°Cday would convert into 398 kWh/m².

The annual heating energy demand was labeled inside the bar chart in the above figure as well. The table results are in Annex.4.

Annual fuel consumption (figure 16 and annex.3) is in the 7th column below table 10, and annual specific fuel consumption is added for group comparison.

Table 10 Comparison of the fuel consumptions

1	2	3	4	5	6	7	
Insulation types(Nb.HH)	Nb.HH using electric heater	Fuel consumption for monitoring duration, kWh/m²			Annual specific fuel consumption,	Annual fuel consumption,	
		Improved fuel	Wood	Electricity for heater	kWh/m²a	kWh/a	Projected ton of lignite
EES 1- Full insulation (6)	4	132.4	2.9	55.4	**421.9**	20481.3	**5.1**
EES 2- Roof insulation (2)	0	238.7	0.0	0.0	**677.9**	33131.4	**8.3**
DIY insulation- Wall+Roof (1)	0	230.5	6.9	0.0	**526.0**	33770.0	**8.4**
DIY insulation- Wall (2)	0	305.2	17.5	0.0	**921.2**	42981.8	**10.7**
No insulation (14)	2	231.9	3.9	3.0	**1045.4**	36689.6	**9.2**

Note that electricity for heating is included in annual specific fuel consumption for comparison.

- Specific fuel consumption in Column 6 is highest for the groups “No insulation” and “DIY insulation-wall” due to lack of insulation, whilst it is lowest for the “EES-1 Full insulation” group.
- Both DIY groups had only a few HHs monitored. It is not enough to draw any conclusion. However, the results are normal as two HHs in the “DIY insulation-Wall” group had wall insulation with only 5cm EPS, and it is not really effective insulation. Meanwhile, the HH131 (DIY insulation wall +roof) insulated the wall with thinner insulation (10 cm thick EPS) and roof with a proper thickness (20cm) of fiber insulation shows better results than roof insulation group, however thinner insulation on wall, done by house owners without any supervision or participation of the project, does not work effectively as EES 1 group.
- EES-1 group shows outstanding results with specific fuel consumption of 422 kWh/m²a while the No Insulation group has maximum fuel consumption among all groups with 1045 kWh/m²a. No Insulation group consumes almost 2.5 times more fuel compared to fully insulated EES-1 houses. Also, the group EES-2 consumed two-thirds (64.8%) of fuel used in group No insulation.
- 4 of 6 houses in the EES-1 groups use electric heaters instead of stoves, while most houses (12 of 14) in the No Insulation group are using the stove. It is still early to draw any conclusion; however, it can be stated that better-insulated houses tend to use electric heaters whilst non-insulated houses use stoves more commonly.
- In most cases, the households use wood as additional fuel to start firing the stove. Hence, the quantity of wood used is small compared to coal.

Table 11 Comparison of heating energy demand

Insulation types(Nb.HH)	Nb.HH using electric heater	Specific heating energy demand per degree day (monitoring), kWh/m²°Cday				Annual heating energy demand, kWh			
		Improved fuel	Wood	Electricity for heater	**Total**	Improved fuel	Wood	Electricity for heater	**Total**
EES 1- Full insulation (6)	4	0.016	0.000	0.019	**0.035**	6364	164	5443.3	**10883**
EES 2- Roof insulation (2)	0	0.050	0.000	0.000	**0.050**	16566	0	0.0	**16566**
DIY insulation- Wall+Roof (1)	0	0.038	0.001	0.000	**0.039**	16398	487	0.0	**16885**
DIY insulation- Wall (2)	0	0.065	0.004	0.000	**0.068**	20295	1195	0.0	**21491**
No insulation (14)	2	0.067	0.001	0.002	**0.071**	16179	263	600.6	**17042**

Again, specific heating energy demand per degree day shows clear differences in heating energy demand of houses without any interferences of time of the monitoring, weather condition and heating area.

- EES 1 group has the lowest specific heating energy demand per degree day (0.035 kWh/m²°Cday), which is almost 2 times less (49%) when compared to that of the No insulation group (0.071 kWh/m²°Cday)
- Group EES 2 shows 1.4 times more (143% more) heating energy demand than the EES 1 group and having 70% of the heating energy demand of group No insulation.
- As mentioned before, the 2 HHs in DIY insulation-Wall do not have sufficient insulation; thus, its specific heating energy demand turns out to be similar to the No Insulation group.
- The group “DIY insulation- wall + roof”, shows low heating energy demand similar to EES 1.

2.9. GREENHOUSE GAS EMISSION

According to the fuel log, all 25 HHs analyzed in this report used between one to three different fuel types (improved fuel, wood, electricity) with one or a combination of two heating devices (traditional stove, improved stove, and electric heater). As aforementioned before, wood is mostly used as additional fuel to start firing the stove.

GHG emissions from the improved fuel and wood were calculated with the following formula and emission factor, which are stated in ADB guideline(Guidelines for estimating GHG emissions of Asian Development Bank projects, 2017):

$$GHG\ Emissions = FC * EF_{fuel}$$ tCO2/a, where:

- $GHG\ emssion$ – GHG emission from fuel consumption, tCO_2/a
- FC - Fuel consumption, ton.coal/a
- EF_{fuel} – fuel emission factor, tCO2/ton

Emission factor for improved fuel and wood were considered as 2.521 $TeqCO_2$/ton.coal (94.60 tCO_2/TJ with NCV 0.0282TJ/ton) as stated in ADB guideline and 1.747 $kgCO_2$/kg.wood as stated in IPCC respectively.

- GHG emission from electric consumption is calculated with the following formula and emission factor, which are stated in the ADB guideline:

$$GHG\ Emissions = EC * EF_{elec}/(1 - \%L)$$ tCO2/a, where:

- EC - Electricity consumption, MWh/a

- EF_{elec}–electricity emission factor, tCO2/MWh; (if electricity is from the grid, this refers to the grid emission factor), (1.192 tCO2/MWh)
- $\%L$ – transmission and distribution losses expressed as decimal equivalent (0.138, stated in the Energy statistics-2019, ERC)

Please see Table 12 for the GHG emission from each monitored house.

Table 12 Annual GHG emission from the houses

ID	Annual GHG emission, tCO2/a			
	Improved fuel	Wood	Electricity for heater	**Total**
111	0.0	0.0	16.1	**16.1**
114	5.7	0.3	0.0	**6.0**
122	14.5	0.0	0.0	**14.5**
123	0.0	0.0	11.8	**11.8**
127	14.4	0.3	5.0	**19.7**
130	0.0	0.0	12.3	**12.3**
131	11.8	0.3	0.0	**12.1**
133	11.7	0.0	0.0	**11.7**
134	10.2	0.3	0.0	**10.5**
135	14.0	0.3	0.0	**14.3**
136	11.8	0.3	0.0	**12.1**
137	15.3	1.2	0.0	**16.5**
138	6.9	0.0	0.0	**6.9**
139	9.3	0.0	0.0	**9.3**
140	10.4	1.0	0.0	**11.4**
141	18.2	0.0	0.0	**18.2**
142	18.5	0.0	0.0	**18.5**
143	9.8	0.8	0.0	**10.6**
144	10.5	0.0	0.0	**10.5**
145	15.6	0.0	0.0	**15.6**
146	13.9	0.0	6.0	**19.9**
147	12.8	0.0	5.6	**18.4**
150	13.6	0.0	0.0	**13.6**
151	10.4	0.0	0.0	**10.4**
152	17.0	0.0	0.0	**17.0**
Average	11	0.2	2.3	**13.5**

The average annual CO_2 emission from the monitored house is **13.5 tCO2/a**. This value differs from the result of the last year's monitoring (**7.6 tCO2/a**) due to improved fuel which has a higher NCV value than coal and electric heaters. This also varies among the houses related to the thermal performance of the house as well as floor area of the house.

To see the differences in GHG emission between each group, the annual average GHG emission is estimated separately as shown in Table 13.

Table 13 Comparison of average GHG emissions per EES groups

Insulation types(Nb.HH)	Nb.HH using electric heater	Area, m^2	Annual GHG emission, tCO2/a				Annual total GHG emission per area, tCO2/m²a
			Improved fuel	Wood	Electricity for heater	Total	
EES 1- Full insulation (6)	4	46.2	5.3	0.1	7.5	**12.9**	**0.28**
EES 2- Roof insulation (2)	0	48.4	11.9	0.0	0.0	**11.9**	**0.25**
DIY insulation- Wall+Roof (1)	0	64.2	11.8	0.3	0.0	**12.1**	**0.19**
DIY insulation- Wall (2)	0	46.6	14.6	0.8	0.0	**15.4**	**0.33**
No insulation (14)	2	37.2	12.8	0.2	0.8	**13.8**	**0.37**

Annual total GHG emission per area is added in table 13 to normalize GHG emissions for EES groups.

- The majority of the emission is from improved coal as most monitored houses use the stove for heating.
- Emission from EES 1 group being higher due to electric heaters is installed in most of the houses in this group (4 out of 6). Carbon emission from electricity consumption tends to be higher due to the low efficiency of power plants and grid systems.
- Group “DIY insulation wall+ roof” has the lowest GHG emission per area (0.19 tCO2/m²a) because having a house with a good insulation level and heated with a stove, not the electric heater.
- “No Insulation” shows the highest GHG emission per area (0.37 tCO2/m²a) among all groups evidently.

3. CONCLUSIONS

This winter monitoring had 29 HHs, and out of these households, 6 HHs participated in previous winter monitoring, and energy-efficient solutions were implemented in these houses as well. Unfortunately, the number of households, implemented EES solution to be compared in terms of energy savings reduced to 2 (1 EES-1 and 1 EES-2) households because three houses were eliminated from the analysis in the previous report due to unusual low consumption, and one house was taken out of analysis due to the same unusual low consumption in this winter monitoring. Therefore, it made before and after comparison analysis impossible. **A total of 4 HHs (14%) were taken out of the thermal performance analysis** because of unusual low temperature and high consumption bringing the total number of HHs analyzed to 25. **Out of 25 HHs, three were heated by an electric heater solely, and two houses were heated by a combination of electric heater and stove. The rest of the houses were using either conventional or improved stoves for heating.**

Parameters such as PM2.5 and air quality index were measured for the duration of 7 days in each household due to the availability of a measurement device; therefore, the time of each measurement did not happen to overlap at the same time. Measurement data were inherently not possible to make the comparison; thus, outdoor PM2.5 and outdoor AQI historical data were obtained from two available stations located at the U.S. embassy (AQI) and M.N.B. (PM2.5). Hence, we assume some limits for comparing indoor and outdoor air quality parameters because of differences in locations.

The winter condition recorded an average outside temperature of -15.5°C, which is warmer compared to previous winter (-19.2 °C) monitoring.

Air quality parameters, temperatures, and fuel usage were monitored, and estimations were done for each house to identify indoor air quality, thermal comfort, heating energy consumption, and GHG emission of each monitored house.

- **Forty-eight percent of the measured median RHs were in a comfortable range** which is stated in the MNS4585:2016 "Air quality. General technical requirement" standard. **RH increases depending on occupant's behavior,** such as not ventilating kitchen or rooms immediately after cooking or washing clothes, not ventilating the house long enough, or for houses with the ventilation system, it can be keeping wall vents closed or not operating fans regularly.

- **CO_2 concentration was within the acceptable limit for most of the houses**. CO_2 during evening and night-time was the highest due to house was more occupied and lower air exchange while CO_2 is the lowest during the afternoon due to fewer occupants in the house.

- CO_2 concentration was **high for HH111 and HH130 due to occupants' behavior of not properly ventilating (figure 6 and figure 11) even though these houses had the electric heater on top of proper insulation and ventilation system**. In contrast, similar houses with insulation and electric heater (**HH123 and HH127) had lower RH and lower indoor CO2, which means that these houses adequately utilized the ventilation system installed by the project.**

- **PM2.5 was higher than the acceptable limit for 72% of the houses** according to MNS4585:2016 "Air quality. General technical requirement" standard. The two houses (HH123 and HH127) show better indoor air quality with 66% and 74% differences in indoor and outdoor PM2.5 because houses were using electric heater instead of stove addition to full insulation and ventilation (with filter) by the project. The houses were ventilating properly as average RH, and lower carbon dioxide concentration was observed in figure 6 and figure 11. Thus**, the proper insulation and proper ventilation combined with an electric heater can decrease indoor PM2.5 concentration significantly. In contrast, HH111 and HH130 showed that even the house adequately insulated and installed the ventilation with filter, and having an electric heater did not necessarily provide a drastic decrease in the indoor concentration of PM2.5 as occupant's behavior of properly ventilating their house is essential.**

- **Air quality index turned out to be unhealthy for the majority of the houses (79%).** Among 4 of 6 insulated houses, which were using the electric heater, two houses (HH123 and HH127) show better indoor air quality with 27% and 24% differences compared to outdoor air quality because houses were using electric heater instead of stove addition to full insulation and ventilation (with filter) by the project. The houses were ventilating properly as average RH, and lower carbon dioxide concentration was observed in figure 6 and figure 11. Thus, **the proper insulation and proper ventilation combined with an electric heater can improve indoor air quality more effectively.** The rest which were insulated by the project and using the electric heater (HH111, HH130), had higher carbon dioxide concentration (figure 11), which is caused by occupant's behavior such as not ventilating the kitchen or rooms immediately after cooking or washing clothes, not ventilating the house long enough or keeping wall vents closed or not operating fans regularly, showed poor indoor air quality as well. **Even though the house is adequately insulated and installed the ventilation, and having the electric heater did not necessarily provide better indoor air quality as it also depends on the occupant's behavior of properly ventilating.** Among uninsulated houses, 6 (HH134, HH135, HH136, HH142, HH143, and HH152) had comparably better AQI due to over-ventilation, which can be seen from lower RH and lower carbon dioxide concentration as shown in figure 6 and figure 11. Also, **Indoor air quality is not only dependent on electric heaters, households' behavior, and level of insulation but depends upon outdoor air quality.** Hence, **outdoor air quality needs to be improved to improve indoor air quality in houses in the ger area.**
- **Depending on the level of insulation and heating device, daily indoor temperature fluctuation and temperature decay differed between the houses, as shown in** Figures {8, 9, and 10}. Indoor

temperature decreases more abruptly and quicker with higher indoor temperature variation between the time period of the day in non-insulated houses than insulated houses. There were were **8^{0}C to 50^{0}C temperature differences** for indoor air temperature, and the overall average temperature for all households throughout the testing period was **23.4℃.**

- **After the stove is fueled in the non-insulated house, the indoor air temperature decreases quicker than the insulated house, causing high-temperature fluctuation, more fuel consumption, and thermal discomfort.** In other words, in an insulated house, the heat stays longer, and indoor air temperature remains stable, improving thermal comfort in the houses. Additionally, the indoor temperature is comparably stable for fully insulated houses with electric heaters because of the electric heater's constant internal thermal regulation.

To see the differences in fuel consumption, heating energy demand, and GHG emissions between non-EES houses and EES houses **monitored houses were classified into five groups with no insulation (14HHs), EES 1-full insulation (6HHs), EES 2-roof insulation (2HHs), DIY wall and roof insulation(1HH) and DIY wall insulation (2HHs)**.

- In terms of fuel consumption and annual heating energy demand, the highest groups were “No insulation” and “DIY insulation-wall” due to poor insulation.

- **EES-1 group showed outstanding results with specific fuel consumption** of 422 kWh/m²a while the No Insulation group had maximum fuel consumption among all groups with 1045 kWh/m²a. **No Insulation group consumes almost 2.5 times more fuel compared to fully insulated EES-1 houses. EES-1 group had the lowest specific heating energy demand per degree day** (0.035 kWh/m²°Cday), **which is two times less (49%) when compared to that of the No insulation group** (0.071 kWh/m²°Cday).

- The group **EES-2 Roof insulation consumed two-thirds of (64.8%) fuel used in group No insulation. This group showed** 1.4 times more (143%) heating energy demand than the EES 1 group and having **70% of the heating energy demand of group No insulation.**

- Both DIY groups had only a few HHs monitored. The sample was not big enough to draw any conclusion. However, the results were normal as two HHs in the “DIY insulation-Wall” group had wall insulation with only 5cm EPS, and its specific heating energy demand was being similar to the No Insulation group showed that the insulation was not being effective. Meanwhile, the HH131 (DIY insulation wall +roof) insulated the wall with thinner insulation (10 cm thick EPS) and roof with proper thickness (20cm) of fiber insulation shows better results than roof insulation group, however thinner insulation on wall, done by house owners without any supervision or participation of the project, does not work effective as EES 1 group.

- 4 of 6 houses in EES-1 groups used electric heaters instead of stoves, while most houses (12 of 14) in the No Insulation group were using the stove. The better-insulated houses tend to use electric heaters, while non-insulated houses use stoves more commonly.

- GHG estimation was done for each household based on annual fuel and electricity consumption for heating. **The average annual CO2 emission from the monitored houses was 13.5 tCO2/a.**
- Emission from EES 1 group being higher due to electric heaters was installed in most of the houses in this group (4 out of 6). Carbon emission from electricity consumption tends to be higher due to the low efficiency of power plants and grid systems. Emission from group EES 2 shows similar results to EES 1.
- Also, group **“DIY insulation wall+ roof” has the lowest GHG emission per area (0.19 tCO2/m²a)** because having a house with an adequate level of insulation and heated with the stove, not the electric heater. **“No Insulation” shows the highest GHG emission (0.37 tCO2/m²a), among all other groups.**

4. FURTHER RECOMMENDATIONS

Previous winter monitoring did not have consumption of improved fuel and electricity for the electric heater. Therefore, a methodology for analysis such as greenhouse gas emission was different for this winter monitoring. When upcoming winter monitoring is conducted, the methodology should follow this report, and if there is any change, necessary modifications should be done.

4.1. NUMBER OF HOUSES MONITORED

For the 23 HH that has not implemented any of our EE solutions from this monitoring, we can consider them as our reference group for the upcoming winter monitoring. Also, these HH should be a priority if the owners have done some insulation work (EES).

In the future, the number of EES1, EES2, and non-EES households needs to be in a similar sample size which is a minimum of 10 HHs for each EES group, to be able to compare the different groups. For selecting the HHs, it is essential to ensure that they are willing to cooperate, for non-EES households, that they are eager to know more about heat loss from their house and to implement insulation in the future.

4.2. MONITORING DURATION AND DATES

The time period (60 days) was sufficient and recommended for upcoming WM. Also, it started early enough (31th December) to contain harsh weather and cold temperature. Therefore, it is recommended to start monitoring no later than December.

4.3. SHEET DATA :

In general, the data collected from the log sheet is entered on an excel sheet. It enabled the collection of data with fewer errors and sped up the process of analysis. For this upcoming monitoring, the data should be inserted in the main “Switch analysis monitoring excel document” using the last document as a template.

- Maps: A map should be done with the location of each HH monitored. Markers placed on a map should not include any personal information of HHs such as names or coordinates; IDs are preferred.
- Fuel consumption log sheet: To achieve precise fuel consumption, the process should be more simplified so that HH members don’t lose interest during the monitoring because of tedious input demand. Additional information should also be inserted for those having or using an electric heater (a special box should be present to log electric index). Also, frequent text messages can be delivered to the cell phone of the person in charge of logging from each HHs for notification purposes or volunteer workers supporting the process to follow up households in the fuel consumption logging process.
- Weather condition log: A daily note should be logged concerning “clear sky, snowy days or cloudy days”.

4.4. TEMPERATURE DATA

- Settings: Important to set each Testo thermometer on a half-hour base starting on the hour. No need to have all Testo start simultaneously (offset can be made later on at the analysis stage). Also, it is important to make sure all testos are calibrated. To do so, you should put all testo ahead of time in a specific place (one cold outside and one warm indoor) and look for outstanding values. They should be taken away, clearly marked as uncalibrated, and sent back to Geres HQ for recalibration.
- Positioning: According to this winter monitoring (2019-2020) analysis, the positioning was properly made. Beware of nearby leaking window or door. Follow the instruction on installation.
- Data collection: No problem detected.
- To calculate and evaluate thermal comfort, an additional temperature sensor should be installed on inside wall surfaces (MAKE SURE TO HAVE DATA LOGGER for the additional sensor) at the same time when the Testo thermometer set-up for monitoring. As using the number of temperature sensors

with loggers to be used on wall surfaces is expensive and complicated to install, collect and process data, it is best to use the globe thermometer when measuring thermal radiant temperature.

4.5. ELECTRICAL MONITORING

- In previous winter monitoring, we had electrical monitoring on either wall heater systems (WHS) coupled with an electric heater or electric radiators. A special wattmeter device will be installed on the electric control board (if available) on the specific fuse connected to the heater (if available); otherwise, it will be installed on the main phase of the house. The settings and instructions will be sent with the units.
- Data collection: A special attention will be made on the data collection as those device does not handle more than 1 month of data. It is crucial to collect data at least every 3 weeks to avoid loss of data. Also, there's specific instruction on collecting these data because 2 UNITS CANNOT BE PLUGGED ON THE SAME COMPUTER. The data on the computer will be corrupted from the first unit download. Therefore a file called 2SEDATA.db has to be deleted every time before plugging the unit on the computer.
- If the Wattmeter device is not available, then house owners should log their usage time of electric heaters and the power of their electric heater. My.tog.mn should have monthly electric meter indexes when logging in with username and password provided from the household.

4.6. CRITERIA FOR SELECTION OF HOUSEHOLDS

Household selection should consider following things :

1. Geographic scope
    - Security aspect, access easiness and closeness between HH.
    - Target khoroos: 7 th , 8 th , 9 th , 10 th , 11 th , 28 th , 31 st khoroo from Songinokhairkhan district and 15 th , 16 th , 17 th , 18 th khoroo from Sukhbaatar district
2. House type should be either Block/Timber/Brick Masonry/Plank.
3. Number of heated rooms
    - 3 heated rooms maximum per house
4. Number, orientation and area of living rooms
    - At least 1 living room per house
    - At least one sleeping room (if applicable)
    - Prefers one story house
5. Fuel Mix
    - the HH selected should be representative of the fuel mix found on the GER area (wood, coal briquette, electricity)
6. Stock of fuel
    - Families who are used to store at least 1 week of fuel for heating purpose.
7. Willingness:
    - As monitoring result depends on accurate and continuous fuel logging by house owners, it is very important to choose houses, with owner who are willing to collaborate with the winter monitoring activity.
    - Beneficial, if house owner is planning to insulate the house in near future.
8. Family situation:
    - Inclusion of vulnerable group should be considered.

4.7. ADDITIONAL REMARKS

Aside from the measures, the HH owners should report the benefits they get from the winter monitoring, such as more awareness on fuel consumption, thermal comfort, or on importance of proper insulation. This needs to be documented in the next winter monitoring.

In order to prevent data loss or further confusion, HHs need to be well informed and be ready to start logging their consumption at the beginning of the monitoring.

The results were based on data that was collected during monitoring. However, some households, who have implemented the energy-efficient solutions in their house by the project, did not much follow the suggestions given by the project team were observed numerous times in the data analysis. Hence, to collaborate better with house owners, further training for the importance of proper ventilation, indoor air quality, and energy-efficient behaviors needs to be given.

5. ANNEXES

5.1. ANNEX 1. PHOTOS OF SOME MONITORED HOUSES

	
ID: HH111	ID: HH114
	
ID: 122	ID: 123
	
ID: 126	ID: 127

5.2. MONITORED INDOOR AIR QUALITY PARAMETERS

ID	Indoor air CO2 ppm					Indoor air PM2.5 µg/m3					Air quality index					Level belong to average value	Average outdoor AQI	Average outdoor PM2.5, µg/m3	Difference in AQI, %	Difference in PM2.5, %
	Morning	Afternoon	Evening	Night	Average	Morning	Afternoon	Evening	Night	Average	Morning	Afternoon	Evening	Night	Average					
	06:00-11:59	12:00-17:59	18:00-23:59	00:00-05:59		06:00-11:59	12:00-17:59	18:00-23:59	00:00-05:59		06:00-11:59	12:00-17:59	18:00-23:59	00:00-05:59						
111	2763	1918	2356	2768	2451	182	167	124	173	162	241	227	205	244	229	Very unhealthy	244	254	6	36
114	1825	1493	1746	1865	1732	184	167	204	190	186	238	229	260	243	243	Very unhealthy	240	256	-1	27
122	1930	1314	1346	2037	1657	108	205	170	115	150	189	257	229	191	217	Very unhealthy	230	257	6	42
123	598	534	842	786	690	75	103	116	51	86	145	167	184	168	166	Unhealthy	228	257	27	66
126	782	779	786	822	792	88	107	138	103	109	156	173	205	162	174	Unhealthy	224	247	22	56
127	673	607	764	655	675	69	45	74	16	51	128	108	148	56	110	Unhealthy for sensitive	145	195	24	74
130	1825	1527	1788	1865	1751	184	173	220	190	192	238	195	273	243	237	Very unhealthy	245	254	3	24
131	785	766	783	709	761	191	166	232	230	205	246	222	282	281	258	Very unhealthy	244	253	-5	19
132	785	857	741	709	773	195	170	239	260	216	260	225	290	278	263	Very unhealthy	237	257	-11	16
133	479	519	547	536	520	195	173	222	211	200	251	230	272	265	255	Very unhealthy	243	253	-5	21
134	1098	937	1349	1372	1219	112	88	138	96	109	179	160	203	168	178	Unhealthy	208	225	15	52
135	954	830	1116	1205	1026	155	146	191	96	147	208	209	247	117	195	Unhealthy	230	238	15	38
136	836	721	746	692	749	74	94	111	39	80	133	163	177	98	143	Unhealthy for sensitive	193	194	26	59
137	988	934	1125	1022	1017	44	37	43	26	38	105	96	113	87	100	Moderate	107	139	6	73
138	694	820	775	678	742	173	149	238	225	196	230	210	288	276	251	Very unhealthy	235	248	-7	21
139	721	923	960	960	891	109	80	96	96	95	167	147	165	165	161	Unhealthy	185	210	13	55
140	903	563	758	959	796	166	131	186	139	156	227	196	241	201	216	Very unhealthy	225	257	4	40
141	1073	819	1062	1133	1022	71	57	71	35	59	134	116	141	99	123	Moderate	128	157	5	63
142	1014	733	622	871	810	32	16	42	29	30	96	58	94	84	83	Moderate	122	151	32	80
143	812	814	936	862	856	40	27	41	18	32	94	80	102	67	86	Moderate	122	151	30	79
144	1380	1179	1325	1673	1389	42	36	51	39	42	117	101	130	126	119	Unhealthy for sensitive	108	142	-10	70
145	1092	986	1096	1147	1080	56	37	57	30	45	114	94	124	94	107	Unhealthy for sensitive	108	142	2	68
146	613	741	814	620	697	40	33	40	26	35	95	89	102	77	91	Moderate	108	142	16	76
147	844	832	969	813	865	42	32	40	23	34	98	86	104	76	91	Moderate	108	142	16	76
148	757	1121	1095	795	942	122	100	106	70	100	179	169	170	132	163	Unhealthy	108	142	-50	30
149	900	650	1150	820	880	80	55	120	75	83	171	160	165	137	158	Unhealthy				
150	1157	997	1284	1347	1196	55	42	79	44	55	126	103	151	120	125	Unhealthy for sensitive	115	145	-9	62
151	643	553	584	708	622	204	161	193	162	180	259	222	246	222	237	Very unhealthy	244	253	3	29
152	799	846	107	926	670	86	111	120	57	94	149	174	188	118	157	Unhealthy	223	237	30	61
Average (25HHs)	**1060**	**916**	**1032**	**1128**	**1035**	**108**	**99**	**124**	**94**	**107**	**168**	**158**	**187**	**155**	**167**	**N/A**	184	207	-	-

5.3. ANNEX.3 THE ANNUAL FUEL CONSUMPTION

ID	Logging			Average air temperatures, °C		Area, m2	Fuel consumption, kg		Fuel consumption, kWh			Specific daily fuel consumption, kWh/m²°Cday				Annual fuel consumption,		Insulation group
	Start date	End date	Days	Indoor	Outdoor		Improved fuel	Wood	Improved fuel	Wood	Electricity for heater	Improved fuel	Wood	Electricity for heater	Total	kWh/a	Projected ton of lignite	
111	2019.12.31	2020.03.20	80	23	-14.6	47	0	0	0	0	5200	0.000	0	0.037	**0.037**	11645	**2.9**	**EES 1- Full insulation**
114	2019.12.31	2020.03.20	80	23.1	-14.6	43	960	80	7104	440	0	0.055	0.003	0.000	**0.058**	16850	**4.2**	**EES 1- Full insulation**
122	2019.12.31	2020.03.20	80	20	-14.6	56	2240	0	16576	0	0	0.107	0.000	0.000	**0.107**	40337	**10.1**	**EES 2- Roof insulation**
123	2019.12.31	2020.03.20	80	23.4	-14.6	32	0	0	0	0	3840	0.000	0.000	0.039	**0.039**	8509	**2.1**	**EES 1- Full insulation**
126	2019.12.31	2020.03.20	80	15.9	-14.6	23	1680	320	12432	1760	0	0.221	0.031	0.000	**0.253**	39173	**9.8**	**EES 2- Roof insulation**
127	2019.12.31	2020.03.20	80	22.8	-14.6	60	2400	80	17760	440	1600	0.099	0.002	0.009	**0.110**	44578	**11.1**	**EES 1- Full insulation**
130	2019.12.31	2020.03.20	80	20.2	-14.6	49	0	0	0	0	3680	0.000	0.000	0.027	**0.027**	8904	**2.2**	**EES 1- Full insulation**
131	2019.12.31	2020.03.20	80	23.4	-14.6	64.2	2000	80	14800	440	0	0.076	0.002	0.000	**0.078**	33770	**8.4**	**DIY insulation- Wall+Roof**
132	2019.12.31	2020.03.20	80	11.8	-14.6	25	1440	0	10656	0	0	0.202	0.000	0.000	**0.202**	33976	**8.5**	**EES 2- Roof insulation**
133	2019.12.31	2020.03.20	80	25.4	-14.6	46.2	2080	0	15392	0	0	0.104	0.000	0.000	**0.104**	32403	**8.1**	**EES 1- Full insulation**
134	2020.01.20	2020.03.20	61	24.3	-12.9	19.6	1281	61	9479	335.5	0	0.213	0.008	0.000	**0.221**	29151	**7.3**	**No insulation**
135	2020.01.20	2020.03.20	61	25.7	-12.9	44.2	1830	61	13542	335.5	0	0.130	0.003	0.000	**0.133**	39723	**9.9**	**DIY insulation- Wall**
136	2020.01.20	2020.03.20	61	25.3	-12.9	46.3	1525	61	11285	335.5	0	0.105	0.003	0.000	**0.108**	33611	**8.4**	**No insulation**
137	2020.01.20	2020.03.20	61	25.9	-12.9	49	2013	244	14896	1342	0	0.128	0.012	0.000	**0.140**	46241	**11.6**	**DIY insulation- Wall**
138	2020.01.18	2020.03.20	63	25.9	-13.1	43.6	945	0	6993	0	0	0.065	0.000	0.000	**0.065**	19197	**4.8**	**No insulation**
139	2020.01.31	2020.03.20	50	26.5	-12.0	40.8	1000	0	7400	0	0	0.094	0.000	0.000	**0.094**	25926	**6.5**	**EES 2- Roof insulation**
140	2020.01.31	2020.03.20	50	22.7	-12.0	38	1000	150	7400	825	0	0.112	0.013	0.000	**0.125**	31974	**8.0**	**No insulation**
141	2020.02.10	2020.03.20	40	24.3	-10.4	32.5	1400	0	10360	0	0	0.230	0.000	0.000	**0.230**	50349	**12.6**	**No insulation**
142	2020.02.10	2020.03.20	40	23.6	-10.4	32.5	1400	0	10360	0	0	0.235	0.000	0.000	**0.235**	51386	**12.8**	**No insulation**
143	2020.02.10	2020.03.20	40	19	-10.4	50.4	640	80	4736	440	0	0.080	0.007	0.000	**0.087**	29693	**7.4**	**No insulation**
144	2020.02.10	2020.03.20	40	23.8	-10.4	30	800	0	5920	0	0	0.144	0.000	0.000	**0.144**	29192	**7.3**	**No insulation**
145	2020.02.10	2020.03.20	40	22	-10.4	30	1120	0	8288	0	0	0.213	0.000	0.000	**0.213**	43140	**10.8**	**No insulation**
146	2020.02.10	2020.03.20	40	22	-10.4	40	1000	0	7400	0	840	0.143	0.000	0.016	**0.159**	42890	**10.7**	**No insulation**
147	2020.02.10	2020.03.20	40	24.7	-10.4	40	1000	0	7400	0	840	0.132	0.000	0.015	**0.147**	39589	**9.9**	**No insulation**
148	2020.02.10	2020.03.20	40	11.6	-10.4	69	800	0	5920	0	0	0.098	0.000	0.000	**0.098**	45395	**11.3**	**No insulation**
149	2020.02.10	2020.03.20	40	11.6	-10.4	27.6	800	0	5920	0	0	0.244	0.000	0.000	**0.244**	45395	**11.3**	**No insulation**
150	2020.02.10	2020.03.20	40	24.1	-10.4	42	1040	0	7696	0	0	0.133	0.000	0.000	**0.133**	37619	**9.4**	**No insulation**
151	2020.02.10	2020.03.20	40	24.3	-10.4	25.9	800	0	5920	0	0	0.165	0.000	0.000	**0.165**	28771	**7.2**	**No insulation**
152	2020.02.10	2020.03.20	40	21.4	-10.4	50	1200	0	8880	0	0	0.140	0.000	0.000	**0.140**	47094	**11.8**	**No insulation**
Average															**0.134**		**8.5**	

EES 1- Full insulation
EES 2- Roof insulation
DIY insulation- Wall+Ro
DIY insulation- Wall
No insulation
Excluded houses

5.4 ANNEX.4 THE HEATING DEMAND

ID	Specific heating energy demand per degree day, kWh/m²°Cday				Heating device	Annual heating energy demand, kWh			
	Improved fuel	Wood	Electricity for heater	**Total**		Improved fuel	Wood	Electricity for heater	**Total**
111	0	0	0.037	**0.037**	electricity			11645.1	**11645**
114	0.027	0.002	0.000	**0.029**	improved stove	7933	491	0.0	**8425**
122	0.053	0.000	0.000	**0.053**	improved stove	20168	0.000	0.0	**20168**
123	0.000	0.000	0.039	**0.039**	electricity	0	0	8509.0	**8509**
126	0.111	0.016	0.000	**0.126**	improved stove	17158	2429	0.0	**19587**
127	0.033	0.001	0.009	**0.042**	trad stove+electricity	13195	327	3602.2	**17124**
130	0.000	0.000	0.027	**0.027**	electricity	0	0	8903.6	**8904**
131	0.038	0.001	0.000	**0.039**	improved stove	16398	487	0.0	**16885**
132	0.101	0.000	0.000	**0.101**	improved stove	16988	0	0.0	**16988**
133	0.034	0.000	0.000	**0.034**	traditonal stove	10693	0	0.0	**10693**
134	0.070	0.002	0.000	**0.073**	traditonal stove	9291	329	0.0	**9620**
135	0.065	0.002	0.000	**0.067**	improved stove	19381	480	0.0	**19861**
136	0.052	0.002	0.000	**0.054**	improved stove	16320	485	0.0	**16805**
137	0.064	0.006	0.000	**0.070**	improved stove	21210	1911	0.0	**23120**
138	0.033	0.000	0.000	**0.033**	improved stove	9598	0	0.0	**9598**
139	0.047	0.000	0.000	**0.047**	improved stove	12963	0.000	0.0	**12963**
140	0.056	0.006	0.000	**0.062**	improved stove	14383	1604	0.0	**15987**
141	0.115	0.000	0.000	**0.115**	improved stove	25174	0	0.0	**25174**
142	0.117	0.000	0.000	**0.117**	improved stove	25693	0	0.0	**25693**
143	0.040	0.004	0.000	**0.044**	improved stove	13584	1262	0.0	**14846**
144	0.072	0.000	0.000	**0.072**	improved stove	14596	0	0.0	**14596**
145	0.107	0.000	0.000	**0.107**	improved stove	21570	0	0.0	**21570**
146	0.047	0.000	0.016	**0.063**	trad stove+electricity	12711	0	4372.3	**17083**
147	0.044	0.000	0.015	**0.058**	trad stove+electricity	11733	0	4035.8	**15768**
148	0.049	0.000	0.000	**0.049**	improved stove	22697	0	0.0	**22697**
149	0.122	0.000	0.000	**0.122**	improved stove	22697	0	0.0	**22697**
150	0.066	0.000	0.000	**0.066**	improved stove	18809	0	0.0	**18809**
151	0.054	0.000	0.000	**0.054**	traditional stove	9494	0	0.0	**9494**
152	0.070	0	0.000	**0.070**	improved stove	23547	0	0.0	**23547**
Average value				**0.065**					**16512**

EES 1- Full insulation
EES 2- Roof insulation
DIY insulation- Wall+Ro
DIY insulation- Wall
No insulation
Excluded houses