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Sustainable housing in Kyrgyzstan

Investigation of two multi-apartment buildings in Bishkek

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Master's thesis in engineering
The Division of Efficient Energy Systems
The Department of Energy Sciences
Lund University | Faculty of Engineering

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This Master's Thesis was performed at the The Department of Energy Sciences at Lund University and in cooperation with the Kyrgyz State University of Construction, Transport and Architecture (KSUCTA).

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Executive Summary

The Kyrgyz Republic lies in the middle of Asia, embedded in the Himalaya mountain range. The country has a population of about 5 550 000, a little more than half the population of Sweden.

The country became independent from the Soviet Union in 1991. The economic decline was rapid after leaving the union. The country was among the first former Soviet Union republics that tried to make its way to a market economy. Since 2007, the GDP has increased each year. Kyrgyzstan has since become independent from the USSR, had two revolutions. The country is since 2011 a parliamentary democracy. There are still political problems in the country. One of the main political problems is caused by ethnic differences, mainly in the south of the country where the population of Uzbek people is the largest. Corruption is also a widespread phenomenon in the country. Poverty has decreased since 1998 but 43.1% in the country was estimated to be poor by the UN in 2005.

Kyrgyzstan is largely dependent on fossil sources for their energy production. They do however also produce hydro power, nearly 90% of the electricity is produced by hydropower and 30% of all supplied energy is from this source. Most of the houses in Bishkek are heated by district heating, from one large CHP-plant in the city.

Sustainable housing is not the highest priority in Kyrgyzstan today, mainly because of a lack of funds. There are shortages of housing, with 4.7 people per dwelling (compared to the European average of just 2.2). In rural areas the infrastructure is lacking in many places. There are shortages of drinking water in particular, where 14% have no access to clean drinking water. Only 40% of the Kyrgyz households have access to a public sewage system.

The examined buildings

85% of the buildings in Kyrgyzstan today were built during the soviet era, where a large part of the buildings built were multi-apartment dwellings. They are now in great need of reparations. This is true also for the two buildings examined in this project, located in Bishkek. The building called House 9 was the subject of an EU-financed energy efficiency project in 1995 – 96 were energy efficiency measures were performed on the building. The building called House 2 was used as a reference object in the same study.

The occupants of the examined buildings own their own apartment. According to the law they also share the ownership of the common parts of the buildings. This is how most housing ownerships are organized in Kyrgyzstan; dwellings are to 96% privately owned, while the rest remains rental housing. The maintenance of the buildings has as a result been neglected. The United Nations (UN) states in a report on Kyrgyz housing that: “the

very high owner occupancy rate is today one of the biggest obstacles for management and maintenance of multi-apartment buildings". There is a possibility to form a condominium (to simplify the shared responsibility of maintenance of multi-apartment buildings) but only 25% of the Kyrgyz housing stock belonged to a condominium 2005. The examined buildings do not belong to a condominium. In this project it was found that the lack of common responsibility is one of the great obstacles for making maintaining of the examined buildings possible. The only retrofitting of the buildings occurring today is done when individual occupants retrofit their own apartment.

There are overall very few energy efficiency measures being performed on Kyrgyz buildings today. The reason for this is that the economic incentives for taking energy efficiency measures are low. Most people in Kyrgyzstan, including occupants of the buildings examined, pay for district heating per floor area and not for their actual consumption. Domestic hot water (DHW) is paid per person and consequently also not paid according to the actual consumption. The electricity price is however dependent on the size of the electricity consumption. Economic incentives are needed for the occupants to be willing to perform energy efficiency measures on *the whole building*, such as insulating it or retrofitting the central heating system.

Results

A survey was performed directed at the occupants of the two investigated buildings. The most important results from this survey are presented here. The survey used is similar to the one used in the BETSI study by the Swedish National Board of Housing, Building and planning (Boverket). To compare the results from the survey with Sweden, the BETSI-results of multi-apartment building are used.

In general, occupants in multi-apartment buildings in Sweden are more satisfied with their homes compared with the occupants in the investigated houses. The Swedish occupants are also more satisfied with the aspects of size, daylight, appearance and comfort in their home. There seem to be behavioural differences between the countries' occupants, in Kyrgyzstan nearly all respondents of the survey said they open their windows every day. Barely 70% of the Swedish respondents open their windows daily. This could indicate a better ventilation quality in Sweden compared to the two buildings in Bishkek.

When the two Kyrgyz buildings are compared, the standard is perceived as more satisfying for the occupants living in House 9. The heating comfort is better in House 9, which was the subject of the project in 1995/96, than in the reference building, House 2. It is more common with some kind of additional heating in House 2 than in House 9. In House 2 there are more respondents who answered that it is often too cold in the winter and that the floors are often too cold. These results show that the project performed in 1995/96 had a positive effect on the heating comfort of House 9 which is still notable today.

Also the air quality is better in House 9. About 20% of respondents in House 2 experience their air quality as bad, while nobody does so in House 9.

The survey results indicate moisture problems in both examined buildings, a little more in House 2. 21% in House 2 often have problem getting rid of moist air in the bathroom, compared to only 5% (1 respondent) in House 9. They also have more water-damages in House 2, over 20%, while the numbers for House 9 are similar to the BESTI-results, about

10%. However, in House 9 there are more respondents who experience smell of mould in their home. Apart from the survey there are indications in this study that the occupants have little knowledge of ventilating system and resulting moisture problems.

Conclusions

According to the UN it is urgent that action be taken to retrofit the roofs, elevators and façades of Kyrgyz buildings. Also windows have in many cases outlived their technical lifespan. Pipes for sewage and drinking water are also in need of replacement. In this study it was found that the most important improvements to be made on the houses are:

- Repairing the roof of House 2 because it is leaking.
- Renovation of the façades of both buildings.
- Investigation of the state of the ventilating system. Probably there is a need for renovation.
- The thermostatic radiator valves placed on the radiators during the former study need to be removed, because most of them are broken and occupants do not know how to maintain them.

In this project there are energy efficiency measures suggested. These measures can be made provided that: economic incentives are created, that the occupants of the building work together and that it is possible to maintain the measures. It is also important that the measures are followed with information about how and why they are done.

Of the improvements made in 1995/96 the only one still in full function is the insulation on House 9. This thesis suggests the addition of insulation for House 2 as well, as it will improve the living standard for the occupants in House 2. When adding insulation to a building it is extra important that the ventilation is working properly to avoid additional moisture problems.

For both houses it is suggested that their central heating system be retrofitted (today too-hot temperatures are supplied to some of the apartments). This measure will save energy and will make it possible to bill the occupants for what energy is actually used.

According to the energy calculations done in this project, a change to new windows will make a great improvement of the U-value of the building. This is a measure already performed by many occupants on their own apartments. However, the windows in the staircases have not been replaced or retrofitted at all in the buildings. Improving them will improve the whole building.

The last suggested energy efficiency measure is installation of DHW meters in both buildings to minimise the use of domestic hot water.

Sustainable housing is possible in Kyrgyzstan but there are many obstacles to pass. In this study, it is shown that it is often simple measures that are needed to make great changes.

Sammanfattning

Huvudsyftet med detta projekt (examensarbete på civilingenjörsnivå) har varit att undersöka två flerfamiljshus och sammanfatta vad som krävs för att förbättra husens prestanda. Byggnaderna är belägna i Kirgizistans huvudstad, Bisjkek. De viktigaste åtgärderna som behövs för att skapa ett mer hållbart boende har identifierats. Dessa åtgärder är också nödvändiga för att kompensera för ett bristande underhåll av byggnaderna. Flera åtgärder för att energieffektivisera byggnaderna har föreslagits och diskuterats. Undersökningen av byggnaderna genomfördes under ett 8 veckor långt studiebesök i Kirgizistan i samarbete med Kirgizistans Statliga Universitet för Konstruktion, Transport och Arkitektur (KSUCTA). En enkätundersökning utfördes bland de boende och mätningar, intervjuer, observationer och beräkningar av teoretiska U-värden genomfördes.

Kirgizistan är beläget i Centralasien, mellan Kazakstan och Kina. Det ligger i norra delen av Himalaya och är ett mycket bergigt land, 94% av landets yta ligger över 1000 m.ö.h. Omkring 5 550 000 personer bor i landet och landets är knappt hälften så stort som Sverige. 1991 frigjorde sig Kirgizistan från Sovjet och upplevde som följd en drastisk ekonomisk nergång. Sen dess har långsam ekonomisk utveckling skett men Kirgizistan är fortfarande ett fattigt land. 2005 uppskattade FN att 43% av befolkningen var fattig. En följd av den ekonomiska situationen är bristande underhåll av byggnadsbeståndet i landet och generellt så är de flesta byggnader i dåligt skick idag.

Detta projekt är delvis en uppföljning av det EU-projekt som genomfördes för 18 år sedan. Den ena av byggnaderna som är undersökta i detta projekt var föremål för ett EU-finansierat energieffektiviseringsprojekt under 1995 – 96, detta hus kallas Hus 9 i denna rapport. Idag upplevs värmekomforten som bättre i Hus 9 än i det hus som var referensbyggnad 1995/96, det hus kallas här Hus 2. Luftkvaliteten upplevs också som bättre i Hus 9 och de boende i Hus 9 är nöjdare med den generella standarden i sitt hus.

Bland alla förbättringar som gjordes på Hus 9 1995/96 är det bara tilläggsisoleringen av huset som fortfarande är fullt fungerande. Detta projekt föreslår att en tilläggsisolering ska utföras även på Hus 2 vilket kommer förbättra boendestandarden för de boende i detta hus.

För båda husen föreslås en renovering av centralvärmesystemet eftersom det inte fungerar som det ska. Ett renoverat system med bl.a. fungerande mätare banar väg för att de boende ska kunna betala för så mycket värmeenergi som huset använder. Nu beror endast fjärrvärmepriset på boendeytan och inte på den faktiska konsumtionen. Boende i Hus 9 betalar alltså lika mycket som de i Hus 2 trots att Hus 9 med största sannolikhet använder mindre fjärrvärme. Ekonomiska incitament för att genomföra energibesparande åtgärder saknas således. Denna rapport föreslår också att det ska finnas mätare på tappvarmvattnet, vilket tycks finnas i vissa lägenheter. Detta för att det även ska finnas ett

pris på den energianvändningen. I studien från 1995/96 fann man att kirgizerna använde 3-5 gånger mer varmvatten än genomsnittstysken.

Beräkningar av husens totala U-värde visar att ett fönsterbyte till PVC-fönster är en bra förbättring. Detta är något som redan görs av många boende i deras egna lägenheter. Dessvärre har fönstren i trapphusen helt blivit förbisedda och är i riktigt dåligt skick.

En slutsats av detta projekt är att det är viktigt att genomförda åtgärder följs upp av information om varför de genomförs och hur de ska underhållas. För att några åtgärder ska kunna genomföras överhuvudtaget i dessa hus så är det väldigt viktigt att det finns ett ordnat samarbete mellan alla boende i byggnaden. Ett förslag är att de boende bildar en förening, likt de svenska bostadsrättsföreningarna, för att lättare kunna utföra underhåll på byggnaderna de bor i. Detta är inte helt otänkbart då 25% av flerfamiljshusen i Kirgizistan tillhör en förening av den typen.

För att få till en hållbar utveckling av boendebeståndet i Kirgizistan finns flera hinder, inte minst ekonomiska. Denna studie visar att enkla åtgärder kan göra stora skillnader.

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Contents

Chapter 1

Introduction

There are over seven billion people living on Earth, and all of us need a place to live [1]. There is a limited amount of space on this planet and this means that we have to live more and more cramped each year. Urbanisation is inevitable. Since 2010, more than half of the world's population live in urban areas. By 2030 it is estimated that 60% will be doing so [2].

For the housing situation to be sustainable in a country there need to be enough housing for all the people living in this country. Houses need to be comfortable and safe for all people. They also need to be sufficiently warm in the winter and cool in the summer and should not cause health problems for the occupants. At the same time, the global warming threat demands energy savings from all parts of society, including housing. 40% of the global energy used in 2011 was used in buildings [3]. Sustainable housing means that the buildings are both energy efficient and safe for the occupants and the environment. To be sustainable, the buildings should also be durable for a long time.

In developing countries there is a dire need for retrofitting buildings but limited funds for doing so. Energy efficiency measures can be a way to save money but capital is needed for the initial investment. However, it might be more important to reduce the health issues caused by badly built or ill maintained buildings. It may be hard to do both health measures and energy efficiency measures.

In Kyrgyzstan the largest part of the population is still living in rural areas. There are however many people moving to the cities. Many of the buildings in the cities are from the Soviet era and are now in very bad condition.

In this thesis, two multi-apartment buildings situated in Bishkek, the capital of Kyrgyzstan, have been investigated. The buildings are situated in the same area in the town and are both from the Soviet era. Throughout the thesis they are called House 9 and House 2. House 9 was retrofitted to be more energy efficient in an EU-financed project performed in 1995. House 2 was in that same project used as a reference object. In both buildings the occupants are also the owners of the apartments.

This degree project contains information on how the dwellers experience their living conditions with respect to heating comfort and air quality. It is also investigated how the living conditions have changed since the former study. Differences between the houses are investigated through measurements, interviews and estimations of U-values. Where relevant, the results from this study have been compared to Swedish conditions.

An energy efficiency plan for both buildings is made in this thesis. In this plan, economic aspects as well as the most essential needs of the occupants are considered.

The investigation part of this degree project was done during an eight-week study visit to Kyrgyzstan. The project was done in cooperation with the Kyrgyz State University of Construction, Transport and Architecture (KSUCTA).

1.1 Objectives

The main objective of this degree project (Master's thesis) has been to investigate the two multi-apartment buildings and conclude the most important aspects to improve for these houses. With these aspects in mind, an energy efficiency plan is also made for the buildings.

Question formulation

Questions answered in this project are:

- What are the differences of Kyrgyz and Swedish building codes and how are they implemented?
- How do occupants experience their living conditions? What is the difference to Sweden in this case?
- Is the heating comfort better in House 9 than in House 2?
- How does the ventilation work in the two buildings? Is there any moisture damage due to a failing ventilating system?
- What has been changed on the buildings since the former study, made in 1996?
- What are the most important aspects in need of improvement for better energy efficiency and living conditions?

1.2 Disposition

This work begins with presenting and discussing the methods used in the thesis. The method is followed by a theory, which consists of Chapter 3 to 6: *The Kyrgyz Republic*, *Building theory*, *Building codes*, *Energy efficiency measures* and *The examined buildings*. The theory is followed by the results. After that comes an analysis of the results and conclusions.

Chapter 2

Method

In this Chapter, the methods used in this study are presented and discussed. Literature studies were carried out on:

- Kyrgyzstan politics, climate, energy- and housing situation.
- Fundamental theory of buildings.
- Possible energy efficiency measures for buildings.
- The Swedish and Kyrgyz building codes. Compared in the analysis.

The two examined buildings were investigated in several ways. The previous study made on the houses was evaluated with help from the scientific article made in connection with this study. Personal contact with one of the authors of the 1996 study complemented the literature study in this case.

A Swedish survey, used for estimating the indoor climate in buildings, was translated to Russian and answered by the occupants of the two buildings. The results were compared with results of the Swedish survey. Additional interviews were held with two of the respondents of the survey, respondents who are responsible for the maintenance of one of the buildings each.

Measurements with an IR-thermometer were made on the buildings, with the purpose of finding thermal bridges (see Glossary, Appendix A) and comparing the buildings with each other. To get a more complete view for comparison of the buildings, other qualitative observations were made and the theoretical U-value was estimated with the calculation program Isover Energy 3.

This study has used both qualitative and quantitative methods: the results of the survey and the measurements can be considered quantitative while the rest (as interviews) of this project have qualitative results. The conclusions drawn from this project consider economic aspects but lacks actual economical calculations.

In general, the results from the survey, the literature study and the observations made during the measurements were most useful for the conclusions drawn in this project. Because the most of this study was done abroad in a country with a language not commanded by the authors, there were difficulties because of language barriers. Translations needed to be made in several steps. Sometimes it also seemed like contradicting statements were made by two persons when maybe it was only a misunderstanding of the translation.

There were also cultural differences that created confusion and in some occasions were obstacles for the work.

2.1 Literature studies

Information for the literature study was found in books and on the internet. For the study on the Kyrgyz republic, reports made by the UN and different development aid agencies was especially useful. Interviews with persons working on the KSUCTA were also very helpful in the literature studies. The fundamental theory of buildings as well as on possible energy efficiency measures were made by studying specialist literature.

The Swedish building codes were studied both in Swedish and in English. The Kyrgyz laws were only available in Russian. They were given to us at a late state of the project. The translation of the laws had to be done without much help from the Kyrgyz persons having helped us before. The results from these efforts could be compared with interviews performed at the time of our visit. In any case, there might easily have been some small misunderstandings during the translations. Only one of five laws sent from Kyrgyzstan was possible to study due to the time-limitations.

The article of the former study was published in a conference proceeding. It did not contain all technical details of properties of the buildings and some additional details had to be found in interviews. Some of the details were time consuming to find, details such as construction year of the buildings, building material and techniques.

2.2 Survey

In this study, a survey was performed directed at the occupants of the two investigated buildings (presented in Chapter 7). The survey is mainly based on a Swedish survey used in an on-going PhD-study [4]. The translation of the survey was made in several steps. First the survey was translated from Swedish to English by the authors. The survey was later translated to Russian by Kamilia Mukhanova [5]. The survey was edited and adapted to Kyrgyz conditions by prof. Erkin K. Boronbaev [6].

The survey handed out to the occupants was in Russian, it is presented in Appendix B.3 As part of the adaptation to Kyrgyz conditions the survey was changed. In Appendix B.2 there is also an English version of the survey, combining the original English version with the changes made in the Russian one. The translation from Russian to English was made by Sandra Sjöstrand [7].

The translation process was complicated. Some problems occurred because the process had to be made in several steps. First of all, there was a plan to delete some questions that was not meant to be used but in the hurried process and because of misunderstandings this was not done. The negative outcome of this is that the respondents might think that the survey was too long and too tiresome to fill in. There was a rather high amount of non-answered questions.

There was some lack in the communication of what changes had been made to the survey in the translation from English to Russian (Appendix B.2). Among the more useful changes made was the adding of a question concerning additional heaters. Other additions to questionnaire gave rise to problems on how they should be interpreted so they had to be removed. For example: one question added was "How long is your cat or dog alone in the apartment?" which was used instead of a question about how long time the apartment is empty. The intended question might have been used to estimate the ventilation need but this question could not be used because the occupants would not answer questions giving strangers a chance to know when they are not home. Of this valid reason the question should have been removed. The new question made some respondents take the survey less serious because they thought it was a strange question.

There are cultural differences on how Swedish and Kyrgyz persons look on anonymity. The survey was intended to be anonymous. In spite of this intention, a question on name and apartment number of the respondent was added in a last step of the translation process. This additions might have caused the respondents to answer untruthfully because they did not know who would read their answer. For example: respondents might have answered untruthfully about how many persons were living in the apartment because they pay for DHW per person and do not want to state the true number of persons living in the apartment. The results from this question could not be used. Anonymity could have helped to get more honest answers.

The anonymity should be kept and the changes made during the last translation should be discussed. Questions with potential of being offensive to the respondents could have been removed to avoid unreliable and useless answers. It would be appropriate to make a 'test'-survey on Kyrgyz persons and then be able to consider cultural differences in advance.

2.2.1 Selection of participants

The survey was handed out to participants on three different occasions. The apartments participating in the study were all the families who were at home and were willing to participate. The survey was on most occasions filled in by the respondents themselves. The surveys were gathered back continuously by visiting the apartments again on a few occasions during three weeks time.

It was not possible to make an entirely random selection of participants for the study. Only persons at home on weekend days and weekday evenings were surveyed. However, each house has respondents on nearly all floors of the house (only from floor four of House 2 there are no respondents) and the selection of participants can be considered fairly good representative of the occupants. The goal of more than 35% frequency of answers from each house was reached.

Because the respondents filled in the survey themselves there might have been some misunderstandings off the questions. This might also be a result of the translation process. For example, it was indicated in comments made on the survey that the respondents have interpreted 'fan in bathroom' as 'ventilation outlet in bathroom'.

There was a high rate of blank answers on some questions. Many of the blank answers to the survey can actually be interpreted as the respondents meant to answer "no" but they did not understand that there was a box for that alternative. The impression is that in some cases, if a respondent had the same opinion on all or some of the sub-questions as on the main question, they just skipped the sub-questions. One reason for the amount of blank answers could also be the length of the survey and that some questions seemed strange or even offensive to the respondents.

The respondents should have been given a guide on how they were expected to fill out the survey. A letter introducing authors and the project was handed out to participants of the survey. The letter as well as a translation of it is found in Appendix B.1 The first occupants who got the survey did not get the introduction letter. However, later it was copied for everyone. The letter lacked contact information to the authors.

2.2.2 Comparison with Swedish survey

The results were in some cases compared with the results from a survey handed out in Sweden. This survey was in Sweden a part of a larger project, called the BETSI study (the Building's Energy, Technical Status and Indoor environment), with the objective to examine the state of Swedish buildings. The survey was assigned by Boverket to be performed by "Arbets- och miljömedicin" at Uppsala University, "Arbets- och miljömedicinska kliniken" at the University hospital in Örebro and Örebro University. The survey measured the experienced living environment in 5 756 multi-family dwellings and 3 890 one-family dwellings. All the results in the comparison are from the multi-family-dwelling part of BETSI. The results shown in this study are the total of all buildings in the BETSI-survey. This means that the numbers used are average values of different types of buildings as well as buildings built different years and from different parts of Sweden [8].

There is a difference between Sweden and Kyrgyzstan in the habit of answering surveys, Swedish people are much more used to it. Because of cultural differences some words might be interpreted entirely different by Swedish and Kyrgyz people. As a result of the translation process some words might also have got a different meaning in the Russian translation.

The alternatives 'yes, often' and 'yes, sometimes' can also be interpreted differently depending on person or situation. In the results from the Swedish survey the alternative 'yes, sometimes' is not even used because it can be interpreted differently among respondents.

2.2.3 Complementing interviews

To know more about whole the building, interviews were made with the Domkoms (housekeepers) of each building. The questions concerned the energy consumption of the whole building, the responsibility for a Domkom and the size of the rent. For House 9 there were also questions concerning the study 1995/96.

There was a lack of cooperation with the occupants and the Domkoms of the two buildings. It probably had been favourable if they had been more included in the planning of the project from the beginning. This project could have used more of their knowledge about the buildings. The project would also had been more useful to the occupants if they had been more involved in it.

2.3 Measurements

2.3.1 Thermography

The measurements during this project were all performed using equipment supplied in Kyrgyzstan.

2.3.2 Thermography

In this study a IR thermometer supplied by KSUCTA was used for establishing energy losses of the buildings, specifically a "Fluke 68" (Figure 2.1). The thermometer measures the temperature on one spot but it is possible to get the maximum, minimum and average temperature of several spots. The thermometer adjusts the measured value according to the surface emissivity. The emissivity is set by the operator of the thermometer. For surfaces like wall-paper, wood and fabric the emissivity was set to 0.95. For glass panes the emissivity used was 0.85.

Measurements were made in apartments and in the staircases. Measurements were done according to a scheme (see Appendix C). The measurements were performed around windows, entrance doors of apartments and the entrance door of the whole building, and on outer and inner walls. The temperature was measured according to the scheme in two or three apartments per building and in the stairway of both buildings.

Some considerations were made to make the measurement more correct. In section 4.8 reasons for interferences with thermography are described. To get as large temperature difference between the outside and inside of the building most of the measurements were made on the shadow side of the building and during evenings or early mornings. Radiators were not in use, the heating period had not yet begun, when the measurements in the apartments were made.

Figure 2.1: The IR-thermometer, *Fluke 68* [9].

2.3.3 Temperature and humidity

In all apartments and staircase floors where the thermography was carried through, also the air temperature and humidity was measured. It was made with an analogue room thermometer and a digital "home weather station" from the company *Auriol*.

2.3.4 Possible ways to improve temperature measurements

There are many improvements that could have been done to the measurements. Mainly the improvements could be made by bringing more equipment from Sweden because it was not available in Kyrgyzstan. Firstly, an IR-camera should have been used instead of an IR-thermometer to get a better overview of the energy losses. It was also to warm outside when the measurements were done, and as a consequence small or no differences between outside and inside temperatures. If the measurements were to be made again the time period chosen would be later in the winter for higher temperature differences between the inside and outside air. The measurements should also be made just before the sun goes up. For estimating a practical U-value of the buildings it would have been convenient to log temperatures during some time, which was not possible to do. For detailed studying of the houses the measurement should have been made continuously during a whole year.

The “home weather station” used for air humidity and air temperature took a long time to reach a new temperature when the location of it was changed so it is not certain that the recorded values are the correct ones. No other thermometer was made available for measurements.

Air-quality indicators such as air humidity and CO_2-levels as well as ventilation flows were unfortunately not possible to perform.

2.3.5 Observations

The measurement sessions gave many valuable observations and possibility for more detailed questions to the occupants. Observations in 1995 – 1996 (see Section 7.4) were compared to the present conditions. Questions were asked to the occupants at the time of the measurements about the former observations:

- How hot is your hot tap water in the winter? Is it very hot (80 – 90 °C)?
- How cold are the rooms in the winter? (As cold as 8 – 12 °C)?
- Have you installed new radiators? If yes, are they larger?
- Do you have to perform draft proofing on ventilation air ducts or windows in the winter?

Additional things (not noted by the former study) observed were if there was a towel dryer in the bathroom and what materials the window frames were made of. It was also noted how many apartments were extended and had taken over the commonly owned laundry room. The laundry room is situated left of the staircase, see Figure 7.3. The overall state of the buildings, such as the state of the façades was also noted.

The observations gave insights useful to further develop the survey.

2.4 Calculation of theoretical U-value

To estimate the buildings mean U-value, the computer program Isover Energi 3 was used. The dimensions used in the program are based on the building dimensions presented in Chapter 7, The examined buildings. The height of the building is assumed to be 29 m. The properties of wall structures, roof and foundation properties are in Appendix D. Most of the material properties come from the database of Isover energi 3. For insulation materials values are the same as in Table 4.1. The rough plaster on the outside has no effect on the total wall according to Burul K. Tentekova [10]. The properties of the wall and roof used in the calculations were given by Erkin K. Boronbaev [6]. The foundation properties are estimated by visual observations.

Variations were made for three aspects of the computer model. The first variation is the differences between the houses examined, for enabling comparison between the buildings. The next variation is which type of windows are used in the model. The last is if the mineral wool in the sandwich wall is assumed to be new and fresh or badly deteriorated with age and moisture. In total, there were U-values calculated for eight different cases:

	Wooden windows	*PVC-windows*
New Mineral wool	House 2 / House 9	House 2 / House 9
Old Mineral wool	House 2 / House 9	House 2 / House 9

More specified properties used in the model are analysed in the result part of this thesis (Section 8.3).

A model is always a simplification of the reality but with the computer programs of today it is possible to do quite complex models. The model made in this thesis was only used for comparison of the buildings. The reason for not making the model as complex as possible was the amount of unknown properties of the buildings. The properties used for the model are all based on qualified guesses from teachers at KSUCTA and visual observations on site. Effects from thermal bridges, for example along corners, were not included in the calculations. This was due to high uncertainty of their properties. Adding thermal bridges would probably raise the U-value.

Due to the simplifications it is hard to compare the result from this calculation with other buildings. The thermal bridges are similar in all buildings of type 105 and it is reasonable to think that the often retrofitted balconies are rebuilt in the same amount in both House 2 and House 9.

Chapter 3

The Kyrgyz Republic

The Kyrgyz Republic lies in the middle of Asia, embedded in the Himalaya mountain range (Figure 3.1). The country became independent from the Soviet Union in 1991 and has worked its way to democracy and market economy ever since. Today the country has a population of about 5 550 000 [11]. The capital Bishkek has a great deal of old soviet architecture, which has been neglected and ill maintained.

Figure 3.1: Map of Asia. Kyrgyzstan is marked in green. The picture has been modified by the authors [12].

3.1 Kyrgyz climate and geography

Kyrgyzstan is a landlocked country with common borders with Kazakhstan in north, China in east and south east, Uzbekistan in west and Tajikistan in south (Figure 3.1).

Kyrgyzstan has an area of 199 951 km^2 [11] which is just a little bit less than half the size of Sweden [13]. There are high mountains all over the country and over 94% of the country lies 1000 m above sea level. The highest mountain peak is Peak Jengish Chokusu at 7 439 m [11, 14, 15]. Only 7% of the country's land is arable, 80% of this land is irrigated [16].

The capital of Kyrgyzstan, Bishkek, is situated in the north of the country, close to the common border with Kazakhstan. The city lies in a valley with an elevation of about 800 m above sea level [11, 14, 15].

The weather in Kyrgyzstan is influenced by the mountains and the continental location, far from any ocean. The winters are cold, with temperatures of about -4 to -6 °C in the lowlands and -30 °C in the mountain valleys. In the summer it is hot, the lowland average is about 16 °C to 24 °C in July. In Bishkek the average high temperature[1] is 31 °C.

The country is sunny, with 300 days of sunshine per year. The national average of precipitation is 380 mm per year. In Bishkek the springtime is the wettest period, with about 40% of the years rain falling in April, May and June [15, 17].

Kyrgyzstan is located in an active seismic zone. Earthquakes occur 10–12 times per year in the country. Smaller tremors on the other hand, occur about 3000 times annually. The seismic activity has so far caused limited damage but as much as 60% of the Kyrgyz population live in houses that might not be able to stand strong earthquakes. Seismic experts are expecting the seismic activity in the area to increase in the coming years, with strong earthquakes measuring about 7 – 8 on the Richter scale [18].

Heating periods

For the district heating networks in Kyrgyz cities the local authorities decide when the heating will start as well as the length of the heating period (Table 3.1). The heating period is the estimated period when the average daily temperature is below 8 °C [10, 19].

Table 3.1: Length and temperatures for the heating period in four Kyrgyz cities: the number of heating days, a mean of the estimated temperatures of the five coldest days, and the average daily temperature of the period [10, 19].

Place	Heating period (days)	Lowest temp. (°C)	Average temp. (°C)
Bishkek	150	-19	0.2
Karakol	187	-12	-1.1
Osh	140	-15	1.1
Narryn	192	-27	-6

3.2 Politics

The Kyrgyz Republic (hereby denoted Kyrgyzstan) became independent from the Union of Soviet Socialist republics (USSR) on the 31st of August 1991 [16]. The economic decrease was rapid after leaving the union. The country was among the first former Soviet Union republics that tried to make its own way to a market economy. Drastic changes were

[1] The mean of the highest temperatures each day during a summer month

made in the country within a few years: a new currency was created, privatisation of public assets took place, and the possibility of external trade was opened [16].

In 2005 there was a revolution in Kyrgyzstan, called the Tulip revolution, when the people found the then-president undemocratic. A new president was elected but in 2010 new violent demonstrations ousted this one as well on account of his corruption. The people of Kyrgyzstan were also discontent with the high unemployment and energy prices. Under the leadership of an interim government and president, a referendum was held in October 2010. The result of this referendum was that the presidential power was decreased and parliamentary democracy introduced. Kyrgyzstan was the first parliamentary democracy in Central Asia [20].

The parliament in Kyrgyzstan is called Jogurku Kenesh. There are seven administrative provinces, called oblasts, in the country. Bishkek is also an administrative region with the same status as an oblast. There are also 49 administrative districts in Kyrgyzstan, which are called rayons [16].

14% of the Kyrgyz population is of ethnic Uzbek minority. However, they make up more than 30% of the population in the south. In June 2010 there were violence acts in the south of Kyrgyzstan, caused by differences between the Kyrgyz and Uzbek ethnicities. At least 400 people died and 100 000 Uzbeks escaped to Uzbekistan. Exactly what caused the conflict is unknown, but there are differences in political opinions between the north and south of Kyrgyzstan, and among people with different ethnicities in the country. This is unfortunately a great problem for the Kyrgyz republic [20].

Poverty

The poverty in the country has decreased in recent years but is still substantial. It peaked in 1998 with 62.4% of the population being poor. Still 51% of the rural population and 31% of the urban population (43.1% in the country as a whole) was estimated to be poor in 2005, according to the UN [16]. The people with less than 1 $ a day income (defined as "extremely poor" by the UN [6]) were 14% of the rural population and 7% of the urban population [16].

Corruption

Corruption is a widespread phenomenon in Kyrgyzstan. In 2012 Kyrgyzstan was ranked 154 out of 176 countries examined in the Corruption Perceptions Index. In 2011 the country ranked 10.4 on a scale from 0 – 100 (100 being very clean) on the World Bank's Worldwide Governance Indicators (WGI). The corruption influences the whole of Kyrgyzstan; it is on all levels in the state and in all sectors of the economy. It is considered a big issue for the country by 72% of the population. It is a big hindrance for companies to start doing business in Kyrgyzstan. Since 2011, when Kyrgyzstan became a parliamentary democracy, there have been many efforts taken by the government to fight corruption. However, it remains to be seen if the efforts will be effective [21].

Economy and employment

The unemployment of Kyrgyzstan is about 9%[2] [11]. About 30%[3] of Kyrgyz people work in agriculture [22] and about 20%[4] of GDP is earned from this sector. Tobacco, cotton, vegetables, wool and livestock are examples of products from the agricultural sector [11].

During the USSR era there were more industries in Kyrgyzstan than there are today. The industries were based on the import and export of material to and from the rest of the union. The industries were also subsidised by the central government of the USSR [16]. Today, the industrial sector employs about 20%[5] of the Kyrgyz population [22] and also about 20%[6] of GDP is earned from this sector [11].

Kyrgyzstan is a country rich in minerals such as Uranium and Gold. During the soviet era a substantial amount of uranium was mined in Kyrgyzstan. The mines are however closed and abandoned now (possibly still leaking radioactive water). The gold-mining industry has earned a large part of the republic's GDP during the 21th century, making the country's economy very vulnerable to the fluctuations of the world price of gold [23]. In recent years this industry has decreased substantially, with the largest gold mining company, Kumtor, suffering a decrease in production of 83% in 2012.

The GDP of Kyrgyzstan has grown since 2007, in that year the growth was 8%. How much the GDP has increased annually since then has dependent largely on the gold price. In 2012 with the decrease of production from Kumtor, the GDP increase was only 1% [11].

Except gold, other important export products are: electricity (to neighbouring countries), antimony, mercury, and rare-earth metals [15]. The industry also produces cement, textiles and shoes, among other things [11].

3.3 Kyrgyz energy statistics

After the independence from Soviet (in 1991) the energy prices got much higher [14]. As a result, the energy supply decreased, as can be seen in Figure 3.2. The decrease in energy supply was in the following years compensated to some extent with an increase in hydro- power production. For electricity production in the country, the increase of hydro-power covered the loss of fossil electricity production. In recent years (2007 – 2011), the electricity production of Kyrgyzstan is on average 12 990 GWh. Nearly 90% of the electricity is produced by hydro-power. About 1000 – 2000 GWh/year of the electricity is exported [24].

The consumption of electricity was in 2007 recorded to be 1761 kWh/person (this can be compared to Sweden's 15 258 kWh/person the same year) [25]. The electricity grid reaches the whole Kyrgyzstan but the electricity is often interrupted, only 5% of the population have access to electricity all of the time [26].

In buildings the energy use varies between 320 and 690 kWh/m^2 per year [27] (3 – 5 times less energy is used in the EU [27]. In Sweden 158 kWh/m^2 was used in 2010 [28]).

[2] 8.6% 2011
[3] 34% 2010
[4] 20.8% 2012
[5] 21% 2010
[6] 23.3% 2012

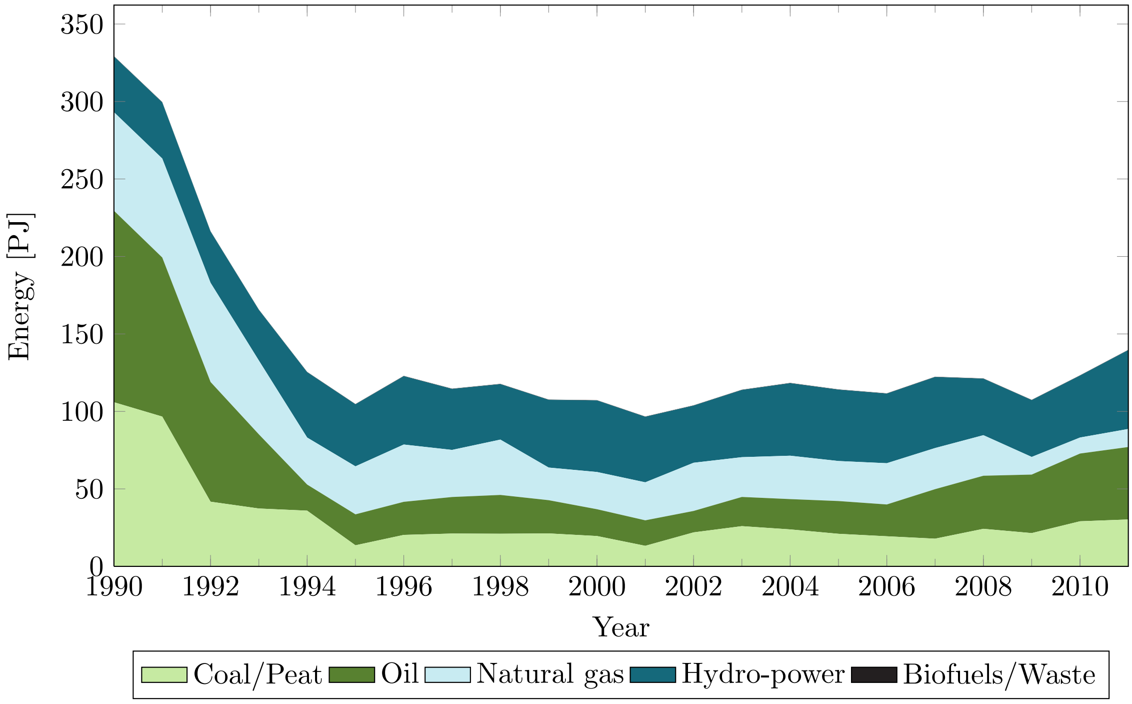

Figure 3.2: Total primary energy supply for Kyrgyzstan. Exports of electricity is included [24].

1.2 metric tonnes of carbon dioxide per person was recorded to be emitted in Kyrgyzstan 2007 (in Sweden the corresponding number was 5.2 tonnes CO_2/person) [25].

Energy production for Bishkek

80% of the electricity used in Bishkek is produced at a Combined Heat and Power (CHP) plant in Bishkek. This plant utilises coal, oil, and gas. The rest of the electricity consumed in Bishkek is produced by hydro-power in Toktogul. The CHP-plant produces the heat for the district heating system as-well. The heating system is covering a large part of Bishkek [10].

3.3.1 Energy prices in Kyrgyzstan today

The price for electricity is 0.7 som/kWh (corresponding to about 0.014 $/kWh) for the whole country. This is unless the consumption is extra large, then it costs 1.2 som/kWh. The price is an average of the price for hydro power and the price for electricity produced in CHP-plants [10]. In Sweden the price for electricity is about 1 SEK/kWh (corresponding to about 0.14 $/kWh).

The price for heating is 715 soms/Gcal (which is about 0.013 $/kWh). The energy usage for heating is estimated for each apartment type and a fixed price is calculated. For example, a one room apartment in the houses examined in this thesis is estimated to consume 3.6 Gcal per year - giving a cost of about 2 600 som per year (corresponding to about 53 $/year) [29]. In Sweden the price for district heating is about 0.80 SEK/kWh (corresponding to about 0.11 $/kWh) [30].

The domestic hot water (DHW) costs 41.1 som per/m^3 (about 0.84 $/$m^3$). It is estimated that one person consumes 4.8 m^3 of hot water per month (corresponding to 160 l/day/person). The bill is most often paid per person living in the household, and the cost is about 200 som per person and month [29]. In Sweden the hot water costs about 56 SEK/m^3 (8 $/$m^3$) [31].

The gross national income per capita in Kyrgyzstan was 1 068 $ in 2011 [22]. In Sweden this was 58 140 $ in the same year [32]. The average national salary was 144 $ per month in 2010 (1 730 $ per year) [33].

3.4 Kyrgyz buildings

3.4.1 Traditional Kyrgyz buildings

200 years ago, when most of the Kyrgyz people were nomads, they lived in yurts (see Figure 3.3). A yurt is a large tent like construction, mostly made out of wool felt. It can be transported easily from place to place, making it possible to move with the seasons [34]. Today there are few people who live in yurts the whole year round. However, some Kyrgyz people still live in them during the summer.

Figure 3.3: Traditional building techniques. To the left: a yurt. To the right: a wall made of clay and straw, like some buildings which are still built in the countryside.

During the second half of the 19th century, the nomadic life style of the Kyrgyz people was changed towards a more settled farm life. In the beginning of the 20th century half of the population were settled farmers and the urbanisation of Kyrgyzstan begun [34]. Common traditional materials for building houses on the countryside are clay and straw as can be seen on the wall in Figure 3.3 [6].

3.4.2 Soviet buildings

The Soviet Union was centred in Moscow and it was there it was decided which types of houses should be built. Standardized constructions were calculated to be less expensive than individualized structures. In 1979 for instance, there were 127 standard building designs possible to choose from. 2.2 million houses were built annually, and all members of the union were dwellings, sometimes shared with other tenants. All utilities were included, except electricity and telephone. The massive destruction of Soviet cities during World War II meant that many houses were destroyed. When building new houses, the latest available technology could be used. This meant that some energy conserving systems, such as district heating, were installed [35].

The most common houses in Bishkek are made out of brick or concrete. The brick buildings are older and often more energy efficient. They are often called "Stalin buildings" because they were made when Stalin ruled the USSR [6].

The newer concrete buildings instead are called "Khrushchev buildings", from the later dictator [6]. The buildings are made out of concrete panels, fitted together in situ. The building stock of Bishkek consists of 35 – 40% concrete panel buildings [36].

3.4.3 The housing situation today

There are about 1.1 million dwellings in Kyrgyzstan which means that there are about 4.7 people per dwelling in the country. This is high compared to the European average of just 2.2. Housing is one of the biggest social problems in Kyrgyzstan. Housing shortages is one of the problems affecting the whole country. Many people have moved to urban areas which has caused the housing shortage in these areas. Of those who have moved to the cities, many people have been forced to live in settlements lacking infrastructure such as drinking water and electricity. In Bishkek, somewhere between 125 000 – 200 000 peoples are living in these settlements [16].

The shortages apply also to rural areas. 65% of the Kyrgyz people live in these areas [16]. In rural areas the infrastructure is lacking in many places. There are shortages of drinking water in particular, where 14% have no access to clean drinking water but use instead the often contaminated streams in the surrounding areas [26]. In the country as a whole only 40% of the households have access to public sewage system and only 27% have flushing toilets. 25% have access to showers or bathrooms [16].

85% of the buildings in Kyrgyzstan today were built during the soviet era, where a large part of the buildings built were multi-apartment dwellings. They are now in great need of reparations. According to the UN, it is urgent that action be taken to retrofit the roofs, elevators and façades of Kyrgyz buildings. Also windows have in many cases outlived their technical lifespan. Pipes for sewage and drinking water are also in need of replacement [16].

The dwellings are to 96% privately owned (98% in Bishkek), the rest remains rental housing [16]. Before independence 100% of the apartment buildings and 32% of the total housing stock was owned by the state or by cooperatives. As early as 1998 the state and cooperative owning of houses was down to 6% [26]. The only rental apartments in Kyrgyzstan are essentially owned by universities or the military (for students and military members respectively) [6]. The maintenance of the buildings has, as a result, been neglected. The United Nations (UN) states in a report on Kyrgyz housing that: "*the very high owner occupancy rate is today one of the biggest obstacles for management and maintenance of multi-apartment buildings*" [16].

Energy efficiency in Kyrgyz buildings today

When new houses in Kyrgyzstan are built, energy efficiency measures are very seldom taken. There are also very few measures being performed on the existing building stock. In essence, the only energy efficiency measures taken in multi-apartment buildings are from individual owner initiatives. The common areas in multi-apartment buildings are to a lesser extent refurbished [16].

The reason for the low amount of energy measures performed is, according to the UN, that the economic incentives for taking energy efficiency measures are low. As mentioned, most people pay for district heating per floor area and not for their actual consumption. Installation of energy efficiency equipment is not affordable for most people [16]. There is an initiative from the government of Kyrgyzstan with the purpose of installing meters for measuring heat consumption on all buildings, including multi-family ones. This would make it easier to pay for the actual consumption [10].

Some adequate initiatives for energy efficiency were however noted by the authors (Figure 3.4). Houses being built in Bishkek were noted to be built with bricks. Insulation, most often expanded polystyrene, is placed outside of the brick façades, followed by plaster. The windows used are mostly PVC-framed.

The energy efficient houses being built in Bishkek are however most often available for the richest part of the population [16].

Figure 3.4: Examples of insulation improvement. Pictures to the left and in the middle: retrofitting of a building on the countryside by adding insulation. To the right: a brick-building being constructed in Bishkek.

Initiatives for bettering the housing situation

There have been programs and initiatives from the government to improve the housing situation in Kyrgyzstan. They have however lacked in funding and consequently have not had the desired effect [37, 26, 16].

In 2012, a State Program of “Affordable Housing in the Kyrgyz Republic for 2012 – 2014” was drafted. Among other things it contains a state subsidy for purchasing housing. The implementation of this subsidy is however not yet in place [38]. The government has also got a slum-upgrading program. This program aims at providing infrastructure improvements in settlements [37].

There is a collaboration project between the UN and the Global Environment Facility (GEF) which aims to reducing the energy consumption and greenhouse-gas emissions in the Kyrgyzstan building sector. So far, two school buildings have been designed and one is being developed [27].

A building made solely out of environmental friendly materials was constructed outside of Bishkek by KSUCTA. The building is a one-story building with an area of 30 m^2. The roof was made in an angle so it would allow maximal shading in the summer and at the same time maximum sunshine-inlet in the winter. The windows are placed to the south and the door to the north. The building was constructed out of straw with wooden gables. It is however not a residential building but instead used as an administrative building for the local community [10].

Chapter 4

Building theory

This chapter presents fundamental theory of buildings. The building as an energy system is presented and basic concepts are explained. The phenomena creating moisture, which is a serious threat to a building, are explained in a separate section. The basic structure of a building, the building envelope, is divided into separate sections and explained. Insulation materials are given their own section because adding insulation is an important way to make a building more energy efficient. Also a change in ventilating system could bring down the energy consumption of a building considerably. To have a comfortable living space it is important that the heating and cooling system of the building work effectively. Different kinds of systems for heating and cooling are explained last in this chapter.

4.1 Building as energy system

There are many energy flows which affect a building. In Figure 4.1 all the main flows are illustrated. The theory behind each flow is explained further down in this Chapter. In general there is a steady state between the energy outflow and inflow of the building. This means that flow 1 -– 3 in Figure 4.1 is equal to flow 4 -– 10. If an energy flow is changed it could take a while for the system to reach a steady state. Depending on building materials and the volume of the building, reaching a steady state can take from half a day up to a couple of days. Of course the size of the change has a large impact on the time it takes to reach the steady state. If the weather changes it is mainly flow 2 and 6 -– 8 which are affected. Flow 1 and 4 are mainly used to control and keep a balance between the sum of all flows. It is important to keep the balance for the indoor climate to be comfortable and to keep a stable indoor temperature [39, 40, 41].

4.1.1 Indoor climate

The most important factors which affect the indoor climate and a person's perception of it is:

- Temperature of air
- Speed of air (from draught and ventilation)
- Temperature of surrounding surfaces

- Humidity of air
- Physical activity and clothing of the persons who stay in the building

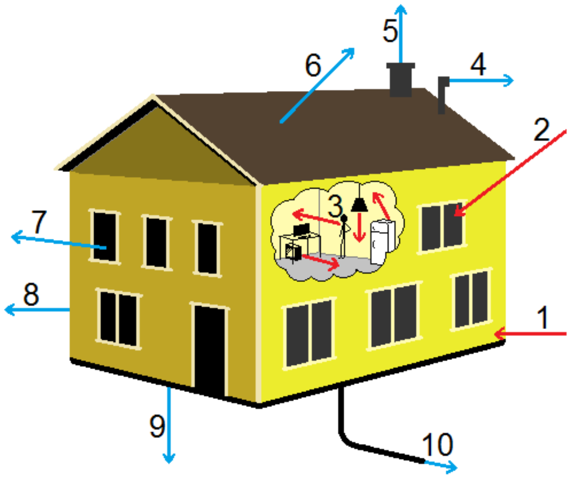

Figure 4.1: All thermal flows connected to a building. Thermal flows into the building:
1. Central heating
2. Sunlight generated heat
3. Heat generated by humans, electronics, lamps etc.

Thermal flows out from the building:

4. Heat-losses with ventilation
5. Heat from furnace exhaust
6. Heat radiation
7. Infiltration from open windows/doors or cracks in building envelope
8. Thermal conduction to air
9. Thermal conduction to ground
10. Heat-losses from sewer

One important aspect is illustrated in Figure 4.2. The human body experiences temperature through both convection, conduction and heat radiation (see Glossary Appendix A). The experienced temperature is called the *operative temperature*. If the surfaces are colder than the air the operative temperature will be a combination of the temperature of the surfaces and the air.

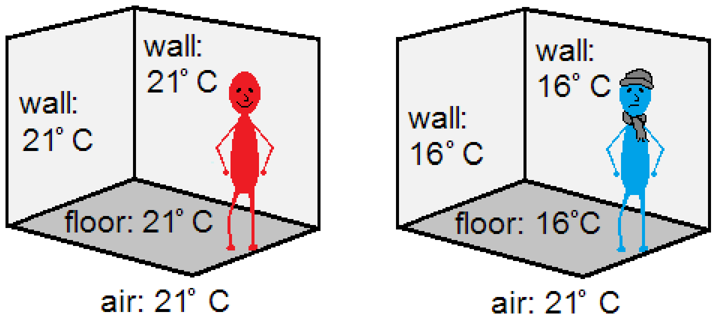

Figure 4.2: The person in the left room experiences a temperature of 21 °C but the temperature for the person to the right room is lower.

4.2 Moisture

Moisture in a building can harm the structure and influence the thermal performance of building materials. A moist material is also a favourable habitat for fungi, which will create mould in the building. Sources for moisture to a building can be [42]:

- Indoor and outdoor air humidity. The indoor air humidity is dependent on the ventilation, moisture sources indoors (e.g. boiling water, showers), cold surfaces (condensation) and wet surfaces (evaporation).
- Construction damp. It is important to dry materials well before they are inserted.
- Precipitation: snow and rain.
- Water leakage, e.g. from leaking pipes.
- Moisture in the ground that spreads through the foundation and to the building envelope.

4.2.1 Thermal aspect of moisture

Moisture can be transported inside a building material in different ways. In this section different physical phenomena leading to this transport are presented [42].

Diffusion, from the more humid air surrounding the material, into the material. A low humidity brings single water molecules into fine pores of the building materials. At higher levels of humidity the water may be in multi-layers in the wall because of diffusion. Also with higher levels of humidity larger and more pores are filled with water [42].

Capillary suction occurs primarily from wet surfaces. In a pore with a small diameter the water is sucked up because of attraction between the water molecules and the wall of the pore. If capillary suction occurs it is more rapid and a larger contributor to moisture transport in the materials than diffusion is. In pores with no liquid water, no capillary suction occurs, only diffusion. In pores filled with water however, there will be only capillary suction between the pores. There are also pores where both phenomena occur at the same time [42].

Convection can transport moisture inside the wall. When air is flowing from warmer to colder regions of the materials, condensation might occur if the humidity by volume of saturation (see Glossary, Appendix A) is lower in the colder region. If the transport occurs from colder to hotter regions, drying of the wall is possible instead, because the air can take up moisture.

Convection may also transport moisture to and from a surface of a material and the surrounding air. Condensation can occur also in this case. When condensation occurs heat is released. This might make the surface warmer and in turn reduce the condensation. Also, analogously, evaporation can occur if a surface is wet, because of the relative humidity being lower in the surrounding air than on the surface [42].

Pressure difference leads to transport of water if a material is exposed to liquid water for a long time. The amount of water transported in this case is dependent on the permeability of the material. There can also be transport of water through a hole in an otherwise watertight layer because of a water pressure difference between the material and the water [42].

4.2.2 Damages by moisture

Moisture in buildings can cause physical damages such as frost weathering and salt precipitation. Moisture is also a prerequisite for fungi to be able to establish themselves in a building. Fungi thrive in temperatures of about 20 – 30 °C. Common fungi that you can find buildings are Ophistostomatales, dry-rot-fungi and mould-fungi.

Ophiostomatales, of the class Sordariomycetes, attacks wood and its colour is blue, black or green. The strength of the wood is however not usually affected [39].

Fungi causing dry rot are a serious threat to the structure of a building. They do however need a vast amount of water to be able to thrive. One common example, *Serpula lacrymans*, does not need as much moisture inside the building, but can transport the water from a source a long distance from the building. It can also decompose the cellulose and thereby gain water. It is dependent on lime to grow and can grow on mortar. It can grow on both wood and stone buildings [39].

Mould is a name for the mycelium part of some fungi, visible because of its vastness [43]. These fungi do not harm the building construction themselves but make way for other types of fungi. The fungi form spores to reproduce. The spores, of which they release huge amounts into the surrounding air, are harmful for humans to inhale. These types of fungi have a specific mould smell. The mould fungus does not need as much water to grow as the dry-rot-fungus. There are also mould fungi that cause dry rot.

There is a phylum of bacterium, called *actinobacteria*, similar to mould fungi in smell, which also decomposes building materials [39].

4.2.3 Moisture in concrete buildings

In general, concrete is both a water tight and airtight material as long as it is free from cracks and of reliable quality. It has low capillary suction ability. However, two critical aspects are [44]:

- Precipitation can cause moisture to penetrate through joists (see Glossary, Appendix A) between concrete panels.
- Construction damp.

Because waterproof layer is unnecessary for concrete, the construction moisture will generally have no critical obstruction to dry out. It is however more important how the joints (see Glossary Appendix A) between the single panels are formed. The joints can either be of a so-called *one step*-type. In this case both water and wind are blocked with one structure. In the *two-step*-type the water and wind proof is separated in two different structures. In the two-step-joint there is a space of at least 5 mm between two panels on the outer side; the capillary forces are too weak to let the rain get inside. An airtight seam is placed some centimetres in the gap between the panels where rain never reach [44].

When prefabricated panels are used it is important that the inner wall is airtight to prevent convection of moisture, especially to the top floors [44].

4.3 Building envelope

The building envelope is the physical separator between the exterior and the interior environments of a building.

4.3.1 Doors and Windows

For both windows and doors it is important to avoid thermal bridges (see Glossary, Appendix A) in the frames surrounding them. The frames should be built in a material with favourable insulating properties (wood is a good example of this). There is a risk otherwise that condensation will form on the frame in the winter when it is cold [39]. According to Swedish building standards a dwelling built in Sweden should always have windows that can open [45].

The entrance door of a building should be well insulated and able to withstand the weather forces, such as harsh winds and precipitation of different kinds. When it is cold outside heat gets transferred outside every time the entrance door is opened. To lessen the heating demand of the building it is appropriate if the entrance hall is separated with closed doors to the other parts of the building. In this case the small room area is essentially the only part of the building being cooled down when the main door opens.

The windows of a building are commonly a source of heat leaking from the building. In figure 4.3 it is shown how heat is transported through a window due to convection, conduction and radiation (concepts which are explained further in the Glossary in Appendix A).

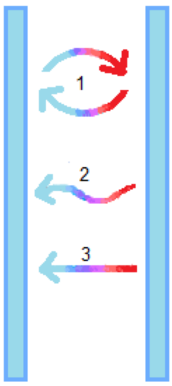

Figure 4.3: A window with double-glazing: 1. Convective heat transferral because heated air will rise on the hot side of the glazing and sink on the cold side and thus create a movement of the air. 2. Long wave (IR) radiation 3. Thermal conduction in the glass and in between them [39].

Condensation is common in the winter on single or double glazed windows because of a convective heat transfer of air. Radiators are often placed below the windows to reduce the formation of condensation and heat any leaking air coming in from the outside.

To reduce the convective heat transfer between a window and the surrounding air, more glazing can be added to the window. Today, windows can have up to four layers of glazing. It is important to note that the closer the distance between the layers of the glaze, the less convection will occur, but there will be more thermal conductivity. One downside with more layers of glazing is that each new glaze will decrease the amount of sunlight let through the window [39].

Another gas than air can be added between the layers of glazing of a window to reduce both the conduction and convection. Gases used for this today are argon or krypton, among others. Another way to reduce the thermal conductivity in the windows is to induce a vacuum between the layers of glazing, this is however not commonly done [39].

Today there are windows where a layer of metal oxides are added to the glazing to give it low emissivity. This way more of the long wave heat is reflected off the glazing and consequently the glazing emits less heat. The glazing is also less transparent to the visible wave length. A clear window let about 75% – 80% of sunlight pass through, whereas for a window with coating, this number is reduced to 60% – 70%. There are both soft and hard coatings. The hard coatings are more durable but the soft coatings have both higher IR-reflectance and higher transparency to the visible wave length [46, 39].

Well insulated windows can in the summer lead to overheating indoors and create a cooling need. There are windows today with a special layer where the amount of sunlight that is let through can be varied electronically [39].

4.3.2 Roof

The purpose of a roof is to prevent rain from getting inside the building and without it heat would freely escape upwards. Roofs can have a steep, moderate or no slope. Roofs with moderate or no slope needs to be totally waterproofed. During rainy periods water can otherwise gather in pools on the roof. Rain gutters can also get clogged with leafs and dust and will cause water to stay on the roof longer than desired. Steep roofs do not have to be totally waterproof as long as they are decent in draining off the rainwater [44, 39].

The properties of the attic have an impact on the roof and the building's energy flows. The attic can be cold or warm. A cold attic has proper ventilation with the outside air. A roof to a warm attic has no ventilation. Moisture has to be blocked out in the ceiling to protect the roof [39].

4.3.3 Walls

The building's walls must offer protection against wind and water and be able to create a comfortable indoor climate. There are moisture threats both from the outside and the inside of a building.

The side of the wall facing the indoor air needs to be air tight, mainly to reduce the convective transportation of moisture through the wall. The diffusion is a lesser threat to the wall and it is more important to make sure that it is easier for the air to diffuse out from, than into, the wall.

On the outside it is precipitation that can cause moisture damage, the building needs protection against rain and snow, pelting rain being the most common to cause harm to the building's walls. This can be solved by an impermeable layer on the outside of the wall, such as concrete. The wall can also be allowed to absorb the water; if the inside wall can withstand it and it can dry up completely after the precipitation has stopped. An example of this is a brick wall with plaster. A wooden house with an outer wall made of brick or wooden panel is not completely water resistant but the water penetrating will be drained or ventilated out from the building before it can reach the inside of the wall.

Inside the wall structure there must be insulation to make the indoor climate comfortable. The insulation is made to hold as much gas with low thermal conductivity (most often air) as possible, but also reduce the amount of convection in this gas. There will be some conduction and radiation occurring in the materials of the wall. In Section 4.4 information about different materials used to insulate buildings is presented.

When building a wall it is important to reduce thermal bridges. If there are thermal bridges it is most often because the insulation is not assembled correctly round the supporting structure, creating gaps where air can pass through [39].

4.3.4 Building foundation

The building foundation again needs different properties to the roof and walls. The ground has a more stable temperature than the outdoor air but it does also contain more water. By capillarity suction, convection or diffusion moisture will be transported into the building if it is not stopped. There are two main methods to stop the moisture-spread. First, the foundation can be built in such way that the water cannot pass and/or is ventilated away. Secondly, the house can be placed so that precipitation and groundwater will flow from the building rather than towards it. A proper drainage around the building will contribute to less moisture spread to the building [39].

There are different types of building foundations. A basement (finished or unfinished), a slab-on-grade or a crawl space (ventilated with air). In all types, appropriate insulation is important, not only for the indoor temperature but also to avoid moisture. All types of foundations except for some types of crawl space-foundations have a concrete slab as the base. Usually insulation is put underneath the slab so the slab will never be as cold as the ground. In the ground the relative humidity is 100% and the warmer slab has a lower relative humidity. The humidity by volume is the same. If the insulation is put on top of the concrete instead there has to be a waterproof foil between the insulation and the concrete to avoid too much water vapor to pass through the building envelope.

Bottommost in the foundation is coarse gravel. Not only does it work as drainage for rainwater, but also as a barrier against upward travel of water with capillarity. The gravel has to be clean for this to work.

During cold winters there can be problems with frost wedging in the foundation. One safeguard against this can be to have an insulating “collar” on the foundation. The collar is placed in the ground and runs out from the foundation parallel to the ground surface. This will prevent the frost line stretching in underneath the house [39].

4.4 Insulation materials

There are many different materials that can be used when insulating a building. Some of the most common materials are mineral wool, expanded polystyrene and extruded polystyrene and polyurethane foam. Other materials are being developed as well, for example in Sweden cellulose wool is a quite common insulation material. Wool from sheep is used as an insulating material in Australia among other countries [34]. Insulation material from renewable sources (such as flax and hemp) are under development. Cellular glass, made out of recycled glass, may be used more in the future. Some properties of the materials mentioned will be examined in this section.

4.4.1 Common insulation materials

Mineral wool is a man-made insulation material containing a variety of minerals, the most common of them being lime stone, dolomite, diabase, bauxite and resovite. Mineral wool accounts for about 60% of the European market of insulation materials. There are two main types of mineral wool: glass wool and stone wool [47, 48].

Glass wool is as the name suggests is made of mainly glass, namely borosilicate glass. The fibres for Glass wool are created by heating the glass and then pulling it through a rotating nozzle [49].

Stone wool (sometimes denoted rock wool) is made mostly out of melted stone. In the manufacturing process there is also industrial waste, mainly from steel and cement production, added to the material. Ammonia and silane are also added. In the process of making stone wool a large airflow is used [48].

For both stone and glass wool there is also a binder used, containing phenol, formaldehyde and urea [48]. The binder binds the fibres together and improves other properties of the wool. Oil is also added to decrease the dust forming in all mineral wool production [49].

A higher temperature is used when manufacturing stone wool (about 1500 °C) than for glass wool (about 1400 °C) [49]. This gives the materials slightly different properties and field of application, despite their similarities in mineral content. Stone wool is heavier and has a higher melting point than glass wool [47].

Expanded and extruded polystyrene Expanded and extruded polystyrene are two insulation materials based on polystyrene which is a polymer fabricated from crude oil. Expanded polystyrene (EPS) is made of small spheres of the polymer containing an agent, commonly pentane, which will expand when the spheres are heated with water vapour. The spheres will be fixed together at the contact area as the gas expands.

To create extruded polystyrene (XPS) the polystyrene is melted and then an expansion gas, commonly hydroflourocarbons (HFC), carbon dioxide or pentane, is added [49].

To improve fire resistance of the materials, different additives have to be used for both of the insulation materials [47].

Polyurethane foam Isocyanates and polyols reactes to form polyurethane. An expansion gas, commonly HFC, carbon dioxide or pentane, fills pores in the material. The foam may be used to seal around windows for example, as well as an insulation material inside the building [49].

4.4.2 Insulation materials from cellulose

Cellulose wool can be made from either recycled paper or wood fibre. Boric acid and borax are added in the production process [49] to reduce the risk of fire or mould spreading [50].

Cellulose wool made from newspaper is produced in England, France, Germany, Sweden, Denmark, Finland and Poland [48].

Flax (also known as linseed, *Linum usitatissimum*) can be grown to produce fibre for insulation. The fibres are removed from the plant (the linseed and the leftover plant material are used in other applications) and mixed with heated polyester binder (in one production site 15% w/w binder was added) to form the insulation. Fire protection agents are corresponding to about 10% w/w [48].

4.4.3 Other insulation materials

Sheep wool can be used as an insulation material. To make thermal insulation out of sheep wool the wool has first to be washed. In the washing process a rubber is used to add a lasting insect protection to the wool [51]. The wool is then carded and formed to insulation boards. According to the company Sheep Wool Insulation, no binders and glues need to be used [52]. The company Thermafleece however, uses a polyester binder (15%) [53].

The wool is in some cases impregnated with halogen organic compounds to reduce the possibility of moths in the material. Also boric salt is used in the product [50].

Cellular glass is made from recycled glass as well as sand. To produce cellular glass the material is melted and then cooled in a controlled fashion [54] .

Table 4.1: Thermal conductivity (λ) and moisture properties for the examined insulation materials. The (dry) λ-values are calculated average values from [55].

	$\boldsymbol{\lambda}$[55] $mW/(m^2K)$	**Moisture properties** [50]	$\boldsymbol{\lambda}$ **at 10 vol% moist** [56] $mW/(m^2K)$
Glass wool	39	Moisture resistant	55
Stone wool	38	Moisture resistant	55
EPS	40	Moisture resistant	54
XPS	38	Moisture resistant	44
Polyurethane	35	-	46
Cellulose fibre	40	Moisture buffering	65 (at 5 vol%)
Sheep wool	39	Moisture buffering	-
Cellular glass	46	Moisture resistant	-

4.4.4 Insulation and moisture

In Table 4.1 it is shown how the moisture properties differ from different insulation materials. Which insulation material to use depends on how the building is constructed. Some materials can *buffer* moisture and later release it. This can create an even air moisture content inside a building. It is in this case very important that there are no layers which are watertight in contact with the insulation, as these layers prevents the moisture from being released. Insulation materials from cellulose fibres or wool are examples of moisture buffering materials.

If the material is moisture-*resistant* it is then important that there are impermeable layers around the insulation because the moisture that reaches inside the insulation material will not be released from there, decreasing the insulation properties of the material. Moisture is taken up by the materials and not released again, causing the insulating properties to decrease over time. This has been seen in polystyrene materials [50].

As can be seen in the Table 4.1, the moisture buffering material made of cellulose fibres has a more rapid increase in thermal conductivity when it is exposed to moisture [56]. The difference is that this material will be able to release this moist more easily than the moisture resistant materials [50].

4.4.5 Environmental properties of insulation materials

When choosing insulation material it is important to consider environmental aspects of the material. Aspects to consider are [50, 48, 47]:

- Which basic material were used to create the insulation material. Is this basic material from a renewable source or otherwise existing in a vast amount?
- Can the material be recycled when it has been used?
- How much energy is used in the products life cycle and how much greenhouse gas is released as a result of the production?
- Are there other environmental problems caused by the production?
- How many chemicals are used in the material? Chemicals in the insulation material can be released from the material to the indoor air and cause health problems to the residents of the house.
- Release of dust or other health problematic properties of the material.

Material origin and energy demand

Neither of the common insulation materials is made out of renewable materials. The minerals used to form mineral wool exist in a great amounts but are not renewable. The cellulose materials and the sheep wool are made out of renewable sources (Table 4.2).

As can be seen in Table 4.2 the embodied energy (see glossary Appendix A) can vary a lot for the materials. Polyurethane has however got considerably lower embodied energy than the other materials, per cubic metre.

The renewable materials are not always responsible for less energy usage and greenhouse gas emissions in a life cycle perspective than the other materials. As can be seen in Table 4.2 the material responsible for the largest amount of greenhouse gases of the three materials examined in the study by [48] is flax, even though it originates from a

Table 4.2: Recyclability of the materials, from [47] if nothing other is stated. Embodied energy (MJ/kg material, see Glossary, Appendix A) from [47] if nothing other is stated. Greenhouse gas emissions in a life cycle perspective for three materials (g CO_2-equivalents/kg material), from [48].

	Base material	Recyclable/ reusable	Embodied energy (kWh/m^3)	CO_2-eq (gCO_2/kg)
Glass wool	Minerals	yes/no	90-430	
Stone wool	Minerals	yes/no	110-660	2250
EPS	Crude oil	yes/yes	151-269	
XPS	Crude oil	yes/yes	85-114	
Polyurethane	Crude oil	no/no	15.8-36.1	
Paper wool	Renewable	yes/no [48]	20 MJ/kg [48]	1020
Flax	Renewable	yes/no [48]	40 MJ/kg [48]	2970

renewable source. However, paper wool, also of renewable origin, is responsible for the least emissions of greenhouse gases of the three materials examined.

The high greenhouse gas emission of the flax insulation material is mainly due to the polyester binder in the product [57]. Also for sheep wool insulation, a polyester binder is sometimes used to stabilize the product. No information of greenhouse gas emissions was found for this product but the amount of polyester binder used in the production might have a substantial impact on the environmental performance in this case.

Cellular glass can be made out of recycled glass, which saves on resources. It is however still expensive and is a very energy demanding process, according to [50].

The embodied energy for different insulation materials is according to [57] however probably compensated for, because the insulation will help reduce the use of energy consumption many-fold the amount it takes to produce and get rid of it [57].

Other environmental aspects of insulation materials

Table 4.3: Some environmental aspects of the common insulation materials [47, 50].

	Toxic in case of fire	Other environmental aspects
Mineral wool	No	Emissions of dust when manufactured and installed
EPS	Yes	Toxic production.
XPS	Yes	HFCs used in production. Toxic production.
Polyurethane	Yes	Additives used against biological impact. HFCs used in production.

Among the common insulation materials the materials made from polymers (the polystyrene materials and Polyutethane) distinguish themselves as being toxic in the case of a fire. In the case of polystyrene, Xylen and Styrene is released, both toxic gases [50]. The mineral wool products as well as cellular glass are inflammable. Also sheep wool has got quite good fire properties, although some boric salt is added for fire protection. For most renewable materials boric compounds needs to be added to reduce the risk of fire spread. Boric acid and borax have been proven to have hormone disruptive properties (Table 4.4)[50].

Table 4.4: Additives to renewable insulation materials. [50].

	Boric comp.	Dust emission	Polyester binder	Halogen organics
Paper wool	X	X		
Flax	X		X	
Sheep wool	X		X	X

Freons (Chloro flouro carbons) have in some cases been replaced by HFCs in the production of polymer insulation materials (Table 4.3). HFCs are not, as freons are, harmful to the ozone layer but they are however forceful greenhouse gases [58]. In the case of using carbon dioxide instead of HFC the green house effect is smaller but not negligible [47].

Mineral wool products release small dust particles when installed, causing health problems in humans if the proper protection equipment is not used (Table 4.3). This is also the case for cellulose wool products, such as paper wool (Table 4.4). The production process for manufacturing of polystyrene products is health hazardous [50].

4.5 Ventilation

Appropriate ventilation is important for the building to be healthy and long-lasting. The major reasons for having a ventilating system is to:

- Add fresh air and remove contaminated air. The indoor air is slowly filled with gases such as CO_2 and radon and particles of different sorts, which can harm the people living in the building.
- Prevent pollution from spreading within a building. For example the cooking smell from one apartment should not reach the other apartments.
- Create an underpressure inside the building. This is important to prevent moisture in walls and in the long run avoid sick building syndrome, SBS (see glossary, Appendix A). The air indoors is usually moister than outside air and the underpressure prevents moisture penetrating though the walls.
- Ventilation can also be used for heating or cooling. Cooling in particular with regard to ventilation.

The quality of the indoor air is important for a healthy indoor climate. In e.g. a classroom or a store, where there are many people at the same time, the CO_2-concentration has to be kept at a low level for everybody's comfort [40].

Another gas that may create health problems in buildings is radon. Radon is a noble gas that may come from the tap water, the ground or building materials. Exposure to the gas may cause lung cancer. It is created from radioactive decay of radium, which in turn is created from radioactive decay of Uranium-238. Also the daughter products of radon (the products of radioactive decay) can cause health problems in humans [39].

Insufficient ventilation will also lead to the particle concentration of the indoor air reaching unhealthy levels for humans. Particles in the indoor air may come from a varied number of sources, such as cooking food, burning of wood or candles, dust and small fibres from furnitures [59]. Also mould spores (see Section 4.2.2) may spread in the indoor air creating heath problems.

4.5.1 Types of ventilation

The main types of ventilation are: natural ventilation and forced ventilation. In buildings with *natural ventilation* there are usually inlets of air in connexion with windows and doors and outlets through a channel leading to the roof. This gives a useful stack effect when there are a temperature differences between outside and inside of the building. Figure 4.4.a) illustrates the schematics of natural ventilation with stack effect. Natural ventilation is usually ineffective when it is warm outside but when it is cold outside the ventilation flow might instead become too high because it is driven by temperature differences. On the other hand it does not need high maintenance. If the stack effect is to work properly the ventilation channels have to be large and straight. In a multifamily apartment block there also has to be one channel for each apartment, otherwise there is a risk of air flowing backwards in the system. The natural ventilating system tends to take up lot of space.

Forced ventilation exists in different, greater and lesser types of advancement. The simplest type is illustrated in Figure 4.4.b). The system is similar to natural ventilation but there is a fan placed on the outlet. When the outlet is controlled it is easier to handle cold and hot days, when the stack effect does not work in a desired way. There is smaller risk for backward airflow and the outlet channels do not have to take up the same amount of space. Another satisfying thing is that the excess heat can be recovered, saving energy use for the building.

The ventilation can also be controlled in both inlet and outlet as shown in Figure 4.4.c). Usually a heat exchanger is connected in this type of system. The outlet heat up (or cool down) the inlet air to minimize energy losses. This is necessary when there is a great need for ventilation and is commonly used in office buildings and schools etc. In this system there has to be filters to protect the equipment and regulating scuttles. It is also common to have cooling, heating and/or dehumidification systems within the ventilation machinery. In total, a system like this gives economical and energy savings but the maintenance need is much higher than a building with only natural ventilation [40]. A combination of the heating, ventilation and cooling systems is usually referred to as the HVAC-system (Heat, Ventilation and Air Conditioning).

It is possible to use the ventilating system for cooling and heating. More about this can be found in Section 4.6 and 4.7.

4.5.2 Infiltration

Infiltration is air leakages through cracks and holes in the building envelope, it is all the airflow that is not passing the ventilation scuttles. The airflow is driven by the pressure

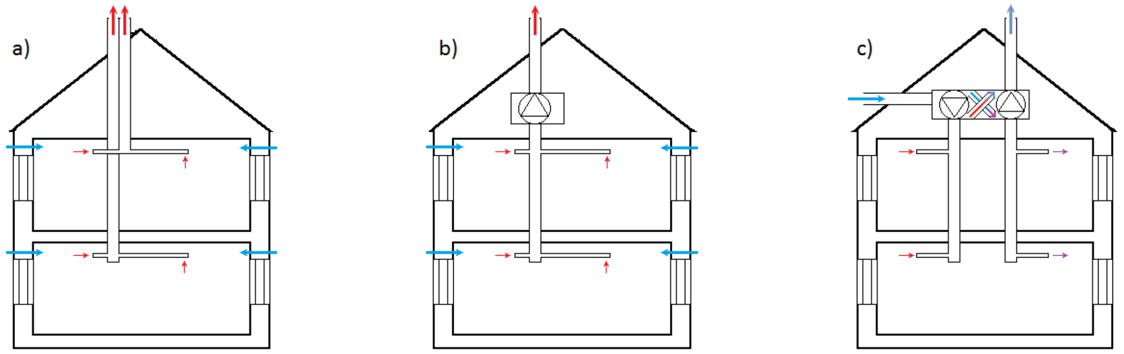

Figure 4.4: The three main types of ventilation. a) Natural ventilation b) Simple forced ventilation c) Forced ventilation with heat exchanger.

difference inside and outside, due to the temperature difference or by the wind. In low buildings it is mainly the wind that is the reason for the infiltration and in high buildings it is mainly the temperature difference. Infiltration is almost always something not wanted. Infiltration can carry both unwanted moisture and influence the spreading of indoor pollutants. In moisture-damaged buildings the infiltration can carry spores from mould fungi to the indoor air. Most importantly, infiltration has a high impact on the heating and/or cooling demand. Consequently, the infiltration can have a great impact on the building's energy needs [60]. Infiltration can cause up to 25 – 50% of the heating demand according to a review about air infiltration through building envelopes [60].

There are two main leakage paths of infiltration. The leakage through large openings is classified as *concentrated air infiltration*. It can be caused by cracks in window and doorframes. Also open windows and doors are part of this. In commercial buildings the entrance door can give a heavy load to the ventilation-system when lots of people are using the door [60].

The other type of leakage is called *diffuse air infiltration*. The diffuse infiltration is when the leaking of air occurs through tiny cracks and pores in the wall. The air has to travel some decimetres inside the wall to be called diffuse air infiltration. One important difference between concentrated air infiltration and diffuse air infiltration is that the diffuse air infiltration is heated up by the wall and does not have the same impact on the HVAC-system as concentrated air infiltration [60].

Infiltration is a concept often utilized in natural ventilating systems. The houses may actually not get enough ventilation without the infiltration. This is important to consider for example when retrofitting old wooden houses with natural ventilating systems. With infiltration moist air is transported into the building. The wooden houses were able to release this moisture. However, when adding insulation such as mineral wool, which is moisture resistant, the building is made airtight. Without the infiltration the building might be lacking inlet airflow and the ventilation need will not be covered. If some small hole is made in the airtight layers surrounding the insulation, moisture will accumulate in the walls [50, 39].

4.5.3 Recommendations for natural ventilation

Swedish National Board of Housing Building and Planning (Boverket) has made a report on how natural ventilating systems should be designed [45]:

- Boverket recommend an electric or hot water driven towel dryer to increase the temperature in the bathroom and create a thermal driving force.
- The system should work in all normal weather conditions. To avoid over-ventilation when the temperature difference inside and outside the building is large Boverket suggest that the air inlet or outlet (see Glossary, Appendix A) can have variable opening areas. The volume of the inlet or outlet air can then be varied automatically depending on the outside temperature and wind speed. The natural ventilating system should be designed to not exceed the intended flow by more than 20% when it is cold.
- The ventilating system should not be dependent on inlet through open windows, but should work as desired regardless.
- The channels of the ventilating system should not be connected joining different apartments with each other. One main channel could instead be used, where the separate channels from each apartment are joined.
- In Sweden, kitchens, and sometimes bathrooms, often have additional forcing of the ventilation, even when the building has a natural ventilating system. This can create a lower airflow through the outlets in other rooms, when this force is activated, which in turn can create a back suction. The suggestion from Boverket is that the inlet air speed should be increased when the outlet is increased in the case of this happening. The ventilation can also be configured so that forcing on all outlets at the same time is activated.

4.6 Cooling

In general, the amount of cooling needed in a building is hard to estimate because the building is storing an undefined amount of energy. The energy is generated whenever the sun is shining, and electronics and humans generate heat continuously. One of the most common and effective ways to cool a building is to cool the inlet air. The cooling can in this case occur in combination with dehumidification. It is important to keep the inlet air at 15 – 18 °C, otherwise the air will not mix properly. When the new and old air does not mix as desired there can be draughty spots and the people occupying the building feel uncomfortable. If the cooling is not enough, more ventilation has to be used [40].

There are more ways to cool a building other than in combination with the ventilating system. To lower the temperature with air conditioning (AC) is energy demanding. A less energy demanding measure is to block sunshine from reaching the building. This can be done by sunscreens, sun blinds on the outside, curtains on the inside or having special window glass which block heat radiation but not light. The sun block prevents the heat from reaching the inside in the first place. The downside with this is that there will be a higher need for lights inside if the sun is shaded [61].

The temperature difference between night and day can also be used to minimize hot temperatures during the day. By extra ventilation during night the whole building is cooled down before next sunrise [6].

4.7 Central heating

In this thesis, *central heating* is defined as the system providing heat to a building. From a central heating unit the heat is delivered to all rooms. The heat unit can either be something producing the heat by itself, like a boiler, or a substation to e.g. a district heating net.

In warm climates, or in buildings with a really suitable building envelope, a simple heating system, or none at all (see Section 4.7.5), is enough for a comfortable indoor climate to be reached in the building. A simple heating system can be a heater connected to the air conditioner or simply a stove. For places with a colder climate a simple heating system is insufficient; the buildings need a central heating system. In a central heating system it is most common to have water as a heat carrier. Other central heating systems use air as heat carriers, in this case in combination with a well-functioning ventilating system. Houses with electrical radiators are usually sorted under central heating even if every single radiator has its own heater. It is due to that the radiators are well distributed in the building. Electrical radiators are usually used in areas with low electricity prices and it is rare to put them in new buildings nowadays, at least in Sweden [40].

The central heating system can be divided into four parts

- The radiators or similar which are used to “deliver” the heat to the rooms.
- Distribution system, in a water-circulation system this consists of the pipes from the heat source to the radiators.
- The heat production, examples of heat sources are presented below.
- Regulation, with control unit and sensors or manual regulation.

When planning the heating system for a building it is important to ascertain the extent of the heat required. This depends on many things, such as the thickness of insulation and impenetrableness of building envelope. It also depends on how fast or slow an outdoor temperature change will affect the inside. Two buildings with same insulation will react differently to temperature changes, if one is a small house with light framework (like wood) and the other is a big block with heavy framework. The extent of ventilation and if/how the inlet air is treated has a huge impact on the indoor temperature and will affect the need of heating. The location of the building on the small scale is also important, is the building in shade most of the day or is it exposed to a lot of sunshine? It is usually warmer in the centre of a city than in the suburbs. Will the wind reach and affect the building to a great extent? Another important aspect when planning a heating system is what kind of excess heat there will be. Humans, lights and electronics all spread heat, a human has for example an effect of about 80 – 200 W [40].

An equation over the heat flows of a building, including all factors mentioned above, is used when the need of heat is estimated. Two important variables are also the desired indoor temperature and the coldest expected outdoor climate. The standard in Sweden is to estimate the coldest temperature to be a temperature that will occur only 30 times in 30 years [40].

There are many types of heat sources that can serve a central heating system. The most common are: district heating, a furnace, a heat pump with different types of heat sources and solar collectors. These sources are presented below. Some buildings are built with nearly no heating needed, how this heating need is covered is presented last in this Section, in 4.7.5.

4.7.1 Furnace

A furnace is an old and simple central heating system. The principle is to heat water with the fire burning in the furnace. The fuel for the furnace can be oil, gas, coal, wood, pellets or residues from wood industries or farming. Furnaces, especially the ones for solid fuels, work most efficiently on maximum burning. The system usually has a hot water storage tank, which makes it possible to run the furnace at maximum for shorter time-periods. The chimney has to be long enough to create a proper natural draught and it has to be in good condition for safety reasons. Emissions of CO_2 (although climate neutral for biofuels), soot and other particles are hard to avoid [40]. In urban areas, where wood burning is common, the level of particles in the air can cause health problems [62].

The benefits of a furnace as heat source are [40]:

- The furnace is independent of outer climate conditions
- Different kind of fuels are possible to use, both fossil and renewable, however not with the same stove.

The disadvantages are [40]:

- The heating costs are highly dependent on energy prices. If firewood were used, a lot of time could be required to prepare it before it can be used.
- Emissions of particles and greenhouse gases to the air.

4.7.2 Heat pump

A heat pump works in the similar way to a refrigerator. The heat pump takes thermal energy from some source (examples of sources are presented below) and transfers it to the radiators and hot-tap. The refrigerator on the other hand, takes away some heat from the inside, and deposit it outside the refrigerator-box. Extra electricity input is needed in a heat pump because the thermal energy source is colder than the temperature in the radiators or hot tap water. The electricity needed is about one third to half of the electricity needed in a heating system powered with only electricity. The important thing with the thermal energy source is that, when it is used, the temperature decrease of it is insignificant. The warmer the source, the lesser electricity is needed to heat the building. The main types of energy sources are [40]:

Outdoor air The heat pumps that run on air are often easy to install and exist as both air-to-air and air-to-water heat pumps, depending on what kind of heating distribution system the building have. The downside with this source is that the outside air is cold when heating need is the largest and more electricity is in that case needed to make the heat pump deliver high enough temperature [40].

Ground and lake The ground or the lake can be used as thermal energy source. A tube is put at least 0.5 m down in the ground (below the ground frost) or on the bottom of a lake to collect the thermal energy. The tube is filled with water containing an anti freeze medium and the length have to be at least 300 meter for a normal single-family house usage. This system have much higher efficiency than the air system because of the temperature in the ground being more stable and because the system has a higher winter temperatures [40].

Bedrock and groundwater The thermal energy is collected through one or some boreholes. Either groundwater is used or a tube with circulating water is put in the borehole. This system is similar to the one with a tube in the ground or a lake. A borehole costs more but a large area do not have to be dug up as in the other case [40]. In regions with a high temperatures in the bedrock, e.g. close to volcanoes and earthquake areas the use of heat pumps with the bedrock have high efficiency.

Outlet air The thermal energy in the outlet air of the ventilating system can be captured and reused in the building. There are always losses in this system and it can never be used alone due to the second law of thermodynamics.

Most of the systems presented above can be used as a cooling as well, depending on what kind of HVAC-system the building has and the model of the heat pump. Often the air-to-air heat pumps are made to work in both directions. The benefits of a heat pump as heat source are [40]:

- About two thirds of the energy comes from a free source.
- The systems are independent of outdoor climate and weather (except when outdoor air is the source).
- Some heat pumps can be used when there is a need for cooling as well.

The disadvantages:

- Some electricity input is always needed.
- There are high installation costs, except for the case with outdoor air as a thermal energy source.

4.7.3 Solar collectors

The sunshine is a free and environmentally friendly energy source. Since the oil crisis in the seventies the development of solar thermal technology has been ongoing. The benefits of solar thermal collectors as a heat source are [63]:

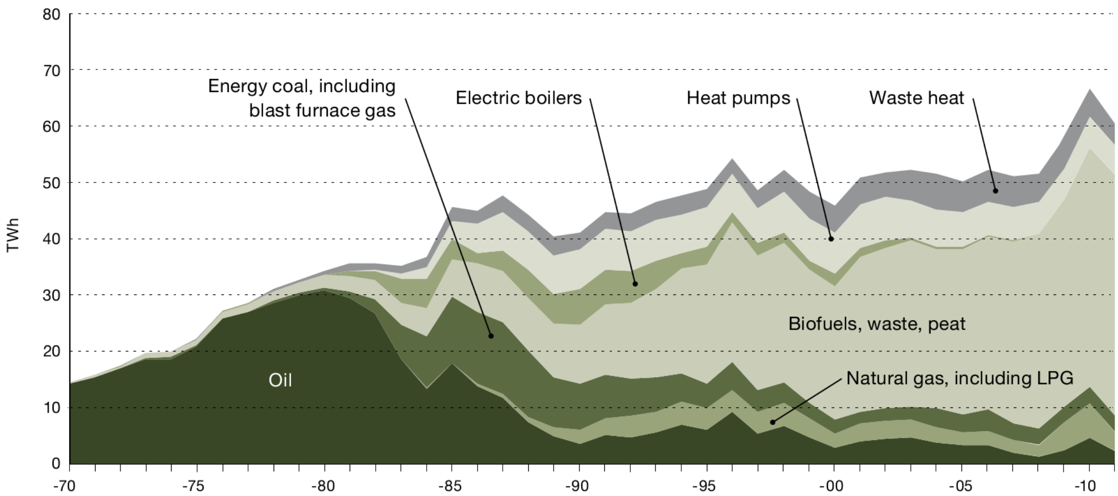

Figure 4.5: Energy sources for district heating in Sweden, 1970 – 2011, TWh [64].

- It is a free energy source.
- It has low maintenance needs.

The disadvantages are:

- The sun is not always shining: solar thermal collector cannot be the only heat source in many countries.
- The sun shines more in the warm seasons and less in the cold seasons, which is the opposite to the needs.

There are two main types of collectors, *flat plate collectors* and *evacuated tube collectors.* The flat collector is formed as a flat box with all sides, except the front, well insulated. Inside the box there is a pipe filled with water or air to collect the heat. The bottom of the box and the pipes are well connected and made of a material with suitable thermal conductivity, together they are called the absorber. The *absorber* and sides are painted with a black color with extra high absorbing to collect as much sunlight as possible. The front has a transparent cover through which the sun radiation can pass with reduced heat loss.

The evacuated tube collectors are made out of two tubes with vacuum in between them. The outer tube is made of glass and the inner is either a glass tube covering a metal pipe (or pipes) with the heat carrying liquid, or there is only a metal pipe. As in the flat plat collectors, the inner glass tube or the metal pipe is covered with black, high absorbing surface [63].

Solar collectors shall not be mixed with solar cells (also called solar panels) which produce electricity.

4.7.4 District heating

District heating is a way to produce heat in a large-scale for many buildings and households, usually for a whole town. In Sweden, 91% of all multi-apartment buildings has district heating [3]. Normally, water is the heat carrier and it is transported through pipes in the district heating area. In an *indirect* district heating system the building receiving the heat has a heat exchanger instead of a e.g. a heat pump or furnace. In Sweden the district heating system is not only indirect but usually also *closed*. A closed district heating system indicates that the DHW consists of cold tap water which is heated by a heat exchanger [40]. A district heating system can also be *direct* and *open*, this is the case in e.g. Bishkek. The water heated in the heat plant goes through the radiators and comes out the hot water tap and no heat exchangers are used [14].

On the production side of the district heating system there are plenty of energy sources. The more common ones are: burning of biofuels (as wood chips) or fossil fuels and the use of waste heat from industries. Many of the waste treatment plants in Sweden use the heat from the burned waste products for district heating purposes. There can also be combined heat and power plants (CHP plants) which both generate electricity and heat. These plants reach a high efficiency level, about 70 – 90% (a power plant just producing electricity have an efficiency of 35 – 40%). Figure 4.5 presents the mix of energy sources of Swedish district heating [40, 65].

4.7.5 No central heating

High energy savings are made when a house is designed and built to have minimal heat losses. There are some buildings in Sweden, so called *passive houses*, that do not need central heating because they have very thick insulation and the best types of windows. The natural ventilation is for these houses fully suppressed which means that they need to be equipped with a HVAC-system of high standard. These buildings have heat exchange between the outlet and inlet air. The heat saved from the outlet air together with heat generated from humans, lights and electronics is enough to cover the heating need of the building, except for on really cold days. Usually these really cold days (-10 °C and below) are solved with some additional heating from electricity connected directly to the ventilation [39].

4.8 Building measurement methods

4.8.1 Thermography

Thermography is a technique to study the temperature of the surface of an object. It measures the surface IR-radiation. IR-radiation stretches from 700 nm – 1000 µm. The IR-radiation can be emitted from the object itself, reflected from the surroundings or transmitted from something behind the object. When analysing the measured temperature it is important to be aware of the properties of the surfaces. A shiny surface will respond differently to a dull one even though they have the same temperature. Objects which transmit a large portion of the radiation that hit them also have to be handled carefully [66].

Thermography is a suitable technique to study energy properties of a building. By studying the temperature differences on a wall, thermal bridges can be discovered. It can be used both from the inside and outside of the building. The best technique is to take pictures of the IR-radiation, then it is easy to discover a thermal bridge. To avoid some of the interferences when the IR radiation of a building is measured, it is advisable to [66, 41]:

- Avoid sunshine. It's best to measure the IR-radiation during night when surfaces are not heated by the sun. Also avoiding light bulbs, warm radiators and other warm sources which will interfere with the measurements.
- Measure the IR-radiation in an angle of $50° – 90°$. If the angle is lower the reflectance from the surroundings will interfere too much. When the measurements are taken perpendicular there is a risk of getting reflectance from yourself as well.
- When measuring the IR-radiation outside it is important to be quite close to the object. Otherwise the radiation from the atmosphere will interfere with the measurements.

Testing of airtightness To better find the thermal bridges a test of airtightness can be made at the same time as IR-radiation pictures are taken. An excess pressure is created on the building and air will leak out on places where the building is not airtight. Because the air is leaking out at a higher amount, the spots are easily discovered at the thermograms (IR-pictures). It is important to be aware that all thermal bridges will not necessary appear on the thermograms with this method [66, 41].

Chapter 5

Building codes

5.1 Building codes in Sweden

Swedish building law consists of (with latest versions in parenthesis) [67]:

- Planning and Building Act (PBL) (SFS[1] 2010:900), the main law for buildings in Sweden.
- Planning and Building Ordinance (SFS 2011:338),(PBF).
- Building regulations (BBR) (BFS[2] 2011:6), the Swedish National Board of Housing, Building and planning (Boverket) mandatory provisions and general recommendations, following PBL and PBF.

The last BBR was made in 2011 with changes added two times, the last one in 2013 [68].

BBR is valid for buildings, but not all types of constructions. It is for example not valid for wind turbines or for moving a building. BBR is however valid for construction of new buildings. The newest BBR (from 2013) is also valid for applying changes to a building [68].

There are specific sections in BBR (2011:6) for:

- Accessibility, design, room height and utility rooms
- Mechanical resistance and stability
- Fire safety
- Hygiene, health and environment
- Noise protection
- User safety
- Energy management

There are also other mandatory provisions and general recommendations, which are not given in BBR (2011:6), for some of these fields [67].

[1] Svensk författningssamling, Swedish statute book
[2] Boverkets författningssamling, Boverket's statute book

5.1.1 Responsibility

A *general building contractor* is the person who, for their own sake, is constructing a building. They are required to follow the laws and the mandatory provisions and decisions.

The owner is responsible for the maintenance of the building. A building should be kept so that the technical properties of the building (stated by the building law valid at the time the building was built) is preserved to the extent it is possible, from a reasonable economical lifetime perspective [69].

For Swedish multi-family houses there are two common ways of ownership: a tenant ownership association (bostadsrättsförening) or an organisation offering regulated tenancy (hyresrättsförening) [8].

Joint ownership of buildings

Tenant owners can form an economic association in Sweden according to the Tenant owners association law, Bostadsrättslag (1991:614). This economic association will have the legal responsibility for the building. The association must consist of at least three people. It must also have a board, regulations and an accountant. The association can sell an apartment to someone; this apartment must be a living space, with all utilities included, such as kitchen, toilet and bathroom. The person buying this apartment must be a member of the tenant owner association.

The owner of an apartment in a house owned by a tenant owner association can only use their apartment for the intended use. The association can however only report changes that matter substantially to the association itself or to a member of the association. The owners cannot, without permission from the board, alter a supporting structure, pipes for sewage, gas or water, or in other ways change the apartment substantially.

The owner of the apartment must see that the apartment is in good condition. They are however not responsible for repairing sewage pipes, electricity, heating-, gas-, ventilation or water supply systems. This is if the pipes and wires have been installed by the association and serve more than one flat. If there are damages by fire or leaking water the owner can be responsible for reparations if it can be proven that they caused the damage by not being careful enough.

Rented housing

Rules for regulated tenancy are in the Swedish land code (Jordabalk (1970:994), chapter 12) [70]. Chapter 12 of the Swedish land code deals with the renting of houses or part of houses, such as apartments. The landlord is the owner of the building, granting the living space to the tenant in return for payment. According to the law, the dwelling unit should (as a minimum) have the lowest acceptable standard, which means it should be equipped with [70, 71]:

- Continuous heating
- Continuous access to domestic hot and cold water
- Waste-water drainage
- Toilet, washbasin and bathtub or shower for personal hygiene

- Electric power supply
- Cooker, sink, refrigerator for cooking

The tenant should also have access to storage rooms and laundry facilities. The house should not have other than reasonable defects of mechanical strength, fire safety and sanitary conditions. The tenants must approve any changes to the property that affects the property value significantly. They also need to approve any essential changes to a dwelling or communal parts of the building [70, 71].

5.1.2 Alterations of buildings

According to BBR (2011:6, Chapter 1) it is very important that care is taken if a building has architectural, historical, cultural, environmental and artistic values and the building is to be altered. How to maintain the building's character must be considered [67].

5.1.3 Constructing a new building according to BBR

Energy requirements

Chapter 9 of BBR (2011:6) deals with energy management of buildings.

> *"Buildings must be designed in such a way that energy use is limited by low heat losses, low cooling demands, efficient use of heat and cooling and efficient use of electricity."* BBR 9:1[67]

For new residential dwellings the average *thermal transmittance* must be 0.4 W/(m^{2}K) in all climate zones of Sweden. The calculation of the average thermal transmittance for the building envelope should include thermal bridges. The method of calculation is determined by an ISO-standard through a specific formula.

The building's *specific energy use* (in kWh per year and per area intended to be heated to more than 10 °C) for new buildings in Swedish law is different for different climate zones. It is also dependent on if the building is heated by electricity or has another heating source. If the building is heated with electricity, 55 – 95 kWh/(m^{2}year) is allowed (depending on climate zone). The installed power rate for heating (in kW) is also specified by the law in this case. If the building is not heated by electricity 90 – 130 kWh/m^2/year is allowed. The specified values can be exceeded by up to 20% if there are special circumstances leading to it and it is impossible to follow the regulations. Special circumstances can be cultural value reasons or it is impossible to install the proper technical instruments [67].

The thermal comfort of a building is dealt with in Chapter 6 of the BBR (2011:6). When modelling before building a new house, the operative room temperature (see Section 4.1.1) should not be lower than 18 °C – 20 °C (depending on application of the rooms). The floor should be at the lowest 16 °C. The air velocity should not to be higher than 0.15 m/s during the heating period. However, 0.25 m/s is acceptable in other periods of the year [67].

Ventilation

> *"Ventilating systems shall be designed to ensure the required outdoor air flow can be supplied to the building. They shall also be able to carry off hazardous substances, moisture, annoying odours and emissions from people and emissions from building materials, as well as pollutants from activities in the building."*BBR 6:924[67]

When designing the ventilating system for a building, the outdoor airflow should be at least 0.35 l/s per m^2 floor area according to the requirements. When the rooms are being used they should have a continuous air exchange. If the ventilation is controlled separately for each dwelling, with presence and demand control systems, the ventilating system needs at least an outdoor air flow of 0.10 l/(s m^2), when nobody are in the dwelling. When there are persons present in the dwelling, the outdoor air flow should always be 0.35 l/(s m^2) as minimum. The requirements of the ventilating system should be verified by calculations and measurements. In the calculations, changes that may occur to the system over time have to be considered. Such changes could be dirt in ventilation ducts reducing the air flow or changes in the pressure over filters.

Moisture

> *"Buildings shall be designed to ensure moisture does not cause damage, foul odours or hygienic nuisance and microbial growth, which could affect human health."* BBR 6:51[67]

During construction of buildings, it is important that the building parts are protected from moisture damage. This should be ensured through inspections, measurements or analyses. Critical moisture levels, which must not be exceeded, should be determined for materials used in the construction. Extra care must be taken for materials where mould and bacteria can grow. It is also important to consider the combination of materials used to prevent moisture damage [67].

5.2 Building codes in Kyrgyzstan

The history of Kyrgyz law on housing and land

The Kyrgyz republic is a new state and the laws are still in development. The following is an overview of the development of the laws on buildings since 1991.

- In 1991 the Law on privatization of the Housing Fund was accepted. This was the beginning of the extensive privatisation of the housing stock mentioned in Section 3.4.3 [16, 26].
- The Civil code from 1996 says: *"Apartment owners in multi-apartment buildings own as common shared property the common shared premises, building bearing constructions, mechanical, electrical, sanitary and other equipment outside or inside apartments designed to serve more than one apartment."* [26]. Before this code there were problems with knowing who was responsible for the common parts of a multi-apartment building [16].

- In 1997, the Law on Partnerships of Home owners (Condominiums) was approved by the parliament, it had been in practice since 1995 in Bishkek. The law was made to simplify the shared responsibility of maintenance of multi-apartment buildings (more on condominiums in Section 5.2.1 below). In 2002 the Law on Condominiums was changed to among other things simplify the registration of a condominium as a legal entity [26].
- In 1998 it became possible to own, sell and rent land in Kyrgyzstan [16].
- The latest version of the Kyrgyz construction rules were legislated in 2001 [26].
- In January 2010 there was a new building standard accepted called "Thermal engineering (Thermal performance of buildings)" (SNiP KR 23 – 01:2009) [27, 19]. There has also been developed a guide to the SNiP called "Design of Thermal Performance of Buildings" [27].
- The regulations on land use are in the Land Code of Kyrgyzstan. The latest amendments regarding housing issues in this code were made in 2011 [26].

Building codes valid today

Relevant laws for buildings in Kyrgyzstan are [72]:

- Law on Energy Efficiency of Buildings (# 137 from 26 July 2011).
- Law on Town-planning and architecture (# 234 from 12 December 2011).
- Thermal engineering — Thermal performance of buildings (SNiP KR 23 – 01: 2009). There are six different kinds of "SNiP" on different areas of building systems.
- Thermal performance design of buildings (SP: KR 23 – 101:2009). This is a copy of the law made in Russia, a Kyrgyz version will however be available soon.
- Regulation on the rules and procedure of energy certification of buildings (resolution #531 from 2 August 2012).
- Regulation on rules and procedures of periodic energy inspection of boilers, heating and hot water supply systems (resolution # 531 from 2 August 2012).

In this thesis the SNiP (KR 23 – 01: 2009) above is examined when dealing with the alternations of buildings (Section 5.2.2) as well as the construction of new ones (Section 5.2.3).

5.2.1 Responsibility

There are mainly two state organizations at the Kyrgyz government responsible for supervising housing and land issues: the State Agency for Construction and Regional Development and the Department of Cadastre and Real Property Right Registration of the State Registration Service [26].

In 2010 the UN made a study on the housing situation in Kyrgyzstan [16]. They recognised different ministries responsible for different part of the housing framework at the national level:

- The Ministry of Finance, which is responsible for developing mechanisms to provide affordable housing to the part of the population in greatest need of it [16].
- The Ministry of Economic Development and Trade is responsible for utilizing the external assistance and funding for affordable housing in an efficient way [16].
- The Ministry of Industry, Energy and Fuel Resources, has branches at the oblast and rayon levels. It is responsible for the developing of Kyrgyzstan's industrial and energy sectors. The Ministry is also supposed to introduce regulations for environmental values to constructing buildings. Such as the use of locally produced building materials, the reuse of discarded industrial material and the use of effective technology [16].
- The Ministry of Labour and Social Protection implements the State policy on social development and labour. The Ministry is developing norms and standards for improving the living conditions for the Kyrgyz citizens [16].
- The Ministry of Health defines health and epidemiological requirements for new buildings and approves the health conditions of building plots. It has not however got any responsibility for monitoring existing buildings. The Ministry's requirements and recommendations are based on the Soviet-era building regulations, which have not been updated since then [16].
- The National Statistical Committee is performing population analyses, on a self-sustained budget. It reports observed data only and publishes no forecasts [16].

At the local level no program on housing issues has been developed [26] but the rayons and oblasts have some responsibility for the housing situation. There is a state agency for registration of rights to immovable property which has offices in all 49 rayons. The UN states in the report from 2010 that there is a need for the Kyrgyz Government to delegate some of the responsibilities for the housing situation to the local and regional level.

Overall the UN recognizes a need for simplifying the Kyrgyz responsibilities for housing [16]. For example, it is very complicated and expensive to obtain a building permit. Seven agencies have to be visited and paid. The cost for obtaining the permit is not fixed but about 40 000 som or more needs to be paid [26].

Joint ownership of apartment buildings

The privatization of the Kyrgyz building stock lead to the maintenance of the common areas in apartment buildings was neglected. Since 1996 the common areas in the apartment buildings are jointly owned, for all multi-apartment buildings. Since 1997 and the Law on partnership of homeowners, it is also possible to form a condominium for organised maintenance of the common areas.

In the condominium the idea is that the owners set their own maintenance priorities and decides on the fees and rules for the building. Leaders are elected to speak for the condominium. They are responsible for the condominium which in turn is responsible for the maintenance of common spaces as well as the management of the whole building [73, 16].

In 2005 25% of the Kyrgyz housing stock belonged to a condominium, quite a small share of the total housing stock. According to the UN it is too small a share to be an organisation of great importance to the whole country. The condominiums are consequently recognized legally but the economic position is weak [16].

Rented housing

There is no law on rented housing in Kyrgyzstan [16, 26]. Rents are however regulated by the Civil Code at the national level. Local governments can also determine rents because they have jurisdictions [16].

5.2.2 Alterations to a building

Chapter six of the SNiP (KR 23-01:2009) is called "Improving the energy efficiency of existing buildings". When reconstructing a building it is stated that energy efficiency measures should be taken. It is also important to maintain the "air permeability" of the building (see below).

5.2.3 Constructing new building according to the SNiP

For the construction of new building a certificate should be filled in on how the building is to be designed. The completed building should also be monitored to see if the law is fulfilled (chapter 11 and 12) [19].

Energy requirements

According to the SNiP (KR 23 – 01: 2009) Chapter 5, the *thermal resistance* (m^2K/W, see Glossary, Appendix A) should not be below the standardised values which depends on three variables:

- What kind of building is to be built, three categories of buildings are stated.
- Which part of the building, the thermal resistance is allowed to be lower for windows than on the floors or walls for example.
- How many "heat-degree-days" the area has, a parameter due to the local climate. Heat-degree-days is a measure of the differences in temperature between indoor and outdoor during the heating period, times the length of the heating period (in days). The SNiP has five different cases to this parameter. The thermal resistance must be higher if number of heat-degree-days is large (that is in colder regions).

For Bishkek the thermal resistance of a wall in a dwelling should be about 2.5, giving a U-value for walls of 0.4 $W/(m^2K)$ [10].

The *specific energy use* of a building is in Kyrgyzstan measured in $kJ/(m^2\ °C\ d)$ or $kJ/(m^3\ °C\ d)$. The value varies if the building is heated with district heating or not. It is also dependent on the type of building and the number of floors of the building.

Kyrgyzstan has special rules for buildings in areas where the warm season has an average July temperature above 21 °C. In these areas there should be shading devices on the buildings (SNiP Capter 7).

There are also rules for the "Heat absorption surface of the floor area". This is given in W/(m^2K) and the regulative values are different for different kinds of buildings (SNiP Chapter 10) [19].

Ventilation

In Chapter 8 of the SNiP there are rules for the "air permeability/breathability" of buildings. It is dependent on type and part of building. It is given in kg/(m^2h). The maximum allowed breathability varies between 0.5-10 kg/(m^2h) [19].

Rules for ventilation have not been a priority in Kyrgyzstan before. The KSUCTA is trying to get more established rules for ventilation and moisture present in Kyrgyz laws [6].

Moisture

Chapter 9 of the SNiP is dealing with protection against moisture. The "maximum allowable increment calculated weight ratio of moisture in the material" is among other things given in percent for 11 different walling materials.

Also Chapter 5 of the SNiP deals to some extent with moisture. For limitation of the temperature and "moisture condensation" there is a design temperature difference set by the law, which is not to be exceeded. It is dependent on type of building (there are in this case five types) and varies for different parts of the building envelope. It takes into consideration the temperature difference between outside and inside air temperature in the heating season, the thermal resistance and the inner heat transfer coefficient. If a basement is considered in the calculations a factor reflecting the external façade surface with the outside air temperature is also used [19].

Chapter 6

Energy efficiency measures

Energy efficiency measures are done to keep the building in good condition and to improve heating comfort as well as save money for heating. When planning to retrofit a building, the first thing to do is to find where all energy is used in the building and where the major energy losses occur. During the cold season, the major energy losses are to the largest part heat losses. When the most important possible improvements are found, it is time to find the appropriate efficiency measures [50]. If a measure is effective or not depends on:

- Energy pay-back time.
- Economical pay-back time.
- Environmental aspects, such as CO_2 emission pay-back time.
- Size of interference with existing construction.

There are several different energy measures. The ones examined in this project are: adding of insulation, adjusting the heating system and DHW-system, changing or adjusting of the ventilating system, preventing infiltration in the building envelope and changing the behaviour of the energy user.

6.1 Adding insulation

Addition of extra insulation is an effective energy efficiency measure. It is often a relatively cheap measure [47]. In one study, all of the tested insulations materials had energy savings of over 100 times greater than the invested energy for the production and installation [57].

One downside to adding insulation has to do with physical properties. It has to be physically possible to install the insulation in the building, without interfering too much with the existing structure of the building. It is also very important to consider ventilation aspects of the building when adding insulation. If the airflow in the building is to low, moisture might get trapped in the walls. Mould growing on moist insulation can create health problems to the occupants (more on insulation in Section 4.4). It is better to insulate the building from the outside than from the inside to avoid moisture problems later [50].

Adding insulation often also results in a high initial cost. The economical pay-back time might be quite long for the investor, depending on the cost of energy for heating the building. A low energy cost will give a much smaller economical incentive for adding insulation [14].

6.2 Adjusting heating system and DHW-system

In multi-apartment dwellings one energy efficiency measure is to adjust the radiator systems. In central heating systems, the heat effect may with time not be evenly distributed through the whole building. One apartment may get too high a level on their radiators while others at the same time get too little effect. When some of the dwellers complain about cold temperatures it might be an easy fix to raise the temperature for everybody. Radiators adjusted to work equally throughout the building can consequently contribute to energy savings [74].

Insulation is not only important in the walls, but all pipes transporting hot water (to radiators and taps) may be insulated as well. Well-insulated pipes are more energy efficient. It is also important to have valves and other parts of the heating system in good condition. To adjust the temperature of the heating system with the outside weather conditions is also an appropriate energy efficiency measure.

In some cases the heating system needs to be changed entirely to save energy and environment [50]. Different heating systems are presented in Section 4.7.

The DHW-system should be looked over from time to time to make sure it does not supply consumers with unnecessary hot temperatures of the domestic hot water [14].

6.2.1 Installing thermostatic radiator valves

Thermostatic radiator valves (TRV, were the v in some cases means values) adapts the flow of hot water entering the radiator to the room temperature; if the room is cold, more water will flow through and vice versa. It is a simple apparatus where wax or a bubble of gas expands or contracts according to the surrounding temperature. This can save energy in a room, if they work as they are supposed to. One problem with the TRV is that they only sense the temperature right next to the radiator. This can bring them to sense too cold, and consequently open the valve more. When the TRV break they most often get stuck in the off-position, and the radiator does not get hot any more [75].

6.3 Changing ventilating system

In general, HVAC-systems (see Section 4.5.1) account for about one fifth part of all energy use in the developed countries and 50% of the total building energy use. These numbers are lower in places where there is no use of air conditioning [76].

In case of natural ventilation the stack effect is larger when it is cold outside due to bigger density difference of air between the outside and the inside the building. The air going out carries heat with it and it is important that the size of the airflow should not be larger than necessary to keep the air quality the same. Otherwise an unnecessary amount of heat is lost [39]. ith forced ventilation the size of the flow can be controlled [40]. The infiltration, outside the ventilating system, will also be important, see next section.

If forced ventilation is used in the building there is a big potential in making energy saving measures in the HVAC-systems. For example, Demand Controlled Ventilation, DCV, can be used. With DCV the ventilation is controlled automatically or manually to only be in use when there is a need. Automatic DCV can either be controlled by sensors for temperature or CO_2 etc. or by pre-programmed schedules [77]. More on ventilating systems can be read in Section 4.5.

6.4 Preventing infiltration

In a draughty building the experienced temperature will be low (see Section 3.1.2). The infiltration will also risk a ventilation flow higher than necessary which means an unnecessary amount of fresh air needs to be heated. Common places were air leaks in from the outside are around windows and doors. One proper energy efficiency measure is to see to sealing all joints along windows and door frames [50]. Cracked patty around the glazing on old windows can also be a leakage source [14].

There can also be infiltration straight through the wall (see Section 4.5.2). A brick wall without cracks is windproof by itself but a wooden wall needs a wind proof layer. To avoid a ventilation flow higher than necessary it is beneficial to search for other leakages than only around windows and doors and seal them in the best way [50].

6.5 Changing behaviour

Energy savings can be made if changing of the behaviour concerning how energy is used. When somebody owns their own house it is possible for them to have beneficial control of their energy usage. To lower the temperature by only one degree can save a lot of energy, it might be possible to lower the temperature in only the hallway for example [50]. It is easier to change behaviour when there is an economical incentive for saving energy. For the house owner it is for example obvious that a sparse use of DHW is economical.

In multi-family dwellings it can be harder to change the behaviour of the occupants. The heating of one apartment is for example dependent on energy flows from neighbouring apartments. An economical incentive is possible to introduce for the domestic hot water by installing meters on the water and individualise the billing [14].

Chapter 7

The examined buildings

In the micro region Asanbay in Bishkek lie the two houses which are examined in this thesis (see Figure 7.1). They are nine-story buildings made of concrete panels. The buildings were built in 1984 [6].

In January 1995 to July 1996 there was a project called "Improving the energy efficiency of buildings in Kyrgyzstan" which was financed by the Technical Assistance for the Commonwealth of Independent States (TACIS), a program of the European Union. This project performed a number of alterations and repairs on House 9 in the Asanbay area. House 2 of the same area was in this project used as a reference building to see the effect of the energy efficiency measures applied to House 9 [14].

7.1 Responsibility for the houses

The two buildings do not belong to a condominium, described in Section 5.2.1. There is however a *Domkom* in each house, which is an occupant who takes the role of housekeeper.

Figure 7.1: The examined buildings. To the left: House 2. To the right: House 9.

It is in Kyrgyzstan common that multifamily houses has a house committee and the Domkom is the chairman of that committee [5]. The Domkom has the responsibility if something happens to the building. The Domkom is not economically responsible but should organise the reparation. If an occupant wants to make a major alteration on their apartment they have to tell the Domkom and also get permission from the city architect authorities [78, 79].

7.2 Building structure

The buildings are of the Soviet building type 105 (more on soviet buildings can be read in Section 3.4.2). This is a building type first constructed in 1965. It is made out of prefabricated concrete panels.There are steel reinforcing bars located in the panels. There are also steel dowels in the foundations to ensure fastening of the bars and the panel joints. This building type is considered to be one of the most earthquake-resistant construction types made in the former Soviet Union [36].

The walls of the building type 105 are of a so-called sandwich construction, it has mineral wool insulation in the middle, surrounded by two concrete panels. The roofs of the buildings in Asanbay are made out of expanded clay, concrete, and screed. In Figure 7.2 the principle structure of the roofs and walls of the original buildings in Asanbay is shown. These are still the structures for House 2 today. The structure of Asanbay 9 looks a little different, according to the changes made on the building in 1995/96 (see Section 7.5, below). For comparison see Figure 7.4 [6].

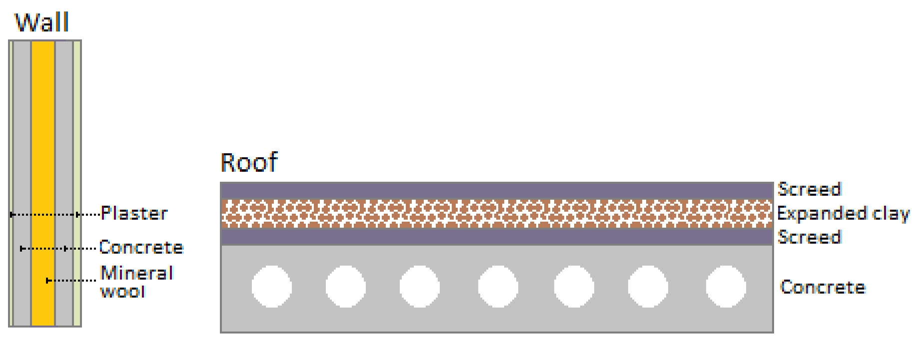

Figure 7.2: Wall and roof profile of House 2 today, the original structure of building type 105.

In Figure 7.3 the plan drawing for soviet building type 105 is shown. Each building has two staircases. On each floor of the buildings there are six apartments. All apartments each have two balconies. The apartments have one, two or three rooms, one bathroom and one toilet (or one room used as both bathroom and toilet), and one kitchen (always equipped with a balcony). On each floor there is a common room for drying laundry (situated to the left of each staircase in the figure).

Heating system

The buildings are connected to a district heating system [14]. The district heating system for these buildings is in Kyrgyzstan called the “Deutsch system”. It is an direct and open

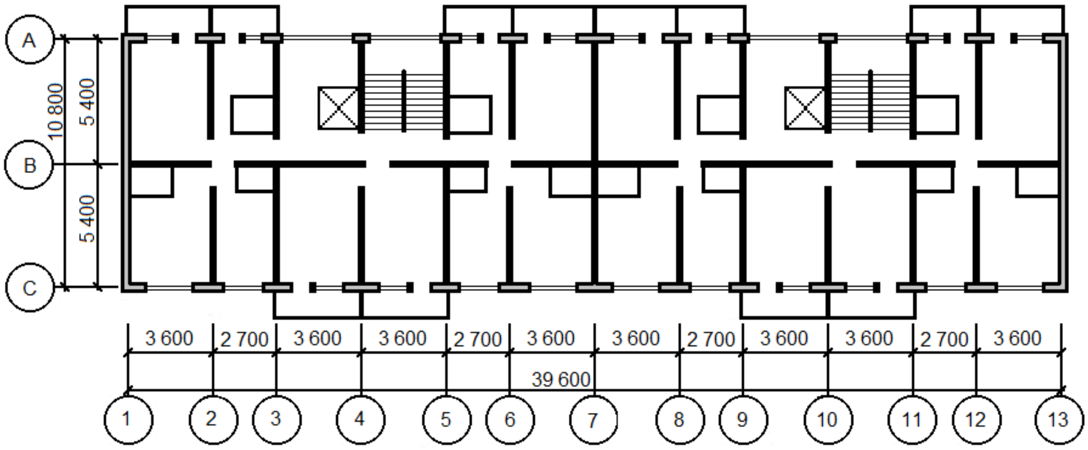

Figure 7.3: Plan drawing for building type 105. Numbers are in mm.

district heating system. The heat is produced at the CHP-plant in Bishkek [10].

When the former study was made on the Asanbay houses, the amount of heat used was 240 – 360 kWh/m^2. Of this 140 to 175 kWh/m^2 was used for space heating and 110 to 210 kWh/m^2 was used for domestic hot water.

Ventilating system

The ventilating system of the buildings is a natural ventilating system. There are no planned ventilation-inlets, other than through open windows. There are two or three ventilation outlets in each apartment. They are situated in the kitchen, the toilet and the bathroom (sometimes the two latter rooms are combined, giving only two outlets in these apartments) [6].

7.3 Energy losses in 1995/96

The study performed as part of the TACIS program found the major heat losses of the building envelope to be [14]:

- Heat losses through prefabricated panels. This was thought to because of a low quality of the materials used or of material shortage when the material was installed.
- Heat losses due to draught was responsible for up to 50% of the total energy consumption for space heating. This draughtiness is mainly caused by
  - Poor quality of the windows, i.e. buckled frames, which do not close thoroughly and windowpanes that are mounted without glazing putty.
  - Insulation material is missing or unsuitable leading to those joints between window frames and walls are not suitably constructed and joints between panels are not draft proof.
  - The windows have two layers of glazing and the heat loss through them is comparatively low.

When the study was conducted, 120 – 140 litres per person per day of hot tap water was used in these houses. Up to 58% of the buildings energy consumption was used for heating domestic water. This the authors compared to Germany were they used about 20 – 40 litres per person and day when the study was made [14]. In Sweden today we use about 75 – 100 litre of domestic hot water per person and day [80].

7.4 Observations in 1995/96

The authors of the 1996-study made some observations they thought were noteworthy. These observations are listed here. In this project they will be compared to present conditions of House 2 and 9.

- Maintenance to windows and entrance doors was insufficient, e.g. broken entrance doors was not replaced.
- Leaking water taps in the apartments was not repaired.
- In winter, consumers may have been supplied with domestic hot water with temperatures of 80 °C to 90 °C.
- Room temperatures were between 8 °C and 12 °C on colder days in the heating periods prior to the study.
- The occupants were larger radiators to compensate for low temperatures. Additional electric heaters was used.
- The occupants were performing draft-proofing measures on the windows and ventilating system, e.g., sealing of air ducts in the kitchen and bathrooms and draft-stripping of windows.
- Occupants frequently used balconies as additional living space. For this purpose balconies were enclosed with single pane windows and frequently it was observed that additional radiators were installed. In some cases the main window and balcony door had been removed.

7.5 Energy efficiency measures applied to House 9

To make House 9 more energy efficient some equipment was added to the building. The equipment installed was (cited from [14] except references in parenthesis):

- Thermal insulation of façades and roof (see Figure 7.4).
- Thermostatic values (TRV, see section 6.2.1).
- District heating sub-station with weather compensation and controls for domestic hot water.
- Balancing valves and hydraulic alignment.
- Pipe insulation.

- Heat allocation meters at each radiator.
- Water meters for domestic hot water in each flat.
- Heat meters in the district heating sub-station.
- Heat meters for space heating and domestic hot water.

The insulation added to House 9 was polystyrene. It was added on the outside of the façade (as in Figure 7.4) except for the north side, where the insulation was put on the inside of the staircase. Plaster was added on the outside of the building and it was also painted yellow. On the roof, the expanded clay was removed and replaced with polystyrene, followed by new screed (Figure 7.4) [6].

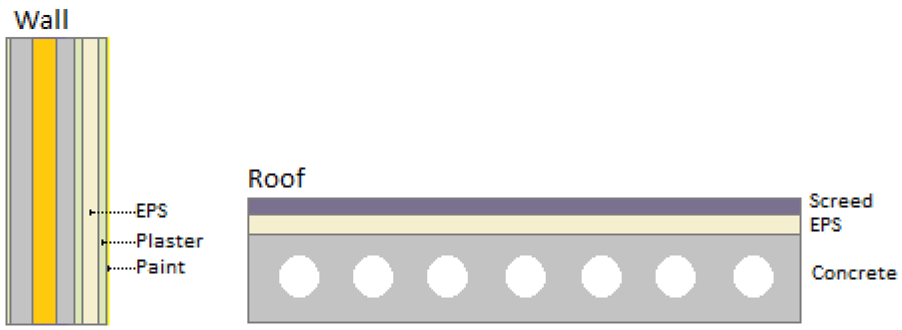

Figure 7.4: Wall and roof profile of House 9 after energy efficiency measures. EPS is an abbreviation for Expanded polystyrene.

The meters added for space heating were only for use in the study and not to individualise the heat-bills. It is hard to measure the space heat on individual level due to other factors which will influence the temperature indoor. However the meters on domestic hot water were there to individualise the payment and in that way influence the user behaviour [14].

According to the study, after renovation of House 9, energy savings for space heating were measured at 40% of the consumption of the reference building (House 2) in the heating period 1995/1996. Savings of 22% were recorded for domestic hot water.

The savings attained by the insulation of the building envelope are estimated to be 20% to 25%. For insulation, the payback time is more than 10 years, which was the payback time-limit of the study. It is according to the authors therefore better to make insulation improvements if the building is to be renovated in any case. In this way, only the marginal costs of the retrofit are attributed to the added insulation, giving the measure a better economic validity. Occupants were however very satisfied with the better heating comfort achieved with the insulation.

The measures applied to the central heating system were to make it more adaptable to weather conditions. This saved about 15% to 20% of the energy use. A new district heating substation was installed where, unlike in the former case, the temperature of the domestic hot water could be controlled. After the study there were a temperature of hot water of 65 °C supplied to the net. The payback time for the investments were calculated to be about seven years.

From an energy saving and economic perspective it was according to the study very favourable to reduce the domestic hot water consumption, since this represented a large part of the energy consumption of the building. This measure was easy to install and had a low pay back time (0.7 years) [14].

Chapter 8

Results

8.1 Survey

In total, there were 44 respondents of the survey. 20 people answered the survey in House 9 and 24 people answered in House 2, corresponding to a percentage of answers of 37% and 44% respectively. Observe that one respondent of House 9 is represented by 5% of the total respondents for this house. The same number for House 2 is 4,2%. All the Swedish results are from the BETSI study by Boverket (which had a percentage of answers of 49%) [8].

8.1.1 General standard

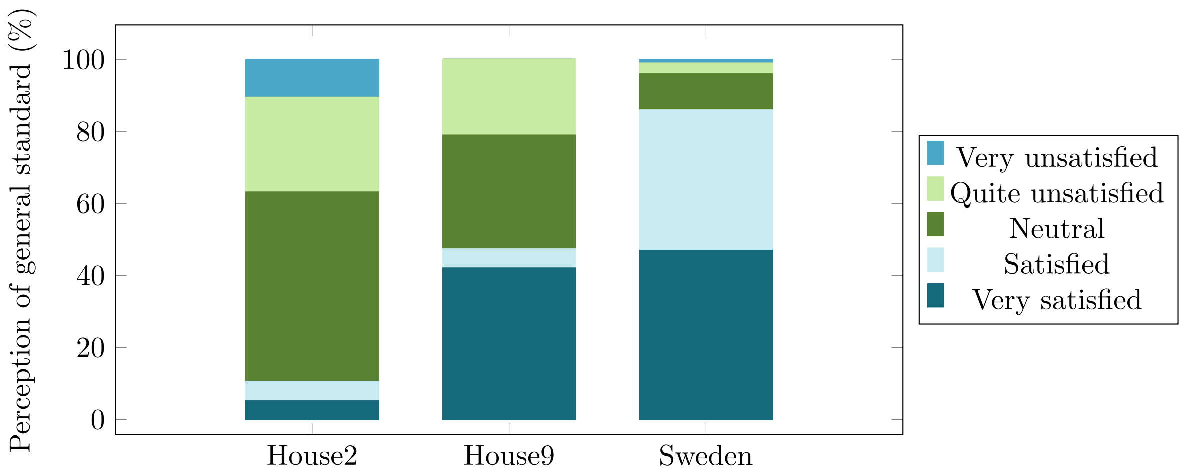

Figure 8.1: Results from question "Are you satisfied with the standard of your home in general?". 5% from House 9 and 21% from House 2 did not answer this question, they are not included in the diagram.

In Sweden 86% of all respondents are *very satisfied* or *satisfied* with their home in general (see Figure 8.1). This is high compared to the Kyrgyz respondents. In House 9

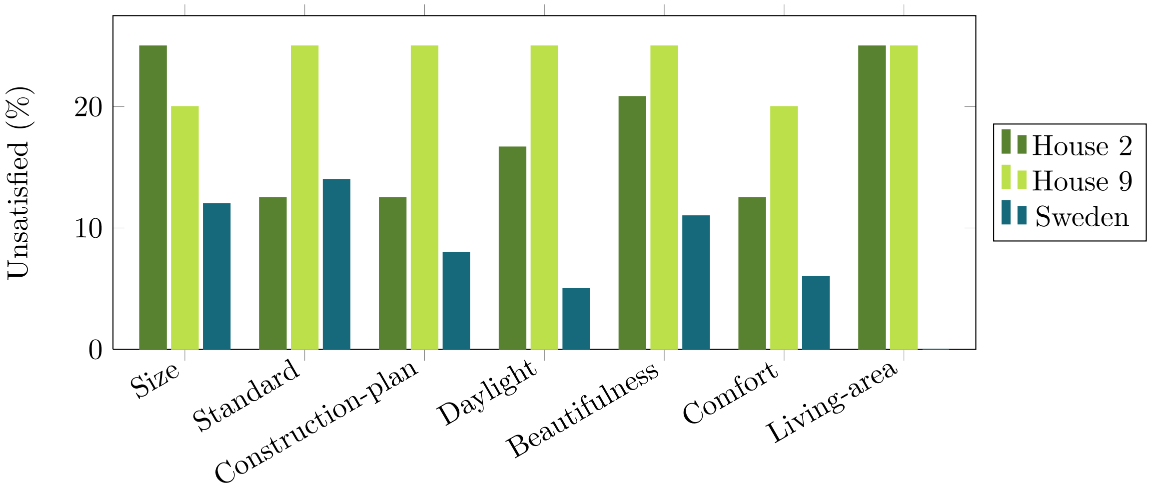

Figure 8.2: Share of respondents who are "unsatisfied" or "very unsatisfied" with different aspects of their home. Both Kyrgyz and Swedish answers are included in the figure, except for in the *living area*-part, where no Swedish answers were available.

the corresponding value of satisfied occupants is 50%, which is higher than in House 2 with 13% satisfied respondents.

In Figure 8.2 the results of the question "How satisfied are you with the following aspects of your home?" are presented. It is clear that people who live in House 2 and House 9 are more unsatisfied with these indicators of satisfaction than the Swedish respondents. Especially the amount of *daylight* and *comfort* are more satisfying for the Swedish respondents. The two Kyrgyz buildings have the same constructions plan. Still more respondents in House 9 than in House 2 are unsatisfied with the construction plan.

On the question "Have you in the last 3 years felt uncomfortable with the following factors of your home" it was possible to answer either *Yes-often*, *Yes-sometimes* or *No*. The share of yes-answers are presented in Figure 8.3. In House 9, families are more uncomfortable with *noise* and *dust* than in House 2. The reason for the differences could be the location of the houses. House 9 lies in the outer part of the Asanbay-area, and is situated close to a big road. House 2 is on the other hand surrounded by other houses in all directions. In House 2 more respondents are uncomfortable with *too high temperature*, *dry air* and *unpleasant smell* than in House 9. As seen in Figure 8.9 respondents of House 2 also seem to have more problems with water damage which could be a reason for the unpleasant smell.

The level of comfortableness was compared to the Swedish study. To make the comparison possible, only the alternative *Yes-often* could be used (Figure 8.4). The question was also differently worded in the Swedish study, with a different time-frame used (three months was used instead of three years). In all parts of the question, except for *draught* and *tobacco smoke*, the Kyrgyz respondents felt more uncomfortable than the Swedish ones. However, as seen in Figure 8.3, 38 respectively 25% of Kyrgyz respondents are sometimes or often uncomfortable with drought. There might be a difference in the perception of the word "sometimes" or the concept "drought" accountable for the differences in answers in between the countries.

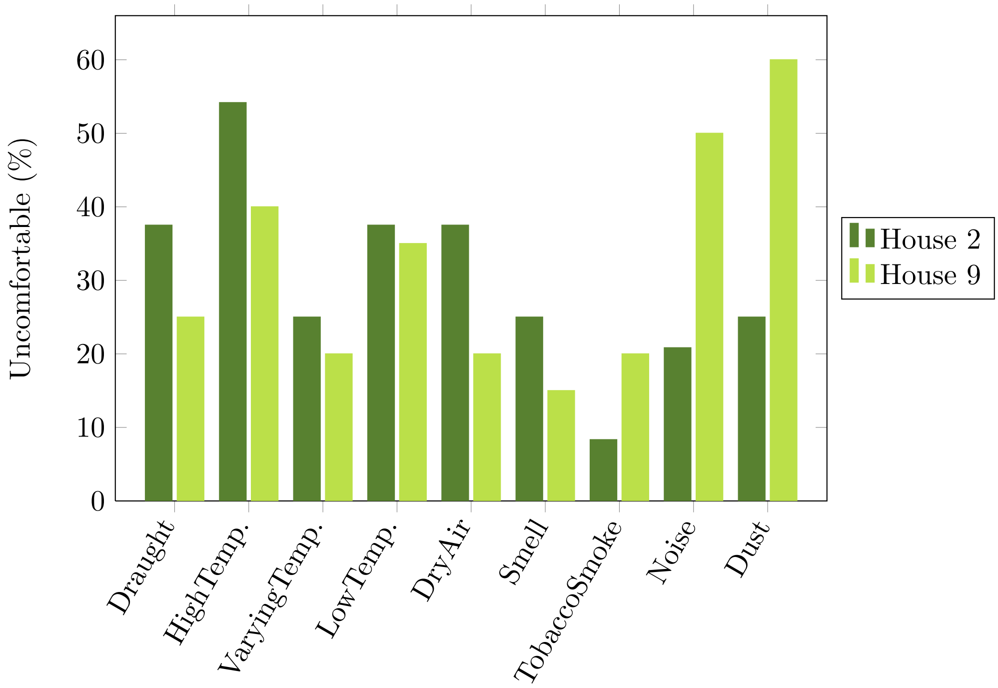

Figure 8.3: Share of respondents answering *Yes-often* and *Yes-sometimes* on the question “Have you in the last 3 years felt uncomfortable with the following factors of your home”.

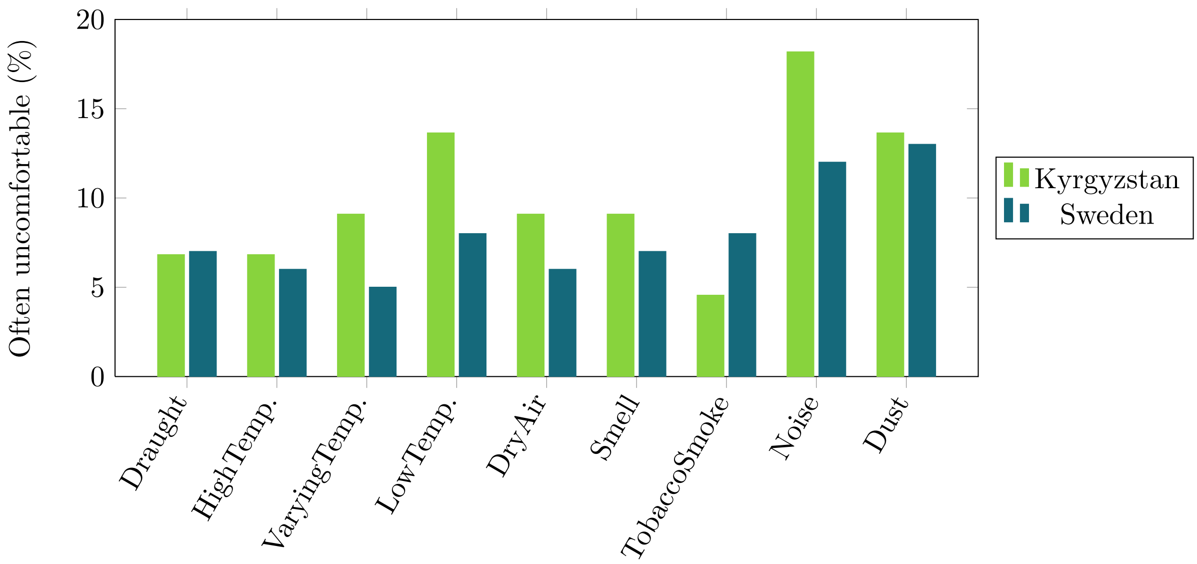

Figure 8.4: Share of respondents answering *Yes-often* on the question “Have you in the last 3 months/years felt uncomfortable with the following factors of your home?”. The BETSI study used three months as time frame for this question while the Kyrgyz were asked the same question with the time frame three years.

Table 8.1: Equipment in apartments.

	Kyrgyzstan	Sweden
Electric stove	11	92
Gas stove	84	7
Combination stove	16	0
Dishwasher	2	21
Washing machine	89	31
Tumble dryer	5	9
Air conditioner	34	n.d.

When it comes to equipment in the apartment there are some differences between Kyrgyz and Swedish homes (Table 8.1). Electric stoves are more common in Sweden than in Kyrgyzstan where more people utilise gas stoves for cooking. There are also in Kyrgyzstan stoves powered with both gas and electricity (Combination stove). The respondents in Kyrgyzstan have sometimes stated to have more than one type of stove. It is quite common with a single electric hot plate as extra stove, this could be the additional stove intended. It is more common to have a dishwasher in Sweden than in Kyrgyzstan.

There is no information about how many people in Sweden have an air conditioner in their home. Quite many of the Kyrgyz respondents do however have this apparatus. Two of the apartments visited when doing measurements were observed to have air conditioners. Both were in this case used mainly for additional heating in the winter (more on additional heaters in Table 8.2).

8.1.2 Heating comfort

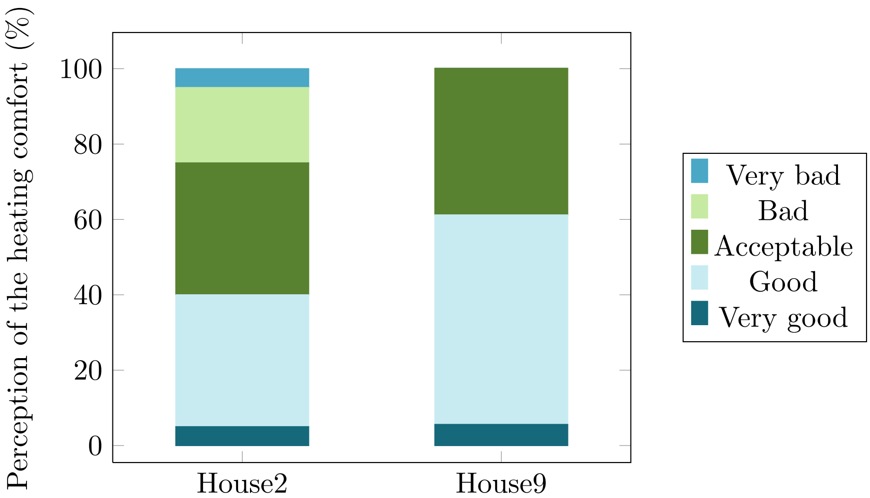

Figure 8.5: Share of persons with different level of satisfaction for their heating comfort. 10% from House 9 and 17% from House 2 did not answer this question, they are not included in this figure.

The largest part of respondents from both houses think that the heating comfort in their home is *acceptable* or are *satisfied* with it to some extent (Figure 8.5). In fact, no one in House 9 think that the heating comfort is *bad* or *very bad*. However, 25% of the respondents in House 2 do think their heating comfort is bad to some extent. The differences between houses could be the result of the insulation which has been installed in House 9.

In some apartments the dwellers have installed an additional heater of some kind (not connected to the district heating system). The percentage of the respondents who has this type of additional heater is shown in Table 8.2. There are more occupants in House 2 who have an additional heater. This indicates lower heating comfort in House 2 than in House 9. The type of heater most common is an electrical radiator.

Table 8.2: Percent of respondents having additional heaters, either electrical or of another type. Some respondents has got more than one type of heater installed, making the sum column be below the sum of individual answers.

	Electrical radiator	Electrical underfloor heater	Other type	Sum
House 2	25	8	17	46
House 9	20	0	15	30

Table 8.3: Share of respondents feeling uncomfortable with different aspects in their home (%).

	Yes, often		Yes, sometimes		No, never		N.a.	
	H2	H9	H2	H9	H2	H9	H2	H9
Too cold in the winter?	25	10	21	25	29	30	25	35
Too hot in the winter?	0	0	4	5	54	50	42	45
Too cold in the summer?	0	0	0	0	63	50	38	50
Too hot in the summer?	13	20	38	20	21	25	29	35
Cold floors?	21	5	25	35	25	15	29	45
Drought from windows?	8	0	13	35	46	25	33	40
Drought from entrance door?	8	5	17	20	38	30	38	45
Varying room temperature when the temperature varies outdoors?	13	5	21	30	29	20	38	45
Difficulty changing the indoor temperature?	17	5	13	20	33	25	38	50

46% of respondents in House 2 and 35% of respondents in House 9 are experiencing problems to some extent with *too cold* temperatures *in the winter* (Table 8.3). 51% of House 2 and 40% of House 9 are experiencing problems with *too high* temperatures *in the summer*. Accordingly, there are more respondents who feel uncomfortable with these indicators in House 2 than in House 9. Nearly no respondents feel uncomfortable due to *too high* temperatures *in the winter* or*to low* temperatures *in the summer*. According to the respondents droughts are seldom a problem for them.

In general, there are many respondents who have not answered the questions in

Table 8.3 at all. This makes it hard to analyse differences between the houses. There is however a difference in the proportion of respondents who has answered *Yes, sometimes* respectively *Yes, often* for the two Kyrgyz houses. In the BETSI study[8] (where all the results for the Swedish comparison comes from) only answers to the *'Yes, often'*-alternative are studied. Following this, the respondents in House 2 do generally feel more uncomfortable with most of the aspects in Table 8.3. When looking at both the "Yes"-answers the differences between houses are evened out to some extent. Respondents in House 9 have ignored to answer this question more often than respondents in House 2, making the results more insecure for this house.

Table 8.4: Results in percent from the question "Are there any condense on any windows during winter time?" In total one respondent left this question unanswered.

	Never	**A little bit**	**Almost whole window**	**Don't know**
House 2	39	39	4	17
House 9	55	25	0	20

In House 9, more than half of the respondents have *never* got any condense on their windows during the winter time (Table 8.4). Only 25% has reported to have condense, and then only stated to have *a little bit*. In House 2, 39% have answered to *never* have condense on their windows. The same number of respondents stated that they had *a little bit* of condensation during the winter. In House 2 there is also a small proportion of respondents stating that they have condensation over almost their *whole window*. The amount of condensation on windows, and if it exist at all, is mostly dependent on the quality of windows. In Kyrgyzstan the type of windows installed depends on the individual occupant and is not the same for the whole building.

All occupants of House 9 had hot water meters installed in 1995/96 (see Chapter 7). Today about 40% of House 9 respondents answer they do not have a meter for DHW (Table 8.5). In the study made in 1995/96 they also installed meters on the radiators for measuring the heat supply. These meters were however used only for the study and have never affected the heat bill. The subject of heat meters are also a part of the observations (see Section 8.2.2 below).

Having meters or not, only 4 people from each building chose to answer the questions about how much energy they use. Additionally, the few answers were mostly missing units. Consequently, no results on amount of energy used can be had from the survey.

8.1.3 Air quality

According to the results presented in Figure 8.6, occupants in House 2 are experiencing more problems with their air quality. No one from House 9 answered that the air quality is *'bad'* or *'very bad'*. Although no one from House 2 think the air quality is *'very bad'*, nearly 20% think it is *'bad'*. The same amount of respondents from each house, about 50%, think the air quality is 'good' or 'very good'.

As can be seen in the 'no answer' column, the percentage of answers was low for all the questions concerning odours (Table 8.6). 13 – 21% of respondents from House 2 are often uncomfortable with smells coming from inside the house (three first questions in the

Table 8.5: Results on question about meters and use of heat and domestic hot water (DHW). The questions were "Is there a heat meter in your apartment?" respectively "Is there a hot water meter in your apartment?".

Has meter for heat	**House 2**	**House 9**
Yes	0	17
No	54	42
Don't know	21	21
No answer	25	4
Has meter for DHW		
Yes	29	38
No	33	21
Don't know	8	13
No answer	29	13

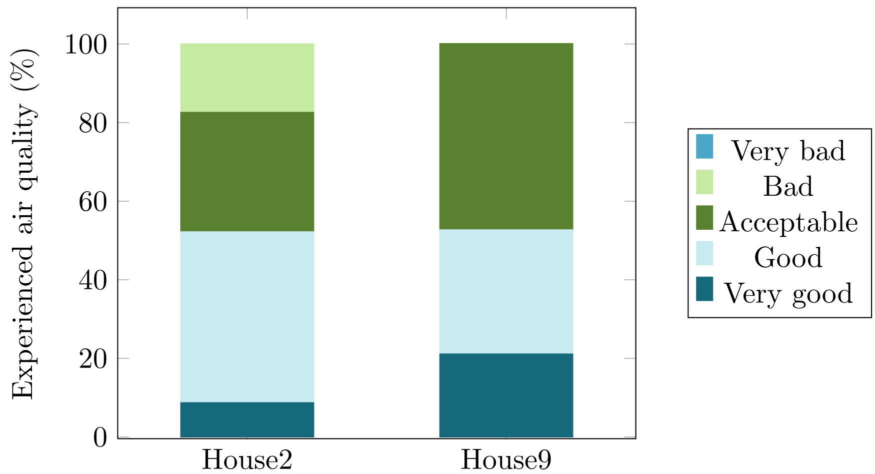

Figure 8.6: Results from question "How are you experiencing the air quality in your home?". One respondent from each house did not answer this question, they are not included in the diagram.

table). The same number for House 9 is 0 – 15%. Share of persons uncomfortable with smells coming from the outside of the house, such as smells from traffic, are in the same magnitude.

Very few respondents are experiencing any mould smell. As in Table 8.3, respondents from House 2 answer *yes, often* to a larger extent compared to House 9, where respondents instead more often are answering *yes, sometimes*. If one combines the two 'yes'-answers about 50% of the respondents from both houses are uncomfortable with odours from neighbours, such as from cigarettes smoke. More smoking does occur in the Kyrgyz houses compared to in Swedish apartments (Table 8.7).

Table 8.6: Results in percent from three questions about smells.

	Yes, often		Yes, sometimes		No, never		N.a.	
	H2	H9	H2	H9	H2	H9	H2	H9
Do you feel uncomfortable in the apartment because of experienced odours:								
When you cook?	13	15	25	45	25	30	38	10
When your neighbours cook?	13	0	17	25	33	50	38	25
From neighbours: cigarette smoke or other source	21	10	25	45	25	25	29	20
Do you in your home feel uncomfortable because you experience odours from:								
Exhaust from traffic?	21	10	13	20	42	35	25	35
Smoke from barbecue, restaurants or industries?	8	10	17	20	46	40	29	30
Wood combustion?	8	0	21	5	42	50	29	45
Do you experience any of the following odours in your apartment:								
Mould smell?	0	0	8	0	63	60	29	40
Other unpleasant smell?	13	5	21	35	46	50	21	10

Figure 8.7 indicates that the Kyrgyz respondents are airing their apartments to a somewhat larger extent than the Swedish respondents. In Sweden 67% are airing daily while for Kyrgyzstan the same number is 93%. If separating the houses, 100% of respondents in House 2 (two blank answers excluded) and 85% of respondents in House 9 (no blank answers) confirms a daily opening of windows. Table 8.8 presents *how* the Kyrgyz respondents are airing when they are doing so. In both houses it is most popular with full draught.

Table 8.7: Frequency of smoking inside (%). Comparison of Kyrgyz and Swedish results [8].

	Every day	Never	No answer
Kyrgyzstan	14	60	23
Sweden	9	84	

Table 8.8: Window airing habits in Kyrgyzstan, answers to the question "How long are the windows open?". Some respondents have answered more than one alternative, the sum will therefore exceed 100%.

	House 2	House 9
24 hours	4	0
Day	25	0
Night	4	0
Few hours	29	25
Full draught	54	60
Never	0	10

Table 8.9 contains survey results of questions indicating problems caused by insufficient ventilation. Especially the question about *getting rid of moist air in the bathroom* shows

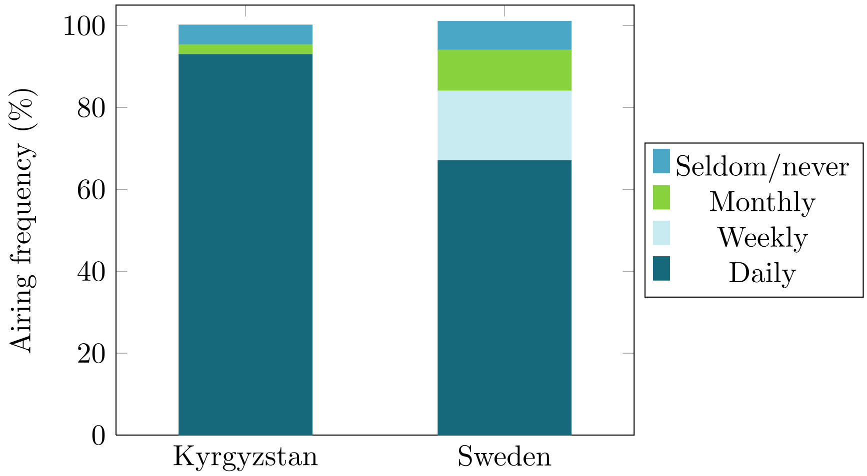

Figure 8.7: Comparison of airing habits between Kyrgyz and Swedish respondents. The question was "How often are windows open in your home?".

Table 8.9: Problems with ventilating system in Kyrgyzstan, answers to the question "Do you have any of the following problems with the ventilating system in your home?". The answers are in percent. N.a. is *No answer*.

	Yes, often		**Yes,** sometimes		**No,** never		**N.a.**	
	H2	**H9**	**H2**	**H9**	**H2**	**H9**	**H2**	**H9**
Problem getting rid of moist air in your bathroom?	21	5	17	20	33	50	29	25
Fog/condence on your window when cooking?	13	0	17	30	42	40	29	30
Difficulties influencing the ventilating system by yourself?	8	5	13	25	46	40	33	30

differences between the two buildings. 21% in House 2 have this problem *often*, compared to only 5% (1 person) in House 9. Including they who *sometimes* have problems the difference is smaller. Still there are totally 38% who have this problem in House 2 and only 25% in House 9. For problems with fog on windows when cooking, in both houses about 30% are experiencing trouble to some extent. In House 9 no one is however experiencing these problems often, while 13% do so in House 2.

The survey also contains a question concerning the presence of a fan in the bathroom. In Table 8.10 the answer to this question is compared to the question about having problems getting rid of moisture in bathroom. More respondents have *no problems* but also *no fan*, than have *no problems* but do *have a fan*. This means that it cannot be concluded from these results that a fan actually helps getting rid of the moisture in the bathroom. There are also families that have got a fan in the bathroom but still have problems with humidity and condensation in the room (more in House 2 than in House 9). It is worth noting that the word *fan* might have been misinterpreted by the respondents. From comments added on the survey there are some indications that some respondents may have thought the ventilation outlet in the bathroom was the part the question concerned. This is something all dwellers have in their apartment but maybe this is not a known fact to all respondents.

Table 8.10: Comparison between question "Problem getting rid of moist air in your bathroom?" and "Do you have a fan in the bathroom?". For both of the questions 28% in House 2 and 30% in House 9 did not answer this question.

	No Prob. & Fan	No Prob. & No fan	Problem & No fan	Problem & Fan
House 2	13	21	21	17
House 9	15	30	20	5

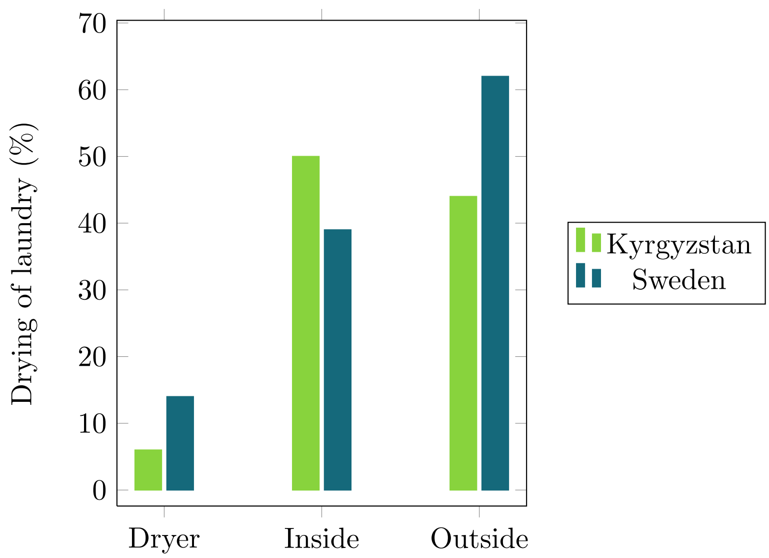

Figure 8.8: Drying of laundry. Some respondents have given more than one alternative for drying their laundry, the sum of the bars therefore exceed 100%.

Moisture can originate from the drying of laundry inside the apartment. To dry laundry in ones own tumble-drier seems to be more common in Sweden than in Kyrgyzstan (Figure 8.8). It seems to be more common for the Kyrgyz respondents to dry their laundry inside of the apartment, without a tumble dryer. The drying of the laundry outside the home is more common in Sweden. The interpretation of the drying laundry outside has probably got a different meaning for the Swedish and Kyrgyz respondents. In the examined buildings in Kyrgyzstan, there were common rooms on each floor, meant to be drying room for laundry when the houses were built. They were however mostly used by the persons living in the flat next to them, as an extra room for storage or as part of their flat. The drying of laundry outside the apartment occurs in the courtyard or on the balcony. In Sweden, it is common with rooms or small houses outside the apartments, with the sole purpose of washing and drying laundry, open for everybody living in the building. As seen in Table 8.1, only 31% have their own washing machine in Sweden while 89% of the Kyrgyz respondents do.

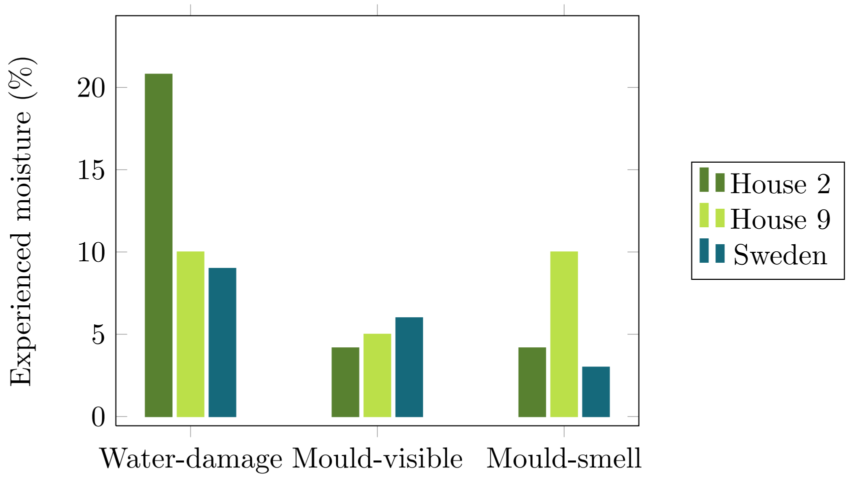

Figure 8.9: Experienced moisture damage among the respondents, during the last 12 months. Three questions were asked: Has there been any "water damage indoors on walls, floor or ceiling?", "visible mould on walls, floor or ceiling?" and "smell of mould in the home?".

The observed water damage is much larger in House 2 than in both House 9 in Kyrgyzstan and in Sweden in general (Figure 8.9). The visible mould has been noticed almost equally as much in the two houses in Kyrgyzstan as it has in Sweden. The smell of mould is noticeable to a somewhat larger extent in House 9 than in the other two places. Observe that the 10% who has experienced the smell in House 9 corresponds to two people. To experience mould smell is consequently uncommon in both of the houses.

8.1.4 Sonic environment

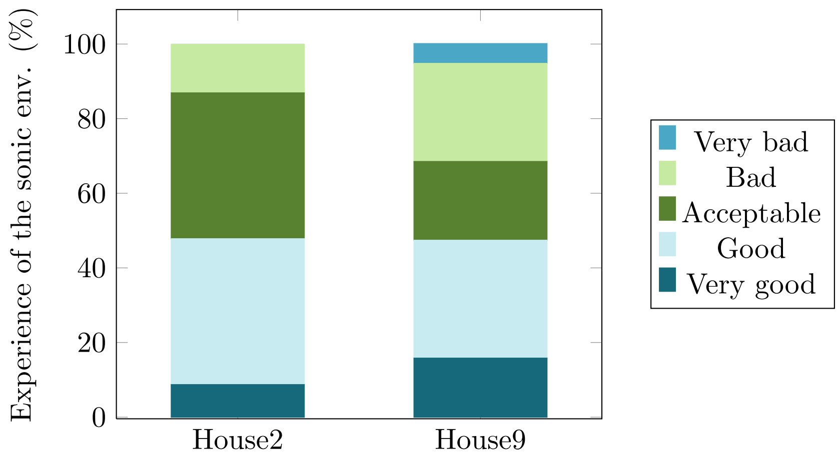

Figure 8.10: Results from question "How do you generally experience the sonic environment in your home". One respondent from each house did not answer this question, they are not included in the figure.

On the question "How do you generally experience the sonic environment in your home" the respondents in House 9 have a more diverse answer pattern. More people answered *very good* but also more said it is *bad* or *very bad*. In general a majority of respondents from both houses find the sonic environment acceptable or good, however more so in House 2 than in House 9. The sonic environment was also examined above, in questions about general standard (Figure 8.3). As mentioned, House 9 is situated close to a highway, and it is possible that this is a cause for the larger discontent with the sonic environment.

Table 8.11: Results in percent from the question "How much have you in the last three months been experiencing problems with noise from:".

	Not bothered		A bit bothered		Very bothered		Doesn't exist		N.a.	
	H2	H9	H2	H9	H2	H9	H2	H9	H2	H9
Pipes?	21	20	4	10	33	20	13	15	29	35
Ventillation/ fans?	8	10	4	0	33	10	21	25	33	55
Voices, radio, TV, music or similar from neighbours?	17	25	4	10	21	15	25	10	33	40
Scraping sounds, foot steps, and similar from neighbours?	29	20	25	25	21	15	17	10	8	30
Stair well/ elevators?	25	30	25	25	17	15	13	15	21	15
From outside the building:										
– Ventilation/ fans/ heating pumps?	8	0	4	5	42	20	21	30	25	45
– Road traffic?	21	35	13	35	25	15	25	10	17	5
– Railway traffic?	0	0	0	0	38	25	33	30	29	45
– Air plane traffic?	4	0	0	0	38	25	29	30	29	45

In Table 8.11 the results from two questions about noise are shown. A large proportion of survey respondents did not answer this question. The question about noise from road traffic seems to have been most engaging, 50% in House 9 and 38% in House 2 are bothered to some extent with this phenomenon.

Table 8.12 shows the result of a question specifying potential problems because of traffic noise. Also here there is a high amount of blank answers, from 21 to 45%. The most respondents do not experience problems with traffic noise. However, in House 9, 20% of respondents have trouble sleeping because of traffic noise.

8.1.5 Comments

All the written comments from the survey are in Appendix B.4. On the question "Do you have suggestions and ideas, that you would like to add for your apartment?" many respondents suggested improvements related to renovations. These were suggestions such as adding insulation and renovate pipes. These kind of answers were found for both houses. One respondent from House 2 also states that "Administrative service is very bad. We pay money for air". One respondent from House 9 wish for growing more flowers in the garden

Table 8.12: Results in percent from the question "Does the noise from traffic bother you in one of the following ways?".

	Yes, often		Yes, sometimes		No, never		N.a.	
	H2	H9	H2	H9	H2	H9	H2	H9
Problem hearing radio/TV	0	5	4	10	67	45	29	40
Telephone call is disturbed	0	0	8	5	63	50	29	45
Conversations are disturebed	0	0	4	0	67	55	29	45
Resting/napping is disturbed	4	20	4	20	63	30	29	30
Hard to fall asleep	13	20	4	10	63	35	21	35
Wakes up	4	20	0	5	67	45	29	30

and having a summerhouse in the yard. This person also wants to repair the coating off the house.

At the end of the survey there was a part not actually meant for the occupier to fill in. Nevertheless some respondents have written their opinions here. For example one respondent from House 9 complains about the domestic hot water: "... cold water comes first and then after 15 minutes hot water comes." In total from the questions at the end of the survey there were ten written answers from House 2 and four from House 9.

Some respondents have also written their own comments to a specific question. One respondent think it is inappropriate to ask ask questions about the energy use of the apartment. One other, who lives on the top floor of House 2 tells us that the roof is leaking. One respondent in House 9 says their heat meter is broken. Two respondents reports about water leakages, it is unknown if they refer to the same accident. One of the respondents says it was fixed by the organisation supplying cold water to Bishkek.

In connexion with the survey handout one respondent orally stated that one of their neighbours has moved their bathroom (or toilet) to another room. More than one of the neighbours to the apartment with changed location of the bathroom complained of a bad smell coming from this apartment.

8.1.6 Complementing interviews

When the Domkom of each house was interviewed they presented their responsibility. The results from this part of the interview is found in Section 7.1. In addition to this the Domkoms also gave some other insights, presented below.

Interview with Domkom in House 2. The Domkom of House 2 does not know what the energy consumption of the building is. She also stated that the building does not have any problems with mould [78].

Interview with Domkom in House 9 The Domkom in House 9 stated that a two-room apartment uses about 5 m^3 of hot water per month. A normal family use electricity for about 150 – 200 som/month (3.07 – 4.10 \$/month), corresponding to about 215 – 285 kWh/month according to current electricity prices (see Section 3.3.1). A very high consuming family spend at maximum 350 som/month (7.17 \$/month) on electricity (corresponding to 500 kWh). According to the Domkom there are still heat meters for the

DHW. Further, she says that the thermostatic valves on the radiators does not work any more. The regulator for the heating system of the whole building's is on the other hand working according to the Domkom. The radiators in the apartments are however very hot in the winter according to her.

The Domkom of House 9 also presented the rent for the building. It is based on the number of rooms of the apartment, for example a two-room apartment pays 153 som/month (3.14 $/month).

8.2 Measurements

8.2.1 Temperature measurements

In Table 8.13 the results from measuring in the staircase of House 2 can be seen. The IR-temperature is lower on the windows and the entrance door compared to the walls facing apartments. It can also be confirmed that the humidity decreases with the height of the building. The hottest indoor temperature was measured on the top floor of the building and the lowest on the ground floor of the building. Since the results from these measurements were not very useful, only the measurements of the staircase of House 2 are shown as an example.

Table 8.13: Measurements in the staircase-area of House 2. The measurements were done during one hour's time.

	IR-temp.	**Temp. inside**	**Humidity**
Floor 1	18.2	15	36
Floor 3	18.6	17.5	35
Floor 7	20.3	16.5	34
Floor 9	206	19	33
Window floor 3.5	14		
Window floor 6.5	16.7		
Entrance door inside	12.3		
Entrance door outside	11.5		

Table 8.14: Temperatures (°C) measured on the entrance door and surrounding wall of the two buildings (average values).

	House 2	**House 9**
Indoor Air	18.9	18
Indoor Wall	15.6	16.2
Outdoor Wall	13.6	13.8
Outdoor air	15.5	15.5

The purpose of the numbers shown in Table 8.14 was to calculate the U-value ($W/(m^2K)$) of the wall for both buildings. As can be seen in the table, the house had not reached steady state with the surrounding air, or otherwise the outdoor air temperature would be lower than the temperature of the outdoor wall. Consequently, no calculations of U-value could be done.

The temperature was measured with the IR-thermometer on three spots off the balcony for a few different apartments. The temperature difference of the highest and the lowest measured temperature on the balcony is in Table 8.15. The difference between four different kinds of balconies, with different fields of application, are shown in the table. On the insulated balcony there is a much smaller temperature difference than on the balcony used as a pantry.

Table 8.15: Temperature differences (°C) of coldest and warmest part of balconies. Four different balconies, used differently, are shown. On the balcony with a pantry there was a refrigerator. The "normal usage" indicates it is used as a balcony and nothing more. For the balconies that were part of rooms the balcony door had been removed. All balconies were equipped with glazing.

How used	Temp. difference
Pantry	3.8
Normal usage	3.1
Part of room	1.8
Part of room, insulated	0.2

In three apartments, two walls of the same room were measured. One of the walls was an outside wall with one window. The other wall was not in contact with the outside. The outside wall was always one or two degrees colder than the inside wall. However, too few measurement occasions were done to draw any conclusions other than the windows are colder then the other part off walls. There were too few temperature differences between the outside and inside temperatures to make any comparison between houses possible.

8.2.2 Observations

When performing measurements, observations were made on the current condition of the two buildings. In Table 8.16 the observations made in the former study (95/96) are compared with the observations made today.

Comparison with former study From visual observations of the façade of the buildings, the number of renovated balconies could be observed. The result is shown in Table 8.17. On some balconies only windows have been installed, as is mentioned in the previous study. Some owners have now also installed new panels on their balconies, making them even more suitable to be used as additional living space. The panels are most commonly made out of brick, wood, plastic and sometimes covered with plaster. In Figure 8.11 pictures of different types of balconies are represented.

During the measurements it was also noticed that the thermostatic radiator valves installed in 1996 are broken in many apartments. This was confirmed by Domkom in House 9 (see Section 8.1.6). This was one reason for the changing of radiators in House 9 (see Table 8.16).

Table 8.16: Observations made in the former study compared with observations made today.

Observed 1995/96[14]	Observed now
Maintenance to windows and entrance doors is insufficient, e.g. broken entrance doors are not replaced.	Entrance doors are quite new and seem to have been replaced in the whole neighbourhood after 1996. Windows are of varying quality. Some have replaced their original wooden framed windows (commonly to PVC-framed windows).
Leaking water taps in the flats are not repaired.	Not observed.
In winter, consumers may be supplied with domestic hot water temperatures of 80 °C to 90 °C.	This is still the case in both houses. And not only in winter according to some dwellers.
Room temperatures were between 8 °C and 12 °C on colder days in recent heating periods.	In House 9 the temperatures are not this low any more. Nor in House 2, were the radiators are reported to be very hot. The regulator for heating is broken in House 2 according to one dweller.
Dwellers have installed larger radiators to compensate for low temperatures. Additional electric heaters are also used.	Now, sometimes larger radiators were observed in both House 9 and 2. Additional heating is still used. As seen in Table 8.2 46% of House 2 and 30% of House 9 have an additional heater, according to survey answers.
Draft-proofing measures on the windows and ventilating system, e.g., sealing of air ducts in the kitchen and bathrooms and draft-stripping of windows.	Not observed.
Occupants frequently use balconies as additional living space. For this purpose balconies are enclosed with single pane windows and frequently it was observed that additional radiators are installed. In some cases the main window and balcony door has been removed.	Balconies are still used as living space, in some cases they are also retrofitted to be part of a room. Almost all balconies has windows and also additional panels have been installed (see Table 8.17). Additional radiators on the balconies were also still observed.

Ventilation The ventilating system has not been changed since the former study was done, but is still a natural ventilating system. The outlets were observed to work. A paper towel was placed on the ventilation wholes in two apartments. Because it was sucked in and got stuck on the vent, it was concluded that air is flowing from the apartment, creating a suction. The size of the flow is however not known.

Observations from visiting apartments, which will influence the ventilating system, were:

- Mould smell was noticed in the lower part of House 2.

Figure 8.11: Different modification of balconies from Asanbay microregion. The balcony in the middle, without windows, got the original shape of a balcony on building type 105. This is however now seen on only 6 balconies on both houses.

Table 8.17: Balconies in Asanbay 2 and 9.

	Asanbay 2	**Asanbay 9**
Only windows	88	62
Panel and windows	18	42
No renovation	2	4

- Kitchens have been moved to different rooms than first intended. This was observed in several apartments.
- In one apartment one ventilation outlet was blocked with wallpaper.
- One occupant had plans to remove a ventilation shaft to get a little bit larger living area.

Additional observations When performing the measurements, there were some additional observations made. For example the apartments to the right of the staircase have in some cases taken over the common laundry room and expanded their apartment. This was not noted in 1995/96 when the former study was made. In House 9, 83% of the owners living next to the laundry room have taken over this room and consequently adding to their living area. In House 2 the corresponding number is 67%.

Lastly, the following observations worth noticing were made. They are from visiting five apartments. The phenomena are however likely to occur in both houses and in other apartments too.

- Altered supporting structure was found in one apartment.
- More than one owner stated that it takes long time (sometimes 10 minuets or more) for the domestic hot tap water water to get hot. When it does however, the water is, as noted in Table 8.16, almost boiling hot.

- More insulation has been added by more than one dwellers, on floor, walls and balconies.
- The lighting in the staircases tend to be private for each floor. One occupant was even observed to have moved the light-switch into their own apartment.
- The façades are in bad condition, see Figure 8.12.

Figure 8.12: The façade of House 9.

8.3 Calculation of theoretical U-value

8.3.1 Model properties

The hardest part of the calculations was to estimate the U-value for the walls behind the balconies. There are many factors making it hard to estimate the U-value for the balconies, mainly because the balconies of the buildings all looks very different:

- The occupants can have put in windows on their balcony.
- The occupants may use the area as living space and have put away door and windows between the balcony and the room.
- The occupants may have insulated the balcony.
- The occupants may have installed radiators on the balcony.

As seen in Table 8.17 only 2.8% have *not* put in windows on their balconies. 28% have put up some panels or walls on the balconies, suggesting that they may use the balcony as living space. It was not possible to quantify the extent of insulation installed on the balconies or how many dwellers had installed radiators on their balconies.

To simplify the computer model the wall behind the balconies was always treated as the outer wall. The wall was given a lower U-value to compensate for the protection the glazed-in, and maybe insulated, balconies give. An U-value half of the value calculated for the outer wall was chosen, as if the balcony temperature is in between outside and inside temperature [74]. In House 9 no extra insulation was added behind the balconies in 1995/96. The same value for the balcony wall could consequently be used used for the two buildings. The U-value for a “standard” wall of a 105-type building (see Figure 7.2) was calculated to 0.346 W/(m^{2}K). The walls behind the balconies was set to 0.173 W/(m^{2}K) in the models.

The estimation with a mean balcony temperature lying in between indoor and outdoor temperature seems reasonable but there is no knowing how well it correlates with reality. Because the same values could be given to both the houses the uncertainties in the U-value for balconies did not matter very much, as the intent was to compare the two houses to each other.

As the balconies, the type of windows used in the buildings varies between different apartments. The most common type of windows are PVC framed windows and wooden framed windows. The two variations in the computer model on account of window types are: all windows are old bad wooden windows *or* all windows are new PVC-windows. The U-value for old wooden windows is assumed to be 3 W/(m^2 K). In one study old, worn, wooden windows of good quality had a U-value of 2.4 – 2.6 W/(m^2 K) [81]. To assume the worst case possible this number was rounded up to 3 W/(m^2 K). The PVC-windows have about 1.6 W/(m^2 K) according to one of the common PVC-windows brand used in Kyrgyzstan, Bauplast [82].

For calculation of the U-value of the walls, the variation on account of mineral wool properties is due to the fact that the buildings are old and the mineral wool may have lost some of its capacity. There were calculations made for both if the building had new standard mineral wool and old, very bad wool. Mineral wool with 10 vol% water has an U-value of 0.055 W/(m^2 K)[56]. In the computer model a worst case has been assumed. Besides the fact that it can be damaged by moisture the material can also have got compressed during its life and the quality was low from the beginning [6]. A U-value of 0.060 W/m^{2}K was therefore used. Behind the balconies the wool is considered undamaged.

8.3.2 Results

Table 8.18: Results from mean U-value calculations, values in W/(m^2 K).

		Wooden windows	PVC-windows
Old Mineral wool	**House 2**	0.90	0.69
— ” —	**House 9**	0.78	0.59
New Mineral wool	**House 2**	0.81	0.61
— ” —	**House 9**	0.74	0.51

Table 8.18 shows the results from the calculations with Isover Energi 3 and the total U-value each house received with described variations. A 25 – 30% smaller U-value was received when changing all windows from old wooden ones to new PVC-windows in the

model. If the mineral wool has aged and had got a larger U-value than it had when it was installed, this gives a 5 – 14% increase of the value for both the houses. House 9 has an U-value 9 – 14% smaller than House 2 because of the added insulation when the former study was made. The properties of the walls have consequently got less impact on the total U-value of the building than the changing of windows. The windows are changed in many of the apartments already, suggesting that the occupants know this to be an efficient way to improve heating comfort.

The real mean U-value for each house should be somewhere between the calculated values. In reality all apartments does not have the same types of windows for example; about half of the windows are replaced by PVC-framed windows on both the buildings. The mineral woolinsulation present in both the buildings probably has a λ-value more close to the one being used in the 'old insulation model' then the 'new insulation model'. It may be better in House 9 due to the extra layers on the façade which have protected the mineral wool better from water penetrations in almost twenty years. This, together with the thermal bridges, gives that the real U-values should rather lie closer to the higher calculated values than the lower.

Chapter 9

Analysis

The main obstacle in solving the housing situation in Kyrgyzstan and make it sustainable, is the lack of funds. There are good initiatives being introduced but without funds they have a limited chance of succeeding. Corruption is also a widespread phenomenon in Kyrgyzstan and might also slow down the improvements of the housing situation. The following sections analyses the questions formulated in the objectives.

9.1 Building codes

The Kyrgyz and Swedish building codes have got both similarities and dissimilarities. The first main difference is in the amount of laws and regulations, where Sweden has an easier legal system to overview, with clearly defined responsibilities. Kyrgyzstan is a new state compared to Sweden. Sweden has consequently had a lot longer time to prepare a clear legal system.

The UN also recognised in their report on housing from 2010[16] a need to simplify the Kyrgyz legal system. They also concluded that the legal responsibilities should be delegated to local authorities. Kyrgyzstan has got a new parliamentary system since the mentioned report was written. It has however still got a complicated system according to latter sources. In Sweden many of the laws and regulations are translated into English. This makes it easier to be transparent towards other countries.

The corruption also needs to be considered when examining the building codes. The regulations might not be followed in Kyrgyzstan regardless of if they are of good quality. Below, the differences in Kyrgyz and Swedish building codes are discussed.

9.1.1 Responsibility

The Kyrgyz condominiums are very similar to the Swedish Tenant owners associations, at least in theory. They both have the purpose of managing the maintenance of the commonly-owned parts of apartment buildings. In Sweden all multi-family houses where the occupants own their apartment, belong to a tenant owners association. In Kyrgyzstan however, only about 25% do. This means that the maintenance of the commonly-owned parts is lacking in many buildings.

The joint ownership of multi-apartment buildings is overall working much better in Sweden than it is in Kyrgyzstan. Swedish citizens are very used to cooperative solutions.

The Kyrgyz people seem to have really tried getting rid of the Soviet traditions of joint ownership since they left the union. The government at the time seems to have been almost in a hurry to privatise all of the multi-apartment buildings in the country.

The possibility to rent an apartment through a regulated tenancy is very small in Kyrgyzstan. There are also almost no regulations concerning this. There are individual owners of apartments renting out their own apartments but there are very few large organisations providing many apartments. As much as one fifth of the people living in Bishkek are living in settlements with none or very bad infrastructure. The Kyrgyz model, with individual ownership of apartments, is consequently not providing affordable houses for all the people living in the country. With more funds it would be advisable that houses, with apartments possible to rent, be built.

The examined buildings do not belong to a condominium. The responsibility of the examined buildings are instead shared, with the Domkom working as a coordinator if something should be considered a problem. The roof seems to be leaking according to survey respondents of House 2. When a simple thing as the lighting of the staircase is handled differently on each floor, the question becomes if the leaking roof is considered a problem for all the occupants of the building or only the ones living on the top floor? The rents are quite low in the Kyrgyz houses, not covering all the common costs. When there is a larger common cost they gather the money for that expenditure. The roof is most likely expensive to repair or change. Do they have all that money needed to pay for a roof-reparation?

Maybe it is a difference in the culture between the countries. The Kyrgyz people are more concerned with the welfare of their family than they are with the welfare of the person living next to them. In Sweden people have instead got used to sharing things with others. When it comes to the maintenance of the Asanbay buildings it would be appropriate if the persons living there had a stronger sense of community. The occupants need to act together when there is a need for larger renovations, and the buildings will need renovations in the foreseeable future.

9.1.2 Alternations to a building

It is not mentioned anything about preserve the characteristic values of a building in the Kyrgyz regulations examined as an aspect of importance to consider during renovations of the building. It is on the other hand stated that the energy efficiency measures should be performed on the buildings when retrofitting them.

9.1.3 Constructing new buildings

Only one regulation from each country was examined thoroughly in this thesis: the SNiP from Kyrgyzstan and the BBR from Sweden.

The thermal transmittance or U-value is given as a calculation requirement when constructing a new building for both countries. In principal the same unit is used, $W/(m^2K)$ (although Kyrgyzstan has chosen to use the thermal resistance which is the inverse of thermal transmittance). There are however some differences between the regulations. In the Swedish regulation, the thermal transmittance should be calculated for the whole building. It should also have the same value in the whole country. In Kyrgyzstan the thermal resistance is calculated differently for different parts of the building envelope. It is also varying dependent on where in the country the building is to be constructed. There are a number of tables defining this value. In Bishkek the thermal transmittance should be about 0.4 W/(m^2K) for a wall while in Sweden the mean thermal transmittance for the whole building should have the same value. This means that the Swedish regulation is somewhat sterner than the Kyrgyz one on this point.

According to the computer model, none of the examined Kyrgyz houses manage to fullfill the Swedish requirements. However three of the four wall variations fullfill the Kyrgyz rules. The case not fulfilling the Kyrgyz regulation is the wall in House 2 assuming it got old and bad insulation.

The specific energy use is given as a requirement for both countries although with slightly different definitions. In Sweden the specific energy use is given in kWh per year and per area intended to be heated to more than 10 °C. In Kyrgyzstan it is instead given in KJ/(m^2 °C day) or KJ/(m^3 °C day). Other than the Kyrgyz unit containing cubic meter in some cases, the units are very similar.

Both for Kyrgyzstan and Sweden the specific energy use can have different values depending on which heating system is used. In Sweden the specific energy use should be lower if the building is heated with electricity. In Kyrgyzstan the specific energy use is instead different if the building is heated with district heating.

Sweden also has rules regarding the thermal comfort of the building, which is lacking in the Kyrgyz code examined.

The rules for ventilating system is in Sweden given as a minimum flow, not to be below. It is measured in litres/s. Kyrgyzstan does not have these kind of rules in the SNiP. There might be rules for ventilation present in other building codes not read in this degree project. Indications have been given that regulations for ventilation have not been developed in Kyrgyzstan. There are however regulations present on air permeability (in kg/(m^2 h)) of the building which might give an indication of the ventilation flow.

The rules for preventing moisture are hard to compare for the two countries. As for the ventilation, regulations concerning moisture might be present in other parts of the quite complicated Kyrgyz system of building codes. It is also possible that these regulations will be further developed in the future, as moisture becomes a more prioritised subject when it comes to the improvement of buildings in Kyrgyzstan. As it is now, the building codes are more focused on establishing the rules for heating comfort.

9.2 Additional differences between Sweden and Kyrgyzstan

There are many differences between Sweden and Kyrgyzstan and between how Swedish and Kyrgyz people perceive their living environment. Noted in this thesis is for instance that the Kyrgyz people pay about ten times less for energy used for electricity, DHW and heating than the Swedish people do. They do however also have a much lower salary in the Central Asian country. The gross national income is about 50 times lower in Kyrgyzstan and the average national salary of 144 $ is also much lower than in Sweden. The prices of energy are corresponding to a larger part of the average salary for a Kyrgyz person. Energy is in other words quite expensive in Kyrgyzstan.

In Sweden we use about 100 litres of hot tap water per person per day. When the former study was made, the Kyrgyz used 120 – 140 litres per person per day. According to the company responsible for the DHW distribution, each Kyrgyz person is now estimated to use 160 litres of hot water per day. Many people may not use as much water and would save money if they got an individual bill. However, the current system makes it possible to hide real facts about how many people are living in an apartment, to save money and by paying less than their actual consumption. An individual billing system may in that case not make it cheaper for them. It would however make people more prone to lessen their water consumption and at the same time save energy.

The electricity consumption is about the same in both Sweden and Kyrgyzstan. The use in Kyrgyzstan (215 – 285 kWh/month) is a bit less than the Swedish mean numbers 240 kWh/month for two people and 340 kWh/month for four people [83, 84]. In Kyrgyzstan they mainly use gas stoves which should reduce the electricity use. A consumer of high amounts of electricity in Kyrgyzstan uses as much as 500 kWh/month, according to the Domkom of House 9.

According to the survey, people in Sweden are more satisfied in general with the standard of their homes than the people asked in Kyrgyzstan. The people of Kyrgyzstan are experiencing more factors which make them uncomfortable. One exception to this is the smoking, where Swedish people are more discontent. This might seem strange when more people are smoking in their apartments in Kyrgyzstan. The difference between the countries lies in this case probably in how tobacco smoke is perceived. All people do not feel uncomfortable from the tobacco smoke. If this question should have been asked in Sweden thirty years ago, when more people were probably smoking inside their apartments, it might have had a different result. This question shows a difference in culture between the countries and it is important to consider that the answers to this survey are in many cases up for subjective interpretations.

There are also probably differences in how words are interpreted in the survey. Many words may even have got different meanings because the translation occurred in many steps. For example the word ”sometimes” was ignored by the creators of the Swedish survey because of its diffuse meaning. Consider how it can be differently perceived in between countries. There might also be differences in how concepts like ”dry air” and ”draught” are interpreted by different people.

When it comes to different types of equipment, Swedish people living in apartment buildings to a great extent all have electrical apparatuses like stoves and dishwashers. A larger share of the Kyrgyz people answering this survey has however got washing machines in their home. The concept of sharing a laundry room is not common in the republic. This becomes obvious in the examined buildings since the common rooms built for drying laundry are mostly used by the occupants in the apartments situated next to the rooms.

The Kyrgyz respondents air more than the Swedish respondents according to the survey results. This might suggest they have a worse ventilating system. There also seems to be more water damage occurring in Kyrgyzstan. The water leakages occurring may get faster taken care of in Sweden with more clear responsibilities of the common areas. The concept of a leaking roof in a multi-apartment building is very foreign to most Swedish occupants.

9.3 Heating comfort

The results from the survey confirm that the thermal comfort in House 9 is better than in House 2. Nobody in House 9 defines the thermal comfort as bad. Additionally, the occupants of House 2 are to a larger extent uncomfortable with too cold temperatures in the winter. The building also has more additional heaters installed. Even if the asked occupants in House 2 said it is never as cold as 8 °C, there seems to be a need for additional heating in this house. The reason the asked occupants did not experience this much cold any more, may apart from additional heaters, be because they changed to larger radiators, installed better windows or added insulation to their apartment.

All the occupants asked (when performing measurements), in both houses, confirmed that radiators are very hot during the heating season, precisely as 20 years ago. At the same time many occupants of both buildings have additional heaters. It is reasonable to believe that the radiator system has not been adjusted for many years and the heat therefore being very unevenly distributed in the heating system. According to the survey 25% do think that it is often too cold in the winter in House 2. Because some occupants have installed larger radiators by themselves the whole radiator system is probably in great need of adjustment.

Even if House 9 have better insulation and nobody thinks the heating comfort is bad, still 10% think it is often too cold in winter and 30% have an additional heater. Also here the radiators may be badly adjusted. It is worth thinking about that the perception of what is *too cold* is subjective and varies dependent on whom you ask.

Most of the occupants that experience draught only do this sometimes. Draught mainly comes from windows, entrance doors or badly refurbished balconies which are factors dependent on the single occupant and not the general shape of the house. Therefore there should not be a difference between the buildings because of the renovation in 1995/96.

The cooling need of the buildings in the summer is considered less of an issue for the examined buildings than the heating need in the winter. It is therefore not thoroughly considered in this project.

9.4 Ventilation and moisture

According to Swedish regulations, there have to be other inlets for ventilation in a dwelling than just through open windows. In the examined buildings there are not any such inlets; the only air inlets are through open windows and maybe cracks around the windows and balcony doorframes.

Many of the occupants have changed to modern PVC-windows with higher thermal resistance than the old wooden ones. This gives higher thermal standard for the occupant. However, the old windows had bad patty, the frames had maybe bad fitting etc., things that work as ventilation inlets. It seems like the Kyrgyz people think about how to improve heating comfort (they do add insulation and try to prevent infiltration) today but have not started to think about problems which can follow when a building is too air-tight. Experts probably know about this but usually people do their minor renovations by themselves.

Maybe people will have to find out the consequences of bad ventilation for themselves, such as rising numbers of people with allergies or mould problems, before they will understand the importance of well-functioning ventilation.

According to the survey results the respondents think the air quality is good. However, about a third said that they have problems with some part of the ventilating system at least sometimes (this was a question with high amount of blank answers; there could be more then a third). Also 10 – 20% have problems with smells in their home. The perception of an acceptable air quality may include fog on windows when cooking and moisture in the bathroom.

When examining airing habits it might also be that the habit of opening windows goes deep. People might want to open their windows even when the ventilating system works perfectly. In this case there is no need for better ventilation inlets.

This survey was made in the autumn and maybe the respondents did not consider their winter habits. The question about air quality may have got other result if the survey was made during the coldest period.

In the examined buildings they have towel driers (heated by the district heating) which is appropriate when a natural ventilation is used according to Boverket (see Section 4.5.3). The buildings also have different ventilation channels for each apartment which is also a requirement for a proper ventilating system. What is missing is the possibility to change ventilation inlet area, which is recommended by Boverket.

Consequently, the ventilating system has the potential to be well-functioning but there is an ignorance of how the ventilation works. The fact that several occupants have moved the kitchen to another room without taking care of the ventilation is one indication of this. In one case the ventilation outlet was covered with wallpaper in the former kitchen. One other occupant did not believe that the outlet in their former kitchen worked. The ignorance, or the non existing belief in the natural ventilating system clear the way for doing things like removing the ventilation shaft to get some square decimetres of larger room area. The consequence of this being that the ventilating system is damaged for their neighbours as well as for themselves.

The occupants have to get, according to the Domkom of House 9, permission from the city authorities if they want to make renovations that will affect the building fundamentally. The destruction of the ventilation shaft would be one such renovation, one would think. The question is how hard it is to get this permission? It is possible that the occupants do not appeal for this permit at all. The country has, as mentioned, also got big problems with corruption.

Unfortunately there seem to be moisture problems in the houses. The Domkom of House 2 stated the opposite but the smell and damp air in the lower floor of the staircases is an indication of that she may be wrong. The survey results also indicate problems with moisture to some extent but there are reasons to believe that the occupants not knowing much about ventilation, they also do not know much about moisture to identify moisture problems in their home.

One reason for the moisture problems could be that there are already occupants who have fiddled with their ventilation. Anything could be the problem with the ventilating system: a bird could have built a nest in the channels on the roof for example. A less insulated house such House 2 is also colder which gives it a higher relative humidity.

The former study did not improve the ventilating system when performing the energy efficiency measures on House 9. Since they did insulate the building, there might have arisen problems with the ventilating system, causing moisture damages.

9.5 Energy efficiency measures

Compared to the former study, the buildings have gone through some renovations. The entrance doors are for example of very good quality now. Popular renovations are otherwise making balconies into part of rooms and changing windows. Not noted in the former study was the taking over of the common laundry room which is also very popular.

It was 17 years since the former study was conducted and the buildings are now 28 years old. Some repairs are in order. Except for the changing of entrance doors, all the renovations to the buildings seems to have been done by individual occupants making improvements to their own apartment. To achieve any repair that have importance to the whole building, it is important that the occupants cooperate. This is especially so for the energy efficiency measures.

Adding insulation

The addition of more insulation was made to House 9, during the former study. It was considered an expensive approach by the authors of that study. The insulation is however still giving the tenants of House 9 a better heating comfort than House 2. None of the other measures done at that time seems to still be working as they ought. Insulation is consequently a measure which gives long lasting improvements to a building.

This does not counteract the fact that it is an expensive investment to make. Some occupants have added additional insulation to their apartments. The measure is however better to perform for the whole building at the same time since it should be added on the outside of the building for moisture reasons. If it is performed for the whole building it should also be more effective since the heating comfort of one apartment is affected of the temperatures of its neighbouring apartments. The system with separate ownerships makes this measure hard to carry through for the whole building.

Adjusting heating system and DHW-system

The regulator (with meter) placed in the basement adapts the heat supply to the outdoor temperature and is thus controlling the central heating system. This regulator is still working in House 9 according to the Domkom of this house. It is however supplying the radiators with very hot water. The regulators probably need some maintenance. There is a system being developed in Bishkek, to make sure the heat is supplied in the right amount to the buildings. This will also give an economic incentive for performing energy efficiency measures, as each house will be paying for their actual consumption. For the maintenance to be a appropriate measure there has to be widespread knowledge about the equipment in the country. The retrofitting of the central heating system and district heating substation was not as expensive a measure to perform as adding insulation according to the former study. It does however require the cooperation of the occupants with each other.

While fixing the central heating system, the adjusting of the radiators should be taken into consideration. One problem with this is the repairer visiting the apartments. The occupants who have installed larger radiators may oppose this measure because of the fear of being fined.

The thermostatic radiator valves installed at the time of the former study are broken in many apartments according to some occupants, including the Domkom of House 9. 25% of the occupants of House 9 occupants have problems with changing the indoor temperature by themselves sometimes or often. Occupants in House 2 do have this problem to a larger extent than House 9 but should the TRV:s be working even fewer should experience this problem in House 9. The broken valves have caused some occupants to change their radiators. As mentioned, when a TRV brakes, it most often gets stuck in the "off"-position, which means it will be interpreted as the whole radiator is broken. Maybe there was no need for changing the whole radiator. This goes to show how important it is to teach how measures should be maintained when performing them in a foreign country. It is also important to follow up the measures performed. If repairs are not possible in this country the measure should be considered very carefully before installed.

In a larger perspective it would be preferred with a closed district heating system than the open one existing today in Bishkek. This would make the DHW cleaner and probably the heat losses smaller. The DHW is very hot today, in both buildings. It also takes long time for the water to get hot. This is hard to influence by the occupants but has to be regulated for the whole building, as the radiator systems. There also might be problems with lime (or other minerals) from the fresh water deposit in pipes and radiators. This could lower the lifetime of the pipes and radiators. It also makes the heat transferral from the water to the room harder when it has to pass through not only the metal but also lime deposits.

Installing meters for DHW is a measure to reduce the individual consumption of DHW. It was the most preferred measure according to the former study. It had an economical payback-time of only 0.7 years which was very favourable. It is unfortunately not possible to know if the meters have contributed to a lower hot water consumption from the results in this thesis. Some survey-respondents of House 9 have reported that the meters for hot water are broken in their apartment. This measure of personalising the billing of DHW does not improve the living comfort for the occupants. It may however save energy.

The saving of energy is however also dependent on the temperature of the water. More energy might be saved if the water does not have the very hot temperatures it is reported to have today. For the DHW consumption to be lowered it is also important that the water coming from the tap is actually hot. If it takes a long time for the water to get hot it will bring the consumer to tap a lot of water that is not used. This must be taken care of before installing meters for DHW.

Changing ventilating system

The natural ventilating system is working, although it is uncertain how well. A possible improvement of this system is to change to simple forced ventilation, to control, and not get too large an airflow in the winter (and a larger airflow in the summer). However, the ventilation is not a big concern for the occupants and they will not finance it. The energy savings made from a forced ventilation will not either benefit the occupants economically as it is today.

Preventing infiltration

The original wooden windows are often in bad shape. Many occupants have changed their windows but the staircase has for example still got the old windows left. Patty and draught excluders could be used to prevent the undesired infiltration from these windows.

However, as mentioned, the only inlet for ventilation is through open windows or infiltration. The PVC-framed windows have no vent, leading to there being a lowered air intake with PVC windows when they are closed.

According to the calculation of U-value done for this project, the changing of windows for the whole building was proven a very good energy efficiency measure. It was better than the adding of insulation and the improvement of the existing insulation. The windows are however already changed to a great extent, and the model is therefore not entirely correct. Adding insulation to House 2 would consequently in practice give rise to a greater change in the U-value for the whole building than changing the windows would. To replace the old insulation would be very hard to do. It would however be required to make an examination to know what shape it is in.

Changing of behaviour

To be able to change the energy consuming behaviour, there must be financial incentives for the occupants to use less energy. The electricity bills are individual and they also have a higher price for high consumers which clears the way for energy saving behaviour.

As it is today, there are no such incentives for the heating costs. The regulators of the heating system and the meters for domestic hot water consumption must be reliable and maintained before individual billing of the heating system can be introduced. When the occupants of House 9, with the added insulation, pay less for heating than the occupants of House 2 do, the economic incentive will be created.

Chapter 10

Conclusions

The conclusions of this degree project are divided into two parts: the needed improvements and the energy efficiency plan. The needed improvements are conclusions regarding what are the most crucial needs of the two apartment buildings. The energy efficiency plan considers the measures important to make for saving energy in the buildings and contains concrete measures. Both parts are important for the houses to be sustainable.

Main conclusions of this project are that with all measures performed, it is important that the measures are followed with information about how and why they are done. It is also important that care is taken to make sure that the proper maintenance is possible after performing the measures. For the improvements to work, there must be cooperation among the occupants, e.g. the buildings could become a part of a condominium. Also, as long as they pay heating according to the standard tariff, the occupants will not have an economic incentive for doing the energy efficiency measures suggested.

10.1 Needed improvements

The roof in House 2 is leaking and fixing it is very important. This is probably the case for all houses of this age and type which have not had the renovation House 9 got in 1995. Dwellers complain over leaking roof and a UN-report indicates bad condition of the roofs. The roofs need general renovation and some extra insulation would not harm the house.

The façades of both buildings need renovation. The paint of House 9 has fallen off in large areas, which indicate a risk that the plaster is damaged. A façade which is not cracked and broken will protect the insulation from moisture damage and minimise the infiltration through the wall.

An improvement to the ventilation in the apartments would be having windows with vents, for improvement of the air intake. With the new installed PVC-windows many apartments only have ventilation inlets through open windows. Inlets in bedroom and living-room would also improve the ventilation. Information needs to be given to the occupants about the importance of ventilation. Especially since some occupants move their kitchen and cover their ventilation outlets.

House 9 needs something done to its broken TRV's. The easiest solution is to demount them. If the radiators are kept in their present conditions this is the suggested solution. Converting the open central heating system into a closed one would help solve the problem with the TRV's. If the radiators are working in a closed system there is no fresh water bringing minerals ready to deposit in the pipes, and no oxygen in the water ready to oxidise the pipes. This can prolong the lifetime of all valves, the TRV's and other parts of the radiator system.

A stronger community in each house is important for the future state of the building. The occupants jointly own quite a lot of space but the cooperation of the maintenance is limited. As the houses get older more maintenance will be needed to be done on them. It is therefore important for the occupants that they are able to cooperate on how the buildings should be retrofitted in order that it is not dangerous to live in.

Further investigations

The authors recommend the following further work:

- Investigate energy losses.
- Investigate the condition of the mineral wool, especially in House 2.
- Investigate the state of the ventilating system. Measure flow and control if any apartment has made renovations which affect the ventilation negatively.
- Make a moisture investigation.

10.2 Energy efficiency plan for Kyrgyz buildings

Below, the suggested improvements for the two buildings are listed.

House 9 and House 2

- Adjustment of radiators. This is a relatively cheap measure but to get full effect it needs to be performed together with next measure.
- Renovation or replacement of main regulation equipment to the central heating system which is not working properly since it is supplying to hot temperatures to the heating system.
- Renovation or replacement of windows:
  - The windows in the staircases has not been replaced or retrofitted at all in the buildings. Improving them will improve the whole building.
  - The windows of the apartments are also important to improve. However this is a measure already performed by many occupants.
- Meters on the DHW would be suitable to install to minimise the use of hot water. New ones should be installed or it should be made sure the existing ones are used and work. This would work not only as an energy efficiency measurement but also as an improvement for the heating company.

House 2

For House 2, there is an additional measure proposed: adding insulation to the walls and the roof. This will probably have a long economic pay-back time, as in 1995/96. However this measure will not need maintenance and will improve the living comfort in the building. The insulation material should be one of the moisture resistant ones, see Table 4.1. When insulating the building, it is important to also retrofit the ventilating system to avoid moisture damages.

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Appendix A

Glossary and abbreviations

Air inlet/outlet	In this thesis an inlet or outlet is simply the place where the ventilation air is going in to or out from the building. If nothing else is stated it is without a fan or similar.
Boverket	The Swedish National Board of Housing, Building and planning.
CHP	Combined Heat and Power. A power plant which deliver both electricity and heat.
Conduction	Thermal conduction is energy transported inside a material due to energy exchange of atoms inside this material (no mass is moving). It could also occur between two different materials as long as they are placed close enough to each other. The thermal conductivity of a material is denoted λ and is given in W/(m·K) [85].
Convection	Also called heat transfer. When thermal energy is transferred by the movement of atoms and molecules. Energy from a hot surface is cooled by a cold and moving gas or liquid. A cold wind is a typical example. Both thermal conductivity and convective heat transfer is driven by differences in temperature but is also affected by material properties, such as density and air moisture.
Embodied energy	The energy used in the production of something.
DHW	Domestic Hot Water.
Domkom	The chairman of the House Committee. Multi-family houses in Kyrgyzstan have a house committee for common interests and the chairman is one of the dwellers in the house.

HVAC Heating, Ventilation and Air Conditioning.

Humidity by volume Water vapour content of air, measured in kg/m^3. Humidity by volume at saturation is a measure of the maximum possible water vapour content of air.

Joints The place where two things are joined, where two parts are fitted together, compare to the Swedish word *fog* or *skarv*.

Joists The timber supporting the floor or ceiling, compare to the Swedish word *regel*.

LCA Life Cycle Assessment. The study of a product or service during its whole lifetime, "from cradle to grave", and the analyse of energy and material flow connected to it.

N.a. No answer.

PVC-windows Windows with frames in Polyvinyl Chloride (a type of plastic).

Radiation Way thermal energy is transferred by. All materials emit radiation, photons. If the material is hot, like for example a fire, the radiation has energy levels of visible light. Colder materials only emit IR-radiation.

Relative humidity (RH) The quotient of Humidity by volume divided by humidity by volume at saturation, given in%.

SBS Sick Building Syndrome. Situations where building occupants experience acute health and comfort effects that appear to be linked to the building.

SEK Swedish currency, rate used here: 1 $ = 7.0 SEK.

Som Kyrgyz currency, rate used here: 1 $ = 48.8 som.

Thermal bridge A thermal bridge is a spot where the building envelope has high conductivity. It could be metal joists between the insulation boards or a poor window/door frame. In winter, when the house is covered with frost, a thermal bridge can be spotted as place where there is no frost [42].

Thermal resistance R (m^2K/W) is the inverted thermal transmittance. A high value of thermal resistance means that the material has appropriate insulating properties [85].

Thermal transmittance U ($W/(m^2K)$) is a measure of a material's insulating properties. Low thermal transmittance gives appropriate insulating properties. The thermal resistance of a wall is based on the thermal conductivity of the material in the wall and the heat transferred from the air to and from the wall [85].

UN United Nations.

USSR Soviet Union or Union of Soviet Socialist Republics.

Wooden-windows Windows with frames made of wood.

Appendix B

Survey

B.1 Letter to dwellers

— which was given along with the survey. With a translation to English.

B.2 Survey to dwellers in English

B.3 Survey to dwellers in Russian

B.4 Collection of written answers

КЫРГЫЗ РЕСПУБЛИКАСЫНЫН БИЛИМ БЕРҮҮ ЖАНА ИЛИМ МИНИСТРЛИГИ
МИНИСТЕРСТВО ОБРАЗОВАНИЯ И НАУКИ КЫРГЫЗСКОЙ РЕСПУБЛИКИ

Н.ИСАНОВ АТЫНДАГЫ
КЫРГЫЗ МАМЛЕКЕТТИК
КУРУЛУШ, ТРАНСПОРТ ЖАНА
АРХИТЕКТУРА УНИВЕРСИТЕТИ

КГУСТА

КЫРГЫЗСКИЙ ГОСУДАРСТВЕННЫЙ
УНИВЕРСИТЕТ СТРОИТЕЛЬСТВА,
ТРАНСПОРТА И АРХИТЕКТУРЫ
ИМЕНИ Н.ИСАНОВА

№ 1044/01
"26" 09 2013 г.
На № ____________

720020, Кыргызская Республика
г.Бишкек, ул. Малдыбаева 34 "б"
тел.: +996 (312) 54-35-61
факс: +996 (312) 54-51-36
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**Уважаемые жители
дома № 9 и 2 микрорайона "Асанбай"**

На кафедру "Теплогазоснабжение и вентиляция" Кыргызского государственного университета строительства, транспорта и архитектуры им. Н. Исанова прибыли для продолжения учебы студенты-магистранты из Швеции Фия Юханнесен и Стелла Бергстром. Их главная задача – изучить особенности комфортных условий в жилых многоэтажных и индивидуальных домов.

В этих целях они изъявили желания побеседовать с жителями квартир, узнать их мнения об окружающей и внутренней среде квартир (например, уровень шума, наличия запаха, свежего воздуха, об ощущениях жарко, прохладно, холодно и др.). По итогам такой беседы и опроса они совместно с местными студентами хотят подготовить некоторые советы и рекомендации нашим жителям с учетом богатого опыта проживания людей в подобных домах в Швеции.

В связи с этим мы убедительно просим Вас помочь студентам, ответив на их очень краткие, простые и интересные вопросы.

Проректор, заведующий кафедрой,
профессор — Боронбаев Э.К.

Translation of this letter:

Dear residents
of house no 9 and 2 of district "Asanbay"

The master students Fia Johannessen and Stella Bergström from Sweden have come to the department "Heat and ventilation" at Kyrgyz State University of Construction, Transport and Architecture named after N Isanova to continue their studies. Their main task is to examine mainly the comfort conditions in multi-storey residential and individual houses.

To this end, they expressed their desire to talk with the residents of apartments, about their opinions on the surrounding and internal environment of apartments (for example the level of noise, the presence of smell, fresh air, the feeling of hot, cool, cold, etc). The results of such a survey and interviews they will share with local students, they want to prepare some tips and advice to our residents with their rich experience of people living in similar houses in Sweden.

In this regard, we urge you to help the students by answering their very short, simple and interesting questions.

Vice-Rector, Head of Department, Professor E.K. Boronbaev

*Added question

¤Removed question

*This question replaces (this one is the new)

¤This question (this one is the old)

***Please answer the following questions:**
***Address and other information: Bishkek, street______, house number _______,**
***flat number ______**
***Your surname_________________ First name____________________**

1. How many people are living in your home?
-Women over 18 years old: ________
-Men over 18 years old: ________
-Children (13-17 years old): ________
-Children (0-12 years old): ________
-Total: ________

¤2.a. How large is your apartment? - m^2 __________

2. How many rooms has your home got? :________

3.a. How long time have you and your family lived in this apartment?
¤Since (year): ____

Less than 6 month	[ ]	3-5 years	[ ]
6-11 month	[ ]	6-10 years	[ ]
1-2 years	[ ]	More than 10 years	[ ]

*3.b. How long is the cat/dog alone in the apartment and misses you (on a regular week day)
*0-4 hours [ ]
*5-9 hours [ ]
*10 hours or more [ ]

¤3.b How many hours /weekday are there no one in the apartment?
¤0-4 hours [ ]
¤5-9 hours [ ]
¤10 hours or more [ ]

*3.c. Whom of you smoke? :________(regularly? _______, where:_______)

¤3.c. How many people in your home are smoking regularly? :_________

*4. Is there a fan in the bathroom? ________
How often is it on? _________

¤4. Is there a fan in the bathroom that activates when the room is used? :________

*5. What type of equipment exists in your home out of the following?
*5.a. Which of them do you use more often?
*- Cooker for food preparation:
- Electric stove [ ]
- Gas stove [ ]
- Combination stove [ ]
*- Iron [ ]
*- Dishwasher [ ]
*- Washing machine [ ]
*- Tumble dryer [ ]
*- Vacuum cleaner [ ]
*- Fireplace (electrical) [ ]
*- TV [ ]..one?________two?
*- Air conditioner [ ] one?________two?

*- Heaters that starts when the room is cold:
- Underfloor heater (electrical) [ ] area______m^2
- Underfloor heater (with water) [ ] area______m^2
- Electrical radiators [ ]
- Other heaters [ ]

*5b. floor covering:
*-Carpeting [ ]
*-Floor: Parquet [ ]
Laminate [ ]
Boards [ ]
*- Linoleum [ ]

¤5. What type of equipment exists in your home out of the following
¤- Electric stove? [ ]
¤- Gas stove? [ ]
¤- Dishwasher? [ ]
¤- Fireplace? [ ]
¤- Broadloam? [ ]
¤- Oiled wooden floors? [ ]

*6. Do you close the kitchen door (is there one?___) while cooking? ___ how often? ______

*6.b. If yes, how often do you close this door while cooking?
*- Always [ ]
*- Often [ ]
*- Sometimes [ ]
*- Never [ ]

¤6. Is it possible to close doors to the kitchen when cooking?
¤-Yes [ ]
¤-No [ ]

*7.a. Do you have a pet in your home?
*- Yes [ ]
*- No [ ]
*- Dog [ ]
*- Cat [ ]
*- Bird [ ]
*- Another pet [ ]

¤7.a. Do you have a pet in your home?
¤-Yes [ ]
¤-No [ ]
¤7.b. If yes: which pets?
¤- Dog [ ]
¤- Cat [ ]
¤- Rodent/gnawer? [ ]
¤- Bird [ ]
¤- Another pet [ ]

8. How often does the following occur in your home?

	Daily,	1-4 times, a week	1-3 times, per month	never:
- Tobacco smoking inside	[ ]	[ ]	[ ]	[ ]
- Cooking	[ ]	[ ]	[ ]	[ ]
- Baking	[ ]	[ ]	[ ]	[ ]

9.a. How often are windows open in your home?
- Daily [ ]
- Once per week [ ]
- Once per month [ ]
- Seldom or never [ ]

*b. How long are the windows open?
*- Twenty-four hours? [ ]
*- Whole day? [ ]
*- Whole night? [ ]
*- A few hours? [ ]
*- Full draught through whole apartment for a few minutes? [ ]
*- The windows are never open. [ ]

¤b. How long are the windows open?
¤- Whole day? [ ]
¤- A few hours? [ ]
¤- Full draught through whole apartment for a few minutes? [ ]
¤- The windows are never open. [ ]

10. What type of equipment do you have in the flat out of:
- Bathtub [ ]
- Shower [ ]
- Washing machine [ ]
- Dryer /tumble dryer [ ]

11. How is your laundry usually dried?
- In tumble dryer/drying cupboard [ ]
- Inside the home? [ ]
- Outside the house? [ ]

*12. Do you get condense on your windows during winter?
*- no, [ ]
*- yes, insignificantly [ ]
*- yes, on most of the window surfaces [ ]
*- don't know [ ]

¤12. In the winter: are there any condense or fog on the inside of any windows in your home?
¤- no, [ ]
¤- yes, less then 5 cm [ ]
¤- yes, 5-25 cm [ ]
¤- yes, more then 25 cm [ ]
¤- don't know [ ]

*13. Has there been any whitewashing/repainting/replacement of wallpaper in the last 12 month?
*- Yes [ ]
*- No [ ]
*- last month [ ]
*- 2-3 months ago [ ]
*- 4-12 months ago [ ]

¤13.a. Have your flat been repainted in the last 12 month?
¤- Yes [ ]
¤- No [ ]
¤13.b. If yes: when was this?
¤- last month [ ]
¤- 2-3 months ago [ ]
¤- 4-12 months ago [ ]

14. if yes: where exactly?
- The ceilings? [ ]
- The walls? [ ]
*- Window or door constructions? [ ]
¤- Details? [ ]
- Floor? [ ]
*- Furniture? [ ]
- Other? [ ]

15.a. Has a new floor been added to your home in the last 12 month?
-Yes [ ]
-No [ ]

15.b. If yes, which types of flooring material?:_____________________________

16: Has in in the last 12 months been found any of the following?	Yes	No
- Water damage/moisture damage indoors on walls, floor or ceiling	[ ]	[ ]
*- Deformation and yellowing of ceilings and outward walls (Where?___)	[ ]	[ ]
¤- Dented/gibbous plastic mats/floor, yellowing plastic mats or blackened parquet flooring.	[ ]	[ ]
*- Visible mould on walls___, floor___ or ceiling___	[ ]	[ ]
¤- Visible mould indoors on walls, floor or ceiling?	[ ]	[ ]
- Smell of mould in your home?	[ ]	[ ]
- Other smell	[ ]	[ ]

17. Has there under the last 5 years been any:	No	Yes, in bedroom	Yes, in bathroom	Yes, in other room
- visible moisture damage on floor, walls or ceiling	[ ]	[ ]	[ ]	[ ]
- visible mould on floor, walls or ceiling	[ ]	[ ]	[ ]	[ ]
- water damage/leakage on floor, walls or ceiling	[ ]	[ ]	[ ]	[ ]

18. Has your home been subject to an investigation to see if there are any moisture damage, water leakage or mould?

- Yes [ ]
- No [ ]
- Don't know [ ]

Heat and air comfort (micro climate) in the rooms?

19. Are you satisfied with the standard of your home in general?

*Fully	okey	partially	fairly	dissatisfied
¤Very satisfied	satisfied	neutral	quite unsatisfied	very unsatisfied
[ ]	[ ]	[ ]	[ ]	[ ]

20. How satisfied are you with the following aspects of your home?

	*Fully ¤Very ¤satisfied	okey satisfied	partially neutral	fairly quite unsatisfied	dissatisfied very unsatisfied
- size?	[ ]	[ ]	[ ]	[ ]	[ ]
*- modern standard	[ ]	[ ]	[ ]	[ ]	[ ]
¤- standard?					
-construction plan?	[ ]	[ ]	[ ]	[ ]	[ ]
-daylight?	[ ]	[ ]	[ ]	[ ]	[ ]
*-view/interior/faced	[ ]	[ ]	[ ]	[ ]	[ ]
¤-how it looks/how beautiful it is?					
-comfort level?	[ ]	[ ]	[ ]	[ ]	[ ]
-living area?	[ ]	[ ]	[ ]	[ ]	[ ]

The internal environment

*21. Have you in the last 3 years felt uncomfortable with the following factors in your home?
¤21. Have you in the last 3 months felt uncomfortable with the following factors in your home?

	Yes often (every week)	Yes, sometimes	No, never
- Draught	[ ]	[ ]	[ ]
- Too hot	[ ]	[ ]	[ ]
- Varying room temperature	[ ]	[ ]	[ ]
- Too cold	[ ]	[ ]	[ ]
- Stale air indoor	[ ]	[ ]	[ ]
- Dry air	[ ]	[ ]	[ ]
- Unpleasant smell	[ ]	[ ]	[ ]
*- Static electricity, when ”hitting” current	[ ]	[ ]	[ ]
¤- Static electricity that makes it easy to get a small electric shock.			
*- Guests smoking cigarette	[ ]	[ ]	[ ]
¤- Other peoples' cigarette/tobacco smoke			
- Noise	[ ]	[ ]	[ ]
- Dust	[ ]	[ ]	[ ]
- Something else? *________________	[ ]	[ ]	[ ]

Thermal environment

22. How are you experiencing the heating comfort in your home?

Very good	Good	Acceptable	Bad	Very bad
[ ]	[ ]	[ ]	[ ]	[ ]

23. Do you feel uncomfortable about that it in your apartment is:

	Yes often (every week)	Yes, sometimes	No, never
- too cold in the winter?	[ ]	[ ]	[ ]
- too hot in the winter?	[ ]	[ ]	[ ]
- too cold in the summer?	[ ]	[ ]	[ ]
- too hot in the summer?	[ ]	[ ]	[ ]
- cold floors?	[ ]	[ ]	[ ]
- drought from windows?	[ ]	[ ]	[ ]
- drought from entrance door?	[ ]	[ ]	[ ]
- varying room temperature when the temperature varies outdoors?	[ ]	[ ]	[ ]
- difficulty changing the indoor temperature?	[ ]	[ ]	[ ]

Air quality

24. How are you experiencing the air quality in your home?

Very good	Good	Acceptable	Bad	Very bad
[ ]	[ ]	[ ]	[ ]	[ ]

25. Do you feel uncomfortable with smells in your home, coming from:

	Yes often (every week)	Yes, sometimes	No, never
- your own cooking?	[ ]	[ ]	[ ]
- your neighbors cooking?	[ ]	[ ]	[ ]
- tobacco smoke or other smells from your neighbours?	[ ]	[ ]	[ ]

26. Do you in your home feel uncomfortable because you smell things like:

	Yes often (every week)	Yes, sometimes	No, never
-exhaust from traffic?	[ ]	[ ]	[ ]
-smoke from barbecue/restaurants/industries?	[ ]	[ ]	[ ]
-wood combustion?	[ ]	[ ]	[ ]

27. Do you smell anything out of the following in your apartment?

	Yes often (every week)	Yes, sometimes	No, never
- mould smell	[ ]	[ ]	[ ]
- other bad smell	[ ]	[ ]	[ ]

28. Do you have any of the following problems with the ventilation system in your home?

	Yes often (every week)	Yes, sometimes	No, never
- Problem getting rid of damp air in your bathroom?	[ ]	[ ]	[ ]
- Fog/condense on your window when cooking?	[ ]	[ ]	[ ]
- Difficulties influencing the ventilation system by yourself?	[ ]	[ ]	[ ]

Sonic environment

29. How do you generally experience the sonic environment in your home?

Very good	Good	Acceptable	Bad	Very bad
[ ]	[ ]	[ ]	[ ]	[ ]

30. How much have you in the last three month been experiencing problems with noise from:

	Not bothered at all	A little bit bothered	Partly bothered	Very bothered	Very strongly bothered	Doesn't exist
-pipes?	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
-ventilation/fans?	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
-voices, radio, TV, music or similar from neighbours	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
-scraping sounds, foot steps and similar from neighbours	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
-stair well/elevators	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

31. How much have you in the last three month been experiencing problems with noise from (outside of the building):

	Not bothered at all	A little bit bothered	Partly bothered	Very bothered	Very strongly bothered	Doesn't exist
- ventilation/fans /heating pumps	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
- Road traffic	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
- Railway traffic	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
- Airplane traffic	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

32. Does the noise from traffic bother you in one of following ways?

	Yes often (every week)	Yes, sometimes	No, never
- Problem hearing radio/TV	[ ]	[ ]	[ ]
- Telephone call is disturbed	[ ]	[ ]	[ ]
- Conversations are disturbed	[ ]	[ ]	[ ]
- Resting/napping is disturbed	[ ]	[ ]	[ ]
- Difficult to go to sleep	[ ]	[ ]	[ ]
*- Happens during the time for sleep	[ ]	[ ]	[ ]
¤- Wakes up			

Current problems

33. Have you in the last 3 months had any problems with anything of the following:

	Yes often (every week)	Yes, sometimes	No, never	*If yes, do you think it's due to your indoor environment?* Yes	No
- tiredness	[ ]	[ ]	[ ]	[ ]	[ ]
- feeling heavy headed	[ ]	[ ]	[ ]	[ ]	[ ]
- headache	[ ]	[ ]	[ ]	[ ]	[ ]
- dizziness/nausea	[ ]	[ ]	[ ]	[ ]	[ ]
- problem concentrating	[ ]	[ ]	[ ]	[ ]	[ ]
- irritated eyes	[ ]	[ ]	[ ]	[ ]	[ ]
- irritated nose	[ ]	[ ]	[ ]	[ ]	[ ]
- dry throat	[ ]	[ ]	[ ]	[ ]	[ ]
- coughing	[ ]	[ ]	[ ]	[ ]	[ ]
- dry skin in your face	[ ]	[ ]	[ ]	[ ]	[ ]
- dry scalp or ears	[ ]	[ ]	[ ]	[ ]	[ ]
- dry skin on your hands	[ ]	[ ]	[ ]	[ ]	[ ]

Energy use

34. Approximately how much energy do your household use per year for:

Heating? :__________ don't know [ ]
Hot tap water? :___________ don't know [ ]
Household electricity use? :__________ don't know [ ]
*Gas? :__________ don't know [ ]

*35.a. What type of heating system do you have?
*District heating (from CHP plant) [ ] (”*central* heating” in russian)
*Micro, ”*one neighbourhood*”, district heating (from boiler) [ ]
*The building has its own heating system (description)_____________________________________
*Don't know [ ]

¤35. What type of heating system do you have? (possible to mark more than one box)
¤The building has its own, waterborne heating system [ ] (”*central* heating” in swedish)
¤No heating [ ]
¤Apartment has its own heating, what type? [ ] ____________________________________
¤Don't know/other [ ]

*35.b. Is there a heat meter in your apartment, if yes, how much energy was consumed for heating?
*Yes [ ] ________kWh (Gcal/year)
*No [ ] ________kWh (Gcal/year)
*Don't know [ ]

*36.a. What system for hot water?
*District heating (from CHP plant) [ ] (”*central* heating” in russian)
**Micro, ”one neighbourhood”*, district heating (from boiler) [ ]
*The building has its own heating system (description)________________________________
*Don't know [ ]

¤36. What type of heating system to hot tap water do you have? (possible to mark more than one box)
¤The building has its own, waterborne heating system [ ] (”*central* heating” in swedish)
¤No heating [ ]
¤Apartment has its own heating, what type? [ ] ______________________________
¤Don't know/other [ ]

*36.b. Is there a hot water meter in your apartment, if yes, how much hot water was consumed?
*Yes [ ] ________Gcal/year
*No [ ] ________Gcal/year
*Don't know [ ]

Other
*37. Do you have suggestions and ideas, that you would like to add for your apartment?
¤37. Do you have anything you would like to add?
____
____
____
____
____
____

*Date_______

*The survey was carried out by (surname, first name?)__________; group________
*More information on this survey____
____
____
*Do add your thoughts and ideas on this survey______________________________
____

This part was meant to be to the student filling out the survey for the dweller. But the dwellers did it themselves.

Пожалуйста, ответьте на следующие вопросы:

Адрес и другие данные: г. Бишкек, Улица________, дом ___,
квартира_______
Ваша фамилия________________________Имя_________________

1. У вас проживают:
-Женщины старше 18 лет: ________
-Мужчины старше 18 лет : ________
-Дети (13-17 лет): ________
-Дети (0-12 лет): ________
____

2. Количество комнат? ________

3.a. Давно ли живете на этой квартире?

Меньше 6 месяцев	[ ]	3-5 лет	[ ]
6-11 месяцев	[ ]	6-10 лет	[ ]
1-2 года	[ ]	Больше 10 лет	[ ]

3.b. Как долго одни остаются на квартире, и скучает по Вас кошка / собака (в обычные дни недели)?
0-4 часа [ ]
5-9 часов [ ]
10 часов и больше [ ]

3.c.Кто у вас курит?_______(регулярно?________, где :______________)

4. Есть ли в ванной и в санузле вентилятор? _____
Как часто он включается? ______

5. Какие из нижеперечисленных оборудований/приборов есть у вас дома?
5 а. Какие приборы более часто используете?
- Плита для пищеприготовления:
  - электрическая плита [ ]
  - газовая плита [ ]
  - комбинированная плита [ ]
- Утюг [ ]
- Посудомоечная машина [ ]
- Стиральная машина [ ]
- Сушильная машина [ ]
- Пылесос [ ]
- Камин (электрический) [ ]
- Телевизор [ ]..один? _______два?
- Кондиционер [ ] один? _______два?

- Нагреватели, которые включаются когда в комнате холодно:
  - «Теплый пол» (электрическое) [ ] площадь _______ $м^2$
  - «Теплый пол» (водяное) [ ] площадь _______ $м^2$
  - электрические радиаторы [ ]
  - другие нагреватели [ ]

5 b. Напольное покрытие?

- Ковролин [ ]
- Пол: паркет [ ]
  ламинат [ ]
  доски [ ]
- Линолеум [ ]

6. Закрываете ли дверь (есть?____) кухни во время приготовления пищи?_____как часто?______

6b.Если да, как часто вы закрываете эту дверь во время приготовления пищи?

-Всегда [ ]
-Часто [ ]
-Иногда [ ]
-Никогда [ ]

7. У вас есть домашние животные?

- Да [ ]
- Нет [ ]
-Собака? [ ]
-Кошка? [ ]
-Птица? [ ]
-Другое животное? [ ]

8. Как часто у вас в квартире?

	Каждый день	1-4 раза в неделю	1-3 раза в месяц	никогда:
- Курение	[ ]	[ ]	[ ]	[ ]
- Приготовление пищи	[ ]	[ ]	[ ]	[ ]
- Выпечка	[ ]	[ ]	[ ]	[ ]

9. а) Как часто открываете окна/форточку в квартире (в зимнее время)?

- Ежедневно [ ]
- Один раз в неделю [ ]
- Один раз в месяц [ ]
- Редко или никогда [ ]

b) На какое время вы оставляете окна/форточку открытыми (в зимнее время)?

- Сутки [ ]
- День [ ]
- Ночь [ ]
- Несколько часов [ ]
- Несколько минут до полного проветривания [ ]
- Окна/форточка всегда закрыты [ ]

10. Что есть в вашей квартире?

- Ванна [ ]
- Душ [ ]
- Стиральная машина [ ]
- Сушильная машина [ ]

11. Как обычно сушите белье?
- В сушильной машине [ ]
- Внутри квартиры [ ]
- За пределами квартиры [ ]

12. «Потеют» ли окна зимой?
- никогда [ ]
- да, незначительно [ ]
- да, на большей части поверхности окон [ ]
- не знаю [ ]

13. В последние 12 месяцев были ли побелка/покраска/замена обоев?
-Да [ ]
-Нет [ ]
-в прошлом месяце? [ ]
-2-3 месяца назад? [ ]
-4-12 месяцев назад?[ ]

14. Если да, то именно?
-Потолок? [ ]
-Стены? [ ]
- Оконные или дверные конструкции? [ ]
-Пол? [ ]
-Мебель? [ ]
-Другое? [ ]

15a. В последние 12 месяцев заменяли напольное покрытия?
-Да [ ]
-Нет [ ]

15b. Если да, какой материал использовали? ___________________________________

16. Наблюдали ли вы нижеследующее за последние 12 месяцев?

	Да	Нет
- повреждение стен, полов и потолков от воды/влаги	[ ]	[ ]
- деформацию и желтизну потолка и наружных стен (где?_______________________)	[ ]	[ ]
- заметная плесень на стенах_______, полу_________ или потолке________	[ ]	[ ]
- запах плесени и сырости	[ ]	[ ]
- другие запахи	[ ]	[ ]

17. За последние 5 лет происходило ли нижеследующее:

	Нет	Да, в Спальне	Да, в ванной	Да, в др. комнате
- заметная сырость на стенах, пола, потолка или в углах	[ ]	[ ]	[ ]	[ ]
- заметная плесень на полу, стенах, в углах или потолке	[ ]	[ ]	[ ]	[ ]
-протекание/затопление пола, стен или потолка	[ ]	[ ]	[ ]	[ ]

18. Исследовался ли ваш дом на предмет сырости, плесени и утечки воды?
-Да [ ]
-Нет [ ]
-Не знаю [ ]

Тепловой и воздушный комфорт (микроклимат) в комнатах?

19. Вы довольны комфортом вашей квартиры в целом?

вполне	нейтрально	частично	довольны	недовольны
[ ]	[ ]	[ ]	[ ]	[ ]

20. Насколько вы удовлетворены особенностями вашей квартиры?

	Вполне	нейтрально	частично	довольны	недовольны
-размер	[ ]	[ ]	[ ]	[ ]	[ ]
-современный стандарт	[ ]	[ ]	[ ]	[ ]	[ ]
-планировка	[ ]	[ ]	[ ]	[ ]	[ ]
- естественное освещение	[ ]	[ ]	[ ]	[ ]	[ ]
-вид/интерьер/фасад	[ ]	[ ]	[ ]	[ ]	[ ]
-уровень комфорта	[ ]	[ ]	[ ]	[ ]	[ ]
-величина жилой площади	[ ]	[ ]	[ ]	[ ]	[ ]

Внутренняя среда помещений

21. За последние 3 года вы чувствовали неудобства, связанные с нижеследующими факторами относительно вашей квартиры?

	Да часто (всю неделю)	Да, иногда	Нет, никогда
-Сквозняк	[ ]	[ ]	[ ]
-Слишком жарко	[ ]	[ ]	[ ]
-Перепады температуры воздуха в комнатах	[ ]	[ ]	[ ]
- Слишком холодно	[ ]	[ ]	[ ]
- «несвежий» воздух в комнатах	[ ]	[ ]	[ ]
-сухой воздух	[ ]	[ ]	[ ]
-неприятный запах	[ ]	[ ]	[ ]
-статическое электричество, когда «бьет» током	[ ]	[ ]	[ ]
-курение сигарет гостями	[ ]	[ ]	[ ]
-шум	[ ]	[ ]	[ ]
-пыль	[ ]	[ ]	[ ]
-что-нибудь еще?________________________	[ ]	[ ]	[ ]

Температурный режим

22. Как вы думаете, каков уровень комфорта относительно температурного режима у вас в квартире?

Отличный	Нормальный	Удовлетворительный	Неудовлетворительный	Плохой
[ ]	[ ]	[ ]	[ ]	[ ]

23. Чувствуете ли вы себя некомфортно в квартире из-за:

	Да часто (каждую неделю)	Да, иногда	Нет, никогда
- Слишком холодно зимой	[ ]	[ ]	[ ]
- Слишком жарко зимой	[ ]	[ ]	[ ]
- Слишком прохладно летом	[ ]	[ ]	[ ]
- Слишком жарко летом	[ ]	[ ]	[ ]
- Холодные полы	[ ]	[ ]	[ ]
- Сквозняк через окна	[ ]	[ ]	[ ]
- Сквозняк через входную дверь	[ ]	[ ]	[ ]
- Изменение комнатной температуры внутреннего воздуха, из-за изменения температуры наружного воздуха	[ ]	[ ]	[ ]
- Трудно регулировать температуру внутреннего воздуха	[ ]	[ ]	[ ]

24. Как вы оцениваете качество воздуха в вашей квартире, по вашему мнению?

Отличный	Нормальный	Удовлетворительный	Неудовлетворительный	Плохой
[ ]	[ ]	[ ]	[ ]	[ ]

25. Чувствуете ли вы себя некомфортно в квартире из-за запаха: …

	Да часто (каждую неделю)	Да, иногда	Нет, никогда
- когда вы готовите пищу?	[ ]	[ ]	[ ]
- когда соседи готовят пищу?	[ ]	[ ]	[ ]
- запах сигарет или другие запахи от соседей?	[ ]	[ ]	[ ]

26. Чувствуете ли вы нижеперечисленные запахи?

	Да часто (каждую неделю)	Да, иногда	Нет, никогда
-выхлопные газы транспорта?	[ ]	[ ]	[ ]
-запахи от шашлыка/кафе/промышленности?	[ ]	[ ]	[ ]
-сжигание различного топлива?	[ ]	[ ]	[ ]

27. Чувствуете ли вы какие-либо из нижеперечисленных запахов в квартире?

	Да часто (каждую неделю)	Да, иногда	Нет, никогда
- запах плесени	[ ]	[ ]	[ ]
- другие неприятные запахи	[ ]	[ ]	[ ]

28. Есть ли у вас нижеперечисленные проблемы с вентиляционной системой?

	Да часто (каждую неделю)	Да, иногда	Нет, никогда
- Проблемы с влажным воздухом в ванной?	[ ]	[ ]	[ ]
- Запотевание окон, когда готовите пищу?	[ ]	[ ]	[ ]
- Трудно регулировать систему вентиляции?	[ ]	[ ]	[ ]

<u>Звуковой фон</u>

29. Как вы обычно оцениваете звуковой фон вашей квартире?

Отлично	Нормально	Удовлетворительно	Неудовлетворительно	Плохо
[ ]	[ ]	[ ]	[ ]	[ ]

30. Как сильно беспокоил вас за последние три месяца шум от:

	Не беспокоил совсем	Беспокоил чуть-чуть	Беспокоил часто	Беспокоил много	Беспокоил очень сильно	Не было
- трубопроводы	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
-вентиляция/вытяжная система	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
-голоса, радио, телевизор, музыка или схожие звуки от соседей	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
-скрежет, шум при ходьбе и похожие звуки от соседей	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
-лестничная площадка/лифт	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

31. Как сильно беспокоил вас шум от нижеперечисленных источников за последние три месяца (снаружи здания):

	Не беспокоил совсем	Беспокоил чуть-чуть	Беспокоил часто	Беспокоил много	Беспокоил очень сильно	Не было
- Вентиляционная система/ Вытяжки/тепловые насосы	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
- Шум транспорта	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
- Шум железной дороги	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
- Шум воздушного транспорта	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

32. Беспокоит ли вас шум транспорта следующим образом?

	Да часто (каждую неделю)	Да, иногда	Нет, никогда
- Проблемно слушать радио/ТВ	[ ]	[ ]	[ ]
- Мешает разговаривать по телефону	[ ]	[ ]	[ ]
- Мешает разговаривать	[ ]	[ ]	[ ]
- Мешает отдыху/сну	[ ]	[ ]	[ ]
- Трудно уснуть	[ ]	[ ]	[ ]
- Будит во время сна	[ ]	[ ]	[ ]

33. Существующие Проблемы на данный момент

15. Были ли у вас за последние три месяца проблемы из-за:

	Да часто (каждую неделю)	Да, иногда	Нет, никогда	Если да, это из-за внутренней среды? Да	Нет
- Усталость	[ ]	[ ]	[ ]	[ ]	[ ]
- Тяжелая голова	[ ]	[ ]	[ ]	[ ]	[ ]
- Головная боль	[ ]	[ ]	[ ]	[ ]	[ ]
- Головокружение/тошнота	[ ]	[ ]	[ ]	[ ]	[ ]
- Проблемы с концентрацией внимания	[ ]	[ ]	[ ]	[ ]	[ ]
- Раздражение глаз	[ ]	[ ]	[ ]	[ ]	[ ]
- Раздраженный нос	[ ]	[ ]	[ ]	[ ]	[ ]
- Сухость в горле	[ ]	[ ]	[ ]	[ ]	[ ]
- Кашель	[ ]	[ ]	[ ]	[ ]	[ ]
- Сухость кожи лица	[ ]	[ ]	[ ]	[ ]	[ ]
- Сухость кожи головы или ушей	[ ]	[ ]	[ ]	[ ]	[ ]
- Сухость кожи рук	[ ]	[ ]	[ ]	[ ]	[ ]

Использование энергии

34. Примерно какое количество энергии вы потребляете в год на:

Отопление? :_________	не знаю	[ ]
Горячая вода? :__________	не знаю	[ ]
Электроэнергия на бытовые нужды? :_______	не знаю	[ ]
Природный газ? __________	не знаю	[ ]

35а. Какой вид системы теплоснабжения?

Централизованное теплоснабжение	[ ]
Районное теплоснабжение (от котельной)	[ ]
Автономное теплоснабжение (описание)?	____
Не знаю	[ ]

35b. Есть ли в вашей квартире тепломер, если да то какое количество энергии потребляется на отопление?

Да [ ] ________________кВт ч (Гкал/год)

Нет [ ] ________________ кВт ч (Гкал/год)______________

Не знаю [ ]

36 а. Какая система горячего водоснабжения?

Централизованное горячее водоснабжение (от ТЭЦ) [ ]

Районное горячее водоснабжение (от котельной)

Горячее водоснабжение отсутствует [ ]

Автономное горячее водоснабжение (описание)?_____________________________

Не знаю [ ]

36.b Есть ли в вашей квартире счетчик на горячее водоснабжение, если да то какое количество горячей воды потребляется?

Да [ ] _______________Гкал/год

Нет [ ] _______________Гкал/год

Не знаю [ ]

Дополнительно

37 Есть ли у вас соображения и идеи, которые вы хотите добавить по вашей квартире?

____

____

____

Дата____________

Опрос произведен (фамилия, имя?)_________________________; группа__________

Дополнительные сведения по данному опросу____________________________________

____

____

Имеете ли добавить свои соображения и идеи по данному опросу____________________

____

____

B.4 Collection of written answers

The last question in the survey is "Do you have suggestions and ideas, that you would like to add for your apartment?". Here respondents could write whatever they liked. These are the written answers from House 2:

> *"Thermal insulation"*
>
> *"It is necessary to supply cycling of hot water during summer time."*
>
> *"I have lived here for 4 months. If this flat were mine I would realise some ideas. But I don't have any rights and wish neither."*
>
> *"Heating is a problem"*
>
> *"Administrative service is very bad. We pay money for air. "*
>
> *"I think if there is a good renovations are made in the flat no cold weather will obstacle living in multistoried buildings."*
>
> *"Improve maintenance of heating pipes (including cleaning of pipes in inside)"*
>
> *"Insulate and put a controller"*

From House 9:

> *"I wish to join balcony to living room in south part with the exit to outside. I wish there was summerhouse in the yard and in the garden in south part of the house and grow some flowers, grass, flowerbeds etc. It would be nice to repair the outside walls coating and give for rent the west-north wall."*
>
> *"Insulate balconies and change radiators if necessary"*
>
> *"Old pipes, need to change them"*

Some respondents also wrote answers to the questions: "More information on this survey" and "Do add your thoughts and ideas on this survey". These questions were not supposed to be answered by the occupants but by students at KSUCTA. The answers are listed here.
From House 2:

> *"Who needs it? It is becoming worse and worse every year. No changes."*
>
> *"When construct the building it is necessary to insulate the building, change the planning of the building, put fans in kitchen, toilet, living room, make rooms larger to place there convenient furniture."*

From House 9:

> *"Often problems with hot tap water. When switch on the hot tap water cold water comes first, and then after 15 minutes hot water comes. Can you solve this problem?"*

Some respondents have written comments on other questions in the survey. The questions (Q) and comments (C) are listed below.

From House 2:

Q:10 What type of equipment do you have in the flat out of:
- Bathtub [ ]
- Shower [ ]
- Washing machine [ ]
- Dryer /tumble dryer [ ]
C: *"Strange question, and answers (alternatives) are strange as well."*

Q:13 Has there been any whitewashing/repainting/replacement of wallpaper in the last 12 month?
C: *"Why do you want to know it?"*

Q:21 Have you in the last 3 years felt uncomfortable with the following factors in your home?
...
- Unpleasant smell
...
C: *"Bad odour from neighbours flat No"* [flat no. cencured by authers]

Q:21 Have you in the last 3 years felt uncomfortable with the following factors in your home?
...
- Something else?
C: *"Ceiling/roof is leaking"*

Q:34 Approximatly how much energy do your household use per year for
C: *"Inappropiate, impolite question"*

From House 9:

Q:16 Has in in the last 12 month been found any of the following?
- Water damage/moisture damage indoors on walls, floor or ceiling
C: *"Flooding from the neighbours above their flat"*

Q:17 Has there under the last 5 years been any:
...
- water damage/leakage on floor, walls or ceiling
C: *"There was a damage of tap woater pipe on the 5th floor. It was repaired by Gorvodocanal"* [The organisation supplying cold tap water in Bishkek, authours comment]

Q:35b Is there a heat meter in your apartment, if yes, how much energy was consumed for heating?
C: *"Used to be heat meter. It is broken"*

Q:31 How much have you in the last three month been experiencing problems with noise from (outside of the building)?
C: *"Music noise coming from restaurants"*

Appendix C

Measuring scheme

C.1 Measuring plan: Apartment

C.2 Measuring plan: Staircase

Measurement plan - Apartment nr:_______________

IR thermometer

Walls facing outside (where?):____

	Temperature			Outer/inner?
	Min	Max	Average	
Window glass,1				-
Window glass, 2				-
Window frame, 3	-	-		-
Window frame, 4	-	-		-
Window frame, 5	-	-		-
Window frame, 6	-	-		-
Window frame, 7				-
Left lower corner				
Right lower corner				
Middle				-
Roof				-
Left wall				
Right wall				

Inner wall (where?):____

	Temperature			Outer/inner?
	Min	Max	Average	
Left lower corner				
Right lower corner				
Middle				-
Roof				-
Left wall				
Right wall				

Entrance door

	Temperature		
	Min	Max	Average
From inside,1			
2			
3			
4			
5			
6			
7			
8			
From outside, 1			
2			
3			
4			
5			
6			
7			
8			

Temperatures and humidity

Room	**Temperature**	**Humidity**
Kitchen		
Bathroom		
Toilet		
Hallway		
Room 1		
Room 2		
Room 3		
Room 4		

Balcony

	IR-Temperature			Balc. Temp. + humidity	Where
	Min	Max	Average		
1. Under window					
1. Wall facing inside f. balcony					
1. Wall facing balcony f. room					
2. Under window					
2. Wall facing inside f. balcony					
2. Wall facing balcony f. room					

-Door? Yes [] No []

-Used as room? Yes [ ] No [ ]

-Insulated? Yes [ ] No [ ]

-Radiator? Yes [ ] No [ ]

-Comments on how it has been renovated:

Ventilation

	Inlet	Inlet	Outlet	Outlet	Outlet	Other place
Where						
Comment						

Measurement plan: Staircase

House nr:

	0-door		**1**	**3 + 3,5**	**6,5+7**	**9**
IR: Door 1		**IR: Window glass, 1**				
Door 2		Window glass, 2				
Door 3		Window frame, 3				
Door 4		Window frame, 4				
Door 5		Window frame, 5				
Door 6		Window frame, 6				
Door 7		Window frame, 7				
Door 8		Wall f. apartments				
Left lower corner		Left lower corner				
Right lower corner		Right lower corner				
Middle		Middle				
Roof		Roof				
Left wall		Left wall				
Right wall		Right wall				
Temp.		**Temp.**				
Ventilation		**Ventilation**				
Humidity		**Humidity**				

U-value

ID	Outside air	Outside surface	Inside surface	Inside air	U-value

Appendix D

Model values

Table D.1: Data used in the computer model for calculating U-value with Isover Energi 3.

Walls

Sandwich with new mineral wool	**mm**	**W/m²K**
Plaster*	10	1
Concrete	70	1,7
Mineral wool	100	0,036
Concrete	70	1,7
Rough plaster	10	0
Sum	260	0,329

Sandwich with old mineral wool		
Plaster*	10	1
Concrete	70	1,7
Old mineral wool	100	0,1
Concrete	70	1,7
Rough plaster	10	0
Sum	260	0,792

Sandwich with extra insulation, new mineral wool		
Plaster*	10	1
Concrete	70	1,7
Mineral wool	100	0,036
Concrete	70	1,7
Rough plaster	10	0
Polystyren, expanded	50	0,04
Plaster	40	1
Sum	350	0,231

* Also including wall finishing like wallpaper etc.

Sandwich with extra insulation, old mineral wool	**mm**	**W/m²K**
Plaster*	10	1
Concrete	70	1,7
Old mineral wool	100	0,1
Concrete	70	1,7
Rough plaster	10	0
Polystyren, expanded	50	0,04
Plaster	40	1
Sum	350	0,392

Roof

Standard 105 roof		
Hollow core slab	220	1
Screed	40	1
Expanded clay	100	0,15
Screed	40	1
Sum	400	0,904

Roof with polystyren insulation		
Hollow core slab	220	1
Polystyren, expanded	50	0,04
Screed	50	1
Sum	320	0,602

Foundation

Ground floor		
Floor finish	12	0,18
Hollow core slab	220	1
Sum	232	2,19

Foundation walls		
concrete	200	1,7

Ground in foundation		
Nothing		

* Also including wall finishing like wallpaper etc.