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switchasia

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CZECH REPUBLIC DEVELOPMENT COOPERATION

AFD

BUILDING ENERGY EFFICIENCY CENTER

REPORT FOR ACTIVITY 1.1.4

"QUALIFICATION OF EXISTING HABITAT AND HEATING SOURCES"

ДУЛААН ШИЙДЭЛ

SWITCH OFF AIR POLLUTION

2018

geres ACTING FOR CLIMATE SOLIDARITY

BEEC

GER COMMUNITY MAPPING CENTER

Монголын Барилгын Үндэсний Ассоциаци

PEOPLE IN NEED CZECH REPUBLIC

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1 INTRODUCTION AND BACKGROUND

1.1 BACKGROUND AND MOTIVATION

Mongolia is a developing country. which shifted from command economic system to market economic system just a few decades ago. causing various problems on one side. but also opportunities to improve and start everything from a new chapter on the other side. However. during this transition period there were formed many “Ger areas” due to poor organization and regulation from the government connected with domestic mechanical migrations of people from countryside to the city. Consequently. Ulaanbaatar city. initially designed and planned for about half million people. is accommodating more than one million citizens now. Accordingly. in “Ger areas” not connected to the central drainage and heating systems. raw coal consumption is increasing day by day causing numerous environmental problems. such as soil. water and air pollution. On the other hand. not only raw coal consumption is adversely affecting the surrounding environment. but poor thermal performance of detached houses and lack of professional knowledge in people when constructing or insulating their houses are some of the critical factors contributing to the currently existing problems in Ulaanbaatar city. Although some legal actions and measures are taken from the government with the assistance of international and domestic organizations. there is no concrete outcome positively impacting on air pollution reduction of Ulaanbaatar city.

Considering the aforementioned problems in Mongolia. in the framework of SWITCH-ASIA project a collaborative action and measurements are planned to be taken jointly from non-governmental organizations. universities. research centers and domestic institutions. Consequently. the main objective of this report is three-fold:

- Understand the general context of detached houses in Ger area

- Determine the existing anomalies and mistakes made when houses are constructed

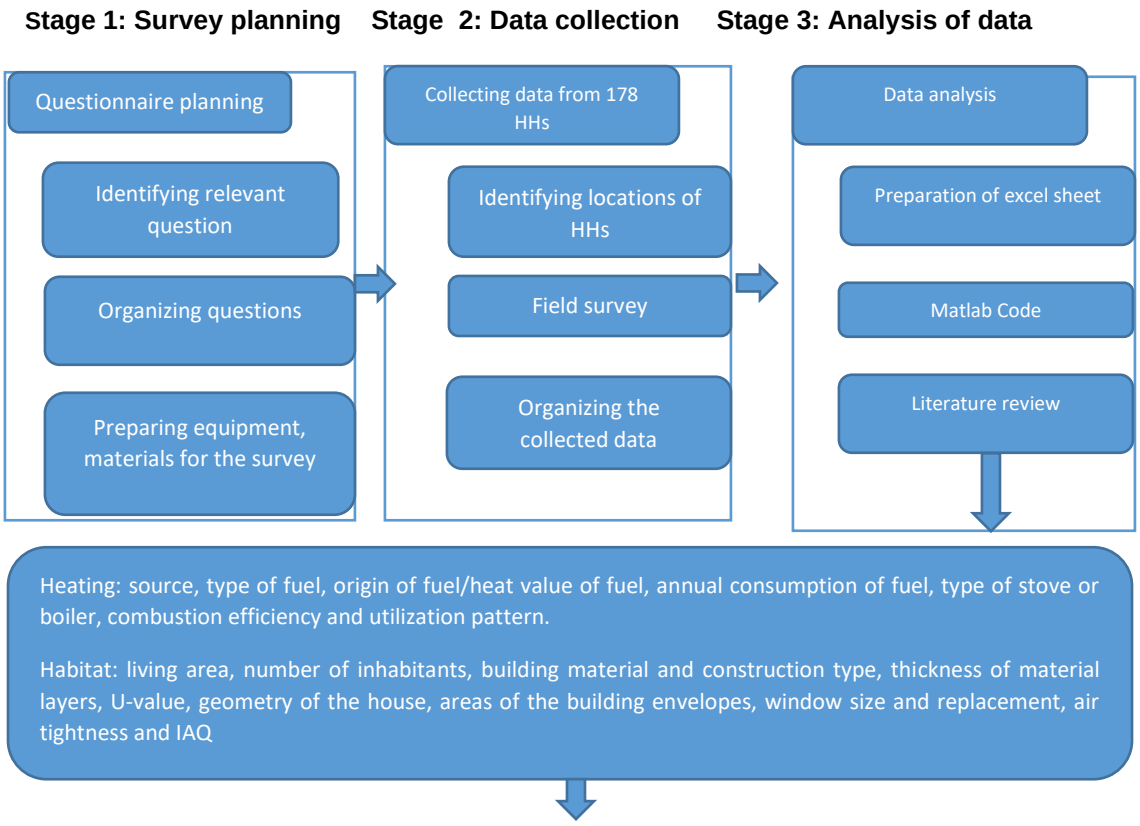
- Evaluate the energy performance of detached houses and use this knowledge for developing energy efficient and low cost solutions on insulation and reduction of raw coal consumption

1.2 COLLABORATIVE PROJECT –SWITCH ASIA

The work presented in this report was implemented as an initial stage to achieve the goal of Activity 1.1.4 - “Qualification of existing heating sources and habitat” of SWITCH ASIA project with the title of “Energy efficiency advisory and financial intermediation for sustainable housing in unplanned areas of Ulaanbaatar” funded by European Union.

1.3 GENERAL OVERVIEW/SCHEM OF THE RESEARCH

This research about energy performance of detached houses in Ger area consists of four different stages or parts, including survey/questionnaire planning, data collection, data analysis and solution proposal stages as shown in Fig. 1.



Stage 4: Solution proposal

Depending on the typology of houses and house materials, proposing solutions that are affordable and energy efficient.

Figure 1. Scheme of the research

2. GENERAL BACKGROUND OF THE SURVEY

2.1 SURVEY

In the framework of the SWITCH ASIA project. data from 178 households in ger areas were collected and analyzed. For the successful improvement of energy efficiency. preliminary background research and study are of crucial importance. Therefore. before the energy performance analysis and the development of energy rating calculation methods. a survey was carried out for each household considering its social. heating. indoor air quality. structural and geometric data.

A set of forms was developed to collect the information of households from various districts of Ulaanbaatar ger areas. The forms consist of four sections including general measurement data. household photo. geometrical drawing of the household and the thermal photo of the building.

In the general measurement section. location. number of people living in the household. heating source. fuel type. frequency of refueling. indoor air quality. insulation type. window and door types were collected. In the household photo section. photos from the four sides. window. heating stove and the general overview of the houses were taken. Based on the measurement of the house. plan view. front view and side view were drawn together with its geometric measurements in the third section of the survey. In the fourth section. the thermal photos of the building were taken to determine the energy heat losses of the households.

In this report. analysis of the collected data is presented mainly focusing on the first. second and third sections of the survey. For further improvement of the data analysis and energy performance calculation. classification of houses into several typologies depending on the wall. roof and floor structure were attempted.

2.2 HOUSEHOLD LOCATIONS

Ulaanbaatar city. located in the north central part of Mongolia. lies in the Valley of Tuul River and is surrounded by four mountains. It has nine districts: Bagakhangai. Baganuur. Bayangol. Bayanzurkh. Chingeltei. Khan-Uul. Nalaikh. Songino-Khairkhan and Sukhbaatar. Moreover. each district is subdivided into khoroos depending on its territory and population. When selecting households for collecting the data. Bagakhangai. Baganuur and Nalaikh were not considered. as they are located in the outskirts of the city center. implying less impact on air pollution. Among remained districts. several khoroos from Chingeltei. Sukhbaatar. Bayanzurkh and Songino-Khairkhan were chosen for the data collection due to its high density of detached houses and gers. not connected to central drainage and heating systems. Khoroos from these districts were selected randomly.

3. DATA ANALYSIS RESULTS

Data collected from 178 households were organized into similar typologies and their respective characteristics. including wall. roof. floor. window. door. heating. indoor air quality and social data were analyzed using MATLAB tools
(See Table 1).

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Table 1. Data analysis of 178 households

Household common pattern							
			Timber house (HH1)	Plank house (HH2)	Block house (HH3)	Brick/Masonry House (HH4)	For all houses
		TOTAL NUMBER OF HOUSES SURVEYED	**178**				
		TOTAL NUMBER OF DAMAGED HOUSES (Impossible to do measurement)	**4**				
0	**General**	TOTAL NUMBER OF HOUSES ANALYZED	**174**				
		Number of total houses surveyed	73	20	42	39	174
		Estimation % of total houses surveyed	42%	11%	24%	22%	100%
		House orientation	South(81%) / West (12%) / North (1%) / East (5%)	South (80%) / West (10%) / East (10%)	South (81%) / West (12%) / East (7%)	South (85%) / West (7%) / East (8%)	South(82%) / West (11%) / North (0.42%) / East (6.73%)
1	**Wall**	**Wall material composition**	**Timber wood + Insulation material**	**Plank wood + Insulation material**	**Block + Insulation material**	**Brick/Masonry + Insulation material**	**Structural material + Insulation material**
		Average wall insulation material, %	EPS (15%) / Wool (15%) / EPS+Wool (4%) / No insulation (66%)	EPS (10%) / Wool (15%) / EPS +Wool (15%) / No insulation (60%)	EPS (26%) / Wool (12%) /No insulation (62%)	EPS (18%) / Wool (10%) /EPS + Wool (3%) / No insulation (69%)	EPS (18%) / Wool (13%) / EPS+Wool (4%) /No insulation (65%)
		Average wall insulation material thickness (mm) - EPS / Wool	65 / 41	50 / 33.3	56.36 / 38	58.33 / 32.5	58.03 / 35.83
		% of houses that can be retrofitted	100%	0%	69%	92%	79%
		% of houses that needs insulation	91%	95%	95%	92%	93%
		% of houses that needs insulation improvement	4%	5%	3%	5%	4%
		% of houses that doesn't need insulation	5%	0%	2%	3%	3%
2	**Roof**	**Roof typology**	**Gable(93%) / Mansard(3%) / Flat(4%)**	**Gable (100%)**	**Gable(98%) / Mansard(2%)**	**Gable(97%) / Mansard(3%)**	**Gable(96%) / Mansard(2%) / Flat (2%)**
		Ceiling (Roof) material composition	Wood + Insulation material	Wood + Insulation material	Wood + Insulation material	Wood + Insulation material	Wood + Insulation material
		Roof insulation materials	Wool / EPS / Saw Dust / Ash / /Keramzit/ Shellac	Wool / Saw Dust / Ash / Shellac	Wool / EPS / Saw Dust / Ash / Keramzit	Wool / EPS / Saw Dust / Ash / Shellac	Wool/EPS/Saw Dust/ Ash / Keramzit/ Shellac
		Average roof insulation material and thickness (mm)	42.18 / 53.80 / 55 / 43.31 / 60 / 40	50 /50 / 47.5 / 50	38.08 / 49 / 48.57 / 26.67 / 85	36.36 / 46.43 / 75.00 / 55.00 / 77.5	37.06 / 50.49 / 54.29 / 42.92 / 76.7 / 56

		% of houses that needs insulation	79%	95%	76%	74%	79%
		% of houses that needs insulation improvement	12%	5%	19%	18%	14%
		% of houses that doesn't need insulation	9%	0%	5%	8%	7%
3	**Floor**	**Floor typology**	**Crawl space (49%) / Slab-on-grade (51%)**	**Crawl space (70%) / Slab-on-grade (30%)**	**Crawl space (7%) / Slab-on-grade (93%)**	**Crawl space (18%) / Slab-on-grade (82%)**	**Crawl space (35%) / Slab- on-grade (65%)**
		Floor material type	Wood/Concrete	Wood/Concrete	Wood/Concrete	Wood/Concrete	Wood/Concrete
		% of houses without any insulation	97%	95%	95%	95%	96%
		% of houses with some insulation	3%	5%	5%	5%	4%
4	**Window**	**Average number of windows**	**3.58**	**3.4**	**3.5**	**3.56**	**3.54**
		Frame type	PVC (58%) / Wood (42%)	PVC (40%) / Wood (60%)	PVC (86%) / Wood (14%)	PVC (69%) / Wood (31%)	PVC (65%) / Wood (35%)
		Layer of glazing	Double (99%) / Single (1%)	Double (85%) / Single (15%)	Double (95%) / Single (5%)	Double (92%) / Single (8%)	Double (95%) / Single (5%)
		Air tightness	Bad: 66% Medium: 30% Good: 4%	Bad: 85% Medium: 15% Good: 0%	Bad: 57% Medium: 43% Good: 0%	Bad: 68% Medium: 32% Good: 0%	Bad: 66% Medium: 32% Good: 2%
5	**Door**	Door type	Metal (53%) / Wood (47%)	Metal (55%) / Wood (45%)	Metal (57%) / Wood (43%)	Metal (59%) / Wood (41%)	Metal (56%) / Wood (44%)
		% of houses that has an entrance	82%	85%	81%	79%	81%
		% of houses without entrance	18%	15%	19%	21%	19%
6	**Heating**	**Average heated area (m2)**	**48.03**	**41.26**	**45.19**	**48.17**	**47**
		Fuel type	CW (84%) / CWE (14%) / E (1%)	CW (65%) / CWE (30%) / E (5%)	CW (83%) / CWE (14%) / CH (2%)	CW (90%) / CWE (10%)	CW (83%) / CWE (15%) / CH (1%) / E (1%)
		Average coal consumption (ton/year)	4.31	4.0125	4.57	4.84	4.13
		Average TeqCO2/HH/year	3.1	2.89	3.3	3.4	3
		Average wood consumption (m3/year)	1.023	0.7871	1.035	0.9929	0.992
		Average heat demand kWh/m2/year	179	199	202	201	176
		Stove types/ Electric heaters	CS combination: 38% IS combination: 52% WHS combination: 8% EH:1%	CS combination: 38% IS combination: 52% WHS combination: 8% EH:1%	C S c ombination: 29% I S c ombination: 55% WH S combination: 14% CH:2%	CS combination: 18% I S combination: 49% W HS combination: 33%	CS combination: 31% IS combination: 52% WHS combination: 15% CH: 1 % EH: 1%
		Average indoor temperature (°C)	**18.39**	**16.74**	**18.77**	**18.25**	**18.3**
		Average humidity	36.8408	35.81	37.91	35.51	36.7

7	**IAQ**	Average CO2 concentration	1070.5	955.73	1004.6	1117.8	1051.8
		Average PM2.5 concentration	44	43.67	38.12	41.54	42.02
		Qualitative thermal comfort	Cold (4%) / Cool (52%) / Normal (29%) / Warm (15%) / Hot (0%)	Cold (10%) / Cool (50%) / Normal (40%) / Warm (0%) / Hot (0%)	Cold (5%) / Cool (57%) / Normal (33%) / Warm (5%) / Hot (0%)	Cold (5%) / Cool (67%) / Normal (26%) / Warm (3%) / Hot (0%)	Cold (5%) / Cool (56%) / Normal (31%) / Warm (8%) / Hot (0%)
		Ventilation	Ventilation: 11% No ventilation: 89%	V e nt i l ation: 30% No ventilation: 70%	Ventilation: 31% No ventilation: 69%	Ventilation: 41% No ventilation: 59%	Ventilation: 25% No ventilation: 75%
		Condensation	Condensation: 60% No condensation: 40%	Condensation: 55% No condensation: 45%	Condens ation:83% No condensation: 17%	Condensation: 77% No condensation: 23%	C o nd e nsation:69% No condensation: 31%
8	**Social**	**No. of inhabitants during day**	**1.5753**	**1.35**	**1.45**	**1.64**	**1.53**
		No. of inhabitants during night	4.0959	4	4.38	4.41	4.22

4 TYPOLOGY OF HOUSEHOLDS

4.1 GENERAL

The initial plan of the study was to measure data from 178 households. from which 4 of them were impossible to further live in. retrofit. improve and measure the relevant parameters for the study. Therefore. in total of 174 households were analyzed to evaluate and understand the current situation of households from technical point of view. All households were divided into 4 different typologies of houses. including timber. plank. block and brick houses depending on their main structural material. Among 174 houses (See Fig.2):

- Timber – 73 households
- Plank – 20 households
- Block – 42 households
- Brick – 39 households

Orientation of the houses were determined depending on the area of the window. The direction. which has the largest area of windows. was defined as the orientation of the house. As can be seen from the summary table. most of the houses face to the south.

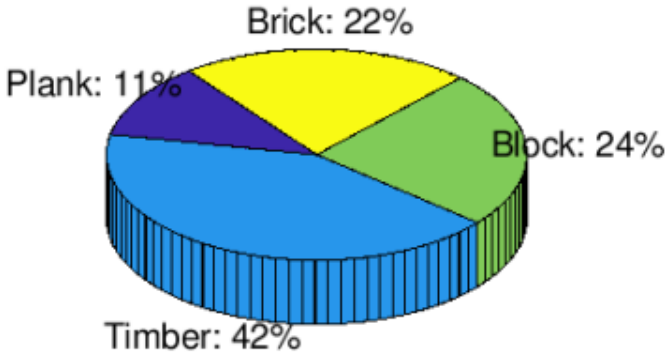


Figure 2. Typologies of households

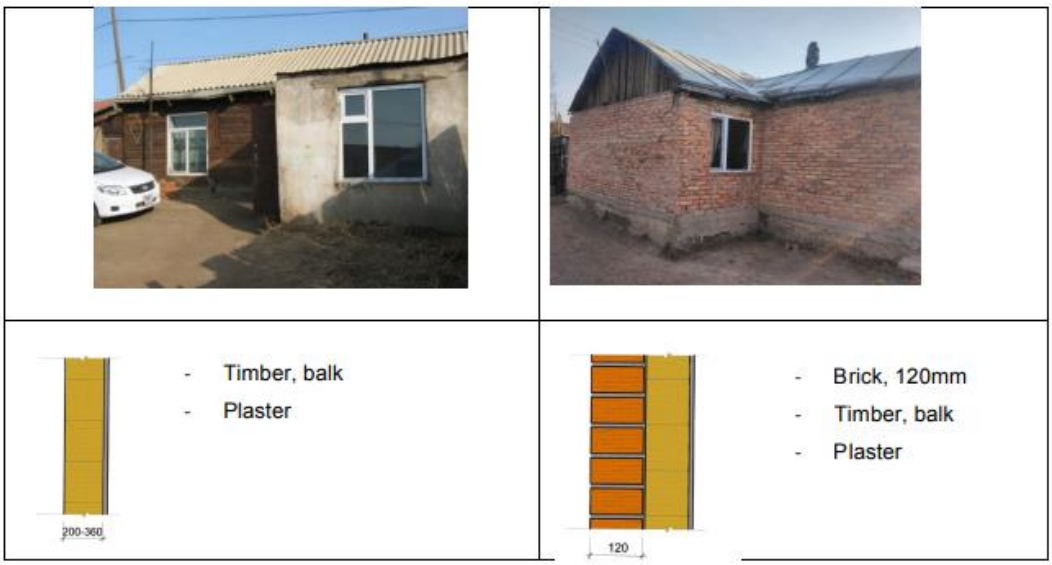
4.WALL

4.2.1 Typology

Depending on the main structural material of the wall households were classified into 4 different typologies. including timber. plank. block and brick.

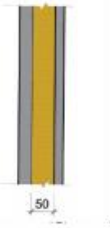
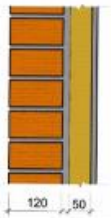
a. Timber – household wall is made of wooden material such as timber and balk. the thickness of which is more than or equal to 7cm. Among the houses that were classified as timber. there were several houses that were made of brick and wood in combination. These houses were classified as timber. because brick was used as a façade material for the house. Some of the representative houses are shown in the Table 2.

Table 2. Timber wall structure



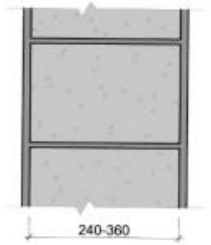
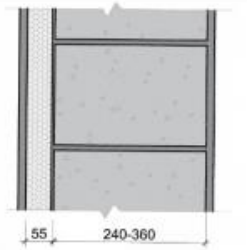
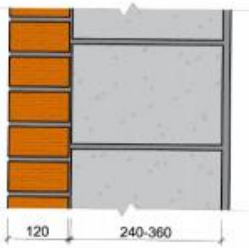
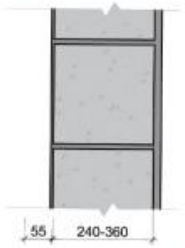
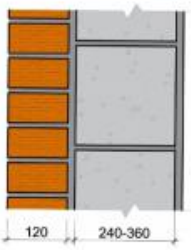
b. Plank – the main wall material is wood with the thickness less than 7cm. It is common to use plaster or clay from both sides of the wall. sometimes brick is used as a façade material (Table 3).

Table 3. Plank wall structure

	
 - Plaster/Clay - Plank - Plaster/Clay	 - Brick, 120mm - Plank - Plaster/Clay

c. Block – the main wall material is light concrete block or concrete block with hole. For some houses brick is used as a façade material (See Table 4).

Table 4. Block wall structure

		
 - Light concrete block - Plaster	 - Plaster - EPS - Light concrete block - Plaster	 - Brick - Light concrete block - Plaster
		
 - Concrete block with hole, 200mm - Plaster	 - Brick, 120mm - Concrete block with hole, 200mm - Plaster	

d. Brick – the wall of the houses is made of a brick (Table 5).

Table 5. Brick wall structure

4.2.2 Wall insulation

Most of the households having some insulation used EPS. wool or EPS and wool combination. Depending on the degree of insulation. houses were divided into three types:

- Houses that need insulation: houses that have no insulation at all or some EPS or wool insulation with thickness less than or equal to 5cm.

- Houses that need insulation improvement: houses that have EPS or wool insulation with thickness more than 5cm. but less than 10cm.

- Houses that doesn't need insulation: houses that have EPS or wool insulation with thickness more than or equal to 10 cm.

Depending on the wall material and its properties. walls were classified according to its possibility of retrofitting:

- **Impossible to retrofit**: Although additional insulation is needed. if the main structure of the wall cannot bear the load from additional insulation or impossible to anchor the insulation to the wall. it is considered as impossible to retrofit. Therefore. the following wall structures are considered as impossible to retrofit:

- Houses made of concrete block with hole – it is impossible to anchor the insulation to the wall (There were in total of 13 houses)
- Houses made of one-layer of brick – in this type of wall it is impossible to anchor insulation (There were in total 3 houses)
- Plank houses – plank houses cannot be insulated. as it cannot bear the additional load from insulation material (There were in total of 20 houses)

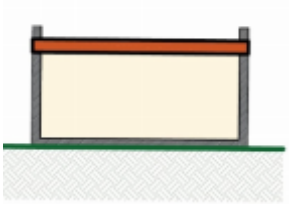
- **Possible to retrofit**: All other houses can be retrofitted.

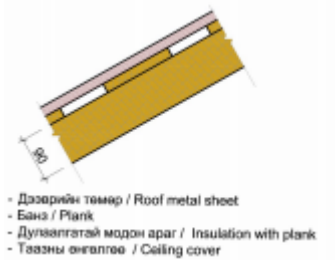
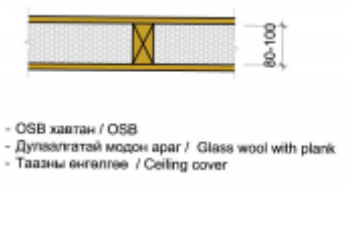
4.3 ROOF

4.3.1 Typology

All of the households regardless of the wall material have wooden frame for the roof (Table 6).

Table 6. Roof typology of households

Roof typology	Gable	Mansard	Flat
Criteria	Roof is angle-shaped Roof insulation is flat Roof space is not livable	Roof is angle-shaped Roof insulation is angleshaped Roof space is livable	Roof is flat shaped Roof insulation is flat No roof space
Schematic drawing			

Representa t ive picture			
Common structures			

4.3.2 Roof insulation

For the roof insulation. households used different types of materials. including foamed insulation (EPS). fiber insulation (glass wool. rock wool. mineral wool. etc.). sawdust. ash. keramzit and shellac. However. besides foamed and fiber insulation. all other material cannot be considered to be good insulation material even though their thickness is quite high. In the summary table. materials used for roof insulation are presented in Roof Insulation Materials row and their respective average thicknesses are presented in average roof insulation material and thickness (mm).

Depending on the degree of insulation. houses roofs were divided into three types:

- Houses that need roof insulation: houses that have no insulation at all or some EPS or wool insulation with thickness less than or equal to 5cm; houses with other insulation materials such as keramzit. sawdust. ash and shellac regardless of their thickness.

- **Houses that need roof insulation improvement**: houses that have EPS or wool insulation with thickness more than 5cm. but less than 10cm.

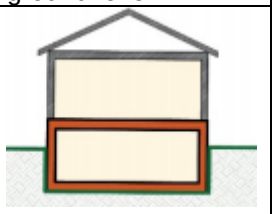
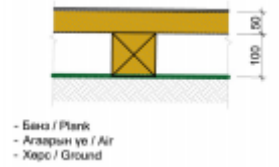
- **Houses that doesn't need roof insulation**: houses that have EPS or wool insulation with thickness more than or equal to 10 cm.

It is possible to do roof insulation for all the households regardless of their roof typology.

4.4 FLOOR

4.4.1 Typology

Table 7. Floor typology of households

Floor typology	With Crawl Space	Slab-on-grade	With Basement
Criteria	Floor is not attached to the soil/ground	Floor is attached to the soil/ground	House has a basement below ground level
Schematic drawing			
Common structures			Зоорьтой сууц байхгүй

4.4.2 Floor insulation

According to collected data. all of the houses need insulation. Therefore. houses were divided into:

- Houses with some insulation: although there is not sufficient insulation. if some insulation with EPS or wool exists

- Houses without insulation

It is expensive and costly to insulate the house from the floor. Consequently. it is better to insulate house foundation rather than the floor.

4.5 WINDOW

According to BNbD 23-02-09 households are required to have triple-

glazed windows. However. most of the houses have double-glazed windows.

Two frame types are commonly used in Ger area households. including wood and pvc frames (Table 8).

Table 8. Frame types of window

Frame type	PVC	Wood
Representative picture		
		

Depending on frame and type. windows can be classified into:

- Need replacement of the window: If the window is single-glazed or its frame is wooden. then window should be replaced.
- Need improvement of the window: If air tightness is not good enough. pvc-framed windows should be improved.

4.6 EXTERIOR DOOR

Exterior door of households were mainly made of wood or metal sheet. It is common to have entrance part to the house (Table 9).

Entrance: additional part outside of the exterior door. which protects house from wind or cold.

Table 9. Door entrance

With entrance	Without entrance
	

4.7 HEATING

1. Stove classification

There are four general types of heating stoves or devices including (Table 10):

o **Common stove / common stove combination**: common stove is a traditional stove used in Ger areas. usually with low combustion efficiency. It can be combined with several other devices such as wall stove and electric heaters.

o **Improved stove / improved stove combination**: improved stoves were distributed to Ger area households in the framework of Stove replacement programs from World Bank and UBCAP projects. Some households use improved stove combining it with wall stoves. electric heaters or common stoves.

o **Water heating stoves / water heating stove combination**: water heating stoves can be either be combined with improved stove. common stove or electric heater.

o Electric heaters: if the household is using electric heaters only. then it will be classified into this category.

Some of the data are compared depending on the type of stove. as shown in Table 11 and Table 12.

Table 10. Stove types

Stove type	Picture	Combination picture
Common stove/ common stove combination		
Improved stove / Improved stove combination		
Water heating stove Water heating stove combination		
Electric heaters		

Table 11. Characterization of heating system for households

a. **CS combination stove**

Average coal consumption (ton/year)	4.4 ton/year
Average wood consumption (m3/year)	0.28 bag/day
Average CO2 concentration	1033
Average PM2.5 concentration	44.8
Average heated area (m2)	52.3
Average indoor air temperature (°C)	18.3

b. **IS combination**

Average coal consumption (ton/year)	4.8 ton/year
Average wood consumption (m3/year)	0.26 bag/day
Average CO2 concentration	1028
Average PM2.5 concentration	39.9
Average heated area (m2)	49.7
Average indoor air temperature (°C)	18.3

c. **WHS combination stove**

Average coal consumption (ton/year)	4.1 ton/year
Average wood consumption (m3/year)	0.28 bag/day
Average CO2 concentration	1175
Average PM2.5 concentration	40.7
Average heated area (m2)	60.6
Average indoor air temperature (°C)	17.4

d. CS combination stove

Average of electricity consumption (kWh/year)	Heater capacity 2.2 kWh so 2.2*14h*210 day = 6468 kW/year
Average CO2 concentration	894
Average PM2.5 concentration	40
Average heated area (m2)	49
Average indoor air temperature (°C)	17.7

e. **CH - Central Heating**

2. Annual heating demand calculation and CO2 emission

Average annual heating demand (kWh/m2/year) was calculated using average coal consumption of households. 4kWh of heat is generated from burning 1 kg of coal and the average combustion efficiency of stove is assumed to be 50%.

Table 12. Some criteria comparison by stove types

Row Labels	# of HHs	Heating area	Daytime /person/	Night /person/	Temp (^{0}C)	Humidity	Coal (tn/a)	Wood (bag/day)	Average CO2	Average PM2.5
Common stove	61	52.3	1.4	4.1	18.3	38	4.4	0.28	1033.5	44.8
Improved stove	92	49.7	1.6	4.3	18.3	35.3	4.8	1.26	1028.1	39.9
Water heater	18	60.6	1.7	4.6	17.4	40.1	4.1	0.28	1175.8	40.7
Central heating	1	88.9	0	4	24	16	0	0	1100	
Electric heater only	1	49	1	3	17.7	44	0	0	894	40
Electric heater only 2	1	90.5	2	5	18	40	0	0	2270	
Grand Total	**174**	**52.2**	**1.5**	**4.2**	**18.3**	**36.7**	**4.5**	**0.3**	**1051.8**	**42**

3. Fuel classification

Most of the households burn raw coal and firewood. In general. fuel were classified into: o CW: coal and wood combination o CWE: coal. wood and electricity combination o E: electricity only

INDOOR AIR QUALITY

Indoor air quality measurement were mainly made once from 7 to 9 am during survey data collection. Devices shown in Table 13 were used for the measurement.

IAQ parameter	Measuring device	Measuring device
Humidity		
CO2 concentration		
Temperature. humidity. CO2 concentration		

PM2.5