# ENERGY AUDITS OF CHOSEN TYPICAL BUILDINGS IN MONGOLIA

## COMMON OVERVIEW AND SUMMARY

Ulaanbaatar city
November 2013

Present energy audit done by

SEVEn

Energy Efficiency Center, Czech Republic

Within the project **"Turning Sheep Wool into Environmentally Friendly Building Material –**

**Integrated Approach for Supply Chain Development"**

**implemented by the People In Need**

**under EU Programme SWITCH-Asia**


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# 1 FOREWORD

Within the scope of the project "Turning Sheep Wool into Environmentally Friendly Building Material Integrated Approach for Supply Chain Development", People in Need with its partner NGO SEVen have successfully completed energy audits of typical Mongolian buildings. A summary is presented to the reader in this publication.

Although foreseeable, the results are stunning. Enormous energy savings could be achieved by adopting simple and reasonably cheap efficiency measures.

We sincerely hope this will be a source of inspiration for the multi-sectoral stakeholders. Policy makers should find here the relevant figures related to energy savings (directly linked to the needs of energy production), rehabilitation costs as well as payback period of investment. The construction sector could use this document to calculate additional initial cost of insulation and eventually use this analysis as a marketing leverage intended for end consumers. Finally the end consumer should be able to figure out his own financial interest in taking energy efficient measures for his habitation.

In rather narrower perspective, which is the one of our projects, the author has suggested to use Sheep wool building insulation as an energy saving measure. Though the product is new and recently emerging on domestic market, we hope that the construction sector stakeholders will take advantage of this new product by introducing it as green and sustainable practice in the construction sector, conducive to economic growth of the country. We also believe the policy maker will take the new product not only as an insulation material, but as one of the very few environmentally friendly products made in Mongolia and hence consider it in their effort to greening of the construction sector.

I would like to thank very much Mr Petr Zahradnik from SEVEn, the Energy Efficiency Center NGO, who led energy audits on the field and authored present publication. Special thanks also go to the owners of the audited buildings, apartments and houses and last but not least to all People in Need NGO team in Mongolia.

Quentin Moreau
Head of Mission
People in Need, Mongolia

Generally, an Energy Audit is a process of examination of an energy consuming equipment/ system to ensure that energy is being used efficiently. This is always supported by calculations based on measured, expertly determined and estimated data.

> By identifying and implementing the means to achieve energy efficiency and savings, not only can energy savings be achieved, but also equipment/system services life can be extended and indoor quality could be improved. All these mean savings in money and possibly improve productivity.
>
> Based on the principle of "The less energy is consumed, the less fossil fuels will be burnt", both the buildings and the power generation companies will generate relatively less pollutants and by-products. Therefore, all parties concerned contribute to conserve the environment and to enhance sustainable development.
>
> (Source: Energy Audit Guidelines, Version 1, The European Greenbuilding Programme, Ispra, 30 September 2005, European Commission, Directorate-General JRC, Institute for Environment and Sustainability, Renewable Energies Unit)

This Common overview concerns general information on energy auditing methodology, surrounding conditions for carrying out these audits. Further, it incorporates common conclusions and recommendations related to energy auditing procedure that took place in Darkhan, Mongolia in November 2013.

This report and five energy audits create a complex energy efficiency related evaluation of chosen so called "sample" buildings in Mongolia.

Energy audits of five defined buildings are carried out as separate documents that can be understood as separate reports on energy audits. Following chapters serve as a summary of these separate energy audits.

# 2 GENERAL BACKGROUND OF ENERGY AUDITING

In this chapter, basic background of carrying out energy audits is being described to make clear its goals, procedures, methodology and overall features.

## 2.1. Selection of typical buildings in Mongolia

Chosen sample buildings were subjects to detailed energy audits, based on which a major renovation with stress on improving thermally-technical parameters of envelope constructions was designed. Following buildings were subject to the auditing

- Pre-cast concrete (panel) apartment building;
- Brick apartment building;
- School - brick building;
- Single family house - wooden structure;
- Single family house - combined wooden and brick structure.

Further, common district heating system of an apartment building was subjected to energy savings potential analysis, where relevant.

## 2.2. Background and motivation for energy auditing in Mongolia

For following energy auditing, four residential and one school buildings (as defined above) have been selected with the objective to demonstrate that the **implementation of energy savings measures could significantlyreduce energy consumption** of the apartments or school **and increase quality of living** there. Further, stress on heat distribution systems of buildings is being laid in terms of heat losses reduction potential searching for.

Energy auditing of chosen typical buildings in Mongolia is focused especially on:

- Improving quality (i.e. thermally-technical parameters and durability) of envelope constructions;
- Reduction of heat consumption in a form of heat from district heating system, coal or other energy carrier;
- Improving quality of indoor environment in buildings including higher internal temperature in winter time and avoiding of vapour condensation and moulds risk;
- Increasing awareness on energy saving potential and its impacts among non-professionals;
- Avoid overloading of existing electricity grids and heat pipelines;
- Further, if energy related measures are applied hand in hand with relevant rehabilitation of a building and/or its technical systems (e.g. heat distribution system), its lifetime (durability) can be noticeably extended.

Following common featuresof Mongolian surroundings were identified as the crucial arguments for supporting energy savings in Mongolia:

- 8 months **long heating season** with more than 6200 heating degree days in average (central public heating season runs from 15 September till 15 May);
- Most widespread existing residential buildings are **pre-cast panel buildings** (over 400 buildings in Ulaanbaatar) with huge heat losses as the heat energy consumption

for heating per year can reach **more than 600 kWh/m²**;

- Other widespread type of housing are **brick apartment buildings** that can reach **more than 400 kWh/m²** of energy consumed for heating;
- In case of single family houses, even new ones, the energy consumption for heating can reach **more than 300 kWh/m²**;
- **Insufficient thermal performance of buildings** (mainly U-value of external constructions of building envelope);
- Buildings, than are undergoing thermal renovation, are being insulated with **use of imported polystyrene insulation although domestic sustainable sheep wool thermal insulation could be used efficiently**, if well designed;
- **Ineffective system of heat distribution, low efficiency** of heat source;
- Heat **energy is still subsidized** and energy **prices are not consumption oriented** very often, but after it changes, costs for energy will rise significantly;
- Main **source of heat** for both own boilers/stoves and power plants **is coal** (with very low efficiency of its burning).

This report and the energy audits contain detailed description of sample buildings, surrounding conditions, and conclusions and recommendations that were identified during auditing process. The energy auditor presents conclusions on a basis of both experience and calculations that are crucial part of the report.

Energy auditor always must bring or accept several **approximations and expert estimations** as precise data or necessary documents are not available. In this case of five energy audits, project design documentation or drawings were not available as well as data on real (i.e. measured) energy consumption. Very often, heat consumption was not measured anyway.

**Energy prices** that are necessary to be taken into account for economic evaluation of the proposed measures were estimated on a basis of auditors investigation and verbal discussion with tenants during the auditing visits. Further, **specific costs for measures** (mostly in EUR/m²) were gathered in the same way.

## 2.3. Outline of the energy audit report

Main aim of energy audit is to describe existing state of a building, to evaluate its state, to find possible, feasible and logical measures that could be installed. Finally, auditor recommends most appropriate solution that usually combines several measures based on the best economical and technical parameters. Energy, costs and emission savings calculations are inputs for this evaluation.

Energy audits are often being defined in national legislation to unify its content, structure and outputs. This situation exists within almost whole the European Union, where energy auditing methodologies are completely in hands of its member states (i.e. they are not defined on EU directives level). It can be said that following principals are rather general and can be found in every energy audits related regulations with minor changes.

For this evaluation purpose, slightly modified structure of energy audits defined in the Czech Republic has been used. Basic outline of energy audits is as follows:

1. Description of current state of a building
    - Identification of energy audit subject
    - Basic description of a building focusing on energy efficiency related parameters

2. Evaluation of current state
    - Thermal characteristics of a building and separate constructions
    - Energy consumers and sources definition
    - Other technical equipment and lighting use – other energy consumers related to a building
    - Basic energy balance – based on measured energy (if possible) or calculated balance, divided to energy for heating, hot water preparation, lighting, cooling, ventilation etc.
3. Suggested energy savings measures and options of energy savings project
    - Measure description by its principle, materials and technology used and by simple cost/benefit analysis. The measures are usually being structured in groups: zero costs, low costs, high costs
    - Individual measures are combined/grouped to form different options of the project
    - For each project option the total values are expressed - investment costs and energy savings, energy costs savings and emissions savings
4. Environmental evaluation
    - Global impacts expressed by emissions of following items are being calculated to define an impact of measures/options on environment: particulates, $NO_x$, CO, $SO_2$, volatile organic compound VOC ($C_xH_y$) and $CO_2$
5. Economic evaluation
    - Simple economic calculations based on initial costs of measures, energy prices and their development and surrounding economic parameters (e.g. discount and interest rates prediction)
    - Evaluation of payback period using calculated energy and cost savings of measures
6. Auditor's recommendation
    - Energy Auditor compares various sets of energy saving measures (alternatives) and recommends the best project option with focus on technical and economic feasibility for investor and environmental acceptability.

## 2.4. Recommended measures setting

Detailed description of sample buildings including unusualness of concrete buildings that were used for this generalization is a part of separate energy audit reports.

Existing state calculations are always being done for both Czech and Mongolian surrounding conditions for comparison purpose only. Further, possible measures focusing on quality of envelope constructions and heat use regulation are being developed separately and relevant savings calculated. These measures are as follows:

### High-cost measures

- Thermal insulation of walls;
- Thermal insulation of roof;
- Thermal insulation of basement ceiling or floor;
- Exchange of windows and doors;

### Low- / Zero-cost measures

- Thermal insulation of common heat pipelines;

- Regulation of heating system;
- These measures relate to building users/owners awareness of energy conscious behaviour (e.g. knowledge of efficient ventilation by short windows opening, necessity of closing main entrance doors to avoid "chimney effect" in common staircases etc.).

Final evaluation parameters defining quality of buildings after energy efficient measures are applied show energy savings potential (and energy cost savings) and emissions savings. The "key monitoring" parameters are:

- U-value of separate constructions in $W/m^2,K$;
- Specific heat losses for heating (separately for walls, roof, floor, windows, doors and ventilation) in W/K;
- **Specific energy performance (delivered energy) for heating, hot water preparation, lighting etc. in $kWh/m^2,a$**;
- **$CO_2$ emissions savings in tons/a**.

## 2.5. Assessment of the energy performance of the building

The evaluation concerns the total annual energy consumption of the building comprising energy for space heating, ventilation, air conditioning, domestic hot water heating and lighting. The resulting value is usually expressed per 1 $m^2$ of floor area and compared to the relevant standards and legal acts. For this purpose, evaluation of existing and proposed measures is being done, but comparison to legal requirements is impossible to be done.

In energy auditing, the energy performance (delivered energy) is the most important result as it is directly related to costs savings and economy of energy savings related project. Further, the primary energy as well as the $CO_2$ emissions savings are very important global indicators that say how big is an impact of building operation on environment.

# 3 DESCRIPTION OF SURROUNDING CONDITIONS

Most important surrounding conditions for energy auditing relate to climatic conditions in the country, economic features of market, energy sources availability and technical accessibility of materials and technologies.

## 3.1. Climatic conditions and overall environment

Mongolia has an eight-month heating season, which starts on September 15 and ends on May 15.Winter temperatures usually fall to -15°C to -30°C in the daytime during December and January and can get to as low as -40°C at night. From this reason, heating is obviously the crucial energy need in Mongolian buildings.

Following figure shows average temperatures for Ulaanbaatar that were approximated for Darkhan.

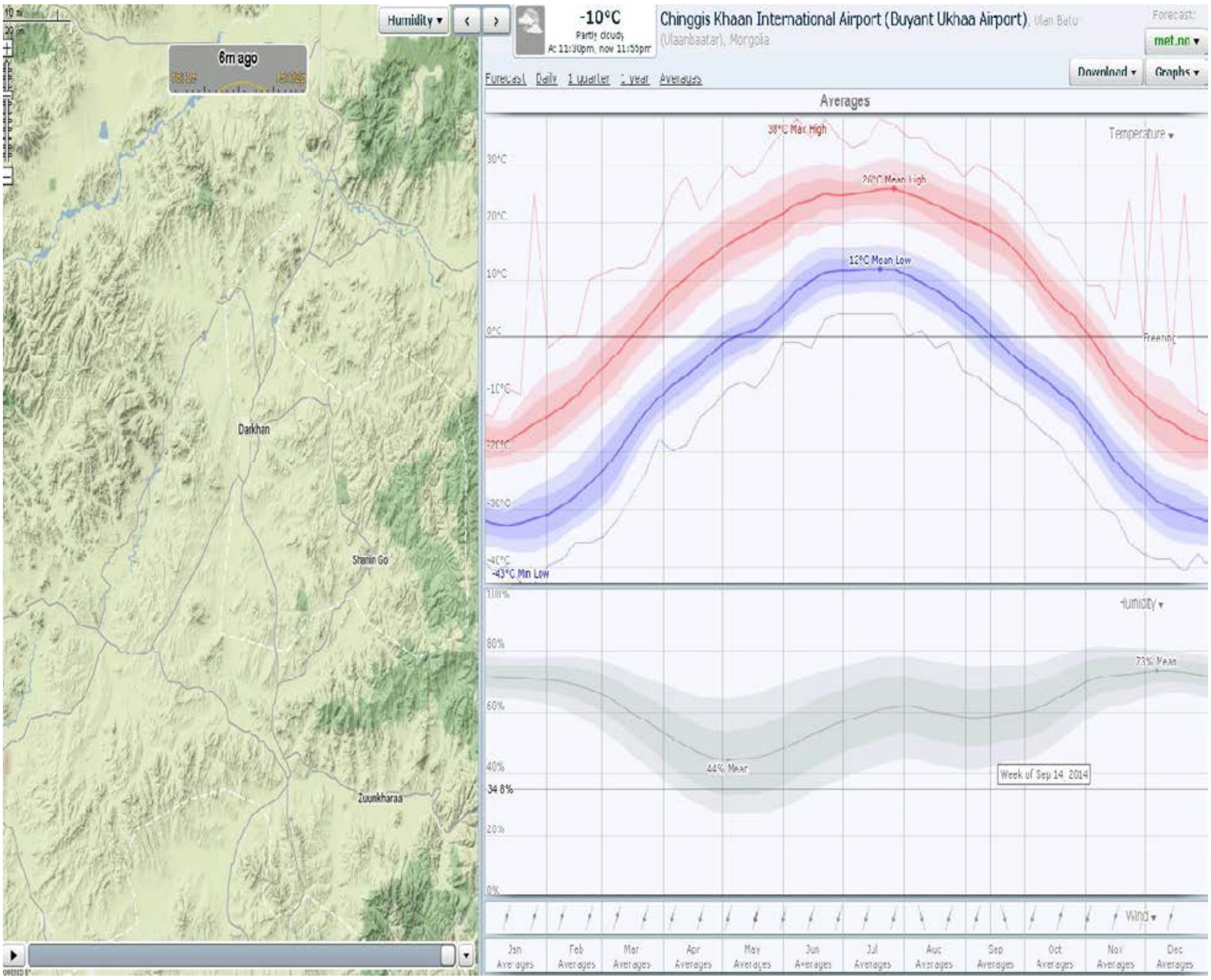



**Figure 3.1-1 - Average monthly temperatures in Darkhan**

(Source: http://weatherspark.com/)

For further calculations of energy consumption of chosen buildings, following values defining surrounding climatic conditions in Mongolia were taken into account.

**Table 3.1-1 - Monthly values of external temperature and relative air humidity used for calculations**

| Month | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperature [°C] | -24,6 | -21,1 | -8,2 | 2,4 | 10,7 | 16,4 | 18,2 | 16,3 | 9,1 | 0,5 | -11,0 | -20,8 |
| Humidity [%] | 71 | 69 | 60 | 46 | 45 | 52 | 60 | 60 | 59 | 64 | 72 | 73 |

(Source: http://weatherspark.com/and SEVEn expert approximations)

Especially in single family houses areas (and ger areas too), the buildings are heated with highly inefficient stoves (burning coal or firewood) that cause huge air pollution during wintertime in these urban areas. The family houses are usually generally under-heated during wintertime as well.

For further comparison, basic models of the same existing state of buildings were calculated using surrounding conditions related to average conditions in the Czech Republic. Obviously, such an approach has theoretical value only and its results serve for comparison of influence of these buildings on surrounding environment in two different locations with different type of use of the buildings and climatic conditions.

**Table 3.1-2 - Typical monthly values of Czech external temperature and relative air humidity used for comparison**

| Month | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperature [°C] | -1,3 | -0,1 | 3,7 | 8,1 | 13,3 | 16,1 | 18,0 | 17,9 | 13,5 | 8,3 | 3,2 | 0,5 |
| Humidity [%] | 83 | 80 | 73 | 66 | 67 | 68 | 67 | 67 | 74 | 79 | 85 | 85 |

(Source: Czech standard ČSN 73 0540 Thermal protection of buildings)

## 3.2. Standards requirements

Existing standards related to evaluation of thermally-technical parameters of building envelope constructions have been used. Requirements defined on national levels (both Mongolian and Czech for comparison purpose) were taken into account.

Mongolian requirements on building constructions given by standard BCNS 23-02-2009 "Buildings Thermal Performance" were compared to the calculated U-values of constructions. Further, newly proposed constructions compositions were designed on a basis of this standard to meet the requirements.As an introduction of consumption-oriented energy tariffs and increase of energy pricescan be expected, the requirements on building energy performance will rise too even more.

Mongolian standard requirements are set as minimum R-values (thermal resistance) of construction types, but Czech requirements given by relevant national standard are set as maximum U-values. For better comparison, both values are parts of a following table.

**Table 3.2-1 - Standard requirements on U-values**

| Construction | Required $U_N$ ($R_N$) [W/(m2K)] in the Czech Republic | Required $U_N$ ($R_N$) [W/(m2K)] in Mongolia |
|---|---|---|
| External wall | 0,30 (3,16) | 0,26 (3,70) |
| Roof | 0,24 (4,03) | 0,20 (5,00) |
| Ceiling above the non-heated space | 0,60 (1,33) | x |
| Floor | 0,45 (2,05) | x |
| Windows | 1,50 (0,50) | 1,30 (0,60) |
| Doors | 1,70 (0,42) | x |

(Source: Mongolian standard BCNS 23-02-2009 Buildings Thermal Performance and Czech national standard ČSN 730 0540-2 Thermal protection of buildings)

It can be stated that the requirements on thermal protection of buildings in these two countries are quite similar, but usual winter conditions differ significantly. After a transition to market energy prices and consumption-oriented billing, further strengthening of these requirements can be expected as it becomes cost-effective.

## 3.3. Energy availability and renewable sources potential

It can be said, that energy (electricity and heat) are available in urban areas of Mongolia, but the grids capacity and their technical state are getting to the maximum with sharply growing economy. This is one of the reasons to focus on energy savings in buildings in general.

Mongolia has large reserves of accessible coal which is the main heating fuel in urban areas both for coal burning stoves and heat power plants. Especially the stoves without any regulation, filtration and with inefficient burning process are huge sources of air pollution during wintertime. Mongolia does not have own gas or oil reserves. Further, in the countryside, the main sources for heating are dung and firewood.

Mongolia as a country has quite significant potential for production of electricity using renewable sources based on water, ground heat, wind and solar energy. Directly for separate buildings, some of these renewable are not possible to be used (hydro power or wind power) as these huge producing plants cannot be installed directly on/nearby the buildings, but must be connected to a grid. From this point of view, biggest potential can be identified in solar power.

One of the crucial facts related to solar energy production is that Mongolia has 270 to 300 sunny days a year in average. Thanks this abundant sunshine (between 2500-3000 hours per year) about 5-6 kWh/$m^2$ per day can be gained for free from this renewable source, that equals to about 1200-1600 kWh/$m^2$ per year.

## 3.4. Economic features

Mongolia is a country with sharply growing GDP value and its economy grows by highest percentage in the world in last two years as can be simply identified from following graphs. Partly it is caused by huge fall in 2010 and 2011. Further, external debt is high in Mongolia with more than 130 percent of GDP.

Following graph shows development of economy in Mongolia in last 3 years compared to other parts of the world. Further, initial investments in buildings sector in Mongolia in last 6 years (last availabledata) is defined by the second graph.

Global Economic Growth (2010-2012)

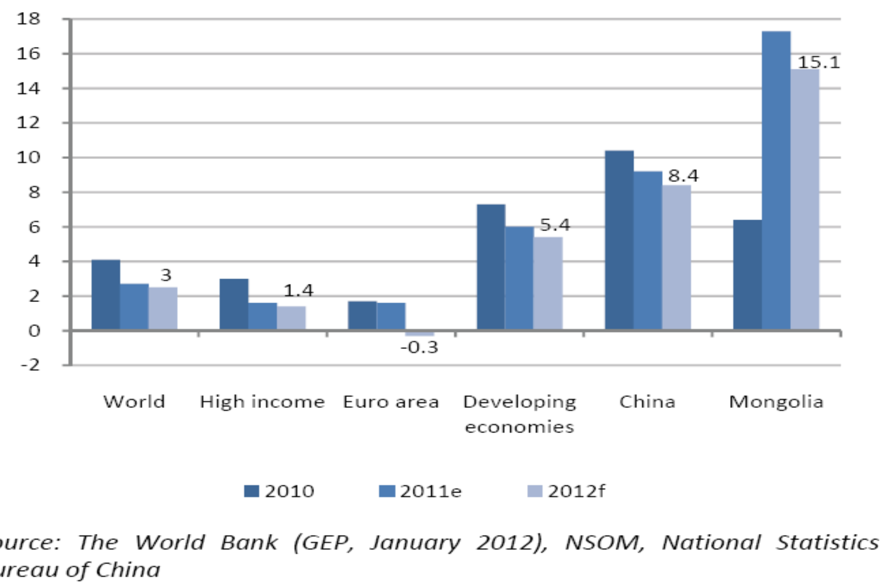



**Figure 3.4-1 - Global economic growth**

(Source: The World Bank, Global Economic Prospects, 2012)

Construction by property type, MNTbn

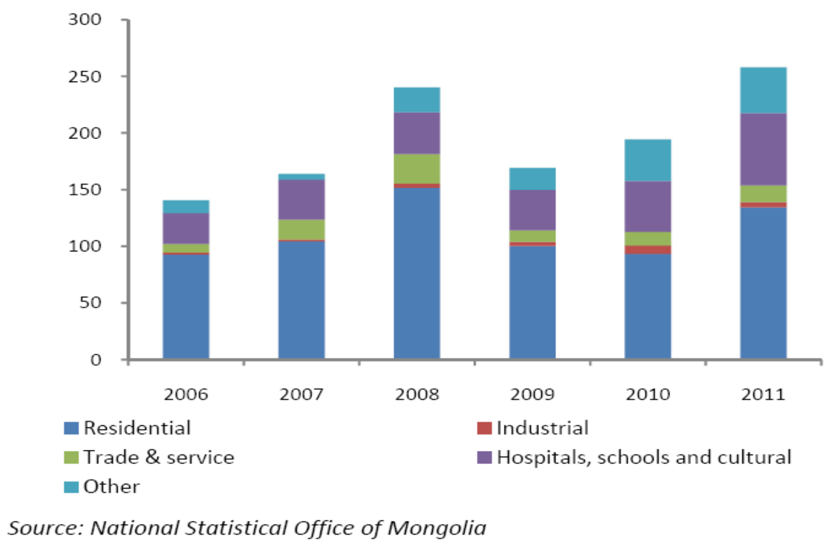



**Figure 3.4-2 - Initial investments of construction by type of a property built in billions MNT**

(Source: The National Statistical Office of Mongolia, 2012)

# 4 OVERVIEW OF BUILDING PARAMETERS AND CONCLUSIONS AND RECOMMENDATIONS

Five buildings that underwent energy auditing procedure evince **similar features in terms of energy efficiency and energy performance**. Deep description and analysis including model-based calculation see in separate energy audits of defined sample buildings.

## 4.1. Description of the sample buildings

Following descriptions are taken from separate detailed energy audits.

### 4.1.1. Brick apartment building

Chosen type of a brick apartment building is, besides the pre-cast concrete buildings, most typical one used for apartment housing in Mongolia.

Data on this sample building were collected mostly from personal visit of an energy auditor and from discussion / investigation with inhabitants. Simplified measurements and photo documentation were done. Data on real energy consumption of a building were not available.

As an example for further investigation of typical brick building, apartment building at New District 6 - 44 has been chosen.

Model building is a 5-story apartment building with 4 separate entrances on Eastern side and 60 flats in total with average useful floor area about 48m$^2$ each. Further, there are several commercial units (typically shops and restaurants) on ground floor. Low basement is being used for heat pipeline distribution purpose. Its height is about 1,6m. The building is rectangular shaped, its basic dimensions are 60 x 15 meters, total height is 15,5 meters. Total height of each floor is 3,0 meters. All the envelope constructions have been measured and current state of constructions composition has been checked on site because design documentation/drawings were not available.

#### Building constructions

Outer walls are made of bricks with total thickness about 60 cm (sometimes a bit more due to different plaster thicknesses). Supposedly, outer part of the wall is made of white full lime-sand bricks that are almost soak-proof compared to common red/orange bricks made of burnt clay.

Mostly old wooden doubled windows (with single glazing each) are installed. Due to lack of quality maintenance, painting, sealing and water leakage, these wooden windows are usually very bad shaped and their lifetime is over. Sometimes, huge holes between a frame and a window wing can be found. Low percent of all the windows has already been exchanged.

Main entrance doors of the building are wooden with small single-glazed part. Entrance doors of flats (i.e. doors between a common staircase and flats) are mostly wooden as well without glazing. Some of them are additionally insulated from their interior side.

The roof is flat simply composed without any thermal insulation. Load bearing part of the roof is made of pre-cast concrete reinforced slab about 20 cm thick.

Floor under the lowest flats has very simple composition of a reinforced concrete slab without any additional layer. On the upper side of it, tiles, carpets or similar layers are used, obviously.

View from Southeast

View from Northwest

Entrance on Eastern side

South facade

**Figure 4.1-1 - Sample brick apartment building**

## Technical systems

District heating system is a source of heat for heating of the building. Main pipe system brings hot water to the basement, where main closing valves are installed. Pipes are insulated with glass or mineral wool and covered partly with gypsum layer or aluminium foil.

Then, heat is directly distributed by central water heating system to all flats. These pipes are insulated partly only (about 50 % of these basement pipes) with felt or synthetic rubber. Heat exchanger is missing. Measurement of heat for heating system is missing as well. Monthly costs for heating are calculated adequately per each flat per square meter of floor area.

Metering of electricity is provided by separate meters per each flat.

Hot water consumption is being measured by metering of hot water volume that is being used in the building as a whole (with about 60 families occupying the flats).

Standard light bulbs or energy saving compact fluorescent lamps (if changed recently) are usually being installed for lighting in common spaces and staircases. Additionally, insufficient daylight will cause an increase of electricity consumption for lighting in these spaces.

The apartments are always ventilated naturally using usual air-change around the windows frames. Additionally, opening of windows helps to rise air exchange if needed. Often in commercial units, and especially in restaurants, artificial ventilation is necessary to ensure good quality air change in a kitchen as high relative air humidity and odour are typical for these premises.

Air conditioning (and especially cooling) split-type units (e.g. with the compressor and heat exchanger placed outside on the wall) are being installed usually in commercial premises as individual cooling units.

### 4.1.2. Pre-cast concrete (panel) apartment building

Chosen type of a pre-cast concrete (panel) apartment building is the most typical one used for apartment housing in Mongolia.

Data on this sample building were collected mostly from personal visit of an energy auditor and from discussion / investigation with inhabitants. Simplified measurements and photo documentation were done. Data on real energy consumption of a building were not available.

As an example for further investigation of typical pre-cast concrete (panel) apartment building, multi-family building at Darkhans New District has been chosen.

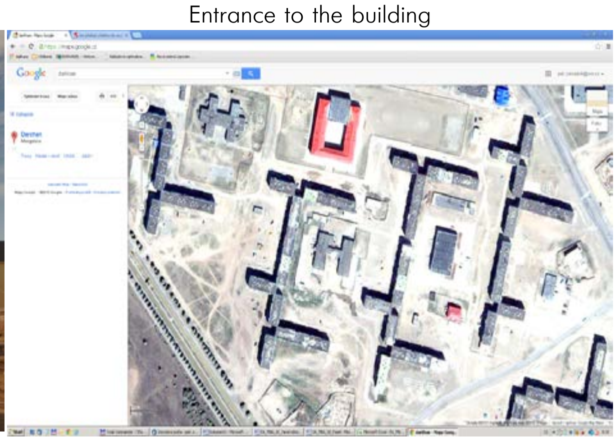
Model building is a 5-above-ground and one underground storied apartment building. These buildings were typically built in larger composition as can be seen in Figure 4.1-2. As these compositions (that are being created from similar rectangular separate buildings) differ a lot, for further calculations only one typical rectangular part has been taken into account.

This typical part of a building has 5 separate entrances on Western side and 94 flats in total with average useful floor area about 55 m$^2$ each. There are 320 people living in this part of a building. Further, there are several commercial units (typically small shops) on ground floor (first above-ground level, i.e. floor above basement floor). Usually very low basement cannot be used for any commercial purposes or for living. It is being used for heat pipeline distribution purpose. Its height is about 1,5 meters.

View from Northwest

Entrance to the building

View from Northeast



Example of buildings composition in Darkhan

**Figure 4.1-2 - Sample pre-cast concrete (panel) apartment building**

The building part itself is rectangular shaped, its basic dimensions are 102 x 13 meters, total height is 15,4 meters. Total height of each floor is 3,0 meters. All the envelope constructions have been measured and current state of constructions composition has been checked on site because design documentation/drawings were not available.

### Building constructions

Outer walls are made of heavy pre-cast concrete blocks with total thickness about 20 cm (sometimes a bit more due to different plaster thicknesses). As the thickness is this low, it is impossible to contain any functioning thermal insulation in it. Plaster made of common cement/lime-cement mortar is applied on interior surface only.

Mostly old wooden doubled windows (with single glazing each) are installed. Due to lack of quality maintenance, painting, sealing and due to water leakage, these wooden windows are usually very bad shaped and their lifetime is over. Sometimes, huge holes between a frame and a window wing can be found. Low percent of all the windows has already been exchanged.

Main entrance doors of the building are wooden with small single-glazed part. Entrance doors of flats (i.e. doors between a common staircase and flats) are mostly wooden as well without glazing. Some of them are additionally insulated from their interior side.

The roof is flat simply composed without any thermal insulation. Load bearing part of the roof is made of pre-cast concrete reinforced slab about 20 cm thick.

Floor under the lowest flats has very simple composition of a reinforced concrete slab without any additional layer. On the upper side of it, tiles, carpets or similar layers are used, obviously.

### Technical systems

District heating system is a source of heat for heating of the building. Main pipe system brings hot water to the basement, where main closing valves are installed. Pipes are insulated with glass or mineral wool and covered partly with gypsum layer or aluminium foil.

Metering of electricity is provided by separate meters per each flat. On its basis, costs for electricity are calculated. The electricity in the building is being used for typical electrical appliances and lighting.

Hot water consumption is being measured by metering of hot water volume that is being used in the building as a whole (with about 20 families occupying the flats).

The apartments are always ventilated naturally using usual air-change around the windows frames. Additionally, opening of windows helps to rise air-exchange if needed. Any artificial ventilation has not been indentified even in commercial units.

Any artificial ventilation has not been indentified even in commercial units.

## 4.1.3. School - brick building

Chosen type of a school brick building is one of the most typical public buildings. Similar building can be found in other sectors of usage (offices, hospitals etc.) in Mongolia.

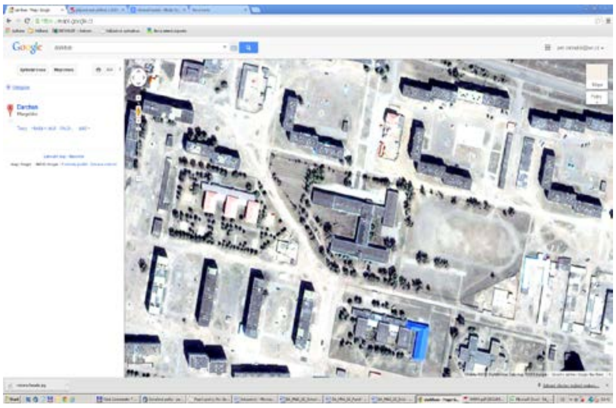
Data on this sample building were collected mostly from personal visit of an energy auditor and from discussion/investigation with school employees. Simplified measurements and photo documentation were done. Data on real energy consumption of a building were not available.

As an example for further investigation, typical school brick building at DarkhansNew District has been chosen.


View from North (main entrance)

View from Southeast

View from Southwest (part of school gym)



Ortophoto map

**Figure 4.1-3 - Sample school building**

Model building is a 2-story brick school building with total useful floor area m$^2$ each. The building has not any basement. The school is connected to district heating pipeline distribution. The building is complicated shaped, composed of several rectangles. Its overall basic dimensions are 76,3 x 100 meters, total height is 7,5 meters. Total height of each floor is about 3,5 meters. All the envelope constructions have been measured and current state of constructions composition has been checked on site because design documentation/drawings were not available.

## Building constructions

Outer walls are made of bricks with total thickness about 65 cm (sometimes a bit more due to different plaster thicknesses). Supposedly, outer part of the wall is made of white full lime-sand bricks that are almost soak-proof compared to common red/orange bricks made of burnt clay. High resistance to soaking water or air humidity is crucial in localities with higher number of freezing days as the probability of soaked water or condensed vapour freezing is very high.

Old wooden windows were already exchanged and new plastic windows with double-glazing unit with vacuum are installed in all the building except a gym. In the gym, there are still original glass bricks instead of common windows.

There is only one main entrance to a building. Main entrance doors of the building are wooden with small single-glazed part.

The roof is flat simply composed without any thermal insulation. Load bearing part of the roof is made of pre-cast concrete reinforced slab about 20 cm thick. A waterproof layer, sometimes significantly damaged and patched is laid over the slab. Thickness of this layer is about 4 mm.

The lowest floor on a ground has very simple composition of a concrete slab without any additional thermally insulating layer. On the upper side of it, ceramic tiles or vinyl layers are used, obviously.

### Technical systems

District heating system is a source of heat for heating of the building. Main pipe system brings hot water to the building, where main closing valves are installed. Pipes are insulated with glass or mineral wool and covered partly with gypsum layer or aluminium foil,allegedly.

Then, heat is directly distributed by central water heating system to all classrooms. These pipes are not insulated.As they lead through heated parts of the building, heat losses are not crucial.

Metering of electricity is provided by separate meter. The electricity in the building is being used for typical electrical office appliances, computers and lighting. Lighting is provided mostly by (saving) fluorescent lamps.

Hot water consumption is being measured by metering of hot water volume that is being used in the building as a whole. Hot water is directly connected to the district heating distribution grid.

All the building is ventilated naturally using usual air-change around the windows frames. Additionally, opening of windows helps to rise air exchange if needed. A common hall is ventilated by additional ventilator that helps to increase the air-change occasionally.

Any air conditioning units are not installed.

## 4.1.4. Single family house - combined timber and brick structure

The chosen wooden/brick single family house is quite typical one used for single family housing in Mongolia. It is a house that was / is being built by the owner himself with a help of several craftsmen for some special works like plumbing, electrical network and installations. The owner started with the building two years ago and the works still continue. As a majority of the house was built by the owner who is not a professional, it can be expected that some mistakes have been done or inappropriate procedures made. The house was not completed at time of the visit. A balcony structure, a terrace above the entrance/kitchen room and masonry of a gable wall were not finished.

As an example for further investigation,combined wooden and brick single family house in Darkhanhas been chosen.

View from South

View from West

View from Southeast

Extension with technical facilities

**Figure 4.1-4 - Sample combined wooden and brick family house**

This model building is a 2-stories(one full story on a ground plus one attic floor) single family house without any basement. An entrance to the house is on its south-eastern side. Windows are oriented on all sides of the house except the north-eastern one, where a shelter for a car is located and directly connected to the facade. Useful floor area of the entire house (its heated area) is 258 $m^2$. Entire house is heated except the shelter for a car as mentioned. The building is T-shaped, its overall dimensions are 14 x 13 meters anda total height is 5,4 meters from a ground to a top of the roof. Calculated volume of the house is 603 $m^3$. All the envelope constructions have been measured and a current state of constructions composition has been checked on site because design documentation/drawings were not available.

## Building constructions

Outer walls are made of very lightweight materials so, the owner decided to add a layer of masonry that helps to increase thermal resistance of a wall and its weight that helps to balance quick changes of internal temperatures due its heat accumulation function. The final composition of the wall is: load bearing timber frame structure (about 150mm thick) covered by wooden boards on both sides. Additionally there is about 40mm of soft mineral wool on outer side of this wooden construction. Further, covering masonry made of 150mm thick wall has been built on exterior side (not around the whole house at time of the visit, as mentioned above).

Combination of new single-framed plastic / wooden windows with double-glazing unit with vacuum inside are being installed. The wooden frames were, allegedly, produced by a domestic joiner. The plastic frames are usually being imported from China and then assembled in Mongolia by local enterprises.

The entrance doorto the house is simple wooden without glazed parts.

The roof is sloped with an attic floor below it. The roof composition is fixed to a load-bearing structure that is being made of wooden beams – rafters. There is 10cm of polystyrene (styrofoam) insulation and additional 4cm of mineral wool (the same material as used in walls composition)between the rafters. The roof is waterproofed by metal sheets fixed to wooden planks that help to make a very thin cavity between the sheets and insulation material.

Floor on a ground of a house is simply made of concrete, covered by vinyl or carpets.

## Technical systems

For the heating of this house, coal and wood burning stoves are installed. Further, the stoves can be used for cooking too. The stoves are connected to a hot water pipe system that distributes produced heat to other rooms. As the owner mentioned, there is a huge problem with heating during the severe winter as it is impossible to reach comfortable temperature in the rooms.

Electricity is being used for lighting, partly cooking and for hot water preparation. Meals are partly being cooked with the coal/wood stoves that serve mainly for heating. For lighting mainly (saving) fluorescent lamps are being used.

Hot water is being prepared simply by using electrical boiler. At present, the owner does not plan to install any renewable technology (e.g. solar thermal collectors).

At present, there is very low number of lighting sources in the house. As usual in the country, quite efficient lighting sources (compact fluorescent lamps) are being used in the house but as quite cheap, the quality of the sources may be low. Additionally, sufficient daylight causesdecrease of electricity consumption for lighting.

Any artificial ventilation is not installed.

Any air conditioning units are not installed.

### 4.1.5. Single family house - timber structure

Chosen type of a wooden single family house is probably not the most typical one used for single family housing in Mongolia but it is an example of active approach of Mongolian citizens to find a way to own energy efficient housing.

As an example for further investigation,wooden single family house in Darkhanhas been chosen.

View from Northwest

View from West

View from Northeast

Entrance with partly glazed shelter

**Figure 4.1-5 - Sample wooden family house**

This model building is a 2-stories(one full story on a ground plus one attic floor) single family house. Entrance to the house is on western side. Windows are oriented on all sides except the east, where an unheated shelter for a car is directly connected to the facade. Useful floor area of the entire house (its heated area) is 213m². Entire house is heated except the shelter for a car as mentioned. The building is almost rectangular shaped, its basic dimensions are 14 x 8 meters anda total height is about 6 meters from a ground to a top of the roof. Calculated volume of the house is 504 $m^3$. All the envelope constructions have been measured and a current state of constructions composition has been checked on site because design documentation/drawings were not available.

## Building constructions

Outer walls are made of lightweight materials, composed of timber frame structure (100mm thick) filled with 50mm of soft mineral insulation. On outer side, half-round wooden timber is being used as a natural wooden facade. On interior side, wooden boards cover the wall so, there is a 50mm thick non-ventilated cavity between the wooden boards and thermal insulation in the framed structure. Any water vapour barrier has not been used.

wsingle-framed plastic windows with double-glazing unit with vacuum inside are being installed. These plastic frames are usually imported from China and then assembled in Mongolia by local enterprises. Fixing of the windows to walls is done using additional wooden frame covering the PUR (polyurethane) foam joint filling.

The entrance doorto the house is simple wooden without glazed parts.

The roof is sloped with an attic floor below it. The roof above a heated bathroom is significantly less sloped but has the same composition. The composition of the main part of the roof (above the attic floor), thatis fixed to a load-bearing structure, is made of wooden beams – rafters. There is about 10 cm of mixed thermal insulation between the rafters. The thermal insulation is uneven and crooked with huge holes.

Floor on a ground of a house is simply made of concrete, covered by a base layer of floor heating (to create even and flat surface, floor heating film with electric cables and a laminate “floating” floor.

## Technical systems

Electricity is being used for all the energy consumers in the house including hot water preparation and the house itself for covering heat losses. Based on information by the owner, it was not allowed to have a three-phase connection to existing electricity grid so, only a simple one-phase connection was installed there.

Simple electric floor heating is being installed in all the floors of the house. The temperature of heating source was set to 38 °C.

At present, hot water can not be prepared in the house as it is still under construction. It is planned to install electricity consuming hot water boiler and, in future, solar thermal collectors.

At present, as the house is still under construction, only a part of the lighting is being installed. Efficient lighting sources (compact fluorescent lamps) are being used in the main living space.

Any artificial ventilation is not installed.

Any air conditioning units are not installed.

## 4.2. Evaluation of current state

### 4.2.1. Thermal characteristics of a building

Generally, it can be said, that **all the evaluated buildings show very similar results in terms of low quality of thermally-technical parameters of envelope constructions and very low efficiency of heat transfer to heated spaces**. Not only **huge heat losses in pipes**, but **missing regulation system** as well are **crucial barriers to good energy management**.

The thermally-technical parameters of envelope constructions are crucial in terms of energy performance and energy savings. Following table summarizes thermal quality of buildings constructions and their evaluation compared to relevant standards.

Additionally,lack of maintenance causes slowdegradation of constructions. It is especially case of waterproof insulation of flat roofs and corrosion of reinforcing steel in case of pre-cast panel buildings.

**Table 4.2-1 - U-values (and R-values) of buildings constructions – existing state**

| Construction | Composition (int. → ext.) | Thickness [mm] | Calculated U (R) [W/(m2K)] | CZ Req. $U_N$ ($R_N$) [W/(m2K)] | MN Req. $U_N$ ($R_N$) [W/(m2K)] | Evaluation MN/CZ |
|---|---|---|---|---|---|---|
| External wall - brick | Plaster interior | 25 | 1,139 (0,71) | 0,30 (3,16) | 0,26 (3,70) | insufficient / insufficient |
| | Bricks | 450 | | | | |
| | Lime-sand bricks | 150 | | | | |
| | Plaster exterior | 25 | | | | |
| External wall - panel | Plaster interior | 10 | 3,281 (0,13) | 0,30 (0,16) | 0,26 (3,70) | insufficient / insufficient |
| | Reinforced concrete | 200 | | | | |
| External wall - panel with interior insulation | Plaster interior | 5 | 0,932 (0,90) | 0,30 (3,16) | 0,26 (3,70) | insufficient / insufficient |
| | Insulation - styrofoam | 40 | | | | |
| | Plaster | 10 | | | | |
| | Reinforced concrete | 200 | | | | |
| External wall - panel with interior insulation | Gypsum board | 12,5 | 0,974 (0,86) | 0,30 (3,16) | 0,26 (3,70) | insufficient / insufficient |
| | Insulation - mineral wool | 50 | | | | |
| | Plaster | 10 | | | | |
| | Reinforced concrete | 200 | | | | |
| External wall - sandwich | Plaster interior | 25 | 0,756 (1,15) | 0,30 (3,16) | 0,26 (3,70) | insufficient / insufficient |
| | Reinforced concrete | 200 | | | | |
| | Insulation - styrofoam | 50 | | | | |
| | Reinforced concrete | 80 | | | | |
| External wall - wooden/bricks | Wooden board | 25 | 0,673 (1,32) | 0,30 (3,16) | 0,26 (3,70) | insufficient / insufficient |
| | Timber | 150 | | | | |
| | Wooden board | 25 | | | | |
| | Insulation - mineral wool | 40 | | | | |
| | Wooden board | 25 | | | | |
| | Bricks | 150 | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| External wall (wooden house) | Wooden board | 25 | 0,628 (1,42) | 0,30 (3,16) | 0,26 (3,70) | insufficient / insufficient |
| | Air space | 50 | | | | |
| | Mineral wool | 50 | | | | |
| | Half-round timber | 120 | | | | |
| Flat roof | Plaster interior | 20 | 3,315 (0,16) | 0,24 (4,03) | 0,20 (5,00) | insufficient / insufficient |
| | Reinforced concrete | 200 | | | | |
| | Waterproof layer | 4 | | | | |
| Sloped roof | Gypsum board | 12,5 | 0,497 (1,87) | 0,24 (4,03) | 0,20 (5,00) | insufficient / insufficient |
| | Insulation - styrofoam | 100 | | | | |
| | Insulation - mineral wool | 40 | | | | |
| | Ventilated air space | x | | | | |
| | Metal sheets | x | | | | |
| Sloped roof (wooden house) | Gypsum board | 12,5 | 0,726 (1,24) | 0,24 (4,03) | 0,20 (5,00) | insufficient / insufficient |
| | Insulation - styrofoam | 100 | | | | |
| | Ventilated air space | x | | | | |
| | Metal sheets | x | | | | |
| Ceiling above the non-heated space | Reinforced concrete | 200 | 1,880 (0,19) | 0,60 (1,33) | x | insufficient / x |
| | Concrete | 50 | | | | |
| | Ceramic tiles | 25 | | | | |
| Floor (wooden house) | Reinforced concrete | 120 | 1,285 (0,61) | 0,45 (2,05) | x | insufficient / x |
| | Thermal insulation | 20 | | | | |
| | Concrete | 40 | | | | |
| | Laminate flooring | 20 | | | | |
| Window wooden | Doubled framing with two single glasses | | 2,800 (0,19) | 1,50 (0,50) | 1,30 (0,60) | insufficient / insufficient |
| Window plastic | Single frame with double glazing unit | | 2,000 (0,33) | 1,50 (0,50) | 1,30 (0,60) | insufficient / insufficient |
| Doors wooden | Full or partly glazed | | 3,500 (0,12) | 1,70 (0,42) | x | insufficient / x |
| Doors metal | Full | | 5,600 (0,009) | 1,70 (0,42) | x | insufficient / x |

## 4.2.2. Energy sources and energy price

For these sample energy audits, where economy and feasibility of energy efficiency measures shall be presented, **consumer-oriented energy prices were considered**, obviously. Otherwise, any financial effect (energy costs savings) of installed measures would not appear.

### Heat

Generally, main source of energy for both heating and electricity supply in Mongolia is coal.

Majority of apartment and public buildings in urban areas are connected to district heating system supplied by coal-burning heat power plants. Common feature of all above described systems is low efficiency. In case of district heating pipeline, its thermal insulation is rather poor and, due to insufficient maintenance, damaged or missing. Efficiency of burning in case of all mentioned sources is very low too (about 50% in case of inefficient heat power plant). Price of heat for households is **about 17 500 MNT/MWh or about 7,96 EUR/ MWh**.

As the heat consumption is not being measured very often and energy price (either price per square meter of a building or price per kilowatthour, gigajoule or other unit) is significantly low, awareness to meaningful energy saving motivated by costs savings is low too. Much more important is indoor comfort for the building users.

#### Coal

In family houses (and gers), inhabitants use coal boilers or stoves. Extremely low efficiency is typical for the stoves as any system of regulation or useless heat accumulation is missing in this case. Efficiency of boiler system is about 60% and 50% in case of boiler.Price of coal for households is **about 96 000 MNT/ton or about 44 EUR/ton** with a calorific value about 19,9 GJ/ton. Final considered price of heat energy produced from **coal is 7,96 EUR/ MWh**.

#### Electricity

Electricity consumption is being measured using usual electricity meters per each flat or family house.Price of electricity for households is **about 90 MNT/kWh (about 40,91 EUR/ MWh)** with a potential to grow significantly in coming years. At present the low electricity price is not well motivating to consumers to be saved enough.

Electricity is being produced in coal power plants with low efficiency of burning process and still high emissions. At present, electricity supply seems to be stable but present economic growth brings potential risk of blackouts due to future overload of existing grid.

### 4.2.3. Other technical equipment and lighting use

In apartment buildings (including grocery stores, shops and restaurants in ground floor), family houses and school, part of electricity is being consumed by common domestic / office appliances that are generally taken into account in calculations.

Lighting systems in buildings usually combine common inefficient light bulbs, energy saving compact fluorescent lamps or commonfluorescent lamps.

### 4.2.4. Basic energy balance

Energy balances of sample buildings are based on calculated energy needs for heating, hot water preparation, lighting, cooling, ventilation and other auxiliary energy. The auxiliary energy means energy needed for running pumps, ventilators and similar equipment that is necessary to run for well working technical systems of a building. Energy balances are being done for existing state and proposed energy options.

## 4.3. Energy saving measures and their combination

### 4.3.1. Measures description

Energy audits are focusing on quality of buildings envelope so, the measures relate especially to improving its state. In principle, materials and technologies used to improve the building quality are taken into account. Further, low-cost and zero-cost measures are being analyzed too to make overall picture of possibilities in terms of improving energy performance. Then, the individual measures are combined /grouped to form a final suggested and recommended combination of measures leading to recommended energy saving project. This combination is evaluated from economic and environmental points of view then. Further, total values are expressed - investment costs and energy costs and energy savings.

**Table 4.3-1 - U-values (and R-values) of buildings constructions – suggested state**

| Construction | Composition (int. → ext.) | Thickness [mm] | Calculated U (R) [W/(m2K)] | CZ Req. $U_N$ ($R_N$) [W/(m2K)] | MN Req. $U_N$ ($R_N$) [W/(m2K)] | Evaluation MN/CZ |
|---|---|---|---|---|---|---|
| External wall - brick | Plaster interior<br>Bricks<br>Lime-sand bricks<br>Plaster exterior<br>**Sheep wool** | 25<br>450<br>150<br>25<br>**140** | 0,235 (4,08) | 0,30 (3,16) | 0,26 (3,70) | sufficient / sufficient |
| External wall - panel | Plaster interior<br>Reinforced concrete<br>**Sheep wool** | 10<br>200<br>**150** | 0,258 (3,71) | 0,30 (0,16) | 0,26 (3,70) | sufficient / sufficient |
| External wall - panel with interior insulation | Plaster interior<br>Insulation - styrofoam<br>Plaster<br>Reinforced concrete | 5<br>40<br>10<br>200 | 0,932 (0,90) | 0,30 (3,16) | 0,26 (3,70) | insufficient / insufficient |
| External wall - panel with interior insulation | Gypsum board<br>Insulation - mineral wool<br>Plaster<br>Reinforced concrete | 12,5<br>50<br>10<br>200 | 0,974 (0,86) | 0,30 (3,16) | 0,26 (3,70) | insufficient / insufficient |
| External wall - sandwich | Plaster interior<br>Reinforced concrete<br>Insulation - styrofoam<br>Reinforced concrete | 25<br>200<br>50<br>80 | 0,756 (1,15) | 0,30 (3,16) | 0,26 (3,70) | insufficient / insufficient |
| External wall - wooden/bricks | Wooden board<br>Vapour barrier<br>**Sheep wool** / timber<br>Wooden board<br>Insulation - mineral wool<br>Wooden board<br>Bricks | 25<br>x<br>**150**<br>25<br>40<br>25<br>150 | 0,25 (3,83) | 0,30 (3,16) | 0,26 (3,70) | sufficient / sufficient |
| External wall (wooden house) | Wooden board<br>Vapour barrier<br>Wooden board<br>**Sheep wool**<br>**Sheep wool**<br>Half-round timber | 25<br>x<br>25<br>**40**<br>**100**<br>120 | 0,258 (3,70) | 0,30 (3,16) | 0,26 (3,70) | sufficient / sufficient |
| Flat roof | Plaster interior<br>Reinforced concrete<br>Waterproof layer<br>**Sheep wool** | 20<br>200<br>4<br>**240** | 0,186 (5,23) | 0,24 (4,03) | 0,20 (5,00) | sufficient / sufficient |

| | | | | | | |
|---|---|---|---|---|---|---|
| Sloped roof | Gypsum board<br>Insulation - styrofoam<br>Insulation - mineral wool<br>Ventilated air space<br>Metal sheets | 12,5<br>100<br>40<br>x<br>x | 0,497 (1,87) | 0,24 (4,03) | 0,20 (5,00) | insufficient / insufficient |
| Sloped roof (wooden house) | Gypsum board<br>Vapour barrier<br>**Sheep wool** between rafters<br>**Sheep wool** under rafters<br>Ventilated air space<br>Metal sheets | 12,5<br>x<br>**160**<br>**100**<br>x<br>x | 0,196 (4,97) | 0,24 (4,03) | 0,20 (5,00) | sufficient / sufficient |
| Ceiling above the non-heated space | **Sheep wool**<br>Reinforced concrete<br>Concrete<br>Ceramic tiles | **80**<br>200<br>50<br>25 | 0,410 (2,10) | 0,60 (1,33) | x | sufficient / x |
| Window plastic | Single frame with high quality thermo-insulating double glazing unit | | 1,300 (0,60) | 1,50 (0,50) | 1,30 (0,60) | insufficient / insufficient |
| Doors wooden | Full or partly glazed | | 1,300 (0,60) | 1,70 (0,42) | x | insufficient / x |
| Doors plastic | Full or partly glazed | | 1,300 (0,60) | 1,70 (0,42) | x | insufficient / x |

## 4.4. Environmental evaluation

Environmental evaluation is usually based on its main indicators –emissions savings. It defines global impacts of building operation on surrounding environment. Buildings, depending on heat and electricity source, emit different types of emissions that are usually being calculated to define an impact of measures/options applied: particulates, $NO_x$, CO, $SO_2$, volatile organic compound VOC ($C_xH_y$) and $CO_2$. $CO_2$ emissions are being calculated only as their impact is multiply higher compared to other emissions.

## 4.5. Economic evaluation

Simple economic calculations based on initial costs of measures, energy prices and their development and surrounding economic parameters (e.g. discount and interest rates prediction). The economic results of the energy saving project options are expressed by four standard economic indicators:

- Simple payback
- Discounted (or real) payback
- Net present value of the project
- Internal rate of return

In energy audits, the economic evaluation is based on the following simplified assumptions:

- 100% financing is provided by the investor (no loans or subsidies)
- savings are assumed to be constant over the whole evaluation period
- the current pricing level is assumed for the whole project lifecycle with no annual price escalation (later, in sensitivity analysis related to expected energy price development, other parameters will be calculated)

Based on these aspects, energy auditor calculates and decides on best option for concrete building.

### Sensitivity analysis

The economic value of the project will depend, among other parameters, on the future development of energy prices (in this case both electricity and heat) and on actual installation costs of the insulation and other energy efficiency measures. The impact of these two factors on the project's economic results was analysed in the sensitivity analysis.

Tocompare, present economic environment in Mongolia is partly similar to the situation in the Czech Republic several years ago. The Czech Republic has already passed through the transition period connected to energy prices. The Czech Republic may be regarded as a typical representative with the Energy Performance of Buildings Directive fully implemented into its legislature and with liberalized prices of energy linked to prices in other regional countries.

Current Mongolian electricity and heat prices are still significantly below market prices (subsidized by state). A deregulation of energy prices most probably comes in near future.

## 4.6. Auditor's conclusions and recommendations

Energy Auditor compares various sets of energy saving measures (alternatives) and recommends the best project option combining defined measures with focus on technical and economic feasibility for investor and environmental acceptability.

Following conclusions and recommendations related to each of the evaluated buildings comes from detailed energy audits that were carried out as separate reports.

From the technical point of view, the **only right solution** of problems defined above and in separate reports on energy audits, **is the complex solution**that consists of whole building envelope improvement (if possible) and heating system regulation installation. It has been stated earlier that the thermally technical parameters of the building constructions are poor so, complex building insulation is the most important basic measure that needs to be applied. As the energy prices are low at present, economic feasibility calculation does not bring good results using present prices. In real, taking into account economic predictions, the energy prices will most probably rise and the payback periods get shorter.

Following chapters summarize the conclusions and recommendations related to concrete sample buildings.

### 4.6.1. Brick apartment building

Very poor thermally-technical parameters of envelope constructions, missing regulation of heating system, insufficient thermal insulation of common pipes in the building basement are the main findings of the audit. These conclusions lead to obvious **recommendations: thermal insulation of walls, roof and ceiling of a basement, windows exchange, improvement of main entrance doors and thermal insulation of heat pipes and hot water pipes in the common spaces of the building**. Further, to achieve predicted energy savings, quality **regulation of heat radiators** must be installed.

In later stage, before transition to consumption-oriented payment for heat and hot water, the metering equipment must be installed – **measurement of heat and hot water consumption** in the building and introduction of a system **that allows to divide total consumption to separate flats**.

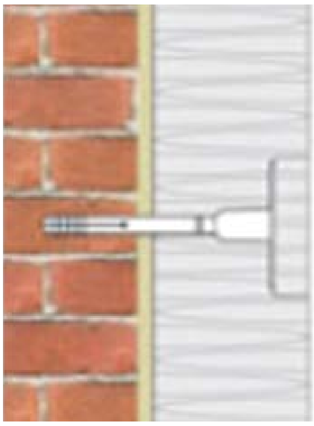
## Walls

**The ventilated facade is recommended to be applied** as it is more secure type of composition and it avoids risk of vapour condensation in the construction. Further, sustainable domestic soft sheep wool insulation can be simply used.

**Figure 4.6-1 - Scheme of ventilated facade composition on a brick wall with wooden bearing structure**

Typical plastic anchor (joint) for thermal insulation fixing

Anchored wool thermal insulation



Anchoring using upgraded solution – covering the anchor with a wool plug

Plugging the anchor with wool

**Figure 4.6-2 - Anchoring of thermal insulation of walls**

All facades will be provided with an insulation system based on 140mm of sheep wool (λ = 0,042 W/mK). Calculation of vapour condensation risk and temperatures inside the construction is done for the same climatic conditions as for other existing constructions.

## Roof

Definitely, **the ventilated (double case) roof is recommended to be applied** as it is more secure type of composition, it avoids risk of vapour condensation in the roof and damage-prone water vapour barrier layer is not necessary to be used.

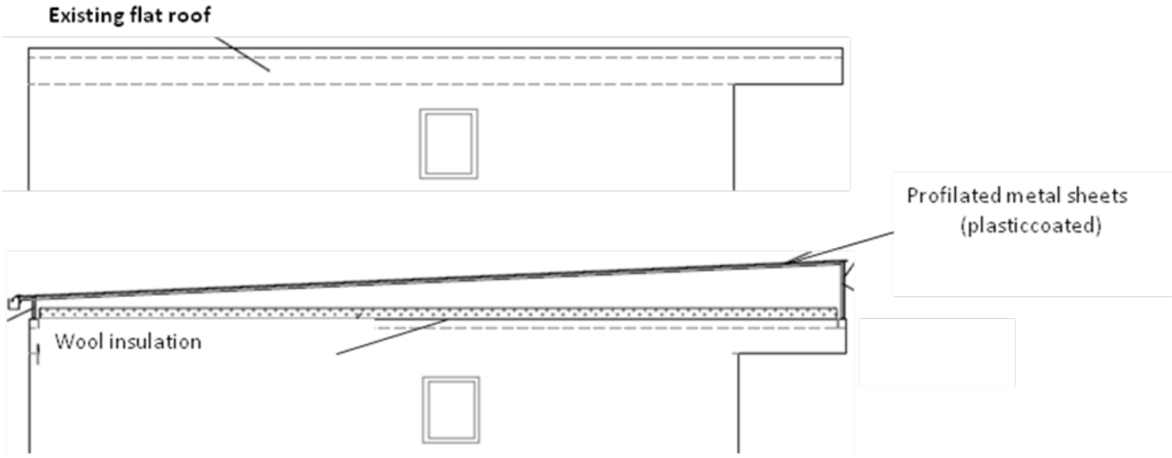



**Figure 4.6-3 - Sketch of added waterproof bearing structure with ventilated cavity underneath**

An insulation layer will be made of 240 mm sheep wool (λ = 0,042 W/mK). The waterproof insulation must be secured against direct UV-rays to provide long-lasting protection so, crushed stone (often a part of the waterproofing) or other similar covering must be applied on it.

## Windows

For this calculation purposes it is expected that all windows and doors are original in the building. It means that **exchange of all these windows and doors** is contained in this measure.

## Floor (ceiling)

Expected thermal insulation of pipes in basement will cause further decrease of basement temperature. Then, the thermal insulation of ceiling of this basement comes to be more efficient. It is suggested to **thermally insulate whole the ceiling of the building basement** using 80 mm of sheep wool (λ = 0,042 W/mK).

## Others

- Thermal insulation of common heat pipelines
- Regulation of a heating system
- Measurement of heat consumption
- Repairing the lighting in common areas
- Awareness increasing

**Table 4.6-1–Economic evaluation of measures combination**

| Basic economic evaluation of suggested measures package | | |
|---|---|---|
| | Unit | Value |
| Calculated energy performance of suggested state of a building | MWh/a | 567 |
| Energy savings | MWh/a | 1 448 |
| Energy costs savings | EUR/a | 13 549 |
| *Average cost savings per apartment* | *EUR/a* | 226 |
| simple payback | years | 6,9 |
| net present value (30 years; 5,0% rate) | EUR | 115 030 |

## Conclusion

From the technical point of view, the right solution of problems, caused by the **poor thermal resistance of the building**, would be solved by **installation of necessary thermal insulation measures for all building envelope constructions and improving heating system**. Concretely, very poor thermally-technical parameters of envelope constructions, missing regulation of heating system, insufficient thermal insulation of common pipes in the building basement are the main findings of the audit.

These conclusions lead to following recommendations:

- thermal insulation of walls
- thermal insulation of roof
- thermal insulation of ceiling of a basement
- windows exchange
- doors exchange (or at least improvement of main entrance doors)
- thermal insulation of heat pipes and hot water pipes in the common spaces of the building
- quality regulation of heat radiatorsinstallation.

In later stage, before transition to consumption-oriented payment for heat and hot water, the metering equipment must be installed – measurement of heat and hot water consumption in the building and introduction of a system that allows to divide total consumption to separate flats.

**These measures lead to significantly high energy consumption reduction**. Concretely in this case, consumption of heat from district heating system decreases from 1995 MWh/a to 547 MWh/a, that means **73% reduction**!In absolute numbers, about **13,5 thousand EUR per year can be saved on energy** costs. Further, **emissions can be reduced by about 554 tons per year.**

The recommended combination of measures is cumulated in suggested project solution that underwent economic and environmental evaluation. Based on assumed measures costs and energy costs development (see the Sensitivity analysis), following results were received:

- **estimated installation costs are about 93 thousand EUR**
- **real payback is about 8,6 years** which is usually well acceptable in case of building improvement investments, the payback period is shorter than measures lifetime.

## 4.6.2. Pre-cast concrete (panel) apartment building

These buildings were typically built in larger compositions of number of separate rectangular buildings. As these compositions differ a lot in their shape and volume, for further calculations only one typical rectangular part has been taken into account.

Very poor thermally-technical parameters of envelope constructions, missing regulation of heating system, insufficient thermal insulation of common pipes in the building basement are the main findings of the audit. These conclusions lead to obvious **recommendations: thermal insulation of walls, roof and ceiling of a basement, windows exchange, improvement of main entrance doors and thermal insulation of heat pipes and hot water pipes in the common spaces of the building**. Further, to achieve predicted energy savings, quality **regulation of heat radiators** must be installed.

In later stage, before transition to consumption-oriented payment for heat and hot water, the metering equipment must be installed – **measurement of heat and hot water consumption** in the building and introduction of a system **that allows to divide total consumption to separate flats**.

In Mongolia, there are several hundreds of these buildings (more than 400 in Ulaanbaatar) so, the total potential for energy savings by application of above mentioned thermally-technical measures is huge.

### Walls

**The ventilated facade is recommended to be applied** as it is more secure type of composition and it avoids risk of vapour condensation in the construction. Further, sustainable domestic soft sheep wool insulation can be simply used. Following scheme shows the composition of ventilated facade including water vapour transfer through it (by dotted arrows).

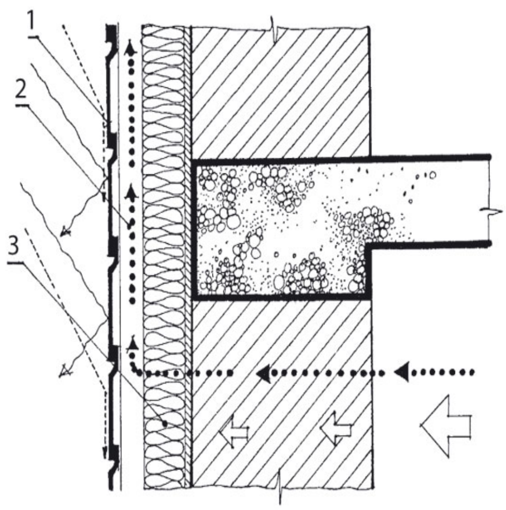
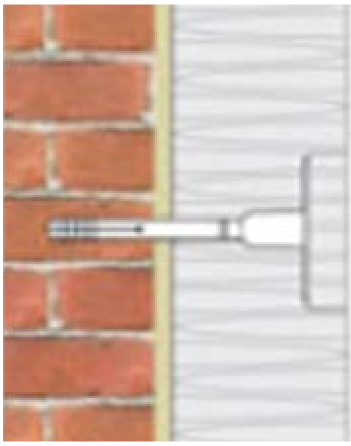



**Figure 4.6-4 - Scheme of ventilated facade composition including water vapour transfer**

Typical plastic anchor (joint) for thermal insulation fixing

Anchored wool thermal insulation



Anchoring using upgraded solution – covering the anchor with a wool plug

Plugging the anchor with wool

**Figure 4.6-5 - Anchoring of thermal insulation of walls**

All facades will be provided with an insulation system based on 150mm of sheep wool ($\lambda$ = 0,042 W/mK). Calculation of vapour condensation risk and temperatures inside the construction is done for the same climatic conditions as for other existing constructions.

## Roof

Definitely, **the ventilated (double case) roof is recommended to be applied** as it is more secure type of composition, it avoids risk of vapour condensation in the roof and damage-prone water vapour barrier layer is not necessary to be used.

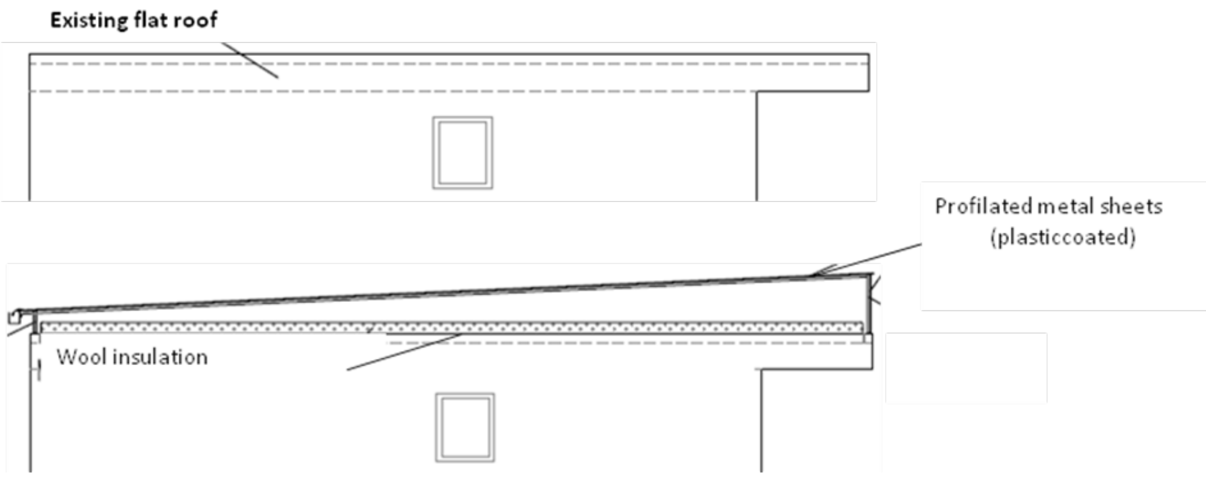


**Figure 4.6-6 - Sketch of added waterproof bearing structure with ventilated cavity underneath**

An insulation layer will be made of 240 mm sheep wool (λ = 0,042 W/mK). The waterproof insulation must be secured against direct UV-rays to provide long-lasting protection so, crushed stone (often a part of the waterproofing) or other similar covering must be applied on it.

## Windows and doors

For this calculation purposes it is expected that all windows and doors are original in the building. It means that **exchange of all these windows and doors** is contained in this measure.

## Ceiling (floor)

Expected thermal insulation of pipes in basement will cause further decrease of basement temperature. Then, the thermal insulation of ceiling of this basement comes to be more efficient. It is suggested to **thermally insulate whole the ceiling of the building basement** using 80 mm of sheep wool (λ = 0,042 W/mK).

## Others

- Thermal insulation of common heat pipelines
- Regulation of a heating system
- Measurement of heat consumption
- Repairing the lighting in common areas
- Awareness increasing

**Table 4.6-2–Economic evaluation of measures combination**

| Basic economic evaluation of suggested measures package | | |
|---|---|---|
| | Unit | Value |
| Calculated energy performance of suggested state of a building | MWh/a | 885 |
| Energy savings | MWh/a | 3 320 |
| Energy costs savings | EUR/a | 31 078 |
| *Average cost savings per apartment* | *EUR/a* | 331 |
| simple payback | years | 4,7 |
| net present value (30 years; 5,0% rate) | EUR | 331 151 |

## Conclusion

From the technical point of view, the right solution of problems, caused by the **poor thermal resistance of the building**, would be solved by **installation of necessary thermal insulation measures for all building envelope constructions and improving heating system**.Concretely, very poor thermally-technical parameters of envelope constructions, missing regulation of heating system, insufficient thermal insulation of common pipes in the building basement are the main findings of the audit.

These conclusions lead to following recommendations:

- thermal insulation of walls
- thermal insulation of roof

- thermal insulation of ceiling of a basement
- windows exchange
- doors exchange (or at least improvement of main entrance doors)
- thermal insulation of heat pipes and hot water pipes in the common spaces of the building
- quality regulation of heat radiatorsinstallation.

In later stage, before transition to consumption-oriented payment for heat and hot water, the metering equipment must be installed – measurement of heat and hot water consumption in the building and introduction of a system that allows to divide total consumption to separate flats.

**These measures lead to significantly high energy consumption reduction**. Concretely in this case, consumption of heat from district heating system decreases from 4177 MWh/a to 857 MWh/a, that means **79 % reduction**! In absolute numbers, about **31 thousand EUR per year can be saved on energy** costs. Further, **emissions can be reduced by about 1273 tons per year.**

The recommended combination of measures is cumulated in suggested project solution that underwent economic and environmental evaluation. Based on assumed measures costs and energy costs development (see the Sensitivity analysis), following results were received:

- **estimatedinstallation costs are about 146 thousand EUR.** The calculated initial costs are related directly to energy efficiency measures only. Any other additional costs that need to be spent within the building renovation are not taken into account.

- **real payback is about 8,6 years** which is usually well acceptable in case of building improvement investments, the payback period is shorter than measures lifetime

### 4.6.3. School - brick building

Very poor thermally-technical parameters of envelope constructions (except windows) and missing regulation of heating system are the main findings of the audit of this building. The results and recommendations are reduced compared to those related to residential buildings as in this case windows have already been exchanged for new plastic ones. Further, any thermal insulation of floor is not taken into account and recommended (until complex refurbishment of a school building is planned) as this measure application has strong influence on building operation.

Energy audit conclusions lead to obvious **recommendations: thermal insulation of walls and roof and** further, to achieve predicted energy savings, quality **regulation of heat radiators** must be installed.

In later stage, before transition to consumption-oriented payment for heat and hot water, the metering equipment must be installed – **measurement of heat and hot water consumption** in the building and introduction of a system **that allows to divide total consumption to separate flats**.

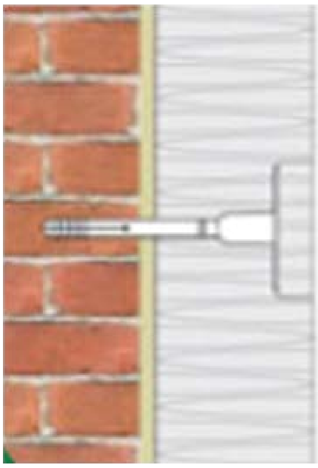
#### Walls

**The ventilated facade is recommended to be applied** as it is more secure type of composition and it avoids risk of vapour condensation in the construction. Further, sustainable domestic soft sheep wool insulation can be simply used.

**Figure 4.6-7 - Scheme of ventilated facade composition on a brick wall with wooden bearing structure**

Typical plastic anchor (joint) for thermal insulation fixing

Anchored wool thermal insulation



Anchoring using upgraded solution – covering the anchor with a wool plug

Plugging the anchor with wool

**Figure 4.6-8 - Anchoring of thermal insulation of walls**

All facades will be provided with an insulation system based on 140mm of sheep wool ($\lambda$ = 0,042 W/mK). Calculation of vapour condensation risk and temperatures inside the construction is done for the same climatic conditions as for other existing constructions.

## Roof

Definitely, **the ventilated (double case) roof is recommended to be applied** as it is more secure type of composition, it avoids risk of vapour condensation in the roof and damage-prone water vapour barrier layer is not necessary to be used.

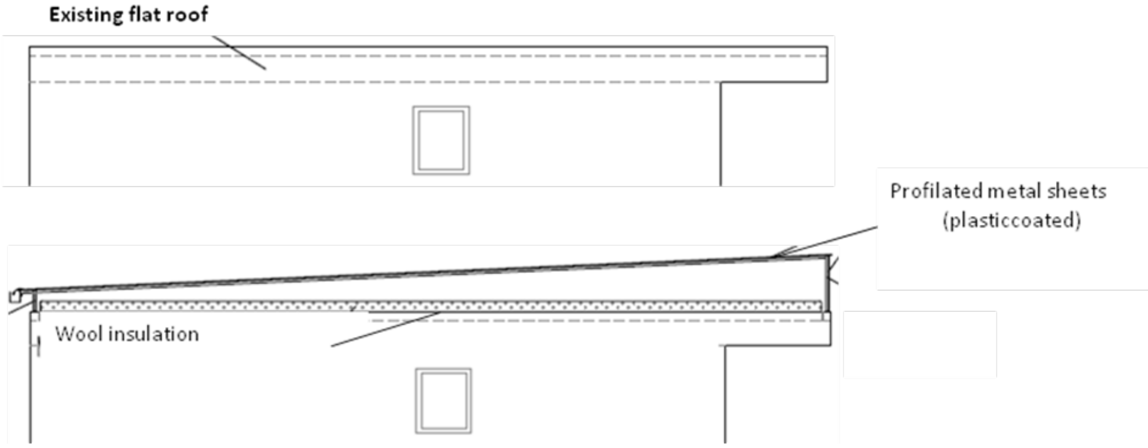



**Figure 4.6-9 - Sketch of added waterproof bearing structure with ventilated cavity underneath**

An insulation layer will be made of 240 mm sheep wool ($\lambda$ = 0,042 W/mK). The waterproof insulation must be secured against direct UV-rays to provide long-lasting protection so, crushed stone (often a part of the waterproofing) or other similar covering must be applied on it.

## Windows and doors

In this case, windows and entrance doors were already exchanged. It means that **all thesenew windows and doors** are already contained in existing state calculation.

## Floor

Thermal insulation of any floor that is not above any accessible space (unheated basement) is a measure that can be provided from heated interior. It is connected with demolishing of existing floor and building operation restriction. This measure is reasonable only in case of total building refurbishment with reduction/stop of building operation during site works. For this sample building audit, this measure is not taken into account as the aim is to show widely possible solution for energy efficiency improvement of buildings.

## Others

- Regulation of a heating system
- Measurement of heat consumption
- Awareness increasing

**Table 4.6-3–Economic evaluation of measures combination**

| Basic economic evaluation of suggested measures package | | |
|---|---|---|
| | Unit | Value |
| Calculated energy performance of suggested state of a building | MWh/a | 1 044 |
| Energy savings | MWh/a | 2 774 |
| Energy costs savings | EUR/a | 25 964 |
| *Average cost savings per apartment* | *EUR/a* | -- |
| simple payback | years | 5,2 |
| net present value (30 years; 5,0% rate) | EUR | 265 330 |

### Conclusion

From the technical point of view, the right solution of problems, caused by the **poor thermal resistance of the building except windows**, would be solved by **installation of necessary thermal insulation measures for all building envelope constructions and improving heating system regulation**. Concretely, very poor thermally-technical parameters of envelope constructions and missing regulation of heating system in the building are the main findings of the audit.

These conclusions lead to following recommendations:

- thermal insulation of walls
- thermal insulation of roof
- regulation of heat radiatorsinstallation.

In this case, windows and entrance doors were already exchanged. It means that **all thesenew windows and doors** are already contained in existing state calculation.

Thermal insulation of the floor is a measure that is connected with demolishing of existing floor and building operation restriction. This measure is reasonable only in case of total building refurbishment with reduction/stop of building operation during site works. For this sample building audit, this measure is not taken into account as the aim is to show widely possible solution for energy efficiency improvement of buildings.

**Above mentioned measures, even reduced by floor thermal insulation,still lead to significantly high energy consumption reduction**. Concretely in this case, consumption of heat from district heating system decreases from 3793 MWh/a to 1019 MWh/a, that means **73% reduction.** Separate roof insulation theoretically brings 58% heat consumption reduction.

In absolute numbers, about **26 thousand EUR per year can be saved on energy** costs. Further, **emissions can be reduced by about 1063 tons per year.**

The recommended combination of measures is cumulated in suggested project solution that underwent economic and environmental evaluation. Based on assumed measures costs and energy costs development (see the Sensitivity analysis), following results were received:

- **estimated installation costs are about 134 thousand EUR**
- **real payback is about 6,1 years** which is usually well acceptable in case of building improvement investments, the payback period is shorter than measures lifetime.

## 4.6.4 Single family house - combined timber and brick structure

Compared to apartment or public buildings, evaluated family house is completely in responsibility of its owner (builder at the same time). It is obvious, that an owners approach differs compared to an approach of apartments owners. During the auditors visit, useful discussion on a possibility of improvement of both a heating system and a roof quality was held.

The energy auditor presents conclusions on a basis of both experience and calculations that are crucial part of the report. Detailed calculation reports (software outputs) are included in an annex.

Insufficient thermally-technical parameters (based on comparison to standard values) of envelope constructions are the main findings of the audit. These conclusions lead to obvious **recommendations: thermal insulation of walls and roof.** Further constructions do not meet standard requirements as well, but it is technically and logically unsuitable to recommend them to be parts of proposed energy saving project.

## Walls

Thermal insulation on internal surface of the walls. This solution always **must be well designed and perfectly installed to avoid vapour condensation** in the construction. Further, the cavity between the masonry and the existing structure must be ventilated (naturally) and a **vapour barrier must be on internal side of the walls (beyond the wooden boards)**. To install the thermal insulation to lightweight construction (from interior side) is usually doable with good possibility to eliminate risk of future vapour condensation risk. It differs from internal insulation of heavy brick or concrete constructions.

Obviously, this **insulation on internal surface** means a **reduction of floor area** in the house as an increase of thermal insulation thickness influences the construction on its internal side. This proposed solution of safe and well functioning thermal insulation application is based on sensitive implementation of physical principals related to partial pressure of vapour in constructions. It means that it is necessary to install well working vapour-proof layer on internal surface (beyond the wooden or gypsum boards).

Another complication is in thermal bridges that are always created in a place of connection of external wall with internal wall and between wall and ceiling.

In this case, when the construction does not have any extremely tight vapour barrier inside or on outside surface, it is usually sufficient to use tightened (with well sealed joints) wooden boards on internal surface. (Possibility and adequacy of such solution should always be confirmed by an energy expert or calculation). Soft sheep wool insulation is suitable for this composition.

All walls will be provided with a sheep wool thermal insulation with thicknessof 150mm of sheep wool ($\lambda$ = 0,042 W/mK). Calculation of vapour condensation risk and temperatures inside the construction is done for the same climatic conditions as for other existing constructions.

## Roof

After inspection of the sloped roof construction it was stated that its composition is critical at present. Thermally technical parameters are not very poor but still, the construction does not meet standard requirements. The worse problem is that the vapour condensation risk in this construction is almost certain.

An insulation layer will be made of 260 mm sheep wool ($\lambda$ = 0,042 W/mK). The wool will be partly put between the wooden rafters and partly to additional (e.g. wooden) bearing structure. Then, airtight (sealed joints) vapour barrier must be well installed. The layer must be securelyfixed against additional holes in it.

## Windows and doors

No measures were suggested.

## Floor

No measures were suggested.

## Others

- Awareness increasing
- Improvement of a heating system

**Table 4.6-4–Economic evaluation of measures combination**

| Basic economic evaluation of suggested measures package | | |
|---|---|---|
| | Unit | Value |
| Calculated energy performance of suggested state of a building | MWh/a | 93,3 |
| Energy savings | MWh/a | 73,4 |
| Energy costs savings | EUR/a | 584 |
| *Average cost savings per apartment* | *EUR/a* | 584 |
| simple payback | years | 12,9 |
| net present value (30 years; 5,0% rate) | EUR | 1 428 |

## Conclusion

From the technical point of view, the right solution of problems, caused by the **insufficient thermal resistance of the building**, would be solved by **installation of necessary thermal insulation measures for those building envelope constructions, where it is technically and logically still relevant.**

These conclusions lead to following recommendations:

- thermal insulation of walls
- thermal insulation of roof

The thermal insulation of both wall and roof need to be well installed including necessary vapour barrier that ensures avoiding vapour condensation risk. Further, wall insulation is understood as an internal thermal insulation that significantly affects floor area inside the building. Obviously, such measure can not be installed widely.

**These above mentioned measures lead to significantly high energy consumption reduction**. Concretely in this case, consumption of coal for heating decreases from 162,0 MWh/a to 88,6 MWh/a, that means **45% reduction**!In absolute numbers, almost **600 EUR per year can be saved on energy** costs. Further, **emissions can be reduced by about 26 tons per year.**

The recommended combination of measures is cumulated in suggested project solution that underwent economic and environmental evaluation. Based on assumed measures costs and energy costs development (see the Sensitivity analysis), following results were received:

- **estimated installation costs are about 7,5 thousand EUR**
- **real payback is about 21 years** which is usually well acceptable in case of building improvement investments, the payback period is shorter than measures lifetime.

### 4.6.5. Single family house - timber structure

Compared to apartment or public buildings, evaluated family house is completely in responsibility of its owner (builder at the same time). It is obvious, that an owners approach differs compared to an approach of apartments owners. During the auditors visit, useful discussion on a possibility of an improvement of roof composition and on hot water preparation system installation was held.

The energy auditor presents conclusions on a basis of both experience and calculations that are crucial part of the report. Detailed calculation reports (software outputs) are included in an annex.

Insufficient thermally-technical parameters (based on comparison to standard values) of envelope constructions are the main findings of the audit. These conclusions lead to obvious **recommendations: thermal insulation of walls and roof.** Further constructions do not meet standard requirements as well, but it is technically and logically unsuitable to recommend them to be parts of proposed energy saving project.

## Walls

Any external thermal insulation of the facade is not possible as it is uneven. Further, the facade has its aesthetical value that should not be destroyed by this technical measure (at least the owner would not agree on such measure).

To install the thermal insulation to lightweight construction (from interior side) is usually doable with good possibility to eliminate risk of future vapour condensation risk. It differs from internal insulation of heavy brick or concrete constructions.

This solution means reduction of floor area in the house as an increase of thermal insulation thickness influences the construction on its internal side. This proposed solution of safe and well functioning thermal insulation application is based on sensitive implementation of physical principals related to partial pressure of vapour in constructions. It means that it is necessary to install well working vapour-proof layer on internal surface. In this case, when the construction does not have any extremely tight vapour barrier inside or on outside surface, it is usually sufficient to use tightened (with well sealed joints) wooden boards on internal surface. (Possibility and adequacy of such solution should always be confirmed by an energy expert or calculation). Soft sheep wool insulation is suitable for this composition as the covering layers creating aesthetical and waterproofing part of the facade are held by separately fixed wooden frame structure.

All walls will be provided with a sheep wool thermal insulation with thickness of 140mm of sheep wool ($\lambda$ = 0,042 W/mK). Calculation of vapour condensation risk and temperatures inside the construction is done for the same climatic conditions as for other existing constructions.

## Roof

Thermally technical parameters are not very poor but still, the construction does not meet standard requirements. The worse problem is that the vapour condensation risk in this construction is almost certain. This fact is given especially by these two reasons:

- Water vapour barrier close to internal surface (beyond the wooden boards) of the roof is missing;
- There are metal sheets on external surface of the roof covering it and functioning as a waterproofing.

An insulation layer will be made of 260 mm sheep wool ($\lambda$ = 0,042 W/mK). The wool will be partly put between the wooden rafters and partly to additional (e.g. wooden) bearing structure. Then, airtight (sealed joints) vapour barrier must be well installed. The layer must be securelyfixed against additional holes in it.

## Windows and doors

No measures were suggested.

## Floor

No measures were suggested.

## Others

- Awareness increasing

**Table 4.6-5–Economic evaluation of measures combination**

| Basic economic evaluation of suggested measures package | | |
|---|---|---|
| | Unit | Value |
| Calculated energy performance of suggested state of a building | MWh/a | 39,1 |
| Energy savings | MWh/a | 33,4 |
| Energy costs savings | EUR/a | 1 367 |
| *Average cost savings per apartment* | *EUR/a* | 1 367 |
| simple payback | years | 7,6 |
| net present value (30 years; 5,0% rate) | EUR | 10 649 |

These conclusions lead to following recommendations:

- thermal insulation of walls
- thermal insulation of roof

## Conclusion

**These measures lead to significantly high energy consumption reduction**. Concretely in this case, consumption of electricity for heating and hot water preparation decreases from 71,5 MWh/a to 38,1 MWh/a, that means **47% reduction**! In absolute numbers, about **1,3 thousand EUR per year can be saved on energy** costs. Further, **emissions can be reduced by about 39 tons per year.**

The recommended combination of measures is cumulated in suggested project solution that underwent economic and environmental evaluation. Based on assumed measures costs and energy costs development (see the Sensitivity analysis), following results were received:

- **estimated installation costs are about 10 thousand EUR**
- **real payback is less than 10 years** which is usually well acceptable in case of building improvement investments, the payback period is shorter than measures lifetime.

# 5 RELEVANT DEFINITIONS

**Building envelope:** Building envelope means the integrated elements of a building which separate its heated/cooled interior from the outdoor environment (e.g. external walls, windows, roofs, the lowest floors etc).

**Delivered energy (Energy use):** Delivered energy refers to energy carrier (coal, heat from district heating, electricity, gas etc.), supplied to the technical building system through the system boundary, to satisfy the uses taken into account (heating, cooling, ventilation, domestic hot water, lighting, appliances etc.) or to produce electricity in the building. This amount of energy contains energy needed for covering lost in heat source, pipes, energy for running ventilators and pumps. See following figure.

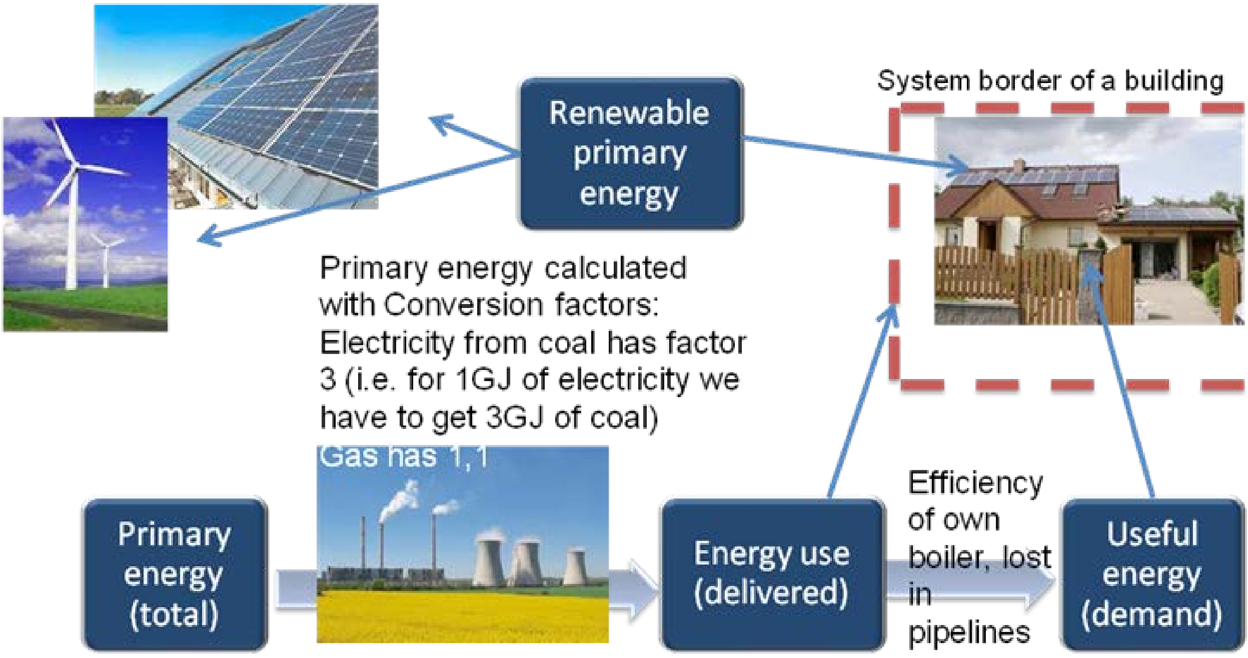



**Figure. 5.1. Schematic system of evaluated energy types**

**Energy Performance of a building:** Energy Performance of a building means the calculated or measured amount of energy demand associated with a typical use of a building, which includes energy demand for heating, cooling, ventilation, hot water preparation and lighting. Further, Energy performance requirement means minimum level of energy performance given by law (e.g. in EU countries) that is to be achieved in case of planned building to be built or in case of major renovation of a building.

**Primary energy:** Primary energy means energy from renewable and non-renewable sources which has not undergone any conversion or transformation process. This energy fits best to define an influence of building operation on environment. See figure above. Example of calculating primary energy using Conversion factor 3,0 for producing electricity in power plants relates to the Czech republic, where the electricity is produced from portfolio of power plants burning mostly coal and natural gas with support of nuclear energy.

**Thermal conductivity (specific):** Thermal conductivity is a measure of the ability of a substance to conduct heat, determined by the rate of heat flow through the substance divided by the area. It is measured in Watts per metre per degree Kelvin. Symbol is $\lambda$, k, unit is W/mK.

**U-value:** U-value (or Heat-transmittance coefficient) is the measure of the rate of heat loss through a material. Lower U-Values are always better because the lower the U-value – the less heat that is being lost. The U-value is measured as the amount of heat lost through a one square meter of the material for every degree difference in temperature either side of the material. It is indicated in units of Watts per meter squared per degree Kelvin i.e. $W/m^2K$.

**Useful energy(Energy demand):** Useful energy equals to demanded amount of energy that is needed to keep planned/expected internal conditions in a building (i.e. expected internal temperature, hot water temperature and amount, sufficient lighting etc.). See figure above.

**Water vapour condensation risk:** The risk calculation helps to predict possible water vapour condensation in construction. Result depends on diffusion resistance of materials used, their thicknesses, relative humidity of air (especially in interior) and on air temperatures both inside and outside. Simply said, the lower is temperature on interior side, the higher risk of condensation on interior surface of construction or in it. Results of vapour condensation are obvious: wet (even freezing) patches especially in colder corners of rooms and further, dark patches of moulds that can be a source of allergy.

# 6 LITERATURE AND OTHER SOURCES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- System of standards based on EN ISO 13 790 "Energy performance of buildings - Calculation of energy use for space heating and cooling" and many other related to this basic one
- Ph.D. thesis, "Project Management for Energy Efficient Houses in Mongolian Climatic Condition", Mr.TurboldBanzragch, Czech Technical University in Prague, Faculty of Civil Engineering, 2013
- Calculation tool "Teplo 2010", Svoboda software ©, used for calculations of U-values and water vapour condensation risk
- Calculation tool "Energie 2013", Svoboda software ©, used for calculations of delivered energy, primary energy, energy savings and emissions parameters
- http://www.beep.mn/,information from the UNDP project BEEP "Energy Efficiency in New Construction in the Residential and Commercial Buildings Sector in Mongolia", project MON/09/301
- http://weatherspark.com/, meteorological data

# 7 LIST OF TABLES

# 8 LIST OF FIGURES