THE ENERGY EFFICIENCY OF PUBLIC BUILDINGS IN ARKHANGAI PROVINCE

Baseline study of Cemaaterr II project

FOREWORD

GERES is an international development NGO created in 1976. It works to improve the living conditions of the most vulnerable and fight against climate change and its impacts. The energy transition serves as a major lever for putting that solidarity into practice. And to that end, Geres encourages the development and rollout of innovative, locally-based solutions and supports territorial climate and energy policies.

Climate-energy: adaptation and mitigation measures in rural areas and secondary cities - CEMAATERR is a multi-countries project launched in November 2016 with the financial support of Agence Française de Development. It involves 4 areas particularly vulnerable to climate change in Benin, Cambodia, Morocco, and Mongolia. Through CEMAATERR, Geres aims to illustrate the importance of a territorial approach to fight climate change to reduce carbon footprint and increase resilience to climate change.

The second phase (2019-2022) aims at the four targeted areas:

- Consolidating multi-stakeholder planning and governance dynamics to initiate the territorial energy transition;
- Practically demonstrating the relevance and feasibility of deploying sustainable energy solutions adapted to the local context;
- Through a transversal component of the program, Geres favors the exchange of experiences, capitalization, and development of know-how to encourage the replication of these solutions on a larger scale and in other territories.

During the first phase of the project implemented in the Mongolian Province of Arkhangai, Geres and its partners conducted a community-based climate vulnerability and risks assessment. We organized training and awareness events allowing Province and Soum decision-makers, civil society, and citizens to understand climate change challenges better.

The building sector has been identified as a priority of the energy transition for subnational stakeholders with real responsibilities and a potential to federate other public and private local actors. The pilot construction of an energy-efficient bioclimatic public building in Erdenebulgan soum in 2018- 2019 has shown the interest and relevance of this type of construction to reduce the consumption of coal dependence, energy expenditure and improve the living conditions of users. Thus, the second phase of CEMAATERR-Mongolia aims at improving education conditions through three complementary axes:

- Pilot interventions in educational buildings demonstrating the feasibility and relevance of optimizing energy efficiency in public buildings to improve the comfort and well-being of occupants and users, reduce energy savings expenses and reduce air pollution;
- A gradual rise in skills of professionals in the building sector, allowing the emergence of a local supply of low carbon solutions related to energy efficiency services;
- Awareness of territorial stakeholders (public authorities, associations, citizens, etc.) and capacity building of subnational institutions for energy-climate planning and monitoring

The partner organizations:

- Geres Mongolia NGO
- Government of Arkhangai province
- Daatstai Khugjliin ireedui (Sustainable future development) NGO
- Arkhangai province Builders Association NGO

- Mongolia GIZ "Energy Efficient Building Refurbishment in Mongolia (EEP)" project

A project steering committee lead by the Deputy Governor of the Arkhangai province has been established, ensuring an inclusive multi-stakeholder process. It includes representatives of the following entities:

- Government of Arkhangai and its relevant departments (Land relations, constructions, and urban development; educational department)
- Arkhangai's Energy Regulation Council
- Citizen's Representatives Assembly of the Arkhangai province
- Arkhangai province's Builders Association NGO, representing professionals of the sector
- A representative of the "Energy-efficient building refurbishment in Mongolia" project implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)
- Daatstai Khugjliin ireedui (Sustainable future development) NGO representing the local civil society
- Geres NGO project team
- Decision-makers of the Soums

ROLE OF THE PROJECT STEERING COMMITTEE AND STAKEHOLDERS IN THE STUDY

1. The project steering committee lead and overviewed the study
   - To review and identify the frame of the study
   - To supervise the whole study, including technical, social, and policy issues
   - To support the multi-coordination between the departments and soum level decision-makers
   - To support the logistic of the study, especially at the soum level, such as supporting the field missions, to provide the inputs on the field work
   - To support the collection of the data and security
2. Project technical committee
   - To make a frame of the study based on the actual conditions of the public buildings in the province
   - To review the available raw data from the province, including 19 soums
   - To make a list and provide the all-existing data and energy consumption information of the buildings
   - To supervise the technical part of the study and regulation frames
   - To make criteria for the selection of the soum for the detail analyze
3. Energy regularity council
   - To collect information on the heating source, fuel consumption, electrical energy consumption, and operational cost data of the whole province
   - To provide the support for the communication between the private companies of the heating system
   - To support the communication between the province and regional level
   - To provide the existing policy frames, advise and review the whole study
4. Urban planning and land, construction department

- To collect the data information of the public buildings of the entire province and provide with necessary information
- To provide the blueprints of the public building's whole province
- To work on each region public building's current conditions and plan

5. A research organization BEEC LLC conducted the detailed analysis in the selected soums
   - To make a detailed analysis on the selected 6 soums to define the actual conditions of the public buildings
   - To perform the field measurement of the public buildings in the selected 6 soums
   - To meet with local decision makers and administration actors to identify the real conditions of the public buildings regarding energy efficiency…etc
   - To identify the main challenges of the public buildings in soum level, and gaps for the existing norm and building standards
   - To collaborate with local technical actors regarding the main challenges of the public buildings in the soum level, make an interview the key actors
   - To introduce the findings of the study to the project steering committee and ensure the result with key actors
   - Make an energy assessment of the public buildings, and provide the energy performance certificate of the 57 public buildings with recommendations
6. Geres GEX expert Mr. Marc Glass
   - To guidance the frame and methodology of the study
   - To review the and guidance estimations of the technical energy efficiency of the public buildings
   - To review the whole support study, support the conclusion and recommendations
   - To support and improve the findings of the study
7. Geres GEX expert Mrs. Marina Dubois
   - To add the energy-gender questionnaire on the survey about the energy efficiency of the household
8. Cemaaterr program coordinator Mrs. Clementine Laratte
   - To support and guidance the frame of the study
   - To review the whole study, support and improve the main findings of the study
9. Ceres Mongolia, country director Mrs.Beatriz Maroto Iqzuierdo
   - To guidance and identify the frame and methodology of the study
   - To review and guide the study, including the administrative support
10. Cemaaterr II Mongolia project, energy expert Enkhee Tsogtbaatar
    - To develop the ToR of the study and deliverables
    - To analyze the primary and secondary data collected from the stakeholders
    - To support and conduct the fieldwork in the soums
    - To develop the full study documents and to work on the study edition
11. Cemaaterr II Mongolia project, project assistant Mrs.Enebish Amarsaikhan
    - To collect the raw data and review it
    - To support the stakeholders for the study, all activity
12. Cemaaterr II Mongolia project, project manager Ms. Oyuntuya Batmunkh
    - To work on the ToR of the study and deliverables
    - To coordinate the stakeholders for the study, all activity
    - To work on the secondary data with stakeholders

- To organize project steering committee and technical meetings
- To support the fieldwork in the soums
- To review and edition, and designing

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ABBREVIATION

MoE-Ministry of Energy
MCUD-Ministry of construction and urban development
DLACUD-Department of Land Affairs, Construction, and Urban Development
ERC-Energy regulatory council
LRCUDD- Department of Land Affairs, Construction, and Urban Development
JSC-Join stock company
NGO-Non-Government Organization
PSC-Project steering committee
WHF-water heating furnace
HDD -heating degree day
GHG-Greenhouse gas
EPS-Expanded Polystyrene Sheet
MeERA- Meteorological and Environmental Research Agency
LEEAP-Local energy efficiency action plan
BNaC-Building Normative and Codes
MW-Megawatt
U value-Thermal transmittance
PRC-People's Republic of China
WHB-Water heating boiler

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SUMMARY OF STUDY

Under the CEMAATERR-II project, Geres conducted a baseline study of the energy efficiency in the public buildings of all 19 soums of the Arkhangai province.

The objective is to better understand the energy and building sector's energy efficiency and classify the issues of public buildings of soums using energy consumption and energy efficiency. In addition, analyzed existing data information of the public buildings regarding the energy efficiency issues in the whole province.

General analysis was covered over the 241 buildings of 18 soums on the available data obtained from the local authorities. An on-site detail study and analysis were conducted in 62 buildings of 6 soums from the 4 regions of Arkhangai selected by the Project steering committee. And, sampling a questionnaire has been addressed to 172 households of the Erdenebulgan soum.

Scope of the study:

To identify the actual conditions of energy efficiency of the public buildings in Arkhangai, the scope of the study have been defined by the Project steering committee and Geres:

- To classify into a common typology of the buildings in Arkhangai
- To identify the energy demand of public buildings, and carbon footprint from fuel combustion
- Energy assessment of the public buildings in the selected soums, identify the gaps
- To identify the actual energy and fuel consumption of the public buildings, and their cost
- Construction sector's applied regulation, standards for the public building, and the implemented programs
- Gender knowledge on the energy efficiency and gender issue at the households at the center of the province

Objectives:

- Classify Arkhangai province's public buildings into common classes by their construction structure and energy consumption.
- Identify the main gaps between the energy efficiency regulation and the field implementation
- Identify the common energy issues of a public building, and develop energy efficiency solutions

MAIN FINDINGS OF THE STUDY:

Construction classification of the public buildings: There are currently 241 public buildings in use of 18 soums of Arkhangai province. The public buildings' construction structure has been classified into four types: wooden construction, brick construction, rock construction, and lava stone block construction. Roughly 74% (178 buildings) have volcanic rock block masonry,19% has wooden structure. A total of sixty-two public buildings were assessed on-site, and heating energy consumption was determined to get an energy efficiency label. Of the 62 public buildings, 45 got "E," and 12 got "D" labels in the selected 6 soums.

Public building envelope: From the fieldwork result, it was clear that the majority of buildings have insulation issues. Out of 57 public buildings, only eight had insulated external walls correctly, and only two had insulated roofs as stated in the normative. The insulation of the floor and over shallow foundations have been disregarded entirely. The U value of the insulation and density is not meeting the norms and standards. Almost 70% of Arkhangai province territory is situated within the continuous and periodic permafrost range. As per construction objects, many buildings have cracks or damages, regardless of the selection of shallow foundation structures that shall prevent permafrost soil degradations.

Types of heating system and heat demand of the public buildings: Five soums of the Arkhangai are connected to the centralized heating system, and the rest 14 soums have individual or partial heating systems with water heating furnaces. Institutions with multiple buildings, such as soum schools and hospitals, have a partial heating system. A system that supplies various facilities from one heating source but not all buildings in the area. Most kindergartens, governor's offices, and police stations have heat-only boilers for the individual heating system. Of 18 soum, except Erdenebulgan, the annual total heating volume of public buildings in the heating season is 708800 m^3. Accordingly, the estimated heating loads of buildings will be Q=16 MW. Summary of the heat installed energy production capacity of the sources is 29.21 MW. (ERC of Arkhangai). Some public buildings have heat energy demand out of the installed capacity of water heating furnaces. The main factor of high demand is the heat loss through the building envelope.

Fuel consumption and greenhouse gas emission from the fuel combustion for the public building heating: The estimated annual coal consumption of the centralized heating system of Erdenebulgan soum and other public buildings of 18 soums is 28650 tonnes. Out of 39000 tons of CO_2 emission by heating public buildings, the maximum amount of GHG emitted in Erdenebulgan soum's centralized heating system with the total annual emission of 20040 tons of CO_2 or 51.4%. In Arkhangai province, most public buildings seem to use coal as a heating source, but in reality, some soums use only wood during the heating season.

Completability of the public buildings at soums with building norm and code: The surveyed buildings were assessed following "Building thermal performance" / BNaC 25-01-20 /. Out of the total 57 buildings surveyed, no facilities are meeting the normative requirements fully. The buildings surveyed were built following the 2009 norms1, so there were significant inconsistencies with the updated norms. One of the problems is the lack of construction norms and standards at the construction and planning stages. There was a building normative before 2020; there is a gap in the field's implementation level and normative supervision.

[1] BNaC 23-02-09 (MCUD, 2009)

STEPS OF THE STUDY

Geres developed the applied methodology of the baseline study. It involves energy consumption, construction structure, and GHG emissions from fossil fuel combustion in public buildings. To make a detailed study of current public buildings represents 6 soums were selected. The study's important information relied on a participative data collection with local authorities and Project steering committee members. Energy and fuel consumption, construction and general public buildings, climate data were obtained during the study. The study was conducted by the following three steps:

STEP 1. The development of research criteria and methodology: Research criteria and methodology were developed by Geres with advice and coordination of the project steering committee. Following actions were made during the 1 step:

- To precise the required data for the baseline study
- Meet with local authorities and PSC members regarding the attachable information
- Select main participants of the baseline study
- Select soums for the field study
- Develop a questionnaire and plan for the data collection

To develop a study frame and select study criteria and methodology following studies and reports were used as a literature review:

- Mongolia GIZ "Energy Efficient Building Refurbishment in Mongolia (EEP)" project
- Geres NGO "Baseline study report of the Switch Off Air Pollution" project
- GGGI Mongolia "Strategies for development of green energy system in Mongolia 2013-2035" 2015
- NAMA of the Republic of Serbia "Energy efficiency improvements in public buildings" project
- National and Arkhangai province's annual statistical report

To do the detailed field study, the Cemaaterr-II Project steering committee selected Khangai, Undur-Ulaan, Tsetserleg, Tsenkher, Ugiinuur, Khashaat soums. By the following criteria, 6 soums were selected:

- Location of soums (Weather and geophysical terms, distance from capital of Arkhangai province)
- The interest of the local decision makers of the soums (the result of the Cemaatter I project)
- Type of the heating system (Individual or centralized)
- Current conditions of the public buildings in the soums

STEP 2. The collection of data and information of public buildings: Data collection is the most important part of the study. To analyze current conditions and classify public buildings into common classifications, many data materials were collected by the local authorities, research organization, and the project team, supported by the Project steering committee. In order to obtain data and information following actions were maid:

- Make a list of necessary data allegeable to classify and evaluate public buildings
- Collection of the necessary data and information from the local authorities

- Field measurements to collect actual information of public buildings
- Data integration and primary data entry

The project steering committee advised and supported every step of the baseline study, especially the provincial Energy regulatory council, Urban development department, and Educational departments. As a result, the following data was collected through the study:

General statistics of soums: Total population, statistical information of soums, number of students and children currently constantly go to the educational organizations, number of employees of educational organizations, public organizations and belonging building number in soums.

Public building primary information: General building data such as established year, total area and volume of the building, blueprint number, and basic structure information of foundation, roof, wall, window types, construction envelope, and insulation types. Types of heating systems and capacity of heat source.

Energy and fuel consumption: Electrical consumption of the last 3 years, types of fuel, and fuel consumption data of the last 3 years.

Metrological data Arkhangai province: Climate data such as temperature, relative humidity, wind speed data of last 3 years.

STEP 3. Field measurement and study: Field measurement was conducted to identify actual public building conditions in the soums. Field measurement and study were carried out for 62 public buildings in the selected 6 soums. "BEEC" LLC has conducted field measurement and research. On the field study, the following activities have been done:

- Clarification of actual structure and measures of public buildings
- Energy efficiency assessment and classify by energy consumption
- Evaluation of heating system and ventilation conditions of the public buildings
- Define actual fuel consumptions and types
- To define electricity and heat energy consumption
- Identify common technical and exploitation issues of the buildings
- Evaluate completability of a public building with norms and standards
- Develop recommendations to increase energy efficiency for each building

As for the household study, households were selected randomly from the 3 zones of the Erdenebulgan soum. Two students from a local vocational training school were selected to conduct the survey. Construction structure, materials, and energy consumptions were studied through the sampling field survey of households and classified into the common classification by the building's structure.

DATA ANALYSIS

Classify public buildings by construction structure: To classify existing buildings into the common structure classification, made a quantitative analysis on the obtained primary information of construction structure.

Building energy efficiency performance: Analysis done by the approved national methodology BNaC 25-01-20 "Building thermal performance." using the field measures and survey results.

Compare public building heat demand and heat source capacity: Analysis of public building heat demand was estimated methodologies stated in the current construction norms and codes BNaC 41-02-05 "Heating system." To identify and compare the heat demand and heat source, quantitative analysis was done on the obtained primary data of the energy system from the local Energy Regulatory Council.

GHG emission of public buildings: Province level heat demand and GHG emission from combustion are estimated based on the public building primary information and fuel consumption data obtained from local authorities. Actual fuel consumption is used to estimate the actual GHG emission of public buildings in the selected soums. IPPC Guidelines for National GHG Inventories 2006 and B.Namkhainyam: Study determining GHG emission factor for Mongolia was used to estimate GHG emissions.

Energy-gender general understanding in the local community: Qualitative and quantitative data obtained through the survey and questionnaire were analyzed to evaluate the energy-gender general knowledge in the local community. The questionnaire included questions about general building information, fuel, and electricity energy consumptions (Annex 1).

Create maps of the analysis: To create maps, analyze quantitatively, and integrate all collected data into a database file on the software QGIS. Used QGIS open data source and Open street maps.

LIMITATIONS OF THE STUDY

Data collection: Some existing data did not cover the whole province, and some did not archive well. Such information on roof structure and insulation materials information was missing. Detailed monthly heating fuel consumption information for each soum was not specified, only information on total annual fuel consumption was recorded. Due to the project timeframe, a field study was held during the summer season. A team could not meet with the users of all public buildings.

To collect some data of public buildings in the province center Erdenebulgan soum had difficulties within the estimated timeframe of the study. So, the public buildings of Erdenebulgan soum were not analyzed in some analysis.

Field measurement and study: Indoor air quality, thermal comfort, related technical, administrative documentation, and well-being questionnaires could not be obtained completely because the baseline study was held throughout the summer holiday without students and administrative people. Identifying and evaluating covert construction works such as wall insulations and waterproofing layers was difficult.

As for households, some detailed information on the construction structure was missing. Some household owners did not know about their house materials because they bought them or did not directly participate in the construction. Our field researchers (students) could not measure insulation materials' thickness due to external wall overlay.

During the questionnaire, surveyors faced some difficulties with interviewers on the energy-gender subject and family members' participation in decision-making.

Data analysis: GHG emission from energy used for heating could not be estimated completely. Because of the installed integrated wattmeter, electricity consumption for the heating system could not be obtained separately from other electricity consumptions.

CHAPTER 1. CURRENT CONDITIONS OF PUBLIC BUILDINGS IN ARKHANGAI

1.1 CLIMATE OF ARKHANGAI PROVINCE

Arkhangai province is situated in the central part of the Khangai mountain range, and its territory comprises mountains, steppe, and plains. Over 70 percent of the province's territory is pasture land, almost 2 percent with hay fields, about 1 percent with the sown area, and 15 percent is covered with deciduous and coniferous forest.

Solar radiation: Solar heat, atmospheric circulation, depressions in the area are key factors to describe the local climate. The global solar radiation in Arkhangai province is 116-136 kcal/cm2 on average. The global radiation becomes 3-4 kcal / cm2 in winter when the sun's height decreases to the lowest level. The average annual global radiation is 30-37.7 kcal/cm2. The lower atmosphere is clear for 232-247 days and cloudy for only 9-18 days. The sun shines 2650-2750 hours a year in the province. The maximum duration of sunshine is 275 hours in June, and the minimum is 169 hours in December. The duration of sunshine is 55-63% of the average annual ratio. It averages 7-8 hours a day, 5.0-6.5 hours in November-December, and 9.2 hours in May-June.

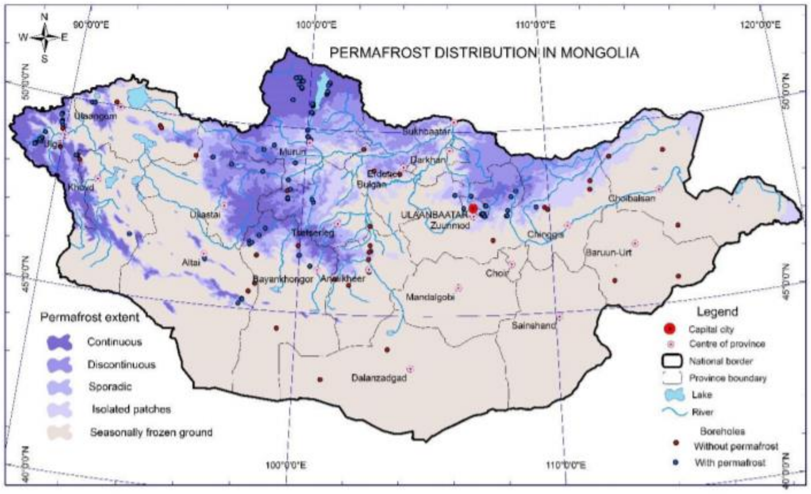
Outdoor air temperature: The average annual air temperature is -2 ...- 5°C in Tsakhir, Tariat, Terkh, North-South Tamir, Chuluut, Hanui and Hunui rivers, 0 ...- 2 ° C in the eastern part of Khangai mountain range, 0°C in Khashaat, Ulziit, Khotont and Battsengel soums that locate in the steppe zone. In January, the average air temperature is -20°C, -22.0 ...- 25.0°C in Terkh and Chuluut river valleys. In summer, the maximum temperature is observed, and the average temperature in July is 10-15 degrees celsius in the Khangai mountain range and 15-20 degrees celsius in other areas. The absolute maximum temperature reaches 35°C in the province, and the absolute minimum temperature reaches -53°C.

Shocking frostbite: In the mountainous areas of Arkhangai province, the soil and air are freezing in the first 10 days of September and the first ten days of October in the forest-steppe zone. In some years, there are cases of frostbite earlier than this average period on August 20 or around late September 25. On average, the last spring frosts are observed on June 1-10 in the back of Khangai mountain range, on May 25-30.

Soil temperature: The average annual ground surface temperature is between 0.8 ... 2.0°C. The average annual ground surface temperature is around -2°C in Tsakhir, Khangai, and Tariat soums. Permafrost is widespread in Arkhangai province. The average ground surface temperature is -16 ...-19°C, and the absolute maximum temperature is -43 ...- 45°C in the coldest month of December. The average ground temperature in July is +19 ... + 21°C, and the absolute maximum is +61…+62°C.

Permafrost: 70% of the Arkhangai province territory belongs to the continuous and intermittent permafrost zone. (Ya. Jambaljav 2017 Permafrost zone of Mongolia)

Figure 1. Permafrost region of Arkhangai



Source: 2016 Mongolia Third National Communication (TNC)

1.2 GENERAL INFORMATION'S OF PUBLIC BUILDINGS IN ARKHANGAI

Dedication of public buildings

Out of 241 buildings in 18 soums, secondary school-related buildings are the most dominant. Secondly, medical centers in soums are using 61 buildings for medical and warehouse purposes. The analysis was made on the quantitative data of public buildings obtained from the construction department. Public buildings of 18 soums of Arkhangai province are classified by the owner social organizations into the following groups:

- Secondary schools: School administration
- Kindergarten: Kindergarten administration
- Medical center: Medical organization of soum
- Government office: Soum governor's administration
- Cultural center: Cultural center administration
- Police stations: The police department of Arkhangai province

The following table shows the dedications of each building by their owning public organizations.

Table 1. Intended use of the public buildings

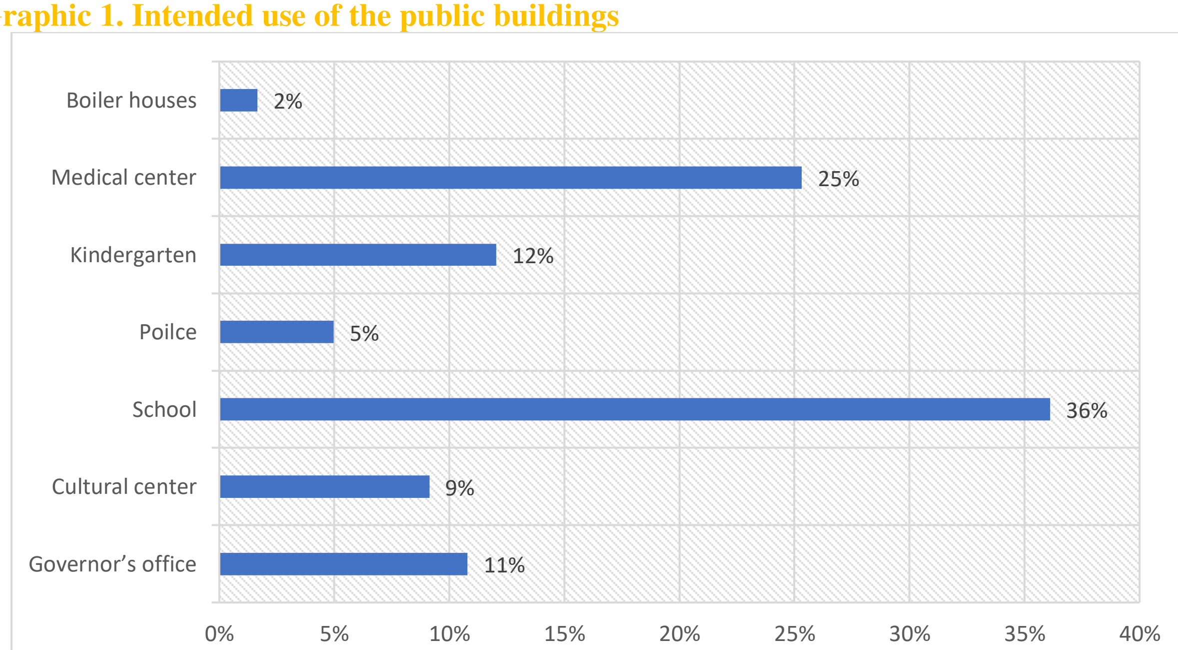
Public organization	Building dedication	Building quantity
Governor's administration	Garage	2
	Office	22
	Boilerhouse	1
	MaERA	1
Cultural center administration buildings	Museum	1
	Library	1
	Cultural hall	18
	Sport hall	2
School administration buildings	Dormitory	33
	Library	1

	Cultural	1
	Sport hall	9
	School building	41
	Boilerhouse	2
Kindergarten administration buildings	Kindergarten	29
Police administration buildings	Office	9
	Police stations	3
Medical center administration buildings	Garage	7
	Veterinary	2
	Morgue	2
	Supply supporting	12
	Boilerhouse	1
	Hospital	27
	Postpartum	10

Source: Arkhangai province LRCUDD database

The following graphic illustrates the designation categories of the public buildings and their ratio amongst all 241 buildings. From the graphic, 36% of all buildings account for classrooms, dormitories for school staff, students, and teachers, and kitchens for secondary schools. Most buildings, or 44%, account for public service buildings as hospitals, cultural centers, and governor's offices. 2% of all buildings are used as a boiler house for operating a centralized heating system.

Graphic 1. Intended use of the public buildings



Source: Arkhangai province LRCUDD database

Users of the public buildings

By the national statistics report of 2019, the Arkhangai province population is 94134. Most of the people are living in the province center in Erdenebulgan soum. As for, other 18 soums, people are more focused on living in the center of soums. Table 2 showing the population of each soum. All public organizations have their branches in each soum. It means everyone can have direct and indirect benefits from the energy efficiency of public buildings.

Around 5712 children, 661 employees, 18079 pupils, and 1789 teachers use educational buildings throughout the province. The following table shows the number of children and employees of each soum's academic organizations.

Table 2. Children and employees of educational organizations

Soum name	Population of soums	Children with age of kindergarten	Currently in kindergarten	Employees of kindergarten	Current student number in schools	Total teachers and staff in schools
Battsengel	3711	216	167	20	513	65
Bulgan	2702	178	99	17	250	41
Chuluut	4144	285	185	28	716	65
Erdenebulgan	21593	2517	2476	237	6582	510
Erdenemandal	5542	428	285	33	1035	103
Ikhtamir	5523	411	210	30	632	79
Jargalant	4371	303	208	25	848	85
Khairkhan	3722	260	160	23	680	75
Khangai	3188	228	127	21	381	50
Khashaat	3181	280	130	18	497	63
Khotont	4325	292	208	26	795	99
Tariat	4903	370	245	25	852	83
Tsakhir	2404	238	163	21	477	47
Tsenkher	5922	246	177	19	663	78
Tsetserleg	3772	253	163	24	671	78
Tuvshruulekh	2924	244	124	19	454	59
Ugiinuur	3099	254	140	21	533	59
Ulziit	3386	319	194	21	719	65
Undur-Ulaan	5720	391	251	33	781	85
Grand Total	**94134**	**7713**	**5712**	**661**	**18079**	**1789**

Source: Arkhangai national statistics association report 2019.

Aging of the public buildings

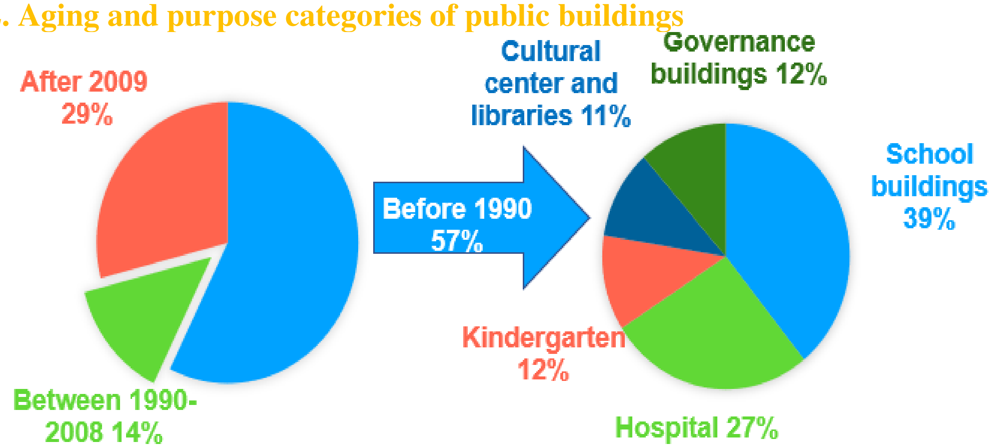
The primary data of 241 construction objects in 18 soum were collected and analyzed within the study's objectives. As for the aging of construction, buildings can be categorized into the following categories:

- Buildings built before 1990
- Buildings constructed between 1990-2008
- Buildings built after 2008

The reason for categorizing buildings by the categories mentioned above is that until the 1990s, public buildings were built according to building codes before 1990s. In 2008, when new building codes and regulations were approved, previously constructed buildings were categorized into the buildings constructed between 1990 and 2008. Rest public buildings are built after 2008.

Based on primary data of all the buildings of the 18 soums, 57% are the construction objects built before the 1990s. Out of these pre-1990 buildings, 39% are the buildings belonging to the schools, such a girls' and boys' dormitories, classroom building, kitchen, and warehouse construction

Graphic 2. Aging and purpose categories of public buildings



Source: Arkhangai province LRCUDD database

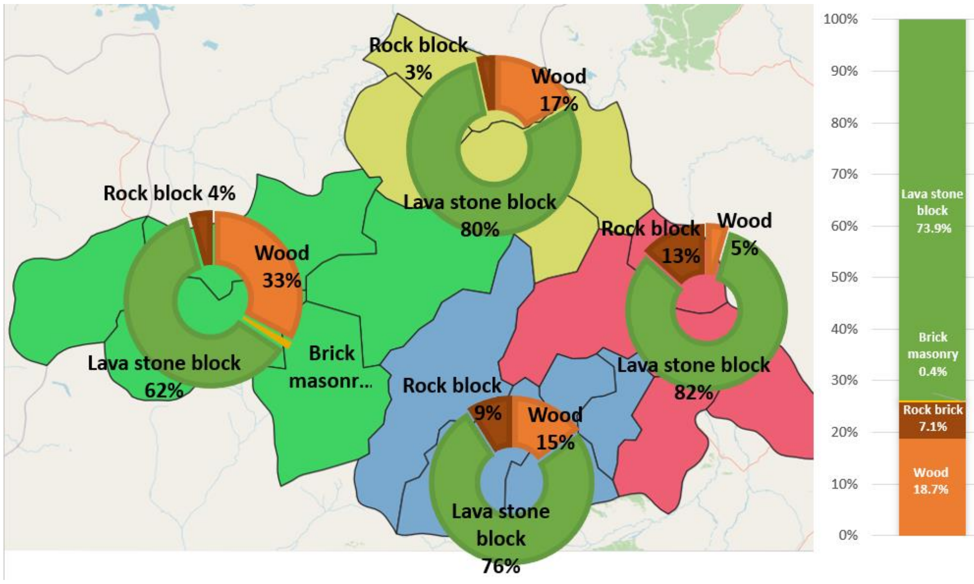
1.3 CLASSIFICATION OF PUBLIC BUILDINGS BY CONSTRUCTION STRUCTURE

Public buildings of the Arkhangai province can be classified into four categories based on the obtained information from the local authorities and from the result of the comprehensive study on the energy efficiency of public buildings in 6 soums. In the integrated database, public building's roof and insulation material information is not specified in detail. However, based on the construction structure materials are buildings:

- Wooden construction
- Brick construction
- Rock construction
- Lava stone block construction

Out of 241 buildings, 178 buildings have lava rock block construction, accounting for 74% of the total buildings. Lava stone is the most commonly used construction material in Arkhangai province. Typically, lava stone is crushed, mixed with cement, molded into the blocks, and used as masonry filling blocks. The following graph illustrates the ratio of construction structure type.

Graphic 3. Classification by construction structure

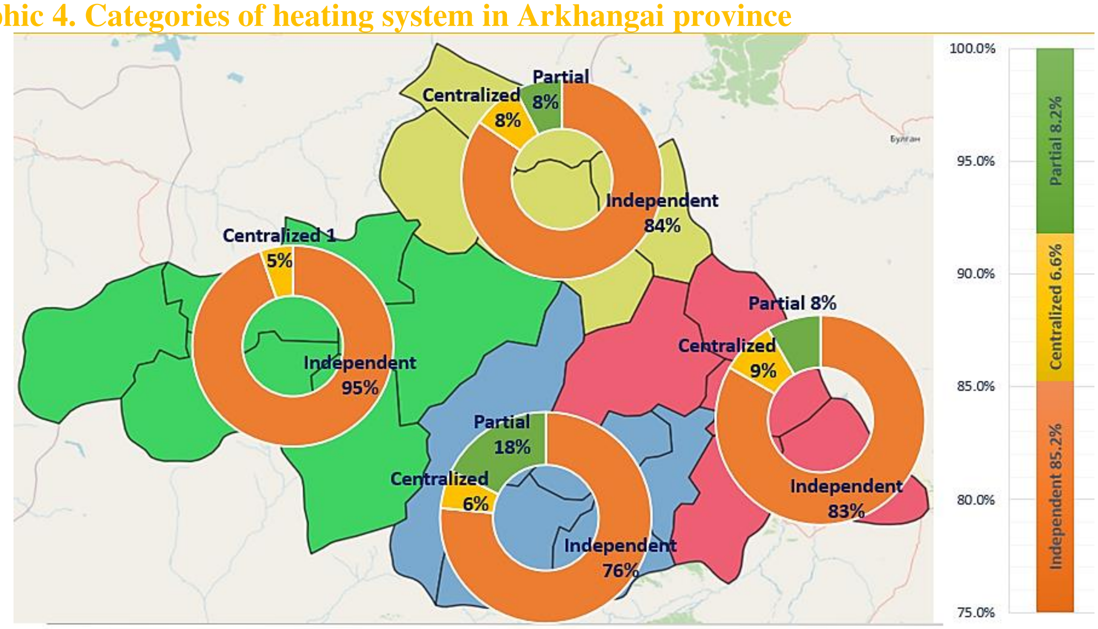


Source: Arkhangai province DLACUD database

1.4 HEATING SYSTEM AND COMMON WATER HEATING FURNACE OF PUBLIC BUILDING

The energy system infrastructure data analysis shows, obtained from the Energy Regulatory Council and General Architecture of Arkhangai, 5 soums are connected to the central heating system. The rest 14 soums have individual or partial heating systems. Public organizations with multiple buildings, such as soum schools and hospitals, typically have a partial heating system. A system that supplies various facilities by contract, from one heating source but not all public buildings in the area. Most kindergartens, governor's offices, and police stations have an individual heating system with heat-only boilers.

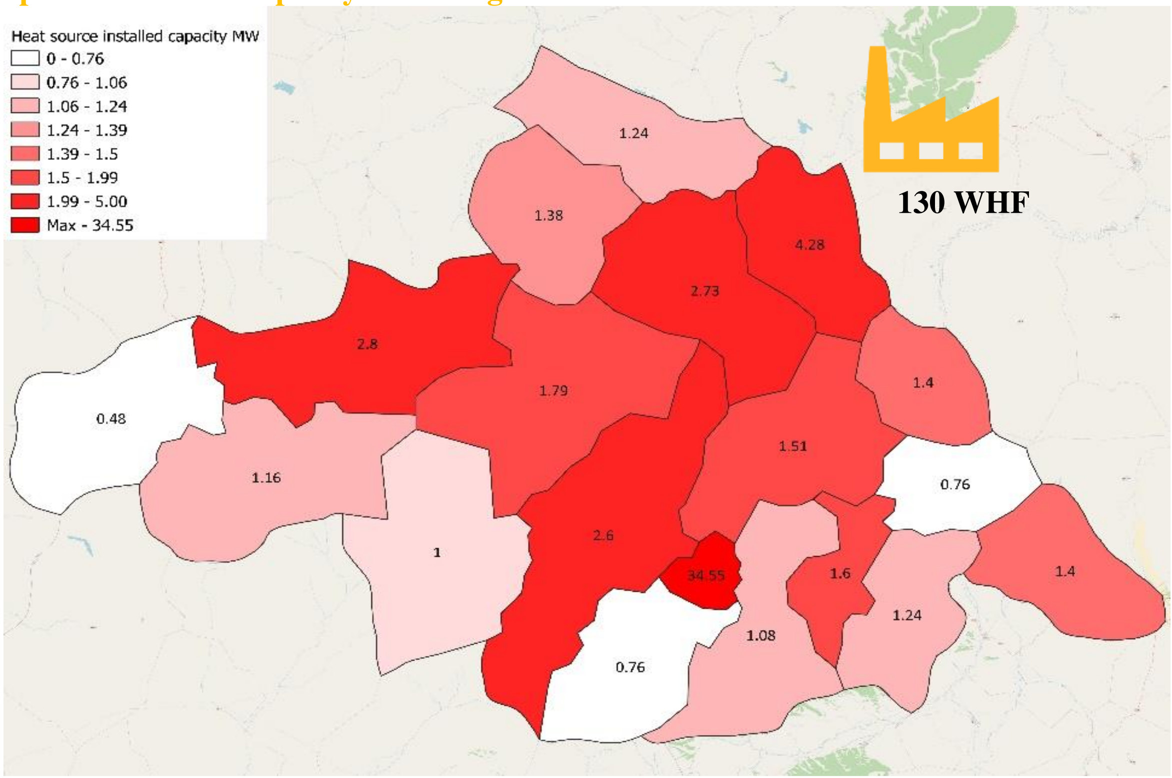
Graphic 4. Categories of heating system in Arkhangai province



Source: Arkhangai province Energy Regulatory Council database

The province center, Erdenebulgan is the soum with the highest heating demand, connected to the centralized heating system with a total capacity of 34.55 MW. On the other hand, the overall heating capacity of the 102 WHBs of the other 18 soum is 29.21 MW. The following graph shows the capacity ranks of WHB.

Graphic 5. Installed capacity of heating sources



Source: Arkhangai province Energy Regulatory Council database

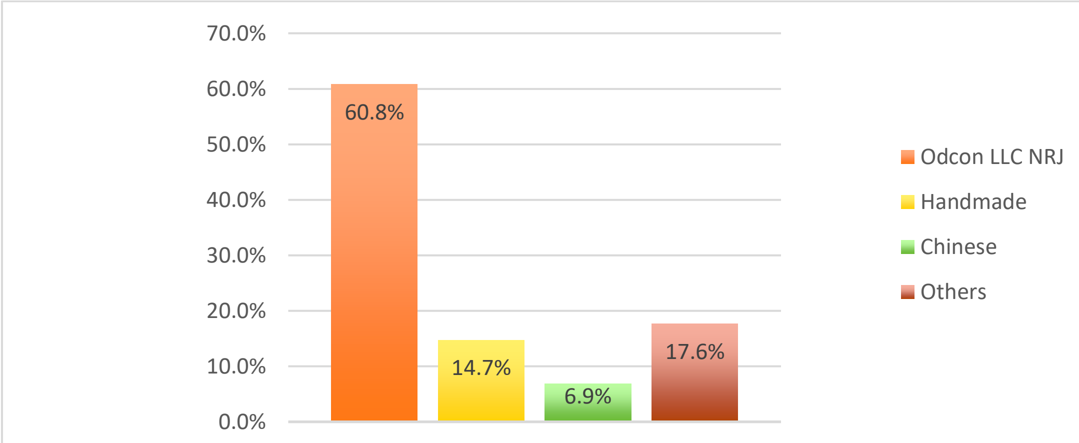
WATER HEATING BOILERS

In the Arkhangai province, except for Erdenebulgan sum, 102 fossil-fueled water heating boilers are installed with 29.21MW capacity. The WHBs can be categorized into the following four categories by the manufacturers, as shown below.

WHB of NRJ make, of Odkon CO.LTD	Handmade WHB	The WHBs of other manufacturers of PRC	The WHBs of different countries and manufacturers
			

Out of all the water heating boilers, 60.8% are the water boilers of Odkon CO.LTD, and 15.8% are handmade furnaces. The following graph illustrates the ratio of WHB manufacturers used in the province.

Graphic 6. Water heating furnace classification by fabrics



Source: Arkhangai province Energy Regulatory Council database

Aging of the water boilers, all of them were installed after 2000. Based on the year of installation, in 2010, 13 water heating boilers were installed. All of them were NRJ type boilers made by Odkon CO.LTD. But in recent years, the number of handmade water heating boilers increased, mostly used to replace damaged or broken NRJ types of Odcon CO.LTD.

Common issues of the water heating system in soums

The operations of the centralized heating system of soums are handled by professional entities (private companies). In soums with individual and partial heating sources, the public organization administration operates the heating system and maintenance. But they have the limitations of the budget, human resources, and lack of technical knowledge. Commonly the following issues have been identified during the field study:

- Unbalanced heat supply regime and malfunction of heating equipment is causing the decrease in energy efficiency
- Missing technical documentation (technical passport, capacity, and operation instructions)
- Inadequate selection of the heating boiler auxiliary equipment (insufficient pumping and clogging of the screening tube with the flue gas ash due to absence of ash catcher)
- Incomplete set of protection equipment and the missing of regulating and adjustment devices
- Pump production and compression adjusted instinctively, demonstrated by around30 percent increase of power energy consumption during the heating season
- Employees lack the operational risks related to safety. And working in a high-risk environment without safety equipment.
- Limitations of the maintenance budget of the heating system. Usually, it is allocated to the operational budget

1.5 HEAT DEMAND OF PUBLIC BUILDINGS

According to the Minister of Energy's resolution, the heating season of the public buildings continues for 242 days, from September 15 to May 15. The outdoor air rated temperature used to estimate heat demand is (-28.6° C) by Mongolian Building Normative and Codes. The absolute minimum temperature reaches (-53°C). During the daytime in winter, the outdoor air's actual mean temperature is (-14°C), and during the night falls to (-25°C).

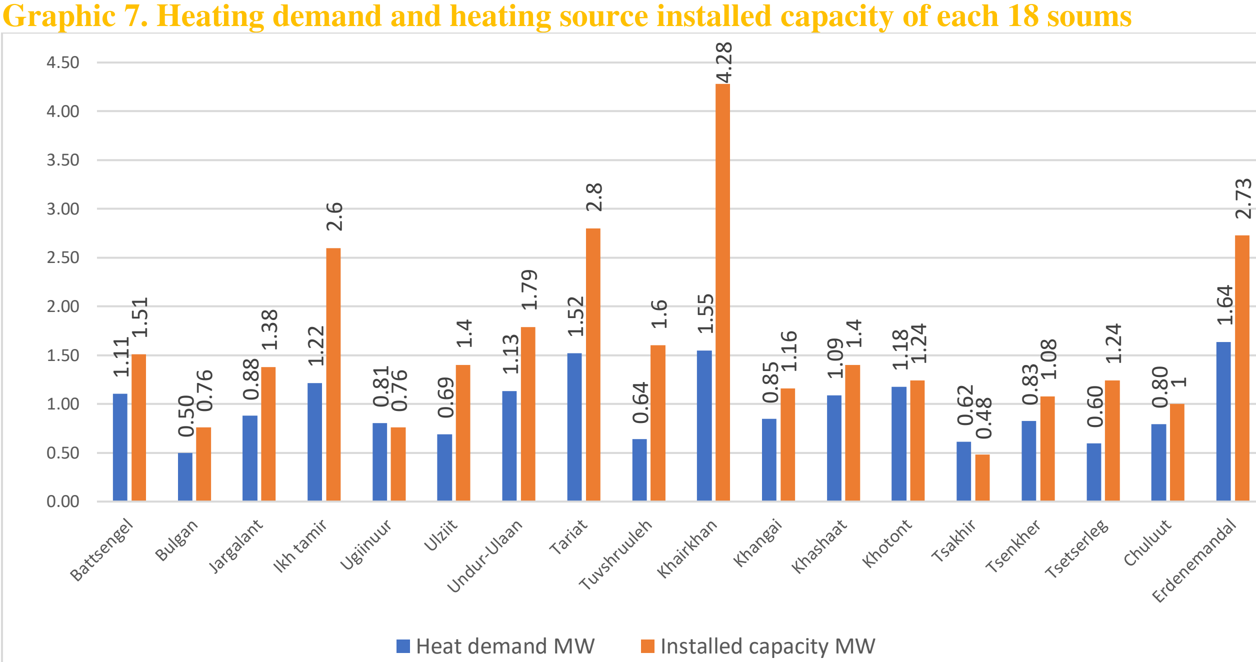
Of 18 soums, except Erdenebulgan soum, public buildings' annual total heating volumen the heating season of 2019-2020 was 708800m³ (ERC of Arkhangai). Approximately the estimated heating demand of public buildings is Q=16MW. The capacity of the installed heat source is 29.21MW. The following table compares the heating volume, heating demand, and the heat source installed capacity. (ERC of Arkhangai)

Table 3. Heating demand and heating source installed capacity of 18 soums

Region	Quantity of buildings	Heating volume (м³)	Estimated heating load (MW)	Heat source installed capacity (MW)
Western (Tsakhir,Undur-Ulaan,Khangai,Tariat,Chuluut)	70	197488.90	4.46	7.23
Eastern (Ulziit,Ugiinuur, Khashaat, Khotont, Battsengel)	45	151403.00	3.42	6.31
Central (Ikh tamir, Bulgan, Tsekher, Tuvshruulekh)	67	172283.94	3.90	6.04
Northern (Tsetserleg,Jargalant, Erdenemandal,Khairkhan)	59	187616.40	4.24	9.63
Total	**241**	**708792.24**	**16.02**	**29.21**

Source: Arkhangai province Energy Regulatory Council
The estimated heat load was calculated following Con.Regulation 41-02-05 2.4

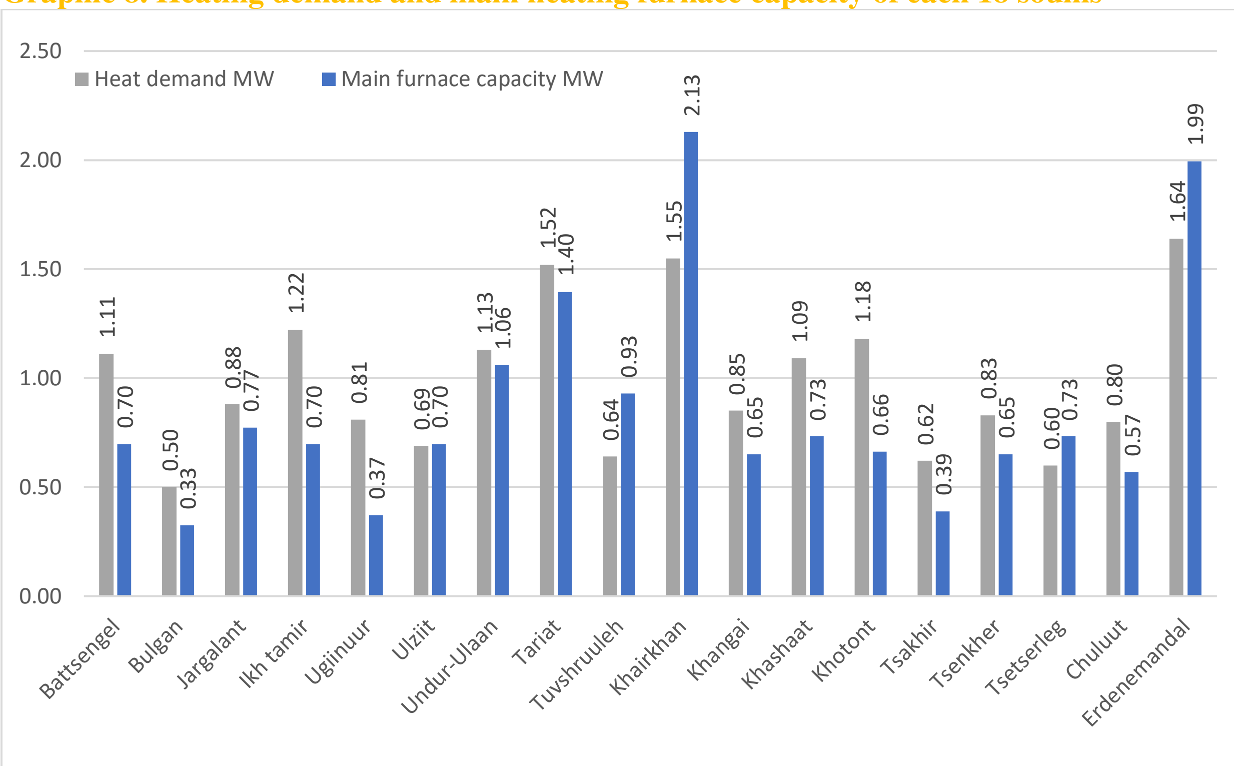
Graphic 7. Heating demand and heating source installed capacity of each 18 soums



Source: Arkhangai province Energy Regulatory Council
The estimated heat load was calculated following Con.Regulation 41-02-05 2.4

According to the system's reliability, technical operation rules, and seasonal heating regime, public heating equipment shall have two water heating boilers, the main heating WHB and the reserve WHB. From the paragraph above, it seems like the total installed capacity of the water heating boiler is sufficient in every soum. However, in reality, main heating and reserve furnaces are operated simultaneously to heat public buildings in the soums. As a result, they are wintering with the source's total installed capacity. Using all installed water heaters is a major factor in providing reliable thermal energy to keep consumers comfortable during peak heating loads. Unfortunately, the main heating furnace's capacity is insufficient in 11 out of 18 soums. The following graph shows the capacity of the main water heating boilers in 18 soums and the estimated heat demand of the consumer.

Graphic 8. Heating demand and main heating furnace capacity of each 18 soums



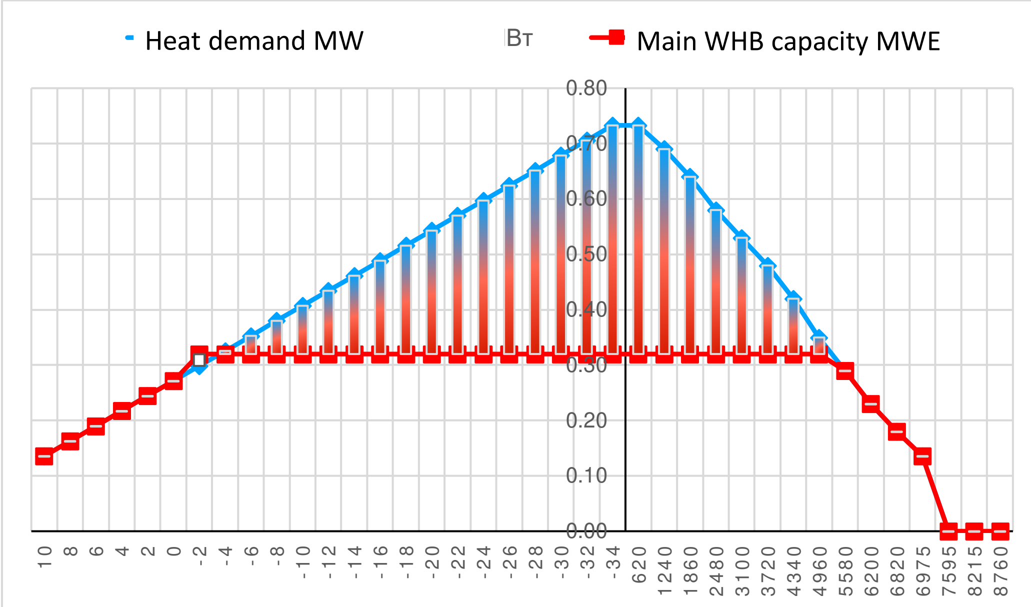
Source: Arkhangai province Energy Regulatory Council

The estimated heat demand was calculated following Con.Regulation 41-02-05 2.4[2]

The following graph illustrates the estimated heating load and the installed capacity of the WHB in Ugiinuur soum. The chart shows that at the beginning of the heating season, when the outside temperature reaches constantly below 0°C, some public buildings with the individual heating system have a deficit of the main heating furnace capacity. So, consumers using the reserved furnaces as an additional water heater boiler. The total heating boilers' total installed capacity is 0.37 MW, while the estimated heat demand for the heating season is 0.81 MW. During the cold winter months, if a kindergarten or school's boilers breaks down, the whole heating system falls apart. Because of this technical miscalculation, users of these organizations cannot winter comfortably.

[2] BNaC 41-02-05 Outdoor heat supply

Graphic 9. Comparison of the annual heat load of Ugiinuur soum and the capacity of the main heating furnace



Source: Arkhangai province Energy Regulatory Council
The estimated heat load was calculated following Con.Regulation 41-02-05 2.4

For example, the maximum air temperature in the kindergarten classroom in Ogiinuur soum is 17 °C. The figure below shows the temperature inside the classroom. Despite the loss of thermal comfort in secondary schools and kindergartens, pupils, children of kindergarten, teachers, and community workers learn and adapt to an uncomfortable environment.

Figure 2. Ugiinuur soum's kindergarten's indoor air temperature during January 2019.

Source: Ugiinuur kindergarten indoor air temperature notes

1.6 USER COMFORT IN PUBLIC BUILDINGS

During the interview with some employees, directors, and users, the following main issues were identified:

- People adapted to what they have (not aware of thermal comfort)
- Loss of control on the thermal comfort and heating system regulations
- Unnecessary energy-saving measures

Thermal comfort depends not only on the condition of the building but also on technical issues, user attitudes, and behavior. Administration of public organizations of soums raises thermal comfort issues, but it takes a lot of time to solve them. Users of public buildings were implementing unstable solutions and adapted to the current conditions by themselves.

Education buildings: Students have colds and flu very commonly during the winter due to the studding environment's insufficient thermal condition. As for kindergartens, indoor air quality, temperature difference, and thermal comfort in classrooms do not meet the health normative. Because of these issues, children are suffering from health problems.

Health centers: Although the hospitals' thermal comfort is relatively good, some rooms are chilling, and some are too hot due to a malfunction of the heating system.

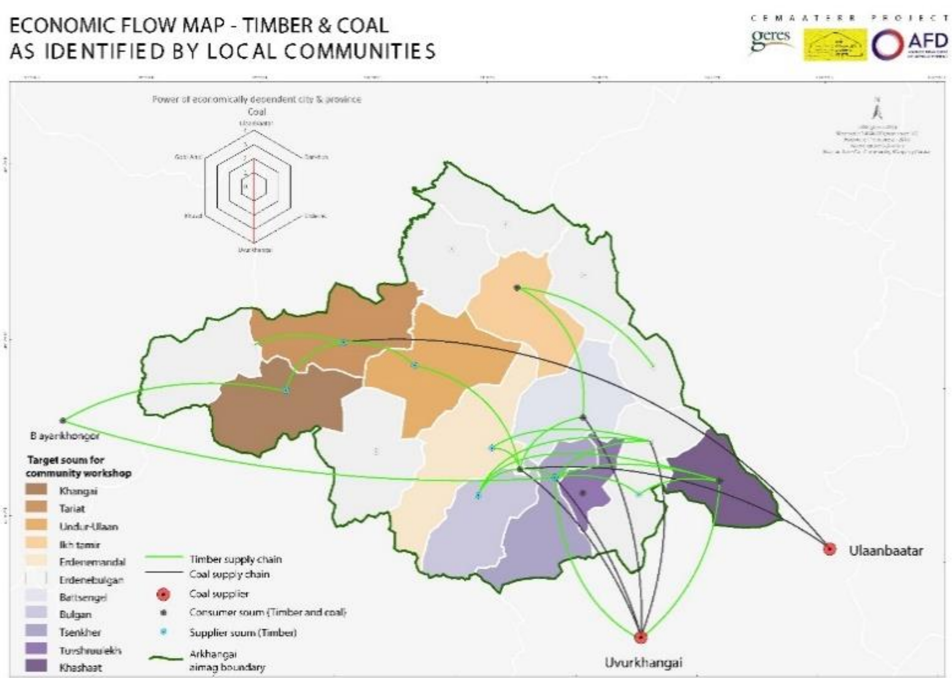
Public service buildings: As for cultural and social service organizations, thermal comfort is lacking. The cultural centers' building's operation is not regular, and heating is not working regularly. Therefore, the cultural center’s staff and local authorities do not pay much attention to thermal comfort. Usually, in the winter, people participate in cultural events with outdoor clothing, and employees work in uncomfortable thermal conditions.

Some public service organizations are taking unnecessary energy efficiency measures, such as reducing heating and decreasing firing. Usually, local people lack knowledge about the efficiency of energy saving solutions. And, they are not aware of the most suitable energy efficient methods for their buildings.

1.7 FUEL CONSUMPTION OF PUBLIC BUILDINGS

The energy source of the public buildings of the Arkhangai province is fossil fuels. The Arkhangai province is one of Mongolia's few provinces without a coal mine regardless of fossil fuel consumption. Therefore, the coal is supplied by the mine site of “Bayanteeg” JSC, a part of the Ongi river coal deposits of the Uvurkhangai province.

Figure 3. Fuel purchase locations



Source: CEMAATERR-I project, Community-based Climate vulnerability risk assessment of Arkhangai province, 2019

The following table shows the results of the official coal quality analysis of the Bayanteeg coal mine, as reflected in the Bayanteeg JSC report of 2019.

Table 4. Quality analysis of Bayanteeg coal (Bayanteeg JSC"Annual report of 2019", 2019)

#	Indicator	Quality measurement
1	Moisture Mad(%) 3.0	3.0
2	Moisture Mt(%) 5.0	5.0
3	Ash Adry (%)	12.9
4	Volatile matters Vdaf (%)	47.5
5	Sulfur Sdtot (%)	0.89
6	Calorie Kcal/Qad	6626
7	Calorie Kcal/Qdb	6833e
8	Carbon content C (%)	78.23
9	Hydrogen content H (%)	5.60
10	Nitrogen content N (%)	1.55
11	Oxygen content O (%)	14.13

Source: Bayanteeg JSC annual report of 2019

The estimated annual coal consumption in total heating 75 water heating furnaces of 19 soums is **28650 tons**. The coal consumption of regions shown in the table below

Table 5. Coal consumption of 19 soums (ERC of Arkhangai)

Regions of Arkhangai province	Number of main boilers/quantity/	Annual coal consumption /tons/
Western (Tsakhir,Undur-Ulaan,Khangai,Tariat,Chuluut)	19	3752.62
Eastern (Ulziit,Ugiinuur, Khashaat, Khotont, Battsengel)	12	2264.42
Central (Ikh tamir, Bulgan, Tsekher, Tuvshruulekh)	31	17597.78
Northern (Tsetserleg,Jargalant, Erdenemandal,Khairkhan)	13	5033.15
Total	**75**	**28647.97**

Source: Arkhangai province Energy Regulatory Council

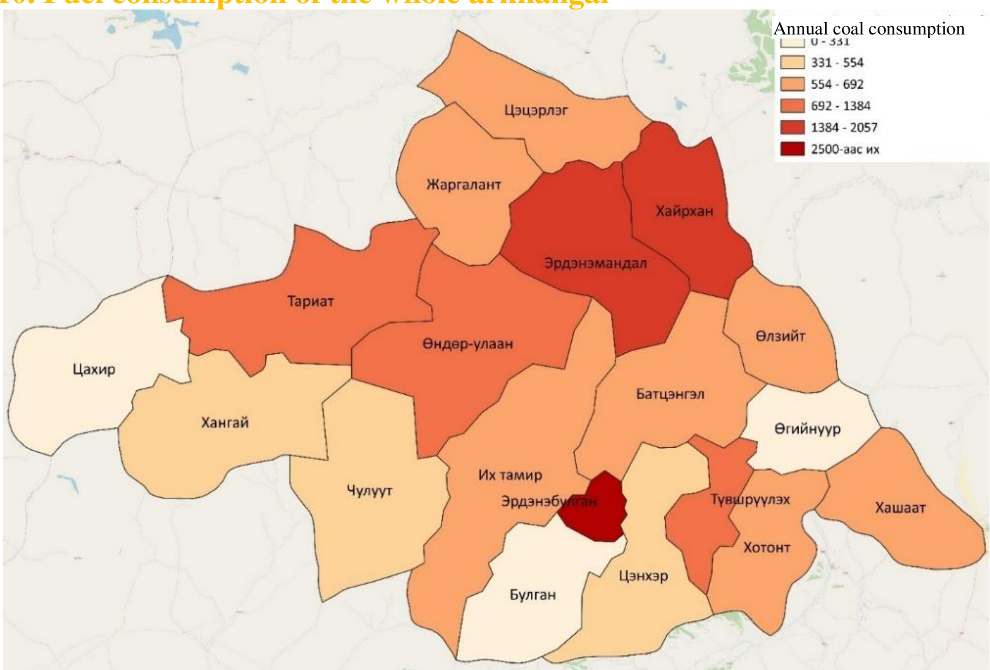
Graphic 10 illustrates the annual coal consumption of each sum of the Arkhangai province. The fuel consumption of each soums directly depends on the following factors:

- Heat consumption of public buildings
- Type and ignite quality of fuel
- Number of public buildings and capacity
- Installed capacity of the boiler

As per Erdenebulgan soum, with the highest population density and largest heat consumers base, spend 14735.11 tons of coal annually.

The above-mentioned "Bayanteeg" coal mine was transported to the Erdenebulgan soum of Arkgangai province via auto road in 406 km. According to the National regulation of Energy tariff, it is the main reason for the high rate of heating tariff in Arkhangai.

Graphic 10. Fuel consumption of the whole arkhangai



Source: Arkhangai province Energy Regulatory Council

Use of firewood

Raw wood is used as the fuel for heating the public buildings in some soums. Wood is much easier to access and cheaper in Arkhangai than purchasing coal from the distant coal mine. But, wood has a much lower caloric value than coal. As a result, it can't produce enough heat to supply thermal comfort to the users during the winter. Some public building's heat-only boiler capacity is not enough to heat the building, and using the wood makes it more inefficient.

On the other hand, some WHB, such as handmade furnaces, are made to use only wood due to the boiler's operational conditions and the low quality of the metal details, which have metal parts that are not suitable for coal.

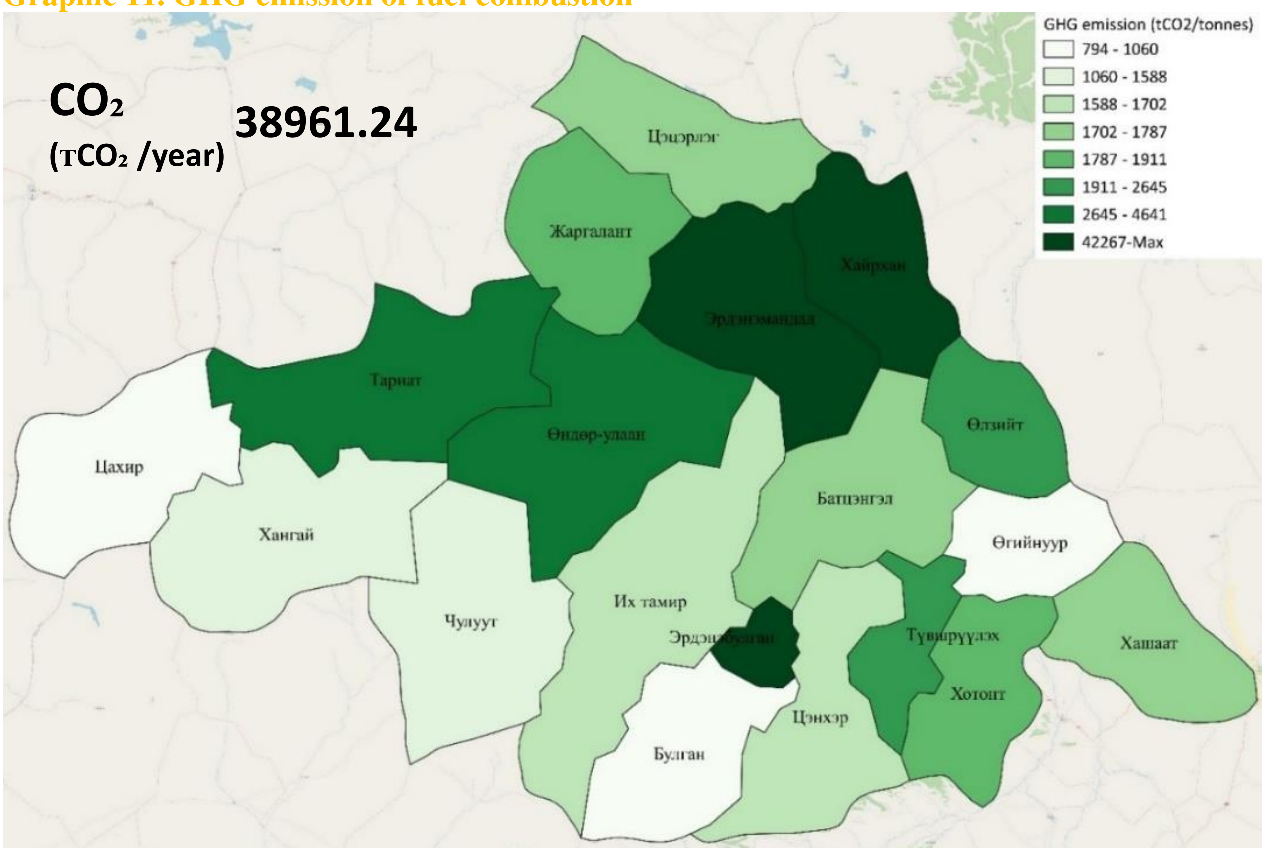
Generally, in the Arkhangai province, households usually use wood for heating all season. Even the nomadic herders living close to the forest use wood for heating and cooking throughout all seasons. Using the wood for domestic purposes also collected wood from any sustainable management plan that contributes to deforestation and climate change. As a result, forest degradation accelerates year by year. The main reasons for substituting coal with wood for the heating of public buildings according to the users. Although the reasons mentioned above give the exception to using wood, it contributes to deforestation and unrestorable damage to the ecosystem.

1.8 GHG EMISSIONS FROM THE FUEL COMBUSTION FOR THE PUBLIC BUILDING HEATING

Including GHG emission from centralized heating system in Erdenebulgan soum and public building's heat only water heating boilers in other soums, the province emits **38961.24** tons of CO_2 per year, of which **20039.75** tons of CO_2 or 51.4% are emitted from the central heating system of Erdenebulgan soum, province.

The following figure demonstrated the CO_2 emission volume and rating of each soum of the Arkhangai sm during the heating season. Fuel expenditure is estimated based on the data record provided by the Energy Regulatory Council of Arkhangai province. The CO_2 emission is calculated using the corresponding methodology, such as IPCC Guidelines, based on the coal analysis report attached to the 2019 Investors report of the Bayanteeg JSC.

Graphic 11. GHG emission of fuel combustion



Source:" Geres" NGO estimated based on B.Namkhainyam etc.: Study determining GHG emission factor for Mongolia, 2013, IPCC Guidelines for National GHG Inventories, 2006

Although the Bayanteeg coal used province-wide has a higher caloric value classified under the D and G category of the coal, it has higher carbon content based on the quality analysis (C=78.23%). Although the coal expenditure is relatively more minor, its GHG emission level is higher by **30.5%** than standard fuel emission.

CHAPTER 2. THE DETAILED FIELD STUDY OF PUBLIC BUILDINGS IN SELECTED 6 SOUMS

2.1 SUMMARY OF FIELD STUDY

Detail study of “The energy efficiency of the public buildings in Arkhangai province” was conducted to measure and collect primary data of public buildings in Khangai, Undur-Ulaan, Tsetserleg, Tsenkher, Ugiinuur, and Khashaat soums, selected by the steering committee of the CEMAATERR-II project. The actual condition of the buildings, heating system, heat, and electricity energy actual consumptions was studied within the field study. A total of 62 public buildings were studied, of which 5 were unusable or demolished due to new construction. In the end, a total of 57 buildings were assessed. The age of public buildings in soums is classified as pre-1990 or pre-market buildings, between 1990-2008 or until the construction sector adopted thermal protection norms. Between 2009-2020 buildings were insulated in some way. 26 were built in pre-1990, 8 between 1990-2008, and 28 between 2009-2020.

The data collection questionnaire and information provided by the Energy Regulatory Council of Arkhangai province, selected 6 soums to consume about 400 tons of coal during the heating season. The amount of CO_2 emitted from coal is 544 tons per year. It is also noteworthy that electricity consumption has increased by at least 30 percent during the heating season. Further research suggests that the unprofessional building owner’s exploitation of the heating system and the workers' poor professional skills affect electricity consumption. Public buildings' heating energy consumption and heat loss estimations were estimated based on the “Building thermal performance” BNaC 25-01-20. Out of 57 public buildings, 44 buildings are included in energy efficiency class E, and 13 buildings are in class D. The energy efficiency performance indicates that the energy efficiency of public buildings must be improved.

The objective of the field study

The study's main objective is to identify the energy and build energy efficiency issues of Arkhangai province and classify public buildings at soums by their energy consumption and building envelopes. Primary data of the public buildings at 6 soums representing Arkhangai province will be collected within the working framework. The heating source, fuel, energy consumption, and building thermal performance were assessed for the mentioned soums.

Figure 4. Selected 6 soums

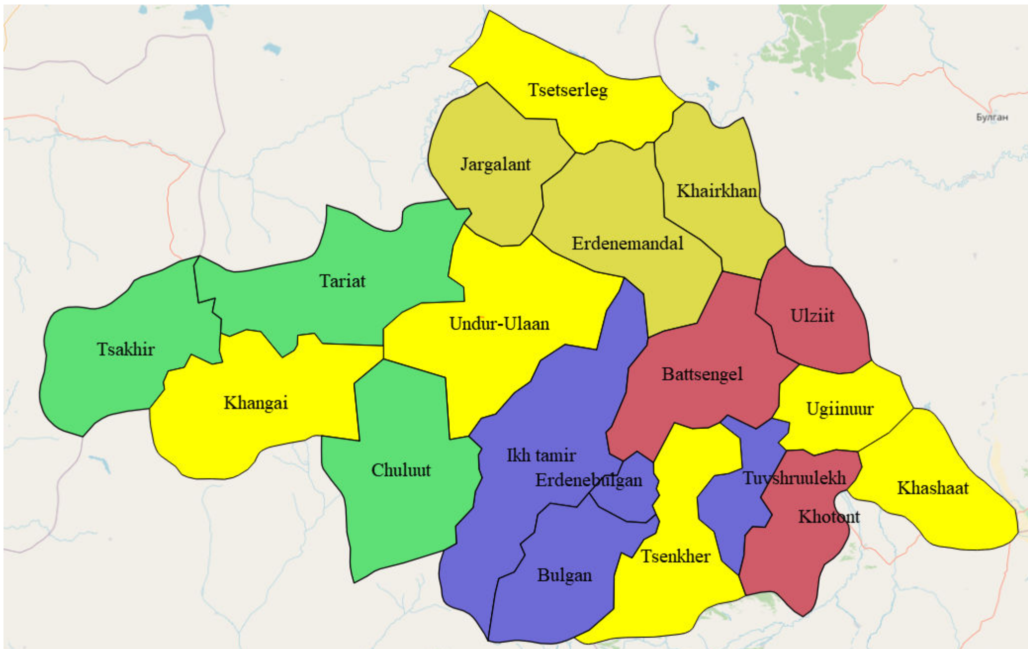


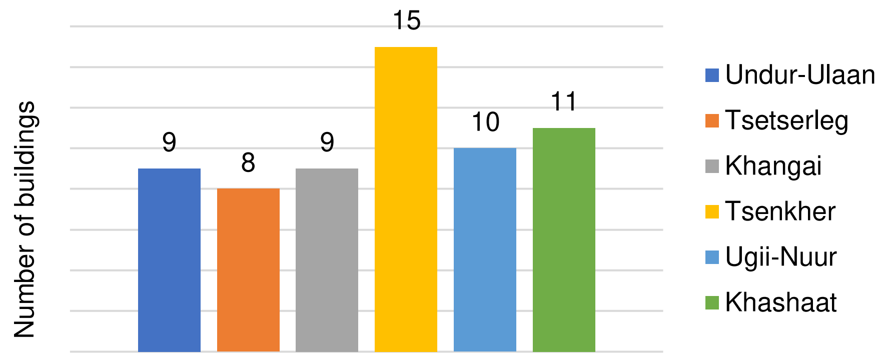
Table 6. 6 soums and types public buildings were studied

#	Name of the soum	Total number of the population	Total number of public buildings	Building designation
1	Khangai	3188	8	1. Governor's office 2. Secondary school 3. Dormitory 4. Health center and related buildings 5. Kindergarten 6. Sport hall 7. Cultural center 8. Police 9. Center for the elderly
2	Undur-Ulaan	5720	6	
3	Tsetserleg (soum)	3772	9	
4	Tsenkher	5922	15	
5	Uginuur	3099	10	
6	Khashaat	3181	10	

2.2 PRIMARY INFORMATION OF PUBLIC BUILDINGS IN SELECTED SOUMS

The Cemaaterr-II Project steering committee meeting decision conducted a detailed field study of "The energy efficiency of the public buildings in Arkhangai province" for Khangai, Undur-Ulaan, Tsetserleg, Tsenkher, Ugiinuur, Khashaat soums by "BEEC" LLC. The building energy consumption, heating system, building envelope, and electricity consumption were studied for 62 buildings with collected primary data. Each soum has approximately 10 public buildings.

Graphic 12. A number of public buildings at soums.

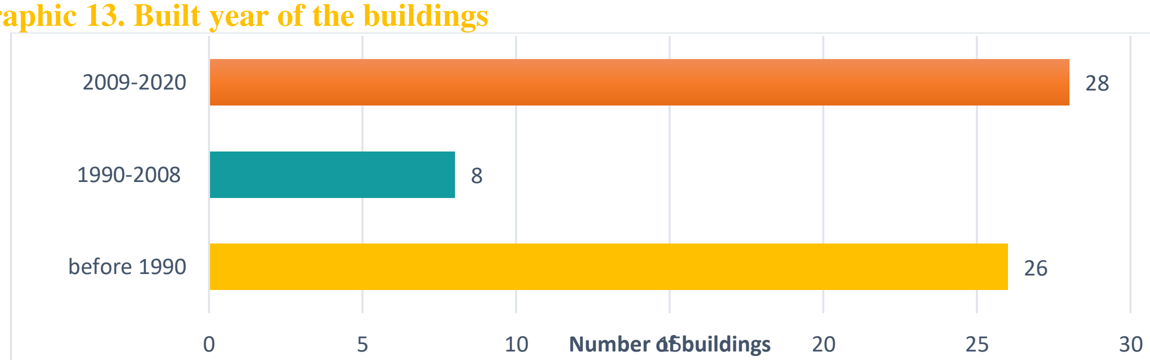


Source: "BEEC" CO.LTD questionnaire survey result. 2020

Aging of the building

In terms of agings, the surveyed public buildings were classified as built before 1990 during socialism, between 1990-2008 during democracy, and between 2009-2020 according to the building thermal performance norm. The below graphic shows that 28 buildings are somehow insulated.

Graphic 13. Built year of the buildings

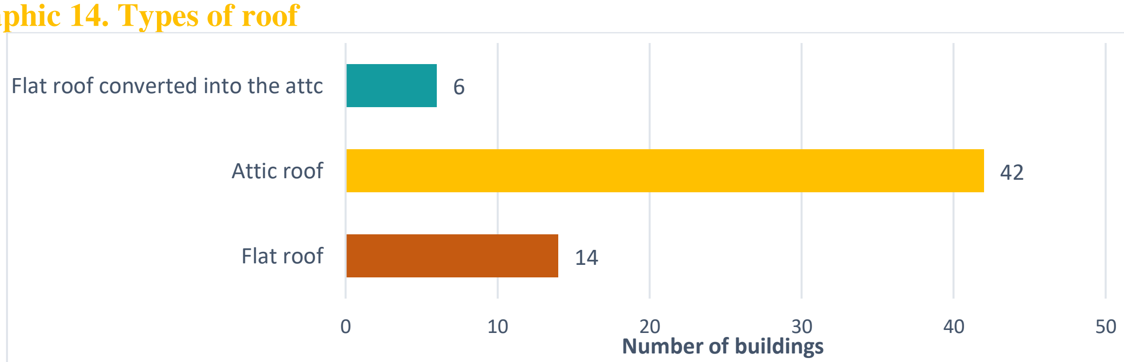


Source: "BEEC" CO.LTD questionnaire survey result. 2020

Building envelope

Roof: Public buildings built before 1990 mostly have gable roofs, while buildings built after 1990 have gable and flat roofs. In some cases, flat roofs were reconstructed with gable roofs due to their poor construction quality and unregular maintenance. For example, the kindergarten of Tsenkher soum has a gable roof, the thickness of the roof insulation was designed to be 20cm in the design drawing according to the building norm of the buildings built after 2009, the actual thickness was 5cm (additional of other types of the material layer).

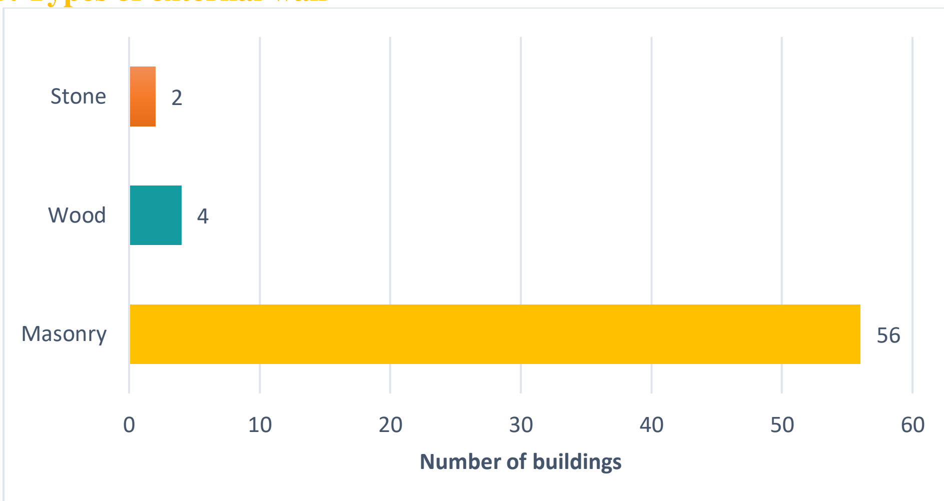
Graphic 14. Types of roof



Source: "BEEC" CO.LTD questionnaire survey result. 2020

External wall: Predominant masonry wall structures are the local materials such as gravel or volcanic rocks. Also, there were very few cases that used wood or stone to construct the external wall. The external wall of the buildings built after 2009 consists of block+EPS+brick masonry structure, while walls of the old buildings are insulated with an aluminum panel with PU insulation. There were cases that of reinsulating buildings that already have insulated.

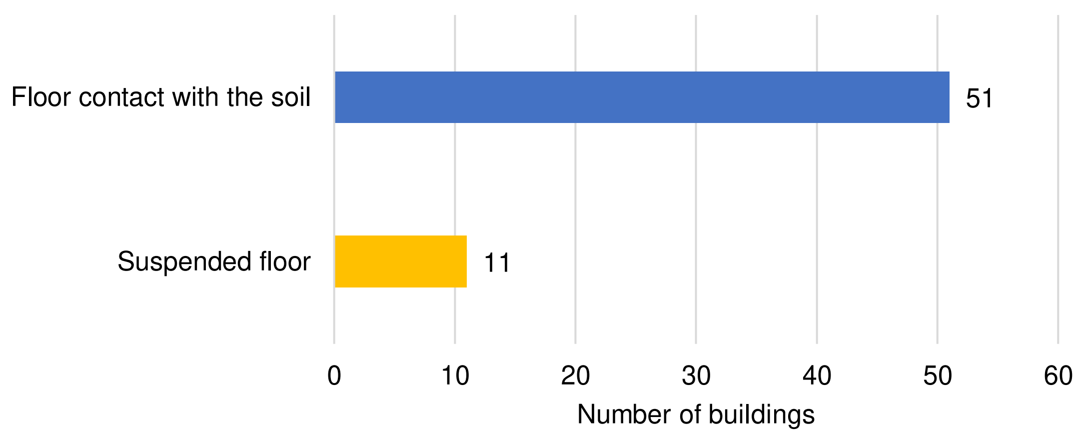
Graphic 15. Types of external wall



Source: "BEEC" CO.LTD questionnaire survey result. 2020

Floor: Depending on the soum location, buildings located at Khangai, Undur-Ulaan, Tsetserleg have suspended floors, while buildings located at Tsenkher, Khashaat, Ugiinuur soum have the floor directly on the soil. Though buildings have suspended floors, there were cracks on the floor as well as on the wall. Moreover, the suspended floor is not sufficiently insulated. Therefore, the suspended floor should be insulated as external wall insulation.

Graphic 16. Types of floor



Source: "BEEC" CO.LTD questionnaire survey result. 2020

Public building's heating source

Tsenkher soum has a central heating system with heat only a boiler among other studied soums. Most of the heat-only boilers are the type of NRJ. However, a few of them are cylinder-type heat-only boilers which are similar to the NRJ. Fuel is supplied from the Bayanteeg mining located in Uvurkhangai province. Moreover, wood is used more commonly in some soums.

Table 7. Types of the heat only boilers

		
Not known	KY10	NRJ 10

The operational condition of the heat only boilers

During the field study, it was observed that the operation of the boiler and the regulating condition is not meeting the boiler regulating and exploitation regime.

- The upper part of the heating pipe is located at the top of the fire pit and passing through the smoke exhaust. So, it is often clogged with ash.
- Coal is wasted through the space between grates of the fuel hopper
- Heat transfer is poor due to insufficient air draft. Some boilers use an additional blower
- Measuring and monitoring equipment are not sufficient and damaged
- Working condition is not safe for heat only boiler operators
- The chimney angle incorrect
- The boiler is open to rainwater
- The boiler room and house are not comfortable to operate, and there is a lot of soot
- The water treatment system is missing

Table 8. Operating condition of the heat only boilers

		
Additional blower	Damaged controlling device	Lack of space
		
Non-straight chimney	Heat only boiler room condition	Damaged devices

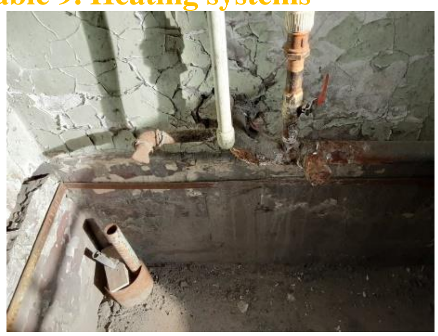
Ownership and employers of the water heating furnace

In individual and partial hating systems, the consumer is responsible for the running water heating furnace becomes a key condition to avoid any complaints. If the heat-only boiler is run by someone else, the responsibility could be taken. Currently, the owner of the building is responsible for the safety of boiler operations and operators. It was found that operators 'knowledge about the operating principle of the heat only boiler is poor, working condition is not safe, water temperature and pump pressure are regulated by operators themselves based on their sense. Operators said that the supply water temperature from the boiler does not exceed 60^0C.

Heating system

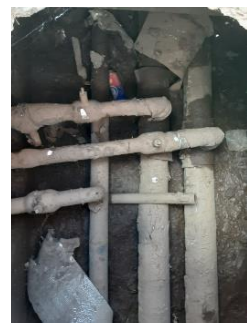
Due to the predominance of older buildings, the pipelines are old. The heating system is a horizontal system with steel pipes and cast iron radiators. The heating system's operation is unbalanced due to poor hydraulic adjustments, and the system has not been adjusted.

Table 9. Heating systems



Pipeline is very old

Cast iron radiator



Regulating devices

2.3 BUILDING DESIGNATION AND ENERGY CONSUMPTION

The heating energy consumption and electricity consumption of the buildings were determined. Fuel types used for heating were determined from the questionnaire survey conducted. The electricity consumption was obtained from the electricity distribution companies through the Energy Regulatory Council of Arkhangai province. The following section shows designations and annual consumptions of fuel and electricity of public buildings in selected soums.

2.3.1 Undur-Ulaan soum

Figure 5. Locations of the public buildings at Undur-Ulaan soum

Table 10. Public buildings at Undur-Ulaan soum and their fuel consumption

#	Organizations	Building designation	Capacity of educational organizations	Heat source	Annual fuel consumption		Electricity consumption kWh/year
					Coal, ton	Wood, m^3	
1	Educational organizations	School. 1st building	781 students	Collective heating with heat only boiler	300	45 (Kitchen)	43245
2		School. 2nd building					
3		Sport hall	85 employees				
4		Dormitory					
		Kindergarten	251 children	Water heat only boiler	60	64(Ger)	18302
			33 employees				
5	Public service organizations	Health center			40	60 (Kitchen)	23873
7		Cultural center			30	48	3700
8		Governor's office			28	48	13264
9	Public sfety organization	Police station					

Source: "BEEC" CO.LTD questionnaire survey result. 2020
Arkhangai province Energy Regulatory Council database

2.3.2 Tsetserleg soum

Figure 6. Locations of the public buildings at Tsetserleg soum

Table 11. Public buildings at Tsetserleg soum and their fuel consumption

<table>
<tr><th rowspan="2">#</th><th rowspan="2">Organizations</th><th rowspan="2">Building designation</th><th rowspan="2">Capacity of educational organizations</th><th rowspan="2">Heat source</th><th colspan="2">Annual fuel consumption</th><th rowspan="2">Electricity consumption kWh/year</th></tr>
<tr><th>Coal, ton</th><th>Wood, m^3</th></tr>
<tr><td>1</td><td rowspan="6">Educational organizations</td><td>School building</td><td rowspan="2">671 students</td><td rowspan="4">Collective heating with heat only boiler</td><td rowspan="4">220</td><td rowspan="4">N/A</td><td rowspan="4">100460</td></tr>
<tr><td>2</td><td>Dormitory for boys</td></tr>
<tr><td>3</td><td>Dormitory for girls</td><td rowspan="2">78 employees</td></tr>
<tr><td>4</td><td>School kitchen</td></tr>
<tr><td rowspan="2">5</td><td rowspan="2">Kindergarten</td><td>163 children</td><td rowspan="6">Water heat only boiler</td><td rowspan="2">25</td><td rowspan="2">32</td><td rowspan="2">14078</td></tr>
<tr><td>21 employees</td></tr>
<tr><td>6</td><td rowspan="3">Public service organizations</td><td colspan="2">Health center</td><td>45</td><td></td><td>23873</td></tr>
<tr><td>7</td><td colspan="2">Cultural center</td><td>New</td><td>New</td><td>New</td></tr>
<tr><td>8</td><td colspan="2">Governor's office</td><td>25</td><td>88</td><td>13264</td></tr>
<tr><td>9</td><td>Public safety organization</td><td colspan="2">Police station</td><td>New</td><td>New</td><td>New</td></tr>
</table>

Source: "BEEC" CO.LTD questionnaire survey result. 2020
Arkhangai province Energy Regulatory Council database

2.3.3 Khangai soum

Figure 7. Locations of the public buildings at Khangai soum

Table 12. Public buildings at Khangai soum and their fuel consumption

#	Organizations	Building designation	Capacity of educational organizations	Heat source	Annual fuel consumption		Electricity consumption kWh/year
					Coal, ton	Wood, m^3	
1	Educational organizations	School building	381 students	Water heat only boiler	200	20	50200
2		Dormitory					
3		Sport hall	50 employees				
4		Kindergarten	127 children		New	New	New
			21 employees				
5	Public service organizations	Health center			70		21940
6		Cultural center		Electrical heating	0	0	4781
7		Governor's office		Water heat only boiler	38	64	6646
8		Public meeting building					

Source: "BEEC" CO.LTD questionnaire survey result. 2020
Arkhangai province Energy Regulatory Council database

2.3.4 Tsenkher soum

Figure 8. Locations of the public buildings at Tsenkher soum

Table 13. Public buildings at Tsenkher soum and their fuel consumption

#	Organizations	Building designation	Capacity of educational organizations	Heat source	Annual fuel consumption		Electricity consumption kWh/year
					Coal, ton	Wood, m^3	
1	Educational organizations	School building	663 students	Centralized heating system	320	N/A	50200
2		Dormitory 1					
3		Dormitory 2					
4		Sport hall	78 employees				
5		Renting buildings of school					
6		Kindergarten	164 children 20 employees	Water heat only boiler		200	11095
7	Public service organizations	Health center		Centralized heating system	N/A	N/A	14398
8		Postpartum					
9		Morgue					
10		Health center garage					
11		Elders building					
12		Bag leader's quarter					
13		Cultural center		Water heat only boiler	New	New	New
14		Governor's office			0	224	6646
15	Public sfety organization	Police station		Centralized heating system			

Source: "BEEC" CO.LTD questionnaire survey result. 2020
Arkhangai province Energy Regulatory Council database

2.3.5 Ugiinuur soum

Figure 9. Locations of the public buildings at Ugiinuur soum

Table 14. U Public buildings at Ugiinuur soum and their fuel consumption

#	Organizations	Building designation	Capacity of educational organizations	Heat source	Annual fuel consumption		Electricity consumption kWh/year
					Coal, ton	Wood, m^3	
1	Educational organizations	School building 1	533 students	Collective heating with heat only boiler	400		60486
2		School building 2					
3		School building 3					
4		Sport hall	59 employees				
5		Dormitory					
6		Kindergarten	140 children 19 employees	Water heat only boiler			22040
7	Public service organizations	Health center			25	80	11650
8		Cultural center					6607
9		Governor's office					15210
10	Public sfety organization	Police station			New	New	New

Source: "BEEC" CO.LTD questionnaire survey result. 2020
Arkhangai province Energy Regulatory Council database

2.3.6 Khashaat soum

Figure 10. Locations of the public buildings at Khashaat soum

Table 15. Public buildings at Khashaat soum and their fuel consumption

#	Organizations	Building designation	Capacity of educational organizations	Heat source	Annual fuel consumption		Electricity consumption kWh/year
					Coal, ton	Wood, m^3	
1	Educational organizations	School building 1	497 students	Collective heating with heat only boiler	230		64427
2		School building 2					
3		Sport hall					
4		Dormitory 1	63 employees				
5		Dormitory 2					
6		Kindergarten	130 students 18 employees	Water heat only boiler	50		21616
7	Public service organizations	Health center			67		13783
8		Cultural center			New	New	New
9		Governor’s office			80		11481
10	Public sfety organization	Police station		Traditional stove	New	New	New

Source: “BEEC” CO.LTD questionnaire survey result. 2020
Arkhangai province Energy Regulatory Council database

2.4 ACTUAL COAL CONSUMPTION OF SOUMS AND ASSOCIATED GHG EMISSION

All soums take coal from Bayanteeg mining located in Uvurkhangai province. The cost of coal was between 110000-135000 tugrik in 2019, depending on the distance from the mining. Ugiinuur soum uses only wood for heating among the studied 6 soums. Also, Tsenkher soum use wood for heating. Although Ugiinuur soum appears to emit CO_2 using wood for heating, it needs to make a more detailed study to estimate the environmental impact. The CO_2 emissions from coal are estimated to be 1.36 kg per kg of coal, and the value was taken from the following sources.

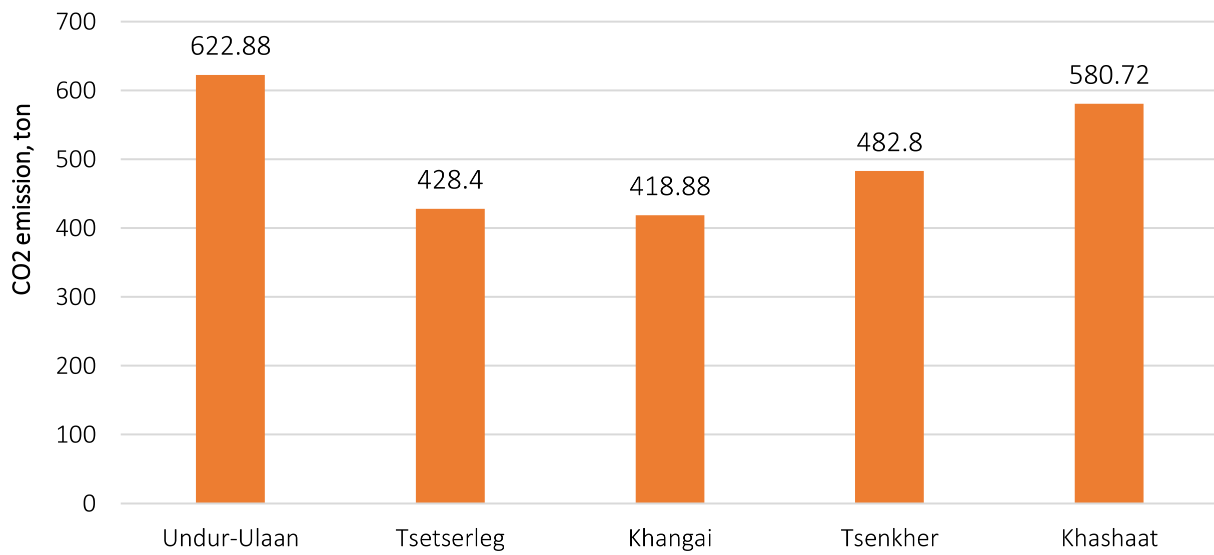
- B.Namkhainyam: Study determining GHG emission factor for Mongolia, 2013
- IPCC Guidelines for National GHG Inventories, 2006

Table 16. Annual fuel consumption

Soum	Organization	Annual, ton	Total
Undur-Ulaan	School	300	458
	Health center	40	
	Kindergarten	60	
	Cultural center	30	
	Governor's office	28	
Tsetserleg	School	220	315
	Health center	45	
	Kindergarten	25	
	Cultural center	New	
	Governor's office	25	
Khangai soum	School	200	308
	Health center	70	
	Kindergarten	new	
	Cultural center	electricity	
	Governor's office	38	
Tsenkher soum	School	320	355
	Kindergarten	Wood	
	Cultural center	New	
	Governor's office	35	
	Hospital	School	
Ugiinuur	School	Wood	0
	Kindergarten	Wood	
	Cultural center	Wood	
	Governor's office	Wood	
	Hospital	Wood	
Khashaat	School	230	427
	Kindergarten	50	
	Cultural center	New	
	Governor's office	80	
	Hospital	67	

Source: "BEEC" Co.Ltd questionnaire survey from Energy Regulatory Council

Graphic 17. Annual GHG emission /ton/year/



Source: BEEC Co.Ltd determined based on: B.Namkhainyam etc.: Study determining GHG emission factor for Mongolia, 2013, IPCC Guidelines for National GHG Inventories, 2006

2.5 ACTUAL ELECTRICITY CONSUMPTION OF THE PUBLIC BUILDINGS IN SOUMS

All the studied soums are supplied with electricity from the central electricity grid, namely "Electricity distribution network of the Erdenet- Bulgan". The electricity supply is reliable, not having voltage deviation and limitation is low. Schools and new kindergartens at each soums consume comparably high electricity because of the bigger area to light and high-performance pumps for the heating system.

Although, above mentioned consumptions, main electricity consumer is food service of schools and kindergartens. Schools in soum centers usually have a food court for pupils from 1st grade to the 4th grade. Every kindergarten in every soum has food services. Every kitchen has an electric stove for mass food, ventilation system for extract vapor from the cooking.

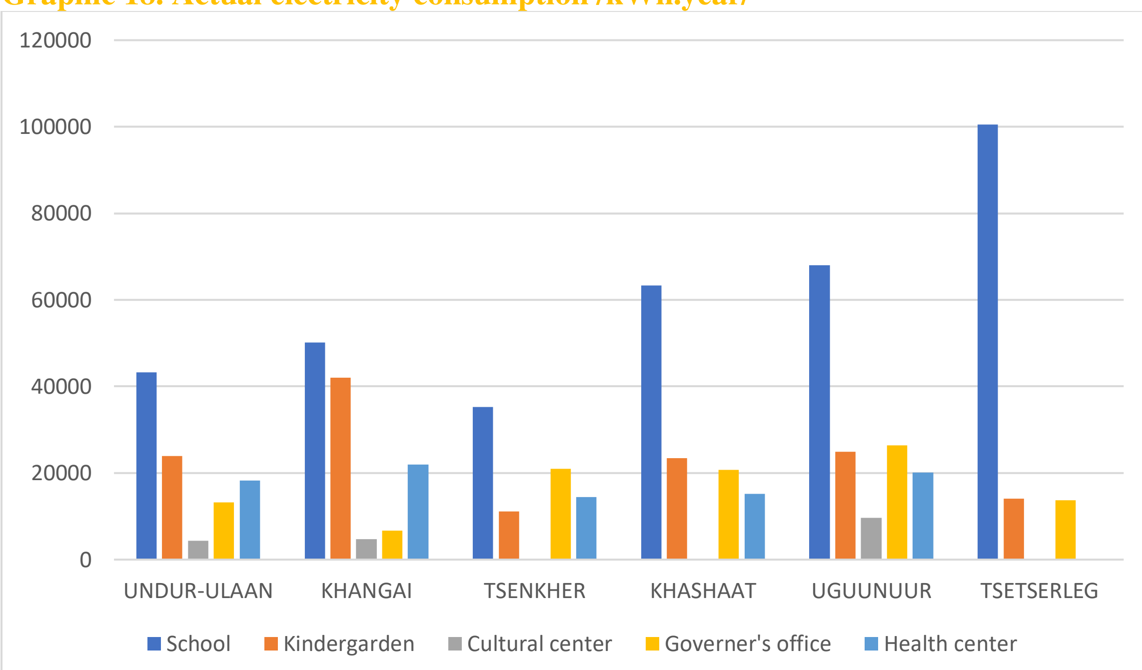
It was easier to determine electricity consumption for each building because the regular wattmeter has been installed on the grid. The following table shows the last three years' average electricity consumption. In Tsenkher, Khashaat, and Tsetserleg soum, cultural centers are new constructions without electricity during the baseline study in 2020.

Table 17. Actual electricity consumption /kWh.year/

Buildings/ soum	Undur-ulaan	Khangai	Tsenkher	Khashaat	Ugiinuur	Tsetserleg
School	43245	50201	35209	63306	68015	100459
Kindergarten	23875	42029	11095	23495	24966	14078
Cultural center	4348	4781			9596	
Governor's office	13264	6656	20928	20735	26428	13759
Health center	18302	21940	14398	15212	20120	

Source: Energy regulatory council of Arkhangai province. Data analyses by "BEEC" Co.Ltd.

Graphic 18. Actual electricity consumption /kWh.year/



Source: Energy regulatory council of Arkhangai province. Data analyses by "BEEC" Co.Ltd.

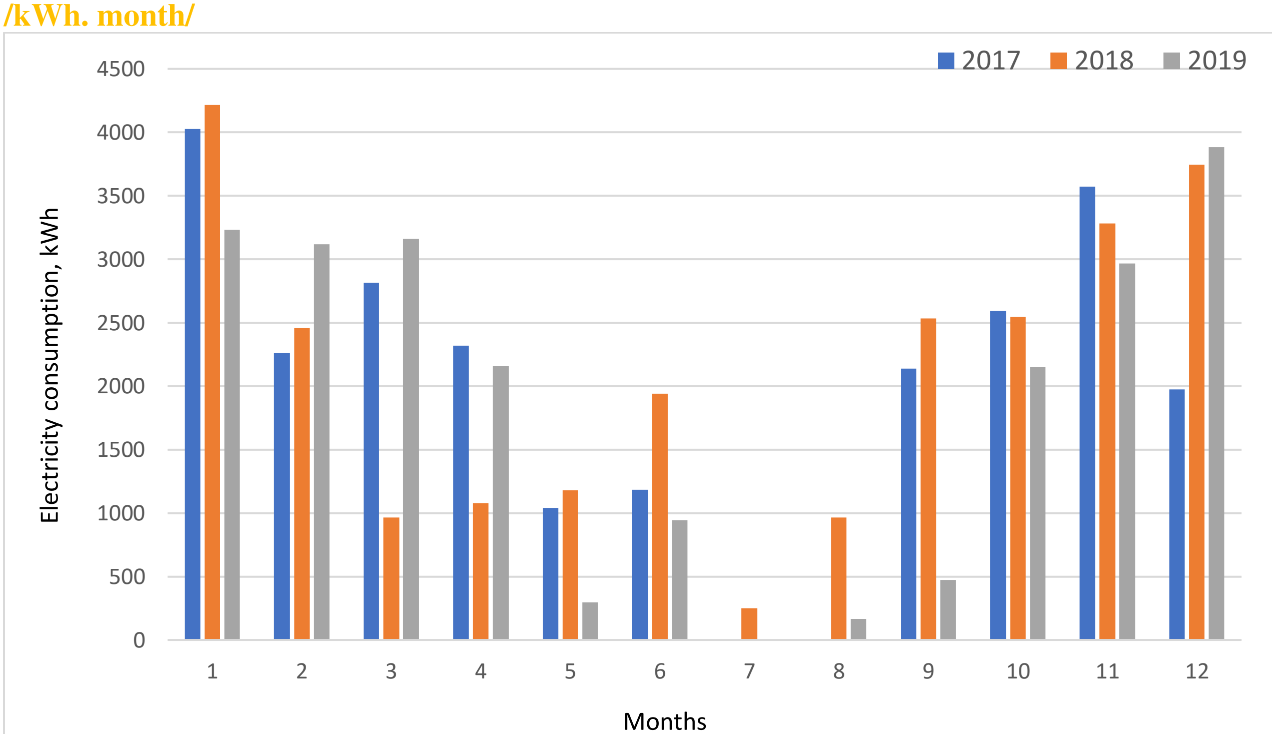
Clarifying the highest electricity consumption from the users during the survey, all answered that it is a heating system pump. This coincided with the monthly electricity consumption. For example, the annual electricity consumption of Undur-Ulaan soum kindergarten is broken down by month, and the figures are shown in Table 18 and Graphic 19. It is estimated that the heating system pumps consume 30-50 percent of the electricity during the heating season. Therefore, it is necessary to make hydraulic balancing for the system and improve operators' professional knowledge.

Table 18. Three-year electricity consumption of the kindergarten at Undur-Ulaan soum /kWh. month/

Soum	Undur-ulaan		
Months	2017	2018	2019
1	4026	4215	3232
2	2259	2458	3120
3	2815	2458	3160
4	2318	1077	2160
5	1041	1180	901
6	1182	1939	943
7	0	250	0
8	0	965	167
9	2140	2532	474
10	2591	2546	2151
11	3571	3284	2966
12	1975	3744	3882

Source: Energy regulatory commission of Arkhangai province. Data analyses by "BEEC" Co.Ltd.

Graphic 19. Three-year electricity consumption of the kindergarten at Undur-Ulaan soum /kWh. month/



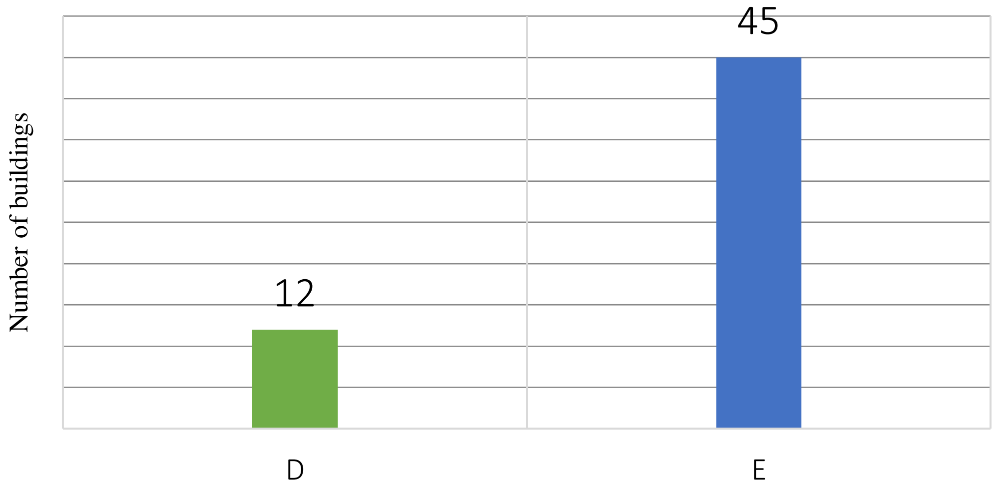
Source: Energy regulatory commission of Arkhangai. Data analyses by "BEEC" Co.Ltd

2.6 HEATING DEMAND AND CLASSIFICATION OF THE PUBLIC BUILDINGS

Out of 62 surveyed, public buildings of the soums, kindergarten, and sports hall in Khangai soum were excluded from the energy efficiency calculation because the kindergarten and gymnasium buildings are out of service due to cracks permafrost out of service time. Also, the cultural centers in Khashaat, Tsetserleg, and Tsenkher soums were not completed and were excluded from the calculation. Therefore, the energy efficiency classification was conducted for a total of 57 buildings. The estimation was performed in accordance with "BUILDING THERMAL PERFORMANCE." From the result, 44 buildings are classified as E class while 13 buildings belong to class D.

The buildings in class D were somehow insulated and built after 2009. Therefore, according to the recommendations shown in table 21, D class buildings shall be rehabilitated, while E class buildings shall be renovated or decommissioning with an economic base.

Graphic 20. Energy efficiency classes of the public buildings at soums



Source: "BEEC" Co.Ltd estimation result according to the BNaC 25-01-20 "Building thermal performance."

Table 19. Energy efficiency classification of residential and public buildings

Class	Class definition	Ration of the estimated and normative value of the specific heating and ventilation consumption, %	Recommendations from the governmental organization
A++	Passive	Less than 20%	Economic support
A+	Low energy building	From 40% to 20%	
A	High energy efficient	From 65% to 40 %	
B	Energy efficient	From 90% to 65%	
C	Normative level	From 90% to 110 %	Normative value should be met
D	Non energy efficient	From 110% to160%	Renovation based on economic condition
E	Non-energy efficient	Above 160%	Renovation based on economic condition or to demolish

Source: BNaC 25-01-20 "Building thermal performance."

Table 20. Building heating energy load and their classifications

Soum	#	Buildings	U wall	U roof	U floor	Class	kWh.year
Khashaat	1	1st school	1.65	1.53	0.55	E	662247
	2	2nd school	1.65	1.53	0.55	E	338271
	3	Sport hall	0.32	0.25	0.55	D	215559
	4	Dormitory 1	0.26	0.2	0.32	D	199349
	5	Dormitory 2	1.65	1.53	0.55	E	251308
	6	Food court	1.65	1.53	0.55	E	246220
	7	Medical center	0.28	1.53	0.55	E	189574
	8	Kindergarten	1.65	1.53	0.55	E	382931
	9	Governor's office	0.26	0.183	0.55	E	212888
	10	Police	0.3	0.25	0.55	D	34975
Ugiinuur	11	1st school	0.26	0.83	0.36	E	431764
	12	2nd school	1.65	1.53	0.55	E	271190
	13	3rd school	1.65	1.53	0.55	E	272732
	14	Sport hall	0.26	0.25	0.36	D	215559
	15	Dormitory	1.65	1.53	0.55	E	556574
	16	Kindergarten	1.65	1.53	0.55	E	382931
	17	Medical center	0.28	0.18	0.55	D	144003
	18	Cultural center	2	1.53	0.55	E	414649
	19	Governor's office	1.65	1.53	0.55	E	239255
	20	Police	0.3	0.25	0.55	D	34975
Tsetserleg	21	School	1.65	1.53	0.55	E	1014985
	22	Dormitory 1	0.32	0.83	0.55	E	168289
	23	Dormitory 2	0.32	0.83	0.55	E	164681
	24	Food court	1.65	1.53	0.55	E	102015
	25	Kindergarten	0.2	0.19	0.55	D	92172
	26	Medical center	1.55	0.83	0.55	E	246821
	27	Governor's office	1.65	1.53	0.55	E	170808
Tsenkher	28	School	1.65	1.53	0.55	E	1020067
	29	Dormitory 1	0.38	1.53	0.55	E	236991
	30	Dormitory 2	0.38	1.53	0.55	E	191807
	31	Sport hall	0.26	0.25	0.36	D	215559
	32	Building for rent	1.65	1.53	0.55	E	250699
	33	Medical center	1.65	1.53	0.55	E	382514
	34	After birth builgins	1.65	1.53	0.55	E	123589
	35	Morgue	1.65	1.53	0.55	E	84733
	36	Garage	1.65	1.53	0.55	E	48629
	37	Elder's house	0.38	1.53	0.55	E	65907
	38	Bag leader's quarter	0.38	1.53	0.55	E	78611
	39	Police	0.3	1.53	0.55	D	34975
	40	Governor's office	1.65	1.53	0.55	E	263083
	41	Kindergarten	0.32	1.53	0.55	E	241678
Khangai	42	School	0.27	0.25	2.2	E	974600
	43	Dormitory	1.65	1.53	3.9	E	529437
	44	Cultural center	1.65	1.53	3.9	E	1186513
	45	Governor's office	1.65	1.53	0.55	E	180655
	46	Citizen's meeting hall	0.27	0.25	0.55	D	56530

	47	Medical center	0.38	1.53	0.55	E	161340
	48	Police	0.3	1.53	0.55	D	34975
Undur-Ulaan	49	1st school	0.32	1.53	2.2	E	668748
	50	2nd school	1.65	1.53	2.2	E	940499
	51	Sport hall	0.27	0.25	0.19	D	145076
	52	Dormitory	1.65	1.53	2.2	E	460944
	53	Medical center	0.27	0.83	3.9	E	278426
	54	Kindergarten	0.27	0.8	3.9	E	436735
	55	Cultural center	0.32	0.22	2.3	E	191441
	56	Governor's office	1.45	1.53	0.55	E	239255
	57	Police	0.3	0.25	0.55	D	34975

Source: "BEEC" Co.Ltd estimation result according to the BNaC 25-01-20 "Building thermal performance."

2.7 COMPLIABLILITY OF THE PUBLIC BUILDINGS AT SOUMS WITH BUILDING NORM AND CODE.

The energy assessment was done on the surveyed buildings in accordance with "Building thermal performance" / BNaC 25-01-20 /. Out of the total 57 buildings assessed, there are no buildings fully meeting the normative requirements. The buildings surveyed were built in accordance with the 2009 norms[3], so there were significant inconsistencies with the updated norms. There was a building normative before 2020, there was a gap in the implementation level and normative supervision on the field.

In 2020 "Building thermal performance" normative has been updated, referring to the following national standards translated from European standards.

- MNS EN 832:2013 Building thermal performance-Calculation of energy use for heating-Residential buildings
- MNS EN 13788:2013 Hygrothermal performance of building components and building elements. Internal surface temperature to avoid critical surface humidity and interstitial condensation. Calculation methods
- MNS EN 13789:2013 Thermal performance of buildings-Transmission ventilation and heat loss transfer coefficients- Calculation method
- MNS EN 13790:2013 Energy performance of buildings - Calculation of energy use for space heating and cooling

NOTE: ***Scope of the "BUILDING THERMAL PERFORMANCE" / BNaC 25-01-20 /: The building norm and code shall be applied to the new and renovated apartments, public, industrial, agricultural, and warehouse buildings (hereinafter referred to as buildings) with an area of more than 50 m2, requiring a certain indoor temperature and relative humidity regime. (This norm shall be effective from January 1, 2021)***

At design stage: In some buildings, the required thermal resistance had been copied directly from the typical modular drawing without calculating it. For example, in Undur-Ulaan soum, the floor heat transmission coefficient was calculated as the floor in contact with the soil, between K = 0.068-0.465 W/m² °C, or for 4 zones, but in reality, the floor was the suspended floor with heat transmission coefficient of K = 3.9 W/m² °C. Therefore, the heat transmission coefficient of the

[3] BNaC 23-02-09 (MCUD, 2009)

floor in direct contact with the outdoor air must be the same as the heat transmission coefficient of the wall equalling K = 0.31 W/m² °C.

At construction stage: The insulation thickness of the surveyed building roof was specified in the design in accordance with the norms, but there were some cases of underperformance. For example, the kindergarten roof at Tsenkher soum was designed to be 20 cm thick but 2 cm thick.

Zoning of heating degree days: According to the normative of 2020, Arkhangai province belongs to zone I. Therefore, heating degree days that buildings need to heat have been considered equal to 7000°C·day.

Table 21. Heating degree days zoning

ZONE NUMBER	HDD, ^{o}C·DAY	CITIES AND PROVINCES
I	**7000**	Ulaanbaatar, **ARKHANGAI**, Gobi-Altai, Zavkhan, Selenge, Uvs, Centreal and Khuvsgul
II	6500	Bayan-Ulgii, Bayankhongor,Bulgan, Erdenet, Darkhan
III	6000	Uvurkhangai, Khovd, Khentii, Dornod, Dundgobi, Sukhbaatar
IV	5000	Dornogobi, Gobi-Sumber, Umnugobi

Source: BNaC 25-01-20 "Building thermal performance."

Thermal performance requirement of the building envelope: The buildings surveyed must meet the requirements shown in table 22. However, during the field measurement, the below indicators were partially met. There were 8 buildings that met the external wall requirement (Table 23), and 2 buildings passed both roof and wall requirements (table 24).

Table 22. Thermal resistance requirement of building envelopes (R_T^{req})

LOCATION ZONE	I (7000)					
BUILDING TYPE/DESIGNATION	1		2		3	
	R, m2K/W	U, W/m2K	R, m2K/W	U, W/m2K	R, m2K/W	U, W/m2K
Wall	3.85	0.26	3.3	0.3	2.4	0.42
Roof	5.7	0.18	4.4	0.23	3.25	0.31
Non heated attic, basement ceiling	5.05	0.2	4.4	0.23	3.25	0.31
Window, balcony door	0.65	1.54	0.55	1.82	0.38	3.08
Tope opening	0.43	2.35	0.38	2.67	0.33	3.08
Floor, basement wall	2.2	0.45	2	0.5	1.8	0.56
Door	1.8	0.56	1.7	0.59	1.6	0.63

Source: "BNaC 25-01-20 "Building thermal performance."

Table 23. Buildings met with a thermal resistance of wall requirement stated in the building norm and code

Soum	Buildings	U wall
Khashaat	Dormitory	0.26
	Cultural center	0.26
	Governor's office	0.26

Ugiinuur	1st school	0.26
	Sport hall	0.26
Tstserleg	Kindergarten	0.2
	Cultural center	0.26
Tsenkher	Sport hall	0.26

Source: "BEEC" Co.Ltd estimation result according to the BNaC 25-01-20 "Building thermal performance."

Table 24. Buildings met with a normative requirement by the U value of both wall and roof

Soum	No	Building designation	U wall	U roof
Khashaat	10	Governor's office	0.26	0.183
Ugii-Nuur	18	Medical center	0.28	0.18

Source: "BEEC" Co.Ltd estimation result according to the BNaC 25-01-20 "Building thermal performance."

2.8 ACTION TO IMPROVE BUILDING ENVELOPE

Based on the collected primary data and the measurement conducted on-site, the following recommendations are given. Reconstruction and demolishing solutions are not the best solutions. For the building that is too old and cannot be retrofitted, the best solution is reconstruction. But for the rest of the buildings is to retrofit and make a regular annual repair.

Table 25 shown possible construction envelope retrofitting recommendations of the buildings in the selected 6 soums. Recommendations are based on the estimation of U value by the BNaC 25-01-20 "Building thermal performance."

Table 25. Recommendation of envelope insulation

Soum	No	Buildings	Structure type	Built year	Insulation of envelope			
					Roof	Wall	Floor	Window
Khashaat	1	School 1st building	masonry	1959	✓	✓	✓	✓
	2	School 2nd building	masonry	1990	✓	✓	✓	✓
	3	Sport hall	masonry	2013	✓	✓	✓	✓
	4	Dormitory 1	masonry	2012	✓		✓	✓
	5	Dormitory 2	masonry	1990	✓	✓	✓	✓
	6	Canteen	masonry	1990	✓	✓	✓	✓
	7	Health center	masonry	2009	✓	✓	✓	✓
	8	Kindergarten	masonry	1990	✓	✓	✓	✓
	9	Governor's office	masonry	2013			✓	✓

	10	Police	masonry	2010	✓	✓	✓	✓
Ugiinuur	11	School 1st building	masonry	2012	✓		✓	✓
	12	School 2nd building	stone masonry	1985	✓	✓	✓	✓
	13	School 3rd building	masonry	1954	✓	✓	✓	✓
	14	Sport hall	masonry	2009	✓		✓	✓
	15	Dormitory	masonry	1975	✓	✓	✓	✓
	16	Kindergarten	masonry	1990	✓	✓	✓	✓
	17	Health center	masonry	2011		✓	✓	✓
	18	Cultural center	stone masonry	1965	✓	✓	✓	✓
	19	Governor's office	masonry	1978	✓	✓	✓	✓
	20	Police	masonry	2010	✓	✓	✓	✓
Tsetserleg	21	School	masonry	1990	✓	✓	✓	✓
	22	Dormitory	masonry	2015	✓	✓	✓	✓
	23	Dormitory	masonry	1989	✓	✓	✓	✓
	24	Canteen	masonry	2013	✓	✓	✓	✓
	25	Kindergarten	masonry	2012	✓		✓	✓
	26	Health center	masonry	1958	✓	✓	✓	✓
	27	Governor's office	masonry	1958	✓	✓	✓	✓
Tsenkher	28	School	masonry	1980	✓	✓	✓	✓
	29	Dormitory	wooden	1980	✓	✓	✓	✓
	30	Dormitory	wooden	1980	✓	✓	✓	✓
	31	Sport hall	masonry	2010	✓		✓	✓
	32	Rented building	wooden	1980	✓	✓	✓	✓
	33	Health center	masonry	1982	✓	✓	✓	✓
	34	Mother resting	masonry	1982	✓	✓	✓	✓

	35	Storage of dead body	masonry	1982	✓	✓	✓	✓
	36	Garage	masonry	1982	✓	✓	✓	✓
	37	Elderly room	masonry	2018	✓	✓	✓	✓
	38	Bag leader's quarter	masonry	2018	✓	✓	✓	✓
	39	Police	masonry	2010	✓	✓	✓	✓
	40	Governor's office	masonry	1980	✓	✓	✓	✓
	41	Kindergarten	masonry	2007	✓	✓	✓	✓
Khangai	42	School	masonry	2016	✓	✓	✓	✓
	43	Dormitory	masonry	1985	✓	✓	✓	✓
	44	Sport hall	masonry	1987	✓	✓	✓	✓
	45	Cultural center	masonry	1987	✓	✓	✓	✓
	46	Governor's office	wooden	1953	✓	✓	✓	✓
	47	Public meeting	masonry	2018	✓	✓	✓	✓
	48	Hospital	masonry	2013	✓	✓	✓	✓
	49	Police	masonry	2010	✓	✓	✓	✓
Undur-Ulaan	50	School	masonry	1988	✓	✓	✓	✓
	51	School	masonry	1975	✓	✓	✓	✓
	52	Sport hall	masonry	2016	✓	✓	✓	✓
	53	Dormitory	masonry	1986	✓	✓	✓	✓
	54	Health center	masonry	2010	✓	✓	✓	✓
	55	Kindergarten	masonry	2011	✓	✓	✓	✓
	56	Cultural center	masonry	2008	✓	✓	✓	✓
	57	Governor's office	wooden	1983	✓	✓	✓	✓
	58	Police	masonry	2013	✓	✓	✓	✓

Source: "BEEC" Co.Ltd recommendations

2.9 RECOMMENDATIONS FROM THE FIELD STUDY

Permafrost and building envelope damage: Almost 70 percent of the territory of Arkhangai province is in the continuous and intermittent permafrost zone. The buildings were designed with a hollow foundation to prevent distortion due to permafrost, but the fact that damage is still occurring indicates that the measures are inappropriate. Therefore, a detailed geotechnical study of the soil and a basic technological solution for the permafrost is needed.

Improve thermal insulation of the buildings: While the dominant energy consumption is energy for heating, the most economical and long-term effective way to reduce heat loss is to insulate the building's envelope. Insulation has many advantages, such as restoring the building's appearance, prolonging the building's life, and creating a comfortable thermal environment. Therefore, all buildings to be renovated or constructed after January 1, 2021, shall be constructed in accordance with BNaC 25-01-20 “Building thermal performance” and the local climate zoning of the heating season of all buildings in Arkhangai province shall be considered as a Zone I building. The roof insulation should be 20 cm thick, the wall insulation 15 cm thick, and the floor and foundation insulation 10 cm thick.

Insulation materials: Insulation materials are currently classified in the Mongolian market as mineral wool and foam types. Mineral wool insulation includes rock wool, fiberglass, and sheep wool insulation, while foam insulation includes EPS board, XPS board, and polyurethane insulations. Note that 20 cm thick mineral wool insulation is equivalent to 80 cm thick lava stone slag.

Decrease heat loss by flat and gable roof: Out of the 57 buildings assessed by the energy efficiency assessment, only 2 buildings fulfilled the BNaC. This result indicates that attention should be paid.

Roof attic: 42 buildings were built with gable roofs, while 6 flat roofs were reconstructed to gable roofs. Insulating the roof attic is the cheapest way to reduce heat loss and be implemented as a priority. In addition, to perform any maintenance following BNaC 25-01-20 “Building thermal performance.”

Flat roof: A common problem in Arkhangai soums is that flat roofs have been retrofitted as gable roofs due to rainwater penetration through the flat roof. In the future construction of new and old flat-roofed buildings, insulation and waterproof layer must be included in the design according to the related norms.

Decrease heat loss by the wall and envelopes of the building: Out of the 57 buildings surveyed, 8 buildings are fulfilling wall and envelope standards. However, by evaluating the insulation work performance of some buildings, the insulation work was not done by the proper technology.

The insulation material thickness was selected depending on the local climate zoning and estimated outside air temperature. Some building’s estimation outside air temperature was selected incorrectly at the design stage. In the BNaC 25-01-20 “Building thermal performance.” the climate zoning of Arkhangai counted as one zone.

Decrease heat loss by the floor: Depending on the specific characteristics of the region, buildings with hollow floors are predominant. Still, the floor has a lot of heat loss due to incorrect calculations during the design. Insulation of new buildings to be constructed and maintained following BNaC 25-01-20 "Building thermal performance."

Decrease heat loss by the window and infiltration: The windows usually had double-glazed windows with PVC frames and double-glazed windows with wooden frames. It should also be refurbished with an authorized laboratory-tested window with a certificate of origin that adheres to building code replacement technology.

Ventilation. The problems of mold and mildew in the corners of the building and high relative humidity had been identified during the site visit due to the non-operation of the ventilation system in kindergarten providing preschool education in Undur-Ulaan soum. Therefore, designing a ventilation system with a heat exchanger, an energy-efficient solution, is advised throughout Arkhangai province.

Training of administrative and operational officers: A training is needed for heat-only boiler operators who control the regime of the local heating system to strengthen their capacity. Provide general knowledge of heating sources, systems, and occupational safety to administrative officers.

Usually, the boiler regime is not adjusted regularly. The pump output adjusts the head pressure by their work experience, increasing the electricity consumption by 30-50 percent during the heating season. There is also a lot of unbalanced heat due to the lack of regular hydraulic adjustments.

Improve the energy efficiency of the heating source: The furnace used in public buildings of soums are mostly NRJ type of water heating boilers. However, in some buildings, the water heating boiler's technical specifications and brands were unknown. The most common operational difficulties of water heating boilers are:

- The upper part of the heating water-wall tubes is located in the upper part of the fire pit over the smoke exhaust, which is causing the ash clogs
- Due to the large space of the fire pit sole, a lot of coal is plugged into space, and the rest is unburned
- Heat transfer is not processing well because of the insufficient primary airflow of the furnace
- The water heating boiler's monitoring equipment number is not enough, such as thermometers and manometers

Additionally, install a heat meter in each public building. Knowing how much energy has been consumed is important to know energy efficiency. Further, data is the main thing to calculate and verify if energy efficiency measures are taken. Metering the individual off-grid heating system also plays an important role in determining operating costs and actual energy consumption.

CHAPTER 3. HOUSEHOLD BUILDING'S CONDITIONS IN ERDENEBULGAN SOUM

Under the development of the LEEAP in Arkhangai province, household building's current conditions were studied. The study objective was to identify the house structure material, energy consumptions, and heat source types of households in Erdenebulgan soum.

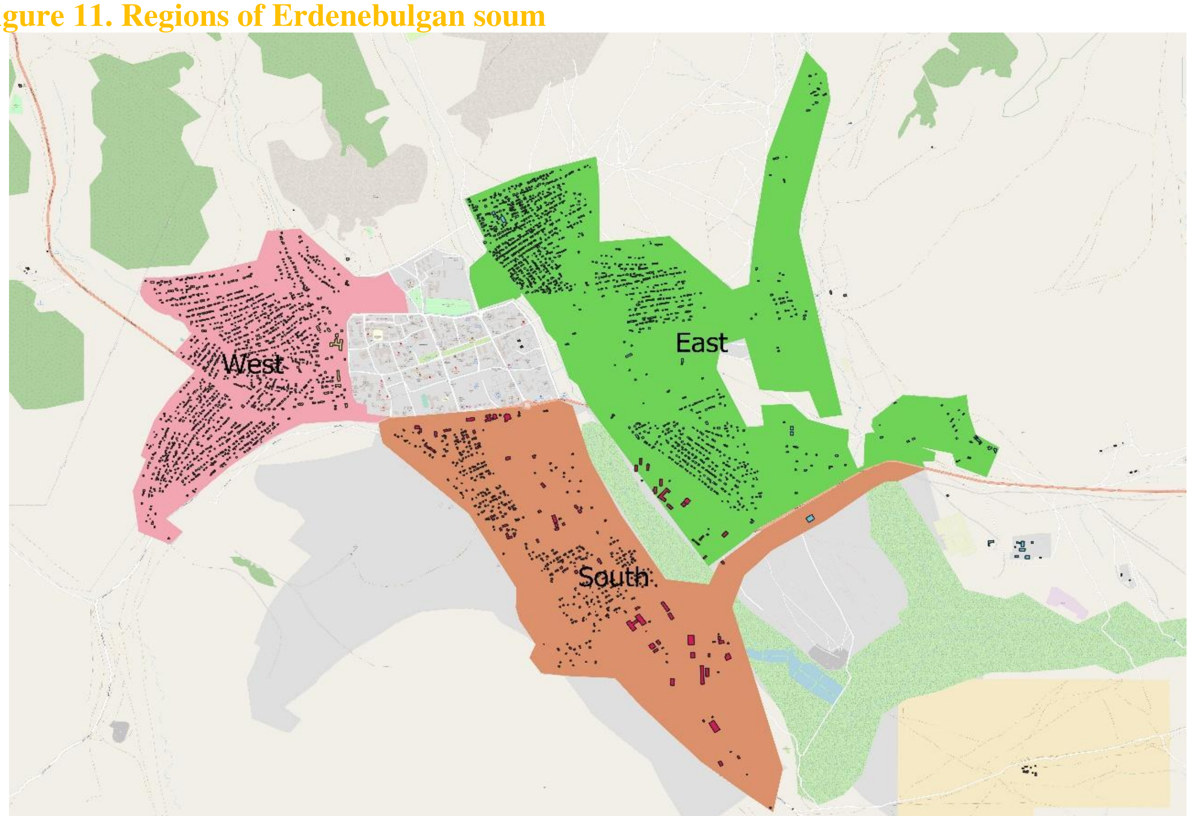
According to the discussion with the Erdenebulgan soum mayor's office and Land relations, constructions, and urban development department, for the study, the private houses of the Erdenebulgan soum were divided into three zones (Figure 11). For the accuracy and representability of the Erdenebulgan soum private houses, the sample houses were selected randomly from the zones. The study areas and methods were discussed and approved by the PSC and technical actors (Annex 1).

The research was conducted using a survey in 172 private houses with on-site measurements. By the results, houses categorized the buildings by structure and identified the fuel and electricity energy consumption. The on-site measurement and a survey from households were conducted by students of the Vocational training center of Arkhangai province.

Within 3 zones of the Tsetserleg sum of Arkhangai province :

- 65 private houses in the western zone or Arslan tsokhio and beyond Tsagaan davaa
- 38 private houses in the southern zone or Tamir district
- 69 houses in the eastern zone or Tsogt mountain, Bor hills, and Naranbulag area were studied.

Figure 11. Regions of Erdenebulgan soum

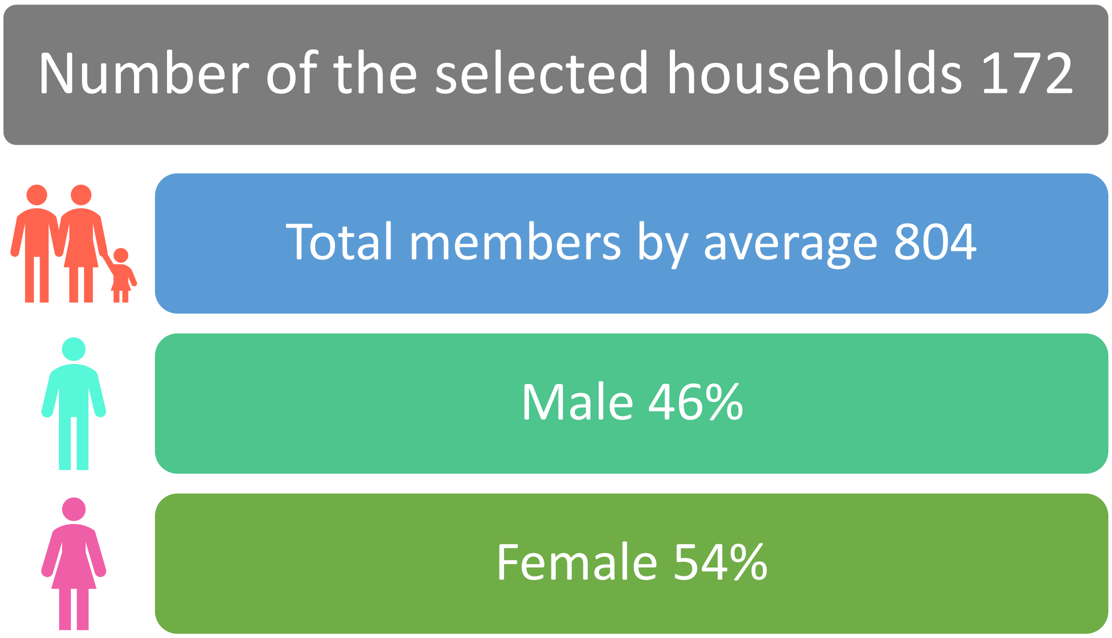


Source: "Geres" NGO and PSC meeting report

3.1 GENERAL CONDITIONS OF THE HOUSEHOLDS IN ERDENEBULGAN SOUM

The study was held in 172 households with 804 people, and the average number of family members is 4. The interview was mostly made with one or two people. The household with the largest number of members had 7 members. Family members were 46% male and 54% female. The following table is shown household members and gender ratio.

Table 26. Household's members



Source: "Geres" NGO 2020 baseline study questionnaire

From the questionnaire result, most households have answered that thermal comfort is normal and warm during the winter. Few households answered it is cold. The following table shows the answer of the owner how has valued the comfort of their houses. *"But we seeing the buildings has heat loss. Basing on the culture, people avoid saying bad things related to their home. And people are familiar with the current conditions of their house."*

Table 27. Answers to the comfort questions

Rating value	Value meaning	Count of answers
2	Bad	9
3	Average	92
4	Good	68
5	Comfortable	7

Source: "Geres" NGO 2020 baseline study questionnaire

The next table shows thermal comfort in the houses during the winter and relates to the building's insulation. As a result of the survey, none of 172 households have the floor and foundation insulations.

Table 28. Thermal comfort rating related to insulations.

Rating value	Count of buildings	Wall insulation	Roof insulation
Cold	23	0	21
Hot	3	3	3
Warm	146	51	148

Source: "Geres" NGO 2020 baseline study questionnaire

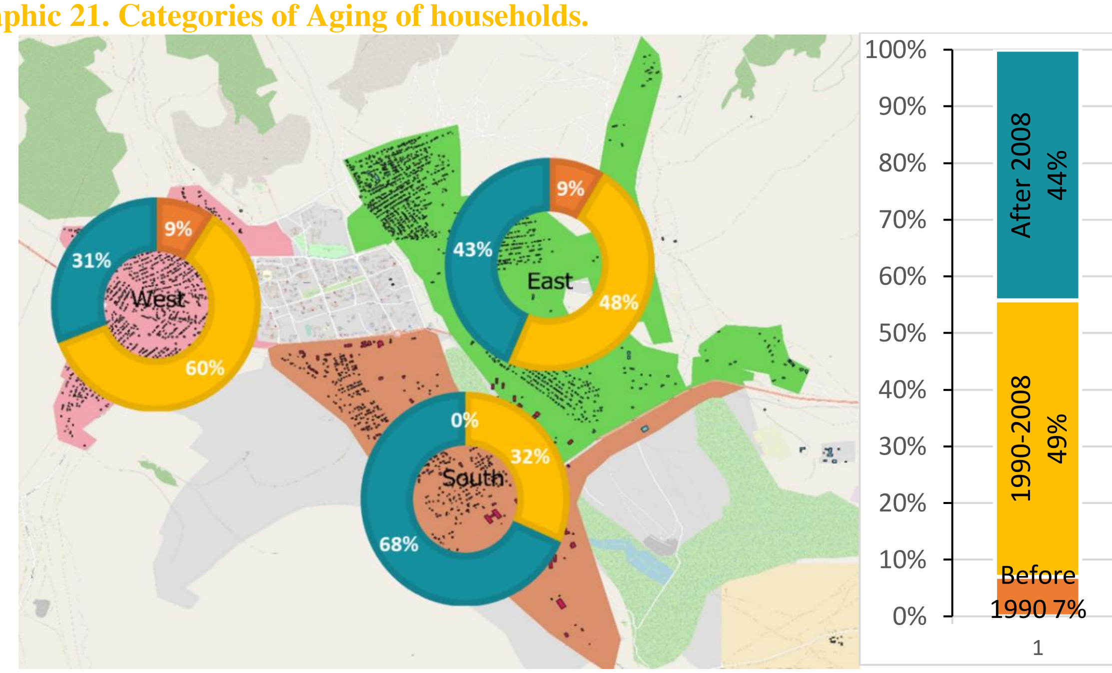
3.2 AGING OF THE PRIVATE HOUSES

The private houses of the Erdenebulgan soum can be classified into three categories based on their aging, as-built before 1990, between 1990-2010, and beyond 2010. Among the surveyed houses, half of 49% of the total private houses were built between 1990 and 2010. According to the results of the study by region (Graph 21):

- The eastern zone is dominated by private houses built between 1990 -2010
- The western zone is dominated by private houses built between 1990-2010
- The southern zone is dominated by buildings constructed after 2010.

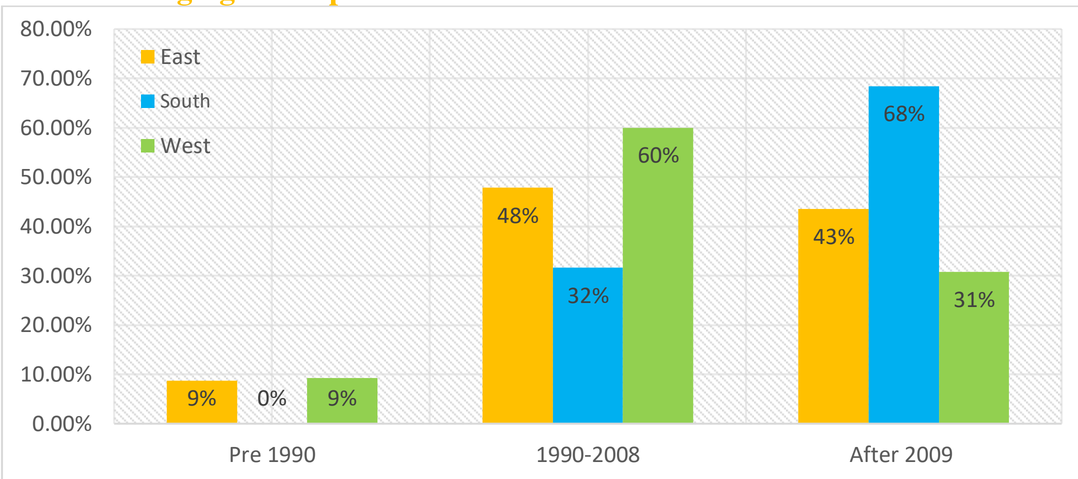
Based on the aging analysis, the southern and western zones of the Erdenebulgan soum contain a higher concentration of private houses (Graph 21). This situation is directly related to recent decades of urban planning and engineering network extension towards the south of the city. Regardless of the absence of the thermal power plant and heating network in the southern zone, the accessibility to the freshwater and sewage water network triggers the interest to settle in the south and west regions of the city.

Graphic 21. Categories of Aging of households.



Source: "Geres" NGO 2020 baseline study questionnaire

Graphic 22. The Aging of the private houses in each zone



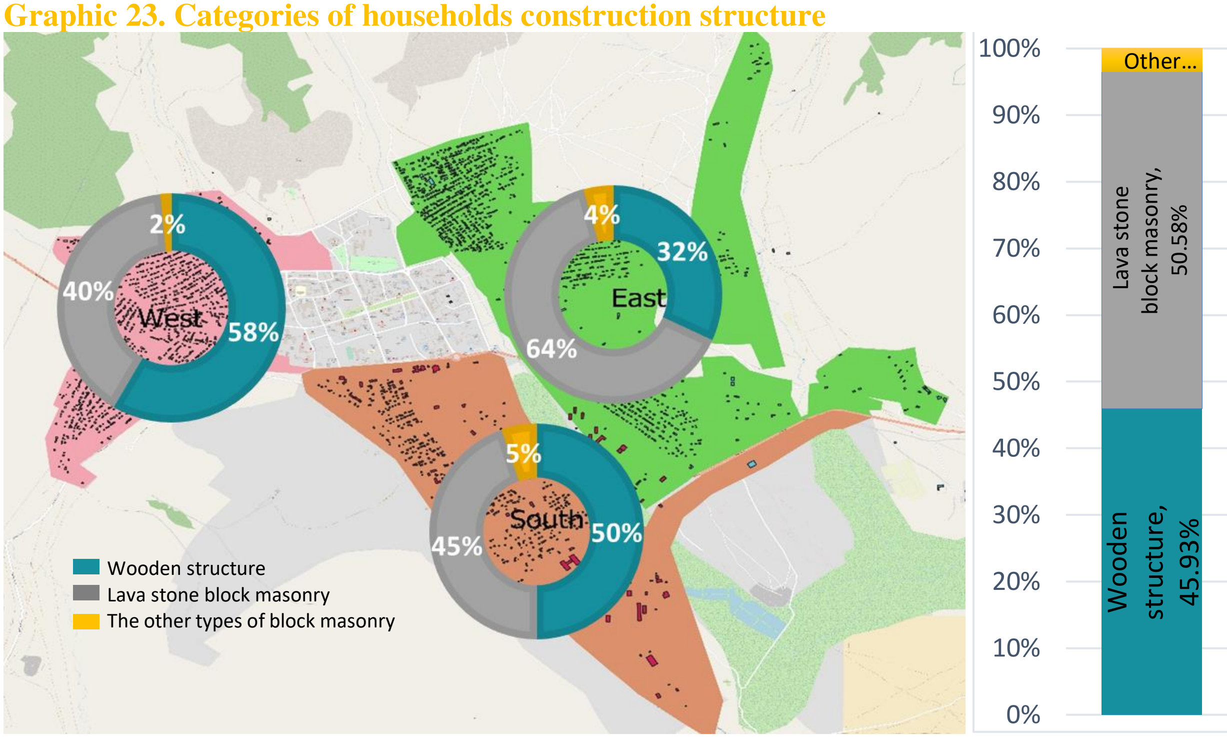
Source: "Geres" NGO 2020 baseline study questionnaire

3.3 CLASSIFICATION OF PRIVATE HOUSES BY CONSTRUCTION STRUCTURE

From the survey result, half of 50% of houses are built of lava stone blocks (Graph 23). The study identifies the following common structure classification of private houses:

- Lava stone block masonry
- Wooden structure
- The other types of block masonry.

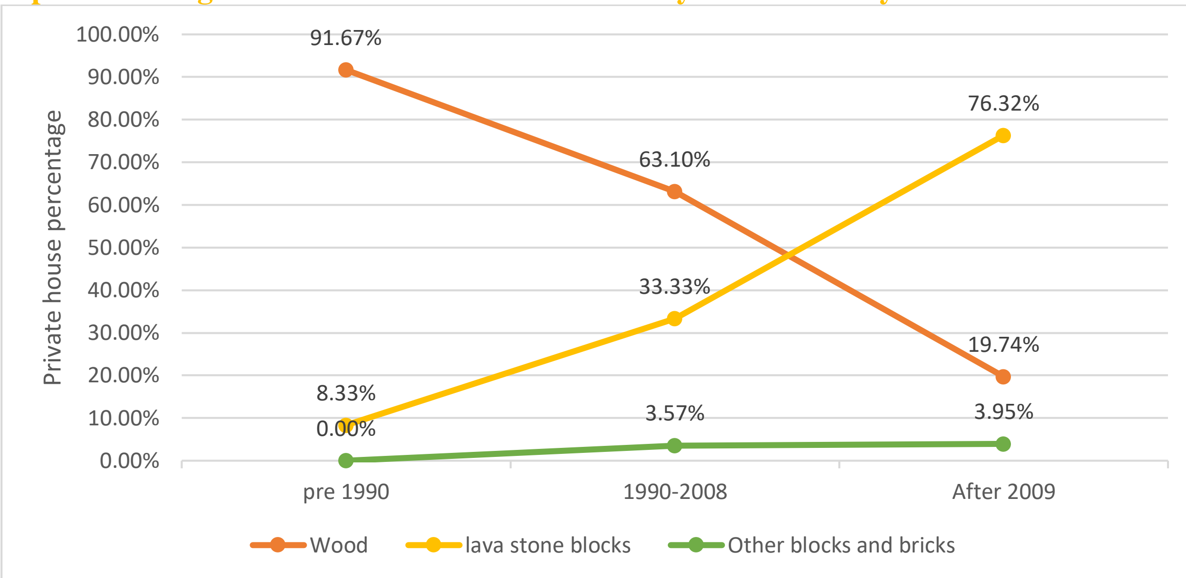
Graphic 23. Categories of households construction structure



Source: "Geres" NGO 2020 baseline study questionnaire

By analyzing n the construction structure and comparing it with the built year, lava stone block masonry in households has been increased since 2010. On the contrary, the construction of wooden buildings was reduced by 78%.

Graphic 24. Usage ratio of construction materials by construction year



Source: "Geres" NGO 2020 baseline study questionnaire

Private houses with lava stone block masonry

Crushing locally available raw lava stone and mold into the block as construction masonry has a reasonable price and accessible construction material. Therefore, lava stone blocks are most commonly used in the construction of houses. The price list of the most common construction masonry materials used in private houses and buildings is shown in the following table.

Table 29. Price list of block types

Block type	Size	U value W/m²k	Price (₮)	Price per 1м³ (₮)
Claydite blocks	390*190*188	0.15-0.35	1612	114 452
Lava stone blocks	390*190*188	0.22-0.33	2200	156 200
Euro blocks	600*200*250	0.09-0.13	5338	181 500
Concrete blocks	390*190*188	0.21	2330	165 430

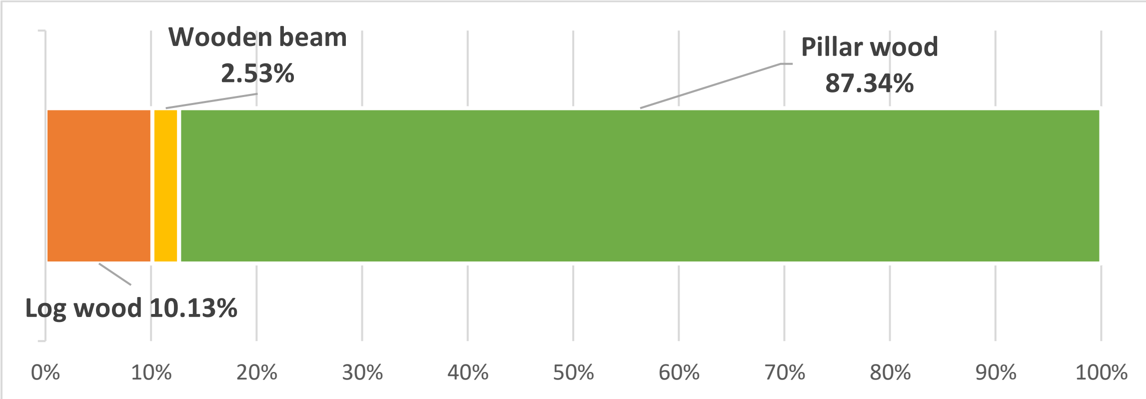
Source: Price list of producing companies and barilga.mn

While lava stone block masonry has several advantages: economical, efficient, fire resistance, and average thermal conductivity (λ=0.75W/mK) compared with other blocks. Depending on the manufacturing process and concentrations, lava stone block quality may vary vastly.

Private houses with wooden construction

Among the private houses, wooden construction accounts for 46% of the houses. The wooden houses are classified into the following three subcategories: logwood, wooden beam, and pillar. Pillar wood is the most commonly used than other wooden materials, and it takes about 87% of all wooden houses.

Graphic 25. Typology of wooden houses

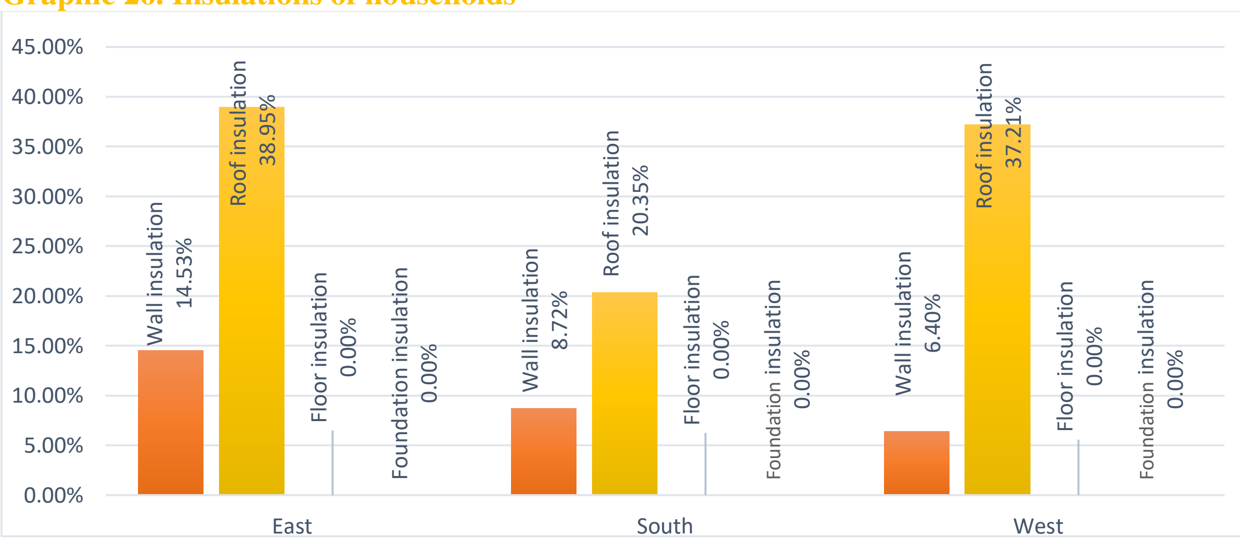


Source: "Geres" NGO 2020 baseline study questionnaire

3.4 INSULATIONS OF PRIVATE HOUSES

According to the survey results, out of 172 households, 51 households insulated their walls, and 166 households somehow insulated their roofs. However, not even a single house has an insulated floor or foundation. The following graphic illustrates the thermal insulation ratio of the private houses within the zones of Erdenebulgan sum.

Graphic 26. Insulations of households



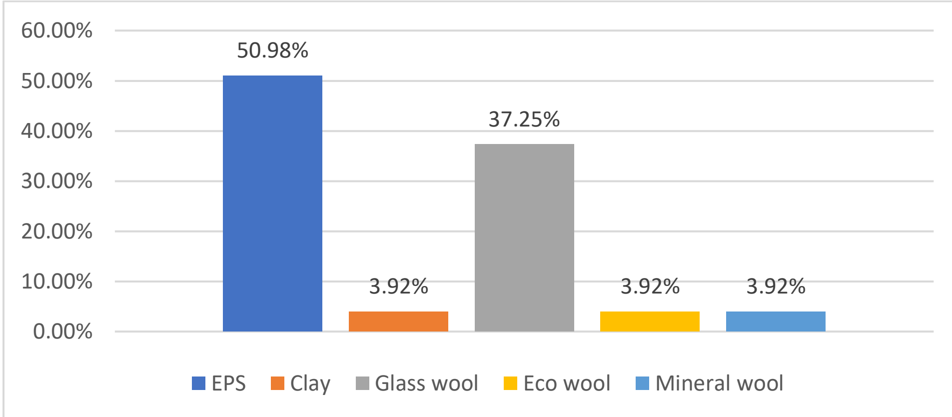
Source: "Geres" NGO 2020 baseline study questionnaire

Wall insulation of houses

Out of 172 families, only 51 houses had insulated the external wall. The most common insulation materials of 51 households are EPS panels, which account for 51%, and glass wool insulation 37%. The insulation method is depending on the insulation materials. Following methods were the most common method of insulation:

- EPS or foam. Placed on the exterior wall of the building and plastered with clay.
- Glass wool, eco wool, and mineral wool. Mostly fitted between the columns or sandwiched between the inner and exterior masonries.

Graphic 27. Wall insulation materials of private houses

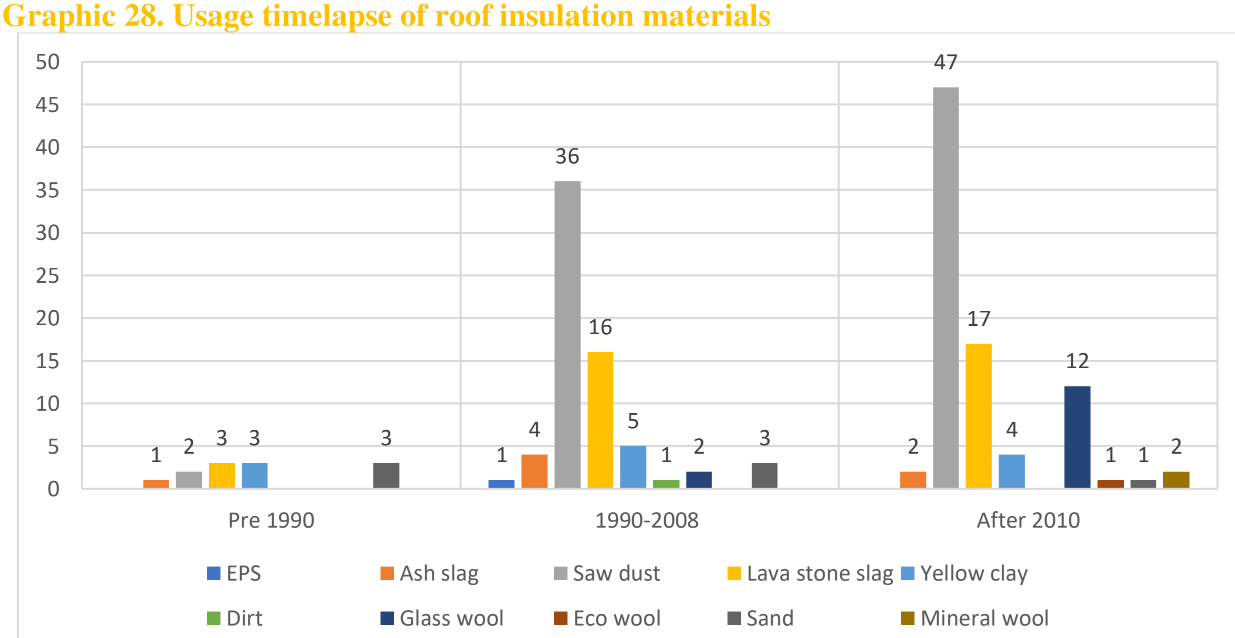


Source: "Geres" NGO 2020 baseline study questionnaire

Roof insulation

All households surveyed had a gable roof structure. Out of 172 households, 166 households had their attics insulated in some way. Households with roof insulation, often insulated with sawdust. Although insulating with sawdust is a very common and easy method, it can easily absorb moisture and lose its insulation quality if not insulated according to sophisticated technology. The following graphic demonstrates the insulation type of roof attic usage ratio compared to the building's age. From the graphic, houses built after 1990 are mostly insulated with sawdust, and some houses are insulated with lava stone slag. But, insulation materials such as EPS, XPS, and fiberglass are used very rarely.

Graphic 28. Usage timelapse of roof insulation materials



Source: "Geres" NGO 2020 baseline study questionnaire

3.5 HEATING TYPE AND FUEL CONSUMPTION OF THE HOUSEHOLD

Common types of heating

In line with the objectives of the study, the heating system and power energy tariffs were surveyed. The households of Erdenebulgan soum are not connected to the centralized heating system. They have an individual heating system and traditional wall cookers. The most common heating systems used in households are shown in the following table

Table 30. Common types of household heatings

Conventional wall cookers

Low-pressure heater

Other heating systems (electric heating and single furnace).

Source: "Geres" NGO 2020 baseline study questionnaire

It is common to use traditional hand-made stoves in conventional wall cookers and low-pressure heating systems. These are constructed in a low-cost and customary method, easier to use, and sales significantly high in the local markets. As a result, hand-made stoves are preferred over other types of furnaces. Out of the total participated households of the study, 97% use a handmade stove.

At roughly dozens of sales points in Erdenebulgan soum of Arkhangai province, hand-made stoves brought from Ulaanbaatar are available. Depending on the thickness of the metal plate, those sold for 35000₮-450000₮. Moreover, at the province level, individual artisans buy materials from Ulaanbaatar and make stoves and sell locally, directly related to the continuous usage of this type of stove.

Table 31. Typology of heating system

Type of heating	Quantity of households use	Percentage
Low-pressure heater	38	22.10%
Conventional wall cookers	131	76.20%
Other types of heating systems	3	1.70%
Only stove	1	0.60%
Electric	2	1.20%

Source: "Geres" NGO 2020 baseline study questionnaire

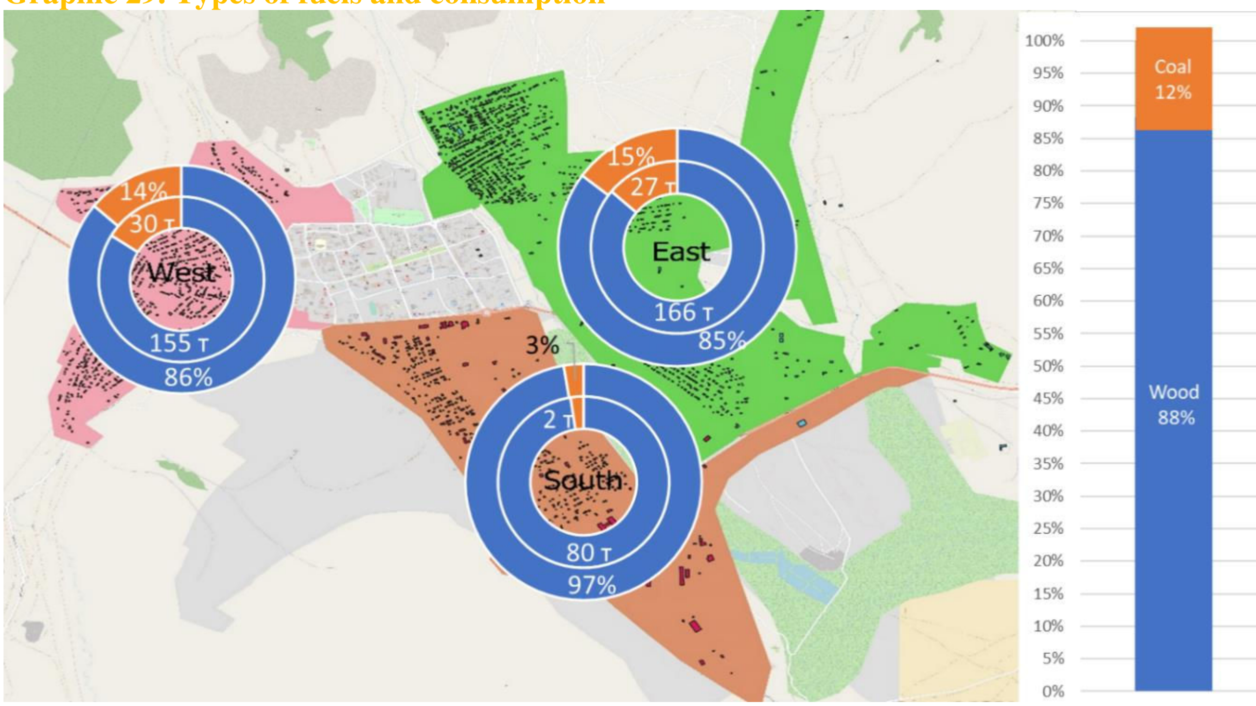
Types of fuel and consumption

The households of Arkhangai province predominantly use wood fuel for their heating. Out of total buildings, 87% use wood fuel, and 11% use coal. The fuel consumption is related to several issues such as building thermal insulations, the volume of buildings, the number of family members, and lifestyle.

The thermal imbalance induces discomfort in consumer well-being and increases energy expenditure. In cases where houses have better coverage insulations, the average fuel consumption is 1 ton, while in uninsulated buildings, the fuel consumption is higher. The following graph illustrates fuel consumption and fuel types. The fuel consumption directly depends on the following factors:

- Building thermal insulation
- Fuel type
- Stove types
- Human behaviors

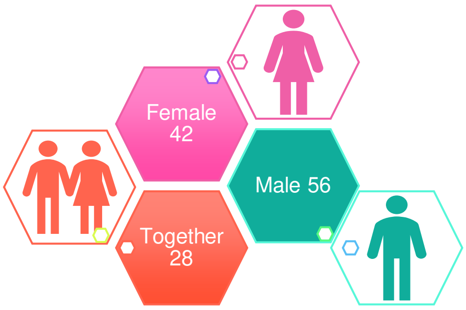
Graphic 29. Types of fuels and consumption



Source: "Geres" NGO 2020 baseline study questionnaire

3.6 GENERAL KNOWLEDGE ON THE ENERGY- GENDER AT HOUSEHOLDS LEVEL

In Arkhangai, the household is not connected to the central heating system. Due to the limitation of the efficient heating source, children, pregnant women, and the elders have more tendency to get sick during the cold season than in resident apartment areas. Women are responsible for heating buildings and provide thermal comfort for the family due to the Mongolian traditional culture (heating the home and pay electricity bills). Mainly, women are not completely satisfied with their thermal comfort, and children often get sick due to the cold environment in the house during the winter. Regarding selecting the fuel type and amount, men are dominant in deciding the type of heat source and the amount of fuel without proper knowledge of their own house. On the other hand, women and girls provide thermal comfort without knowing the fuel characteristics, heating source type, and building energy consumption.



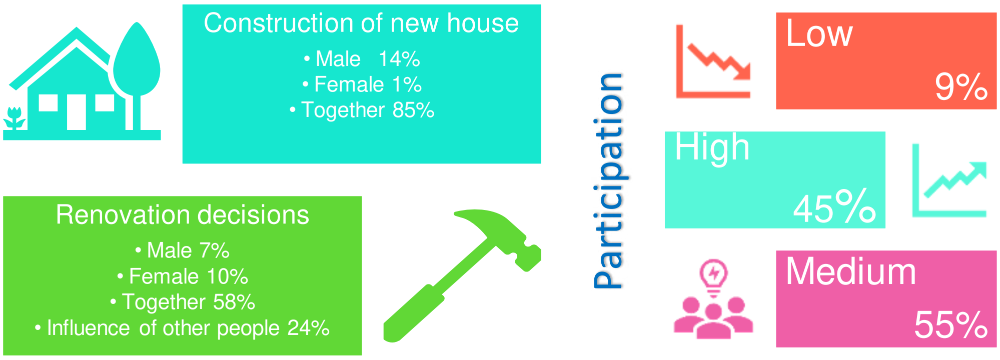
Out of 172 surveyed households, 126 households have answered social and energy-gender questions. The figure on the left shows the gender ratio who answered the survey. Within the questionnaire of energy efficiency in the households of Arkhangai, the following topics were surveyed:

- Construction or renovation decision-making process
- Comfort and microclimate
- Energy consumption control process of family members

The decision-making of renovation and construction of house mainly decided together. Out of 119 households answered, 101 household members responded that the wife and husband have decided to build a new house together. Renovating decisions can be influenced by other people such as friends, relatives.

The survey result shows that other family members somehow participate when the head of a family made decisions. Household members have rated other members on a 3 scale. The next figure has shown the relation of decision-making relation of the household members.

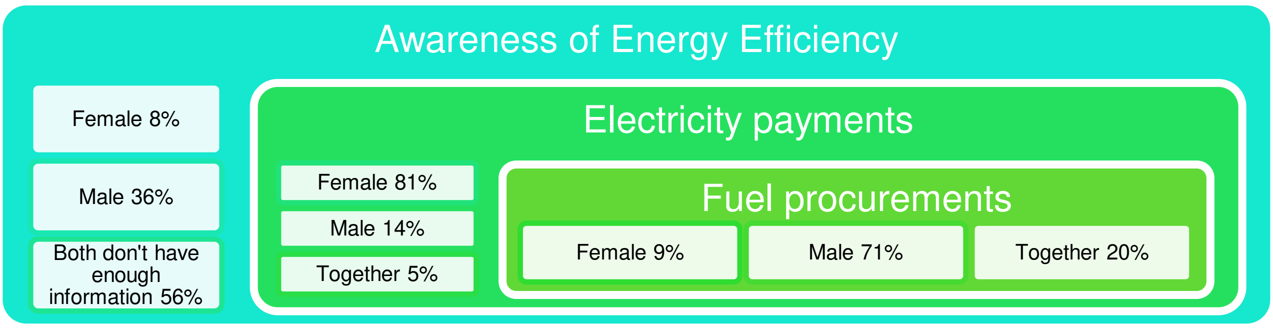
Figure 12. Renovation and construction decision-making dynamics



Source: "Geres" NGO 2020 baseline study questionnaire

From the questionnaire of energy consumption monitoring, households mostly answered they do not monitor and don't aware of their energy consumption. They don't know how much heat energy is consumed to heat the building regarding the heating cost. The following figure shows the gender dynamics of energy consumption.

Figure 13. Gender dynamics on energy consumption



Source: "Geres" NGO 2020 baseline study questionnaire

Women are willing to know the quality of energy sources and keep the energy in the house for a longer time to provide thermal comfort. However, more than half of households don't have enough information about the building's energy efficiency. The study finds that decision-makers and implementers do not have the same understanding level is the main gap in energy efficiency.

CONCLUSION

Public buildings are classified into 4 classes by the construction structure. Out of all public buildings in 18 soums, the most dominant structure is lava stone block masonry. Lava stone is the most available and reachable local construction material. The detailed study and energy assessment were completed on 62 public buildings in the 6 soums. Out of the 62 buildings, 45 buildings have an "E" class, and 12 buildings are classified as a "D" according to the building energy performance certificate.

The annual coal consumption centralized heating of Erdenebulgan soum and heating of public buildings in other 18 soum centers is 28650 tons. The annual emitted CO_2 is 39000 tons from the water heating furnaces. The 6 soum's public building energy performance certificate shows that the actual public building's energy demand is relatively higher than the normative energy demand. It is one of the reasons for the high consumption of fossil fuels for heating public buildings.

Depending on the established year, public buildings have been constructed under the applied Construction norms and regulations at that time. The main National actors provide changes and reforms construction and energy norms, as local actors are responsible for implementing and monitoring. The local actors are limited to modify the norms and regulations. There is a gap in the implementation level and normative supervision in the field. The main identified issue is the lack of guidance and supervision to implement the construction norms at the soum level. Standards and regulations are not properly implemented at the construction and planning stages at the soum level, including public administrative officers and private construction companies.

Study results show that heat loss of the building by envelope, poor management of the heating system, and users' behavior are the most common energy efficiency issues of public buildings in Arkhangai. There is a big need o do the policy gap analysis in the province to identify the reasons for those issues.

High heat loss of building envelope non-compliance of insulation density and U-value, and high infiltration heat loss through cracks such as poor window gaskets and envelope cracks increase the thermal energy consumption of public buildings and private houses. Insulating existing public buildings and houses following the building thermal protection norms will increase the energy efficiency of public buildings, reduce the fuel consumption used to heat the building, reduce greenhouse gas emissions from fuel combustion, and improve the user's thermal comfort.

Some pubic buildings of some soums using raw wood for heating the building. Due to its lower caloric value, it can't produce enough heat to supply thermal comfort to the users during the winter. And, using raw wood is accelerating deforestation. In recent years public buildings' roof structures changed from flat roof design to gable roof due to the high permeability of rainwater from the flat roof. Also, in the higher mountain areas, public buildings are more commonly damaged by permafrost. Therefore, a detailed geotechnical study of the soil and a basic technological solution for the permafrost is needed.

As for the heating system, poor management and an unregulated system reduce the energy efficiency of the public building. Moreover, it is not clear how much heat energy is consumed and produced by combusting fuel during the heating season. So, heat meter and monitoring equipment installation are one of the priorities.

There is a widespread misconception that building energy efficiency is only dependent on electricity consumption. Some authorities and people are unaware of the excessive use of thermal energy and neglect the importance of building heat loss. Users are not sufficiently aware of thermal energy usage to meet their needs. And have adapted to substandard thermal energy or supplying it over the demand.

RECOMMENDATIONS TO IMPROVE ENERGY EFFICIENCY OF PUBLIC BUILDINGS IN ARKHANGAI

To improve the energy efficiency of the public buildings, throughout the enhancing thermal comfort of users and to decreasing the Carbon footprint from heating public buildings, the following recommendations would be implemented step by step.

Reduce the heat loss of the building: The thermal insulation condition of existing public buildings and households needs to be improved step by step. The public building's insulations need to be renovated based on the building energy performance certificate and in accordance with BNaC 25-01-20, "Building thermal performance." effective from January 2021. Gable roof attic insulation, windows, and door insulations have great energy efficiency effects. Also, these insulations can be done through all seasons, with easy methods.

Reducing the heat loss of a building reduces the fuel consumption used to heat the building and increases the thermal comfort of working and studying throughout all seasons. The most common method to decrease the heat loss of the building is to insulate the building envelope.

Improve current heating system: The heating system needs to be improved step by step.

- To identify each building's exact heat demand and capacity of the existing boilers, pumps. It will decrease fuel consumption and electrical energy consumption during the heating season.
- Need to improve heat regulation and exploitation. There were missing regulating and monitoring instruments almost in every heater and boiler. Monitoring energy production and distribution is a main part of the heating system regulation. Heating system regulating will be difficult to manage without monitoring equipment.
- Pipeline and equipment should be insulated. Insulations must be done all over the outdoor and indoor pipelines and in the boiler rooms. A significant amount of heat energy is constantly lost during the heat distribution through the uninsulated pipeline. So, it needs to be appropriately insulated.

Electricity energy consumption: To increase the energy efficiency of the electricity energy consumptions in public buildings, it needs to implement next recommendations:

- To promote energy-efficient electrical appliances into the local procurement.
- Improve user's behavior of daily electricity usage.
- Raise awareness of the importance of energy efficiency and energy savings.

Protection from permafrost-related damages: A detailed study of permafrost impacts on buildings needs to be conducted soon. The study results will help improve the new construction and renovation blueprint of buildings in the areas with permafrost. To protect buildings from permafrost-related damages, implement foundation insulation technology at all construction stages and insulate existing building foundations in permafrost areas.

Awareness-raising activities: Following topics would be included in the awareness-raising activities:

- Spread the information on how to improve the energy efficiency of the buildings.
- Spread information of energy efficiency importance, advantages of the energy savings, and proper energy consumption of user's behavior.
- Spread the energy efficiency laws and regulations, thermal comfort and indoor air quality, and building energy efficiency measures.

Training:

Following topics can be included in the training for the local decision-makers:

- Introduction of construction norms and codes. Highlight the energy efficiency measures.

- Introduction of the energy efficiency law and regulations and their integration, including the responsibility of public actors.
- Guidance on how to improve the implementation of regulation and norms, especially at the soum level.
- Guidance of the heating system's management and select the heating equipment based on the heating demand.

To improve the capacity of local employees of the construction sector following subjects would be included in training:

- Introduction of the building energy efficiency norms, standards, and regulations.
- Introduction of the various insulation and waterproofing materials with thermal performance.
- Introduction and guidance of the building insulation technologies.
- Guidance of the selection of the heating equipment based on the building heat demand.

To improve the capacity of local employees who are working in the water heating furnace, following subject would be included in trainings:

- Operational instruction for the heating system, including the operation and monitoring of furnace.
- Selection of operation temperature regime and distribution and supply heating pipeline regulation related to the outdoor air temperature.
- Operational instruction of the ancillary equipment, such as pumps and thermostats to improve the heating system's energy efficiency.
- Workplace safety training.

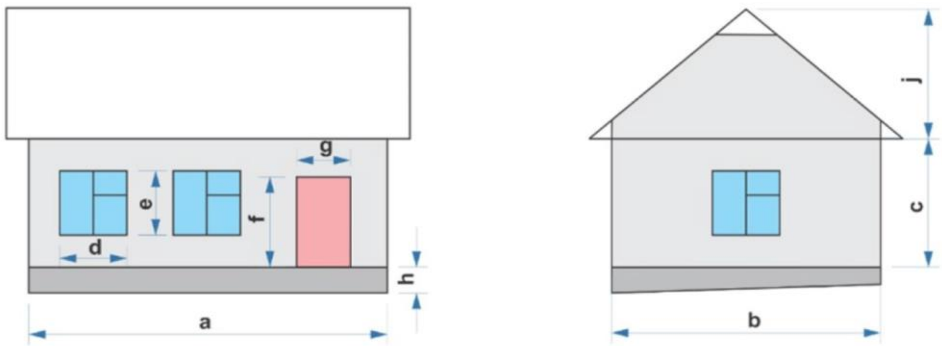
ANNEXES

Annex-1. Household questionnaire

Private household questionnaire

Date:___________

A person who is answering			
1	Female		Head of the family?
2	Male		Head of the family?
3	Both		
Main building			
4	Address		
5	Owner of the house		
6	Number of family members		
7	Established year		
8	Building direction		
9	Building store		
10	Basement		
11	Total area /m²/		
12	Total volume /m³/		
13	Total windows		
14	Total indoor doors		
15	Number of balconies		
16	Number of rooms		
17	Heating type		
18	Diameter of pipeline from heating resource	Providing pipe Ø	
19		Returning pipe Ø	



20	Building length / measured from the outside /	a		m
21	Building width / measured from the outside /	b		m
22	Building height / measured at actual height of 10cm /	c		m
23	Base height	h		m
24	Roof height / in case of attic /	j		m
Construction materials				
Wall		Thickness /mm/	**Floor**	Thickness /mm/
Materials			Materials	
Roof		Thickness /mm/	**Foundation**	Thickness and height /mm/
Materials			Materials	
Insulations				
25	Wall			
26	Floor			
27	Roof			
28	Foundation			
Windows				
29	Type			
30	Glazing			
31	Joinery of the windows			
Outside door				
32	Type			
33	Joinery of the door			
34	Door measures /height (f), widht(g)/	m		
Байшин барих болон засварлах шийдвэрт гэр бүлийн гишүүдийн оролцоо				
35	People involved in the decision to build a house?	M/F/Both	Participation:	
36	People involved in the decision to renovate the house?	M/F/Both	Participation:	

37	Rate the influence of family members in decision-making?	High / Medium / Low			
38	What do you think are the 3 most important indicators for building or renovating a house?				
Microclimate and comfort (room by room)					
39	How cold is it duringheating season	Hot/ Normal / Cold			
40	Air humidity	High / Medium / Low			
41	Air ventilation system	Yes / No			
42	Mold and fungi	High / Medium / Low/ Don't have			
43	Please rate comfort (1-very bad, 2-bad, 3-medium, 4-good, 5-very good				
44	Do you feel that your comfort level is not good enough and that you suffer from some illness?	if YES, who and how often:			
45	Are there any issues in your household that could affect your home that could make you sick?	if YES, from what:			
Stove or electrical boilers					
46	Stove type				
47	Fuel type				
48	Fuel consumption during the heating season /tons/				
49	Daily usage of fuel (winter)				
50	Daily usage of fuel (summer)				
51	Who usually prepares fuel or firewood? Or buy?				
52	Date of installation				
53	Please rate the use of the stove? (1-very bad, 2-bad, 3-medium, 4-good, 5-very good)		If bad, state the reason:		
			If good, state the reason:		
Electrical consumption					
54	Average payment during the heating season	kWh	Average payment during the summer	kWh	
55	Who follows the electricity consumption?				
56	What is your energy-saving practice?				

Note:

Annex-2. Heat loss by the building envelope estimation results

Soum	#	Buildings	Typology of building	Established year	Roof type	Floor-type	U wall	U roof	U floor	S wall	S roof	S window south	S window west	S window north	S window east	Class	kWh.a	Total heating area S	Total heating volume V
Khashaat	1	1st school	Masonry	1959	Gable roof	On the ground	1.65	1.53	0.55	533	1560	49.3	46.24	30.6	54.91	E	662247	606	2714
	2	2nd school	Masonry	1990	Gable roof	On the ground	1.65	1.53	0.55	546	544	1.2	68	6.5	40	E	338271	931	3916
	3	Sport hall	Masonry	2013	Sandwich roo panelf	On the ground	0.32	0.25	0.55	550	496	30.24	9	30.24	0	D	215559	421	3916
	4	Dormitory 1	Masonry	2012	Flat roof	On the ground	0.26	0.2	0.32	705	437	12.15	45	12.15	27.5	D	199349	1135	4018
	5	Dormitory 2	Masonry	1990	Gable roof	On the ground	1.65	1.53	0.55	585	390	2.8	23.8	2.8	12.6	E	251308	667	2807
	6	Food court	Masonry	1990	Gable roof	On the ground	1.65	1.53	0.55	310	450	2.7	16	2	11.56	E	246220	381	1710
	7	Medical center	Masonry	2009	Gable roof	On the ground	0.28	1.53	0.55	343	273	24.75	6.75	20.25	9	E	189574	464	1610
	8	Kindergarten	Masonry	1990	Gable roof	On the ground	1.65	1.53	0.55	568	567	25.5	18.72	14.4	23	E	382931	768	5452
	9	Governor's office	Masonry	2013	Flat roof	On the ground	0.26	0.183	0.55	520	496	41.25	61.5	1.8	52.5	E	212888	843	3571
	10	Police	Masonry	2010	Gable roof	On the ground	0.3	0.25	0.55	133	144	0	6.72	0	4.8	D	34975	122	374
Ugiinuur	11	1st school	Masonry	2012	Gable roof	On the ground	0.26	0.83	0.36	755	775	75.6	13.5	83.7	5.4	E	431764	1318	5584
	12	2nd school	Stone masonry	1985	Gable roof	On the ground	1.65	1.53	0.55	286	465	21	7	9	5	E	271190	395	1674
	13	3rd school	Masonry	1954	Gable roof	On the ground	1.65	1.53	0.55	249	576	36.7	0	30.6	0	E	272732	490	2073
	14	Sport hall	Masonry	2009	Gable roof	On the ground	0.26	0.25	0.36	550	496	30.24	9	30.24	0	D	215559	421	3916
	15	Dormitory	Masonry	1975	Gable roof	On the ground	1.65	1.53	0.55	554	941	29.5	48	13.5	45	E	556574	800	3389
	16	Kindergarten	Masonry	1990	Gable roof	On the ground	1.65	1.53	0.55	568	567	25.5	18.72	14.4	23	E	382931	768	5452
	17	Medical center	Masonry	2011	Gable roof	On the ground	0.28	0.18	0.55	259	468	29.2	6.5	32	6.5	D	144003	398	1591
	18	Cultural center	Stone masonry	1965	Gable roof	On the ground	2	1.53	0.55	435	630	27	0	13	0	E	414649	521	2709

	19	Governor's office	Masonry	1978	Gable roof	On the ground	1.65	1.53	0.55	249	440	16.8	0	14	1.4	E	239255	374	1144
	20	Police	Masonry	2010	Gable roof	On the ground	0.3	0.25	0.55	133	144	0	6.72	0	4.8	D	34975	122	374
Tsetserleg	21	School	Masonry	1990	Gable roof	On the ground	1.65	1.53	0.55	1154	1440	21.6	79	28	116	E	1014985	2511	9216
	22	Dormitory 1	Masonry	2015	Flat roof	On the ground	0.32	0.83	0.55	538	353	11.5	24.63	11.5	27	E	168289	610	2400
	23	Dormitory 2	Masonry	1989	Gable roof	On the ground	0.32	0.83	0.55	430	398	38	2.8	38	2.8	E	164681	738	2308
	24	Food court	Masonry	2013	Gable roof	On the ground	1.65	1.53	0.55	138	155	0	8.5	0	8.67	E	102015	148	465
	25	Kindergarten	Masonry	2012	Gable roof	On the ground	0.2	0.19	0.55	360	360	25.2	16.5	10.8	16.5	D	92172	519	1624
	26	Medical center	Masonry	1958	Gable roof	On the ground	1.55	0.83	0.55	320	610	20	28	11	20	E	246821	585	1830
	27	Governor's office	Masonry	1958	Gable roof	On the ground	1.65	1.53	0.55	232	384	11.2	1.4	11.2	1.4	E	170808	368	1152
Tsenkher	28	School	Masonry	1980	Gable roof	On the ground	1.65	1.53	0.55	1115	1436	133	93	56	103	E	1020067	2369	9009
	29	Dormitory 1	Wood	1980	Gable roof	On the ground	0.38	1.53	0.55	297	512	32.4	2.7	35	2.7	E	236991	440	1792
	30	Dormitory 2	Wood	1980	Gable roof	On the ground	0.38	1.53	0.55	276	416	1.5	18	3	16.5	E	191807	357	1456
	31	Sport hall	Masonry	2010	Flat roof	On the ground	0.26	0.25	0.36	550	496	30.24	9	30.24	0	D	215559	421	3916
	32	Building for rent	Wood	1980	Gable roof	On the ground	1.65	1.53	0.55	276	416	1.5	18	3	16.5	E	250699	357	1456
	33	Medical center	Masonry	1982	Gable roof	On the ground	1.65	1.53	0.55	440	621	18	13	15	18	E	382514	533	2173
	34	After birth buildings	Masonry	1982	Gable roof	On the ground	1.65	1.53	0.55	175.4	180	0	6.3	0	6.3	E	123589	154	630
	35	Morgue	Masonry	1982	Gable roof	On the ground	1.65	1.53	0.55	138	110	2.25	2.25	2.25	2.5	E	84733	94	385
	36	Garage	Masonry	1982	Gable roof	On the ground	1.65	1.53	0.55	100	50	3	0	0	0	E	48629	43	175
	37	Elder's house	Masonry	2018	Gable roof	On the ground	0.38	1.53	0.55	144	131	4.5	4.5	4.5	4.5	E	65907	112	458
	38	Bag leader's quarter	Masonry	2018	Gable roof	On the ground	0.38	1.53	0.55	164	161	4.5	6.75	0	6.75	E	78611	138	563
	39	Police	Masonry	2010	Gable roof	On the ground	0.3	1.53	0.55	133	144	0	6.72	0	4.8	D	34975	122	374

	40	Governor's office	Masonry	1980	Gable roof	On the ground	1.65	1.53	0.55	396	311	21.6	11	11.25	20	E	263083	550	2021
	41	Kindergarten	Masonry	2007	Gable roof	On the ground	0.32	1.53	0.55	284	551	18	6.75	18	6.75	E	241678	525	1928
Khangai	42	School	Masonry	2016	Flat roof	Above grade	0.27	0.25	2.2	1480	1400	96	68	64.4	45	E	974600	3784	15400
	43	Dormitory	Masonry	1985	Gable roof	Above grade	1.65	1.53	3.9	434	388	6.9	37	4.2	37.6	E	529437	744	2328
	44	Cultural center	Masonry	1987	Gable roof	Above grade	1.65	1.53	3.9	878	880	37.8	43.2	32.4	0	E	1186513	1478	7040
	45	Governor's office	Wood	1953	Gable roof	Хөрстэй	1.65	1.53	0.55	308	222	19	4.64	14	1.82	E	180655	213	666
	46	Citizen's meeting hall	Masonry	2018	Gable roof	Хөрстэй	0.27	0.25	0.55	180	261	9	3.64	5.5	5.5	D	56530	250	783
	47	Medical center	Masonry	2013	Gable roof	Хөрстэй	0.38	1.53	0.55	329	301	9	25	2.25	22.5	E	161340	515	1610
	48	Police	Masonry	2010	Gable roof	Хөрстэй	0.3	1.53	0.55	133	144	0	6.72	0	4.8	D	34975	122	374
Undur-Ulaan	49	1st school	Masonry	1988	Gable roof	Above grade	0.32	1.53	2.2	755	775	75.6	13.5	83.7	5.4	E	668748	1318	5584
	50	2nd school	Masonry	1975	Gable roof	On the ground	1.65	1.53	2.2	756	1700	49	47	30	55	E	940499	1445	5950
	51	Sport hall	Masonry	2016	Flat roof	Above grade	0.27	0.25	0.19	493	472	15.75	21.6	0	21.6	D	145076	401	2836
	52	Dormitory	Masonry	1986	Gable roof	Above grade	1.65	1.53	2.2	422	381	4.5	42.57	1.89	45	E	460944	648	2363
	53	Medical center	Masonry	2010	Gable roof	Above grade	0.27	0.83	3.9	387	280	24.75	4.5	21	9	E	278426	477	1820
	54	Kindergarten	Masonry	2011	Flat roof	Above grade	0.27	0.8	3.9	681	510	20.5	30	12.75	30	E	436735	900	3882
	55	Cultural center	Masonry	2008	Flat roof	Above grade	0.32	0.22	2.3	519	573	7.68	52	10.8	52	E	191441	510	2076
	56	Governor's office	Wood	1983	Gable roof	On the ground	1.45	1.53	0.55	249	440	16.8	0	14	1.4	E	239255	374	1144
	57	Police	Masonry	2013	Gable roof	On the ground	0.3	0.25	0.55	133	144	0	6.72	0	4.8	D	34975	122	374

Annex-3. The suggestion of buildings for the energy efficiency pilot

Building selection was more focused on the school or the kindergarten in accordance with the suggestions given by the PSC. The following 2 buildings were proposed as pilot buildings, based on the field study. According to the task of selecting buildings with long-term use and having common problems.

Proposed 1st building for the pilot retrofit: Kindergarten /Undur-Ulaan soum

Challenging issues:

When the team inspected the building on-site, the following issues were found: high indoor relative humidity and rainwater penetrated inside due to poor airtightness. Moreover, the type of floor is given in the drawing to contact the soil directly, but in reality, it was a suspended floor. Therefore, there is a difference between the thermal resistances of the floor directly contacted with the soil and the suspended floor. As a result, condensation occurs on the connection of the floor and wall, and mold grows.

Figure 14. Mold on the inner wall, caused by water seepage from the roof

Measures to be taken are listed according to their importance:

- Floor insulation: / floor area is 480 m2, and the area of the load-bearing columns will be added. A design drawing is needed to be developed by professional designers. Insulating the floor from outside will protect the building envelope, provide healthy and comfortable conditions for children who contact the floor, and prevent condensation or mold growing.
- Installation of the mechanical ventilation system: a design drawing is needed to be developed by professional designers. The selection of energy-efficient equipment called heat exchangers is needed. A mechanical ventilation system is required to be installed for the school and the kindergarten. It should be operated during the infectious disease spread according to the building normative updated in 2020. It is the main method to reduce child illness.
- Roof insulation and stopping rainwater penetration: 520 m^2 area / it shall be renovated as a module because there are cases that flat roofs are reconstructed as gable roofs due to rainwater penetration
- To install water treatment equipment that reduces water ph in the heat-only boiler. If to do so, the life cycle of the heating system will be extended.

Proposed 2nd building for the retrofitting: Kindergarten /Tsenkher soum/

Challenging issues: It is seen from the design drawing; the external wall and the roof of the building are designed to be insulated with 10cm EPS and 20 cm mineral wool accordingly by the support of funds given by World Vision. But only the roof was insulated with 2cm mineral wool. So the heating capacity is not enough for the building, and the indoor environment is cool.

Measures to be taken are listed according to their importance::

Roof insulation (600 m2) is the least investment required but can save about 30 percent on heating energy. The old roof insulation shall be removed, and vapor and waterproof will be layered before putting the insulation evenly.

Points to be considered:

Prevention of water penetration into the attic is needed. Ensure metal sheet sealing. Attic shall be ventilated

Building energy certificate of two pilot buildings

Annex-4. Building energy performance certificate.

BUILDING ENERGY PERFORMANCE CERTIFICATE

Registration number:

Isssued date: **21.01.26**

Valid date:

Type of certificate:	Existing	
Type of building:	School	
Name of Building:	Kindergarten	
Year of comission:	2011	

Address of building

City/aimag:	Arkhangai	**District/Soum:**	undur-ulaan sum
Khoroo/Bag	Teel	**Building number:**	Kindergarten
Name of street:	0	**Zipcode:**	65210

Building energy classification

		Normative / Baseline kWh/(m3.a)	**Design / Real** kWh/(m3.a)	**Difference** %
energy efficient				
A++	< 20%			
A+	20%-40%			
A	40%-65%			
B	65%-90%			
C	90%-110%	51		
D	110%-160%			
E	160%<		133	263
not energy efficient				

Specific building energy demand:	**578**	kWh/(m^2 a)
Annual building Energy demand:	**516378**	kWh/a

Name of auditor:	Gankhuyag		
E-mail	taek_ganaa@yahoo.com	**Phone number 1:**	99033553
Signature	....	**Phone number 2:**	

Issued organisation:

Logo of issued organisation

Issued based on below legal documentation:

BUILDING ENERGY PERFORMANCE CERTIFICATE

(Annex 1)

Registration number:	

Recommend to use this certificate as follow propose:

- to compare energy demand of building to the efficient similar type of building
- to identify and implement energy efficiency measures based on recommendation including technical and economical analyze

Specification	Unit	Value
GEOMETER CHARACTERISTICS		
Number of floor (0,000 above)		2
Number of floor (0,000 below)		0
Heated volume, V_h	m^3	**3882.0**
Heated area, A_h	m^2	**893.9**
Envelope area (heat exchnage), A	m^2	**1802.3**
Compactness	m^2/m^3	**0.2**
Glass wal ratio	m^2/m^2	**0.12**
ENERGY SOURCE AND SOLUTION		
Type of thermal source:	**District heating system**	
Type of heating system:	**2 pipe, water**	
Type of Ventilation system:	**Natural**	
Type of domestic hot water (heat source)	**District heating, open**	
Type of Renewable energy source and capacity:	**0**	
ENERGY CHARACTERISTICS OF HEATING AND VENTILATION SYSTEM		
Transmission heat loss	H_T W/K	**2813.1**
Ventilation heat loss	H_V W/K	**528.0**
Specific heat transmission coefficient	k_{sp} W/(K.m^3)	**0.678**
Specific heat transmission coefficient (normative)	k_{sp}^{req} W/(K.m3)	**0.198**
Specific annual energy consumption of heating (volumic)	Q_{sp}^{cal} kWh/m^3.a	**133.0**
Specific annual energy demand of heating and ventilation (normative)	Q_{sp}^{req} kWh/m^2.a	**199.8**
Annual energy demand of heating and ventilation (normative)	Q_{sp}^{req} kWh/m^3.a	**178630**

RECOMMENDATION

Recommend below measures to improve energy efficiency and energy classification:

- replace old windows by better one (triple glass, EPDM gasket, thick spacer, and frame
- insulate the an attic roofs by 20 cm mineral wool
- insulate wall by 15 cm mineral wool or EPS
- insulate foundation (inlcuding more 50 cm depth in ground)
- improve control system of mechanical ventilation system
- install heat recovery ventilation system
- improve ligthing system by LED and control system
- require detailed energy audit in some measures

BUILDING ENERGY PERFORMANCE CERTIFICATE

(Annex 2)

Registration number:	

1 Building information

1	Name of building	Kindergarten of Undur-Ulaan	Building classification	1
	Number of floor	2	Building user	Kindergarten
	Building addressr: ZIPCODE	65210	Building owner	
	Location (city, aimag/province)	Ulaanbaatar	Address of owner:	
	HDD zone	I 7000	Phone of owner:	

2 Building heat exchanging surface (envelope) area , heated volume and area

2	Envelope area, A (external dimension)	(A_{EW}+A_W+ARO+ANB+AGF+ARF+AAW+AEF)	m^2	1802
3	Heated volume, Vh	covered by A surface	m^3	3882
4	Compactness	A/Vh=	m^{-1}	0.46
5	Glass wall ratio	AW/(AEW+AW)	m^2/m^2	0.12
6	Room height	h_r	m	3.7
7	Heated area, A_N,	V_h/h_r	m^2	894

3 Heat loss and gain

3.1 Transmission heat loss — H_T, W/K

	Heat transmitting structure	ABB.	U (norm.), W/m2K	U (design), W/m2K	Area, m2, A	Temp. corr.	U·A·Fx, W/K
8	External wall (without window)	EW1	0.260	0.270	682	1	184.1
9	External wall (without window)	EW2	0.260	0.270	0	1	0.0
10	External wall (without window)	EW3	0.260	0.270		1	0.0
11	Window South (S)	SW	1.538	2.500	20.50	1	51.3
12	SW	WSW	1.538	2.500	0	1	0.0
13	W	WW	1.538	2.500	30.00	1	75.0
14	NW	WNW	1.538	2.500	0	1	0.0
15	N	WN	1.538	2.500	12.75	1	31.9
16	NE	WNE	1.538	2.500	0	1	0.0
17	E	WE	1.538	2.500	30.00	1	75.0
18	SE	WSE	1.538	2.500	0	1	0.0
19	Vertical	RW	1.538	2.500	0		
20	External door	ED	0.556	2.500	7.00	1	17.5
21	Roof	RO	0.175	0.800	510.0	1	408.0
22	Attic	AF	0.198	1.353	0	1	0.0
23	External floor	EF	0.260	0.260		1	0.0
24	Attic wall	AW	0.198	0.198		0.8	0.0
25	wall and roof of unheated space	NW	1.000	1.000		0.5	0.0
26	low temperature (12-19°C)	LW	0.371	0.371		0.35	0.0
27	wall and window of unheated space						0.0
	- single glass	NG1	4.000	4.000		0.8	0.0
	- double glass	NG2	2.500			0.7	0.0
	- insulated glass	NG3	1.800			0.5	0.0
28	Wall and roof of unheated basement	NB	0.198			0.6	0.0
29	on Grade floor, wall and floor of heated basement space	GF	0.455	0.480	0.00	0.4	0.0
30	Above grade floor	RF	0.455	3.900	510.00	0.9	1790.1
31	Total heat exchanging surface (Envelope), A				1802.25	ΣH_T	2632.9
32	Thermal bridge loss (improved)				+	A·0.05	
33	Thermal bridge loss (common)				+	A·0.10	180.2
34	Transmission heat loss					H_T	2813.1
35	Specific heat transmission coefficient					$k_{sp}=H_T/V_h$	0.678
36	Specific heat transmission coefficient (normative)					k_{sp}^{req}	0.198

3.2 Ventilation heat loss — H_V (W/K)

37	ACH of natural ventilation, h^{-1}	n_{nv}=	0.5	0.5
38	ACH of mechanical ventilation, h^{-1}	n_{mv}=	0.2	0
39	Efficiency of heat recovery, %	eff.	50	0
40	Weekly working time of ventilation system, h	t_m=	50	50
41	Average ACH, h^{-1}	n_{av}	$n_{av}=((n_{mv} \cdot t_m+n_{mv} \cdot (168-t_m))/168$	0.50
42	Ventilation heat loss, W/K		$H_V=n_{av} \cdot 0.8 \cdot V_h$	528.0
43	Total heat loss, W/K		$H=H_T+H_V$	3341.0

Climate data

Location		Ulaanbaatar city	HDD	7000
Longtitude	[°]			47.920
Latitude:	[°]			106.920
Altitude:	[m]			1300

	months		9	10	11	12	1	2	3	4	5	Жил
	days		14	31	30	31	31	28	31	30	14	240
	External air temp.		7.2	-0.5	-11.3	-20.1	-21.7	-18.7	-8	0.8	6.9	-9.17
	Internal air temp.		20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.00
	HDD		179	636	939	1243	1293	1084	868	576	183	7001
Direction		Area	Solar radiation, kWh/m2									
South	WS	20.5	42.4	138	126	118	139	151	173	121	40.8	1049
South west	WSW	0	38.4	116	104	84	105	120	148	119	45.6	880
West	WW	30.0	30	73	56	36	50	68	105	101	44.8	564
North west	WNW	0	18.8	37	25	18	22	33	61	75	35.2	325
North west	WN	12.8	13.6	30	23	18	21	30	48	56	24.8	264
North east	WNE	0	19.2	36	24	18	22	33	61	79	36	328
East	WE	30.0	32	70	46	42	51	67	107	114	48	577
South east	WSE	0	40.4	111	91	93	106	119	152	130	48.8	891
Horizontal	RW	7.0	46.4	91	54	41	50	76	126	149	72	705

3.3 Solar heat gain

	Direction		Талбай	FS=	0.9	FC=	1	FF=	0.7	g□=	0.6		0.378
44	South	WS	21	329	1069	976	914	1077	1170	1341	938	316	8130
45	South west	WSW	0	0	0	0	0	0	0	0	0	0	0
46	West	WW	30	340	828	635	408	567	771	1191	1145	508	6393
47	North west	WNW	0	0	0	0	0	0	0	0	0	0	0
48	North west	WN	13	66	145	111	87	101	145	231	270	120	1274
49	North east	WNE	0	0	0	0	0	0	0	0	0	0	0
50	East	WE	30	363	794	522	476	578	760	1213	1293	544	6543
51	South east	WSE	0	0	0	0	0	0	0	0	0	0	0
52	Horizontal	RW	7	122.77	240.79	142.88	108.49	132.3	201.1	333.4	394.25	190.51	1866.49

3.4 Internal heat gain, Q_i, kWh/month

54	Internal heat gain		W/m2	5	5	5	5	5	5	5	5	5	

4. Annual and monthly heating and ventilation energy demand, kWh/month (kWh/a)

53	**Solar heat gain**	kWh/m	1220	3076	2387	1984	2468	3047	4309	4040	1679	24208
55	Internal heat gain	kWh/m	1602	3326	3218	3326	3326	3004	3326	3218	1602	25745
56	Usage factor		0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	
57	Total heat gain	kWh/m	2460	5762	5044	4788	5203	5446	6871	6532	2882	44957
58	Transmission heat loss	kWh/m	12099	42905	63398	83827	87278	73168	58602	38888	12382	472632.9
59	Ventilation heat loss	kWh/m	2271	8052	11898	15761	16380	13730	10998	7298	2324	88702.27
60	Energy demand (balanced)	kWh/m	11920	45196	70248	94890	98452	81443	62729	39654	11844	516378
61	Energy demand (normative)	kWh/m	3274	14538	24848	34816	38084	29184	20852	11886	2886	178830
61	Specific energy demand									kWh/m³.a		133.0
62	Specific energy demand (normative)									kWh/m³.a		50.6
63	Difference									%		263
64	Classification											E

Annex 5. Climate data used for the estimations

Table 32.Average outdoor air temperature of soums

SOUM	I	IL	LLL	IV	V	VI	VII	VIII	IX	X	XI	XII	ANNUAL
Ugiinuur	-22.4	-18.2	-8.6	1.5	10.4	16.4	18.6	16.8	10.2	0.7	-10.4	-20.3	-0.4
Undur-Ulaan	-22.3	-18.3	-11.4	-0.8	5.4	10.7	12.8	11.0	4.9	-3.9	-12.4	-19.1	-3.6
Khangai	-23.6	-19.5	-12.2	-1.9	4.8	9.7	11.4	9.8	4.9	-2.2	-12.4	-20.0	-4.3
Khashaat	-19.2	-14.6	-6.5	2.9	10.4	16.6	17.8	16.2	9.6	-0.1	-9.4	-17.2	0.5
Tsenkher	-16.5	-14.1	-7.6	1.4	9.0	13.7	15.2	13.2	8.6	0.7	-8.1	-13.9	0.1
Tsetserleg	-16.1	-14.2	-7.7	0.1	7.8	12.9	14.0	12.1	6.6	-0.3	-8.5	-14.6	-0.6

Source: BNaC 23-01-09

Table 33. Heating season duration and an average temperature of the heating season.

Soum	Heating season				
	Start date	End date	Days	The average temperature of the heating season, °C	The specific temperature of the heating season °C (-t)
Ugiinuur	21.IX	6.V	227	-9.9	-2246.4
Undur-Ulaan	1.IX	1.VI	273	-8.6	-2351.0
Khangai	26.VIII	5.VI	283	-8.5	-2418.1
Khashaat	20.IX	7.V	229	-7.6	-1731.6
Tsenkher	18.IX	12.V	236	-6.8	-1605.9
Tsetserleg	8.IX	16.V	250	-6.5	-1617.2

Source: BNaC 23-01-09