MSc Program "Building Science & Technology"

A Systematic Approach to Thermal Adaptation of Detached Single Family Buildings in Kosovo

A master's thesis submitted for the degree of
"Master of Science"

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Affidavit

I, **Agron Islami**, hereby declare

1. That I am the sole author of the present Master Thesis "A Systematic Approach to Thermal Adaptation of Detached Single Family Buildings in Kosovo" and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. That I have not prior to this date submitted this Master Thesis as an examination paper in any form in Austria or abroad.

Vienna, June 2007

Signature

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Abstract

The research focuses on thermal behaviour of non-insulated single detached family units in the region of Kosovo. The region has experienced a massive construction of illegal housing especially after the conflict of 1999. Such construction resulted in poor thermal behaviour of the houses due to the lack of insulation. The poor thermal behaviour resulted in degradation of thermal comfort for the inhabitants of the houses. This phenomenon occurs due to energy savings to heat the house or more accurately, a specific part of the house.

The simulation is based on parametric studies in an hourly basis to compute the thermal behavior of three specific houses. The first simulation is performed on a non-insulated house whereas the other simulations are performed with improved thermal insulation in order to understand the importance of a thermal envelope and its impact in this type of houses. The generated results emphasize the energy savings if thermal envelope is improved in existing houses. Simulation program "TAS" was used to extract figures and numbers related to the cases.

The research aims to inform the local population on possibilities for increasing the thermal performances of their houses by improvement of the thermal envelope. It raises the quality of living in their dwellings as well as the quality of the environment, subject to a considerable degradation caused by pollution, generated by the outworn power thermal power plants in Kosovo.

1 Introduction

1.1 Motivation

Thermal behavior in buildings is an important issue for the thermal comfort of the people living in them. It can be ensured by a designed control of heat input and output represented by the heat losses and heat gains. By such a design, conditions are created to meet the human needs and, being subject to a designed control, such conditions have a direct impact on living comfort and human health. Thermal comfort can be "A condition of mind that expresses satisfaction with the thermal environment" (*Szokolay 2004*). The achievement of a thermal comfort by the human body depends on four environmental and two personal parameters. The environmental one includes: Dry bulb temperature, mean radiant temperature, relative humidity and air velocity, whereas in the personal part are included: clothing insulation and amount of activity (*Huynh 2001*).

For the accommodation of the thermal comfort in a building, its thermal behavior has to comply with the needs of its occupants. But for the thermal behavior of a building, various factors are decisive, one of which is the construction materials of the building which makes an envelope of the living environment. It creates the skin of the building, which encloses it and protects the interior from atmospheric phenomena.

According to ASHRAE (The American Society of Heating, Refrigerating and Air-Conditioning Engineers), the building can be divided into three categories; a) Tight – good construction with tight fittings. b) Medium – with medium construction and average fit openings, c) Loose – Loose structures with poorly fitted windows and doors (*ASHRAE 2001*).

1.2 Background

A single detached family house, with a loose structure as according to ASHRAE 2001, with poorly fitted windows and doors is rather a common building type in Kosovo. Such a loose structure causes a high degree of heat losses from its interior and therefore a higher demand of energy for heating purposes in winter months is observed.

After the NATO Bombing of Yugoslavia in 1999, Kosovo has experienced frequent shortages in supply of electrical energy which represent a serious problem not only for a satisfactory supply of electric power energy to the population, but also for the economic sector of Kosovo.

Although the electric power producing facilities (thermal and water power plants) of Kosovo were not directly targeted by the Allied forces, Kosovo is still facing an electrical energy crisis, i.e. low energy production caused mainly by the worn facilities, insufficient and inadequate maintenance during the last decades of the Twentieth Century.

The Kosovo electrical generation industry consists mainly of thermal power energy producing units ("Kosova A" and "Kosova B") and several small water driven power plants. The two main thermal power plants are located about 10 km north-west of the capital Prishtina. The first unit of "Kosova A" with a capacity of 30 MWh started production in 1962 and reached 450 MWh. The remaining four units where completed until 1973. The erection of "Kosova B" was completed in 1984. It consists of two production blocks with a nominal capacity of 290 MWh each (*UNMIK 2006*). The total amount of actually produced electrical energy reaches approximately 600 MWh which still cannot meet the needs of the Kosovo citizens. Both these power plants operate in very poor conditions,

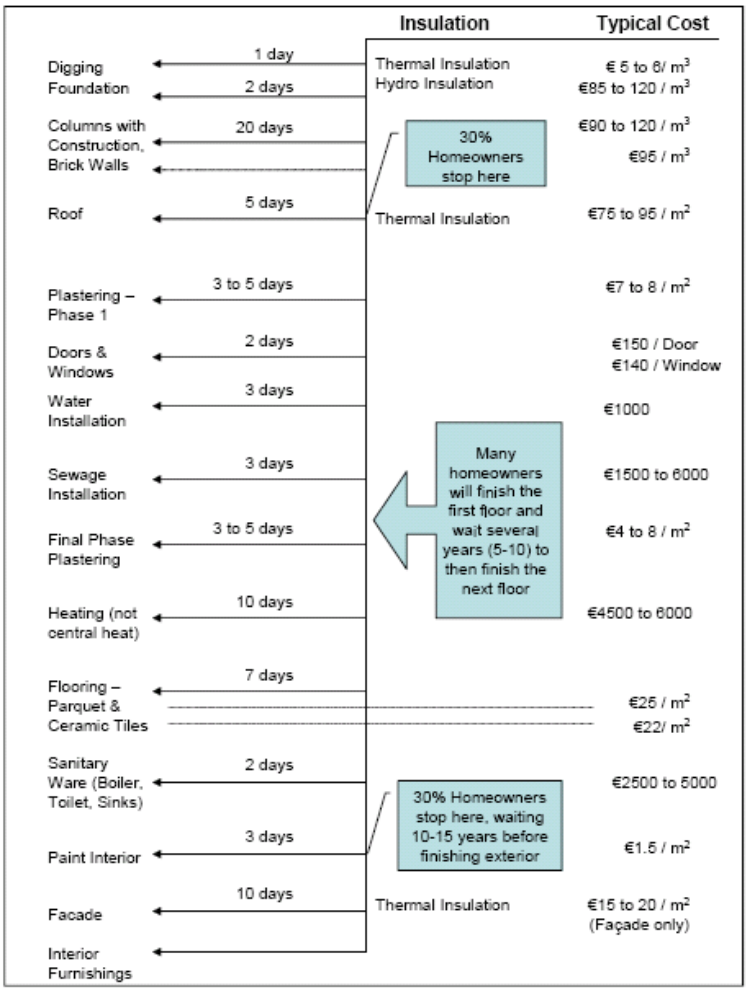
particularly “Kosova A” which faces very frequent stoppages caused by its unreliable and old equipment and constant damages.

After gradual stabilization of the political and economic situation in Kosovo, an increase in the demand of electrical energy has been observed. This is an additional reason why the power cuts are more and more frequent, although a considerable amount of electrical energy is imported from neighboring countries, especially in winter period.

Another reason that has influenced the pertaining electrical energy crisis is the way the population undertook the reconstruction of houses destroyed or burned down during the last Kosovo conflict or newly built houses. For many reasons, the thermal behavior of such houses was not the most important element that had been taken into consideration by the investors. In the other hand, the UN led administration of Kosovo has not promulgated appropriate laws to regulate architectural and civil engineering rules. The lack of an appropriate legal basis and the inefficient administration enabled a huge uncontrolled illegal and wild construction of private houses both in private and state owned land all around Kosovo (mainly in and around its main cities, such as Prishtina, Peja, Prizren, Ferizaj, Gjakova, etc.) and such an uncontrolled building is still continued without necessary administrative permissions, architectural designs, static of the buildings, installations and all other requirements for a legal project.

Most of the investing population, whose houses had been burned down to the ground was poor and therefore built their houses step by step. The following table shows the percentage of citizens and their progress in construction of a single family house.

Table 1: Timeline of a single unit house construction (*Daniel 2003*)



Most of the housing is built until completion of its enclosure (walls, roof, doors and windows). Based on the table above, this category of houses makes part in the group of 60% of the total housing in Kosovo. It is the most common way of building and aims to meet the elementary needs of the citizens to live in them. One of the most important building phase, i.e. creation of a thermal envelope is usually left uncompleted and “for a better and wealthier time”. The simulations will be performed on houses belonging to the group of the 60% of the housing in Kosovo.

A general house design in Kosovo is a 10x10m corpus usually with two stories. It consists of a living room, a dining room, a kitchen and a

bathroom on the ground floor whereas on the second floor there are three to four bedrooms. According to a CHF (Cooperative Housing Foundation) observation, the house consists of a layout with three rooms on the first and three rooms on the second floor with two bathrooms (*Daniel 2003*). There are cases where a single family house has 4 to 5 stories with approximately 15 rooms but such cases do not represent the majority of houses in Kosovo.

In most cases these houses have no thermal insulation at all. Based on the survey, the materials used for the outer walls consist of hollow masonry blocks of dark red color, due to their high consistency of clay. Kosovo is rich in clay which is the reason for mass production of such types of blocks. The interior part of the wall consists of a thin layer of cement or lime mortar that makes a smooth surface for esthetical reasons only. On the external side, no layer has been brought on the blocks and this reveals the lack of thermal insulation that would produce a thermal envelope for encapsulation purposes of the heat in the winter and protection of the house from overheating during the summer months.

It is assumed that the consumption of energy in such types of houses might be very high, particularly in cold winter days. One of the easiest but not cheapest energy sources to which the population has access is the electrical energy, either produced by the Kosovo power plants or imported. And, as mentioned above, this is one of the reasons for electrical energy shortages. Therefore these houses are qualified as loose type based on ASHRAE Standards.

The survey revealed that not all rooms are continuously heated. According to the local tradition, people use to build big houses, even though there are a few family members and this leads to construction of

2 to 4 story houses. In many cases only few rooms are used upon enclosure of the house. Most of the owners cannot afford to complete the second part of their houses.

Another reason for a discontinuous heating of the bedrooms is simply their low occupancy. The most commonly heated place is the living room and the kitchen, the least heated are the bedrooms, whereas the toilets and the corridors are not at all heated. According to UNMIK World Bank research, 86% of the houses have heating in the kitchen, 77% in the living room, 56% in the bedrooms and only 10% in the whole house (*UNMIK 2001*). In big cities like Prishtina, Peja, people have started living a more modern way, which lead to construction of small single family units. But the percentage of such family houses is small in comparison with the total number of built houses. In Kosovo, a one story family house also can be found, but one reason is not the modernization of the culture, but the lack of funds to build a bigger one. In many cases such houses have been donated by foreign NGO's (Non Governmental Organization). The survey reveals that these houses still have no thermal envelope, even though they consist of a one story structure.

The problem with such houses occurs in the rooms which are either unheated or heated for a short period of time during winter days. The heat from the occupied rooms is transferred by conduction through the walls aiming to balance the temperature in the whole building. The unheated rooms act as a buffer zone between the inner and the outer temperature. This means that there are two or more temperature ranges in a single house. The first one is around 22 °C in a fully occupied and heated room. The temperature in the neighboring rooms varies and depends on many factors, such as the orientation of the room, amount of glazing, heating period, occupancy level, surface to adjacent heated

room etc. The temperature ranges in these rooms is presented in the simulated cases in the respective section of this paper.

The main energy source for room heating in a house is wood as a fully reliable source and electrical energy. Rarely and in a small percentage bottled gas heating is used. Firewood is used at 56% whereas electricity at 36% of cases (*UNMIK 2001*). In this regard it is worth to mention that there is a difference between the source of heating and type of room in which it is applied. The explanation to firewood, as a primary source for heating is directly connected with the frequency of occupancy of the space. It is mainly used in living rooms or in kitchens, in which a wood stove is installed. The living room is occupied almost during the whole day and the stove is often used for cooking. The other rooms, including the children's bedrooms are used mainly for sleeping and rarely for some other activity. This is one of the reasons for short term heating in these spaces. According to the UNMIK World Bank research "The average amount of heating for Kosovo is set at 226 $kWhm^{-2}$, it is the lowest in the Prishtina distribution area, 204 $kWhm^{-2}$, while in other areas it ranges from 230 to 240 $kWhm^{-2}$. Given the 3000 degree-day established in Kosovo in 2000, these figures show that housing facilities have relatively poor thermal insulation level" (*UNMIK 2001*). This example demonstrates the quality of the bricks used for construction and their thermal performance. It also illustrates the importance of thermal insulation in order to create thermally comfortable conditions inside the house.

According to the ministry of urban and Regional planning in Kosovo, "Illegal housing" is defined as: a structure which in an arbitrary concept occupies part of a land which is not based on regulations of urban planning and has no documentation for property release. The number of "illegal houses" in Kosovo built after the 1999 is 15000 from which only

3000 are built only in the capital Prishtina. In 90,8% of the cases represent private construction on private land and 9,8% are construction in governmental property. Only 1,5% have got permissions prior to start the building and have been legalized whereas 2,5% have been demolished (*Dokument pune 2004*). Based on such official figures the building quality of the houses has decreased and as a consequence, a degradation of suburbs is caused. "The key to the illegal housing can be caused by a number of factors: lack of knowledge, frustration with bureaucratic obstacles, general negligence in following the law etc." (*Daniel 2003*).

Immediately after the end of the Kosovo conflict in June 1999, a massive return of the Kosovo population from neighboring countries such as Macedonia and Albania took place. The returnees found their houses burned to the ground, damaged or only looted but undamaged. During the very first days of their return, the most of the rural population was accommodated in tents installed in their own gardens. Wealthier groups started the repair of their damaged house or built new ones. Another group continued living in tents until donations of the International Community and NGO's were provided for the repair or building of new houses. Both the building from own financial sources or international donations was not sufficient to complete the houses including their thermal insulation.

In most of the cases the construction was managed by a non professional worker. Some of the surveyed cases reveal that these non professional workers were relatives of the owner. They were hired because they worked for low cost or in some cases for free. This is another reason that the house is missing crucial elements like insulation, all this because of the lack of professional experience and

knowledge. Hiring such a person also reduced the cost of the total construction of the house.

Asked whether the owners of the houses would invest on insulation of their houses, the answers were mixed, according to CHF. The table below shows the percentage:

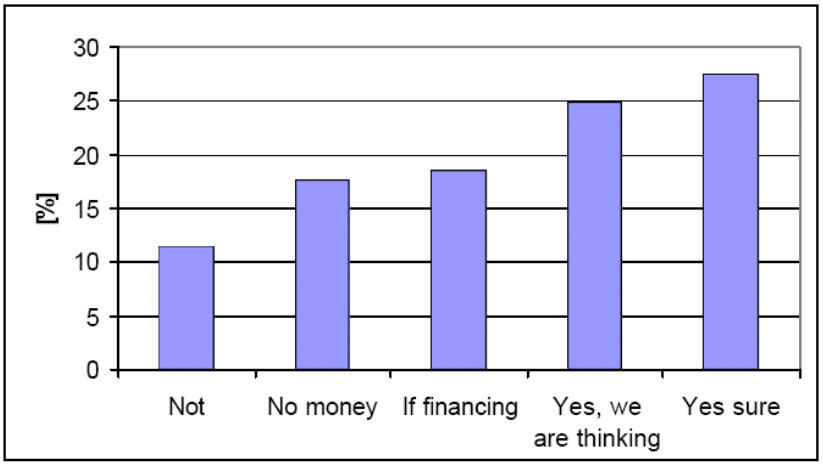


Figure 1: Willingness to invest on insulating houses (*UNMIK 2001*)

2 Objective

The intention of this research is to show an overview of thermal behavior in buildings located in the region of Kosovo. It focuses on houses that have no thermal insulation which degrades the living conditions in a house. The results would assist the local population to take action in order to improve the thermal envelope of their houses.

In order to perform a simulation, single detached family houses were selected and a calculation of the thermal performance of three buildings was carried out. The characteristics of the buildings vary in number of stories, number of occupants, number of heated and unheated rooms, orientation etc. These parameters were taken into account, because they can affect different heat loss and gain values which in the end demonstrate the demand for energy to heat that particular space. Another reason is that most of the buildings in Kosovo range in two or three story homes which would encapsulate the biggest percentage of single detached units in Kosovo.

3 Approach

3.1 Collection of data

In order to find out the cause and amount for heat loss, a detailed analysis of the materials used for the existing buildings had to be carried out. An important role plays also the behavior of occupants and all the heat generating electrical appliances, called internal gains. In total, fifteen different buildings have been evaluated. The parameters taken into consideration for the study are:

Table 2: Documentation data for surveying

Orientation	Degrees north
Size	Overall corpus dimensions
Distance to neighboring buildings	Shadow calculation
Family members	Total number of occupants
Cost for heating	Approx. electricity, wood and gas
Construction layers	Walls, Slabs, Roof
Type of heating	Wood, Coal, Electrical, Gas, other
Approximate cost of construction	Investment until today
Number of rooms and spaces	Heated and non heated
Internal conditions	Occupancy behavior
Light gain	Types and position of lighting
Photographic documentation	Facades and construction details

3.2 Climatic data

The climatic data for the simulations have been generated by MeteoNorm® for the city of Prishtina. Prishtina is located at 42,4° North, 21,1° East at an altitude of 652 meters above sea level (Wikipedia 2007).

The climate is classified as continental with warm summers reaching up to 36 °C and cold winter dropping down to -10 °C.

The parameters generated for the simulation are:

- Global solar radiation
- Diffuse solar radiation
- Cloud cover
- Dry bulb temperature
- Relative humidity
- Wind speed
- Wind direction

Data generated by MeteoNorm® were used because it was not possible to find detailed meteorological data from the local government. The local institutes provided only monthly mean values (IHMK 2006) of temperatures and they were insufficient for a simulation which required statistics based on an hourly data.

The results of weather data generated by MeteoNorm® came up close to the actual weather conditions found in the region as presented in the following graph:

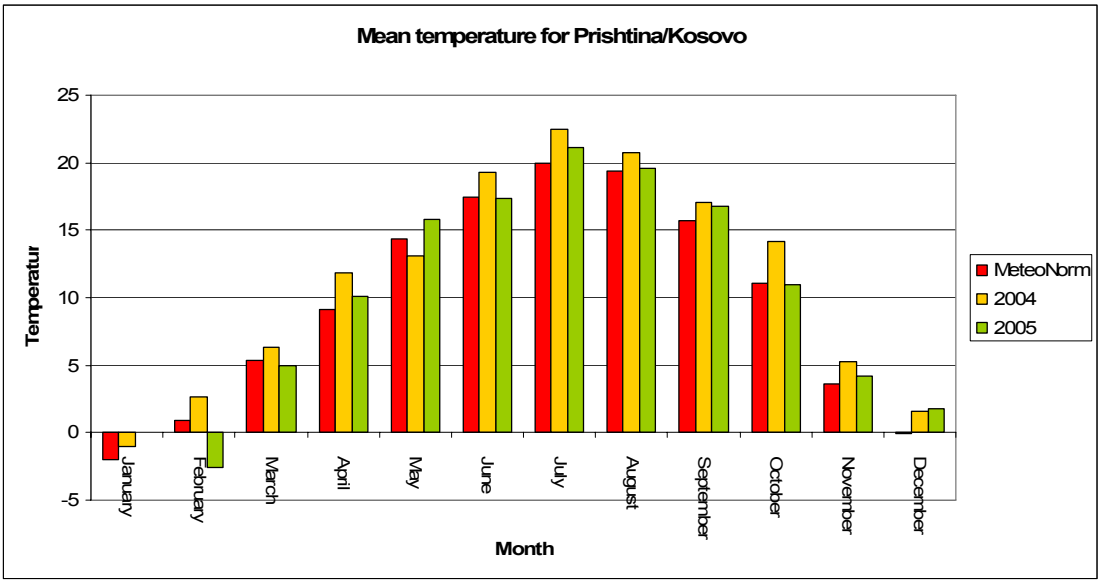


Figure 2: Mean temperature in Prishtina/Kosovo

3.3 "TAS" – simulation program

The software has been developed by the EDSL (Environmental Design Solutions Limited) in Cranfield Institute of Technology in United Kingdom. It is a 3D based geometry software (EDSL 2007). The module "The Building Designer" is used for the case studies and is capable of performing heating/cooling simulations. The results of the simulations are hourly based for the performance of a building.

3.4 Current state of housing

3.4.1 Construction and materials

Kosovo is located in a seismic zone, where high level earthquakes in Richter's scale may occur. Therefore the main construction used consists of a reinforced skeleton – columns and beams. Such a construction standard was approved by the former "JUS" regulations according to Yugoslav norms. Usually the columns have dimensions of approximately 25x25cm and that of the beams depend on the choice between a reinforced concrete slab or a lightweight slab, as well as the distance between the axes. Due to the lack of the insulation layer, the construction is visible on the buildings, as shown on the following images:

Figure 3: Visible construction elements on the facades

On the interior side of the masonry wall, the construction part, especially the columns are not visible as they are loricated for esthetical reasons.

All houses have pitched roofs and the space underneath makes in most cases a not usable loft. The pitched roof was a standardized part of the JUS regulations, which was obligatory in house building. The attic roof space acts as a buffer between the internal heated areas and the external air conditions. All analyzed cases showed that there is a lack of thermal insulation in the roof to protect the internal space in the house. The roofs consist of only a wood construction and roof tiles on top, whereas in some cases there is wood decking underneath the tiles. This reveals that no thermal insulation between the rafters could be found, as it is supposed to be. As a conclusion, the roof's main purpose is to protect the house only from precipitation which, in many cases does not function due to the lack of appropriate materials to stop the water getting through cracks or small holes.

On the other hand, the walls are constructed from a simple composition of cement mortar bound masonry blocks. The block's main compound is clay. Their dimensions measure 190 x 190 x 250mm and have a density of 701,43kg/m^3 (*Kabashi 2007*). On the interior side of the masonry wall, the blocks are covered with a layer of 2cm mortar. The blocks are positioned with holes vertically, filled and bound by a layer of cement mortar. An important question is whether the blocks are well sealed and if yes, in what extent? Insufficiently sealed blocks may have a higher conductivity value due to the circulation of air through the holes of the blocks, moving the warm air upward and allowing the penetration of the cold one during the winter seasons. Motionless air has a good thermal property and as such it can have a thermal conductivity of 0,025

$Wm^{-2}K^{-1}$ (*Szokolay 2004*). For the simulation it is assumed that the air inside the blocks is motionless.

Slabs are the only elements to possess a multiple layer structure. On the structural aspect, it can be qualified as a lightweight slab. It is mainly composed from a construction type (locally known as FERT) with beams and infill hollow blocks which rest on the main reinforced concrete beams. In all cases there was only a 3cm layer of Styrofoam which is found underneath the screed.

3.4.2 Thermal properties

The reinforced concrete used for such buildings and construction has a high conductivity factor, 1,4 $Wm^{-2}K^{-1}$ at a density of 2500 kg/m^3 with a specific heat of 840 J/kg K (*Szokolay 2004*). Being exposed, such areas have a high potential of heat loss, which create thermal bridges. These potential spots can be found at the corners of the house but also on column in the middle of the length of the exterior wall.

The clay masonry block, locally categorized as "thermal block-TB5", has a conductivity of 0,81 $Wm^{-2}K^{-1}$(*Schäffler et al. 2005)*. The value has to be based on German (DIN) standards for thermal properties because no laboratory tests for this specific type of blocks have been performed in Kosovo. The lambda value is calculated for the clay consistency including the holes of the block. The blocks are covered in the interior part by a fine rendering with a value of 0,70 $Wm^{-2}K^{-1}$.

Based on the calculations, the conduction of the wall has a rate of U=2,30 $Wm^{-2}K^{-1}$. This value is more than five times higher than the one prescribed by Regulations of the European Union, which is 0,45 $Wm^{-2}K^{-1}$. To achieve a similar thermal property just with hollow blocks

as with insulation, 5 rows of blocks should be used to drop to U=0,50 $Wm^{-2}K^{-1}$. To achieve a U-value as according to the EU Norms which is 0,45 $Wm^{-2}K^{-1}$, the thickness of the wall should be almost 1meter.

The interior walls consist from the same blocks with lime mortar layer on both sides. The thermal conductivity of the wall is U=1,81 $Wm^{-2}K^{-1}$. These walls, including the exterior ones do not have any structural carrying capacity but they are used only as separation walls between the rooms and spaces.

In the basement, the same blocks were used as for the interior and exterior enclosure. In some cases no water insulation for protection of the walls from ground waters was observed. Therefore, mold and flooding of the basement was present.

Windows and doors are mainly made of plastic frames and the wooden ones were very rarely observed. The U-value of the window is 1,8 $Wm^{-2}K^{-1}$ which is similar to the norms of the European Union regulations of window heat flow (*Wilberforce 2005*).

For slabs, the type of insulation used is not for any thermal properties, but for reduction of acoustical properties. Concerning the internal upward flow direction, the U-value of such a slab is 0,70 $Wm^{-2}K^{-1}$.

As mentioned before, the roof has no insulation properties which results in high U-values such as in this case 1,9 $Wm^{-2}K^{-1}$. The lack of insulation in the buffer zone allows massive cooling in winter seasons and overheating in hot periods which has a direct impact on the thermal behavior in the spaces below the roofs attic space.

4 Simulation of houses

4.1 Simulation of existing housing

For simulations of thermal performance, a limited number of single detached houses were selected. The three types of selected houses vary mainly in the number of the stories, the first with one storey, the second with two stories and the third with two stories and a basement. Most of them have been built after 1999 from the same materials which result in a similar U-value in: interior and exterior walls, slabs and roof construction.

For reason of air leakage points through unsealed openings, such as doors or windows, an infiltration rate of 0,2 ach was adopted. Natural ventilation provided by the occupants has also been taken into account with a value of 0,2 ach. In total, the air exchange rate for the houses is 0,4 ach and this means that 40% of the total air quantity is exchanged on an hourly basis. Internal conditions are an important factor for thermal calculations which result in building behavior. Such parameters create heat gain depending on the type of heat source which can reduce the demand for energy input to heat a space. Internal heat sources include human sensible and latent gain, light and equipment heat gain. On the basis of the survey, these internal conditions have been adopted for the simulation. For interior lighting, incandescent bulbs of different power are used, and their heat gain has to be calculated for each house separately, depending on the Net floor area. Regarding the occupancy gain, a value of 90 W of sensible and 15 W of latent heat per person has been adopted. The values represent a person at rest.

The first simulation from each of the three houses is performed with schedules based on the questionnaires representing real time heating in them. The rooms are heated in occupancy time only, leaving them unheated during the remaining hours. The following heating time schedules have been reported:

Table 3: Time schedules for heating

Living room	7:00 – 23:00	
Bedrooms	7:00 – 9:00	18:00 – 23:00
Bathroom and toilet	7:00 – 9:00	18:00 – 23:00

Based on the local tradition, the living room is the only one to be occupied whole day long and it is heated up to approximately 22 °C. The bedrooms are generally used only for sleeping and they are heated for a short period of time up to around 20 °C or even 22 °C where at night there is no heating present. There are cases where bedrooms aren't used at all. The bathroom is also a space of the house to be heated up to 21 °C for a short period during daytime, i.e. while used. On the other hand, the corridor is the only space which always remains unheated.

The first case simulation cannot predict the actual energy demand for heating of the related spaces. For reasons of a discontinuous daytime heating, the assumption of the total load will not represent a true value. The simulation results cannot be considered fully valid because there is a lack of thermal comfort during the non-heating period. For this reason, the room temperature in winter mornings drops to approximately 12 °C which, compared to normal living conditions represents a thermal discomfort. And yet, as we deal with a so called "energy efficiency by freezing" the houses are not qualified for a low energy house.

A second simulation showed as necessary to obtain an actual energy demand of the entire house by providing both day and night heating. It will be referred to as regular heating. Depending on the occupancy the room temperatures were set as follows:

- 20 °C – Occupied room at daytime
- 18 °C – Occupied room at nighttime
- 16 °C – Non occupied room

Such room parameters were set to ensure a thermal comfort independently of the state, period or frequency of their occupancy. The entire space of the three houses will be subject to the mentioned strategies in order to obtain comparable values.

The following cases (3 and 4) are the simulations with improved insulation material properties which are described in the improvement section of this paper.

4.2 Simulation of House 1

This is a one storey house. It comprises of the following spaces:

- Corridor – 15.67m^2
- Living room (including a kitchen and a dining room) – 31.3m^2
- Bathroom – 7.23m^2
- Bedroom 1 (North) – 15.6m^2
- Bedroom 2 (South) – 16.41m^2

The house consists of a total net area of 86.21m^2 and a gross area of 97,49m^2. Its geometry is a simple 10x10m house, covered with a pitched roof of 25 degrees, creating an attic space, neither insulated nor used. As far as the internal gain from inhabitants is concerned, the

simulation is performed with three occupants representing the number of family members. The house is located in a rural area with low rise buildings and has no shadows directed from the neighboring structures. The arrangement of rooms in this house is shown in the following figure:

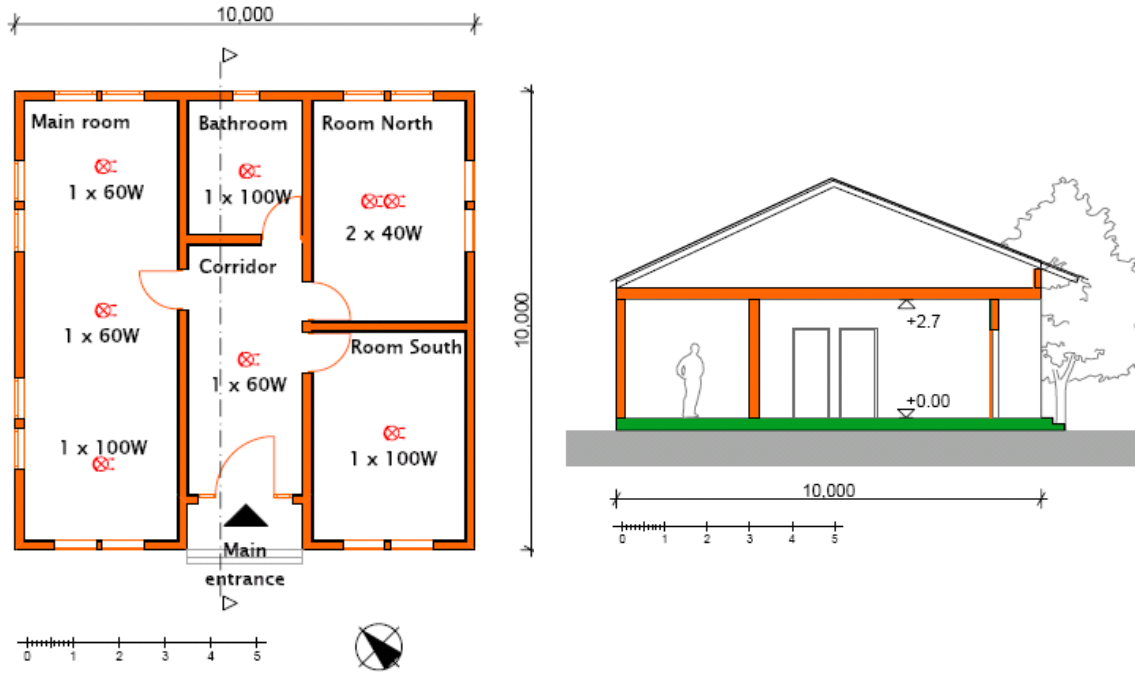


Figure 4: Floor plan and section

Various types of internal heat gains are generated in the house and they are different in each space. The simulation for this house is performed with the values shown below:

Table 4: Heat gain distribution for house 1

Type	Light load (W/m²)	Occupancy load (W/m²)		Equipment load (W/m²)
		Sensible	Latent	
Living room	7,03	8,62	1,43	11,18
Bedroom North	4,83	5,43	0,9	6,04
Bedroom South	6,09	10,96	1,82	-
Bathroom	13,83	12,44	2,07	-
Corridor	3,83	-	-	-

4.3 Simulation of House 2

A two storey house comprising the following spaces:

- Corridor – 33,99m^2
- Living room (including kitchen and dining room) – 41,65m^2
- Toilet – 7.87m^2
- Bedroom 1 (North-East) – 15.6m^2
- Bedroom 2 (North-West) – 21,51m^2
- Bedroom 3 (South-West) – 20,10m^2
- Bathroom – 9,21m^2

The total Net area of the house is 149,93m^2; on the first floor 71,02m^2 and the second 78,82m^2. The gross area is 166,11m^2. The house measures 10x8,5m on the first floor, 11,1x8,5m on the second floor and it is covered with a pitched roof of 25 degrees. In this case it also creates an attic space which is neither insulated nor used. It is inhabited be four family members. The house is positioned in a low urban density area of a city suburb. The neighboring houses are too far to cast shadows on the building. The interrelation and the orientation of the rooms are available in the following floor plans:

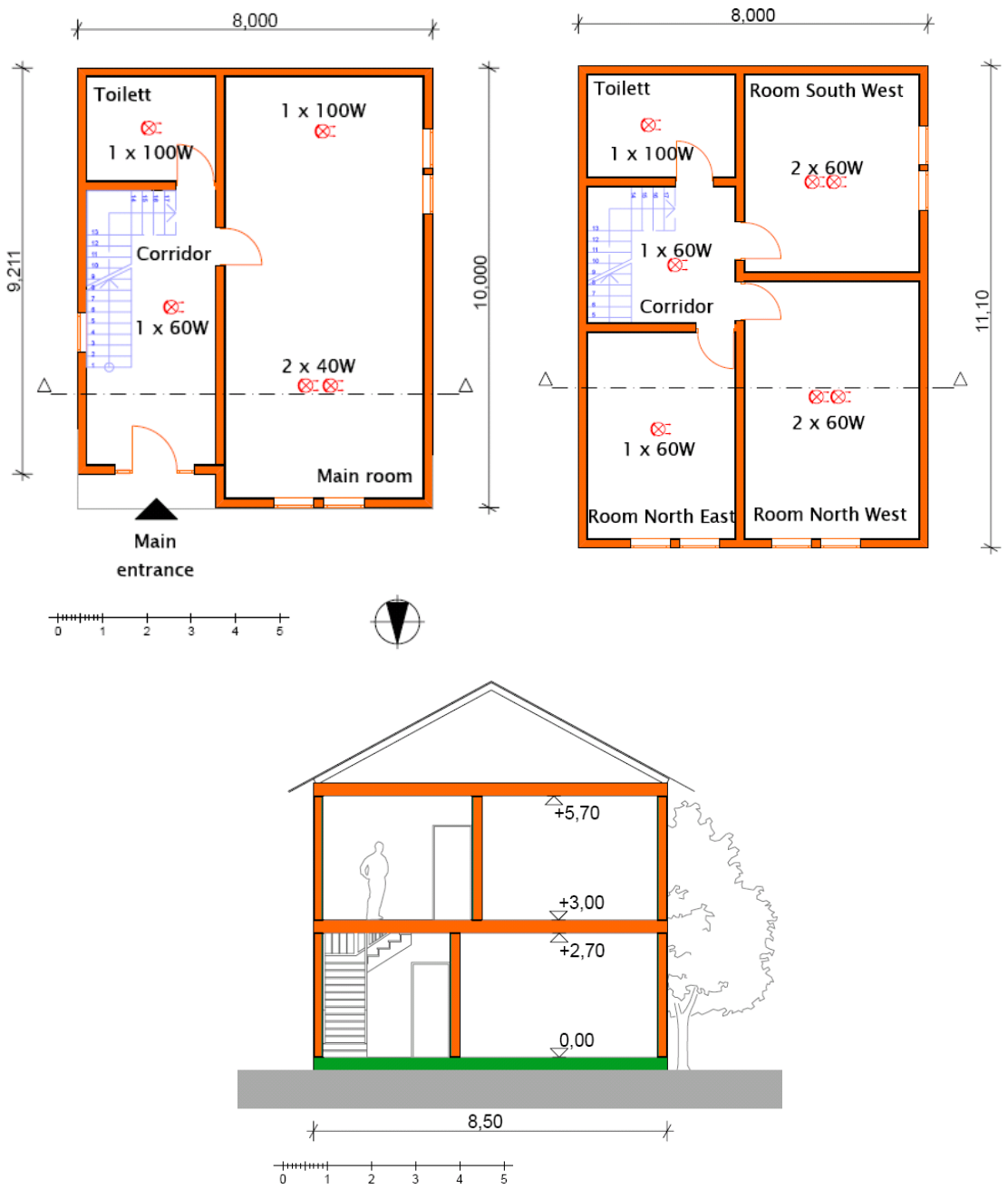


Figure 5: Floor plans and section for House 2

The different heat gains that are present in the house are shown in the following table:

Table 5: Heat gain distribution for house 2

Type	Light load (W/m²)	Occupancy load (W/m²)		Equipment load (W/m²)
		Sensible	Latent	
Living room	4,32	4,32	0,72	8,40
Bedroom 1 (NE)	–	–	–	–
Bedroom 2 (NW)	–	–	–	–
Bedroom 3 (SW)	5,97	8,95	1,49	4,97
Toilet	10,16	–	–	–
Bathroom	10,85	9,76	1,62	–
Corridor	3,53	–	–	–

4.4 Simulation of House 3

It is a three storey house that comprises the following spaces:

- Corridor – 45,67m²
- Living room (including kitchen and dining room) – 44,03m²
- Toilet – 4,86m²
- Room 1 (ground floor) – 15,45m²
- Bedroom 1 (North) – 21,49m²
- Bedroom 2 (East) – 27,29m²
- Bedroom 3 (South) – 12,42m²
- Bathroom – 4,86m²
- Basement – 64,78m²

The total Net area of the house is 240,1m². The gross area is 270,41m² where on the ground floor 88,74m², first floor 92,93m² and the basement 88,74m². The house measures 10,2x8,7m on the ground floor and the basement whereas on the second floor 10,7x8,7m. It is covered with a pitched roof of 30 degrees. Three family members live only in the ground floor. The interrelation and the orientation of the rooms are shown on the floor plans:

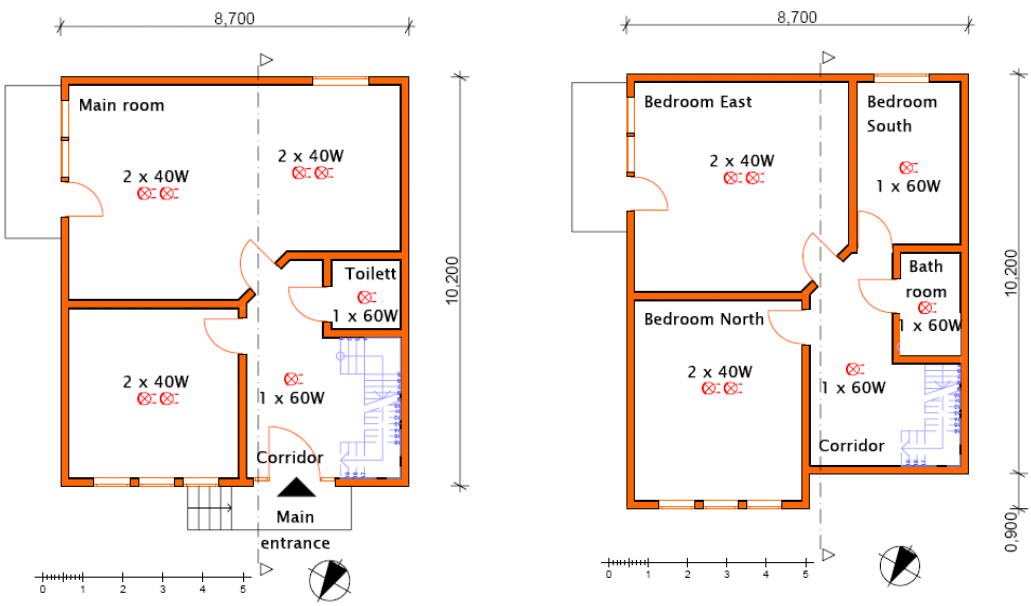


Figure 6: Floor plans of basement and ground floor for House 3

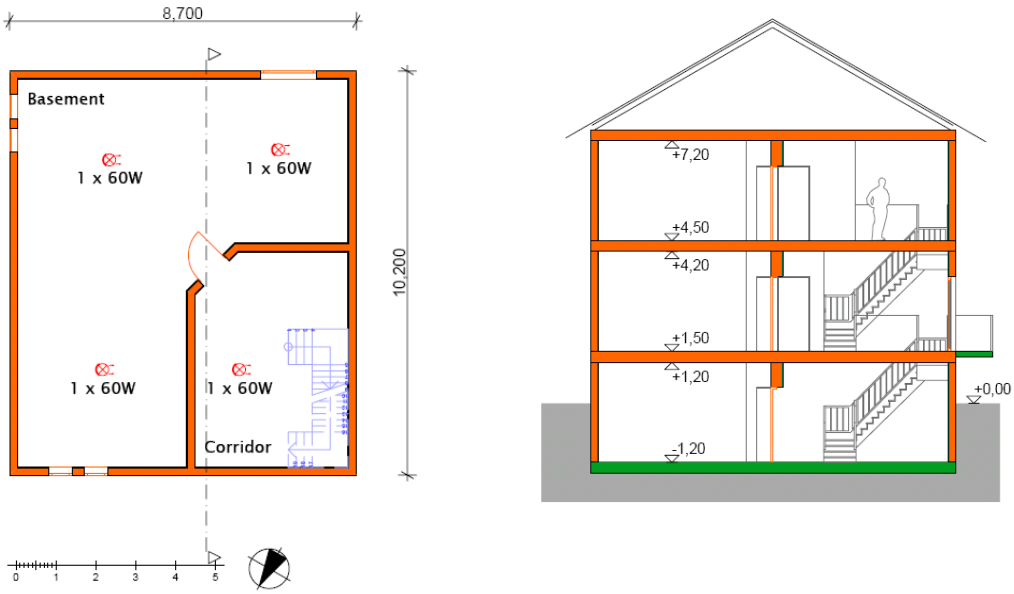


Figure 7: Floor plan of first floor and section for House 3

Heat gains that are present in the house are presented in table 6:

Table 6: Heat gain distribution for house 3

Type	Light load (W/m²)	Occupancy load (W/m²)		Equipment load (W/m²)
		Sensible	Latent	
Living room	4,32	4,32	0,72	8,40
Bedroom 1	5,17	5,82	0,97	-
Bedroom 2 (N)	-	-	-	-
Bedroom 3 (E)	-	-	-	-
Bedroom 4 (S)	-	-	-	-
Toilet	12,34	18,51	3,04	-
Bathroom	-	-	-	-
Corridor	3,53	-	-	-

It is noticeable that only one storey is heated during daytime. This means that from the total net area, only 20% of the house has day heating, 9,5% with partial heating and the rest of 70% is not heated at all.

4.5 Overheating period

Because the houses have no thermal envelope, a risk appears in the hot summer time when they may gain too much heat from solar radiation and as a consequence, an overheating of the house and specifically its south oriented spaces might take place. In the region of Kosovo the outdoor Dry Bulb Temperature might reach 37 °C. MeteoNorm generated a maximum temperature of 33 °C.

Overheating is assumed when the temperature in the room rises over 27 °C. In order to calculate the overheating, the difference between indoor air temperature and the reference temperature of 27 °C is summed up for each room. The formula is as follows:

$$OH_{Rj} = \sum_{i=1}^{n} (\Theta_{Rj} - \Theta_{ref}) \qquad [\ Kh\ ]$$

OH_{Rj} – Overheating of Room j

Θ_{Rj} – Indoor hourly temperature of Room j

Θ_{Ref} – Reference temperature of 27 °C

In order to generate the overheating of the whole house the following formula is used:

$$OH_{tot} = \frac{\sum_{j=1}^{m} OH_{Rj}}{m} \qquad [\ Kh\ ]$$

OH_{tot} – Overheating of house

OH_{Rj} – Overheating of Room j

m – Number of rooms in the house

The simulation is performed on two cases: a non-insulated and a thermally improved house. With the results obtained, it is possible to compare the rate of overheating on a non-insulated house and the effect of thermal insulation. The infiltration and the ventilation values are set to 2ach for the non insulated house whereas the insulated one has a rate of 1ach.

5 Improvement

5.1 Selection of insulating material

At the moment Kosovo is mostly importing insulation materials from abroad such as Serbia, Macedonia, Austria, Slovenia etc. However, there are a number of companies that started production locally in small scale. There are also branches of companies from other countries. The prices of the insulating material do not vary much throughout Kosovo. The major insulating materials used and produced are Styrofoam and Glass Wool. The region offers mainly insulation materials of small thickness such as 5cm or 8cm. Thick insulation materials are difficult to find since there is no demand from the local population. For this reason the retailers do not import such types of insulation. The prices for a square meter depending on the type of insulation are shown below:

Table 7: Prices for Styrofoam type N3

5cm	2,48 €
8cm	4,05 €
10cm	4,65 €

Table 8: Prices for Styrofoam type N4

5cm	3,12 €
8cm	5,10 €

Table 9: Prices for Glass wool

High quality	8 €
Low quality	3 €

In order to complete the façade, except the thermal insulation, the finishing material has to be applied. This will protect the thermal insulation and give an esthetical finishing look to the house. The price range for these elements is shown below:

Table 10: Price for façade finishing

Net (m^2)	0,32 €
Glue (25kg)	4,45 €
Façade (25kg)	8,0 €

Adding all the elements to complete a normal facade, the price for square meter would sum up to approximately 7 €/m^2. This represents the price only for the material as mentioned above. The simulations with improved properties are performed with Styrofoam N3 insulation and thickness 8cm. The price for work and additional elements such as scaffolding circles around 15-20 €/m^2 and it depends on the company that does the insulation.

With an insulated façade with the above mentioned materials, the house is simulated to compute the energy demand which is referred as case 3 of the research. The houses are heated in regular basis during night and day with schedules referring to case 2. The last case 4 is a simulation based on partial daytime heating as in case 1 but with improved thermal envelope. The results in case 4 make it possible to calculate the savings if the house is not going to be fully occupied. This case is possible if in the near future the house will remain occupied as nowadays.

5.2 Properties of the insulating material

The improvements of the house consist mainly on insulating the exterior walls and roof. The task is to generate the U-value of the wall around 0,50 $Wm^{-2}K^{-1}$. In order to do so, the type of Styrofoam N3 with thickness 8cm is chosen to encapsulate the houses. This type of Styrofoam is used in all the cases of the simulation. The 8cm Styrofoam is glued to the wall by means of a special glue.

The insulation material has a conductivity factor of λ = 0,04 $Wm^{-2}K^{-1}$. It is a value declared on laboratory tests from the producer. Due to transportation and operational conditions, the material might undergo inevitable damages and as a consequence a reduction of the insulation properties is caused. In order to obtain more accurate values, the λ should have a correction factor which depends on the method the insulating material is applied. In our case the insulating material on the outer part is applied with cement render which has a correction factor κ=0,25 (*Szokolay 2004*).

$$\lambda_{design} = \lambda_{declared} \times (1 + \kappa_1) = 0{,}04 \times (1 + 0{,}25) = 0{,}05 \qquad [\,Wm^{-2}K^{-1}\,]$$

This explains that upon application on the wall, our insulation material will have a conductivity value of λ =0,05 $Wm^{-2}K^{-1}$ instead of λ =0,040 $Wm^{-2}K^{-1}$. The corrected value is acquired for the improvement of the wall.

The roof is improved with glass wool with a thickness of 20cm. It is placed between the wooden rafters. On both upper and lower sides of the insulation a vapor diffuse foil for protection from condensation is

placed. After applying the correction factor κ=0,10 for glass wool on the roof, the conductivity of the material is λ = 0,44 $Wm^{-2}K^{-1}$.

6 Results

As mentioned above, the simulation is performed on 3 different types of houses: a single storey, a two storey and a three storey house including a basement. The results are shown in house order, starting from the smaller whereas the sub ordering depends on the simulated cases (partial heating, regular heating, improved insulation).

6.1 House 1

6.1.1 Case 1: Partial daytime heating

The total energy demand for heating during the winter season for this case is 7642 $kWha^{-1}$ where per square meter is 85,22 $kWhm^{-2}a^{-1}$. The figure below shows the monthly demand:

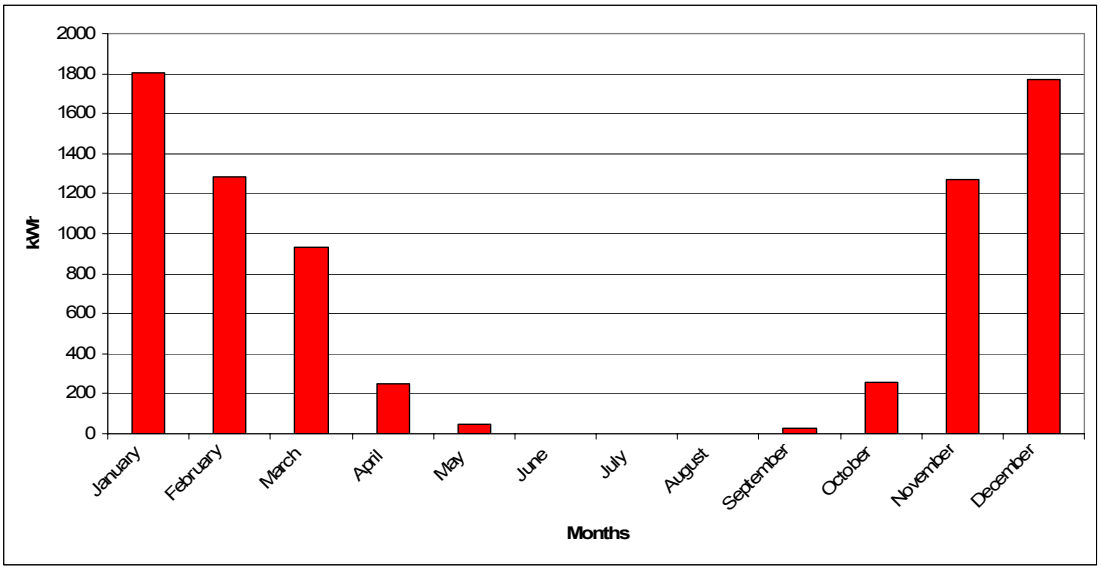


Figure 8: Heating energy demand for house 1 with partial heating

For the analysis the 12 January has been taken as the coldest day of the year for Prishtina/Kosovo. According to the MeteoNorm the outside temperature drops to -15.8 °C in the morning hours of the 12 January.

Each room responds differently to the outside temperature, because they have diverse heating periods. This thermal performance is shown on the two following graphs:

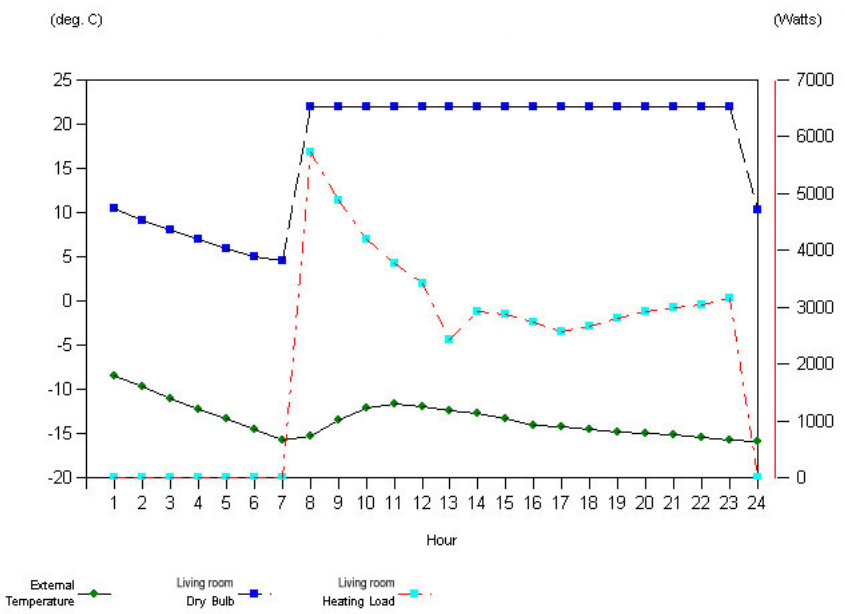


Figure 9: Hourly heating load as well as indoor and outdoor temperature for living room on January 12

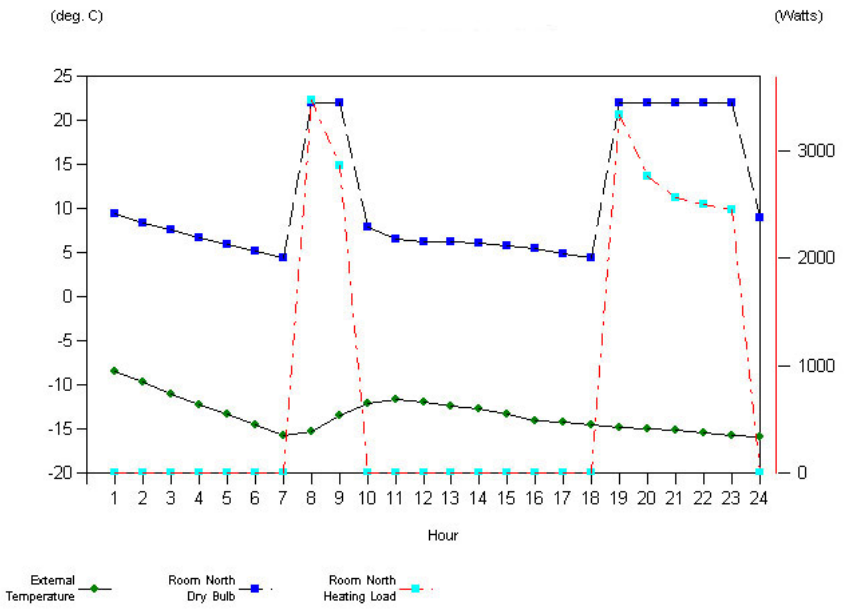


Figure 10: Hourly heating load as well as indoor and outdoor temperature for Bedroom North on January 12

It is evident that due to the "energy efficiency by freezing" the temperature in the morning in the living room drops to 4,6 °C, north bedroom to 4,4 °C, south bedroom to 3,8 °C, bathroom to 7,7 °C and in the corridor to 6,3 °C. The highest peak heat load to heat up the space up to 22 °C reaches 5,7 kW, and it has been recorded in the living room as it is shown in figure 9. As the coldest day of the year is discussed, the room heat gain cannot counterbalance the heat losses through the exterior walls and the ceiling. The graph for this specific day shows that the peak heat load for the entire house for this specific day reaches 14,3 kW. The hourly load is shown in Figure 11:

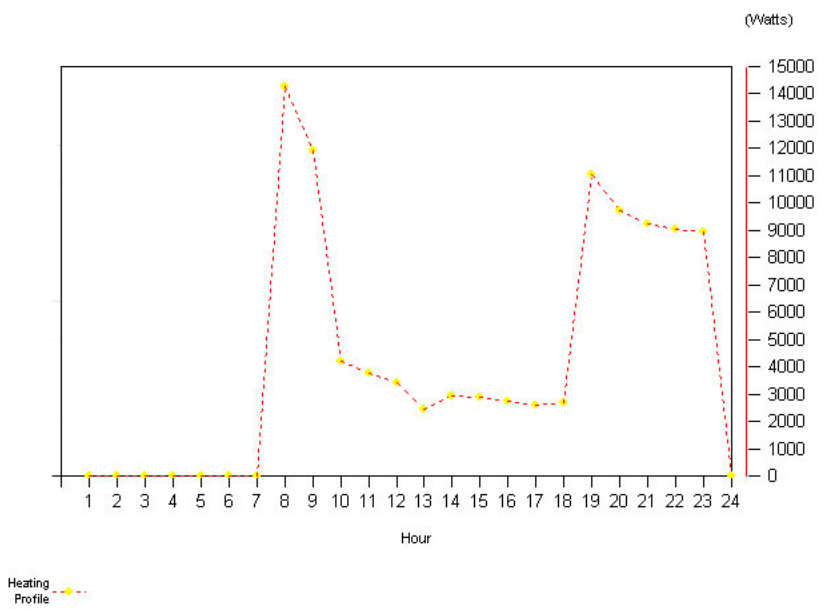


Figure 11: The total heat load for January 12 for the entire house with partial heating

6.1.2 Case 2: Regular heating

The energy demand for heating in this case reached 9954,6 $kWha^{-1}$ and by dividing it by heated floor area of the house a value of 102,1 $kWhm^{-2}a^{-1}$ is obtained. The amount of energy to heat the whole house is

25% higher than the value in case of partial daytime heating. The heat demand is not that high in comparison with case one (partial heating) since the volume of the house is not so large and almost all the spaces in the house are used. The following figure shows the monthly energy demand:

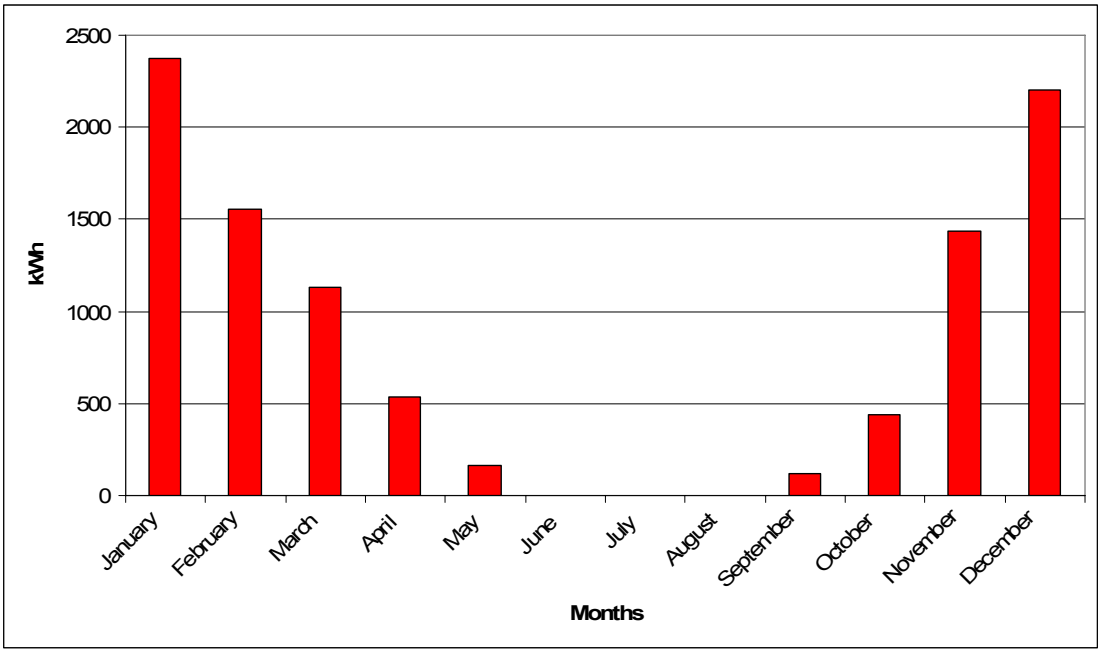


Figure 12: Heating energy demand for house 1 with regular heating

It is expected that the thermal behavior of the house is going to be different if compared to case 1. As all the rooms are heated simultaneously and the temperature does not drop below 16 °C, the demand for energy to increase the temperature by few degrees is not high as in case 1. In the living room the demand for energy drops after the morning peak because it is compensated from the heat gains in the room like occupants, appliances and light. The following figures show the thermal behavior of the rooms and the energy demand in two rooms for this case:

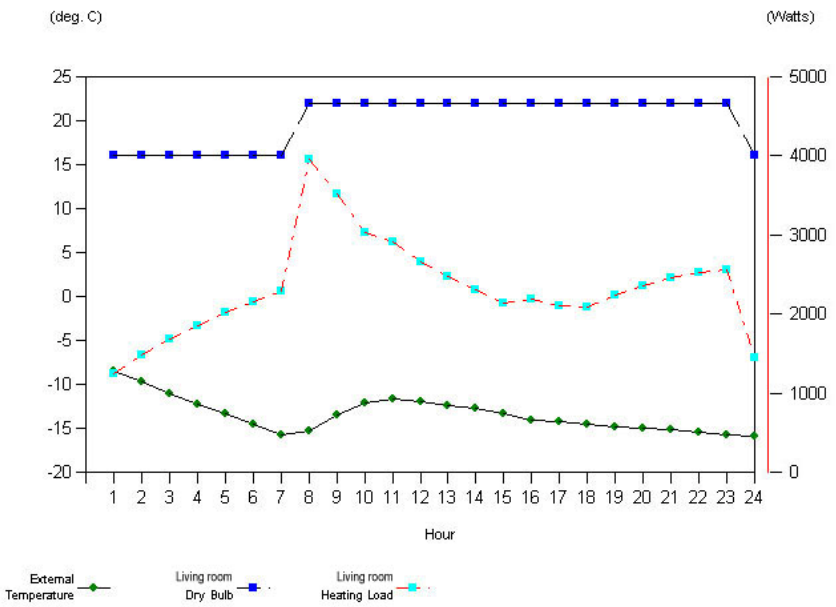


Figure 13: Hourly heating load as well as indoor and outdoor temperature for Living room on January 12

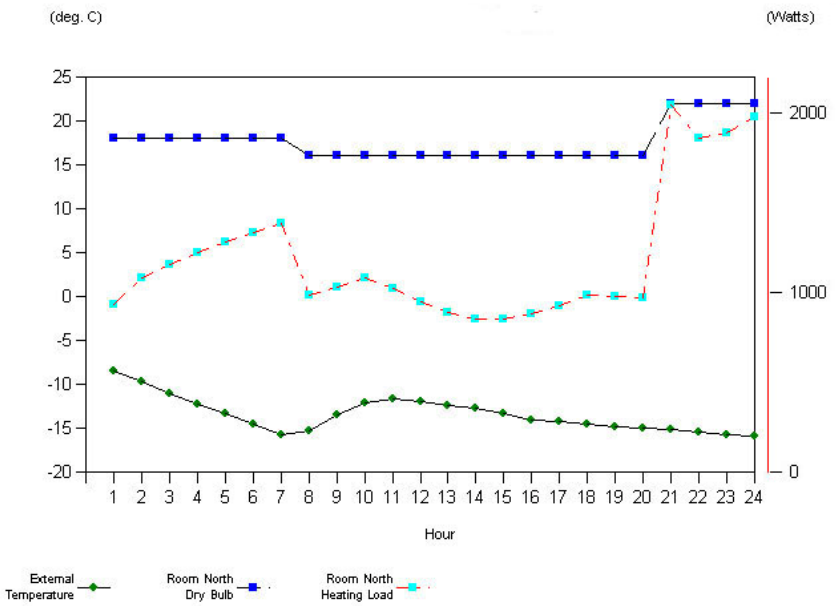


Figure 14: Hourly heating load as well as indoor and outdoor temperature for Bedroom north on January 12

On January 12, two peaks were observed for the entire building: the first reaches a value of 7,3 kW at 7:00 o'clock in the morning and the second one a value of 7,4 kW in the evening, as shown in the following figure:

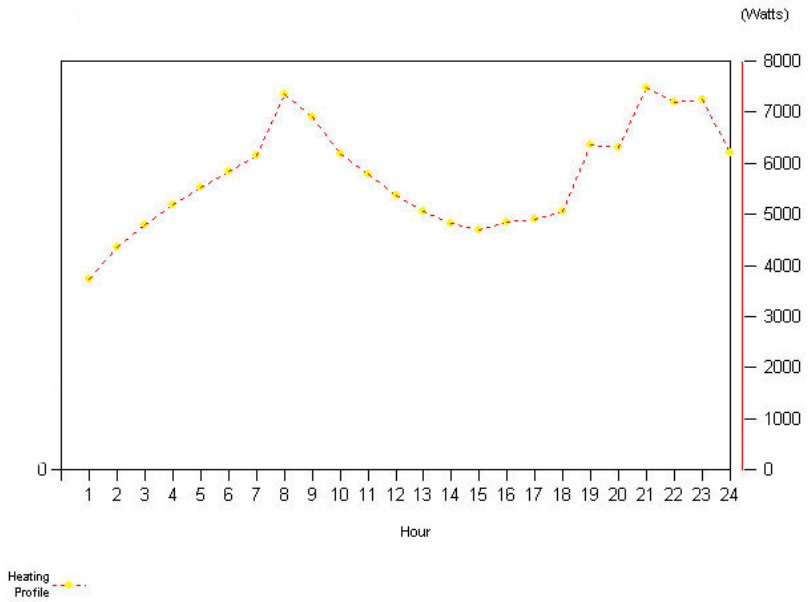


Figure 15: The total heat load of January 12 for the entire house with regular heating.

6.1.3 Case 3: Improved thermal envelope

The improvement resulted in significant change in this house where the annual demand of energy dropped to 5565,2 $kWha^{-1}$ and for heated floor area is 57,09 $kWhm^{-2}a^{-1}$. The monthly energy demand is shown in the following figure:

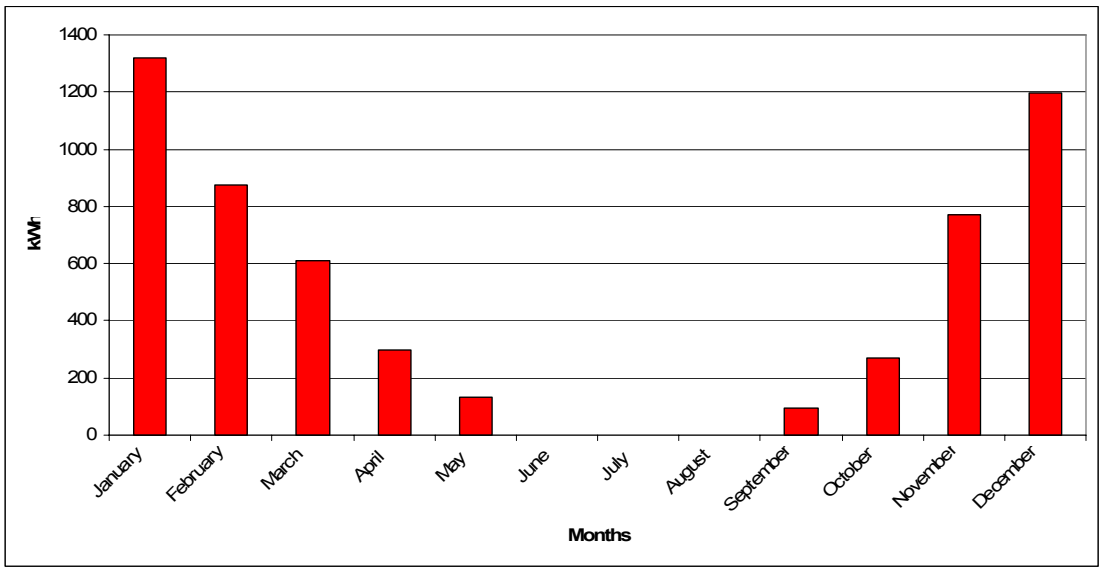


Figure 16: Heating energy demand for house 1 with improved conditions

According to the temperature schedules for full time heating, the energy demand for heating has dropped by almost the half. Based on January 12 as in previous examples, the peak heat load reaches 3,77 kW at the evening hours as shown in Figure 17. The explanation for such a low heat load in the morning hour is the time lag of the walls. The thermal mass radiates the heat stored from the previous day resulting in a more balanced temperature also to the fact that the temperature in the rooms does not drop below 16 °C. The heat load for this case for January 12 is shown in the following figure:

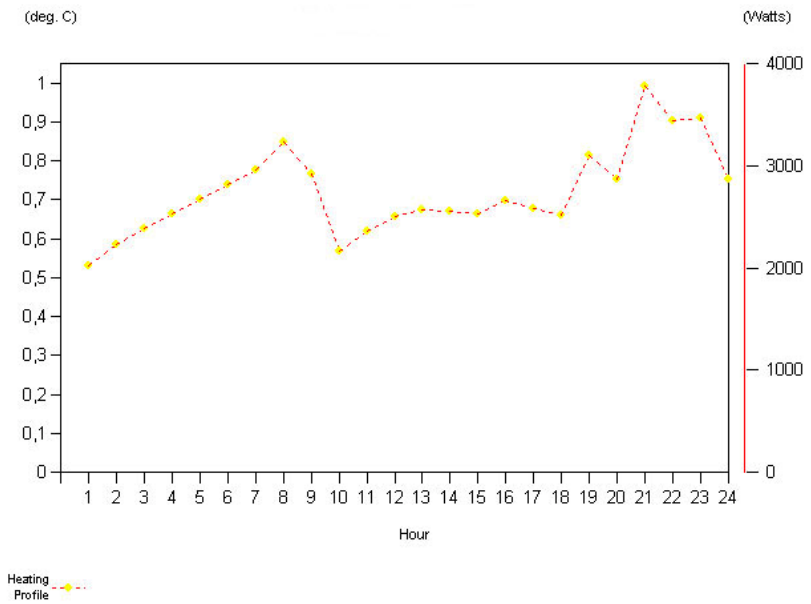


Figure 17: The total heat load of January 12 for the entire house with improved conditions.

6.2 House 2

6.2.1 Case 1: Partial daytime heating

Based on the simulation, the total energy demand is 7543 $kWha^{-1}$ where the value per square meter is 63,39 $kWhm^{-2}a^{-1}$. The explanation for such a low energy demand in a two storey house is that only 52 % of the total net area of the house is occupied, and in this case partially heated. The monthly energy demand for this case is shown as follows:

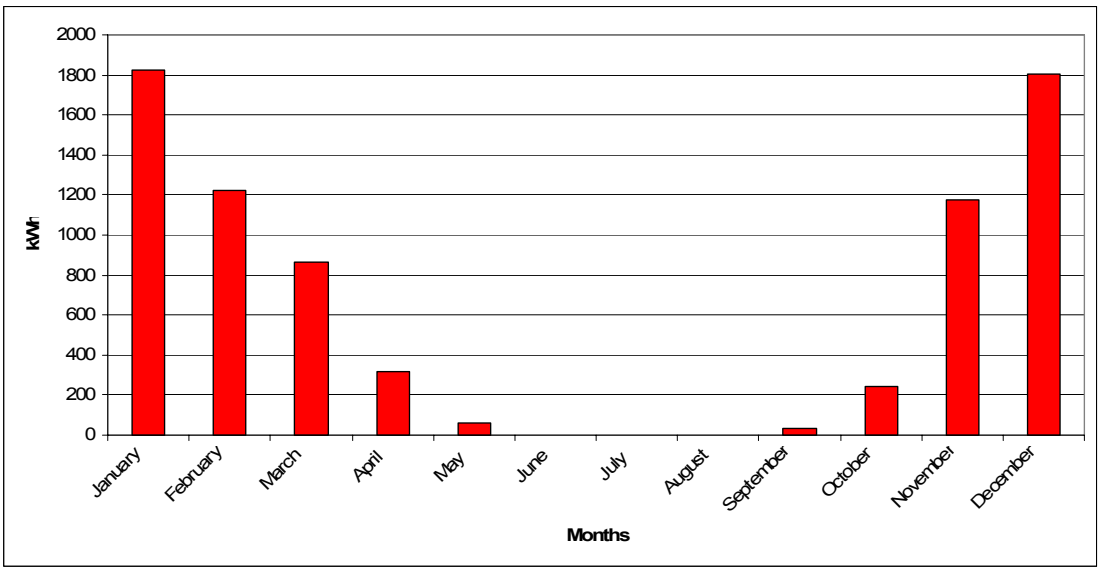


Figure 18: Heating energy demand for house 2 with partial heating

Taken the coldest day on January 12, the peak in the living room reaches 7,3 kW in the morning as shown in the following figure:

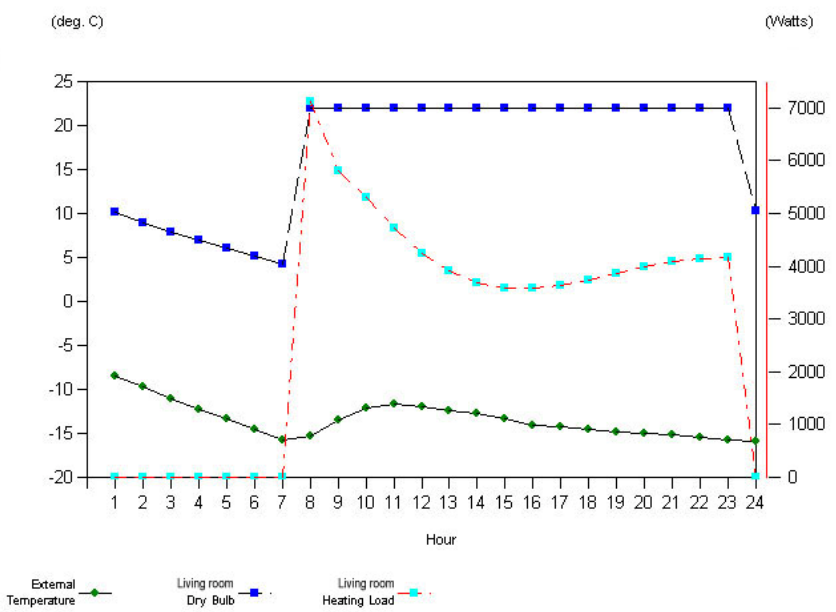


Figure 19: Hourly heating load as well as indoor and outdoor temperature for Living room on January 12

As in the case of house one, the simulated temperature drops below thermal comfort during the morning hours. The indoor temperatures for the coldest day are: living room 3,8 °C, Bedroom 3 (SW) 4,7 °C, Bathroom 4,3 °C, Toilet 4,0 °C. The two other bedrooms and the corridor have different thermal behavior and reach an extreme case of thermal discomfort. The temperature in the morning in these spaces dropped to: Bedroom 2 (NW) 0,2 °C, Bedroom 1 (NE) -2,6 °C and the Corridor 1,7 °C. The thermal behavior of Bedroom 2 (NW) is shown in the figure below:

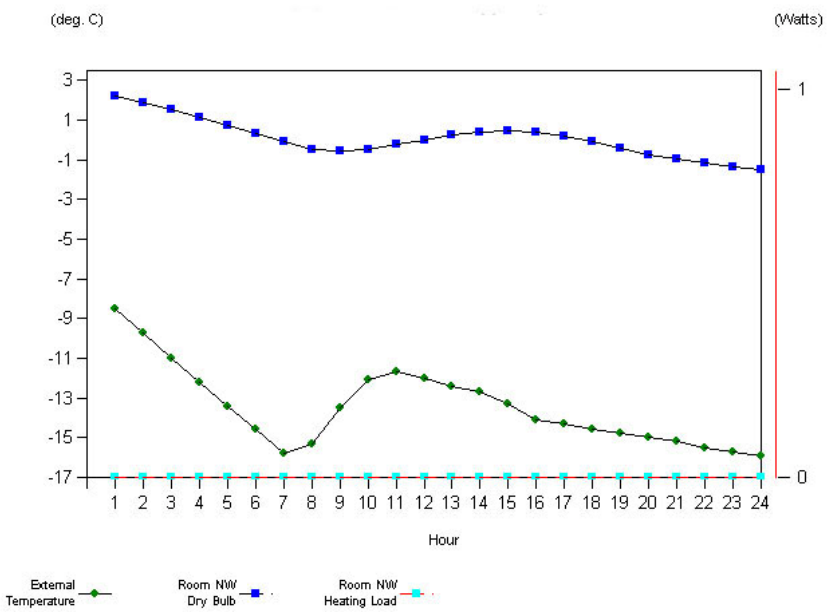


Figure 20: Hourly heating load as well as indoor and outdoor temperature for Bedroom NW on January 12

The total heat load for this day reaches a peak of 15,3 kW as it is observed in the following figure:

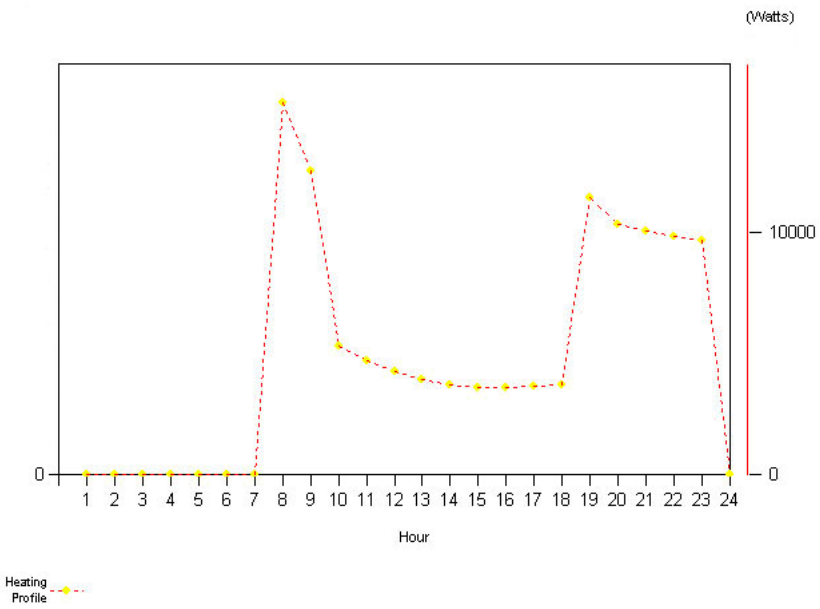


Figure 21: The total heat load for January 12 for the entire house with partial heating

6.2.2 Case 2: Regular heating

According to the temperatures set for full time heating, the demand for energy to heat the house in this case reached 14199 $kWha^{-1}$ and for heated area 97,27 $kWhm^{-2}a^{-1}$. In this case the non occupied rooms have a constant temperature of 16 °C during night and day. These rooms are: bedroom 1 and 2, and corridor. It should be cited that in bedroom 3, toilet and bathroom there is no regular heating where the temperature is 20 °C when occupied, otherwise it is constantly 16 °C. The monthly energy demand for heating is shown in Figure 22:

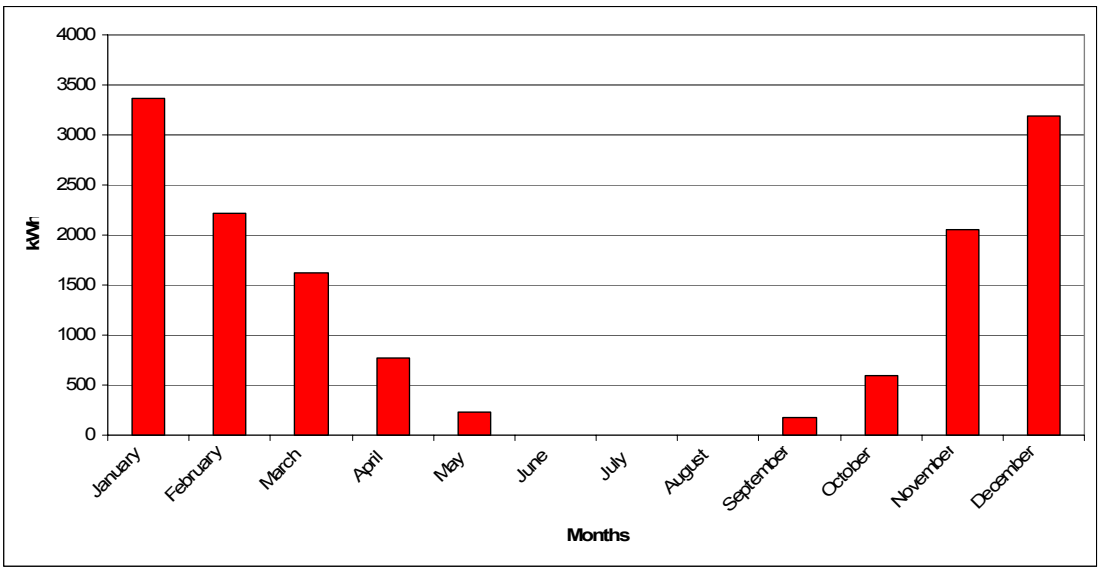


Figure 22: Heating energy demand for house 2 with regular heating

The living room is occupied also during night which means that the temperature does not drop below 18 °C. That is why the peak heat load to increase the temperature in the living room for 2 °C (from 18 °C to 20 °C) is low in comparison with the previous examples.

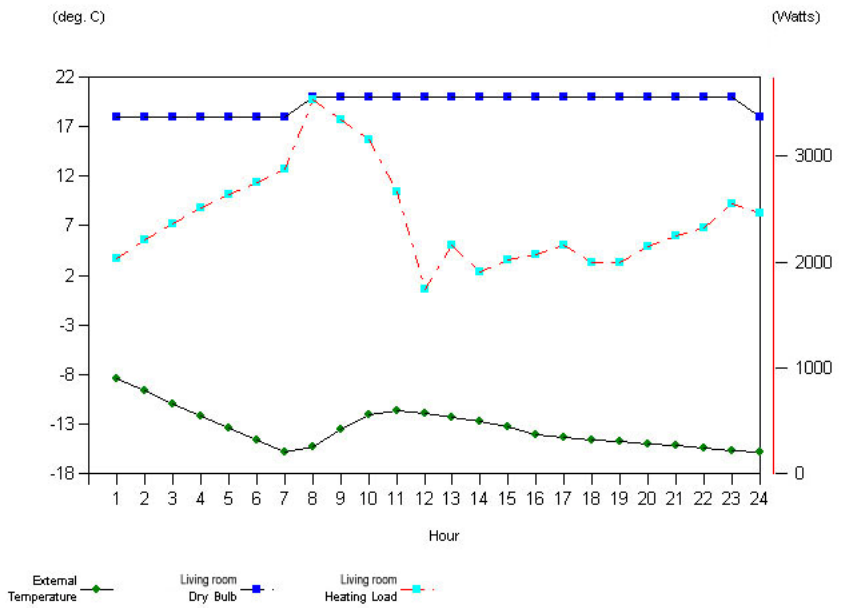


Figure 23: Hourly heating load as well as indoor and outdoor temperature for Living room on January 12

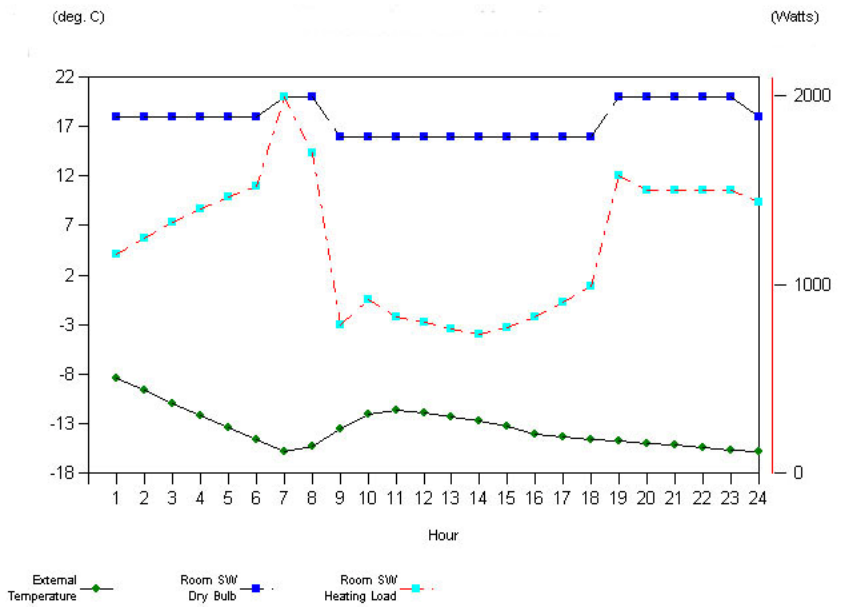


Figure 24: Hourly heating load as well as indoor and outdoor temperature for Bedroom SW on January 12

In house 2, the peak heat load for January 12 appears only in the morning hours reaching 12,0 kW as compared to House 1 where there were two peak loads (morning and evening). The heat load for this date is shown below:

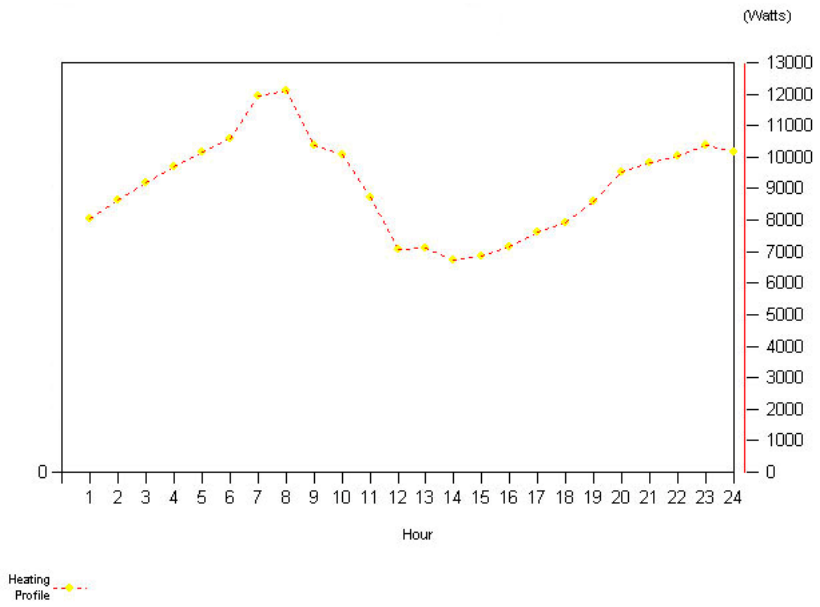


Figure 25: The total heat load for January 12 for the entire house with regular heating

6.2.3 Case 3: Improved thermal envelope

For this type of house the energy demand for heating is 8919 $kWha^{-1}$ and for the whole heated area is 53,69 $kWhm^{-2}a^{-1}$. Such value is close to the energy demand of house 1. With the improved conditions the demand for energy to heat the spaces in house 2 has dropped less than by the half. The monthly energy demand is shown in the following figure:

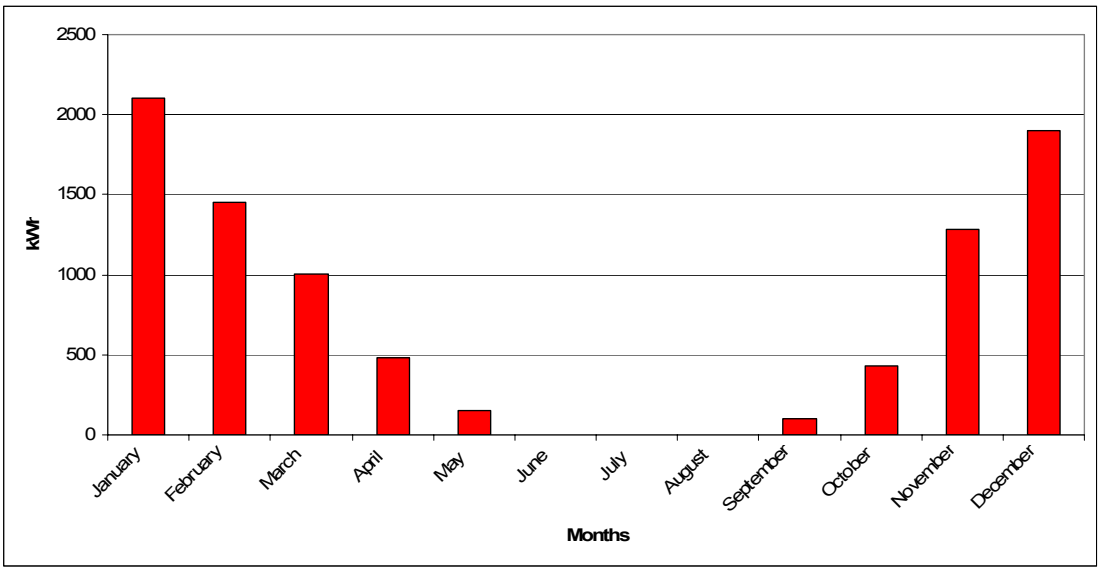


Figure 26: Heating energy demand for house 2 with improved conditions

The heating load for this case achieved by thermal improvement is shown on the following figure:

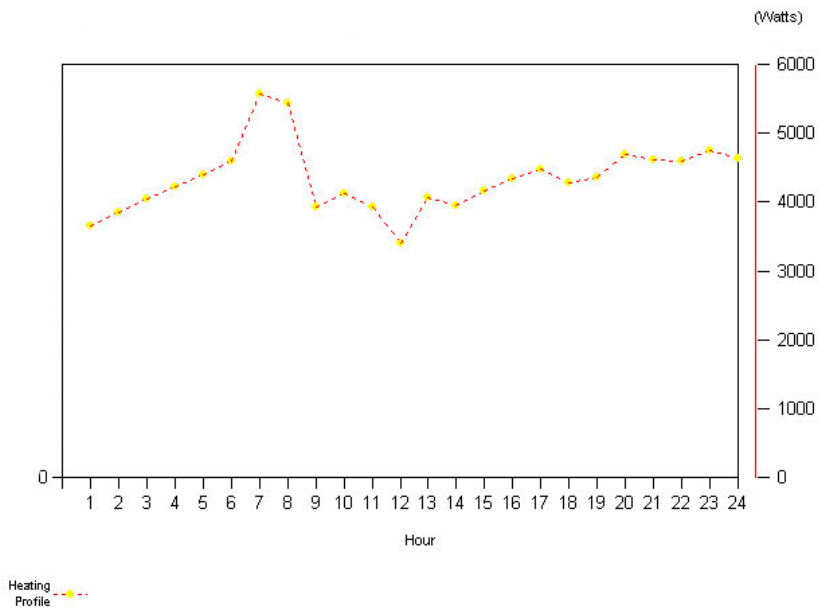


Figure 27: The total heat load for January 12 for the entire house with improved conditions

6.3 House 3

6.3.1 Case 1: Partial daytime heating

The demand for energy to heat the mentioned rooms is 5106 $kWha^{-1}$ and per square meter is 57,53 $kWhm^{-2}a^{-1}$. In comparison with House 2 the value is small even though House 3 has a basement. The reason for a lower energy demand is the fact that only two rooms on the ground floor are occupied and are partially heated during the day. The energy demand is shown below:

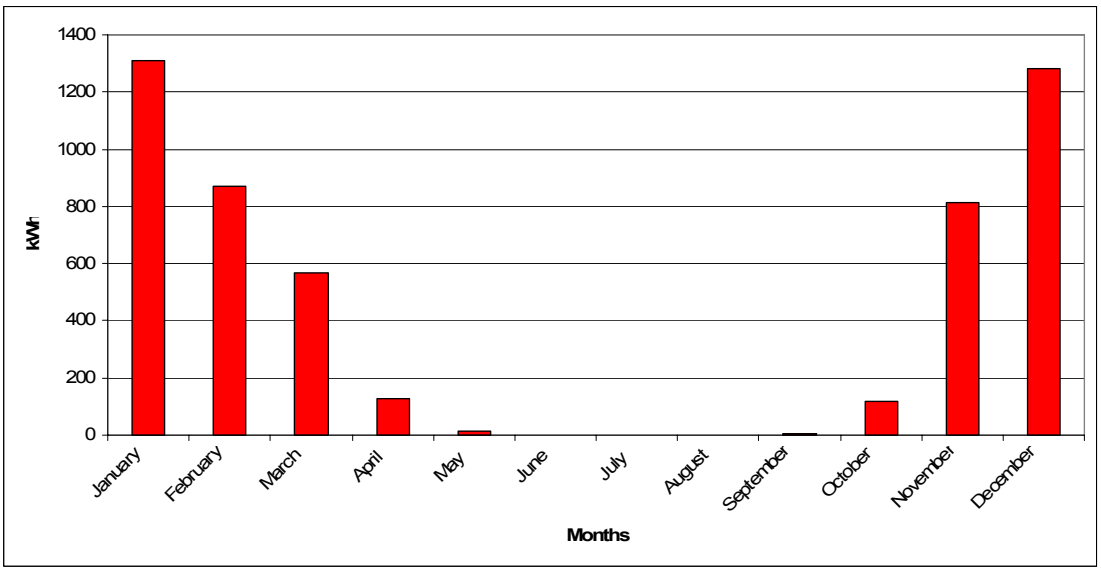


Figure 28: Heating energy demand for house 3 with partial heating

The thermal behavior and the heating load the living room are shown in the following figure:

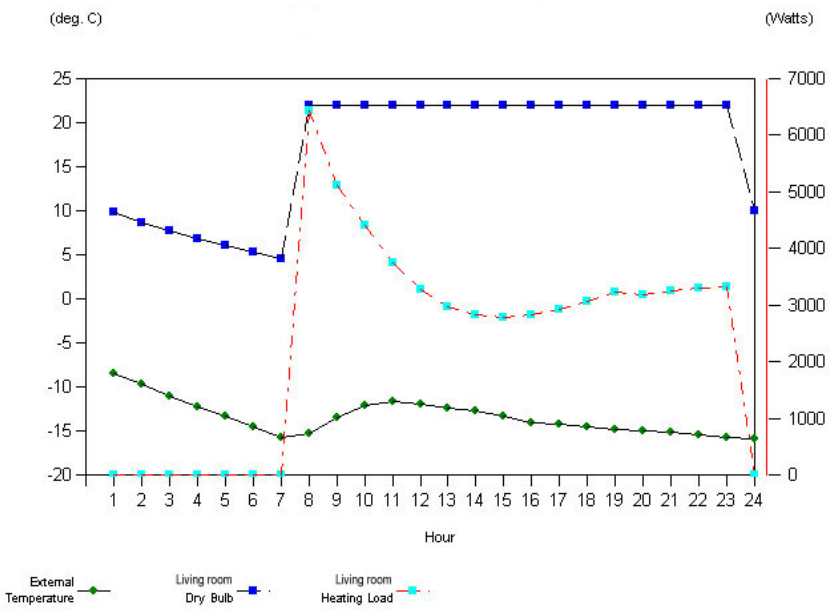


Figure 29: Hourly heating load as well as indoor and outdoor temperature for Living room on January 12

The fact that the rooms on the first floor are not heated at all during winter time, their thermal behavior depends on heat gain through the

ceiling of the ground floor, via upward heat flow. The temperatures recorded in the rooms on the first floor during the coldest day are: Bedroom 1 (N) −2,3 °C, Bedroom 2 (E) −0,2 °C, Bedroom 3 (S) −0,2 °C. All these values are at freezing point or below and do not represent any thermal comfort. This is not only a problem of thermal discomfort but also freezing of material surfaces resulting in damages. Another risk is the growth of mold in critical areas where most of these cases are found where the thermal bridges are present. Surprisingly the basement on January 12 for 24h keeps a temperature of 8 °C. This happens due to the small surface that is exposed to the outside environment. The heating load for the occupied spaces is shown below:

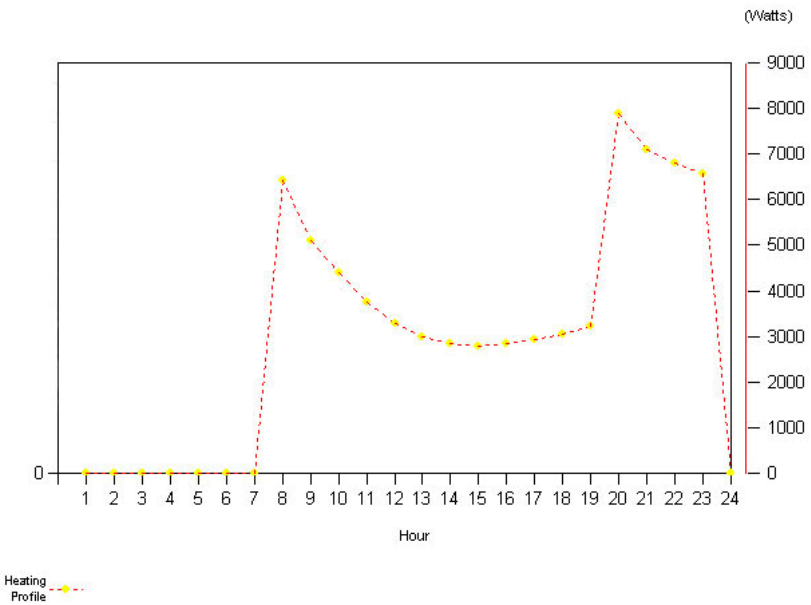


Figure 30: The total heat load for January 12 for the entire house with partial heating

6.3.2 Case 2: Regular heating

To heat the whole house according to the set point temperatures for regular heating, the annual demand for energy is 16748 $kWha^{-1}$ whereas

for square meter is 100,83 $kWhm^{-2}a^{-1}$. The value of regular daytime heating is 43% higher in comparison with partial heating. The monthly energy demand is shown in figure 31:

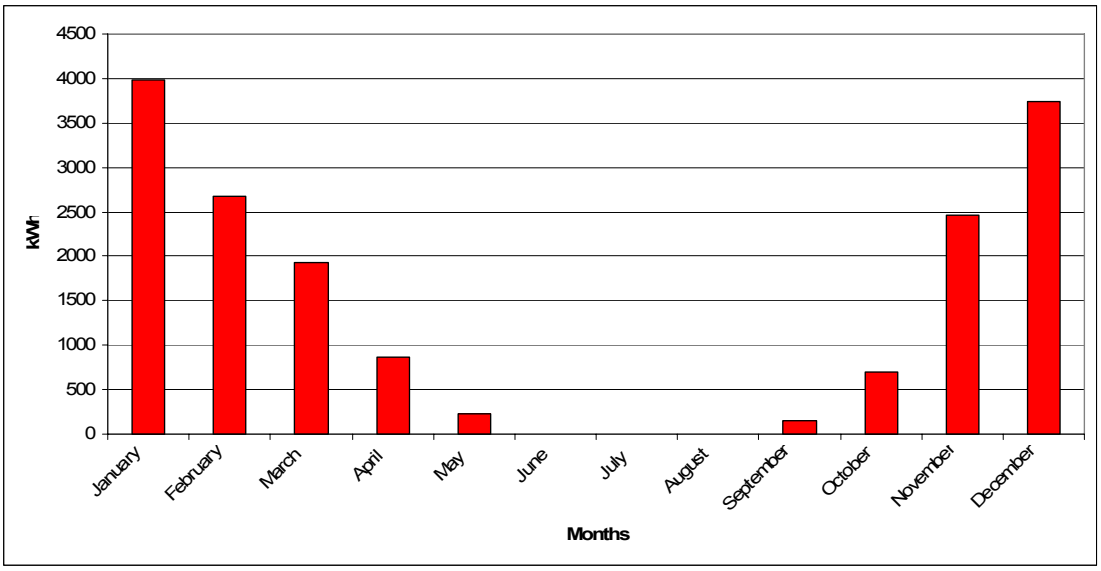


Figure 31: Heating energy demand for house 3 with regular heating

The reason for a high energy demand is partially caused by the thermal behavior in the first floor. In regular daytime heating schedule, the upper floor has a constant temperature of 16 °C due to no occupancy. All the heat produced in the upper floor is lost in all directions while there is a great demand of energy to hold that temperature of 16 °C. The energy demand in the living room on the ground floor is different compared to case 1 (partial heating) and all of this due to the heating of the first floor. The temperature difference between ground and first floor is smaller than in case 1 which reduces the rate of upward heat flow. The thermal behavior and the heating load are shown in figure 32:

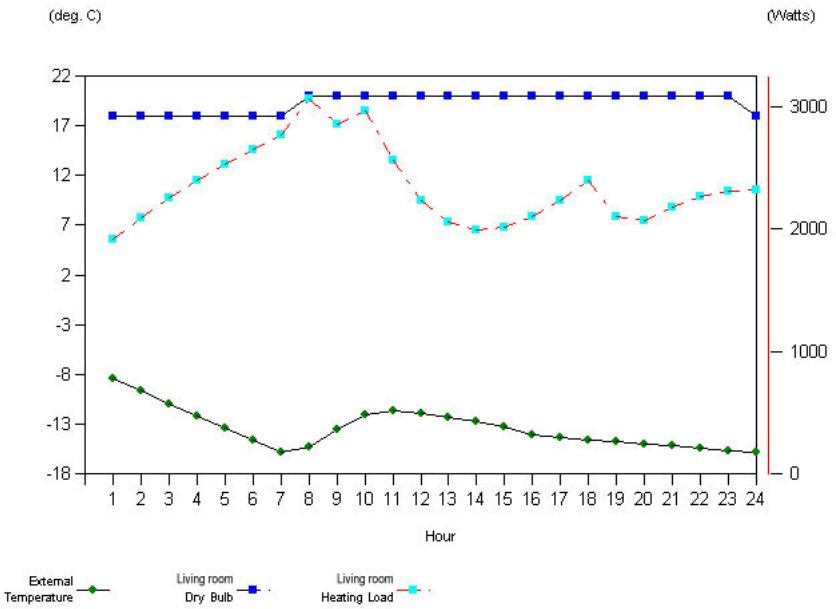


Figure 32: Hourly heating load as well as indoor and outdoor temperature for Living room on January 12

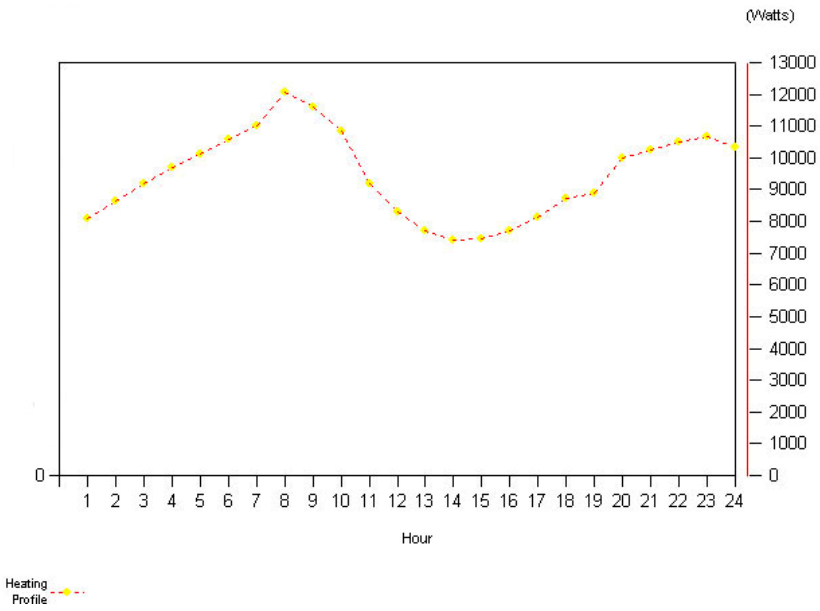


Figure 33: The total heat load for the entire house on January 12 with regular heating

6.3.3 Case 3: Improved thermal envelope

The energy demand after improving the thermal envelope of the house is 10680 $kWha^{-1}$ and for the heated floor area is 58,8 $kWhm^{-2}a^{-1}$. The monthly energy demand is shown on the figure below:

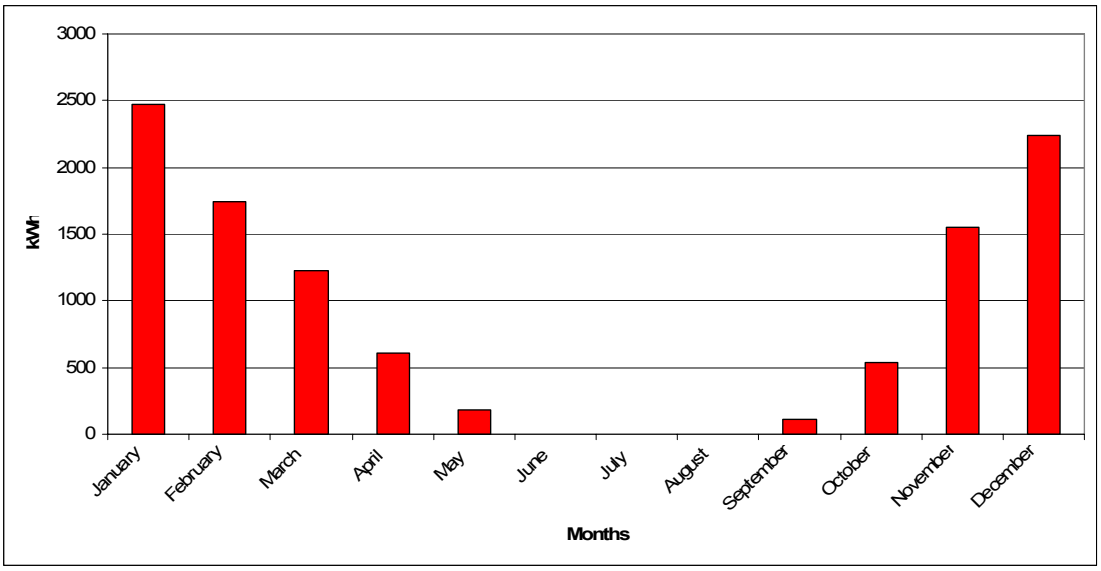


Figure 34: Heating energy demand for house 3 with improved conditions

The computed results of the energy demand per square meter of the house with an improved envelope are slightly higher than the result of the house with partial heating. The heat load for the living room on January 12 is shown below:

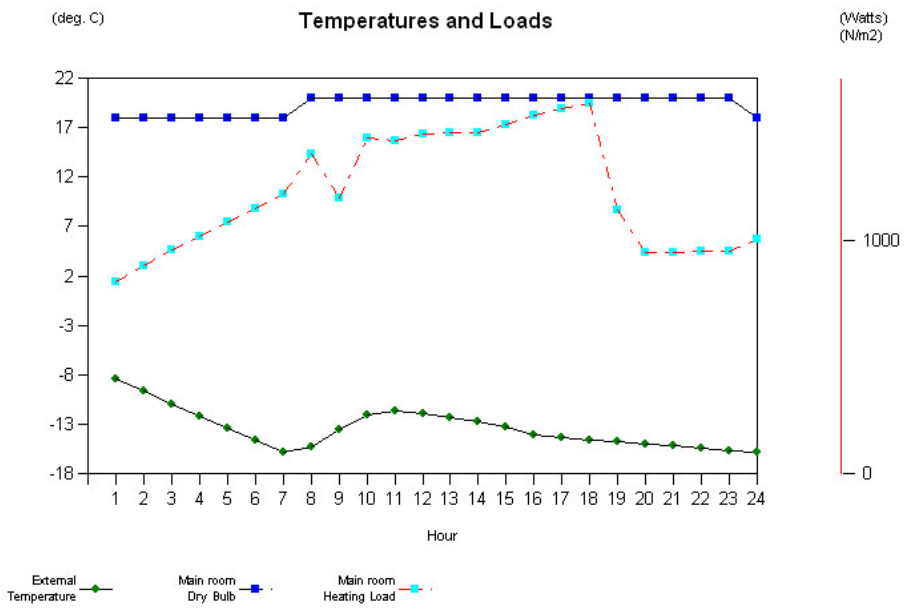


Figure 35: Hourly heating load as well as indoor and outdoor temperature for Living room on January 12

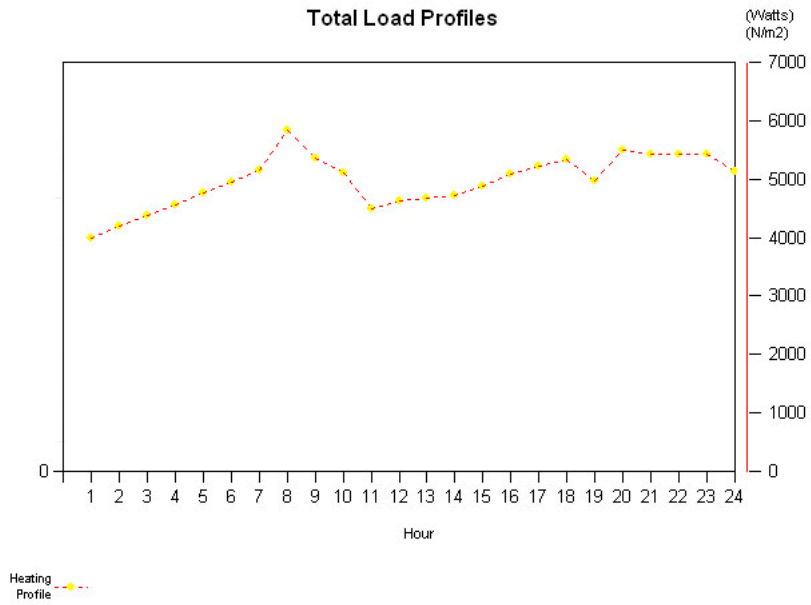


Figure 36: The total heat load for the entire house on January 12 with improved conditions

6.4 Overheating results

6.5.1 Overheating of a non insulated house

According to the first formula in section 4.5, overheating is calculated. For the case of a non insulated house, the indoor temperature in several summer days exceeded the reference temperature of 27 °C. This depends mainly on the orientation, internal gains and the properties of the material. After the calculation, the following values have been recorded for each house:

Table 11: Overheating for House 1 [in Kh]

House 1	May	June	July	August	September
Living Room	158	492	743	916	210
Bedroom (N)	71	348	492	261	20
Bedroom (S)	222	503	890	956	152

Table 12: Overheating for House 2 [in Kh]

House 2	May	June	July	August	September
Living Room	244	795	1224	1134	309
Bedroom (NW)	50	379	501	349	59
Bedroom (NE)	156	542	965	1082	276
Bedroom (SW)	197	605	960	753	112

Table 13: Overheating for House 3 [in Kh]

House 3	May	June	July	August	September
Living Room	475	1068	1879	1878	643
Bedroom	99	485	729	359	58
Bedroom (N)	86	414	640	323	42
Bedroom (NE)	198	518	1020	928	180
Bedroom (S)	225	670	1152	1391	408

Based on the second formula in section 4.5, the total overheating of a non insulated house is as follows [in Kh]:

- House 1 – 2144
- House 2 – 2673
- House 3 – 3173

The temperature in several days in some rooms exceeded the thermal comfort. The maximum room temperature recorded from the simulation reached 46.3 °C even though the simulation is performed with an infiltration rate of 2 ach for the non insulated house.

6.5.2 Overheating of the house with improved insulation

The insulation of the house brought significant improvement for the warm season. The overheating of the rooms has been eliminated in most of the rooms. It can be observed in the following tables:

Table 14: Overheating for House 1 [in Kh]

House 1	May	June	July	August	September
Living Room	7	118	313	367	28
Bedroom (N)	0	0	0	0	0
Bedroom (S)	0	0	30	69	0

Table 15: Overheating for House 2 [in Kh]

House 2	May	June	July	August	September
Living Room	1	125	282	161	11
Bedroom (NW)	0	0	4	0	0
Bedroom (NE)	0	0	7	0	0
Bedroom (SW)	0	37	143	157	9

Table 16: Overheating for House 3 [in Kh]

House 3	May	June	July	August	September
Living Room	32	285	761	527	82
Bedroom	0	2	31	5	0
Bedroom (N)	0	0	6	0	0
Bedroom (NE)	0	8	76	27	0
Bedroom (S)	0	2	65	81	0

According to the formula in section 4.5, the total overheating of the simulated houses with improved thermal envelope is as follows [in Kh]:

- House 1 – 311
- House 2 – 89
- House 3 – 398

The thermal envelope has brought significant changes reducing almost to minimum the overheating. For House 1 the overheating is reduced by 85%, for House 2 by 96% and House 3 by 87%.

The following graph shows the percentage of the reduced overheating for each house separately. The maximum overheating values of a non insulated house in this case are considered as 100%.

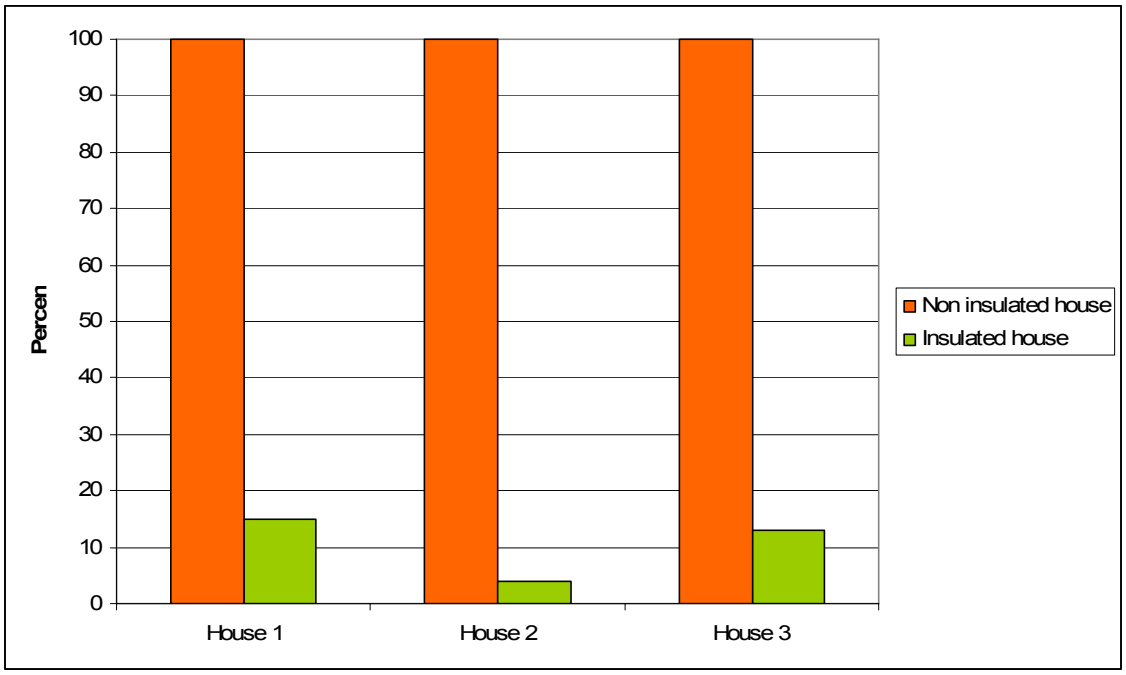


Figure 37: Percentage of overheating reduction for each house separately.

7 Discussion

Houses should react to the outside environment in a similar way as humans do. Humans use different organic mechanisms to obtain the desired heat loss depending on the outside air conditions, while tending to keep a constant temperature of 37 °C (±1°C). A non-insulated house is similar to a improperly dressed man. But the difference lies on the mechanisms that tend to keep a constant temperature where in humans it is observed with muscles contraction or shivering to produce heat (*Todorovic 2000*). A house compensates the heat loss only through electrical, wood or other means of energy. In order to preserve the heat, the house should have proper insulation parameters and allow consequently a thermal comfort in the indoor environment. Such phenomenon does not currently occur in Kosovo because of the lack of insulation. The results show that some of the houses may be of low heating energy consumption types, but it harms the occupants who are not offered good living conditions. The simulations recorded that the indoor temperature in a not heated room during winter periods might drop to 12 °C in morning hours. This temperature has also been confirmed by the questionnaires on a normal winter day where the outdoor temperature was above 0 °C.

7.1 Energy demand comparison for the simulated houses

In all the simulated houses, the results of the first case are relatively small and differ between each house. The explanation for this phenomenon is the low energy demand from the occupants which causes “energy efficiency by freezing”. When such energy efficiency is

present there is also thermal discomfort in the house due to the low temperatures recorded in rooms. In case 2 on a not insulated house when there is heating for the entire house, there is also great amount of heat loss. It is obvious that the higher the net area of the space, the more energy is used to heat that particular room. The insulation of the houses has brought significant changes in the thermal behavior of each type of house. The figures 38, 39 and 40 compare each case from all three houses which represent the monthly energy demand for heating:

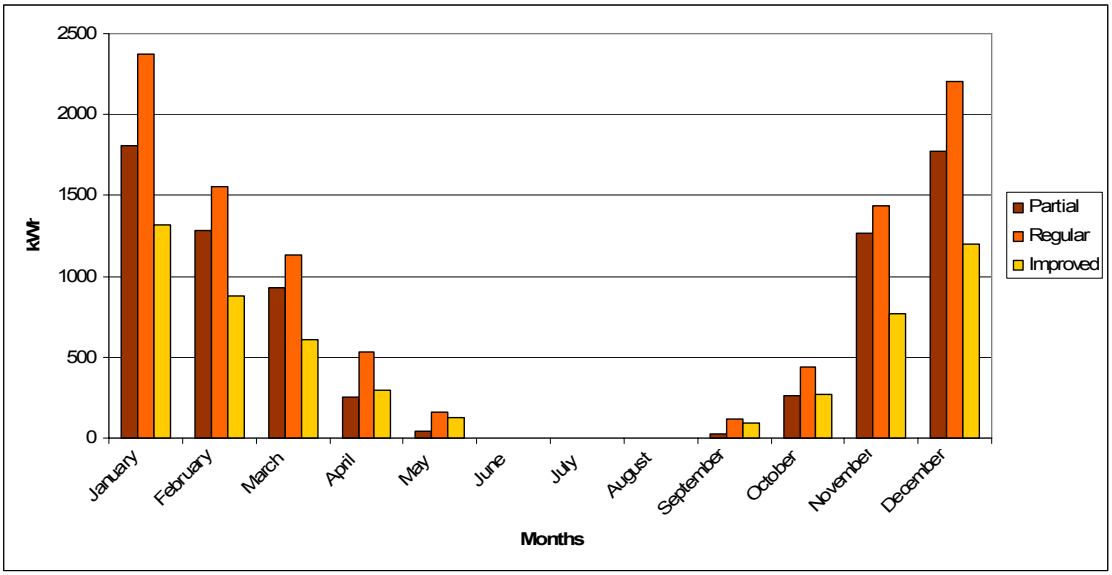


Figure 38: Energy demand for house 1

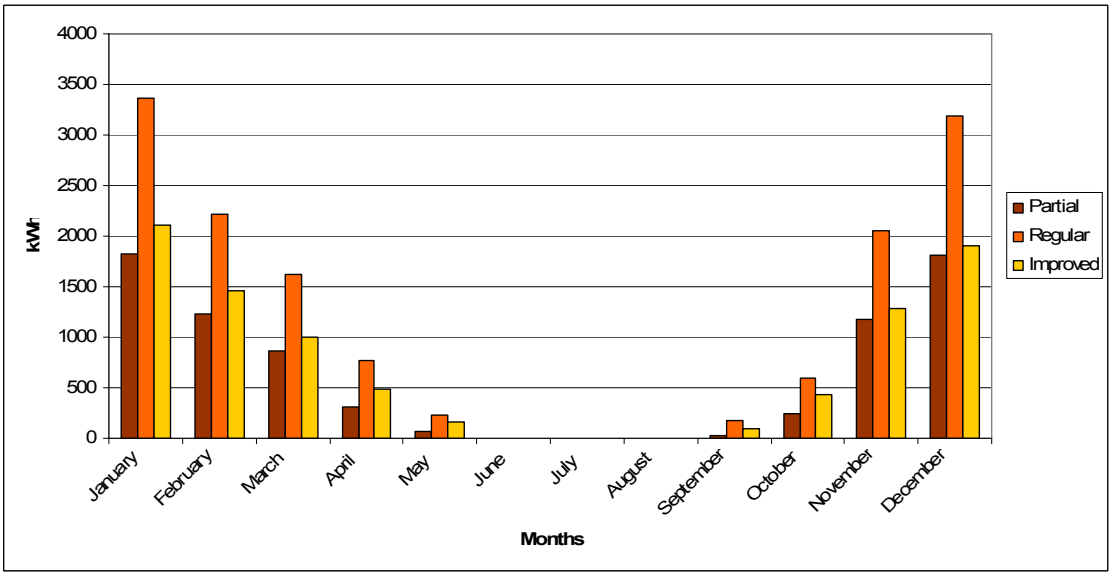


Figure 39: Energy demand for house 2

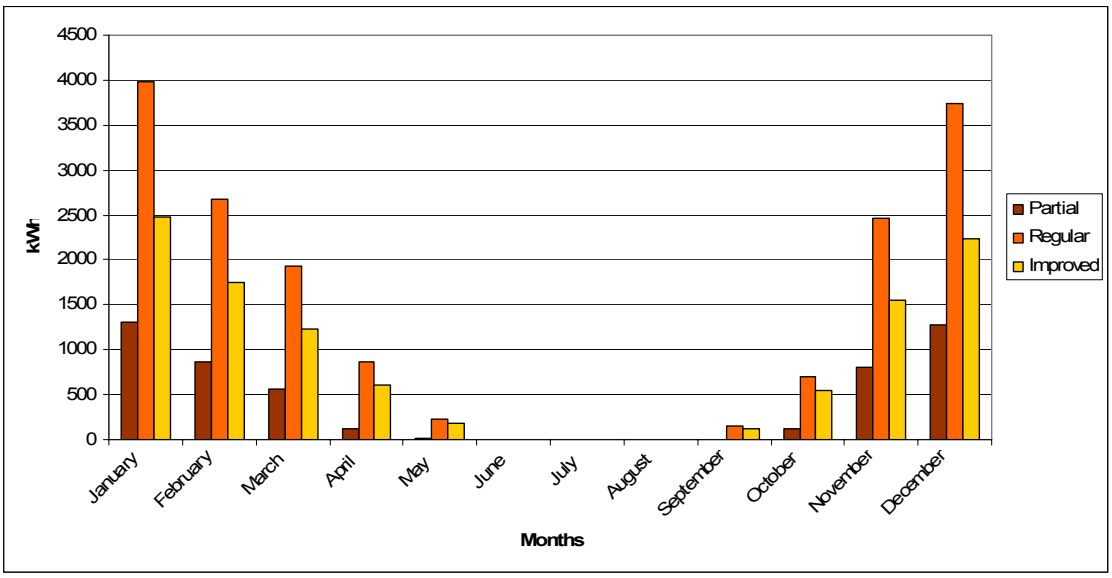


Figure 40: Energy demand for house 3

If all cases are compared in point of view of the type of the house, the effect of the insulation is clearly and quite comprehensible. In the case of partial daytime heating with an improved thermal envelope almost half of the energy needed to heat the spaces will be saved. The detailed values for this case of the annual energy demand [in $kWha^{-1}$] are shown in the following table (in brackets is shown the energy demand per square meter, in $kWhm^{-2}a^{-1}$):

Table 17: Energy demand with partial daytime heating

	Basic house	Improved insulation	Savings in percentage
House 1	7642 (85,22)	5119 (52,51)	33%
House 2	7543 (63,39)	7044 (59,2)	8%
House 3	5106 (57,53)	3950 (44,51)	22%

In the case of regular heating it is obvious that the energy demand is higher, since all the spaces of the house are heated. If in near future the whole house is used, the energy demand in comparison with partial heating would rise as follows: House 1 – 23%, House 2 – 46%, House 3 – 70%. By applying a thermal envelope these values will decrease so that there is less heat loss. The insulation of 8cm will reduce the energy demand for the houses in comparison with a not insulated house as shown in table 18. The following table shows the difference in energy demand for heating [in $kWha^{-1}$] for all houses (in brackets is shown the energy demand per square mete, in $kWhm^{-2}a^{-1}$):

Table 18: Energy demand with regular daytime heating

	Basic house	Improved insulation	Savings in percentage
House 1	9954 (102,1)	5565 (57,09)	44%
House 2	14119 (97,27)	8919 (53,69)	37%
House 3	16748 (100,83)	10680 (58,8)	36%

7.2 Solutions for the future

When asked the question “Why did they invest in other elements such as interior furnishing rather than on thermal insulation?” the survey revealed another indication to the statistics of willingness for creating a thermal envelope. A conclusion was reached that people were not investing on creating a thermal envelope for their houses because of the total price to pay. The second reason for this is the notorious lack of

knowledge about the properties and advantages of the insulating material. In many cases their financial status did not offer the possibility to encapsulate the immediate price in order to start work on insulating the house. It was possible and easier for them to bye interior decorative elements and to make the house look esthetical on the inside. This resulted in marble finishing, modern kitchens, new bedrooms etc. These elements are possible to buy in rates whereas a thermal envelope does not have this possibility.

The raised questioned in this case; how affordable is to create a thermal envelope and what is the payback time? As mentioned in the improvement section, a price is acquired to calculate the elements needed to create a thermal envelope. Based on calculations, the price to insulate the house amounts to 15€/m^2. It includes material, work and scaffolding if needed. The total price to create such a thermal envelope is shown below:

- House 1 – 2000 €
- House 2 – 3300 €
- House 3 – 4200 €

The formula for the payback time is:

$$\text{Paybacktime} = \frac{\text{Investment}}{\text{Savings}}$$

According to the energy savings based on heating with electricity with a price of 0,06 Euro/kWh, in all the cases the approximate payback time ranges from 7 to 10 years. The price per kWh is adopted according to the actual status of payment. Annually the houses might be able to save up to 370 € for heating. The price does not include savings in electrical appliances and hot water heating.

8 Conclusion

Solving the thermal conditions in Kosovo's housing will decrease demand for electrical energy and increase the level of thermal comfort. Most of the lost energy through poor material properties can be used in an efficient way to improve the quality of living during the cold seasons. The parametric studies in the simulations have shown that by reducing the energy demand for heating or even keeping it at the same level, thermal comfort can be achieved for the whole house.

The problem of maintaining thermal comfort occurs in night time periods during cold seasons when the heating is shut down by the inhabitants and lets the building to cool down to very low temperatures. The temperatures recorded by the simulation are almost the same with the outdoor temperature at some days for some rooms with no occupancy. This is the case of house 3 where the temperature drops to freezing point in some rooms.

The energy demand during the cold seasons in a non insulated house turned to be rather high. The non insulated structures loose around a quarter of the energy for heating to keep the thermal comfort due to the weakness of thermal envelope. All the lost energy contributes to raising the CO_2 level in the atmosphere by the power plants with an assumption that for the production of 1kWh of electrical energy, 1kg of CO_2 is released into the atmosphere.

Thermal insulation proves to be an important element not only for winter season but also for the hot and dry periods of the summer. It also protects the house from overheating whereas in winter it keeps a thermal comfort by reducing the heat loss. The overheating in an

insulated house can be reduced up to 90% with a threshold temperature of 27 °C with an infiltration rate of 1ach. In a non insulated house, in part due to the weakness of the thermal envelope during the summer periods additional heat is accumulated in the house, leading it to overheating. Thus thermal insulation balances these two requirements (reduced energy used for heating in winter and reduced overheating in summer) towards better thermal comfort conditions and better energy performance.

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