Improving energy efficiency of existing buildings

- Recommendations and approaches to consider in Poland and Kosovo

LUNDS UNIVERSITET
Lunds Tekniska Högskola

LTH School of Engineering at Campus Helsingborg
Housing Development & Management

Bachelor thesis:
Alan Esad
Fatri Rexhepi

Non scholae, sed vitae discimus

LTH School of Engineering
Lund University
Box 882
SE-251 08 Helsingborg
Sweden

LTH Ingenjörshögskolan vid Campus Helsingborg
Lunds universitet
Box 882
251 08 Helsingborg

Printed in Sweden
Media-Tryck
Biblioteksdirektionen
Lunds universitet
Lund 2012

Abstract

Improving energy efficiency of existing buildings – Recommendations and approaches to consider in Poland and Kosovo

The energy issue has in recent years become a hot topic around the world. Discussions about how to reduce the greenhouse gases in a sustainable manner have been raised. Given that this is an emerging problem, and that many people lack knowledge regarding this subject, it is about time that they get the information needed to be able to contribute in some way. In general, the building sector represents a high proportion of the total energy consumption in all countries. By letting people get acquainted with the benefits of building energy-efficient, the building sector would be seen as a major contribution towards reducing the overall energy consumption in a country.

In this report we have chosen to take a closer look on two houses, one in Poland and the other one in Kosovo. At present, 40 % of all houses were built during the 1970’s in Poland, with an older building technology. By improving such a large amount of buildings, positive results can be achieved energy wise. After the war ended in Kosovo in 1999, thousands of housing units have been built all over the country in an expedited manner. Most of the houses are poor from an insulation point of view, therefore it is important to provide them with a basis of the benefits when building energy-efficient.

We began by studying the thermal performance of the two houses, to be able to see what errors that gave increased energy consumption. From there we came up with various improvements that we later on simulated in a program called DEROB-LTH. This program provided us with values of how much each improvement contributed in reducing the use of energy. Calculations of how much it costs to implement the proposed improvements were also made. All materials that we used in our improvements are available in respective countries.

The results that we received were found to have a long payback period if the house was already relatively well insulated. On the other hand, if the house was poorly insulated we received a payback period that should be taken in consideration.

Keywords: Energy-efficient, existing buildings, Poland, Kosovo, insulation, windows, simulation, payback period.

Sammanfattning

Energieffektiviseringsåtgärder av befintliga byggnader – Rekommendationer och tillvägagångssätt att beakta i Polen och Kosovo

Energifrågan har under de senaste åren blivit ett hett ämne runt om i världen. Diskussioner har framtagits där man nämner hur man skall minska växthus-gaserna på ett hållbart sätt. Eftersom detta är ett växande problem och män-niskor saknar kunskap om detta, är det på tiden att de får den information som krävs för att mer eller mindre kunna bidra. Generellt, så står byggsektorn för en stor andel av den totala energiförbrukningen i alla länder. Genom att få människor att bli bekanta med de fördelar som finns med att bygga energi effektivt, så kommer byggnadssektorn att ses som en bidragande faktor för minskningen av den totala energiförbrukningen i ett land.

I denna rapport så har vi valt att titta lite närmare på två hus, ett i Polen och det andra i Kosovo. För närvarande är 40 % av alla byggda hus i Polen från 1970-talet och är byggda med en äldre byggnadsteknik. Genom att förbättra en så stor mängd av byggnader, kan positiva resultat uppnås energimässigt. Efter att kriget slutade i Kosovo år 1999, har man under en kort tid byggt tusentals hus över hela landet. De flesta husen är dåligt isolerade, därför är det viktigt att visa vilka fördelar det finns att bygga energieffektivt.

Vi började med att göra en byggteknisk analys med fokus på energi, för att se vilka felaktigheter som gav ökad energiförbrukning. Därefter diskuterade vi fram olika lösningar som vi sedan simulerade i ett program som heter DEROB-LTH. Utifrån detta program så fick vi värden på hur mycket varje förbättring har bidragit med till att minska energiförbrukningen i kWh. Vi gjorde också beräkningar på hur mycket det kostar att utföra varje förbättring. All material som vi använde i våra beräkningar finns på marknaden i respektive land.

Resultatet som vi fick, visade att om huset redan var bra isolerat så fick man en lång återbetalningstid. Men om huset var dåligt isolerat, så fick vi en återbetalningstid som bör tas i beaktande.

Nyckelord: Energisnål, befintliga byggnader, Polen, Kosovo, isolering, fönster, simulering, återbetalningstid.

Streszczenie

Termomodernizacja w istniejących budynkach – Rekomendacje oraz propozycje które należy uwzględnić w Polsce i Kosowie

Kwestia energii w ostatnich latach stała się gorącym tematem na całym świecie. Prowadzone są rozmowy i opracowania dotyczące ograniczenia emisji gazów cieplarnianych. Ponieważ jest to rosnący problem, społeczność międzynarodowa prowadząc dyskusje na ten temat wskazuje w jaki sposób ograniczyć zużycie energii zwracając szczególną uwagę na zalety budownictwa energooszczędnego. Powszechna świadomość i wiedza w śród ludzi dotycząca efektu cieplaniarnego i konieczności budownictwa energooszczędnego, spowoduje stosowanie wyłącznie nowoczesnych technologi budowlanych i materiałów izolacyjnych, zmniejszając jednocześnie zużycie energii.

W prezentowanym raporcie zdecydowaliśmy się dokonać oceny energetycznej domów jednorodzinnych,jednego w Polsce i jednego w Kosowie. Obecnie 40 % istniejących budynków mieszkalnych w Polsce było wybudowanych w latach 1970 do 1989r. według starej technologi budowlanej i niskich parametrach izolacyjnych. Zastosowanie nowoczesnych systemów dociepleń w tych budynkach w znacznym stopniu ograniczy zużycie energii, a tym samym emisję gazów cieplarnianych. Po zakończeniu wojny w 1999r. w Kosowie wybudowano tysiace domów, lecz bez odpowiedniej izolacji cieplnej, dlatego też istotnym jest wykazanie korzyści jakie wynikają ze stosowania technologi budownictwa energooszczędnego.

Dokonaliśmy analizy strukturalnej ze szczególnym uwzględnieniem parametrów energetycznych budynków w celu wykazania błędów jakie popełniono i w konsekwencji których następuje zwiększone zużycie energii. Następnie opisaliśmy różne rozwiązania i symulacje przy zastosowaniu programu DEROB-LTH. Za pomocą tego programu otrzymaliśmy wartości na ile każda poprawa w strukturze budynku przyczyniłaby się do zmniejszenia zużycia energii w przeliczeniu na kWh, oraz obliczenia kosztów dokonując tych zmian. Do obliczeń i symulacji przyjęto charakterystyki materiałów budowlanych znajdujących się obecnie na rynku budowlanym obydwu krajów.

Uzyskane wyniki wykazały, że jeżeli budynek został dobrze izolowany to poniesione koszty na obniżenie energochłonności podlegałyby długiemu okresowi zwrotu. Natomiast w przypadku domu niedostatecznie izolowanego okres zwrotu kosztów poniesionych na poprawę parametrów energetycznych

budynku jest znacząco krótszy, a tym samym powinien być brany pod uwagę przy realizacji tego przedsięwzięcia.

Słowa kluczowe: energooszczędne, istniejące budynki, Polska,
Kosowo, izolacja, okna, symulacja, okres zwrotu.

Përmbledhje

Masat e efiçiencës së energjisë në ndërtesat ekzistuese - Rekomandimet dhe qasjet për t'u marrë parasysh në Poloni dhe në Kosovë

Çështja e energjisë në vitet e fundit është bërë një temë e nxehtë në mbarë botën. Diskutimet janë zhvilluar duke u përmendur reduktimin e gazeve-serë në mënyrë të qëndrueshme. Që kjo është një problem në rritje dhe njerëzve ju mungojn njohurit në lidhje me këtë, është koha që ata të marrin informacionin e nevojshëm për gjendjen dhe pak a shumë për të kontribuar. Në mënyrë të përgjithshme, sektori i ndërtimaris qëndron prapa një pjesë të madhe të konsumit të energjisë totale në të gjitha vendet. Duke marrë njohuri ekzistuese njerëzit njifen më mirë me përparësitë e ndërtimit efikas të energjisë, atëherë sektori i ndërtimit do të shihet si një faktor që kontribuon në reduktimin e konsumit të përgjithshëm të energjisë në një vend.

Në këtë raport ne kemi zgjedhur për të marrë një vështrim nga afër dy shtëpive, një në Poloni dhe një në Kosovë. Aktualisht, 40 % e të gjitha shtëpive të ndërtuara në Poloni jan ndërtim i viteve 1970 dhe jan të ndërtuara me një teknik të vjetër ndërtimi. Duke përmirësuar një numër të madh të ndërtesave, mund të arrihen rezultate pozitive në kursimin e energjis. Pas përfundimit të luftës në Kosovë në vitin 1999, brenda një kohe të shkurtë jan ndërtuar me mijëra shtëpi në të gjithë vendin. Shumica e shtëpive janë të izoluara dobët, kështu që është e rëndësishme për të treguar se çfarë përfitime ka për të ndërtuar energji-efektive.

Ne kemi filluar të bëjmë një analizë tekniko-ndërtimore me fokus në energji, për të parë cilat ishin gabimet që kan rezultuar në rritjen e konsumit të energjisë. Pastaj kemi diskutuar zgjidhje të ndryshme që ne pastaj i kemi modeluar në një program të quajtur DEROB-LTH. Përmes këtij programi, kemi marrë vlerat në çdo përmirësim që ka kontribuar në reduktimin e konsumit të energjisë në kWh. Ne gjithashtu kemi bërë llogaritjet se sa kushton për të kryer çdo përmirësim. Të gjitha materialet që i kemi përdorur në llogaritjet tona janë në tregjet e secilit vend aktual.

Rezultati që ne kemi marrë, treguan në qoftë se shtëpit ishin te izoluara mirë ata do të ken një periudhë të gjatë të përfitimit. Por në qoftë se shtëpia është e izoluar dobët, do të kemi një periudhë përfitimi që duhet të kemi kujdes.

Fjala kyçe: Energji-efikas, ndërtesat ekzistuese, Poloni, Kosovë, izolimin, dritare, simulimi, kushtet e përfitimit.

Foreword

Dear readers,

This bachelor thesis has arisen subsequent to a discussion with Johnny Åstrand and Erik Johansson from the department of Housing Development and Management at the University in Lund. It has been written during the spring of 2012, and it was the last part of our education before we were provided the title as Bachelors of Science in Civil Engineering.

First of all we would like to thank both our examiner Johnny Åstrand and our tutor Erik Johansson for helping us developing this subject, during our first meeting in the fall of 2011. Apart from that we would like to express a special thank to Erik Johansson, who has shown great commitment concerning this report and for providing us with all the assistance that was needed to make this report possible.

Then we would like to express our deepest thanks to our respective beloved relatives in Poland and Kosovo, who have been very helpful by organizing our interviews and various meetings during our visit. We also want to thank our families and friends, who have supported us, not only during the accomplishing of this report but also throughout our whole education.

Finally, we wish a pleasant reading, with the hope that the information in this report can contribute to give you a sense of how the process of making existing buildings energy efficient works.

Helsingborg, June 2012

Alan Esad, Fatri Rexhepi

Division of work

Alan Esad: 2, 3.1-3.2, 4, 5.1, 6.1, 7.1-7.3, 8.1.

Fatri Rexhepi: 3.3, 5.2, 6.2, 7.4, 8.2.

Together: 1, 9, Foreword, Abstracts, Simulations and Interviews.

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1 Introduction

In recent years the issue of energy has created quite a stir because of the global warming. It is increasing due to the greenhouse gases emitted from factories, cars etc. This in turn means that the atmosphere gets less permeable to long-wave radiation, which means that it becomes thicker and the average temperature on earth increases sharply (Climate, 2012). If the mankind does not come up with a sustainable solution in the near future, we can expect some devastating damage to our planet. It has become an important topic around the world, and the question everyone is asking themselves, is how to reduce the energy consumption in a sustainable manner.

The use of energy is as of today a huge part of our society, and the usage varies depending on the countries needs, economical finances, conditions and climate. To obtain a structure of energy consumption several countries have joined various types of agreements such as the Kyoto Protocol and the European Climate Change Program. These agreements contain different types of goals on how to achieve a greener environment (Energy, 2012).

These agreements which we mentioned in the previous paragraph are often achieved politically. It is therefore vital that ordinary citizens get the knowledge needed to contribute towards a greener environment. One way which we believe in and that probably will solve plenty of problems is the energy efficiency measure of buildings. The building sector represents a high proportion of the total energy expenditure in a country, it is therefore important to let people get acquainted with the benefits of building energy-efficient.

The EU government has together with its members come to an agreement which says that all new buildings should be “near-zero-energy” by the year 2020 (Energy buildings, 2012). This is now seen as a very positive act, but still there are plenty of existing buildings left that needs to get modernized to even get close to the requirements of being a “near-zero-energy” building. People who have already built their houses before this agreement do not have to modernize it. But it is important to give them the proper information if they eventually would consider making a modernization. This information should include the benefits that exist economically and energy wise, and further on declare what savings they can make over time.

In this chapter we will discuss how we will carry out the process of making existing residential buildings energy-efficient in Poland and Kosovo.

1.1 Background

Energy is distributed between different sectors. In both Poland and Kosovo the building sector represents a high proportion of the total energy expenditure as seen in figure 1.1 and figure 1.2. This means that a domestic energy based improvement in that particular sector can have positive consequences.

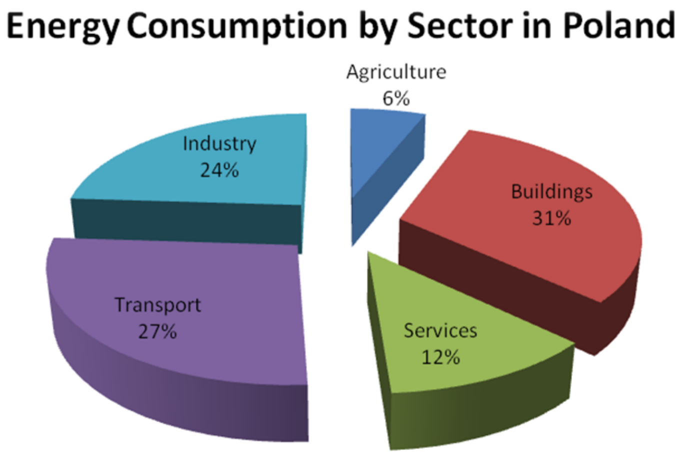

Figure 1.1 Energy Consumption by Sector in Poland 2009 (Modified: Central Statistical Office 1, 2009)

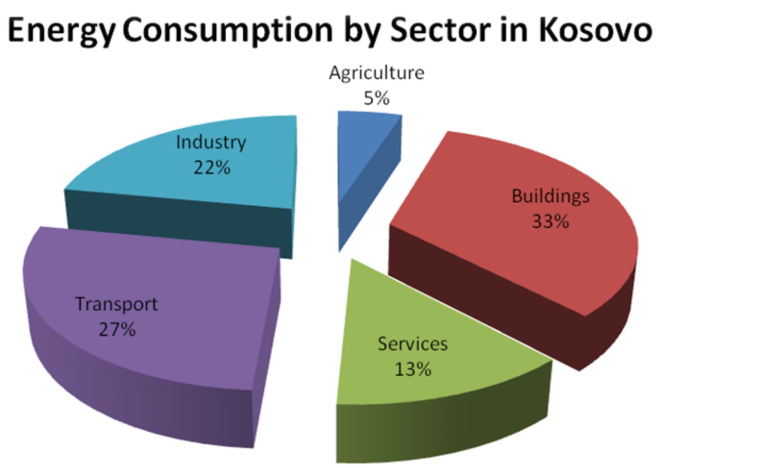

Figure 1.2 Energy Consumption by Sector in Kosovo 2003-2007 (Modified: Berisha Lirie, 2010)

By comparing both countries, it is seen that the energy consumption is almost identical divided over the sectors. As seen the building sector (including the housing sector) is one of the biggest, followed closely by the transport sector. While the prices for electricity are becoming more expensive every year, we strive to be more efficient with our use of electricity, since we want to pay less for heating. The main reason for that is because of the technological development in the last decades. We now have much richer equipment in the households than before; like computers, washing machines, televisions etc. The usage and extraction of energy sources has led to an increased concentration of carbon dioxide in the air. In both Poland and Kosovo the production of electricity is coming largely from fossil fuels.

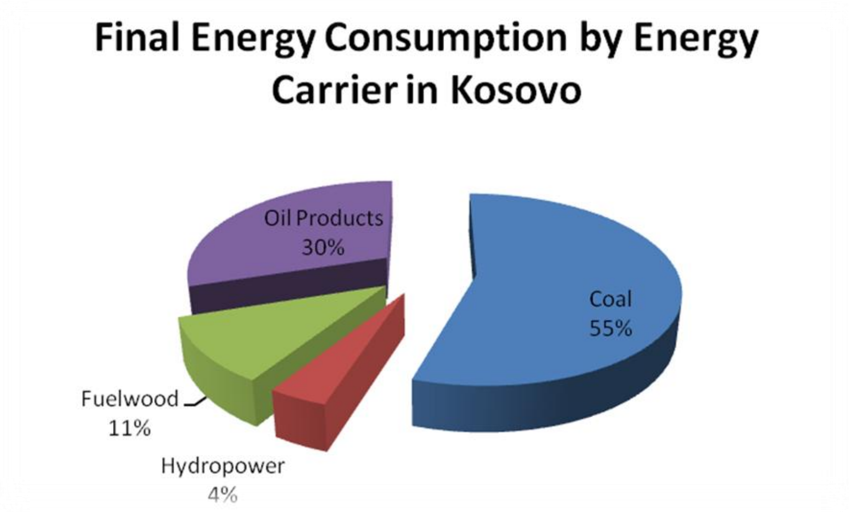

Figure 1.3 Final Energy Consumption by Energy Carrier in Kosovo 2007 (Modified: Energy development, 2007)

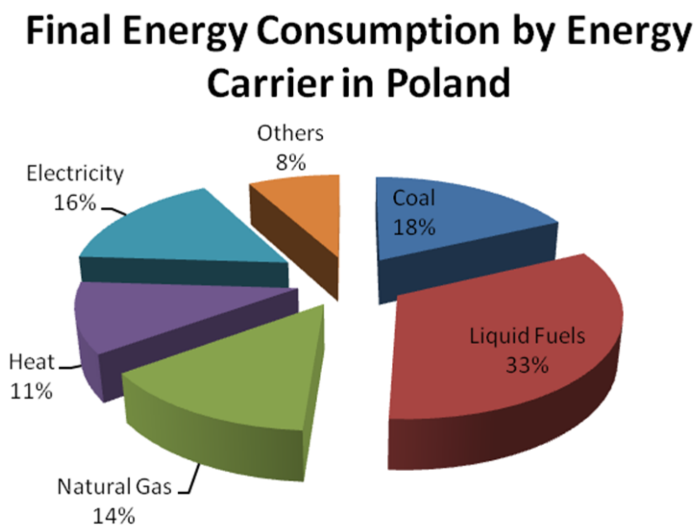

Figure 1.4 Final Energy Consumption by Energy Carrier in Poland 2009 (Modified: Central Statistical Office 2, 2009)

The constant use of fossil fuels is not sustainable in the long run. Therefore, countries that have the opportunity must take advantage of the technology that exists, which is not dependent of fossil fuels. Measures to improve existing buildings are one solution; the idea with this is to minimize the use of heating as much as possible.

1.2 Objectives

The purpose of doing this bachelor thesis is to create sort of a guideline to follow on how to modernize your own house in terms of local costs and availability of materials. We want to provide a basis for our target group on how to make this kind of procedure as efficient and economical as possible.

This research will be written in a reasonable level so that a person that is not familiar with this subject can understand and perform our recommendations. Our intention is to come up with various proposals on how to make a building energy-efficient. Further on we will describe which of the proposed solutions that is most profitable and energy-efficient, this will give our target group the opportunity to make a choice on how they want to modernize their building based on their economical life and needs.

1.3 Target group

This research is primarily intended for the inhabitants in Poland and Kosovo, since all the calculations are based on their energy- and material costs. Concerning the selection of the houses that we have studied, we chose to look at our relative’s houses. We think that they represent very well the houses that have been built in recent years in both countries. When it comes to the execution of the modernization, we would gladly encourage others than our target group to take part of this research and use it as a guideline.

1.4 Method

By doing this research we want to assure ourselves that this bachelor thesis is qualified to be as complete as possible. Therefore we have chosen to travel to both destinations, and once there collect vital information such as material costs and availability of materials. We stayed for a week in both countries; the trip to Kosovo was in 11th-17th of March and from 29th of March to 5th of April in Poland. We also want to illustrate in this report with plenty of pictures that has been taken during our trips, in this way the reader will more easily understand what we describe. In order to collect information about materials we contacted a building company or a person who works within the building sector. What we did was that we interviewed those persons about the development of building houses over the last years and what requirements there exist. The costs that we wanted to obtain from each country are the following:

Energy Carrier

- Electricity (kWh)

Energy Source

- Fuel oil

Materials

- Windows
- Insulation

Apart from that we have sent devices to each house that measure the inside temperature under a longer period of time. Both devices were sent in November 2011. In Kosovo, the device measured the indoor temperature from 5th of December to 11th of March. In Poland the measuring started in 1st of December and ended in 4th of April. Those measurements are meant to help us when we do our energy simulations, so that we can compare our measured values against the values we get from the simulation.

To help us simulate our improvements in our buildings we have received an application called DEROB-LTH. This is an energy simulation application which was at the very first developed by the University of Texas, and later on further developed by LTH. This will help us to see how the solar radiation, sun blinds and the given climate affect the energy balance in our two buildings.

1.5 Limitations

Our study includes two houses; the first one in Poland and the second one in Kosovo which represents the houses built in recent years. In our simulations and calculations, we use parameters and values that cannot be used on other buildings in similar studies.

We have laid focus on the improvement of windows, external walls and roofs. Other factors that can affect the energy consumption are also mentioned, but no further calculations have been made.

1.6 Structure of thesis

Chapter 1 – An introduction of the problem and further on what method we will use to answer it.
Chapter 2 – Explaining how the housing unit looks in Poland and Kosovo as of today, and how the building technology has evolved over the years.

Chapter 3 – A climate analysis for the two houses, where we mention the various recommendations that the Mahoney tables and the Givoni chart gives us.
Chapter 4 – Simplified theory, where we explain the various factors that affect and influence the energy consumption of a building.
Chapter 5 – An investigation of the various building elements that we want to improve. Here we discuss and analyze what disadvantages there is with the existing buildings.
Chapter 6 – With the knowledge that we acquired from the investigation, we follow up with a discussion where we propose solutions that contribute to an energy efficient building.
Chapter 7 – We simulate the proposals that we have come up with, and obtain what reduction in energy consumption there is.
Chapter 8 – We calculate the profitability of each improvement, where we show how long the payback period is.
Chapter 9 – A discussion of our results that we obtained from each house, where we make our own conclusions.

2 Historic development of housing and building technology

2.1 Historic development of housing

In this section we looked at how the number of housing units has changed in the recent years in both Poland and Kosovo, and how the building sector has evolved in terms of materials and the way the buildings are built.

2.1.1 The growth of housing units in Poland

After the fall of communism in Poland in the year 1989, the housing supply that existed was less than the demand. Therefore, they started to build a lot of houses and apartments to cover this demand. After about a decade, more precisely in the year of 2002 there was still a deficit in the household sector which approximately was estimated to 1.5 million.

Many houses in Poland were built during the 70's; together they account a total amount of 40 % of all houses built in Poland. These houses are built with older technology and will definitely require some sort of renovation to meet the energy requirements as of today. By improving such large percentage of houses, positive results can be achieved from an energy point of view (OECD, 2012).

2.1.2 Evolution of building technology in Poland

From the interview with Zbigniew Stempak (2012), we were told that Poland had undergone a major change when it comes to the building technology. Under socialism, everything in terms of materials was highly limited. Because of the lack of materials, people had to wait a long time before they could get their order of materials. This is why it could take several years to complete a house. In many cases, you had to make your own concrete on site, something that is unimaginable in today's Poland. Zbigniew Stempak (2012) further on explained that as of today there is no limitation but your financial pocket, when it comes to how you want to build your own house. After Poland joined the European Union in 2004, the availability of materials expanded even more, since then they have now access to the latest technology within the building sector.

2.1.3 The growth of housing units in Kosovo

The growth of housing units is something that is increasing dramatically worldwide, because more and more people would rather have a house than an apartment if the economy permits. In Kosovo, the household growth increases due to the increased population in the country.

Hereby, we present some data from the Federal Office of Former Yugoslavia on how the growth of households has moved forward between the years 1948 and 1991. In 1948 Kosovo had a total of 733 132 inhabitants and 115 293 households scattered over the country. In under 50 years, more precisely in the year 1991 the total amount of inhabitants had grown to 1 956 196 and the households had increased to 289 246 (Households in Kosovo, 2008).

As of the year 2009 the total population of Kosovo was around 2 207 000 inhabitants. The households has compared to the statistics from 1991 decreased to 274 223 (Population in Kosovo, 2010). The reason for the reduction of households may depend on different factors. As Latif.Jashari (2012) pointed out in the interview, he said that many houses built outside the cities are not being correctly registered as they should be, that is why the number of household may be higher than presented.

2.1.4 Evolution of building technology in Kosovo

Since the war ended in 1999, Kosovo has steadily progressed in terms of building technology. Before the war, Latif Jashari (2012) explained that there were a lot of houses built by inexperienced and uneducated people, which lead to an outcome of building errors. Plenty of single family houses have been built all over the country. They all use pretty much the same material in the building framework, in this case hollow bricks. This is probably due to the limited choice of materials, and because there exists a relatively huge difference in terms of costs if you eventually would consider a building framework built of wood or concrete. A huge part of the materials that were available were imported from Slovenia.

3 Climate analysis

3.1 General information

In the spring of 2012 we had a course called International Sustainable Construction (ABA600) within our education. During that course we got acquainted with how to build sustainably in different kind of climates around the world. We also got an Excel-document where we were able to input various climate data and then obtain results from the Mahoney tables and the Givoni chart (Givoni, 1998).

The Mahoney tables give general recommendations to consider when choosing to build a house in the specified climate. To mention a couple of the recommendations that is given in the table; such as orientation, air movement, openings in the building etc. As for the Givoni chart you get a diagram with various zones where one of them is a comfort zone. Based on the given climate we can see how well it relates to the comfort zone during the different months. In certain months the given climate will not be in the comfort zone, instead it ends up in other zones which tell you if heating, ventilation, cooling etc is required (Givoni, 1998).

3.2 Poland

The house in Poland is located in a small village called Mierzwin, it was completed in 2002. Since we were unable to obtain climate data for that particular village, we use climate data from the nearest city which is Wroclaw.

Figure 3.1 The house in Poland

3.2.1 Climate

In this section we will write briefly about the recommendations that we received from the Mahoney tables and Givoni chart.

3.2.1.1 Climatic factors

Hereby we present a graph showing how many hours of sunshine the given climate is exposed to. As you can see in figure 3.2 the real hours of sunshine in Wroclaw are around 6 hours a day during the summer period, but during winter it is only exposed for sunshine for 1 hour. Given that there are not so many hours of sunshine in Wroclaw, we would not recommend installing any type of solar panels since it would not be that profitable. But if you have not started building a house, you should definitely consider optimizing the orientation of the building that eventually will generate some incidental heat gain during the winter.

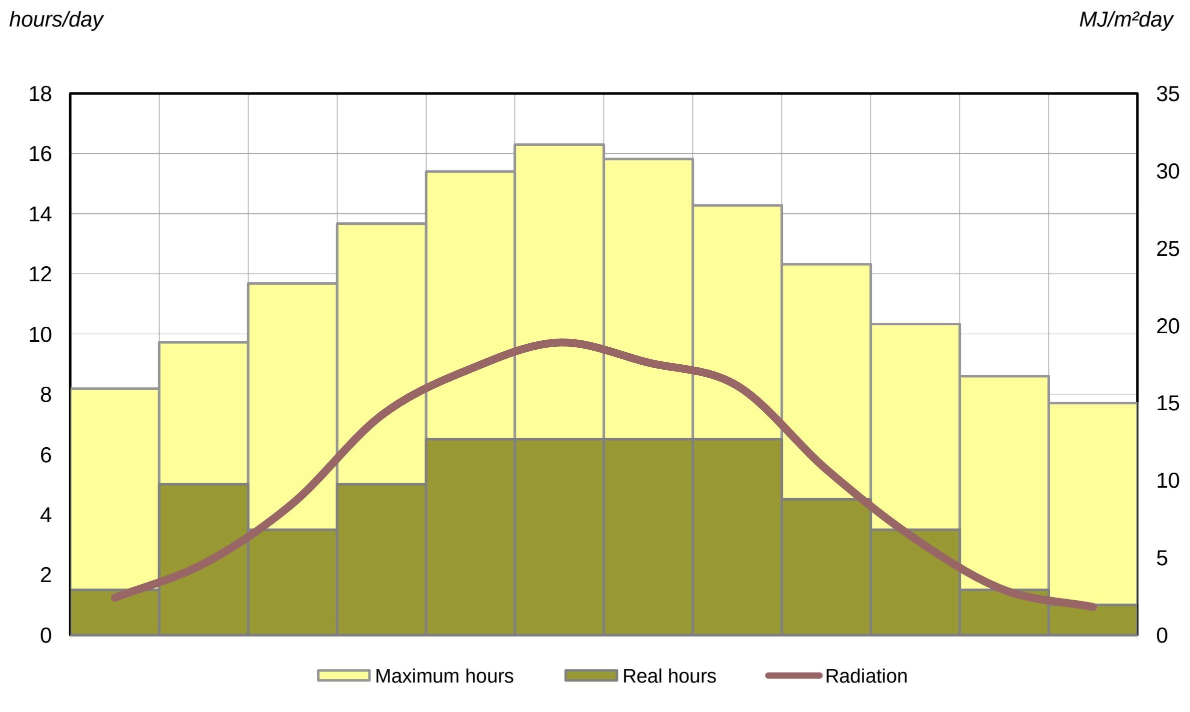

Figure 3.2 Sunshine on the left axis and Radiation on the right axis.

The graph of temperature variations as seen in figure 3.3; shows us relatively huge differences in temperature from winter to summer. In winter, the house will be exposed to cold temperatures which therefore require heating to obtain the desired temperature in the house. In the summer we get a temperature slightly over 20°C. It is not critical warm and the house should be in the comfort zone mostly without any form of cooling.

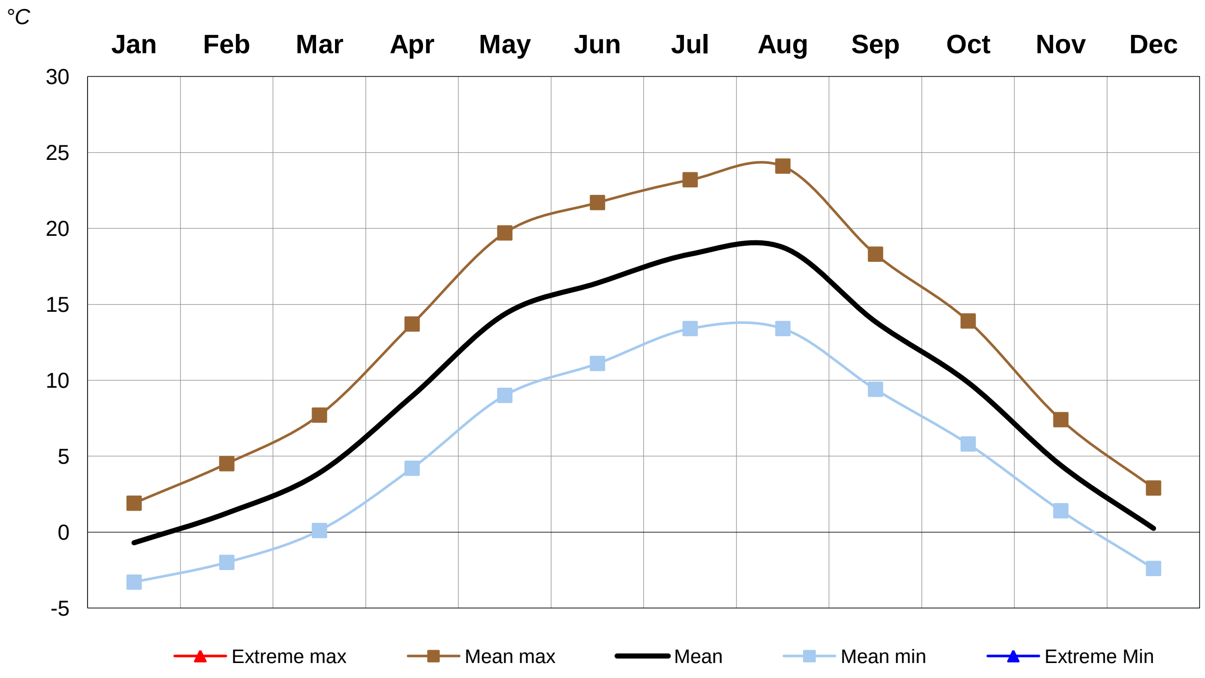

Figure 3.3 Temperatures in Wroclaw

3.2.1.2 Mahoney & Givoni recommendations

As we mentioned earlier in this chapter, the Mahoney table gives you certain recommendations to consider when building a house in the given climate. Regarding the orientation of the building it is recommended that the long axis of the building is placed from east to west in order to take maximum advantage of the solar radiation. The positive thing here is that the house in Poland fortunately is placed in that particular way. When it comes to wall and roof recommendations, it says that lightweight constructions should be applied with short time-lag. Note that time-lag is a description of how fast a structural component can claim the heat that is produced by the nature.

From the Givoni chart we noted that all the summer months are placed in the comfort zone, and it would be enough with internal gain from human beings needed if it tends to get slightly colder. The remaining months need heating to be able to reach the comfort zone.

The full recommendations of Mahoney and Givoni for the given climate are attached in the annex.

3.3 Kosovo

The house that we have chosen to study in Kosovo is located in the outer edge of Mitrovice. This house is relatively new considering that it was completed in 2008. The same conditions applies here as in the house in Poland; we could not get hold of the climate data for Mitrovice, so instead all data is based on the climate in Pristina which is located barely 40 km from our target.

Figure 3.4 The house in Kosovo

3.3.1 Climate

In this section we will write briefly about the recommendations that we received from the Mahoney table and Givoni chart.

3.3.1.1 Climatic factors

Figure 3.5 shows how many hours of sunshine Pristina is exposed to. During the summer we can get up to 9 hours of sunshine. When being exposed to the sun that much, the house can easily obtain a high temperature and become uncomfortable indoors. In figure 3.4 you can note that the house in Kosovo has a relatively large window area on one of the elevations, and therefore it is vital to consider having proper sun protection, if possible external. In winter we have about 2 hours of sunshine, and by having this huge amount of windows may help generating incidental heat gain.

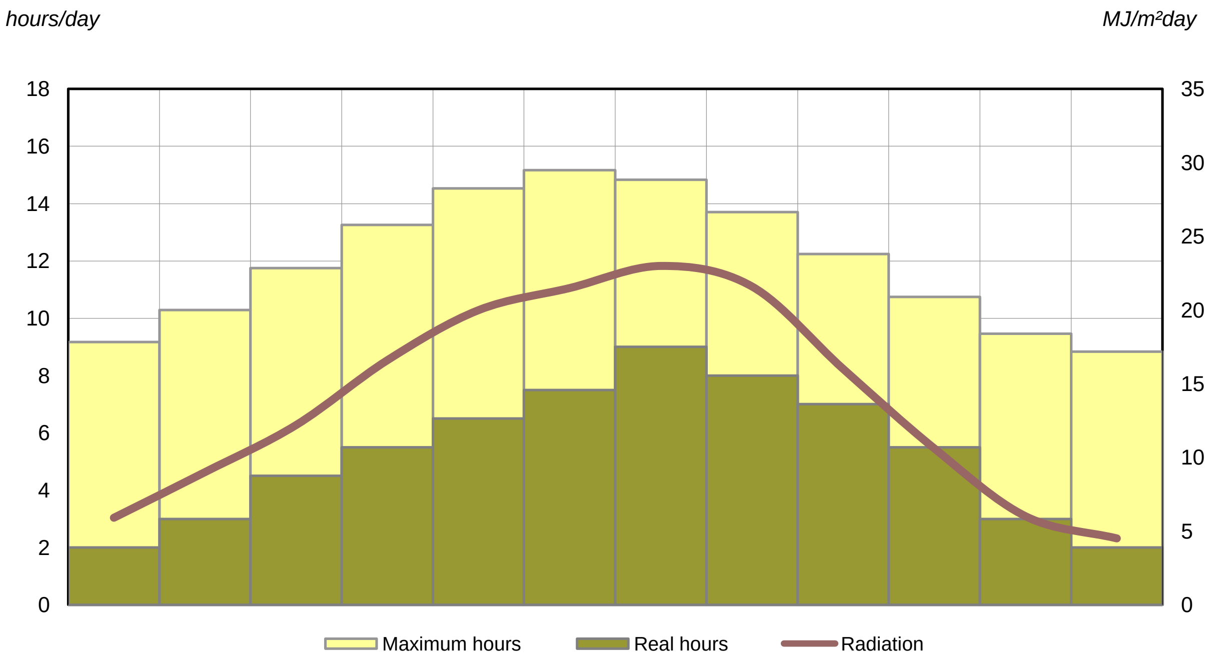

Figure 3.5 Sunshine on the left axis and Radiation on the right axis.

In figure 3.6 we are showing a graph of how the temperature varies during the year in Pristina. During the summer the temperature is at least 20°C. Combining the high temperature with the high amount of sunshine hours, the building's indoor climate can become pretty uncomfortable if no ventilation and shading is used.

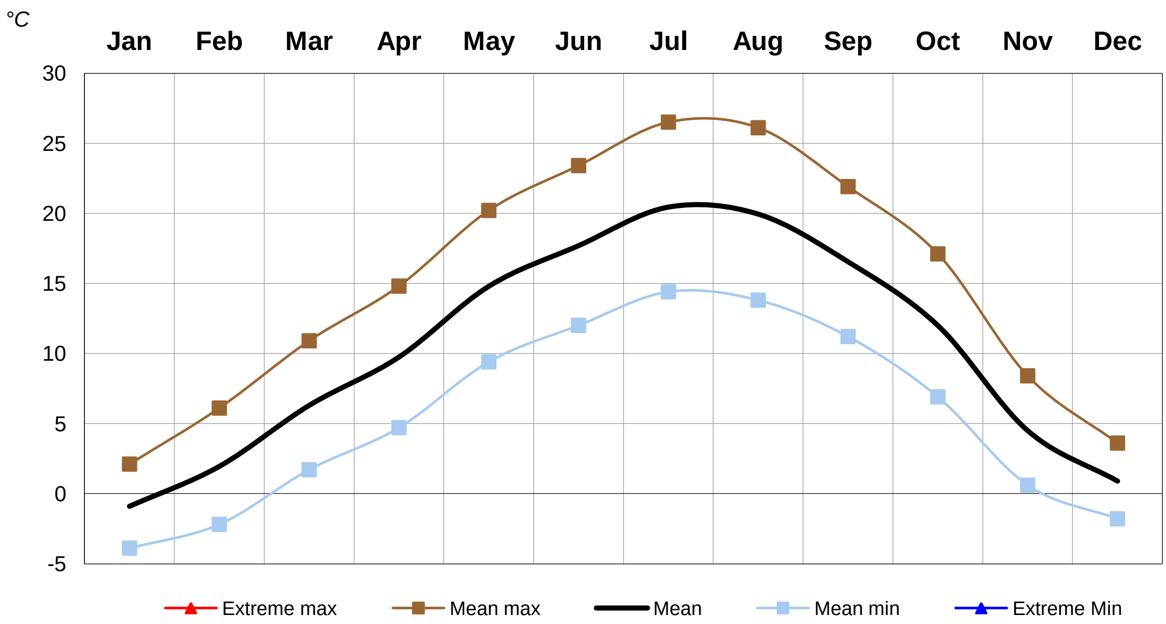

Figure 3.6 Temperatures in Pristina

3.3.1.2 Mahoney & Givoni recommendations

From the Mahoney results we can note that they are pretty much the same as for the house in Poland. However, it appears that there is a difference when it comes to how the walls should be built. Instead of lightweight walls with a short time-lag, it is recommended to build heavy external and internal walls with an 8 h time-lag. The main reason for this may be that the house is exposed to many hours of sunshine. When having an 8 h time-lag it will take longer time for the wall to receive the heat, instead the heat will be absorbed at night and with that prevent the temperature from lowering drastically.

All the summer months are placed in the comfort zone when looking on the Givoni chart. We also noted that the summer months reached the ventilation zone; therefore it is good if the house has a higher air exchange rate than recommended. Apart from that the remaining months are all in need of heating to be able to reach the comfort zone.

The full recommendations of Mahoney and Givoni for the given climate are attached in the annex.

4 Theory

In our bachelor thesis we will go deeper in how to make a building more energy efficient, therefore our research and calculations will only be energy based. But still there will be other important factors that affect the buildings construction, materials and indoor comfort. Such factors as heating, solar radiation, thermal bridges etc. may have a vital impact. Those factors will be further explained in an understandable level in this chapter so that the reader can understand different terms, what complications and possible solutions the buildings have when we describe them in detail in our structural examination.

4.1 Energy theory

As mentioned earlier heating buildings stands for a relatively huge proportion of the total energy consumption, this in turn means increased carbon dioxide emission. We heat our buildings with different types of energy sources, depending on what heating energy requirement there is. The choice of using one specific energy source is usually based on availability and costs.

4.1.1 Energy sources

From each type of fuel different amount of kWh can be extracted. In table 4.1 there is a list of different fuels and their specific energy value.

Table 4.1 Heating values of fuels
(Modified: Energifakta, 2010)

Amount/unit	Fuel	kWh/unit
1 tonne	Coal	7560
1 m^3	Oil	10070
1 m^3	Rapeseed oil	9340
1 m^3	Motor gasoline	9100
1 m^3	Ethanol	5900
1000 m^3	Natural Gas	11048
1 tonne	Pellet, 11 % moisture	4670
1 tonne	Fuel wood, 30 % moisture	3530
1 tonne	Peat, 35 % moisture	3550
1 tonne	Household waste	2800
1 kg	Natural uranium	140000

Here comes a general description of the most common energy sources in Poland and Kosovo. And further on an explanation of what advantages and disadvantages there may be with each specific energy source.

4.1.1.1 Coal

Coal is a fossil fuel that is widely used around the world. Its main purpose is to be used as an energy feedstock in the production of electricity and heat. In Poland and Kosovo there is a huge amount of coal and it is considered being an important energy source. The most notable negative impact that coal has on the environment is that it generates a huge amount of carbon dioxide emissions when extracted that in turn affects the climate (Coal, 2012).

4.1.1.2 Oil Products

Oil products are as of today one of the most if not the most used energy source around the world. It is very easy to come by, that is why it is mainly used as fuel by the transport sector and the industry sector. Like coal it is affecting the environment negatively when used. More and more people are using oil when heating up their buildings during winter. To prevent the central boiling heater from releasing greenhouse gases when oil is being burned there is a modern technology which filters out most of the toxin (Oil, 2012). In terms of disadvantages, besides emitting greenhouse gases the price of oil has increased dramatically in recent years.

4.2 Climate and its natural influence

In this section we will write briefly about how various factors from the environment affects the building's indoor climate. Further on mentioning how to deal with them to make the building as efficient as possible.

4.2.1 Indoor comfort

Information in this section is taken from, "Projektering av VVS-installationer". (Source: Warfvinge and Dahlblom, (2010)).

Everyone wants to experience the best possible indoor comfort in their own house. The requirement for what we as individuals think is the most suitable indoor temperature varies. There are a couple of factors that influence the indoor comfort, some are dependent on individuals and the other depends on the environment. We will mainly focus on the factors that are influenced by the environment, since they have the greatest impact on the behaviour of the indoor temperature. The factors are as follows:

- Air temperature
- Air velocity
- Ambient surface temperature
- Air humidity

The measuring of **air temperature** is something that we all are very familiar with. We use the temperature as a measure of how comfortable it is in a place where we are staying. Under a whole year period the indoor temperature varies depending on the seasons, in winter it usually should be around 20 °C and in summer up to 25 °C.

High **air velocity** can contribute to a local cooling of the body. The reason for an increase in air movements may be due to leaks and cold downdraught caused resulting from the cold surface of the window.

Given that the thermal conductivity varies depending on the materials, it creates temperature differences on the **ambient surfaces**. An example of that is when we approach a window which usually has a lower temperature, what happens is that the human body loses heat through thermal radiation and that leads to a local cooling of our body temperature which often can be perceived as discomfort.

During the summer when the air temperature rises inside a building, the **air humidity** can have a negative impact on the human body if it tends to rise. The reason of high air humidity can be due to increased sweating by us human beings, it is therefore important to have different kind of apertures so that airing can be applied when needed.

4.2.2 Orientation

To reduce the cost of heating during the winter we want to have access to as much incidental heat gain in form of sun heat as possible. But during the summer we want the contrary, instead we strive to reject as much as sun heat as possible. Therefore, we have to find a balance in between that suits us perfectly, that is why orientating a building plays a major part.

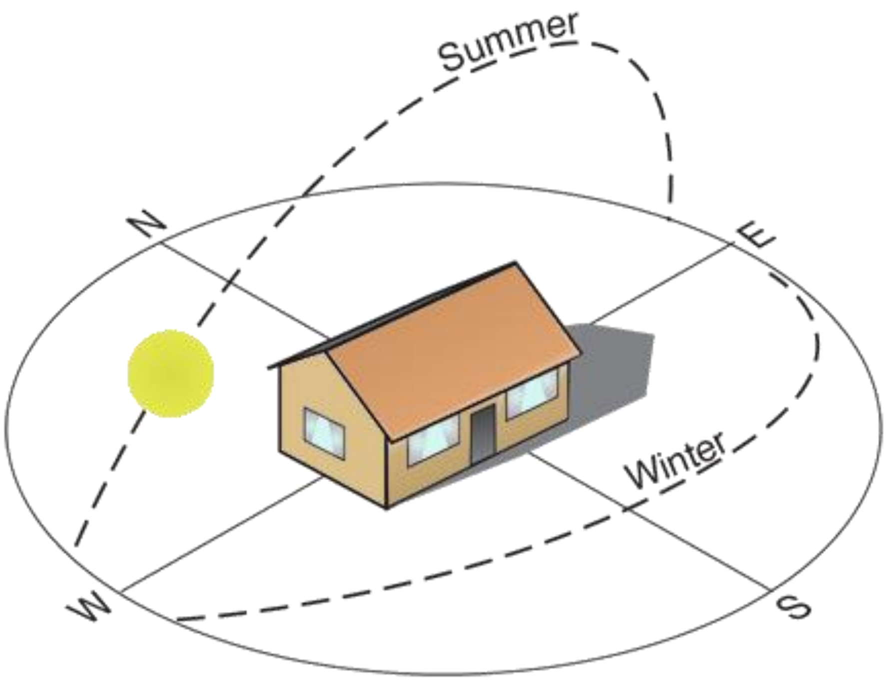

Figure 4.2 Movement of the sun during the winter and summer.
(Source: Orientation, 2011)

The most optimum solution is to place the long axis of the building from east to west as seen in figure 4.2. By placing a relatively huge area of windows on the southern elevation the building will be able to generate plenty of incidental heat gain during the heating season if correctly done.

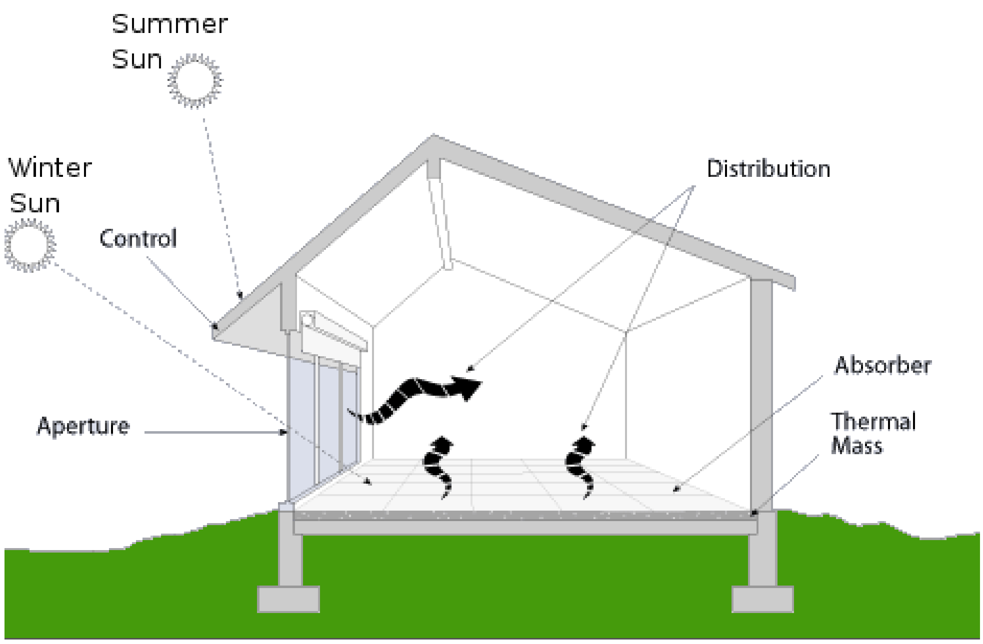

Figure 4.3 Function of a Passive Solar House
(Source: Passive Solar, 2011)

In figure 4.3, we can see how it might look like when trying to build with solar radiation in mind. It is not only important to get incidental heat gain during winter. What also must be in mind is to adapt the building so that it can protect the building from solar radiation during summer, when the sun is positioned higher up in the sky. By having a sufficient depth to the eaves (control in figure 4.3), you will be able to prevent the solar radiation from entering the building (Passive Solar, 2011).

4.2.3 Wind direction

When building a house, it is positive if you can use the wind direction effectively as a cooling mechanism during the summer. Given that the wind direction varies depending on where you are, it becomes difficult to orientate the building effectively if you also are having the solar radiation in mind. A dilemma arises and you will have to study which of the factors that is most rewarding based on the climate. What you can do is to orientate the building so that it partially can take advantage of both the sun and wind, or just totally focus on one another (Wind direction, 2009).

4.2.4 Solar Radiation

Part of the information in this section is taken from, "Praktisk Byggnadsfysik". (Source: Sandin, (2009)).

Solar radiation can have a major impact on a buildings energy balance. If a house is poorly insulated you can get major heat losses in the form of transmission. Therefore it is good if a building can take advantage of the solar radiation that exist in the given climate, and by that get incidental heat gain to somewhat compensate the heat losses (Solenergi, 2010)

Solar radiation is measured in W/m². When the solar radiation is directed perpendicular to the surface it strikes it is measured 1090 W/m². This value is called the solar constant. The solar radiation varies around the world depending on the climate; if it tends to be cloudy often it will definitely inhibit the intensity of the solar radiation.

4.3 Moisture theory

Information in this section is taken from, "Praktisk Byggnadsfysik". (Source: Sandin, (2012)).

Moisture can cause major problems and cause poor thermal insulation in a building. Therefore it is important to notice that when a modernization is being made, building only from an energy perspective is not that clever. It is also vital to be aware of what moisture consequences there exist.

Moisture can be transported through the construction in two different ways; by water vapour convection and water vapour diffusion.

Water vapour diffusion occurs when there is a difference in the vapour concentration. What happens then is that the vapour concentration wants to equal on both sides which creates a moisture transfer. **Water vapour convection** is more complicated to resist, it is caused by differences in the atmospheric pressure. This difference in pressure is created by the action of internal wind, temperature differences and ventilation arrangements.

4.4 Heating theory

Information in this section is taken from, "Praktisk Byggnadsfysik" and "Fukt handbok". (Source: Nevander and Elmarsson, (2006) and Sandin, (2009)).

A building can lose thermal energy in two ways; through transmission and ventilation. It is therefore important to reduce these losses by carrying out certain basic steps. Transmission losses mean that you lose heat through windows, walls, roof and ground. By properly insulating the building envelope you can obtain minimal heat losses. When it comes to ventilation losses the real culprit here are the air leakages that exist around the building. This can be reduced by applying airtight layers where the risk can occur. Those risks can usually be found where the roof and wall meet and even in the air- inlet and outlet.

The thermal energy will transport as soon as there is a temperature difference between two spaces, because it wants to equalise the temperatures. This heat transfer can be divided into three different procedures; those are radiation, convection and conduction.

- The phenomenon **radiation** is generated when heat is transferred from a warmer surface to a colder surface. An example of this is during winter as the window surface becomes cold it absorbs the heat from the ceiling that in turn becomes cooled down remarkably.
- **Convection** means that a gas or a fluid flows past surfaces transporting heat. The causes of convection can be described as natural and forced. Natural convection occurs due to the temperature differences in the air, further on providing density differences where warm air rises and cold air drops. Forced convection is a result of external influences such as winds and fans.

- **Conduction** occurs when thermal energy is transported through solid materials such as concrete, steel and bricks. The coefficient of thermal conductivity differs among all materials, which is why we human perceive certain materials colder than others even though they have the same temperature.

When performing calculations regarding heating a term called U-value is often used. The definition of U-value is as follows "*the amount of heat that per unit time is passed through a unit area of the structure when the difference in air temperature on both sides of the structure is one degree*".

Apart from that there is also a measure of how well the thermal insulation capacity is in a given material. This term is called thermal conductivity and often in calculations written as λ-value. It's defined as "*the amount of heat that per second is passed through an m² of a material with a thickness of 1 m when the air temperature difference is one degree*". The lower the value is the better it is from an insulation point of view.

4.5 Air tightness

In Sweden there is an administrative authority named Boverket, this agency is in charge of matters relating to the built environment and conservation of land and water areas, land-use planning, construction and management of buildings and housing issues (Boverket 1, 2012). Within Boverket there is an established collection of building codes named BBR, this lattice contains the requirements and rules on how to build and should be approached as a helping guide. Here is an excerpt from chapter 6 in BBR about air tightness.

6:531, Air tightness

General recommendation

"To avoid damage due to water vapour convection the buildings climate separated parts should have as good air tightness as possible. In most buildings the risk of water vapour convection is huge in the upper building parts, i.e. when there's an internal overpressure. Special care in achieving air tightness is advised when there's high moisture loads in swimming facilities or at very high temperature differences. The air tightness can affect the moisture condition, thermal comfort, ventilation and the buildings heat loss. Method for determining air leakages is described in SS-EN 13829. For the determination of possible air leakages it should also be examined whether the air leakage is concentrated to any building part. If so the risk of moisture damage exists".

(Boverket 2, 2012)

4.6 Thermal bridges

Information in this section is taken from, "Fukthandbok". (Source: Nevander and Elmarsson, (2006)).

Thermal bridges in all types of constructions can be very energy consuming; therefore it is good if they can be located and minimized if not eliminated completely. If there is a structural part with a relatively homogenous thermal resistance, there should not be any problems at all with thermal bridges. However if a structural part with lower thermal resistance passes through the more homogenous structural part it will work as a thermal bridge as seen in figure 4.4.

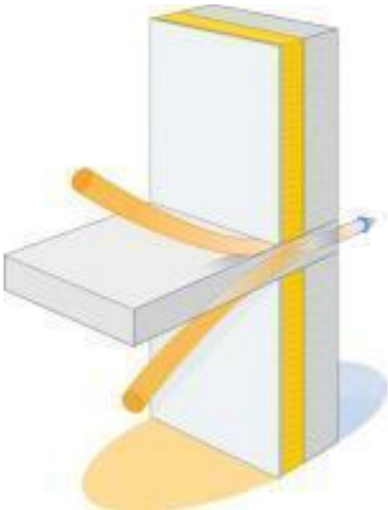

Figure 4.4 Intermediate floor made of concrete with lower thermal resistance passing through the layer of insulation creating a thermal bridge.
(Source: Isover Saint-Gobain, 2012)

Problems that may occur are primarily condensation due to water vapour diffusion and presence of mould.

5 Thermal performance of the buildings before improvements

In this chapter we will take a closer look at different structural parts of the buildings. With the knowledge that we now possess from chapter 4, we will analyze the different parts and finally come up with theoretical conclusions on its structure. In this way we will be able to discuss the disadvantages and advantages of how it is structured and further on how we can improve it to make it more energy efficient. Note that all measurements are written in mm.

5.1 Poland

This is a structural analysis of the building in Poland. All photographs of the building have been taken by us during our visit there.

5.1.1 Floor plan

The house in Poland is a one-storey house; it consists of four rooms, kitchen, utility kitchen, laundry room and two toilets. All rooms have a single window, except the living room that has a more open space with multiple windows. As of today two people lives in this house, that is why only half the house area is being heated during the winter. The reason for this is that these people only stay in the living room and kitchen during the day and at night in their bed-room. In consequence, the heating of all rooms would generate unnecessary costs.

5.1.2 Elevations

The building itself is well placed in terms of orientation to the sun. The long axis of the building runs from east to west. The majority of all windows are installed on the southern elevation, which eventually will lead to some incidental heat gain during the winter. In summer it can instead get pretty warm inside if the sun radiation is allowed to go through the windows. Luckily the depth to the eaves is enough to prevent a majority of the sun radiation from entering.

5.1.3 Roof

The roof has a structure that is quite common among all one-story houses built last 10 years in Poland. It is a none-insulated traditional tiled roof over a wind space with an intermediate insulated ceiling. Hereby, we present two tables of what the roof and loft floor is built of.

The none-insulated roof is built of:

Material	Thickness (mm)
Concrete tiles	-
Tiling batten	50
Counter batten	50
Tongue and groove (T&G) board	25
Foil (Damp-proof course)	-
Roof truss	140
Attic space	-

The loft floor is built of:

Material	Thickness (mm)
Chipboard	12.5
Beam	225
Air space	20
Loose-fit mineral wool	200
Foil (Damp-proof course)	-
Gypsum board	12.5

The U-value of the roof is 0.23 W/m^2K, this value is taken from the drawings of the house in Poland.

The roof has a low height so there is no way for someone to live there. We can also see that there are plenty of beams across the attic space, which helps to support the roof. As we said the roof is a none-insulated roof, which contributes to lowering the temperature remarkably during the winter period. The same applies during summer when the roof will be heated by the sun; it will lead to a higher temperature in the wind space.

Figure 5.1 Roof construction

There are small ventilation openings that go through the ceiling; their task is to provide the indoor space with some fresh air during the summer. But as we noticed, these ventilation openings have given rise to some major problems. First of all, you get a thermal bridge, which makes it possible for the heat to easily transfer from the inside. Those living in the house have tried to eliminate that problem by covering the openings with some sort of cloth, so that the heat cannot pass though.

During the winter when the attic space is cold due to the low temperature, the water content in the air is also low. Inside the house the temperature is higher and in combination with some activity from the people, the water content in the air becomes higher. What happens is that the water from the inside transports through the ventilation opening, freezes when it reaches the attic space. After some time when the attic space becomes warmer, the water that earlier breezed now instead melts and in turn that gives some major moisture damage around the ventilation opening as seen in figure 5.2.

Figure 5.2 Moisture damage in the ventilation opening

5.1.4 Exterior walls

An external wall built of wood is not very usual to encounter in Poland. Instead, it is usually heavy structures where the building carcass is built on concrete. Externally directly on the concrete, you apply insulation where the thickness varies greatly depending on how much you are prepared to invest financially. There is no real requirement set on how much insulation that is required. But Zbigniew Stempak (2012) told us during the interview, that the average thickness of insulation in external walls usually nowadays is around 150 mm.

Material	**Thickness (mm)**
Render	10
Mineral wool	120
Aerated concrete	240
Gypsum plasterboard	13

The external wall has a U-value of 0.27 W/m²K, this value is taken from the drawings of the house in Poland.

As we mentioned earlier the most common building frameworks in Poland are built on concrete and in some cases hollow bricks. The house in Poland is built on aerated concrete which is seen in figure 5.3. This is a relatively brittle material, and must therefore be handled with caution during the construction and delivery. The structural strength in the concrete varies depending on how much moisture is stored inside. If the moisture content exceeds 10 %, you will get major changes in the structural strength. It is therefore important to have insulation on the outside so that the concrete does not under any circumstances get exposed to any form of moisture. The thermal conductivity is pretty low if you compare it to standard concrete, this in turn means that it is a good alternative from an insulation point of view (Burström, 2010).

Figure 5.3 External walls built of aerated concrete

5.1.5 Windows

All windows in the house are double glazed windows with a U-value of 2.6 W/m²K. The U-value of these windows is not good enough considering the options that are available as of today. The windows can be opened in two different ways; one way in which you open the whole window inwards and the other way where you can tilt the top of the window inwards. The feature where you can tilt the window inwards is very helpful during the summer, when ventilation is useful.

All windows have a solid sun protection that can be mechanically regulated. The good thing with these kinds of sun protections that are placed on the outside is that it during the summer stops the heat from entering the house. Those living in the house are claiming that the room obtains a comfortable temperature when protected against the sun; making it easier to sleep during the night.

Figure 5.4 Window with external sun blind

5.1.6 Air tightness

Air tightness is important to consider as it can provide unnecessary heat losses during winter if not properly executed. In this house we noticed two culprits that most likely affect the air tightness. In each room there is an opening under the window that can be regulated as seen in figure 5.5. In this way you have the opportunity to ventilate the house with the air from the outside. We feel that this feature is unnecessary given that you have the window that can be tilted and fix this need. On the other hand, it can provide similar moisture damage in the wall as in the ventilation openings in the ceiling which we described in section 5.1.3.

Figure 5.5 Ventilation opening in the external wall construction

Speaking of the ventilation openings in the ceiling, we suspect that it is the other culprit for harming the air tightness. This feature has also been found to be unnecessary since it has not given the desired effect. Considering that the roof is about to get some supplementary insulation, this opening will not be used anymore and instead hopefully provide better air tightness. When performing our simulations we have assumed how much impact the air tightness has on the indoor climate. Since we have the ventilation openings in the external wall and ceiling, we have set the leakage flow to 8 l/s, m² at 50 Pa pressure difference.

5.1.7 Measured indoor climate in the house

During a four month's period we measured the indoor temperature in this particular house. The measurements started on 5th of December and ended on 5th of April. Based on our temperature values we can confirm that they match pretty well, since throughout the whole period as the device measured the indoor temperature, the hallway was heated to 21 °C.

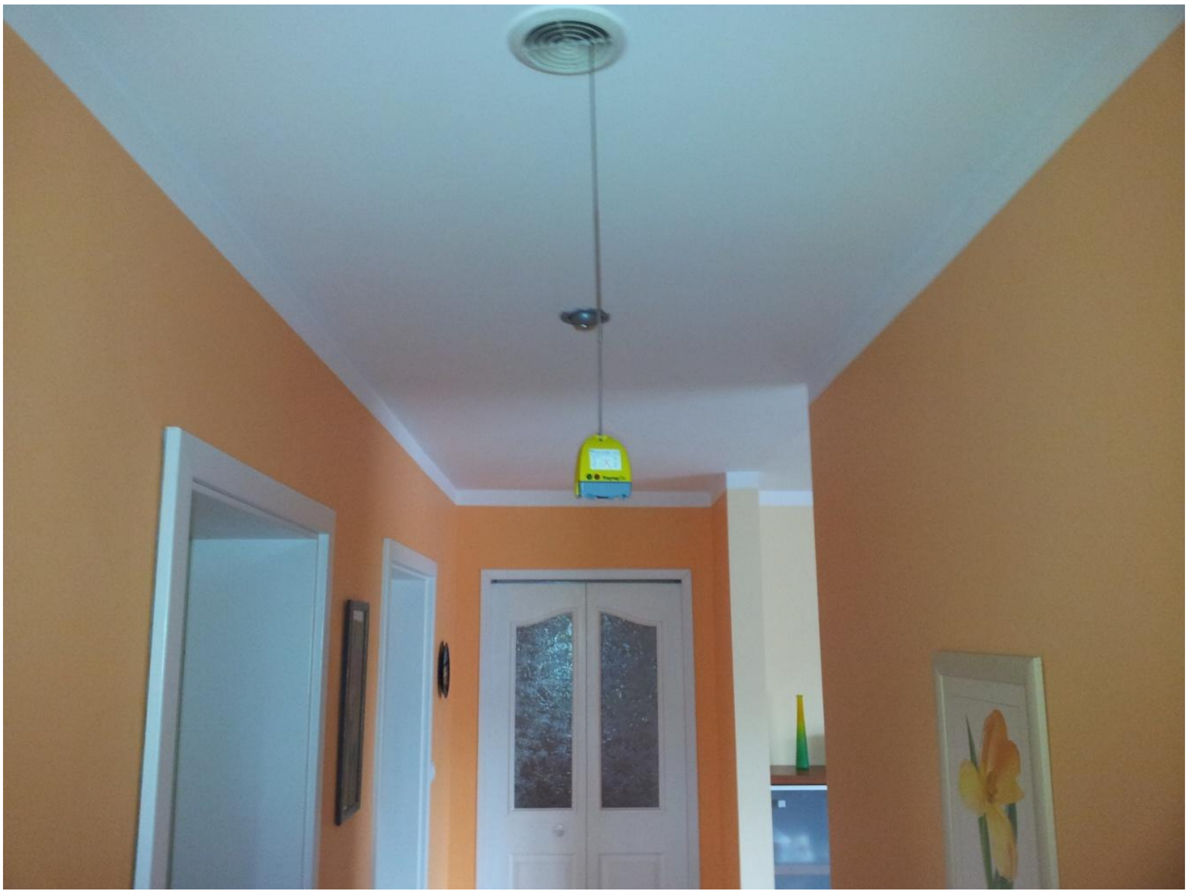

Figure 5.6 Device measuring the indoor temperature in the hallway

In figure 5.6 you can see how we placed the device in the hallway.

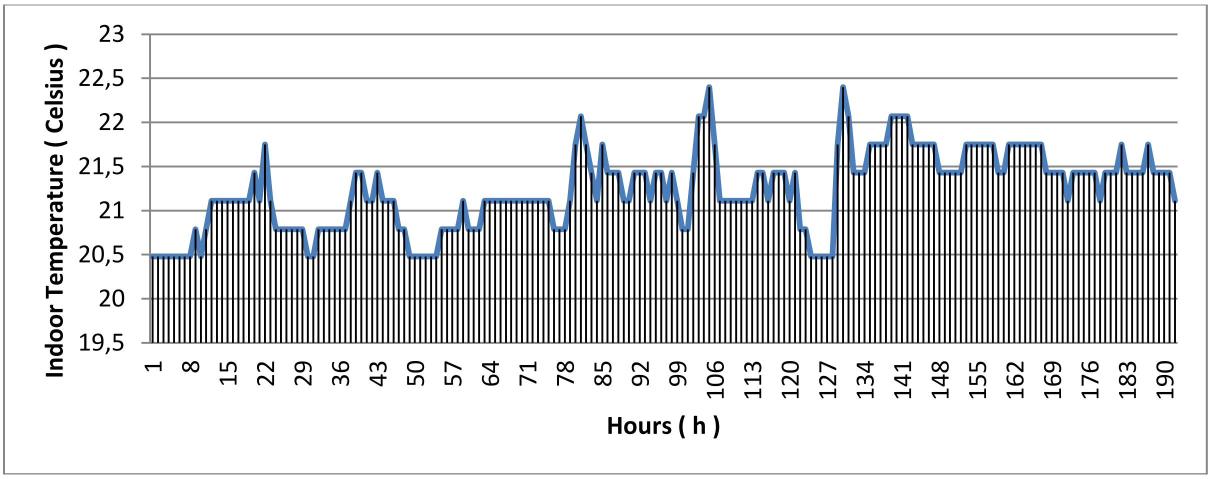

Figure 5.7 Indoor temperatures during 20th-27th December of 2012

In figure 5.7 we present a graph of how the indoor temperature varies under a one week period in December. The temperature goes up and down but you can clearly see that it tries to adhere to 21 °C.

5.2 Kosovo

This is a structural analysis of the building in Kosovo. All photographs of the building have been taken by us during our visit there.

5.2.1 Floor plan

This is a two-storey house which consists of 4 rooms, two toilets and a kitchen. The lay out plan is simply formed; with a toilet, living room and kitchen on the ground floor and with the second toilet and three bedrooms on the 2^{nd} floor. To get to the 2^{nd} floor you have an opening in the corner where there is room for a staircase. If there would be some heating on the ground floor, some of the heat would more or less affect the temperature on the second floor, given that hot air rises.

5.2.2 Elevations

The house has a square type of structure, which probably is not the most optimal when it comes to the use of sun radiation. One problem that we found with this house is that it is oversized with windows on one of the elevations. If you do not have a proper heating system or solid sun protection, it will definitely get very cold during winter and warm during summer in that part of the house. By looking on the elevation you can directly see that the house is complicated built, with many construction elements that stand out and causes unnecessary thermal bridges.

5.2.3 Roof

The roof has no insulation in the roof between the roof trusses neither directly on the loft floor. That is why it becomes pretty cold during winter, as we mentioned earlier in the previous chapter. Hereby, we present a table of what the roof is built of.

Material	**Thickness (mm)**
Concrete tiles	-
Tiling batten	45
Counter batten	45
T&G Board	20
Top chord	140

The loft floor has no insulation, and it only consists of 250 mm of hollow bricks.

Figure 5.8 Roof trusses with a centre distance of 900 mm.

The roof has a U-value of 0.64 W/m²K, this value comes from the simulation program DEROB-LTH, when we specified what materials the roof consists of.

Under the roof there is space for a large room of 8.8 x 3.7 m. If this room eventually would be used for living purpose it would have to be insulated, to keep the indoor temperature somewhat comfortable. When we entered the room under our visit we could feel the cold coming from the top of the building, because the temperature was rising further down the house we came. During the summer the temperature rises to a level where it is not comfortable, and this can be due to the low heating capacity. The whole building's climate is thus affected by the non-insulated roof. In the ceiling there are three chimneys, these are built of bricks. One of them is placed in the room area and the other two in each side of the room.

5.2.4 Exterior walls

The exterior walls are constructed by hollow bricks. On the outside there is a layer of 50 mm Styrofoam with a render of 10 mm on it. On the inside the external wall is covered by a thin internal plastering to stop the moisture from entering the hollow bricks. An electricity and water installation goes inside of the hollow bricks.

Material	Thickness (mm)
Render	10
Insulation (Styrofoam)	50
Hollow bricks	250
Gypsum plasterboard	10

The external wall has U-value of 0.52 W/m²K, which we also received from the simulation program DEROB-LTH.

Figure 5.9 Exterior wall built with hollow bricks.

According to Latif Jashari (2012), the hollow bricks are the best option when building a house in Kosovo. That is why they are basically used in nearly all buildings around here. The question is if 50 mm insulation is sufficient enough to stop the heat from the inside to escape. The winter can be pretty cold here around, and therefore a good U-value in the construction parts is something that must be considered. Just to mention the requirement of insulation that is needed in Sweden, there is a recommendation which says that there should be at least 200 mm (Isover 2, 2012). The hollow bricks are good in some aspects in comparison to massive bricks. Since there are small holes filled with air inside the brick that improves the U-value, and apart from that it also becomes cheaper than the massive bricks.

5.2.5 Windows

The windows are double glazed windows with a plastic construction. The U-value is 2.6 W/m²K. This leads to a lot of transmission losses from the house. We asked Latif Jashari (2012), why double glazed windows are used and if there possibly are any better options. He said that there nowadays also are triple glazed windows available on the market. But that almost no one was willing to invest so much money on such windows, since they are almost twice as expensive as the double glazed windows. All windows in the house contain internal window blinds for sun protection. Those blinds will create a shadow so that it will be more comfortable to stay in the room. But it is also important to mention that the internal sun protections, does not prevent the room from heating up. In that case we will have to use external sun protection, which not only creates a shadow, but it also stops the heat from entering. The window is constructed in such manner so that you can open it in two different ways. You can either open the whole window inwards as you can see in figure 5.10, or by just tilting the top of the window. This works as a great ventilation function, especially during the summer when it can become pretty warm inside.

Figure 5.10 Double glazed windows with a U-value of 2.6 W/m²K

5.2.6 Air tightness

The air tightness of the roof is a major problem here. Throughout our whole examination we discovered small air holes all over the place. The air tightness was worst executed where the chimneys and roof meet. You could see out from inside the attic. There are three chimneys in the house, which is too many because everyone releases hot air from the house. The air tightness was also poorly executed in the connection between the roof and the exterior wall.

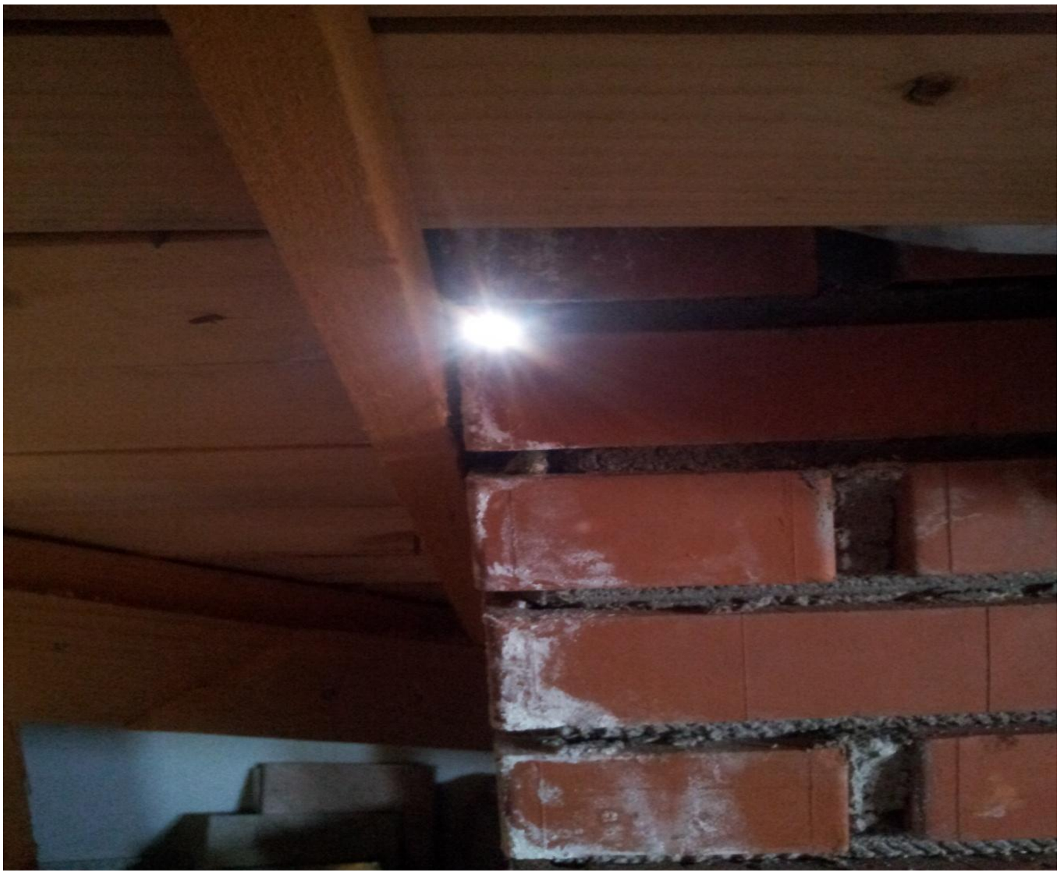

Figure 5.11 Air transfer in the connection between the chimney and roof

We can hereby conclude that the air tightness is poorly done, therefore in our simulations we have assumed a leakage flow of 10 l/s. m² at 50 Pa pressure difference.

5.2.7 Measured indoor climate in the house

At the moment there is no heating system installation in this house, but there are pipes laid for future installment of radiators. However, since there is no heating the indoor temperature becomes remarkably cold during winter. By looking on the data that we received from our measurements, we discovered that the temperature was unacceptably low. The measuring device was placed on the 1st floor in the hallway; from the hallway you can take the stairs up directly to the attic space. When we recently described the air tightness in the attic space, we mentioned that there were plenty of air holes from where the outside air could easily enter. Since there is no separation from the 1st floor and the attic space in form of a door, the 1st floor ends up having a low temperature and making it uncomfortable to stay in for a human being.

Figure 5.12 Device measuring the indoor temperature on the 1st floor

Hereby we present a graph in figure 5.13 of how the indoor temperature looked like during a one week period in December.

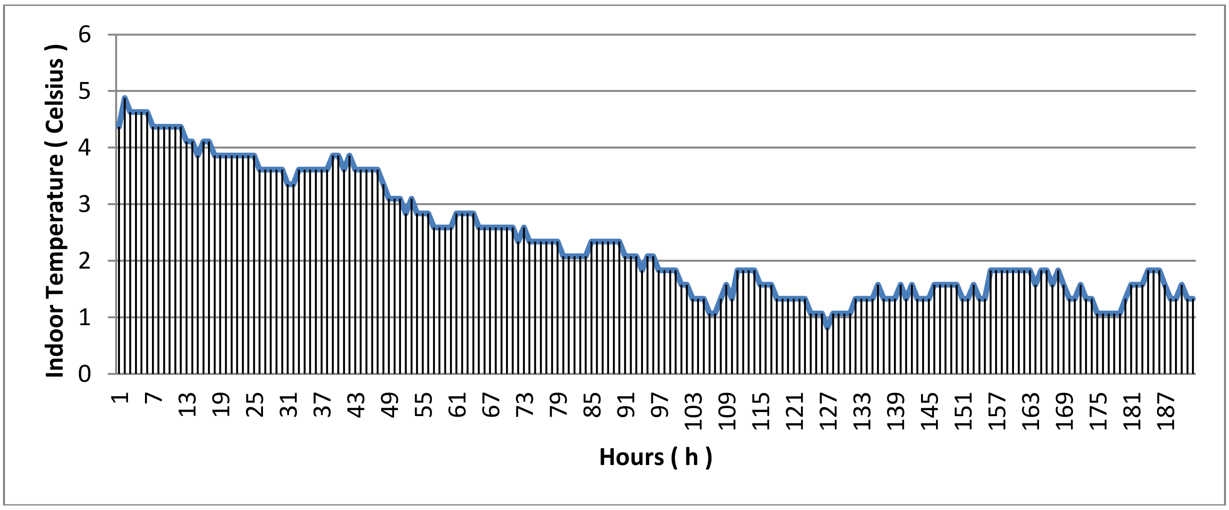

Figure 5.13 Indoor temperatures during 20th-27th of December 2012

As you can see the temperature is below 5 °C, and is almost down to zero temperature. When all the different building materials and pipes in the house get exposed for these kinds of temperatures, you can get devastating outcomes since they all are more or less susceptible to frost damage.

6 Measures to improve the energy efficiency

Now that we have gone through the most vital building elements and analyzed them in detail, we will now propose possible measures which eventually can contribute to energy conservations.

6.1 Poland

6.1.1 Roof

Insulating the attic space is a great way to save heating costs, it can provide up to 25 % in savings and it is possibly the easiest action to perform. Given that no one will stay in the attic space during the year, there is no point to insulate to roof. The loft floor already has an existing insulation of 200 mm. By looking on ISOVER Sweden's website, they recommend a total insulation of 500 mm (Isover 1, 2012). Therefore, we want to apply a supplementary insulation (glass wool) of 300 mm above the loft floor. This measure will also contribute to a remarkably lowering of the U-value.

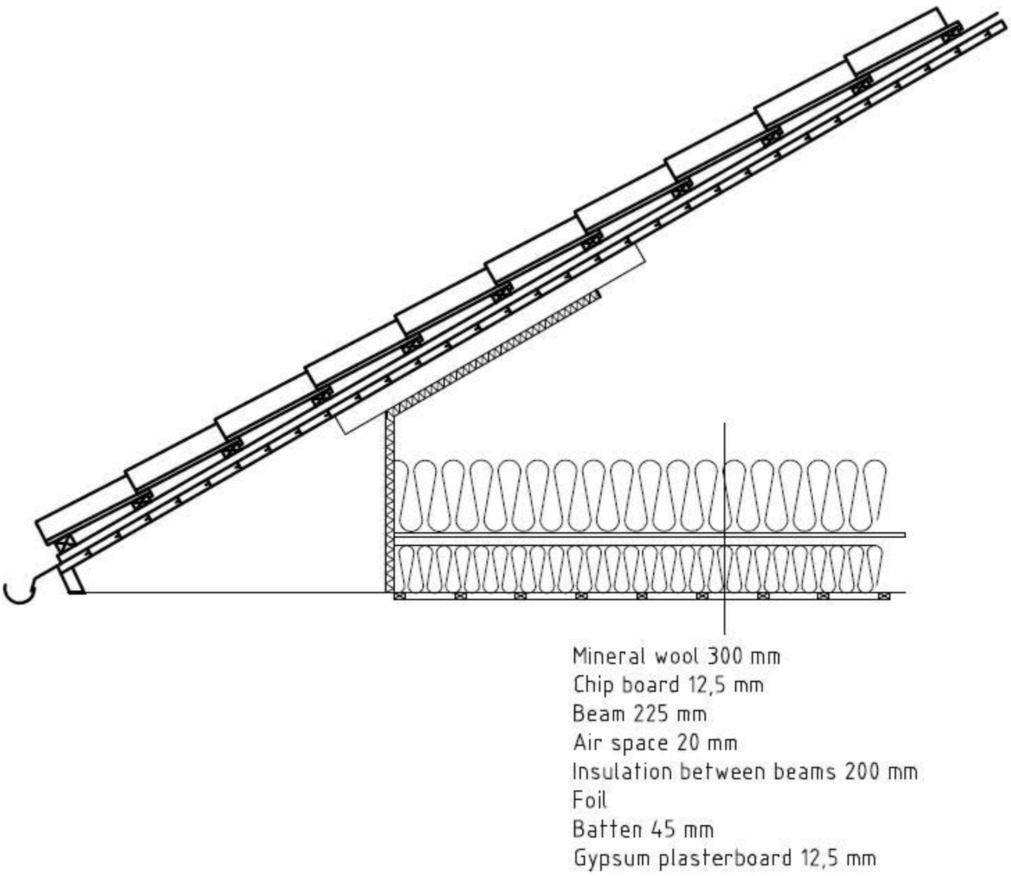

Figure 6.1 Improvement of the roof with 300 mm of supplementary insulation

When adding supplementary insulation it is important to notice that the wind space will become colder, since it will stop the heat from the inside. Therefore, there must be a moisture barrier in form of a plastic foil so that no moisture transfer can occur. In our case there already is one so there is really nothing to worry about. But if there would not be one this is something that definitely must be considered, if you do not want any moisture damage in the construction.

In figure 6.1 you can see how we want it to look like when the supplementary insulation has been added. You can see a wind deflector that runs parallel to the roof; its function is to lead the wind so that it does not go directly into insulation. If the wind eventually would go directly through the insulation, it would reduce the insulation capacity.

6.1.2 Exterior walls

Our external wall unit consists of aerated concrete with an exterior insulation of 120 mm. When you are about to add supplementary insulation in your wall, there is a requirement in Sweden from BBR that wants you to achieve a U-value of 0.18 W/m²K. This U-value equals a thickness of 200 mm of insulation (Isover 2, 2012). You can either add 80 mm insulation or remove everything and then apply the total of 200 mm. Given that it is more expensive to remove the existing insulation, we will simply add 80 mm and later count on what costs and energy savings that particular action will generate.

From the construction drawings for the specific house we could see that the current U-value for the exterior wall without any improvements is 0.27 W/m²K.

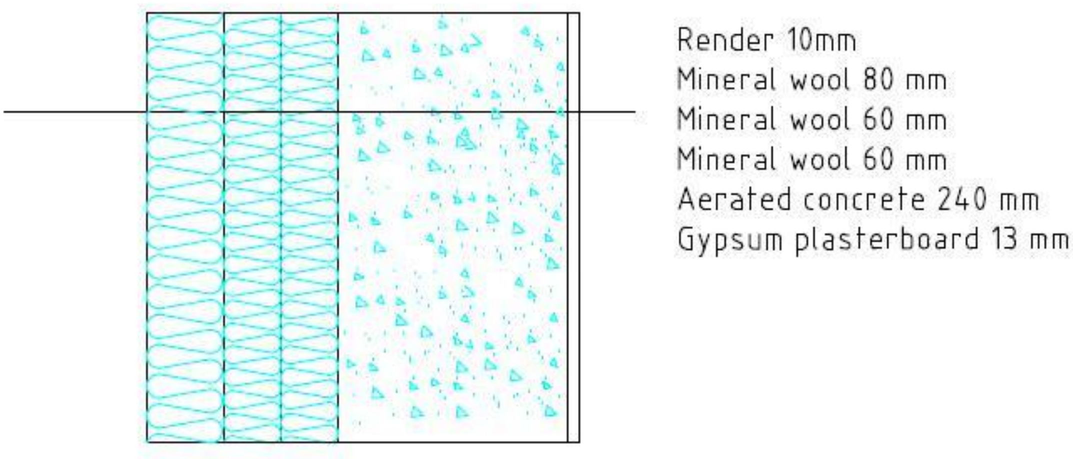

Figure 6.2 80 mm of insulation added to the exterior wall

6.1.3 Windows

The existing double glazed windows have a U-value of 2.6 W/m²K, which nowadays is classified as poor from an energy perspective. Their area is relatively huge compared to the facade, if we now replace the existing windows with triple glazed windows we will hopefully be able to obtain staggering downsizing in energy costs.

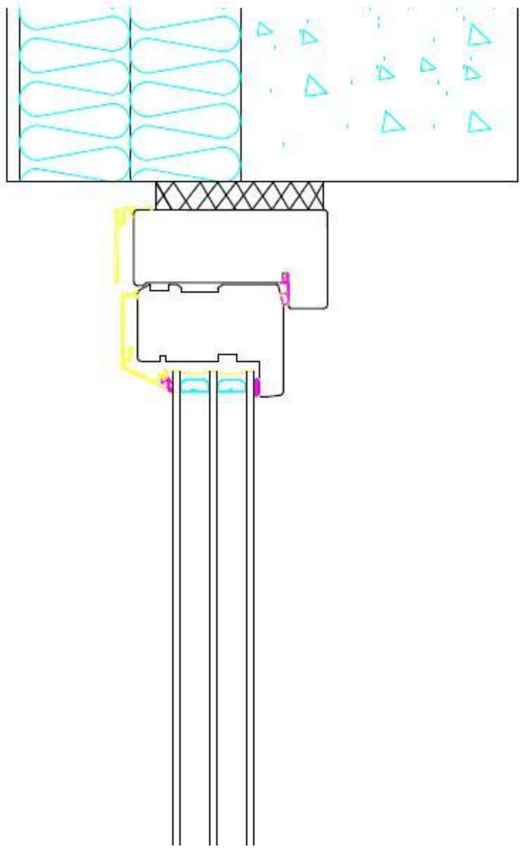

Figure 6.3 Recommended triple glazed windows

By improving the U-value of the windows from 2.6 W/m²K to 0.8 W/m²K it will probably lead to higher indoor temperatures during the summer, if no form of ventilation/cooling is applied. Therefore it makes sense if the new windows have the same sort of mechanical features as the previous ones, which we explained earlier in section 5.1.5. Especially the external sun protection, as it stops the sunlight from entering the house. Many people believe that internal sun protections in form of venetian blinds are enough to protect the house from the heat. The only thing they do is to create a shadow inside, but the sunlight will continue through the window and heat up internally. Consequently, we strongly recommend that you install external sun protection unless you already have these, even if they are slightly more expensive. When increasing the insulation in the external wall, the window will automatically be positioned deeper into the wall and it will naturally reduce direct solar radiation.

6.1.4 Air tightness

Earlier in the structural examination we localized two culprits which probably prevent proper air tightness in the house. When adding supplementary insulation in the roof and the external wall, both of these ventilation openings will be clogged and not used anymore. This action is very crucial, especially during winter if you want to save money so that no unnecessary heat energy is lost.

Another problem that we did not mention in our examination, are eventual leaks from the windows that may arise. Given that the windows are relatively new and of good quality, we assume that the yarning on the outer edges of the window are well applied. The problem of leakage is more likely to occur if the window is old and built in an old fashioned way. In any case a window replacement will be good, but be sure to apply the new yarning properly so that minimal leakage can occur.

6.2 Kosovo

6.2.1 Roof

The first priority is to insulate the non-insulated roof. There are two options to choose from in this situation. We can either insulate between the trusses on the roof or put insulation directly on the loft floor. If you by any mean want to take advantage of the attic space, you would have to consider the first option. The second option will be most effective in terms of energy because we can basically put how much insulation we want to. We think the house is big enough without using the attic space as a living space. Therefore we have chosen to sacrifice that space and go with the insulation directly on the loft floor. Beyond that, it is also much easier to accomplish and will surely give us positive results from an energy point of view.

As of now the loft floor has no insulation at all. It is composed of hollow bricks, and it is the only layer which separates the floors from each other. Since the hollow bricks have a pretty high thermal conductivity, the heat that you generate can easily transfer and in turn you get unnecessary heat losses. Our proposal is to add some supplementary insulation directly on the loft floor; so that we can prevent the heat from escaping and the cold from entering. When we earlier wrote about the roof in Poland, we mentioned the requirement that Isover in Sweden has, which is 400-500 mm of insulation on the roof. To be more accurate we will add 360 mm of insulation and from there see how it affects the energy consumption. We will also test with 120 mm to be able to see if there is a huge difference in energy use.

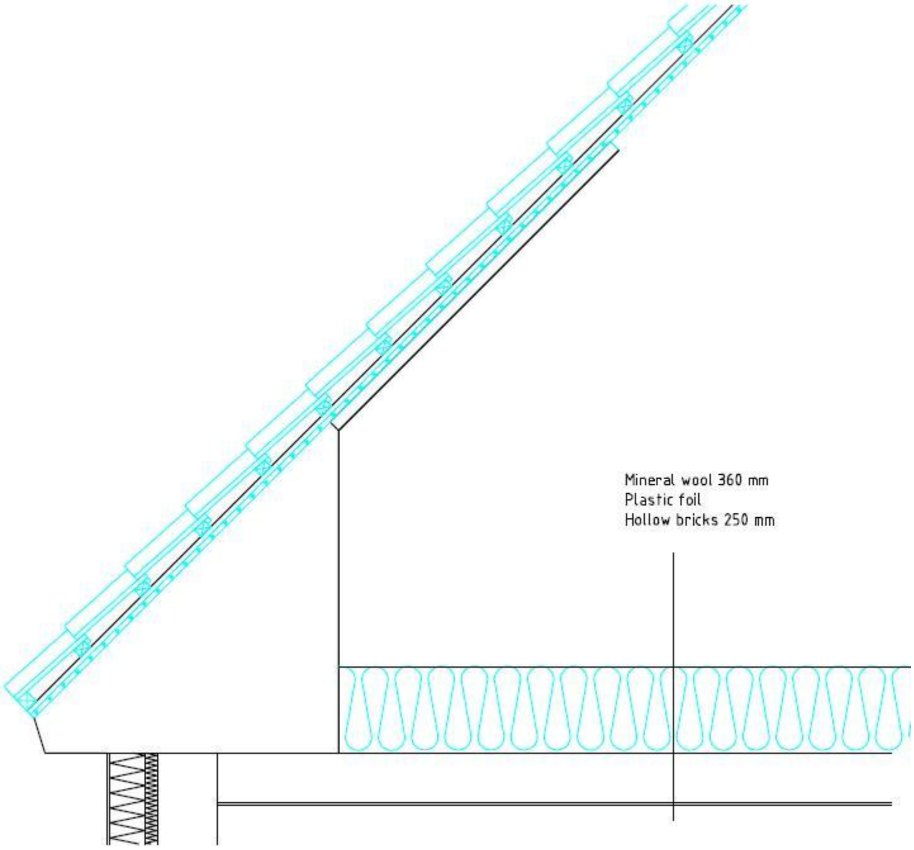

Figure 6.4 Roof in Kosovo with supplementary insulation

6.2.2 Exterior walls

Usually they say that if a material has a very good insulation capability, its heat capacity suffers. The same applies when it is on the contrary, and as we mentioned earlier the external wall is built of hollow bricks. Hollow bricks are in this case a middle ground; it has a good insulation capability and a good heat capacity.

The wall has an external insulation of 50 mm; the most optimal would be to add 150 mm of insulation so that the total would be 200 mm which we strive for. But since the insulation in Kosovo is sold in 120 mm in thickness we will not be able to choose 150 mm of insulation. Therefore we will add a total of 120 mm of supplementary insulation. In this way we will somewhat be able to match the requirement from BBR in Sweden.

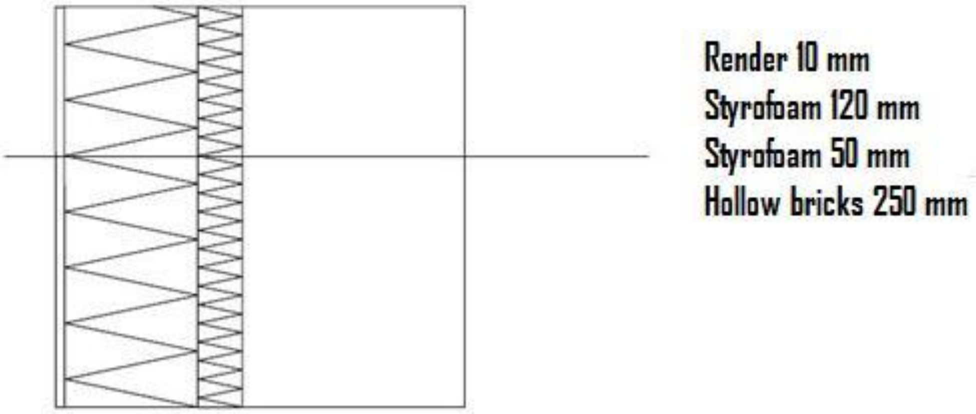

Figure 6.5 120 mm of insulation added to the external wall

6.2.3 Windows

The current windows are not that good from a U-value point of view. Since this house has a large window area, by replacing the current windows with triple glazed windows we can obtain positive energy results when we simulate. The house has balconies that act as sun protection for the windows. The windows also have internal sun protection in form of venetian blinds, but as we explained earlier they are not enough to protect the house from the sun radiation. Therefore, we also recommend that you consider external sun protection. This will help a lot, especially during the summer when it can become pretty warm in Kosovo.

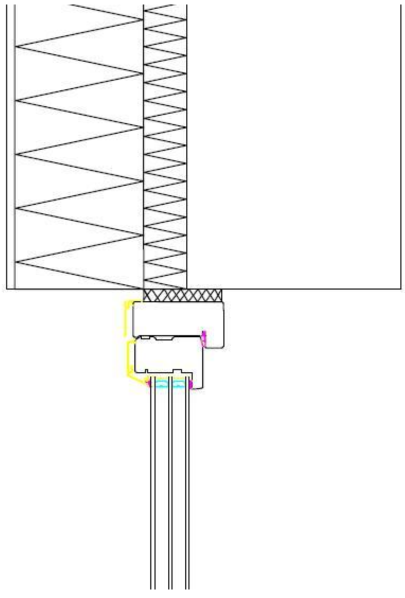

Figure 6.5 Triple glazed windows

6.2.4 Air tightness

Earlier in our structural examination, we could conclude that the air tightness was not the properly executed up in the attic space. This leads to a chain reaction, when the wind space get cold during winter so will the rest of the house. The reason for that is because there is no form of separation from the attic space to the rest of the house, instead there is an opening through the loft floor and intermediate floor to make room for the stairs.

When we insulate the loft floor we will separate the attic space from the remaining floors, thus the poor air tightness will not matter anymore since it will not affect the rest of the house.

7 Simulations & calculations

7.1 Simulation program

In order to help us perform our simulations we used an application called DEROB-LTH. As we described earlier in chapter 1, this is an energy simulation program which will provide us with results of how efficient the improvements we make actually are. In the program we have built a 3D-model of the houses that we are studying in Poland and Kosovo. For each house we have got a climate file that we set in the program, in this way our results became more realistic. During the simulations the program takes sun radiation and sun protection into account, from there it calculates the indoor temperature, energy demand and air leakage flow.

7.2 Conditions

During our simulations we had exactly the same settings for both houses. The production of internal loads was set to 500 W during the day and 150 W during the night. Both houses have a light-coloured facade, thereof we have set the absorptance to 35 %. Indoors there are also light colours but the absorptance was set to 25 %. The roof has a darker colour and the absorptance was set to 70 % for both houses. The leakage flow is set individually since it is based on how well the assumed air tightness is for that specific house.

7.3 Poland

In figure 7.1 we can see a simplified model of the house in Poland that we have sketched in DEROB. The house is divided into two volumes, because the house was heated differently. The first volume was heated up to 21 °C during a six month period, and the second volume was only heated up to 16 °C.

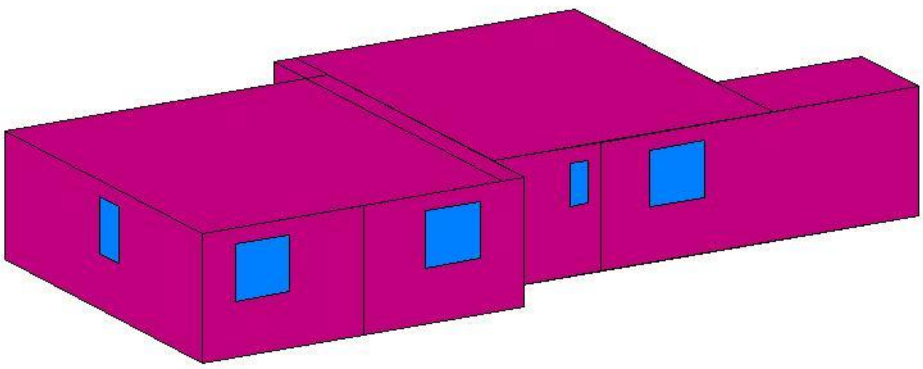

Figure 7.1 Model of the house in Poland – Note that volume 1 is on the right side and volume 2 is on the left side

With this simulation we have a couple of things that we want to accomplish. First, we simulated the house without any improvements to see how many kWh it requires to get up to 21°C in volume 1 and 16°C in volume 2. Then we compared the value of kWh that we get from the simulation with the real amount of kWh that was used. After that, we individually simulated the various proposals that we have come up with. In this way we were able to see which of the measures that gave us the greatest reduction in kWh. Finally, we brought up all the proposals together and simulated them simultaneously, and from there we could see what the total reduction of kWh was.

7.3.1 Case 1 – Before improvements

We simulated the house as it stands today, and from there we could see how much kWh is required. Then we compared the number of kWh that we receiv-ed from the simulations with the real amount of kWh that was during a one year period.

Before we started the simulation we had to put in some data into the program. In our walls, windows and roof we have the exact same materials that we described earlier in chapter 5. We have also thought about the poor air tightness and since there were some deficiencies, we made an adoption and have put the average leakage flow of the wall and roof to 8 l/s, m².

7.3.1.1 Calculated results

Figure 7.2 Oil burner

From our simulation we got that the average air exchange rate was **0.84 ach/h** when the leakage flow is set to 8 l/s, m². Today they usually say that the air exchange rate should be at a maximum of 0.5 ach/h to be classified as good. When we improve the air tightness we will surely be able to meet the requirement.

All water that is sent to the radiators is heated up by a burner driven on oil. During a one year period the house used 1100 dm³ of oil for heating purpose, and by looking on chart 4.1 we can calculate that 1100 dm³ of oil equals **11077 kWh**. Since the oil burner has an efficiency set at 80%, the real amount of kWh produced is **8861 kWh**. From our simulations we could tell that the house needs **8457 kWh** when being heated to 21°C in volume 1 and 16°C in volume 2. By comparing those two values we can conclude that they match pretty well. If you instead would like to heat the whole house to 21°C, according to the simulations it would require a total of **10367 kWh**. This value will be seen as a reference point that we start from when we improve the different parts of the house.

Table 7.1 Input data before improvements

Building element	**U-value (W/m²K)**	**Leakage flow (l/s, m²)**
Roof	0.23	8
External wall	0.27	8
Windows	2.6	-

7.3.2 Case 2 – Improvement of air tightness

In this case we will improve the air tightness by lowering the leakage flow from 8 l/s, m² to 4 l/s, m². Hopefully we will be able to reduce the air exchange value to 0.5 ach/h or below. And that will in turn lead to a less required amount of energy.

7.3.2.1 Calculated results

By lowering the leakage flow we received an improvement in the air exchange. In the previous case when the leakage flow was set to 8 l/s, m² we had an average air exchange of **0.84 ach/h**. Now when the leakage flow instead was set to 4 l/s, m² we received an average air exchange of **0.42 ach/h**. By this we can conclude that this value match the requirements that we mentioned in the previous case. To prove that good air tightness in the building envelope results in less energy losses, we also simulated how much energy that now was required to heat the house to a temperature of 21°C. From the simulations we could now tell that the house requires a total of **8081 kWh** which is a decrease of **2286 kWh**. We will not calculate how much it costs to improve the air tightness. But by looking on the improvement it provides in kWh, and how cheap it is to fix we can conclude that this is a very profitable measure.

Table 7.2 Input data when improving the leakage flow

Building element	**U-value (W/m²K)**	**Leakage flow (l/s, m²)**
Roof	0.23	4
External wall	0.27	4
Windows	2.6	-

7.3.3 Case 3 – Roof with 300 mm of supplementary insulation

Now we will add the 300 mm of supplementary insulation on the roof and see what results we get from the simulations.

7.3.3.1 Calculated results

We get a significant improvement of the U-value when we apply loose-fit mineral wool directly on the top of the loft floor. The new U-value is 0.1 W/m²K and gives us a reduction of **526 kWh**.

Table 7.3 Input data when adding supplementary insulation on the loft floor

Building element	**U-value (W/m²K)**	**Leakage flow (l/s, m²)**
Roof	0.1	8
External wall	0.27	8
Windows	2.6	-

The improvement in kWh is much lower than we had expected, you should almost consider not doing any improvements on the roof. In a short-term this affair can become pretty expensive. The reason we got such a small improvement when we added the supplementary insulation, may be due to the fact that there already was an insulation of 200 mm.

7.3.4 Case 4 – External wall with 80 mm of supplementary insulation

The external wall consists, as we mentioned earlier of 120 mm insulation. In this case we added 80 mm of insulation with a λ-value of 0.039 W/mK, so that the total would be 200 mm.

7.3.4.1 Calculated results

Table 7.4 Input data when improving the external wall

Building element	**U-value (W/m²K)**	**Leakage flow (l/s, m²)**
Roof	0.23	8
External wall	0.169	8
Windows	2.6	-

As in the previous case, we expected a greater improvement. As you can see the new improved U-value in the external wall after adding the supplementary insulation is 0.169 W/m²K, and that gives us a reduction of **529 kWh**. The former U-value of the external wall was 0.27 W/m²K which is not bad; therefore the improvement of kWh is not that overwhelming.

7.3.5 Case 5 – Improvement of windows

At the moment the double glazed windows in the house has a U-value of 2.6 W/m²K, and in this case we did replace them with triple glazed windows with a U-value of 0.7 W/m²K.

7.3.5.1 Calculated results

Table 7.5 Input data when adding triple glazed windows

Building element	**U-value (W/m²K)**	**Leakage flow (l/s, m²)**
Roof	0.23	8
External wall	0.27	8
Windows	0.7	-

By replacing the windows we received an improvement of **833 kWh**. Besides the improvement of the air tightness, this is the best reduction that we received in kWh from our simulations. In this case we may have wished for a better improvement, since triple glazed windows cost twice as much as double glazed windows.

7.3.6 Case 6 – Combined improvement

In this case we simulated all the improvements at once. In other words the improved U-values of the building elements and the lowered leakage flow.

7.3.6.1 Calculated results

Table 7.6 Input data when combining all improvements

Building element	**U-value (W/m²K)**	**Leakage flow (l/s, m²)**
Roof	0.1	4
External wall	0.169	4
Windows	0.7	-

When combining everything, we get a reduction of **4349 kWh** which equals **432 dm³** of oil. This means that we almost halved the use of energy, which can generate positive results economically.

7.3.7 Conclusion over results from DEROB-LTH

After having worked out how much each case contributes to the decreasing of kWh, we have set up a chart that shows the improvement of each case in percentage.

Table 7.7 Improvement in percentage

Case	**Improvement**	**Energy use (kWh)**	**Improvement (%)**
1	-	10367	-
2	Air tightness	8081	22
3	Roof	9841	5
4	External wall	9838	5
5	Windows	9534	8
6	Combined	6018	42

If we start by looking on the air tightness, you can see that it contributes to as much as 22 % of the improvement. This is by far the best of all cases and demonstrates the importance of having an airtight building envelope.
By adding supplementary insulation in the roof and external walls, it appeared that it gave the same improvement in percentage. Before the simulations we thought that we would have a greater reduction in kWh. It may be due to the fact that we simulated the improvement of air tightness individually. Because when you add insulation there are always small openings in the existing insulation that can be clogged by applying the new insulation tightly. The same procedure goes for the windows, as you can see in the chart we received an improvement of 8 %. This value could get slightly higher if the air tightness would be taken in consideration. When replacing windows, you always apply new yarning around the window, which often improves the air tightness as well. Looking at the case where we combined all the improvements, we received a reduction of 42 % in energy use. As we mentioned earlier, this means that we almost halved the previous energy use.

7.4 Kosovo

Now it is time to simulate the house in Kosovo, and as you can see in figure 7.3, this is our model that we have sketched in DEROB. In reality the house has a more complex structure; with oriels and balconies. Therefore, we had do simplify the model a lot by making the house more square like and adding basic shading screens.

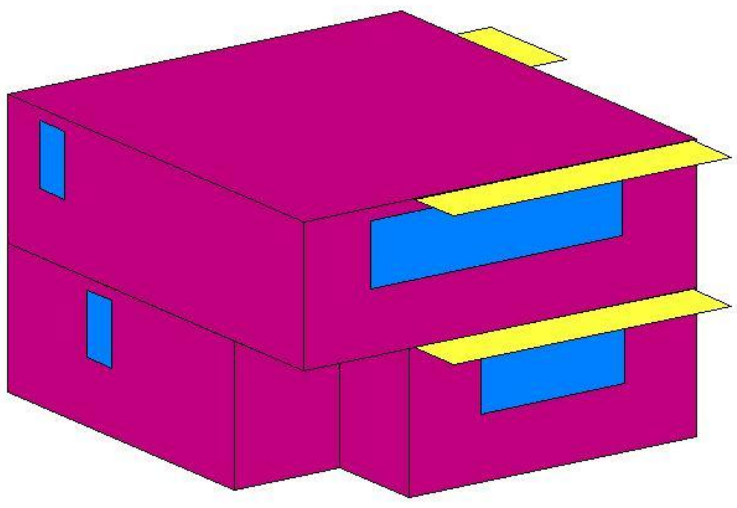

Figure 7.3 Model of the house in Kosovo – The house is divided into two volumes, of which volume 1 is the ground floor and volume 2 is the 1st floor

The house has no heating system installed; there are only pipes laid through the external walls and intermediate floors for possible future installation. We started by looking what indoor temperature the house gets without any heating and compared it with our measurements that we received from our measurements. Thereafter we simulated how many kWh it requires to get up to a temperature of 21 °C indoors without any improvements in the building elements. Lastly we simulated all the proposals that we came up with; individually and simultaneously. As we did with the house in Poland, we made a chart at the end that shows us which measurement that gives us the greatest reduction in kWh.

7.4.1 Case 1 – Before improvements

In this case we started by simulating the house without any heating, so that we could see what indoor temperatures we receive. Followed by a simulation, that shows us how many kWh that is required, to achieve an indoor temperature of 21°C when the house is being heated.

7.4.1.1 Calculated results

As you can see in table 7.8 the U-value is not acceptably good in the building elements. As for the leakage flow, we have assumed a value of 10 l/s, m² since we found it to be very cold due to the poor air tightness.

Table 7.8 Input data before improvements

Building element	**U-value (W/m²K)**	**Leakage flow (l/s, m²)**
Roof	0.64	10
External wall	0.52	10
Windows	2.6	-

When we have a leakage flow of 10 l/s, m² we receive an average air exchange rate at **1.08 ach/h**. As we mentioned earlier, the air exchange should not exceed 0, 5 ach/h to be classified as good. Since the house is poorly insulated, the various building elements have a high U-value. That is why we received a pretty high value of energy consumption from our simulations, more precisely **11626 kWh**. This energy value is required when the house is being heated to 21°C, and will be seen as a reference point as we improve different building elements.

We also compared the minimum indoor temperature we obtained from the simulation, with the average indoor temperature that we received from our devices that measured on site.

Table 7.9 Comparison of average indoor temperatures during a whole month

Month	**Measurements (°C)**	**Simulation (°C)**
January	0.4	-2.5
February	-3.0	-0.9

As seen in table 7.9, the values do not match completely, but still the differences are not that huge. The gap may be due to the weather of that specific period which varies from year to year, which affect the outdoor temperature. However, the important thing here is to demonstrate that the values match reasonably.

7.4.2 Case 2 – Improvement of air tightness

We have assumed a leakage flow of 10 l/s, m² and in this case we lowered it to 5 l/s, m² and from there we could see what energy savings we got.

7.4.2.1 Calculated results

By improving the air tightness with a lowered leakage flow of 5 l/s, m² we received an average exchange rate of **0.55 ach/h**, unfortunately we could not get under 0.5 ach/h and match the requirements, but still it is a great improvement. But this value can be useful in a relatively hot climate, where the high air exchange can act as ventilation. Apart from that, the lowered air exchange rate also manifests itself in reduced energy consumption. From our simulations we could now tell that the house requires a total of **9032 kWh**, which is a decrease of **2594 kWh**.

Table 7.10 Input data when improving the leakage flow

Building element	**U-value (W/m²K)**	**Leakage flow (l/s, m²)**
Roof	0.64	5
External wall	0.52	5
Windows	2.6	-

7.4.3 Case 3 – Roof with 120 mm of supplementary insulation

In this case we will add 360 mm of insulation in the roof as we proposed in chapter 6. We will also test with 120 mm of insulation in order to see how huge the difference is. And from there see what amount of energy that is required.

7.4.3.1 Calculated results

The U-value of the roof section before improvements was 0.64 W/m²K, and after adding the supplementary insulation of 360 mm we received a significant improvement. The new U-value is 0.095 W/m²K and the total energy consumption ends up at **9505 kWh** which is a decrease of **2121 kWh**. The mineral wool which we use for this house in Kosovo, are sold in 120 mm in thickness. For this improvement we used three layers, but we also tried and simulated with only one layer of 120 mm mineral wool, to see what energy savings that particular measure would provide. By adding 120 mm our new U-value ended up at 0.22 W/m²K and gave us a reduction of **1890 kWh**. We can conclude that when removing 240 mm of insulation we get an increase of **231 kWh**. The difference is not remarkably huge; therefore we have considered adding 120 mm of insulation instead of 360 mm as planned, which surely will be more profitable economically in the long run.

Table 7.11 Input data when adding supplementary insulation on the loft floor

Building element	**U-value (W/m²K)**	**Leakage flow (l/s, m²)**
Roof	0.22	10
External wall	0.52	10
Windows	2.6	-

7.4.4 Case 4 – External wall with 120 mm of supplementary insulation

The current exterior wall is very bad from an insulation point of view. With its measly 50 mm of insulation we receive a U-value of 0.52 W/m²K. This is far too high; therefore we added 120 of supplementary insulation (Styrofoam) with a λ-value of 0.039 W/mK. As in the previous case like the mineral wool, the Styrofoam is only sold in 120 mm in thickness.

7.4.4.1 Calculated results

As you can see in table 7.12, the new improved U-value when adding 120 mm of insulation the external wall receives a U-value of 0.20 W/m²K. From our simulation we can tell that the total energy consumption after this improvement was **10484 kWh** which is a reduction of **1142 kWh**.

Table 7.12 Input data when improving the external wall

Building element	U-value (W/m²K)	Leakage flow (l/s, m²)
Roof	0.64	10
External wall	0.20	10
Windows	2.6	-

7.4.5 Case 5 – Improvement of windows

The double glazed windows in this house have a U-value of 2.6 W/m²K. In this case we will replace them with triple glazed windows with a U-value of 0.8 W/m²K.

7.4.5.1 Calculated results

Table 7.13 Input data when adding triple glazed windows

Building element	U-value (W/m²K)	Leakage flow (l/s, m²)
Roof	0.64	10
External wall	0.52	10
Windows	0.8	-

The improvement is much lower than anticipated; it is by far the poorest improvement of all cases for the house in Kosovo. According to the simulation we the total energy consumption is **11379 kWh**, this gives us a reduction of **247 kWh**.

7.4.6 Case 6 – Combined improvement

This is the final case, where we simulated all the improvements simultaneously. We did not use the U-value that we received when adding 360 mm of insulation in the roof as intended from the beginning. Instead we used the U-value when adding 120 mm, since it almost gave the same reduction in kWh.

7.4.6.1 Calculated results

Table 7.14 Input data when combining all improvements

Building element	**U-value (W/m²K)**	**Leakage flow (l/s, m²)**
Roof	0.22	5
External wall	0.20	5
Windows	0.8	-

After simulating all the improvements at the same time, we get a total energy consumption of **5437 kWh**; this in turn gives us a reduction of **6189 kWh**. Although the replacement of windows proved us wrong and did not give us the desired effect, we got a good improvement in the roof and external wall to compensate from an energy point of view.

7.4.7 Conclusion over results from DEROB-LTH

Now as we are finished with all the simulations, we have set up a table that shows how much each case has improved in percentage.

Table 7.15 Improvement in percentage

Case	**Improvement**	**Energy use (kWh)**	**Improvement (%)**
1	-	11626	-
2	Air tightness	9032	22
3	Roof	9736	16
4	External wall	10484	10
5	Windows	11379	2
6	Combined	5437	53

First up comes the air tightness, where we obtained an improvement of 22 %. Once again we want to point out the importance of having an enclosed building envelope, since it generates less energy losses. From the very beginning, the house was poorly insulated. No insulation up in the roof, and only 50 mm of Styrofoam in the external wall. After improving both of these building elements, we received great reduction in kWh. The reason for this great reduction may be due to the fact that there practically was no insulation at first. So by adding some supplementary insulation on the roof and external wall, we received great improvements in percentage and they will surely give us some great results when we count on the payback time. When it comes to the windows, we were a little bit shocked by the results that the simulation gave us. We only received an improvement of 2 %, which is unacceptably low and can almost directly be considered as not worth improving. The reason why the improvement is that low, can depend on many factors. We believe that it can be due to the fact that the windows area is not equally divided over the elevations. Instead the house almost has all the windows on the western elevation, while the remaining elevations only have a small window area. However, even though we received a bad result from the case with the windows, the combined improvement must be seen as a success. It gives a total reduction of 53 % in energy use; with the roof, external wall and air tightness playing a major role.

8 Payback time for increasing the energy-efficiency

In this chapter we calculated how long the payback time is for each improvement. The materials that we use in our calculations are all available in each country. We were recommended to use these when we visited and talked to the different salesmen in each country.

8.1 Poland

8.1.1 Materials

We will use the same insulation material in the roof and exterior wall, as seen in figure 8.1 the insulation is called Climowool and it is developed by Schwenk Insulation. The material is made of glass wool and for the roof and external wall we use the one that has a λ-value of 0.039 W/mK.

Figure 8.1 Insulation that we use on the roof and external wall

When it comes to the windows we will use windows created on the basis of VEKA profiles. It is PVC (polyvinyl chloride) windows and they give you a high acoustic insulation and further on they also help to increase the indoor comfort by maintaining good air tightness (Amma, 2012).

8.1.2 Costs

The cost of the insulation in the roof and external wall are both retrieved from the same vendor. In this case as we mentioned earlier from Schwenk Insulation (Schwenk, 2012).

Table 8.2 Material costs for the roof and external wall

Improvement	**Material**	**Price (€/m²)**
Roof	DF1 039	11.5
External wall	FD1/ V 039	6.7

To obtain the price for triple glazed windows we talked to Andrzej Udzielak (2012), who works at a company called Amma in Boleslawiec, Poland. He told us that a triple glazed window with a U-value of 0.7 W/m²K costs **75 €/m²**. In this price the labour costs were also included.

We must also know how much 1 dm³ of fuel oil costs when we do our calculations. The owner of the house that we are studying told us that at present time **1dm³** of fuel oil cost **0.84 €**. This price is relatively cheap in comparison to Sweden's oil prices. Therefore, you should keep in mind that the payback period in our calculations will be longer, due to the cheap price of oil. But given that the oil prices will increase year by year in Poland and that the energy-efficiency of buildings will continue, the payback period will become shorter and the improvements in total will become more profitable.

8.1.3 Calculations

In this section we calculated how much each improvement will cost to implement. In table 8.3 you can see the total area of the various building elements.

Table 8.3 Total cost for each improvement

Building element	**Area (m²)**	**Price of material (€/m²)**	**Total cost (€)**
Roof	154	11.5	1771
External wall	202.9	6.7	1359
Windows	29.47	75	2210

As we expected, the improvement of windows turned out to be the most expensive. Followed by the improvement of roof and the cheapest improvement to carry out is the external wall.

8.1.3.1 Savings after measures

Table 8.4 Payback period of each improvement

Recommended improvement	**Energy Savings (kWh/year)**	**Cost savings (€/year)**	**Implementation cost (€)**	**Payback period (year)**
Roof	526	44.2	1771	40
External wall	529	44.5	1359	30
Windows	833	70	2210	31

Herby, in table 8.4 you can see how long time it will take to repay the recommended improvements. We can confirm that we have received a very long payback time, which can be interpreted as, if it is even worth making any improvements. The reason why it will take such a long time to repay the improvement of the roof and external wall must certainly be due to the fact that there already was existing insulation. Thereof, we had no substantial reduction in energy use. Regarding the windows, we thought that the payback period would be shorter. We did not have huge reduction in energy consumption after doing our simulations, which is why the energy saving for a year is low.

8.2 Kosovo

8.2.1 Materials

For the roof we have chosen to put mineral wool manufactured by Knauf Insulation, which we were referred to from the company Izolimi Dekor (2012) in Mitrovice. Knauf Insulation is a well known company in Kosovo, and they produce insulation for all parts of the house. The insulation that we will count on has a λ-value of 0.038 W/mK (Knauf, 2012).

The existing insulation on the external wall is made of Styrofoam, which is one of the most usual insulation materials used when insulating external walls in Kosovo. That is why we have chosen to add 120 mm of Styrofoam from Izolimi Dekor (2012) as supplementary insulation. You can see the insulation that we are about to use for the external wall in figure 8.5, it has a λ-value of 0.039 W/mK.

Figure 8.5 Styrofoam which we will use to insulate the external wall

As for the windows, we were not able to come in contact with a vendor who sells windows. But when we were interviewing Latif Jashari (2012), he told us that there are triple glazed windows with a U-value of 0.8 W/m²K available in the market.

8.2.2 Costs

Information regarding costs for both the roof and external wall was received when interviewing the employees from Izolimi Dekor (2012). To insulate the roof with 120 mm of mineral wool would cost **4.50 €/m²**, and to insulate the external wall with 120 mm of Styrofoam would cost **9.40 €/m²**. Note that labour costs are not included.

In terms of the prices for windows we talked to Latif Jashari (2012). He told us during the interview that the prices for triple glazed windows are twice the price of double glazed windows. Therefore, we went and looked at the receipts for the windows that they used for this particular house. From the receipts we could tell that double glazed windows cost 125 €/m², which means that triple glazed windows cost approximately **250 €/m²**.

We also had to know the kWh price, to be able to make our calculations. From October 1st to March 31st a kWh cost **0.064 €** (KEK-Energy, 2012). As the price of oil in Poland, this price is low in comparison to Sweden's as well. In turn the payback period in our calculations becomes longer. Therefore, be aware of the fact that the kWh price will surely increase in Kosovo.

8.2.3 Calculations

In this section we calculated how much each improvement will cost to implement. In table 8.6 you can see the total area of the various building elements.

Table 8.6 Total cost for each improvement

Building element	**Area (m²)**	**Price of material (€/m²)**	**Total cost (€)**
Roof	81.34	4.5	366
External wall	152	9.4	1429
Windows	25.16	250	6290

We received about the same cost when we improved the roof and external wall, and as you can see in table 8.6. Hopefully the payback period will not be so lengthy. But to improve the windows turned out to be an expensive affair, given how expensive the triple glazed windows are per m².

8.2.3.1 Savings after measures

Table 8.7 Payback period for each improvement

Recommended improvement	**Energy Savings (kWh/year)**	**Cost savings (€/year)**	**Implementation cost (€)**	**Payback period (year)**
Roof	1890	122.7	366	3
External wall	1142	74.1	1428	19
Windows	247	16.03	6290	392

In table 8.7 we present the payback period for each improvement. If we begin by looking on the windows, we must admit that we were not surprised over the payback period, considering how expensive the triple glazed windows are. As Latif Jashari (2012) pointed out in the interview, there is only a small fraction of the population that has these windows in their houses, which is totally understandable. We can already now conclude that it is not profitable to install these windows in Kosovo as of today. Before we improved the roof, there was no insulation as known. After the improvement we got a positive reduction in energy consumption, whereas the costs were not so high either. This resulted in a payback period of **3 years**, which is acceptable and should certainly be considered. When it comes to the external walls, the results here were pretty good as well. The payback period turned out to be about **19 years**, and if you think about it in a long term, this improvement should also be taken in consideration.

9 Discussion and conclusions

We begin with an individual discussion about the simulations and results for each house. After that we proceed with a common conclusion, to close it all together.

Before we started with improvements for the house in Poland, it was not that bad from an insulation point of view. The loft floor which separates the attic space from the indoor space had an existing insulation of 200 mm. While the external wall with aerated concrete as a building framework, had an exterior insulation of 120 mm. When adding supplementary insulation to both the roof and external wall, we did not receive any significant reductions in the total energy consumption for the house. The total implementation cost for each improvement was not so high, given that the total area was huge. But still this led to a payback period that exceeded 30 years.

When we changed the windows from double glazed with a U-value of 2.6 W/m² to triple glazed with a U-value of 0.7 W/m²K, the reduction of kWh was about 60 % higher than the improvement for the roof and external wall. On the other hand the implementation cost was pretty expensive, which also led to a payback period of 30 years.

So what conclusions can we make from here, is it even worth improving anything in this particular house? One thing that must be clarified is that this house was properly insulated from the very beginning, the better the house is insulated, the smaller reduction you get in kWh when improving with additional insulation. Since not all the houses built in Poland in the last 10 years have the same amount of insulation applied, there is no reason to stare blindly on these results and believe that it is not worth it. Not to mention all the buildings built during the 70's and after the fall of socialism, they represent a large proportion of all buildings in Poland. As we explained in the first chapter, these houses were built with an older building technology, when insulation materials were not the most effective.

But as for the triple glazed windows, we think that at the present it is not worth spending money on this improvement in Poland. It is the most expensive measure to carry out, and it generates a long payback period. In our simulation we showed you how the air tightness affected the total energy consumption when we lowered the leakage flow. It gave us by far the best reduction in kWh, so instead of replacing the windows, focus should be laid on the yarning around the frame of the windows.

The house in Kosovo was not good at all from an insulation point of view, before we started with the improvements. The roof was found to have the largest deficiencies, with its poor air tightness and with no insulation applied anywhere. The external wall with the hollow bricks did only have an exterior insulation of 50 mm. The U-value for both the roof and external wall exceeded 0.50 W/m²K, which is way too bad. It was also shown in the measurements that we collected from the devices, where the indoor temperature in December was around 5°C. When adding the proposed insulation in the roof and external wall we received major reductions in the total energy consumption. From the very beginning we wanted to add 360 mm of insulation on the loft floor, but the simulations showed us that a thickness of 120 mm gave almost the same reduction. Associated with relatively low implementation costs we received a payback period of 3 years. We also added 120 mm of supplementary insulation in the external wall, and this improvement gave us a payback period of 19 years.

When replacing the existing doubled glazed windows with the triple glazed windows, we knew that it would give us a very long payback period, since they were very expensive. It turned out that the payback period was 393 years.

So what conclusions can we make regarding the windows? One thing that we want to point out is that they are way too expensive. And as we mentioned earlier when discussing the windows in the house in Poland, focus should instead be laid on the yarning around the window frame to improve the air tightness. When it comes to the roof and external wall we received good results, especially when improving the roof. The reason for that is because there was no insulation before, and by only adding a thickness of 120 mm, the U-value of the roof improved from 0.64 W/m²K to 0.22 W/m²K. The U-value in the external wall improved from 0.52 W/m²K to 0.20 W/m² when adding 120 mm of insulation. By coming down to a U-value around 0.20 W/m²K, you can obtain somewhat great reductions in kWh. After that there is no sense to lower the U-value further, considering that the reduction of kWh levels out and does not improve that much.

So far in this discussion we have only mentioned a little bit about the air tightness and its impact on the energy consumption. The air tightness was found to give the greatest reduction in kWh in both Poland and Kosovo. In both cases we had a decrease of at least 2000 kWh, when we halved the assumed air leakage flow. As we have already mentioned we did not calculate the costs of materials that are required when improving the air tightness. Therefore, we want to emphasize the importance of having an airtight building envelope. By using materials such as; airtight layers and weather strips you can obtain major cuts in the total energy consumption. At the same time the total cost will be much cheaper than the improvements that we have focused on.

The common conclusions of the two houses from an insulation point of view are as follows:

- Not worth to improve the existing windows with triple glazed windows in both Poland and Kosovo. Applying proper yarning around the window frame should be more profitable, since it surely is less expensive.
- If the U-values of the roof and external wall are around 0.20-0.30 W/m^2K. There is no sense to add more insulation since it gives a long payback period. Focus instead on applying weather strips to get an air tight building envelope.
- However, if the U-value is way over 0.30 W/m^2K, it surely is due to the fact that there is no insulation or that there is only a low thickness of insulation. In that case there is no need to add an excessive amount of insulation and spend unnecessary costs on materials. Instead reach a total thickness around 150 mm with the supplementary insulation.

The costs of insulation were quite similar in Poland and Kosovo. The mineral wool costs about the same in both countries per m^2. The payback period after improving the external walls in Kosovo was 19 years, and the main reason for that is because we used Styrofoam. Styrofoam is in general more expensive than mineral wool, but still the most usual insulation to use in Kosovo. Mineral wool is not that common in Kosovo, as it is in Sweden. One explanation could be that more houses are built of wood in Sweden, and in that case mineral wool is a better option since it is easier to pack tightly between the studs. To wrap it all up, the payback period for improving the external walls in Kosovo, could be lower if mineral wool would be used instead.

As we mentioned earlier the majority of all houses in both Poland and Kosovo are built of bricks and concrete, therefore the use of Styrofoam is very usual. But in Poland in recent years, the mineral wool is starting to get more commonly used, not only because it is cheaper than the Styrofoam but also due to the fire risks that the Styrofoam holds.

Regarding the windows, it was a huge difference in prices when comparing between Poland and Kosovo. The price for a triple glazed window with a U-value of 0.8 W/m^2K in Poland was 75 €/m^2, in Kosovo you have to pay 250 €/m^2 for a similar window. The difference may exist because these windows are more common in Poland, and self-produced as well. This leads to competitiveness among the vendors and in turn the price must be lowered. In Kosovo, triple glazed windows are imported from other countries where the purchase price is pretty expensive, that is the reason why they are sold at such a high price.

We also want to provide you with guidelines, in which we recommend how to make your building energy efficient. The guidelines are based on our conclusions and they are made for each of the houses. They are presented in a numerical order, where the first one is the most important to consider.

Guidelines in Poland

1. If there is no insulation applied in the roof, this will definitely be the first measure to improve. Add enough insulation so that the roof achieves a U-value around 0.20 W/m²K.
2. Improve the air tightness in the building envelope. The first thing to do is to yarn properly around the window frame. Secondly, look at the loft floor and see if there are some openings that affect the air tightness and can cause moisture damage, these can be eliminated by applying an airtight layer.
3. In general, the buildings built in the last 10 years have an insulation thickness that exceeds 100 mm in the external wall which is good from an energy point of view. There is no sense to add more insulation but if a facade replacement will be performed, check that the insulation is well packed to improve the air tightness.
4. Replacing the windows is not really recommended, but nowadays there is an option where you can add a glass to the existing window. This measure will reduce the U-value and it is also cheaper than replacing the entire window. This measure should only be considered if the previous recommendations are fully fulfilled.

Guidelines in Kosovo

1. Start by insulating the roof; do not use an unnecessary amount of insulation. Instead aim to reach a U-value around 0.20 W/m²K.
2. Improve the air tightness around the window frame. During the same time install external sun protection, this will not only improve the air tightness but also work as a cooling mechanism during summer.
3. If the exterior walls have an insulation thickness less than 100 mm, add supplementary insulation so that the total thickness ends up around 150 mm. If possible, use mineral wool instead of Styrofoam since it is less expensive per m².

4. A replacement of windows is not to recommend because of the high price, focus should instead be laid on the previous recommendations in this guideline.

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Interviews

Latif Jashari (2012). Bachelor of Science in Engineering, Civil Engineering, Co-owner of AlfaING in Mitrovice.

Zbigniew Stempak (2012). Bachelor of Science in Engineering, Civil Engineering, Safety Inspector, E-mail: Zbigniewstempak@op.pl

Annexes

1 Interviews

1.1 Interview with Zbigniew Stempak, Poland

1. What requirements are there to fulfil for a client to get building permission for a single family house?

Answer: The client must pass the following requirements:
- Being in disposition of property for construction purposes
- Have a building project
- A physical development plan
- Compliance with the terms of the project (document containing the objectives that has to be achieved during the project).
- Agreement with various types of suppliers; such as energy, electronics, water supply and sewerage. To be able to come to an agreement with the suppliers, the client must meet the requirements.
- The land, on which the house is to be built on, cannot be cultivated land.

2. What requirements are there regarding the total energy consumption of a single family house?

Answer: As of today we have no exact standard on how much the total energy consumption can be. But we usually say that a house up to 220 m² shall have a maximum energy consumption of 140 kWh/m²*year.

3. What kind of heating systems are available in the market, and which is the most common?

Answer: Here in Poland we have all kinds of heating systems available and all depends on how much you are ready to sacrifice financially. Of the more modern there are:
- Solid fuels (Coal, wood)
- Liquid fuels (Heating oil)
- Gas fuels (Liquid gas, natural gas)
- Electric heating
- Heat pumps

4. What type of insulation is used in single family houses?

Answer: The most basic and least expensive systems used are as follows:

- Thermal insulation of styrofoam
- Thermal insulation of mineral wool
- Glass wool

Of course the price of the insulation varies depending on the U-value and its density.

5. Which window type is the most common?

Answer: In recent years the window market has introduced all kinds of windows with different U-values. The most common to encounter in a single family house as of today is double glazed windows, with a U-value of at least 2 W/m²K. Then there are also triple glazed windows with a U-value down to 0, 8 W/m²K, but these are twice as expensive. But I believe that going with the triple glazed windows will pay off in the long run, and that is why I recommend installing them even to my clients.

6. What is the biggest difference in terms of materials and technology from the period of socialism and today?

Answer: During the socialism period in Poland, there was a poor variation of materials available for construction. Those that luckily were available were in poor condition and did not meet the requirements at that point. I remember that for construction of houses we used very basic materials such as:

- Concrete block of very poor quality
- Concrete of sand for the basement
- Brick by poor quality
- Adhesives for brick masonry was very bad

The carpenters did not have the latest technology in the manufacturing of windows, doors etc. Exterior walls were built in a old fashioned way, were the top priority was to make the building carcass solid without paying much attention to the insulation. Most of the materials as concrete, cement and nails had to be done on your own; since it was difficult to get. A house built at that time was not allowed to exceed 110 m². After the fall of socialism, Poland was up for a great change in terms of construction technology. The availability of materials was now much wider and in better quality, especially for single family houses. At the moment the, the availability of materials is virtually unlimited, and their quality allows the construction to present a huge level within the European standard.

1.2 Interview with Latif Jashari, Kosovo

1. What requirements must be met to obtain building permission?

   Answer: There have been major problems in obtaining building permissions in the city, because we had no official city plan. It was not until the 17 of June 2011 that the first official city plan came in force. This plan applies only to the centre of the city, with the help of the plan it is easier to decide how high the building can be and where you can build them. In order to obtain a building permission you must present:
   - Proof of ownership of the ground
   - Material plan for the house
   - Plan for electric installations of the house

Owners of older and poor built houses can often not afford to renovate, apart from that they don't want to sell their land. This is a huge problem for the city's growth.

2. How are these laws against the EU laws?

   Answer: As of today we have come up with a proposal of new construction laws in the parliament. When they come into force, they will be equivalent to the EU laws.

3. In Sweden there is a requirement which says that the total energy consumption in a single family house should be around 110 kWh/m^2*year. Is there a similar value here in Kosovo?

   Answer: These requirements are not yet available here, as I mentioned before we are still waiting for the new construction laws to come in force. However, there are requirements regarding the external wall which says that the insulation must be at least 50 mm thick.

4. What kind of heating systems are used here?

   Answer: The use of heating systems is a huge problem here. Wood, coal and direct electricity is the most used here around. The problem is that these systems are not that very environmentally friendly in the long run. We also have other systems that use gas, solar radiation and earth heat. Solar cells would practically work pretty well here during the summer since we have a lot of sunlight during the day. But it is very expensive to purchase and install. Earth heat has been tested and it is very effective because the ground is warm enough already in a depth of three meters. But yet again, the economy is also a problem here. In short you can say that people in Kosovo overall cannot afford to buy and install a heating system. Therefore they often buy a less expensive fireplace which is driven by coal or wood.

5. What type of insulation is used and which parts is most commonly insulated?

Answer: Styrofoam with a thickness of 50-120 mm is used most often in the external walls. There is also mineral wool, but it’s not used that often as the Styrofoam. When it comes to the ground, in many cases you never insulate it since the ground is warm enough. The roof is something that I personally always recommend to insulate, but people in Kosovo usually do not do it because of the economy. They often strive to save some money, and in their case the roof is always the one that has to suffer.

6. Is there a difference in how you build today and before the war (1999)?

Answer: Yes, there are huge differences. The technology has advanced and everything is built faster and more carefully now. Before the war there were a lot of inexperienced and uneducated people whom built houses. One problem that we have is the availability of proper materials. Most of our materials are imported from Slovenia, such as insulation and concrete. Hopefully in the near future we will be able to provide a huge variety of materials, but as of today we are unfortunately limited.

7. We have seen that the hollow bricks is practically used on every building, why is that?

Answer: The answer is simple; because they are seen as the best option with the following reasons:

- Price – it is the less expensive option
- Weight – Its weight is light and therefore easy to work with
- Acoustics – Provides good acoustics in the house
- Environmental – It has passed the environmental requirements
- Strength – It is solid

8. What type of windows is most used?

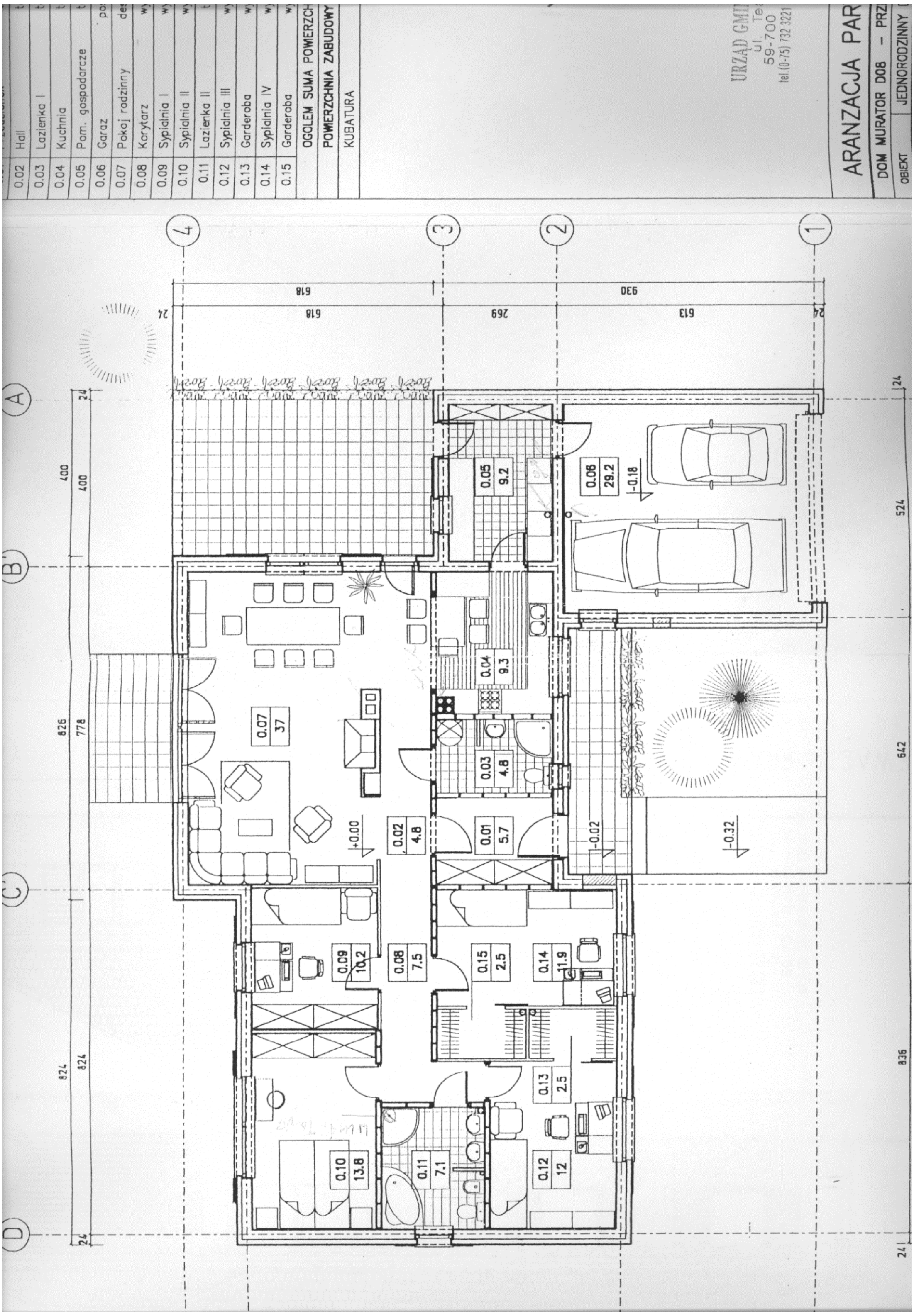
Answer: Double glazed windows with a plastic frame are very common here. We also have double glazed windows with wooden frames imported from Slovenia. Triple glazed windows have recently been received and very few have them since they are twice as expensive. They are as well imported from Slovenia, and even Germany.

9. Kosovo strives to join the EU. There is a goal which says that all buildings must consume 20% less energy by the end of 2020, what are you opinions regarding that?

Answer: Every year we make calculations on how many kWh that are needed to heat a single family house every year. But since many people heat their own house with coal and wood, it is hard to estimate how much is needed. People need to start using heating plants that pays off in the long run, they also need to spend more money on insulation.

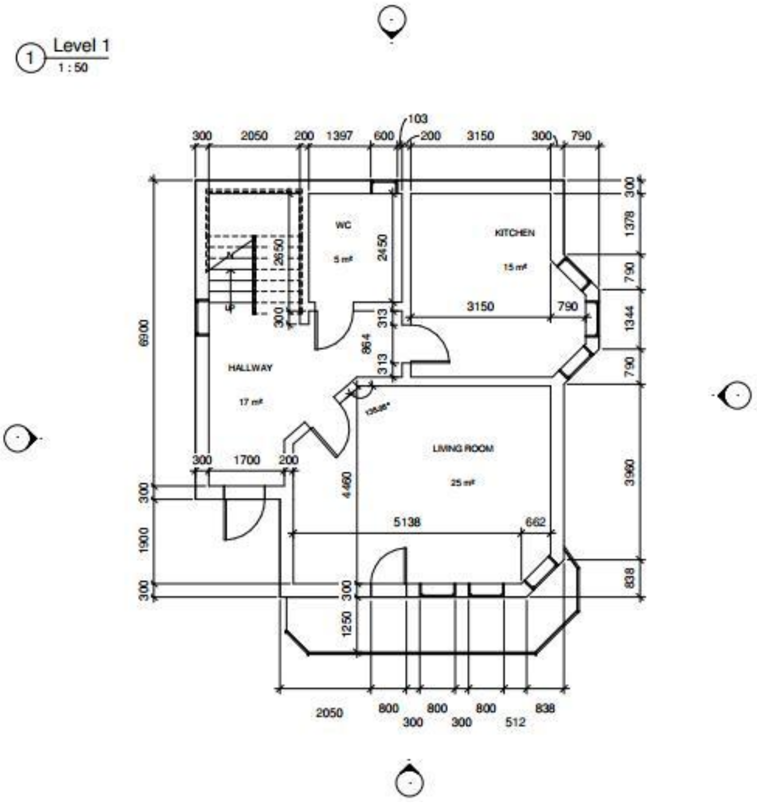
2 Floor plan

2.1 Poland

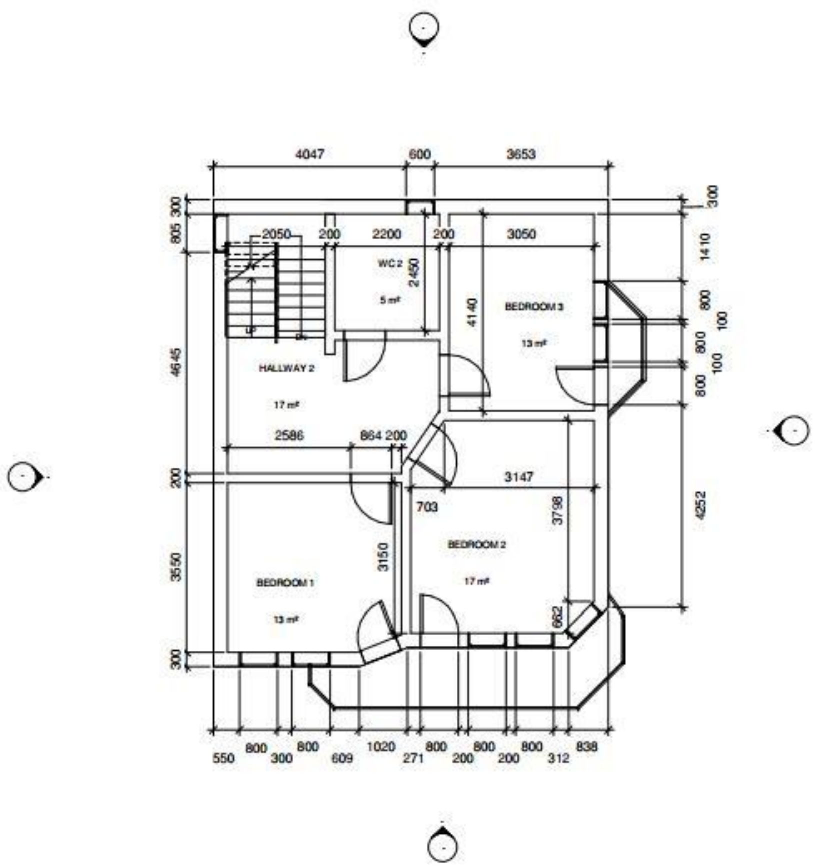


2.2 Kosovo

1 Level 1
1 : 50

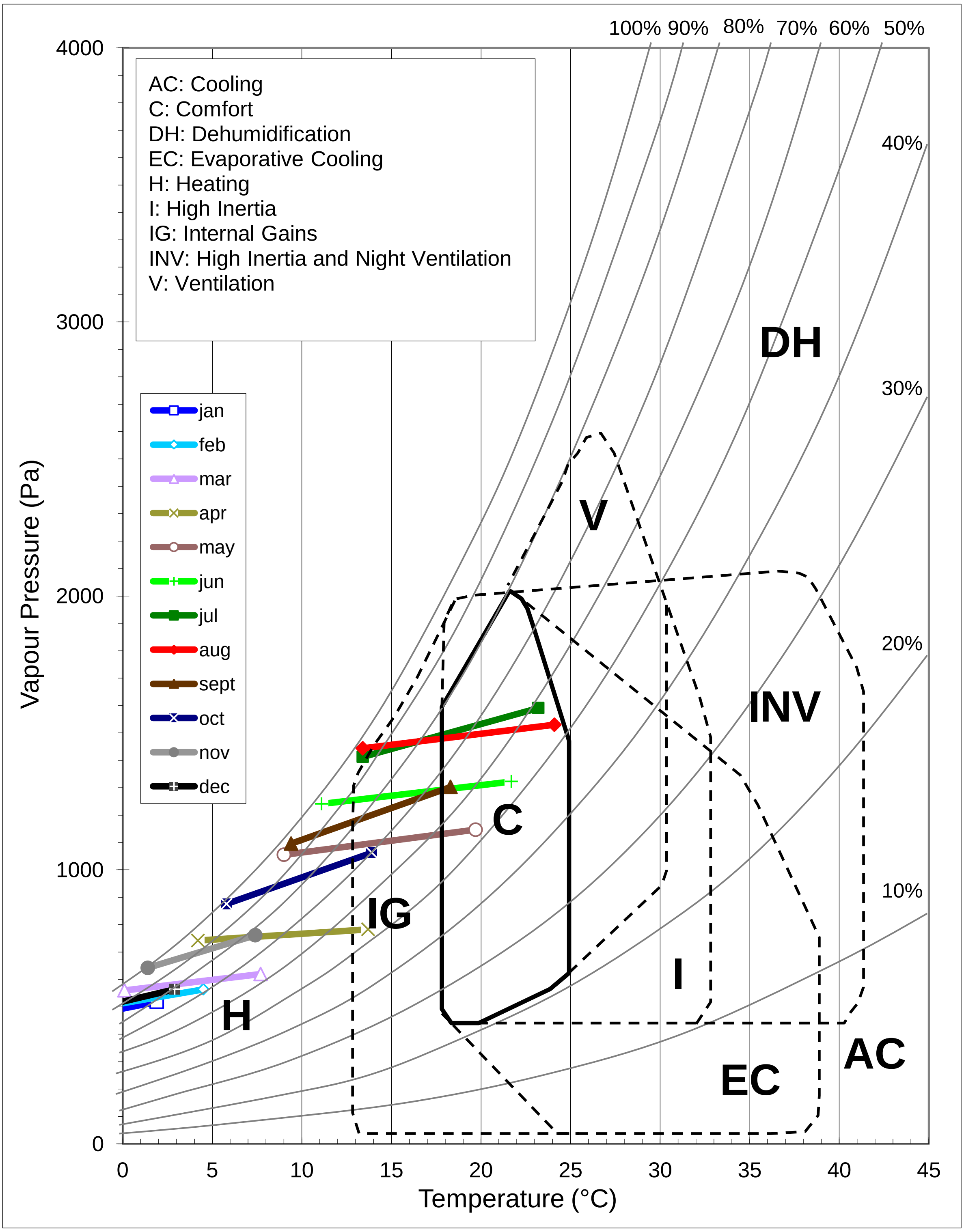


1 Level 2
1 : 50

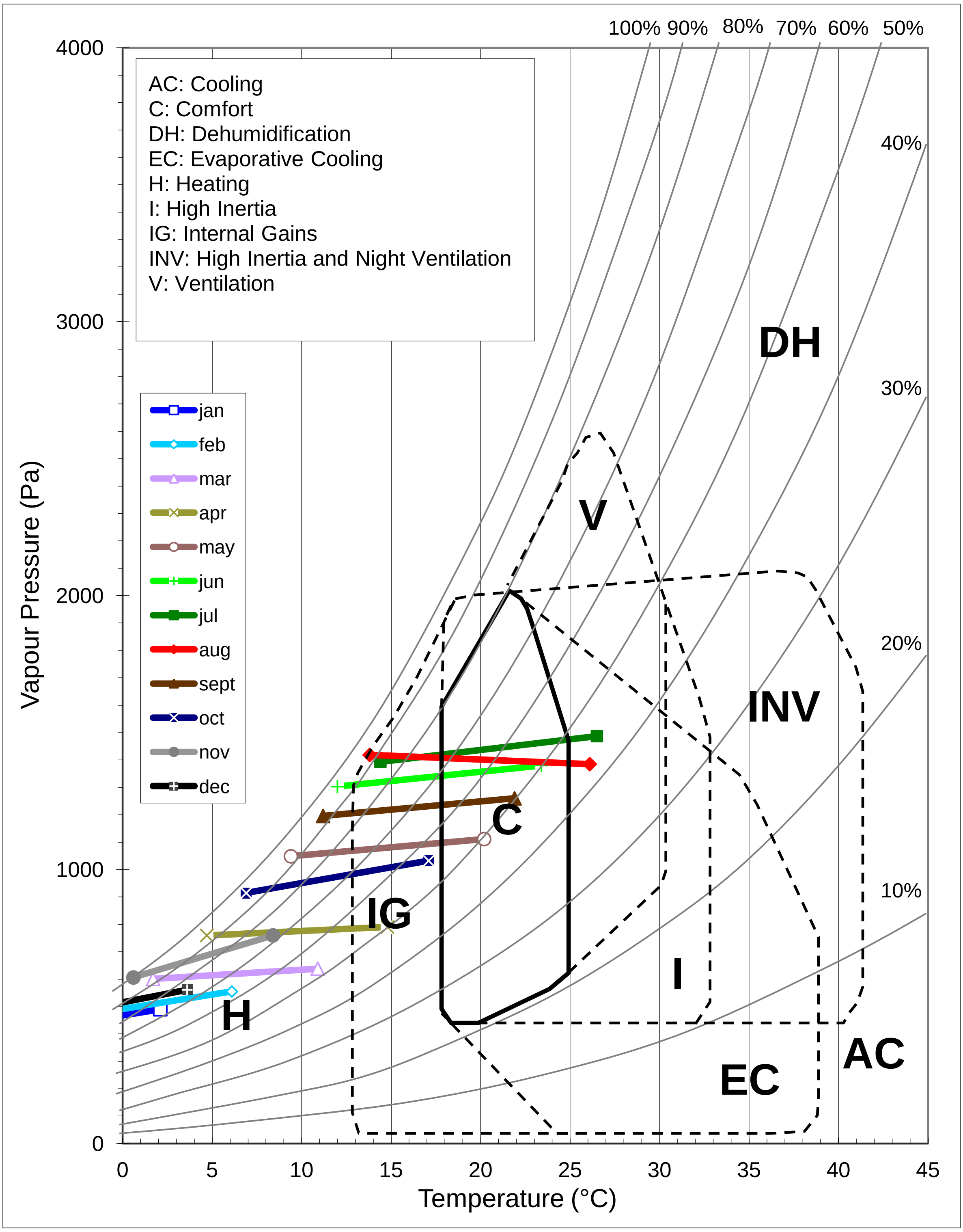


3 Givoni charts

3.1 Wroclaw



3.2 Pristina


AC: Cooling
C: Comfort
DH: Dehumidification
EC: Evaporative Cooling
H: Heating
I: High Inertia
IG: Internal Gains
INV: High Inertia and Night Ventilation
V: Ventilation
jan
feb
mar
apr
may
jun
jul
aug
sept
oct
nov
dec
100% 90% 80% 70% 60% 50%
40%
30%
20%
10%
DH
V
INV
C
IG
I
H
EC
AC
Vapour Pressure (Pa)
4000
3000
2000
1000
0
0 5 10 15 20 25 30 35 40 45
Temperature (°C)

4 Mahoney table

4.1 Wroclaw

General Recommenation

Layout

			0–10			X	Orientation north and south (long axis east–west)
			11–12		5–12		
			11–12		0–4		Compact courtyard planning

Spacing

11–12							Open spacing for breeze penetration
2–10							As above, but protection from hot and cold wind
0–1						X	Compact layout of estates

Air movement

3–12							Rooms single banked, permanent provision for air movement
1–2			0–5				
1–2			6–12			X	Rooms double banked, temporary provision for air movement
0	2–12						
0	0–1						No air movement requirement

Openings

			0–1		0		Large openings, 40–80%
			11–12		0–1		Very small openings, 10–20%
Any other conditions						X	Medium openings, 20–40%

Walls

			0–2			X	Light walls, short time-lag
			3–12				Heavy external and internal walls

Roofs

			0–5			X	Light, insulated roofs
			6–12				Heavy roofs, over 8h time-lag

Outdoor sleeping

				2–12			Space for outdoor sleeping required

Rain protection

		3–12					Protection from heavy rain necessary

Detailed recommendations

Size of opening

			0–1		0		Large openings, 40–80%
			0–1		1–12	X	Medium openings, 25–40%
			2–5				
			6–				Small openings, 15–25%

			10				
			11–12		0–3		Very small openings, 10–20%
					4–12		Medium openings, 25–40%
							Position of openings
3–12							In north and south walls at body height on windward side
1–2			0–5				
1–2			6–12			X	As above, openings also in internal walls
0	2–12						
							Protection of openings
					0–2		Exclude direct sunlight
		2–12					Provide protection from rain
							Walls and floors
			0–2			X	Light, low thermal capacity
			3–12				Heavy, over 8h time-lag
							Roofs
10–12			0–2				Light, reflective surface, cavity
10–12			3–12			X	Light, well insulated
0–9			0–5				
0–9			6–12				Heavy, over 8h time-lag
							External features
				1–12			Space for outdoor sleeping
		1–12					Adequate rainwater drainage

4.2 Pristina

General recommendations

Layout

			0–10			X	Orientation north and south (long axis east–west)
			11–12		5–12		
					0–4		Compact courtyard planning

Spacing

11–12							Open spacing for breeze penetration
2–10							As above, but protection from hot and cold wind
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Air movement

3–12							Rooms single banked, permanent provision for air movement
1–2			0–5				
			6–12				Rooms double banked, temporary provision for air movement
0	2–12						
	0–1					X	No air movement requirement

Openings

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			11–12		0–1		Very small openings, 10–20%
Any other conditions						X	Medium openings, 20–40%

Walls

			0–2				Light walls, short time-lag
			3–12			X	Heavy external and internal walls

Roofs

			0–5			X	Light, insulated roofs
			6–12				Heavy roofs, over 8h time-lag

Outdoor sleeping

				2–12			Space for outdoor sleeping required

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		3–12					Protection from heavy rain necessary

Detailed recommendations

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			0–1		0		Large openings, 40–80%
					1–12	X	Medium openings, 25–40%
			2–5				
			6–10				Small openings, 15–25%
			11–		0–3		Very small openings, 10–20%

			12		4–12		Medium openings, 25–40%
						Position of openings	
3–12							In north and south walls at body height on windward side
1–2			0–5				
			6–12				As above, openings also in internal walls
0	2–12						
						Protection of openings	
					0–2		Exclude direct sunlight
		2–12					Provide protection from rain
						Walls and floors	
			0–2				Light, low thermal capacity
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						Roofs	
10–12			0–2				Light, reflective surface, cavity
			3–12			X	Light, well insulated
0–9			0–5				
			6–12				Heavy, over 8h time-lag
						External features	
				1–12			Space for outdoor sleeping
		1–12					Adequate rainwater drainage