POTENTIALS FOR HEATING ENERGY SAVINGS BY APPLYING STANDARD AND ADVANCED REFURBISHMENT MEASURES ON THERMAL ENVELOPE OF THE RESIDENTIAL BUILDING STOCK IN PRISHTINA

Petrit Ahmeti

A research project submitted to the Department of Breuer Marcell Doctoral School of Architecture in partial fulfillment of the requirements for the award of the degree of PhD in Architectural Engineering program of UNIVERSITY OF PÉCS - Pollack Mihaly Faculty of Engineering and Information Technology

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Declaration

This thesis is my original work and has not been presented for a degree in any other University

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Signature *Date*

This thesis has been submitted for examination with my approval as University Supervisor

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Signature *Date*

Acknowledgement

Firstly I would like to express my gratitude to my supervisor Prof. Dr. István Kistelegdi for his support during the whole process of my Ph.D. study.

I am grateful to the members of my Dissertation Committee who provided me valuable recommendations and guidance. I am grateful to all of those with whom I have had the pleasure to work during all phases of my research work related to my Ph.D. study, in Kosovo and abroad.

Special thanks go to my family including my father, mother, brothers and particularly my wife Blerta and two sons Rron and Uliks, to whom I have not been close during my four years of research and study and to whom I dedicate this dissertation.

"*You cannot get through a single day without having an impact on the world around you. What you do makes a difference, and you have to decide what kind of difference you want to make.*" — Jane Goodall

C.

Abstract

Prishtina as the capital city of Kosovo is a city that has been continuously developed during different phases and stages and which is still persistent. This development without any exception influenced the development of building in general and housing quality as a result of evolving building methodologies and standards. Standards of building quality during different phases represented different approaches and priorities in terms of living comfort. The living comfort represented various components depending on the economic and social wealth of the society. Nowadays the living comfort is inevitably connected to the energy in general and heating energy in particular.

The purpose of the research is to analyze and structure the building typology of the residential building stock (RBS), identify specific structural deficiencies and propose an approach for improvement of methodology of renovation and refurbishment in residential sector in city of Prishtina, based on their specificities and characteristics to achieve better results in decreasing the energy demand for heating. A more detailed structuring of building stock will lead to more efficient solutions to achieve energy efficiency in existing residential buildings but also would offer potential guidelines for upcoming investments for decrement of energy consumption in Kosovo in general.

Creation of a database which will contain sufficient technical data for the building stock in city of Prishtina, based on field research and measurements and recommendations based on conclusions for specific solutions of different building typologies may be considered as an essential platform for Kosovo's legislation and community of designers and builders.

Key words: residential building stock, heating energy, building refurbishment, energy efficiency

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List of abbreviations:

AB – Apartment Blocks

IEE - Intelligent Energy Europe

KAS – Kosovo Agency of Statistics

MESP - Ministry of Environment and Spatial Planning

MFH – Multi Family Houses

NZEB - Nearly zero energy buildings

ReEx – Real Example Building"

RBS – Residential building stock

SFH – Single Family Houses

TH – Terraced Houses

TRTSTPB - Technical Regulation on Thermal Saving and Thermal Protection in Buildings

WWR – Window to wall Ratio

CHAPTER ONE

1. INTRODUCTION - BACKGROUND OF THE STUDY

1.1 Introduction

The growth of the energy demand in general has become a global concern, especially in countries in transition as Balkan's region countries. According to Heating Strategy of Kosovo 2009-2018 the annual net consumption of energy for space heating and domestic hot water in the period 2012-2018 will increase in yearly average of ca. 3% (Ministry Of Energy And Mining, Energy strategy of the republic of Kosovo 2009 – 2018, 2009, p.15). Except the growth of the energy demand in general, also the production of the energy and the resources used for the energy production which have a negative impact on the environment are becoming serious concern in case of Republic of Kosovo.

Production of the electrical energy in Republic of Kosovo is mostly based on fossil fuel, more precisely on coal (lignite) burning, which is a local natural resource. It covers about 95% (915 MW in 2012) of the overall energy production in Kosovo (Kosovo Transmission, System and Market Operator, Generation adequacy plan, 2016, p 14). Besides the fact that it is one of the most non-efficient processes of energy production, coal burning causes pernicious effects on the environment and surrounding. Also according to calculations (in global scale), the coal and petroleum stocks are running out and they can assure the energy necessity of the world till around 60–80 years (Tóth N., Szemes P. T., 2013).

The residential sector occupies first place in the consumption of energy resources in Kosovo, accounting for 32.85%. Since 2000, the energy supply and demand for space heating, cooking and domestic hot water (using mostly fuel woods) have remained more or less in balance (Ministry of Energy and Mining, 2011, p. 13).

Prishtina as a capital of Republic of Kosovo, represent the largest city in terms of economy, development, population growth and also residential building stock.. As a result of migration this influenced development of construction industry and especially in residential sector. According to informal analysis and information obtained by several sources, the Kosova capital, consists of 400- 500 inhabitants or 1/5 of the whole population of Kosovo live (Ministry of Environment and Spatial Planning, 2010,p. 125).

As a consequence of various problems accumulated, the urban sprawl phenomenon was inevitable. The city not only expanded, but its urban areas actually exceeded city borders and spread to cadastral parcels of neighboring cities (Mejzini I. 2015)

Uncontrolled development of construction industry, particularly in residential sector as a result of absence of legislation, field monitoring, uncontrolled materials and, degraded the overall quality of new constructed buildings and renovations of existing buildings, in terms of energy conservation, building sustainability and energy efficiency. In addition, application of different methodologies for calculations such as building codes and standards, generated divers results in building industry.

On the other side, the European Parliament from 2021 will have nearly zero-energy building (NZEB, Net Zero Energy Building) (European Commission, Energy Roadmap 2050, 2011) as a consequence of the increasingly high building energy requirements as a result of which the construction industry and the building environment are undergoing a general change. In the current domestic and international professional and scientific circles the significant inaccuracies are evident between theoretical building energy calculations compared to the measured energy consumption results of existing buildings.

Based on the abovementioned and other numerous components regarding the energy production, resources and energy demand, it is inevitable and urgent to seek for alternative solutions for reduction of the current energy consumption. To reduce the current energy consumption, it is vital to identify the present energy consumption by the residential sector. The process of present energy consumption identification would also be an inducement beside the initiative of ‘Codes for Sustainability Assessment of Construction’ appliance (Nushi V. 2011].

This study analyses and elaborates the residential sector buildings stock and the heating energy demand based on the current situation of the physical condition and local heating energy resources. Based on the findings of this study it will be possible to hypothesize the current heating energy consumption by different resources in city Prishtina based on which it will be possible to initiate practical scenarios of building renovations refurbishments towards decrement of heating energy loss as one of the crucial factors on energy savings and efficiency in buildings.

Even though numerous studies which dealt with the current situation of residential building stock in city of Prishtina and Kosovo in general, never offered a practical approach which would improve the quality of life by increasing the living commodity within dwellings on one hand and reducing the heat loss of residential buildings as the largest energy consumer on the other hand.

1.2 The Initial Interest and the Aim of the Study

The idea of conducting this study resulted from previous and current researches and engagements in pertinent professional bodies, daily work with construction industry during which technical obstacles were always present. First step towards this topic started with my master's thesis "Translation and adaptation of the Passive House Planning Package in Albanian language", through which I tended to initiate the using of specific calculating tools in construction industry in Kosovo, which would lead to an enhancement of professional and scientific level compatible to EU standards. Being aware that the domain of building sustainability and energy efficiency in architecture consists of multiple and diverse components, I was pushed to continue with crystallizing my ideas for further engagement on this topic.

My previous engagements on field researches, publications, result presentations, leaded me to identify greater deficiencies in construction industry and especially residential building sector, which was in most cases ignored and left aside. This fact leaded me to decisiveness to focus and be engaged to a greater challenge and generation of valuable results. Considering the research as a challengeable task but with valuable outcomes, the idea was presented to the competent professionals with great academic background within University of Pécs, which was supported and guide lined for further clarification of the research focus and outcome. According to the recommendations given which were mostly based on high professional experiences and practices, I was able to give the preliminary structure of my study and dissertation.

1.3 Statement of the problem and research questions

Investments towards existing buildings renovations in Republic of Kosovo in general and city of Prishtina i particular is an unenviable need to increase the living and working commodity and decrease the current high energy consumption as a result of heat loss and non-efficient way of energy use. Based on current official data it is obvious that the majority of buildings in city of Prishtina consist of residential buildings which makes the largest building stock and the largest energy consumer. In this case the uncontrolled and informal construction of residential buildings after 1999 contributed in the current sorely situation of residential sector. According to Urban Development Plan Prishtina 2012-2020, it is obvious that the largest area of the land in city of Prishtina consists of residential buildings. Built area of city of Prishtina is 2365.6 ha or 30,45% of the overall land (Urban Development Plan Prishtina 2012-2020, September 2013p 70), where:

1. Residential zone consists of 2011.58 ha and it is characterized with dominance of individual residential buildings. Around 23.17% is individual low rise buildings (1800 ha) and 2.72 % multifamily and high-rise buildings (211.58 ha) parlty with commercial use.
2. Economic zone – with area of 217.94 ha, or 2.81% of the built land.
3. Educational institutions - with area of 34.7 ha or 0.45% of the built land.
4. Healthcare institutions - with area of 33.9 ha or 0.44% of the built land.
5. Administration with area of 50.08 ha or 0.64% of the built land.
6. Buildings of worship - with area of 7.13 ha or 0.10% of the built land
7. Greenery - with area of 5023.05 ha or 64.06% of the built land.
8. Specific area - 149.11 ha or 1.92 % of the built land.
9. Transport - with area of 231 ha or 2.97 % of the built land.

The housing state currently is not good and this is indicated by the responses that have been taken regarding it this issue during a specific survey as an integral part of Prishtina's urban development plan. About 40% of cases indicate that the housing situation is poor or unfavorable. As for the living conditions, 77% of homes have habitable conditions, while 23% of homes have no housing conditions. Also about 77% of houses were built after the 1970s, while the rest before the 1970s meant that the age of residential buildings is also the element that affects the living conditions (Urban Development Plan Prishtina 2012-2020, September 2013, p. 75). Considering the fact that residential sector is one of the main sectors in terms of land use and energy consumption but also as a largest potential for improvement of the current situation by decrement of uncontrolled energy use as a result of heating loss by intervening in building stock, it is of public and national interest to initiate a master plan of concrete measures.

Currently there are deficiencies of fundamental data and studies to identify the current state of the RBS and also intervention plans towards improvements. This leads to some fundamental questions which derived to the main research questions of this study:

1. What is the current state of physical components of the residential building stock in city of Prishtina?
2. How could all technical data of the current state of RSB stock based on the building typology and construction period be structured in a unified database?
3. How could the identification of the current general state help on a proposition of a large scale building renovations on achieving the decrement of heat energy loss by the residential buildings?
4. Which are the potential improvement intervention possibilities to achieve optimal and advanced solutions towards heating energy savings?

1.4 Aim of the Study

The main aim of this study is to conduct an evaluation of the current state of the residential building stock in city of Prishtina, create a matrix based database of building stock and offer practical solutions for each and specific type of building towards energy efficiency which would meet the current and future energy efficiency standards in Kosovo.

1.5 Objectives of the study

The general objective of this study is the improvement of the current state of the residential building stock in city of Prishtina, in terms of energy efficiency on one hand and the living commodity on the other hand. This will be conducted and elaborated based on findings which will be provided by the statistical data from official sources and finding from field data gathered.

1. Structuring of the residential building typology and designing of the matrix based database using official statistical data.
2. Analysis of current state of the residential building stock based on building typology referent building.
3. Designing of two scenarios for building renovation and refurbishment, which would meet optimal and advanced energy efficiency standards in Kosovo, based on current state of the residential building stock findings
4. Conclude and propose recommendations based on results and findings.

1.6 Justification

Currently the region of ex-Yugoslav republics the residential building stock is being also a burden in terms of energy consumption for space heating which is being treated for several years now by offering practical solutions. This has become a concern but also an obligation for achieving minimum standards of the EU for building quality and energy consumption for residential buildings as one of the preconditions to become an EU member state.

The outcome of this study and its results will contribute with a valuable support on establishing a platform for future developments of accurate and scientific approach on increment building quality of residential sector and decrement of heating energy loss.

Therefore this study will endeavor to facilitate two interconnected topics:

1. Structuring of the building typology of the residential sector in city of Prishtina. Absence of documented professional structuring of building typology with main relevant construction data and construction year is a considerable gap which caused preclusion for practical steps on genuine scientific processes that could create strategies for development and improvement of building quality and living comfort in residential sector. Official and documented structuring of building typology and structuring of specific typology on their construction periods would create bases for a more detailed analysis of building stock on identifying specific components by generating accurate and practical solutions.

2. Creation of matrix with referent buildings containing detailed relevant construction components of building stock based on the building typology and period of construction.
3. Generate scenarios with practical application of building refurbishments and renovation for achieving measurable energy savings used for heating, based on building stock data base which would be a derivate of building typology structuring and matrix of referent building with all relevant construction specifics using specific methodology of calculations.

1.7 Scope of the study

The scope of this study is focused only in residential buildings within city of Prishtina. All the results which will be generated by the analysis within this study may be used as valuable data for proper and correct renovation measure of residential building stock in city of Prishtina, based on their current state and needs to achieve desirable energy efficiency standards. The same data may be used for new design buildings in future as preclusion for further interventions toward energy efficiency standards and living commodity.

As a pilot project in city of Prishtina, this can be used as an approach for other cities in Kosovo of the overall residential building stock of Kosovo.

1.8 Summary

This study aims to identify the current state of residential building stock in terms of their physical components that affect directly the heating energy loss and living commodity within dwellings based on which tends to offer solutions towards improvement of building state by concrete recommendations. To achieve this point the study aims to structure all the data into a database matrix by documenting the current state of the residential building stock and create a database which would be a great contribution to engineers and architects community, private building sector, inhabitants of city of Prishtina and especially official institutions to whom all the data will be of great support to amend current building legislative documentations and draft future binding regulations regarding buildings and energy consumption in residential sector.

CHAPTER TWO

2. THE CONTEXT OF THE STUDY

2.1 Introduction

The aim of this chapter is to provide additional information about the field of the study and the geographical coverage. This chapter first provides a comprehensive description of the field of the study in City of Prishtina and secondly, it presents the current residential building stock in city of Prishtina. Most of the information for this chapter use data from different official sources.

2.2 General information on the study area

The study focus in geographical terms covers the area of city of Prishtina. This part of the thesis provides all relevant data and information on demographic, urban development, residential sector development, heating energy source and administrative division of the city. These data and information will subserve on highlighting the understanding of the current situation of residential building sector and the challenges with regard on energy efficiency.

2.2.1 Size, location and climate of city of Prishtina

Prishtina is the capital city of Republic of Kosovo. The city of Prishtina has a central position in Kosovo, accommodating government institutions, administration and research and development institutions (Ministry of Environment and Spatial Planning, 2010, p. 139).

The city of Prshtina is located on the northeastern part of Kosovo and it extents in latitude 42°40’00” and longitude 21°20’15”. It covers an area of 7768 ha (Fig. 2.1). The city has an altitude between 535-730m and it is known for hilly terrain mostly surrounded with slope terrain in a theatric form (Urban Development Plan Prishtina 2012-2020, September 2013, p. 27).

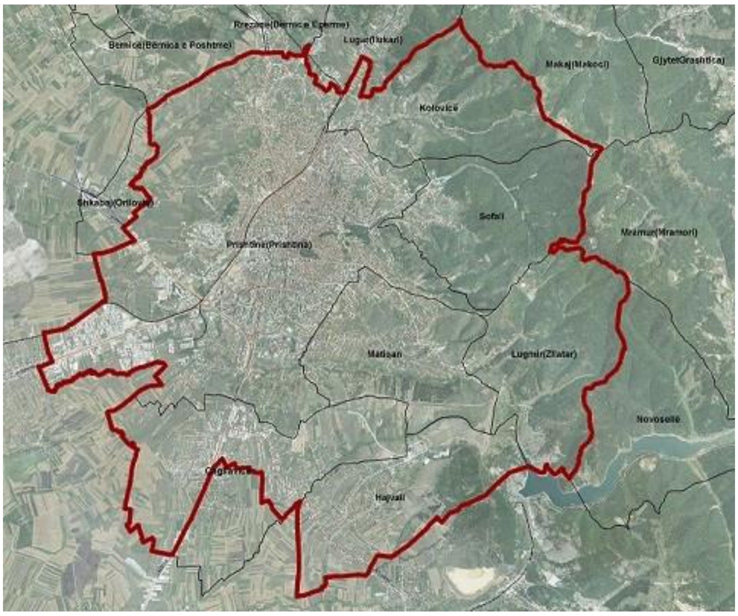
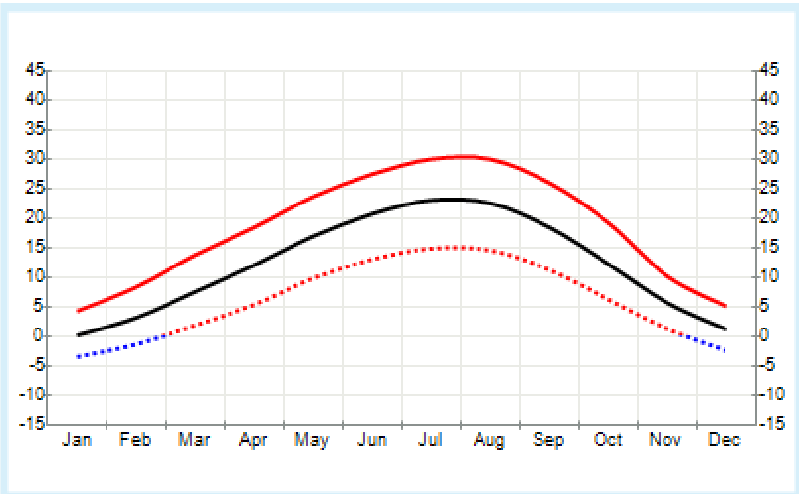


Figure 2 1 Urban boundaries of Prishtina

Source; https://kk.rks-gov.net/prishtine/wp-content/uploads/sites/45/2018/02/PZHU-_Prishtina.pdf
Accessed; 07.08.2018

Prishtina belongs to a region of Kosovo with continental climate which is characterized with hot summers and cold winters with an annual average temperature of 10,4°C and 600 mm of average annual precipitation. Temperature range from 30°C during July to – 0,6°C during January (graph 2.1) (9* https://sq.wikipedia.org/wiki/Prishtina).



Graphic 2. 1 Temperature range of city of Prishtina during a year, source: https://www.yr.no/place/Kosovo/Prishtina/Pristina/statistics.html, Accessed on: 22.08.2018

2.3 History and development of residential sector

Development of Residential sector in city of Prishtina has been closely linked with the political and economic developments. The analysis of social change during prewar periods (Table 2.1) shows that development starts shortly after Second World War in 1946, when Prishtina became the capital of the Socialist Autonomous Region of Kosova (F. Bejtullahu, 2015, p. 8)

Table 2. 1 PrishtinSocial changes during prewar periods, source: http://pea.lib.pte.hu/bitstream/handle/pea/14084/Demand%20for%20housing%20quality%20and%20urban%20livability%2C%20potential%20for%20establishing%20a%20new%20identity%20of%20Prishtina.pdf?sequence=1, Accessed: 14.08.2018

	Periods	Plans	Year	Population	Politics	Economy
	I until 1940	Prishtina Regulative Plan	1937	16,000 inhabitants	World war II	Shift away from Agriculture
	II 1940-1950	Second Regulative Plan	1948	16,587 inhabitants	Centralized	Start of industrialized economy
	III 1950-1960	General Urban Plan	1953	50,000 inhabitants	Mono party	Semi industrialized economy

	IV 1960-1980	Directive Plan of traffic and land-use of the town	1967	10,000 inhabitants	Social legislation	Agriculture and industry
	V 1980-1999	General Plan of Prishtina	1988	250,000 inhabitants	Political Activism	Tendency to open free market economy

Political and economic developments also changed the social structure by influencing the philosophy of residential development especially during 60's when Multi-family houses (MFH) started to be a new way of habitation as a more sociable way of living in comparison with Single family houses (SFH) which were the only popular way of dwelling. 70's and early 80's is the period that influenced further more social changes and initiated a progress towards larger urban areas that consisted of high rise Apartment blocks (AB), which also initiated an urban sprawl till nowadays (Figure 2.2).

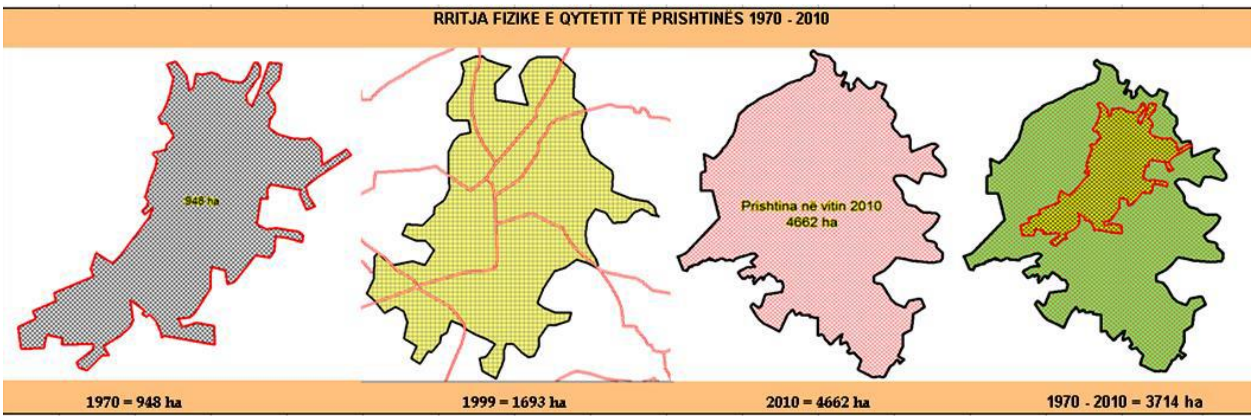


Figure 2 2 Expansion of city of Prishtina from 1970 to 2010 Physical growth of city of Prishtina 1970-2010 source: https://www.researchgate.net/publication/303838862_SOCIO-URBAN_DEVELOPMENTS_IN_KOSOVO_STUDY_CASE_PRISHTINA Accessed: 14.08.2018

Different and specific phases of political, economic and social developments initiated different approaches to the building typology, functionality and construction, by creating specific building typology that corresponds with respective epoch.

An analysis of urban areas in seven largest centers of Kosova, it is clearly seen that the largest developments in space were those of housing facilities. The average urban growth for the last 20 years (1980-1999) or the area of each center has grown for 2.7 times. An estimate may be given only for the Prishtina Municipality: in 1980 Prishtina used to have 450 ha coverage, and after 20 years, it has grown into 1500 ha or at least 1000 hectares more (Fig. 3.2) (Ministry of Environment and Spatial Planning, 2010, p. 31]

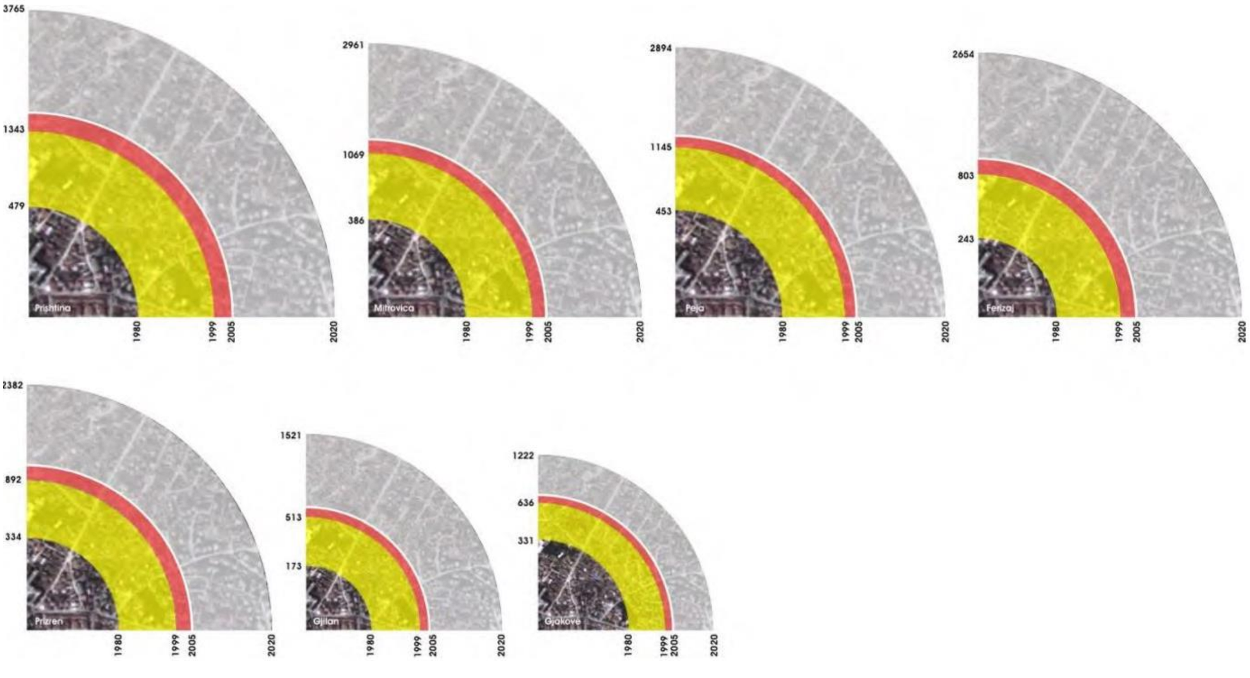


Figure 2 3 Urban growth in seven major centers of Kosovo - the 1980 - 1999 and forecasts growth through 2020. Source: http://www.kryeministri-ks.net/repository/docs/Spatial_Plan_of_Kosova_2010-2020.pdf, Accessed: 22.08.2018

Since 1999, informal housing settlements had sprung up on agricultural land on the city's fringes, sometimes connecting illegally to water and electricity (Kosovar Stability Initiative/European Stability Initiative, 2006, p. 3)., by creating uncontrolled zones in terms of energy use.

2.4 Building typology characteristics

Residential sector comprises the largest number of buildings in city of Prishtina. Residential sector's development in terms settlements, urban design level approach and also building typology and quality evolved based on political and economic progress.

Currently Prishtina consists of different varieties of residential buildings which represent different specific phases of city developments by creating diverse city zones which comprises specific building types.

To have a more structured approach towards residential building stock, Ministry of Environment and Spatial Planning (MESP) created a categorization of residential buildings through the Administrative Instruction of MESP on Spatial Planning main types of residential buildings by creating 2 main categories including by three sub categories for each group. According to MESP Administrative Instructions residential buildings are structures as follows:

1 **Single unit residential buildings**

- 1.1 **Detached houses** – Represent buildings which are free of other buildings from all four sides, with all of its facades withdrawn from the boundaries of neighboring parcel/ parcels and public roads or public green spaces.
- 1.2 **Semidetached houses** – Represent buildings which are free of other buildings from three sides, with a lateral side of the building delineating the boundaries of the neighboring parcel/ parcels, and with the other three facades withdrawn from the boundaries of neighboring parcels and public roads or public green spaces.
- 1.3 **Terraced houses** – Represent buildings which are free of other buildings from two sides, with two lateral sides of the building delineating the boundaries of the neighboring parcel/ parcels, and with the other two facades, front and rear, withdrawn from the boundaries of neighboring parcel/ parcels and public roads or public green spaces. The building occupies the entire width of the parcel, except in the cases when at the end of the row, when it delineates one of its boundaries. The row must be interrupted after 7-10 buildings.

2 **Multi-unit residential buildings**

2.1 **Detached houses** – Represent buildings which are free of the other buildings, which depending on the size, proportion and number of residential units may have more than one entrance to the building.

2.2 **Rowed buildings** - Represent collective buildings which are placed within a range of detached buildings, which are inter- connected to one-another, respectively which bound on lateral facades with neighboring buildings.

2.3 **Terraced buildings** - Represent collective buildings that suit the terrain slope by forming terraced areas in front of the residential units, oriented on one side. This type of building can also be developed in flat terrain, in which case the terraces are created on both sides of the building (Administrative Instruction of Ministry of Environment and Spatial Planning, 2017).

2.5 Energy saving regulation

The only current official mandatory legal document that considers and regulates the issue of energy saving in buildings is the Technical Regulation on Thermal Energy Saving and Thermal Protection in Buildings drafted by the MESP in Kosovo. This Technical Regulation regulates technical requirements for thermal energy saving and thermal protection. Requirements relate to:

1.1. New building projects, and

1.2. Existing buildings adoption and reconstruction projects with internal heating temperatures of more than 12ºC.

2. This Regulation regulates technical specifications and other specifications of construction products used for building construction for the purpose of thermal energy saving and thermal protection. (Technical regulation on thermal energy saving and thermal protection in buildings, 2009)

This regulation tends to offer sufficient technical information and regulate the building sector in terms of energy savings including residential sector. In general the regulation determines main requirements for minimum required levels of heat loss and energy demand for heating considering different components but requirements in some cases contains discrepancy in setting the limits which should be considered for amendment and improvements. The outputs of this study might be of important contribution to make specific corrections and adding additional high standard requirements as a second possibility for perspective.

2.6 Summary

The data and information presented on this chapter which has been provided from official sources and documentations aims to synthetize the context of the study, by analyzing the history of residential building sector in city of Prishtina, the climate of the region, structuring of the RBS. Also by revising the current official regulations it has been possible to understand the legislative and regulative state toward energy savings in Kosovo, including city of Prishtina.

As a summary of this chapter it is evident that there is sufficient documentations which clearly contribute on designing a platform for the study initiation and structuring for further development based on literature review and foreign practices and experiences on the same field of research.

CHAPTER THREE

3. LITERATURE REVIEW

3.1 Introduction

This chapter presents the current situation of studies, empirical data and all other sources of documentation and data that helped the study to identify deficiencies at current legislation and structure the approach towards practical solutions for the current state of residential building stock in city of Prishtina. This chapter will review literature with main focus on statistical data of the residential building stock in city of Prishtina, which is considered one of the main columns on creation of building typology, continuing with literature review of studies with similar emphasis on building typology structuring and analysis with focus on building refurbishment towards heating energy savings. Furthermore, other country's practises will be elaborated to obtain best approaches and methodologies that shall be included in the following chapters and support the conclutions and practical recommendations.

3.2 Residential building stock (RBS) in city of Prishtina

Residential building stock (RBS) represents the largest building sector in city of Prishtita and the largest energy consumer in a level of Republic of Kosovo. According to data provided by Kosovo Agency of Statistics, in 2011 Prishtina represents around 14,4% of the overall existing dwellings in Kosovo, followed by Prizren with around 9,61%, which makes Prishtina with the highest share on the overall number of buildings in Kosovo.

RBS consists of various building types and construction periods by creating diversity of building typology in terms of building height, building geometry, materialization and building quality. This diversity creates a heterogeneous structure of building stock within city of Prishtina (Table 3.1). In case of Prishtina the diversity of building typology is closely linked with diversity of zones within the city a component that creates zones which consists of specific building type of a specific period by creating zones with specific building

Table 3.1 The diversity of building typology in city of Prishtina

3.3 Energy efficiency as an important component of living commodity

Energy poverty is a situation where a household is unable to access a socially-and materially necessitated level of energy services in the home (Bouzarovski et al., 2010). The three main components that determine the energy poverty are building energy efficiency, energy costs and family income (Vlerësimi i performancës së energjisë në ndërtesa përmes konceptit të varfërisë energjetike, 2018, p. 6).

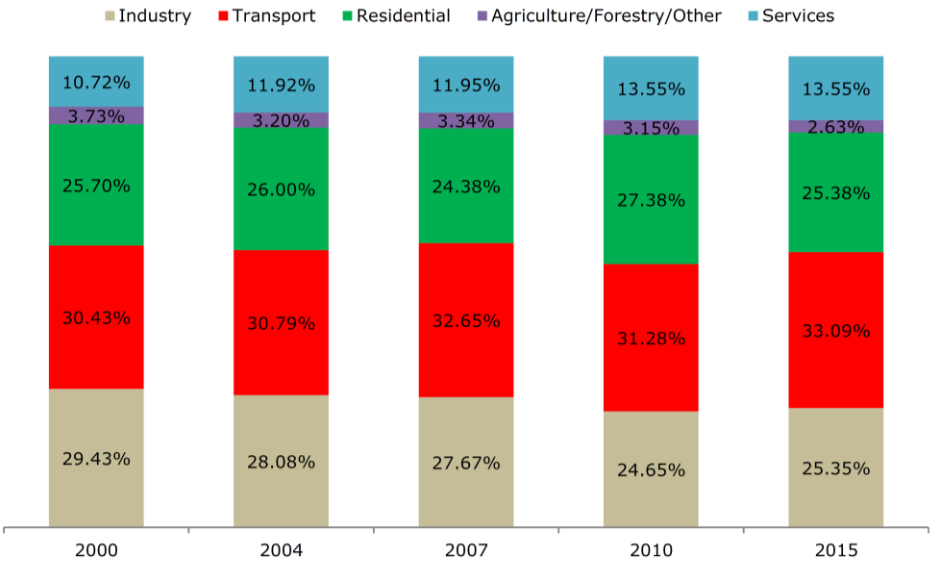
The building energy efficiency is tighly linked to the living commodity as one of the main components. Building energy efficiency consists of a various factors which affect the building performance. Building performance can be influenced by number of factors: Age of the building, Size of the building, Efficiency features of the building, Management, Occupants engagement (Skopek J., 2013, p1). In this case, three of the main components are age, size and efficiency features of the building which are also a research subject of this study and will be treated in details during the following chapters.

3.4 Energy Consumption and Energy Efficiency Trends

Kosovo as part European continent and a country with aspiration to become an EU member has a long and challenging way ahead to achieve required standards aside political challenges. A number laws regarding building sustainability, building standards and energy efficiency must be commensurate with EU regulative and directives.

One of the five ambitious objectives of the European Union regarding the strategy for Europe 2020 focuses on climate and energy, and energy efficiency is at the heart of the EU's Europe 2020 Strategy for smart, sustainable and inclusive growth (COM (2010)2020, A strategy for smart, sustainable and inclusive growth, 2010).

In 2015, the residential sector represented 25.38% of the final energy consumption in the European Union, being the third consuming sector after transport with 33.09%, and industry sector with 25.35% (graph. 3.1). By analyzing the data concerning the residential consumption, it is possible to observe that the final energy consumption in the residential sector followed a fluctuating dynamics, with a significant decrease of 11.25% and 11.97% in 2011 and 2014 respectively. (Bertoldi P., Diliuiso F., Castellazzi L., Labanca N., Serrenho T., 2018).



Graphic 3.1 Final Energy consumption shares by sector in the EU-28, 2000, 2004, 2007, 2010 and 2015. Source Eurostat, https://www.researchgate.net/publication/322952753_Energy_Consumption_and_Energy_Efficiency_Trends_in_the_EU-28_2000-2015_Efficiency_Trends_of_Energy-related_Products_and_Energy_Consumption_in_the_EU-28/figures?lo=1 Accessed; 15.08.2018

Kosovo still stands in a worst situation regarding energy consumption shares in general where residential sector comprises the majority of the energy consumption. A considerable part of the energy consumption derives from the recuperation of the heating energy loss as a low quality of building construction. The current level of heat consumption in Kosovo is estimated to be about 219 kWh/m2 year, compared to 80–150 kWh/m2 year in Western Europe, which indicates that there is a significant opportunity for EE improvements [EPTISA, 2013, p. 7).

3.5 Current heating energy source and energy carrier type used in residential sector in city of Prishtina

The number of researches and studies that are aiming to find current data and improve the models of sustainable consumption of energy in general and heating energy in particular is increasing. Without concrete data and figures that represent current situation of the energy consumption it is very hard to establish strategies and concrete measures for positive changes by implementing practical solutions to improve the non-efficient way of energy use and consumption. The same situation stands within the countries in southeastern Balkans, in which sporadic initiatives are being conducted to identify the current situation of energy consumption. Based on the fact that the residential sector still represents the largest consumer of energy in general and heating energy consumption it is crucial to identify the main heating energy sources and energy carriers types used by the residential sector. This would subserve the following steps for upgrade of the heating systems and also domestic hot water systems that could improve the energy efficiency aside the heat loss caused by transmission throw building envelope.

In this field of research the Kosovo Agency of Statistics provides sufficient data regarding the heating energy sources used by residential sector in respective cities of Kosovo including city of Prishtina. Although the data delivered by official institutions are considered sufficient, additional research studies may be considered as a complementary input in this field.

Another important research with a specific focus on heating energy sources and carriers that has been conducted in city of Prishtina is the “Energy Consumption by the Type of Energy Carrier Used in Residential Sector in City of Prishtina”. The output of this research provides reliable and sufficient data which may support the study.

Including the data from all these research studies and official data, it is evident that still, the main sources used for space heating by the residential sector remain wood, electricity, district heating and coal. A source such as biomass (pellet) is still in a low level of usage but in a continuous up growth.

District heating is one of the main potentials that could influence the shares of sources used for heating by the residential sector and achieve positive environmental results. Currently Prishtina’s district heating company “Termokos” covers approximately 12000 dwelling units, which represents 62% of the total consumption (Urban Development Plan Prishtina 2012-2020, September 2013 p. 95) .A project of cogeneration is one of the most ambitious projects in Kosovo regarding space heating and energy efficiency which aims to use the domestic hot water used for cooling the generators of the power plants and at the same time to reduce the energy loss 50-60% (GAP Insitute, 2015, p.6). The project for rehabilitation of DH system in Prishtinë and Gjakova is in compliance with the Government heating Strategy 2011-2018 and with the National Plan on Renewable Energy Sources 2011-2020 (European Commission, 2015, p.15).

3.6 Building typology structuring approach

Building typology structuring is the crucial component of this study and other studies related to the residential sector in their main focus. The building typology structuring may include all types of buildings depending on what the study is oriented. In this case a specific sector is being studied which has to exclude sector such as industrial, administrative and public institutions.

Different studies conducted different approach related to building typology structuring considering the specificity of the topic. One of the studies that has been conducted in Germany more precisely in region of Bayern, which has been an ambitious study towards identification of the current state of the energy use and potentials of energy saving. The study is known as “Leitfaden Energienutzungsplan“ or “The Guideline for the energy use plan” and included also the building typology structuring for further analysis.
Another approach towards building typology structuring is the Typology Approach for Building Stock Energy Assessment – TABULA, which is well known within the EU

countries as a concept of standardized residential building structuring for studies related to building physical conditions, systems and energy consumption.

3.6.1 "Leitfaden Energienutzungsplan" – Guideline plan for energy use

The "Leitfaden Energienutzungsplan" is an informal planning tool for communities on energy bases of which is an analysis of the current situation with a rough outlook on expected developments (Hausladen G., Hamacher T., 2011, p. 5). The study incorporates the entire building stock of the region including residential sector.

The "Leitfaden Energienutzungsplan" is based on three main phases:

1. Inventory and potential analysis,
2. Concept development and
3. Implementation.

The first phase of the study includes the analysis of community building structuring, which is the initial step towards more specific analysis. In "Leitfaden Energienutzungsplan" case the community structuring has been conducted by structuring buildings typologies into two main groups (Figure 3.1):

1. Residential buildings
2. Non-residential buildings

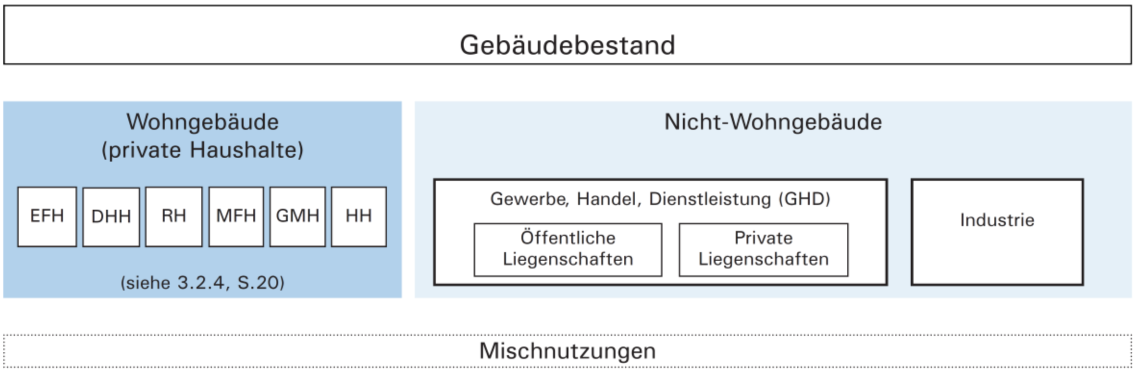


Figure 3.1 Differentiation of the building stock according to building use and types. EFH = detached houses, DHH = semi-detached houses, RH = terraced houses, MFH = multi-family houses, GMH = large multi-family houses, HH = skyscrapers source: Leitfaden Energienutzungsplan, 2011, p11 Accessed on: 20.07.2018

As seen in the figure 3.1 the structuring of building typology is a curtail phase for any analysis of building stock in general and of RSB stock as a particular subject of this study. Furthermore the “Leitfaden Energienutzungsplan” study focuses also on structuring of building based on construction period aside the building typology and use. Synthesis of these important data helped the study to create a grid or a matrix of important data of building stock by structuring the building type, construction period, specific heating demand and domestic hot water demand (Figure 3.2).

Bau-alter	Baujahr	EFH DHH	RH	MFH	GMH	HH
		[kWh/(m²a)]				
A	vor 1918 Fachwerk	210		241		
B	vor 1918	250	204	180	159	
C	1919-1948	194	166	193	164	
D	1949-1957	223	163	211	173	
E	1958-1968	166	135	168	172	119
F	1969-1978	182	159	139	140	103
G	1979-1983	120	129	118	116	
H	1984-1994	140	97	122	82	
I	1995-2001	101	89	98	73	
J	ab 2002	72	70	65	51	

Figure 3.2 Specific heating demand values (useful energy) for residential buildings [kWh / m²a]
source: Leitfaden Energienutzungsplan, 2011, p11; Accessed on: 20.07.2018

The basis of the “Leitfaden Energienutzungsplan” study could be a guideline for an approach of building stock structuring in case of city of Prishtina. Creation of the matrix based database of RBS in city of Prishtina by using the same approach could subserve the study by understanding the current state of the RBS. Additional to the “Leitfaden Energienutzungsplan” study it is important to conduct an analysis of building envelope elements, so the study could offer more precise and detailed information for further developments.

3.6.2 Typology Approach for Building Stock Energy Assessment – TABULA

The Intelligent Energy Europe (IEE) project named Typology Approach for Building Stock Energy Assessment (TABULA) is an initiation to create a harmonized structure for European Building Typology (Info Tabula; http://episcope.eu/fileadmin/tabula/public/docs/tabula-info.pdf). The objective of the project was to create a model for European building typologies, in particular residential buildings (European Commission; https://ec.europa.eu/energy/intelligent/projects/en/projects/tabula). Based on the aim of TABULA project it is evident that the main focus is the creation of a single data base of building stock for different countries of EU. The project currently consists of 20 countries which created their own databases of residential building typologies and other required data.

As TABULA offers three different methodological approaches which are appropriated based on the concrete situation for Building typology structuring.

1. According to the first approach, the definition of the representative building, called "Real Example Building" (ReEx), is based on the choice made based on experience; the building-type is selected within a given climate context as more representative of a specific size and an era of construction. This approach is used in the absence of reliable statistical data.
2. The second approach identifies the building type, called "Real Average Building" (ReAv), through a statistical analysis. The collected data are processed statistically in order to identify a real building that has geometric and constructive characteristics that coincide with the average of the sample of buildings analyzed.
3. The third approach identifies the building-type, or the "Synthetical Average Building" or "Theoretical Building" (SyAv), as an "archetype", which is defined as: "a statistical composite of the features found within a category of buildings in the stock "(ECBCS, 2004). The archetype is not a real building, but a "virtual" building characterized by a set of properties that are statistically identified within a category of buildings.
4. Each of these approaches can however be applied separately to define the building-type in its geometric properties (volume, shape relationship, ...), on the one hand, and in its constructive and plant characteristics, on the other (Corrado V., Ballarini I., Corgnati S.P., July 2014).

Unfortunately there are insufficiencies of specific technical data for specific buildings of specific construction periods in city of Prishtina which could subserve the building structuring and this phase of the study, which in this case predetermined the appropriation of the methodological approach of definition of representative or the referent buildings for each specific building type.

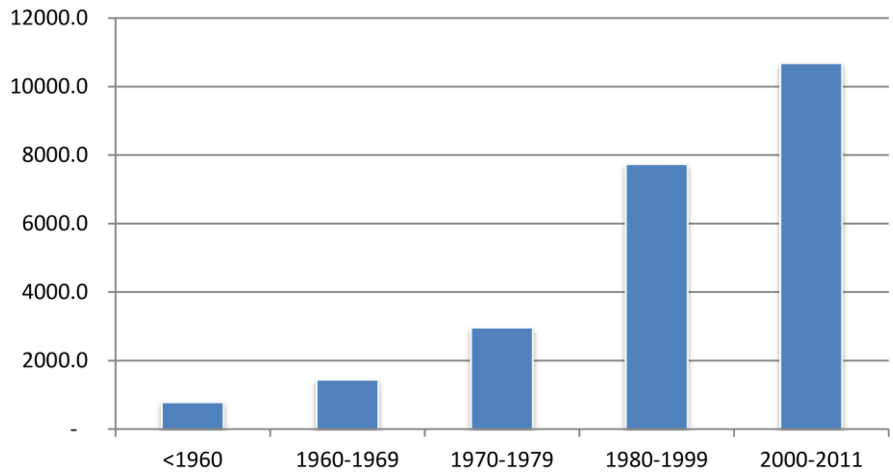
3.7 Missing data

Based on the specificity of this study in which data gathering and analysis, field measurements, data structuring, calculations, geometric and visual analysis are inseparable processes and have their specific importance during the entire process. All the above-mentioned components are in fact specific variables of the research which contain quantitative and qualitative data without which it would be impossible to achieve progress as a research study.

Currently there are considerable insufficiencies of qualitative or non-statistical data such as building layouts and plans, building technical data, previous studies with reliable data which decelerate the findings of this study. Absence of building layouts derives from the last war in Kosovo during which most of official document regarding land and cadastral documents, building technical and graphic layouts have been taken to Serbia by Serbian officials, which still remain in their possession unjustly.

As a result of insufficiencies of qualitative data, field measurements and specific calculations have been conducted to insure and provide sufficient and specific data for the research. By field measurements it was possible to process valuable physical data which have been digitalized and structured properly.

A different situation stands with quantitative/ statistical data, which are more sufficient and reliable for the nature of this study. It was possible to conduct and structure the development and growth of residential building number based on specific periods, which subserved the study for further and more detailed analysis (Graphic 3.2).



Graphic 3.2 Development of residential building construction structured in different periods before 60 till 2011.

As this study is considered to be one of the kind for Kosovo as a result of the specificity of the subject and the outcome that will be generated, the state of the art literature relevant to the study has been mostly used from abroad authors and studies, since there are not enough local relevant studies.

Synthesizing the available official data with all manually gathered and calculated data on field combined with foreign literature, experience and expertise it has been possible to generate important information and data not only for this study.

3.8 Theoretical and Conceptual Framework

Considering the study as a very specific research in case of Prishtina, it is important to identify the starting point and the main direction of the study by including the literature review and establishing the focus of the research. Theoretical and Conceptual framework are two crucial instruments through which it is possible to develop the concept and create a clear structure of the research path and progress.

3.8.1 Theoretical Framework

According to literature review and to worldwide practices we may conclude that building sector is the largest energy consumer in global level. It is also a fact that residential sector within residential sector is the main energy consumer in most of the countries and the largest amount of energy is being used for space heating and cooling. We may also conclude that the heating loss throughout the building envelope is one of the main contributors of the overall energy loss of building sector, a component that has to be seriously and properly treated.

The unsatisfying state of most of the residential building stock in city of Prishtina, indicated that treatment of this specific and very important sector is of a fundamental importance which is closely connected to quality of life, living commodity and energy efficiency. Based on these aspects and facts this study aims to identify the current state of residential buildings by structuring the building stock, assessing referent buildings, identify the gaps and weaknesses and offer concrete solutions for improvement of physical components of residential building.

As a result of lack of similar studies, this study will assess a large building sector with a significant influence in inhabitant's quality of life and energy situation in Kosovo and its outcomes will not only serve to conclusions of this study but will subserve for future studies and developing towards achievements of higher standards of building constructions.

3.8.2 Conceptual Framework

The conceptual framework of a study as a structuring phase of the research process has been considered as the fundamental component of this study by identifying and setting the main processes and sources of relevant information as an input that can be used for the research process and generation of results.

The design of the conceptual framework has been based on previous practices of other countries which have been presented on the previous chapter. Based on practices implemented and experiences gained in several countries of the EU and wider with the main focus on residential sector, building structuring and energy consumption, the conceptual framework of this study was easily designed.

The conceptual framework of this study has been designed based on 3 main phases including sub phases as integral parts of the research process.

First phase consists of processes that are mainly focused on identifying the current state of the RBS in city of Prishtina. To achieve the results, the first phase includes 3 sub phases which are complementary to each other towards completion of the first phase. The main sub phases are as follows: 1. Data gathering which consists of quantitative data and qualitative data, 2. Structuring of the gathered data and 3. Identification of the current energy consumption based on quantitative and qualitative data gathered.

Quantitative data gathering is mostly based on official sources as Kosovo Agency of Statistics, Municipality of Prishtina and Municipal Archive. During this process the main importance has been the relevant data regarding RBS which afterwards will be structured in function of this study.

Qualitative data gathering is based on available building documentations and field measurements as a complementary process. The main importance of this process was to collect sufficient technical data regarding building stock which subserves further calculations.

Only after completion of data gathering, quantitative and qualitative, it is possible to design a matrix based database which consisted of relevant statistical and technical data.

Second phase is focused on finding the realistic potential of energy savings based on refurbishment measures of building elements using the current regulation of energy saving. Based on the findings and data gathered during the previous phase, it is possible to predict or hypothesize the current energy demand for heating. Identifying the current energy demand for heating is a groundbreaking step towards finding the potentials of energy savings. Synthetizing the building structured database and technical data of specific buildings helped the process on dividing energy needs for specific building types and different construction periods.

Third phase is focused on finding the future potentials for energy savings based on refurbishment measures of building elements using the high standards of building energy efficiency with the aim on NZEB. Using the same platform of data and building structuring it is possible to foresee the potentials of energy savings by implementing high quality buildings standards.

As an outcome of all three phases comparative analysis can be conducted between current state of RBS and two scenarios using different building standards. Based on comparison results it is possible to offer recommendations towards building improvements by implementing specific refurbishment measures to the RBS.

Similar approaches have been conducted in several projects and studies worldwide which resulted with valuable outcomes and the same should be adapted for studies on the same field. A graphical representation of the Conceptual framework is a complementary component which offers a visual description of the designed concept (Figure 3.3)

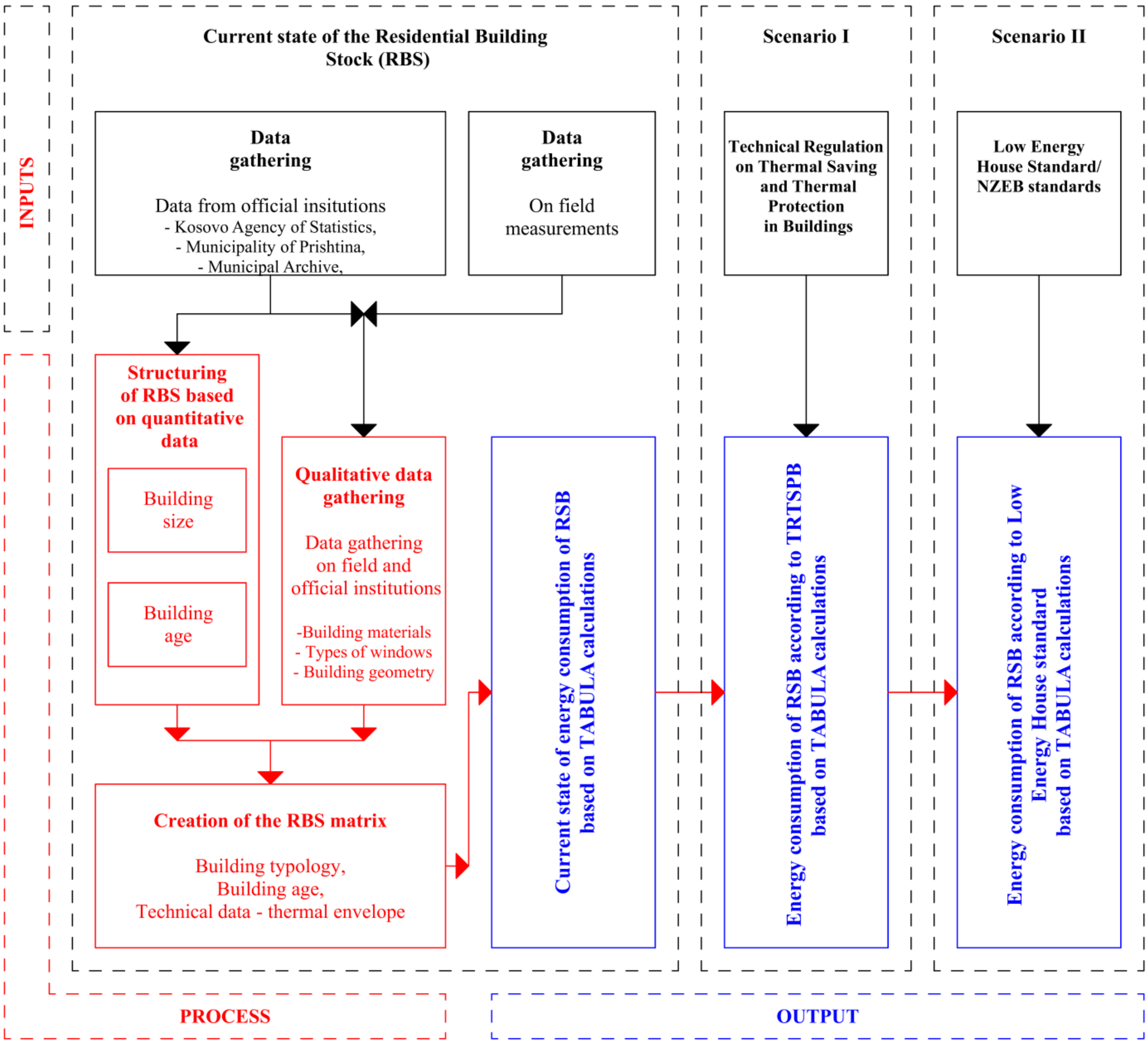


Figure 3.3 The conceptual framework of the study

3.9 Summary

In this chapter aimed to create basis for this study by using international literature and considering the similar research studies implemented in different countries as a guide. Based on up to date literature the importance of studies in this field is evident. Considering the literature review it is evident that quantitative and qualitative data gathering and structuring are of a crucial importance. Creation of a matrix database is the main platform upon which it is possible to design future potential measures for building improvements towards sustainability, energy efficiency and living commodity.

CHAPTER FOUR

4. RESEARCH METHODOLOGY

4.1 Introduction

This chapter represents the methodology which was applied to achieve the objective of the research.

The process of research showed a complexity of diverse phases which needed specific approach and diverse methodologies to achieve measurable data, based on which the analysis and generation of results was possible. In this case a combination of methodologies and approaches were applied including quantitative methodology by statistical data collection and analysis, descriptive data by analysis of project layouts and physical measurements, qualitative data collection by applying an on field survey and physical analysis on field.

All data collection and analysis include a diversity of official documentations, official statistical data, project layouts, physical measurements on field and calculations as a sufficient source for achieving specific results of the research.

4.2 Geographical focus of the study

The study has been conducted within the boundaries of city of Prishtina excluding specific zones which do not contain any residential buildings. Within these boundaries city of Prishtina consists of all residential building typologies constructed during different period of time. As a subject of this study in terms of geographical terms and its content, Prishtina is considered as a representative sample for the whole residential sector in Kosovo in terms of residential building stock, building typology and their physical properties.

The study will analyze the current state of the RBS based on current situation of buildings but also considering the urban sprawl of the city and the future plans of city expansion with focus in residential sector (Fig 4.1).

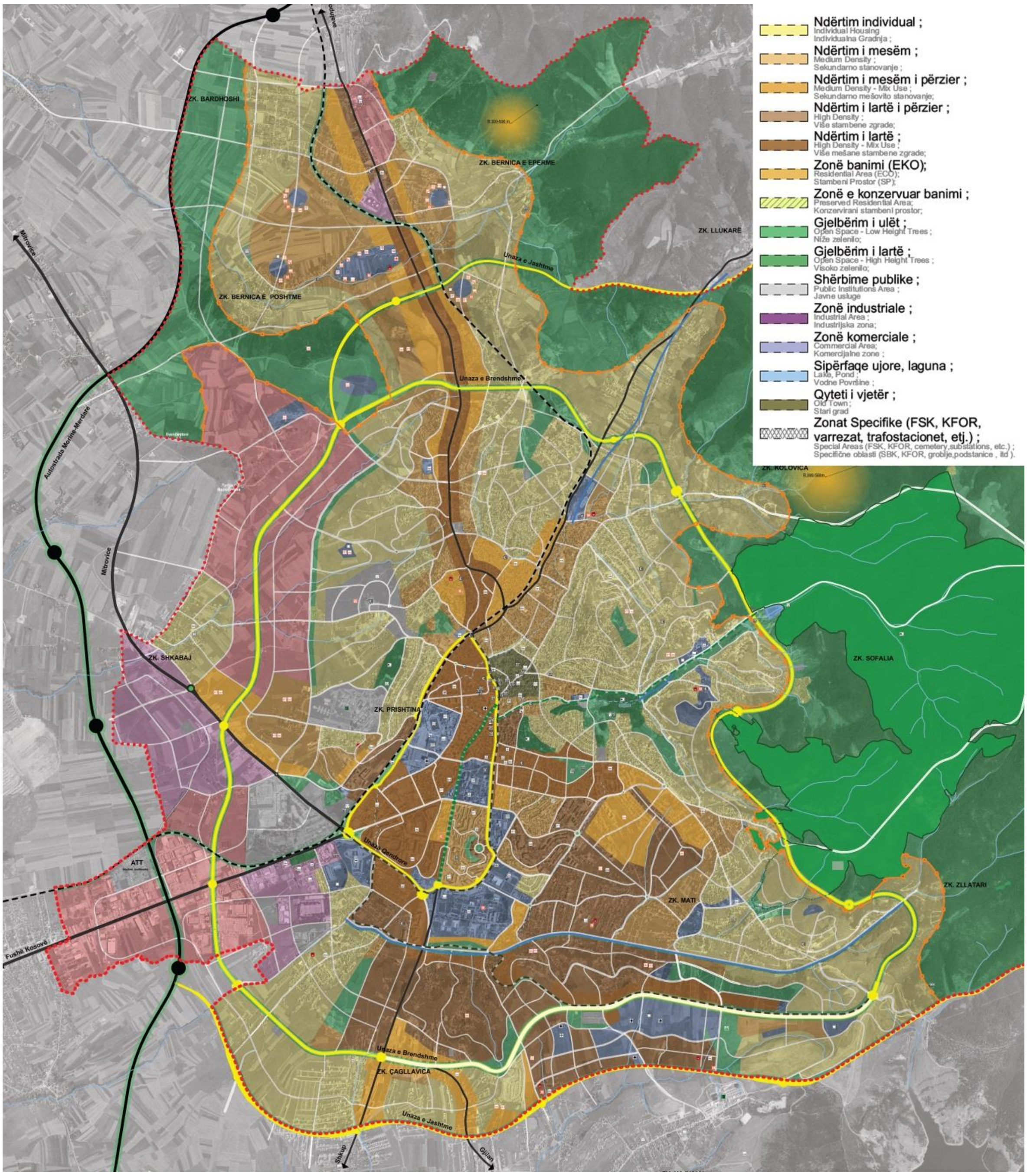


*Figure 4.1*Urban Development Plan of Prishtina – Destination of zones

Source; https://kk.rks-gov.net/prishtine/wp-content/uploads/sites/45/2018/02/06-PZHU-DESTINIMI-I-SIPERFAQEVE.pdf Accessed; 09.08.2018

4.3 Data source and collection

The initial aim of the research was to understand and collect sufficient data regarding residential buildings in city of Prishtina based on which a creation of a database of residential building stock with all relevant data would be possible and could offer a clear image of the current state of the buildings. All collected data may be considered sufficient to understand the insufficiencies of specific building types that lead to energy loss and then generate potential technical solutions for increasing the living commodity and energy efficiency used for heating.

All relevant data has been collected based on its specificity and importance. All statistical data regarding residential building stock were provided by Kosovo Agency of Statistics. Based on these data, it was possible to structure building typology and its construction periods. Data that represented physical components of residential buildings such as building layouts and project designs has been provided by official institutions including Archive of Prishtina Municipality and Public Housing Agency of Prishtina. All other data linked to residential building's physical characteristics has been collected by conducting field visits and measurements which provided sufficient data of a great importance for further calculations.

The study has been divided in two different approaches, which are considered complementary to collect more exact data and generate more precise results.

The first approach of the research is focused in more quantitative data which has been conducted by applying a survey throughout the city of Prishtina, through which it was considered to collect quantitative and qualitative data regarding the buildings, the quality of heating and the inhabitants satisfaction based on heating systems and carriers.

The second and more important approach includes more qualitative data and which has been conducted in a more specific manner, by collecting and analyzing all relevant data based on reference buildings. The second approach was mostly based on field measurements, analysis of building layouts followed creation of a database, structuring of building typology and by specific calculations which leaded to more precise results regarding heating loss and building general current state.

4.4 First approach - Data collection via survey

The first approach has been conducted to generate data which are mostly based on inhabitants experience and their satisfaction level. Survey research is used to answer questions that have been raised, to solve problems that have been observed, to assess needs to establish baselines against which future comparisons can be made (Isaac S., Michael, W. B., 1997.)
This approach help the study to create a greater picture of heating energy sources and carriers, heating systems used by the residential buildings and understanding the quality of heating within the dwellings based on heating energy sources.
The survey covered whole residential zones within city of Prishtina, which was spread and distributed in accordance with dwelling spread throughout city of Prishtina. It is important to present an anatomy of energy end-uses in the residential buildings,to assess the energy performance analysis (Radha C. H., Kistelegdi I., 2017, p. 151-162), so after the creation of residential building typology zones, it was possible to identify the spreading of different residential building types within the urban zone of Prishtina and creates a map of residential building spread based on typology (Fig. 1), (Ahmeti P., Dalipi I., Basha A., Kistelegdi I. , 2017, p. 147–158.

4.4.1 Sample size and survey distribution

Anyone designing a Simple Random Sample (SRS) must decide what amount of sampling error in the estimates is tolerable and must balance the precision of the estimates with the cost of the survey (Lohr S. L., 1999, p. 46]. To validate the survey and the first part of the research within this study, it has been very important to calculate and set the sample size of the research subject. In this case city of Prishtina consists of 49,463 dwellings or 329,800 inhabitants which has been the base of sample size calculation for

$$n = \frac{(z^2 * \mathrm{p} * \mathrm{q}) + \mathrm{ME}^2}{(ME^2 + \mathrm{z}^2 * \mathrm{p} * \mathrm{q})/\mathrm{N}}$$

where *n* is the sample size; *z* is the confidence interval (in this case 95% appropriated, which during calculations is presented as 1.96 standard deviation); *ME* is the margin of error (in this case 3.0% is appropriated and during calculations is presented as 0.035); *p* is constant, if you are unsure of the right value to use, set *p* equal to 0.5. This will produce a conservative sample size estimate *q* =1-*p*; *N* is the number of units.

In this case, *N* is the number of the treated subject, according to Kosovo Agency of Statistics city of Prishtina consists of 49463 dwelling units [2].

Applying the confidential interval 95% and the margin of error 3%, and the first scenario with 49463 dwelling units then:

$$n = \frac{(1.96^2 * 0.5 * 0.5) + 0.03^2}{(0.03^2 + 1.96^2 * 0.5 * 0.5)/49463}$$

The value of 1045.55 represents the sample size of the survey based on which the research results will be validated and representative. In this case the sample number is appropriated as 1046, which represents 1046 dwellings as subjects of the research.

Based on the spread of inhabitants, residential buildings and dwellings the distribution of the questionnaire was conducted on a proportional way so the data gathered represent realistic figures (Table 4.1).

Table 4. 1 Distribution of questionnaires based on number of inhabitants per neighborhood. Data used in this table are provided by Department of Public Services - Municipality of Prishtina and Urban Development Plan of Prishtina.

Nr	Neighborhood	Number of inhabitants per neighborhood	Share of each neighborhood in total number of inhabitants	Number of questionnaires per neighborhood
1	Prishtina e re	20000	6.1%	64
2	Kalabria	12000	3.6%	38
3	Mati 1	14000	4.2%	44
4	Matiqan	20000	6.1%	64
5	Dardani/ Lakrishte	46300	14.0%	146
6	Ulpiane	14000	4.2%	44
7	Kodra e Diellit	29000	8.8%	92
8	Velani	5000	1.5%	16
9	Qendra/ Pejton	21700	6.6%	69
10	Arberi/ Prroi i njelmet	8000	2.4%	25
11	Taslixhe/ Sofali/	20000	6.1%	64
12	Dodona/Muhaxher/Aktash	13500	4.1%	43
13	Kodra e Trimave/Tophane	71300	21.6%	226
14	Vellushe/ Vreshta	6000	1.8%	19
15	Medrese	29000	8.8%	92
	Total number	**329800**	**100%**	**1046**

The fulfillment of questionnaire has been achieved 100% for all 15 administrative zones with diverse residential buildings (Figure 4.2).

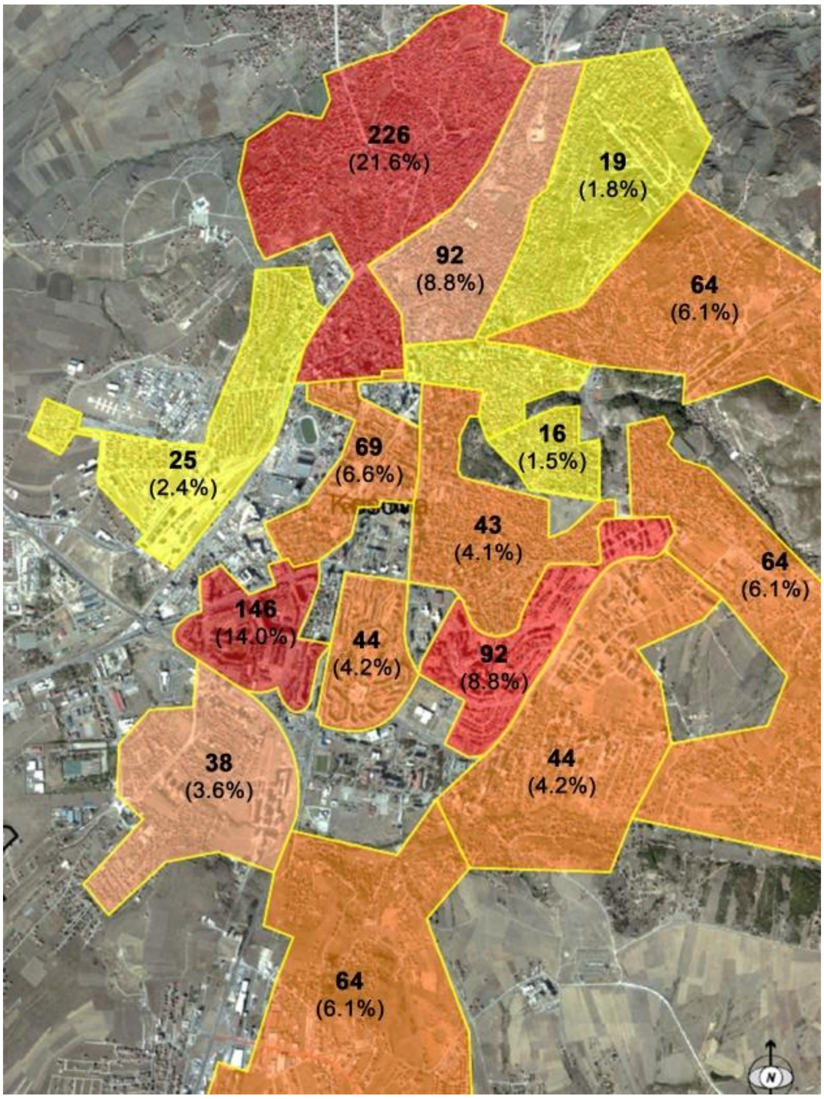


Figure 4.2. Distribution of the questionnaire within each neighborhood - Map created by the author

4.4.2 Questionnaire design

Based on literature, the survey has been conducted by designing a standardized questionnaire. A questionnaire is called standardized when each respondent responds to the same questions and the same coding system (Kothari C. R., 2004). The questionnaire consisted of 15 questions manly focused on primary data and which was drafted on three main parts (Appendix 1).

First part of the questionnaire has been manly focused in location of the dwelling based on which it was possible to identify and create a map of the research spread within territory on city of Prishtina. This part of the questionnaire gathered valuable data regarding building typology, construction period, useful area of the dwelling and number of inhabitants per dwelling.

Second part of the questionnaire has been focused more in physical properties of the building, heating systems and carriers used by the dwelling and the amount of sources used for heating. The second part of the questionnaire gathered data that helped the study to structure buildings on bases of application of thermal insulation, types of windows and also types of heating systems and carriers installed. It is obvious that the aim of this part of the study has been the collection of data for the winter period during which the energy consumption is higher during the year. Therefore, seasonal variation is an important factor in determining residential energy consumption, particularly for heating and cooling of space (Lam JC: 1996;21(1):1–8.)

The third part of the questionnaire has been mostly focused in the level of satisfaction of the inhabitants with the quality of heating and the percentage of heated area in relation with the total area of the dwelling. This part of the questionnaire collected valid data which helped the study to validate the data regarding the currents state of the possibility to heat the living space within a dwelling based on the energy source used for heating.

4.5 Second approach - Building typology and construction period

For more precise and structured research of the residential building stock it has been important to analyze the current state of this sector and structure it based on building typology and construction period. Division and structuring of building typology creates a basis for clarification of current situation of residential buildings of different types and different construction periods by precluding a possibility to generalize the current state of all residential buildings in city of Prishtina.

As an initial step of the research, RBS structuring has been utilized as a tool for structured data gathering and analysis during the phases of data collection and analysis.

RBS structuring also subserved the following phases of the research by facilitating the process as a result of fragmented analysis of each building typology.

The methodology used to produce our analysis consists of several steps [12] (Tabula-Episcop, Scenario Analyses Concerning Energy Efficiency and Climate Protection in Local Residential Building Stocks, 2016, p 34):

Step 1 Clustering of the analyzed housing stock into 5 age groups and 4 size/type groups. The first age group corresponds to the period before 1960, the second one from 1960 to 1969, the third one from 1970 to 1979, the fourth one from 1980-1999 and the fifth one from 2000 onwards. The four size/type groups distinguish between single family houses (SFH), Terraced/Semidetached Houses (TH), multi-family houses (MFH) and apartment blocks (AB).

Step 2 Setting up the models/reference building of "average" (synthetic) buildings for each cluster by adopting average geometrical and physical parameters for these average buildings.

Step 3 Definition of 2 scenarios for each cluster.

4.5.1 Building classification based on construction period

Building classification based on construction period is of a major importance. Periods of construction in case of city of Prishtina represent different approach towards building construction, functionality, geometry and more important materials used for building construction. Division and structuring of RBS based on their construction period is a valuable component which subserves a detailed analysis of geometrical aspects of the building, material based aspects, structural aspects and the similarities or differences between different construction periods.

To achieve more commensurable structuring of buildings based on the construction period, in this case the statistical data provided by Kosovo Agency of Statistics has been applied. According to Kosovo Agency of Statistics, Prishtina consists of 23,606 residential buildings till 2011 (*Kosovo Agency of Statistics*, 2011). The total of 23,606 buildings belongs to six different construction periods (Table 4.2)

Table 4. 2 Division of construction periods of Residential building stock (RBS). Source: http://ask.rks-gov.net/media/1598/banesat-dhe-nd%C3%ABrtesat-sipas-komunave.pdf, Accessed: 14.08.2018

Periods of Residential building construction	
I.	Construction period before 1960
II.	Construction period between 1960-1969
III.	Construction period between 1970-1979
IV.	Construction period between 1980-1989
V.	Construction period between 1990-1999
VI.	Construction period between 2000-2011 (post war period)

In some cases construction of residential buildings throughout different periods contain emphatic dissimilarities within various components. There are specific periods of construction of residential buildings that do not contain any dissimilarity in any component of the building such as the IV period (1980-1989) and V period (1990-1999). In these cases fusion of two construction periods in one period is possible, having into account that there are more similarities than dissimilarities between buildings in any aspect and component, as a rapid downfall of building construction during 1990-1999. As a derivate of initial construction period division with fusion of two construction periods in one it has been possible to generate a new RBS structuring based on construction period (Table 4.5), without any alternation of official data.

Table 4. 3 Derived structuring of RBS based on construction period

Periods of Residential building construction	
I.	Construction period before 1960
II.	Construction period between 1960-1969
III.	Construction period between 1970-1979
IV.	Construction period between 1980-1999
V.	Construction period between 2000-2011 (post war period)

4.5.2 Building classification based on building type and physical characteristics

Division of RBS based on building typology consists of different approaches depending on various components that may be taken as basis of structuring and division. As this study has the main focus on identification of the currents state of RBS and tends to offer building refurbishment solutions to achieve energy efficiency in residential sector as the largest consumer of the energy in Prishtina and Kosovo, than one of the most suitable methodologies is the EPISCOPE TABULA approach as one of the most practical way of building typology structuring and database development.

Based on EPISCOPE TABULA approach the main physical characteristic of the building classification has been considered the size of the building. In this case there are 4 main classes of buildings and in special cases there are sub-classes if there are any specific building types to be considered. The classification is defined as follows:

A. Single Family Houses – SFH
B. Terraced Houses – TH (including semidetached houses)
C. Multi-Family Houses – MFH
D. Apartment Blocks – AB.

4.6 Building typology matrix as a tool for structuring and data base

The RBS data gathering and structuring inevitably leaded to a creation of a Residential Building Stock Matrix (RBSM), which as a final product contained all relevant data for each building type and for each construction period. In this study the RBSM is considered as an important tool for data structuring and analysis with relevant technical and physical details of each building type which later has been developed as a document and database for wider range of use, potentially, beyond this study.

The RBSM has been structured based on TABULA logic which has been most suitable to this study. The RBSM consists of two main parts:

1. The matrix of the RBS based on typology and construction period is basically structured in a way that contains “Real Example Building" (ReEx) for each type and construction period which are most representative for respective type and period (Table 4.4).

Table 4.4 The RBSM sample based on TABULA building typology structuring

		Period of construction 1	*Period of construction 2*	*Period of construction 3*	*Period of construction 4*	*Period of construction 5*
1	*Building type 1*	**ReEx 1.1**	**ReEx 1.2**	**ReEx 1.3**	**ReEx 1.4**	**ReEx 1.5**
2	*Building type 2*	**ReEx 2.1**	**ReEx 2.2**	**ReEx 2.3**	**ReEx 2.4**	**ReEx 2.5**
3	*Building type 3*	**ReEx 3.1**	**ReEx 3.2**	**ReEx 3.3**	**ReEx 3.4**	**ReEx 3.5**
4	*Building type 4*	**ReEx 4.1**	**ReEx 4.2**	**ReEx 4.3**	**ReEx 4.4**	**ReEx 4.5**

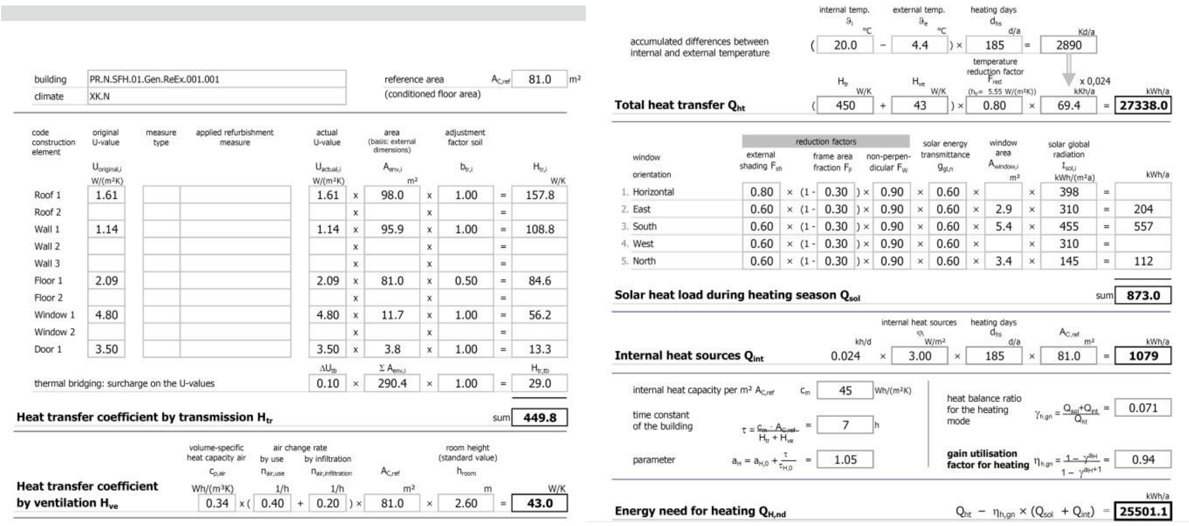
2. The matrix of “Real Example Building" (ReEx) is structured in a way that represents all relevant data and details for each referent building containing construction period and building type, "Real Example Building" (ReEx) photography, graphical content of each element that creates the building thermal envelope, technical data and description of each building element. The data structured in RBSM contain relevant data for the current state of the building and two scenarios generated after all the analysis and calculations (Table 4.5).

Table 4.5 The RBSM sample based on TABULA building typology structuring

Building type/year of construction	*Build. Elem 1*	*Build. Elem 2*	*Build. Elem 3*	*Build. Elem 4*	*Build. Elem 5*	*Build. Elem 6*
ReEx 1.1. photo	Graphic. & descripton of the element	Graphic. & descripton of the element	Graphic. & descripton of the element	Graphic. & descripton of the element	Graphic. & descripton of the element	Graphic. & descripton of the element
	Graphic. & descripton of the element	Graphic. & descripton of the element	Graphic. & descripton of the element	Graphic. & descripton of the element	Graphic. & descripton of the element	Graphic. & descripton of the element
	Graphic. & descripton of the elem.	Graphic. & descripton of the element	Graphic. & descripton of the element	Graphic. & descripton of the element	Graphic. & descripton of the element	Graphic. & descripton of the element

4.7 Calculation tool – TABULA

The method is focused on the energy use for space heating and domestic hot water of residential buildings. Cooling, air conditioning, lighting, electric appliances are until now not considered in the concept but can of course later be supplemented. The TABULA maxim is to image the relevant parameters determining the energy consumption of a building in a realistic way and to keep at the same time the method as simple as possible. In consequence, averages are used when applicable, which of course can be determined by more detailed methods. The energy need for space heating is calculated by applying the seasonal method according to EN ISO 13790 on the basis of a one-zone model (EPISCOPE http://episcope.eu/building-typology/tabula-structure/calculation/). The calculations include important components of the building elements that represent the crucial parts of the thermal envelope. Final generated results represent energy demand for the currents state which contains all relevant data of the current state of the building, energy demand for the first scenario which includes applied improvements in building elements and the energy demand for the second scenario which includes applied high standard improvements in building elements. Results include description of each building element considered in the calculation, values of heat transfer coefficient, total heat transfer through transmission, heat gains from sun irradiation and internal heat gains and the energy needed for heating (Figure 4.3).



building: PR.N.SFH.01.Gen.ReEx.001.001 — reference area (conditioned floor area) $A_{C,ref}$ = 81.0 m²
climate: XK.N

code construction element	original U-value $U_{original,i}$ W/(m²K)	measure type	applied refurbishment measure	actual U-value $U_{actual,i}$ W/(m²K)		area (basis: external dimensions) $A_{env,i}$ m²		adjustment factor soil $b_{tr,i}$		$H_{tr,i}$ W/K
Roof 1	1.61			1.61	x	98.0	x	1.00	=	157.8
Roof 2					x		x		=	
Wall 1	1.14			1.14	x	95.9	x	1.00	=	108.8
Wall 2					x		x		=	
Wall 3					x		x		=	
Floor 1	2.09			2.09	x	81.0	x	0.50	=	84.6
Floor 2					x		x		=	
Window 1	4.80			4.80	x	11.7	x	1.00	=	56.2
Window 2					x		x		=	
Door 1	3.50			3.50	x	3.8	x	1.00	=	13.3
thermal bridging: surcharge on the U-values				ΔU_{tb} 0.10	×	$\Sigma A_{env,i}$ 290.4	×	1.00	=	$H_{tr,tb}$ 29.0
Heat transfer coefficient by transmission H_{tr}									sum	**449.8**

Heat transfer coefficient by ventilation H_{ve}: volume-specific heat capacity air $c_{p,air}$ 0.34 Wh/(m³K) × (air change rate by use $n_{air,use}$ 0.40 1/h + by infiltration $n_{air,infiltration}$ 0.20 1/h) × $A_{C,ref}$ 81.0 m² × room height (standard value) h_{room} 2.60 m = **43.0** W/K

accumulated differences between internal and external temperature: (internal temp. ϑ_i 20.0 °C − external temp. ϑ_e 4.4 °C) × heating days d_{hs} 185 d/a = 2890 Kd/a

Total heat transfer Q_{ht}: (H_{tr} 450 W/K + H_{ve} 43 W/K) × temperature reduction factor F_{red} (h_{tr}= 5.55 W/(m²K)) 0.80 × 69.4 kKh/a (x 0,024) = **27338.0** kWh/a

window orientation	reduction factors: external shading F_{sh}		frame area fraction F_F		non-perpendicular F_W		solar energy transmittance $g_{gl,n}$		window area $A_{window,i}$ m²		solar global radiation $I_{sol,i}$ kWh/(m²a)		kWh/a
1. Horizontal	0.80	× (1 -	0.30	) ×	0.90	×	0.60	×		×	398	=	
2. East	0.60	× (1 -	0.30	) ×	0.90	×	0.60	×	2.9	×	310	=	204
3. South	0.60	× (1 -	0.30	) ×	0.90	×	0.60	×	5.4	×	455	=	557
4. West	0.60	× (1 -	0.30	) ×	0.90	×	0.60	×		×	310	=	
5. North	0.60	× (1 -	0.30	) ×	0.90	×	0.60	×	3.4	×	145	=	112
Solar heat load during heating season Q_{sol}												sum	**873.0**

Internal heat sources Q_{int}: 0.024 kh/d × internal heat sources φ_i 3.00 W/m² × heating days d_{hs} 185 d/a × $A_{C,ref}$ 81.0 m² = **1079** kWh/a

internal heat capacity per m² $A_{C,ref}$: c_m = 45 Wh/(m²K)
time constant of the building: $\tau = \frac{c_m \cdot A_{C,ref}}{H_{tr} + H_{ve}}$ = 7 h
parameter: $a_H = a_{H,0} + \frac{\tau}{\tau_{H,0}}$ = 1.05
heat balance ratio for the heating mode: $\gamma_{h,gn} = \frac{Q_{sol} + Q_{int}}{Q_{ht}}$ = 0.071
gain utilisation factor for heating: $\eta_{h,gn} = \frac{1 - \gamma^{a_H}}{1 - \gamma^{a_H + 1}}$ = 0.94

Energy need for heating $Q_{H,nd}$: $Q_{ht} - \eta_{h,gn} \times (Q_{sol} + Q_{int})$ = **25501.1** kWh/a

Figure 4.3 Calculation sheet with all relevant data and results from the TABULA web tool

4.8 Summary

This chapter aims to clarify the approaches that have been applied for finding, generating specific data and further structuring of the results. The survey, as one of the approaches, aimed to find data related to the heating carriers and sources which are being used by residential sector by including 1046 dwelling throughout the city of Prishtina.

The second approach was focused on RBS structuring which would contribute in following stages of the research. The building structuring has been based on building typology and construction period. The building structuring produced a RBS matrix based database which contains all technical relevant data of each building typology. Furthermore, the following process of the study will be developed on referent buildings as representative samples of each building type end construction period.

CHAPTER FIVE

5 CURRENT STATE OF THE RESIDENTIAL BUILDING STOCK IN CITY OF PRISHTINA

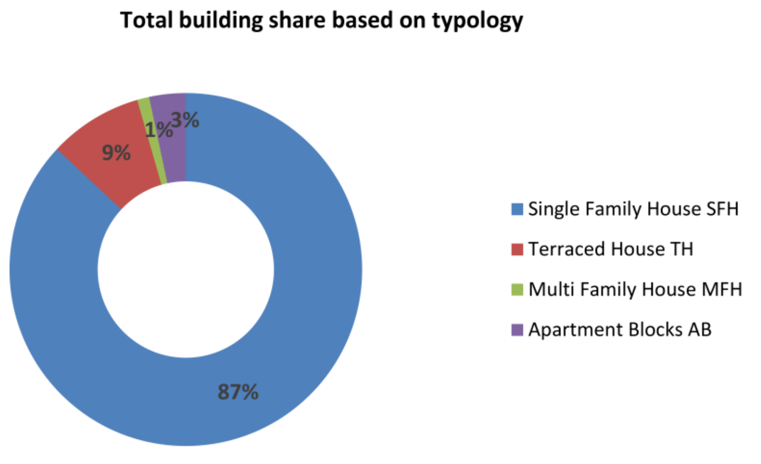
5.1 Introduction

In this chapter will be presented the current state of the RBS based on building typology and construction period. The presented data and figures will be presented exclusively based on findings generated from research methodologies presented in the previous chapter. Identification of the currents state of residential buildings in city of Prishtina is a very important component of this study because of creation of the bases for further analysis and recommendations that will offer practical solutions for improvement of current state of residential buildings in terms of heating energy efficiency. Besides data gathering and generation this phase will also contribute on creation of building typology matrix as the determinative component for conclusive outputs.

5.2 Residential building shares based on building typology – Quantitative results

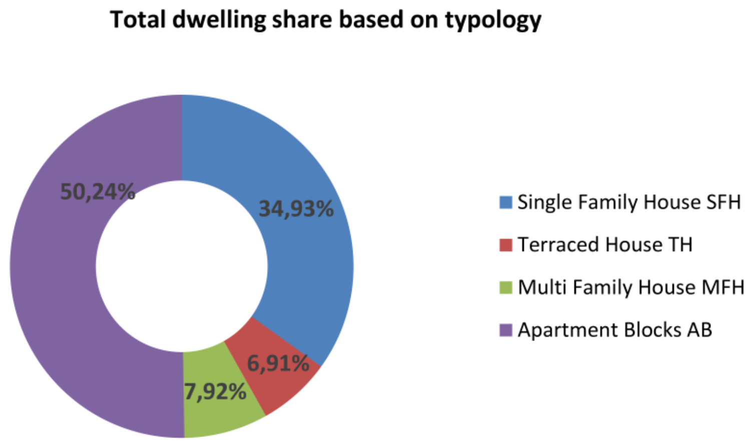
The share of residential buildings in city of Prishtina based on their building type and year of construction has been generated accordingly with statistical data of the Kosovo Agency of Statistics (KAS). The KAS data as official data has been considered sufficient and reliable for further analysis and basis for structuring of the research.

According to official data, Prishtina's residential sector consists of individual low rise houses in majority with 95.55%, followed by apartment blocks with 3.35% and multi-family houses 1.10% (Graph 5.1).



Graphic 5.1 Total residential building share based on building typology

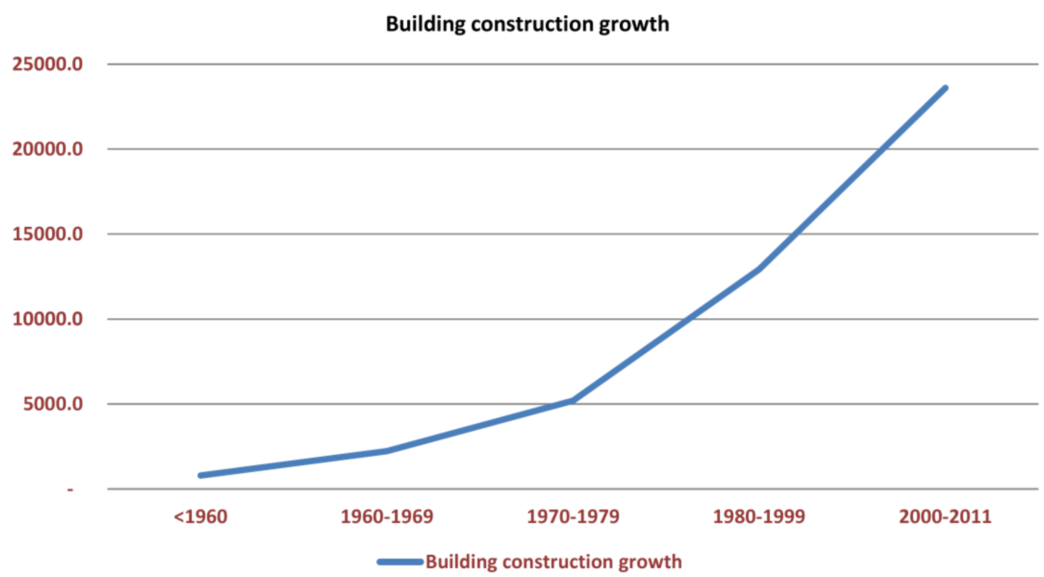
On the other hand the number of dwellings share based on building typology shows different figures as a result of density diversity. RBS consists of 50,24% of dwellings in apartment blocks, followed by single detached houses with 34,93%, multi-family homes with 7,92% and terraced/semidetached houses with 6,91% (Graph 5.2).



Graphic 5.2 Total dwelling building share based on building typology

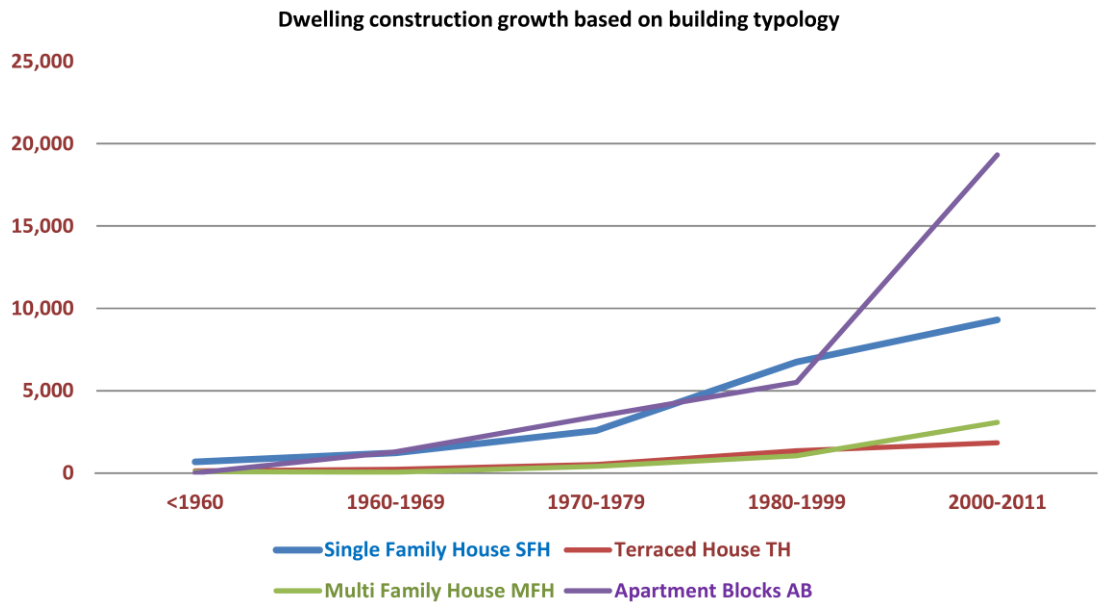
5.3 Residential building shares based on construction period

Prishtina's residential sector showed a continuous growth during 1960 till nowadays (Graph 5.3). It is important to understand the development of each building typology during different periods of time to anticipate future developments of residential sector.



Graphic 5.3 Residential building developments from before 1960 to 2011

During the period of time between 1980 and 2011 the residential sector had the main focus on creating more dwellings within high-rise buildings (graph. 5.4) by using less land and creating more dense settlements and creating a balance between built and green areas.



Graphic 5.4 Development of residential buildings in city of Prishtina based on building typology before 1960 to 2011

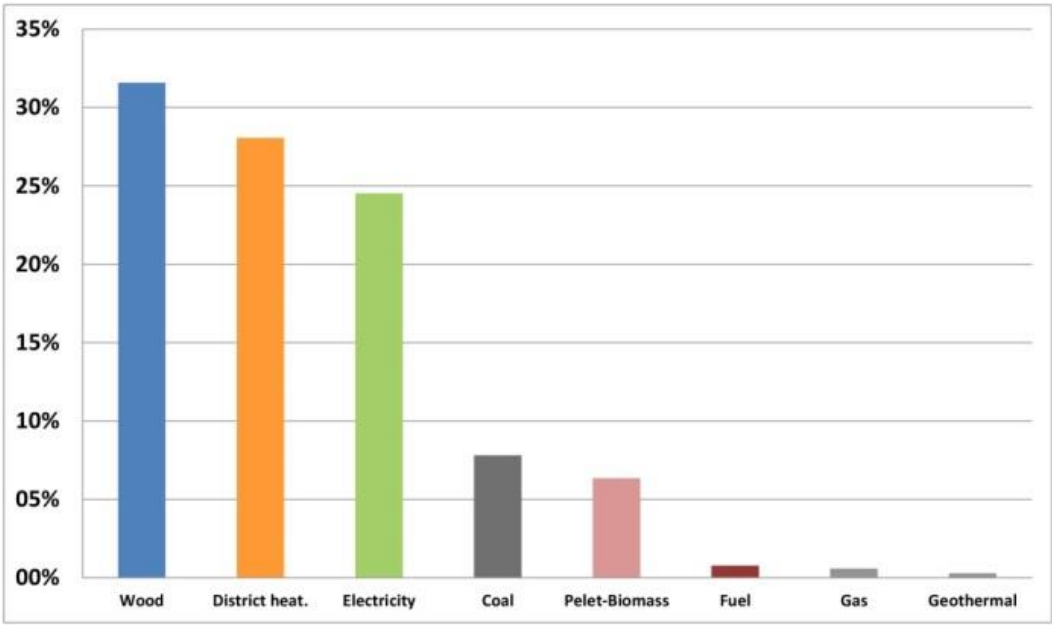
Based on the results generated from the statistical data it is obvious that we may anticipate that the residential building industry will be mostly focused on high-rise buildings with greater density of households.

5.4 Heating energy sources used by residential sector

One of the crucial factors in relation with energy efficiency and especially with environment is the heating energy source used for heating. Heating energy is a component which is also predetermined by heating systems installed and used by the residential sector, but the financial factor is the main factor that predetermines the energy source used for heating.

As part of this study, the data gathered by the conducted field survey it was possible identify all heating energy sources that are being used in city of Prishtina. Not as the main aim of this study but of significant importance, identification of heating carriers and heating systems will help the study to identify the transition of heating systems and heating energy sources in comparison with building developments.

As shown in Graph. 5.5, wood is the main source used for heating by the residential sector with 31.6 % of the overall, followed by district heating 28.1%, electricity 24.5%, coal 7.8%, biomass (pellet) 6.4%, diesel 0.8%, LPG 0.6% and geothermal 0.3% (Graph 5.5).



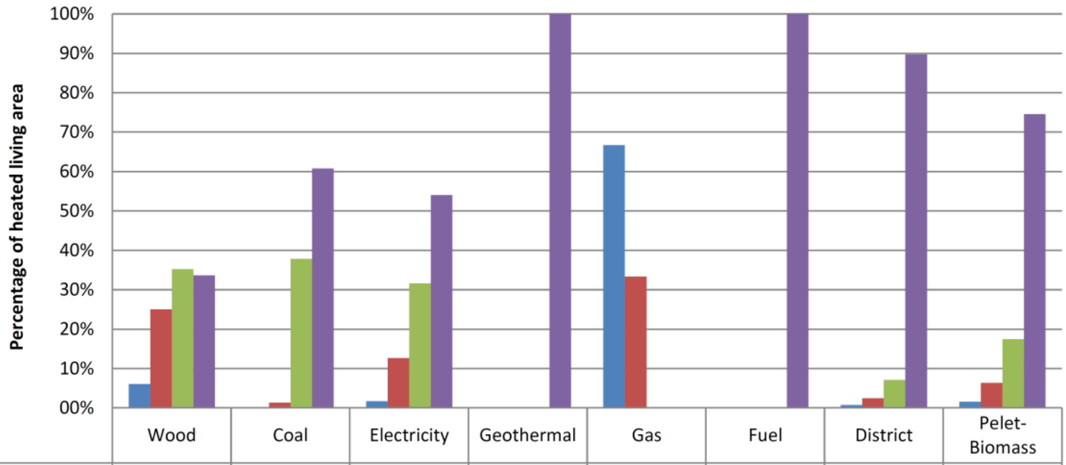
Graphic 5.5 Shares of heating energy sources used by residential sector in city of Prishtina

Figures show that only 36.2% of the overall cases use renewable or environmentally friendly sources for space heating. The majority of residential sector, around 63.8% use wood, electricity, coal and diesel as the main heating energy source.

5.5 Space heating of dwellings based on heating energy sources

Except the environmental impacts and no efficient use of energy sources for heating by residential sector, percentage of heated space of living area is an important indicator that represents the living commodity. According to the survey conducted in city of Prishtina, it shows that the heating energy source and heating systems installed in dwellings, in most cases, predetermine the living commodity based on percentage of heated space of the dwelling.

According to the data gathered on field (Graph. 5.6), the most favorable cases excluding dwellings that use diesel and geothermal which represent only 1% or less of the research results are cases that use District heating and Biomass as a heating energy source. 90% of dwellings that are connected to the District heating heat over 75% of the living space and 75% of dwellings that use biomass with central heating systems heat over 75% of the living space. The most unfavorable cases are dwellings that use LPG of which 67% heat less than 25% of the living space, only 34% of dwellings that use wood heat over 75% of the living space.



	Wood	Coal	Electricity	Geothermal	Gas	Fuel	District	Pelet-Biomass
<1/4 of the living area	06%	00%	02%	00%	67%	00%	01%	02%
1/4 to 1/2 of the living area	25%	01%	13%	00%	33%	00%	02%	06%
1/2 to 3/4 of the living area	35%	38%	32%	00%	00%	00%	07%	17%
above 3/4 of the living area	34%	61%	54%	100%	00%	100%	90%	75%

Graphic 5.6 Percentage of heated area within a dwelling based on heating sources

5.6 Current state of the building elements based on building typology and construction period

To identify the current state of residential buildings in terms of heating loss through transmission, it is crucial to conduct a separate analysis of building thermal envelope elements. By conducting separate analysis it is possible to calculate precisely the heat transmission based on technical specificity of the elements and building type. The calculation and analysis include calculation of heat transmission of opaque elements, assumption of heat transmission of doors and windows, calculation of building shape factor and calculation the thermal envelope area and anticipation of the overall heat transmission for each referent building.

5.6.1 Heat loss through heat transmission/conduction of a referent building

Transmission heat loss through the building envelope is the sum of conductive and radiative heat flows through the building elements (Pietrzyk K. July 2010, p. 80). Majority of heat transfer takes place in buildings through building envelope which consists of walls, roof, floor and windows. In this case main envelope components have been treated separately by dividing the envelope surfaces accordingly (Figure 5.1) with all relevant technical details by analyzing and calculating the amount of heat loss through transmission.

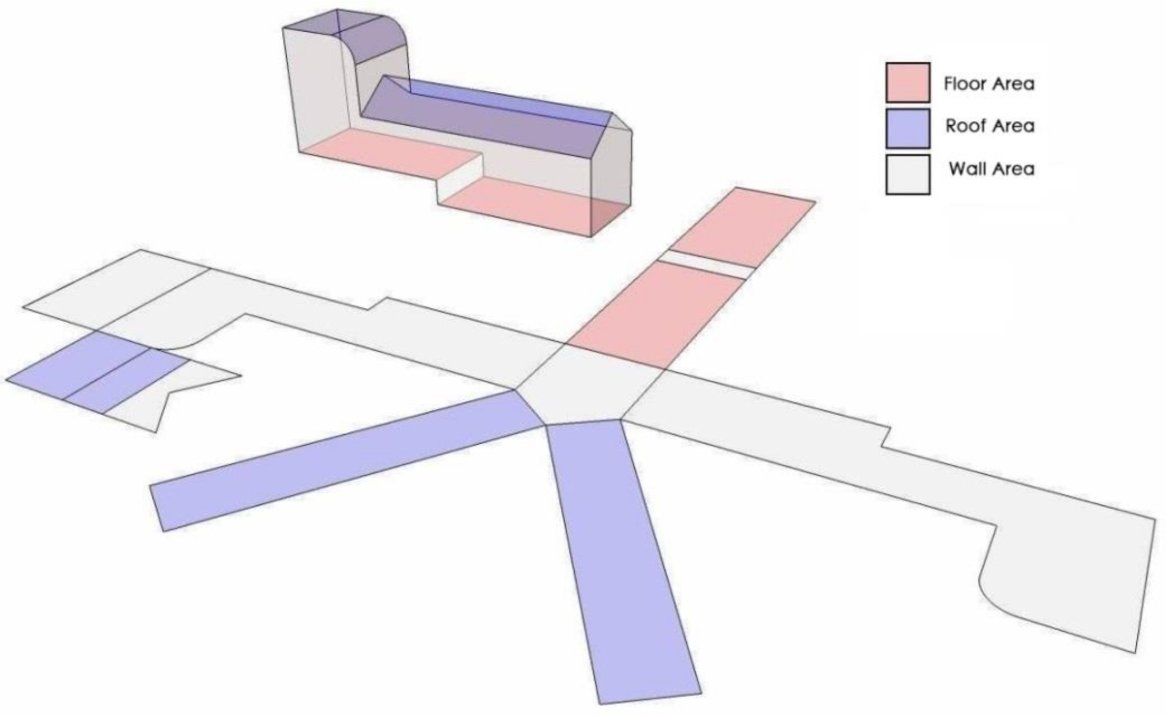


Figure 5.1 The Envelope Area - shown as a flat surface;
Source: https://courses.stroma.com/airtightness/content/1.6%20Envelope%20Area.pdf
Accessed: 07.09.2018

For the calculation of heat transmittance of each building elements (Table 5.1) of each Referent building, all values of thermal conductivity, λ [W/(m·K)], has been use from the Technical Regulation on Thermal Energy Saving and Thermal Protection in Buildings, drafted by the Ministry of Environment and Spatial Planning.

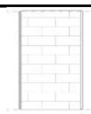
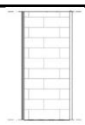
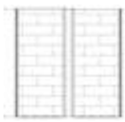
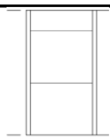
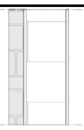
Table 5.1 Calculation of the U-value of building elements of referent buildings

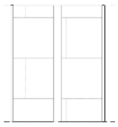
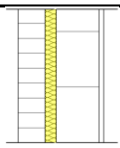
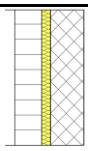
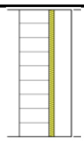
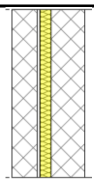
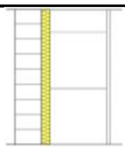
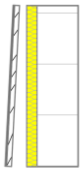
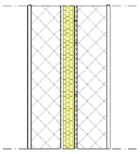
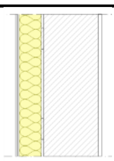
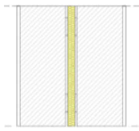
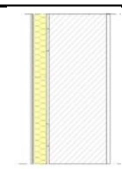
PR.N.AB.04.Gen.ReEx.001			
Wall type 1	1,642.5	m²	
Layer name	d	λ	R
	[mm]	[W/mK]	[m²K/W]
Plaster	20	0.70	0.029
Reinforced concrete	100	2.60	0.038
Glass wool	50	0.04	1.250
Reinforced concrete	100	2.60	0.038
Plaster	20	1.00	0.020
	U-value	**[W/m²K]**	**0.647**

5.6.1.1 Walls

The walls of a building can account for a large proportion of the heat lost through its fabric, and the accurate thermal transmittance of the wall is critically important when assessing energy performance (Soki R. D., Paul B., 2013, p5). Depending on the period of construction and the type of the residential building, walls have been developed with different technical solutions and materialization. Based on analysis and calculations is has been possible identify 16 different types of walls with all relevant technical data (Table 5.2).

Table 5.2 Identified types of walls as part of thermal envelope.

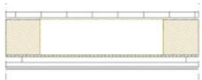
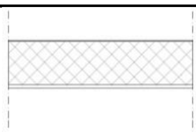
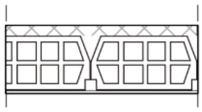
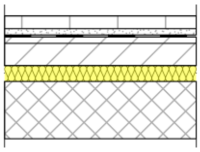
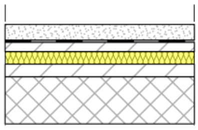
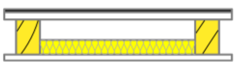
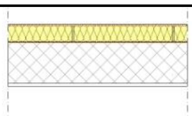
Wall	Layers	Width (m)	Detail	U-value (W/m^{2}K)
Wall 1	Lime plaster Solid clay bricks Cement plaster	0.02 0.45 0.02		1.135
Wall 2	Lime plaster Solid clay bricks Cement plaster	0.02 0.31 0.02		1.45
Wall 3	Lime plaster Solid clay bricks Air cavity Solid clay brick Lime plaster	0.02 0.25 0.03 0.25 0.02		1.19
Wall 4	Lime plaster Clay blocks Cement plaster	0.02 0.25 0.02		1.36
Wall 5	Lime plaster Clay blocks Natural stone	0.02 0.25 0.10		1.27

Wall 6	Lime plaster Clay blocks Air cavity Clay blocks Lime plaster	0.02 0.25 0.05 0.25 0.02		0.785
Wall 7	Lime plaster Clay blocks Thermal insulation Mineral wool Clay brick	0.02 0.19 0.03 0.12		0.737
Wall 8	Lime plaster Reinforced concrete Thermal insulation EPS Clay brick	0.02 0.15 0.04 0.12		0.677
Wall 9	Gypsum wall Thermal insulation EPS Clay brick	0.08 0.02 0.12		0.906
Wall 10	Lime plaster Reinforced concrete Air cavity Thermal insulation EPS Reinforced concrete	0.02 0.07 0.01 0.04 0.12		1.01
Wall 11	Lime plaster Clay blocks Thermal insulation Mineral wool Clay brick	0.02 0.20 0.05 0.12		0.496
Wall 12	Lime plaster Clay blocks Thermal insulation – Mineral wall Air cavity Wooden planks	0.02 0.20 0.05 0.06 0.02		0.479
Wall 13	Lime plaster Prefabricated reinforced concrete Thermal insulation – Mineral wool Prefabricated reinforced concrete Cement plaster	0.02 0.10 0.05 0.10 0.02		0.644
Wall 14	Lime plaster Clay blocks Thermal insulation EPS Cement plaster	0.02 0.25 0.10 0.02		0.289
Wall 15	Lime plaster Clay blocks Thermal insulation EPS Clay blocks Lime plaster	0.02 0.25 0.05 0.25 0.02		0.396
Wall 16	Lime plaster Clay blocks Thermal insulation EPS Cement plaster	0.02 0.25 0.05 0.02		0.57

5.6.1.2 Roof

Limiting the $Uroof$ helps in reducing heat gains or losses from the roof, thereby improving thermal comfort and reducing the energy required for cooling or heating (Bureau of Energy Efficiency Energy Conservation Building Code for Residential Buildings 2017). Considering the roof as one of the main building envelope elements with a significant influence in heating loss the study identified the diversity of roof types in each referent building by generating the thermal transmittance values and graphical presentation (Table 5.3).

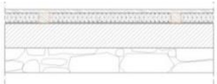
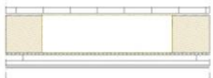
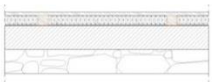
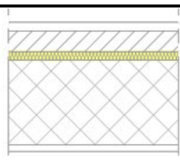
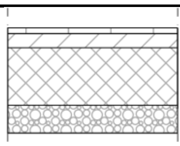
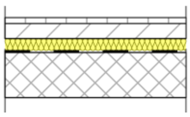
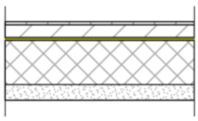
Table 5.3 Identified types of celling-roof as part of thermal envelope.

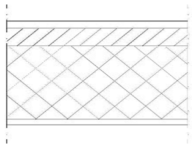
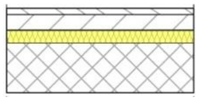
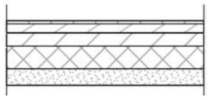
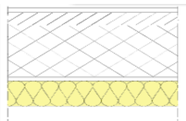
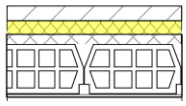
Roof	Layers	Thickness	Detail	U-value (W/m^{2}K)
Roof 1	Straw plaster Air space/timber constr. beams Wooden planks	0.025 0.16 0.015		1.61
Roof 2	Lime plaster Reinforced concrete	0.02 0.20		4.134
Roof 3	Lime plaster Reinforced concrete with hollow clay infill block	0.020 0.20		2.46
Roof 4	Reinforced concrete Thermal insulation EPS Perlite concrete Waterproof layer Sand Concrete tiles	0.18 0.05 0.05-0.15 0.08 0.02 0.04		0.361
Roof 5	Reinforced concrete Perlite concrete Thermal insulation Polyurethane Concrete Waterproof layer Sand	0.18 0.04 0.04 0.03 0.04 0.05		0.565
Roof 6	Gipsum board Timber construct. Beams/air space Thermal insulation – Mineral wool Wooden planks	0.02 0.10/0.05 0.05 0.024		0.624
Roof 7	Lime plaster Reinforced concrete Thermal insulation EPS	0.02 0.20 0.10		0.361

5.6.1.3 Floor

The only floor surface area that should be included in the Envelope Area calculation is that of the lowest floor(s) of the treated building, below which is ground, or unconditioned space (such as a car park or undercroft), or a separate building (Stroma Technology, *Envelope Area Definition, 2008, p. 2*). In the case of this study only residential area has been treated and all other areas have been considered as unconditioned space. During the data collection, analysis and calculations, 13 different types of slabs has been identified with different technical specifications and materials (Table 5.4).

Table 5 4 Identified types of slabs as part of thermal envelope

Slab	Layers	Thickness	Detail	U-value (W/m^{2}K)
Slab 1	Wooden planks Sand bedding Concrete	0.025 0.05 0.20		2.09
Slab 2	Wooden planks Air space/Timber constr. beams Straw plaster	0.025 0.18 0.03		1.61
Slab 3	Wooden planks Lightweight concrete Waterproof layer Concrete	0.025 0.10 0.004 0.10		1.742
Slab 4	Parquet Lightweight concrete Wooden fiber board Reinforced concrete Lime plaster	0.025 0.05 0.02 0.20 0.02		1.339
Slab 5	Parquet Lightweight concrete Waterproof layer Reinforced concrete	0.025 0.05 0.004 0.20		3.27
Slab 6	Parquet Lightweight concrete PVC foil Thermal insulation EPS Waterproof layer Reinforced concrete	0.02 0.05 0.001 0.04 0.004 0.15		0.706
Slab 7	Ceramic tiles Lightweight concrete PVC foil Thermal insulation EPS Reinforced concrete Durisol-cement/wooden fiber	0.01 0.04 0.001 0.01 0.14 0.05		0.90

Slab 8	Parquet Lightweight concrete Waterproof layer Reinforced concrete Lime plaster	0.025 0.05 0.004 0.20 0.02		2.171
Slab 9	Parquet Lightweight concrete Thermal insulation EPS Waterproof layer Reinforced concrete Lime plaster	0.025 0.05 0.004 0.20 0.02		0.588
Slab 10	Parquet Lightweight concrete PVC foil Perlite concrete Water proof layer Reinforced concrete	0.020 0.035 0.001 0.06 0.003 0.20		1.02
Slab 11	Parquet Lightweight concrete Water proof layer Reinforced concrete Thermal Insulation XPS	0.025 0.05 0.004 0.20 0.10		0.338
Slab 12	Parquet Lightweight concrete Thermal insulation EPS Water proof layer Reinforced concrete	0.025 0.05 0.10 0.004 0.20		0.183
Slab 13	Parquet Lightweight concrete Thermal insulation EPS Reinforced concrete with hollow clay infill block Lime plaster	0.025 0.05 0.05 0.20 0.02		0.59

5.6.1.4 Windows

Beside all these positive functions, it must be considered that windows represent the weak element of the envelope of a building, since it is through them that thermal exchanges between indoor and outdoor environments mainly take place (A. Maccari, December 2001, p 75-92.). Windows as one of the most complex elements of the thermal envelope and their properties have been assumed. The assumptions of the values have been based generated from the values presented by other countries in TABULA web-tool and appropriated as an overall average value. In this case the diversity of values have been based on the number of panes, type of glazing (with or without low-E) and frame material (Table 5.5) (Evaluation of the TABULA Database, countries, http://episcope.eu/fileadmin/tabula/public/docs/report/TABULA_WorkReport_EvaluationDatabase.pdf).

Table 5.5 Identified types of windows as part of thermal envelope

Window	**Glazing**	**Frame**	**Assumed U-value (W/m^{2}K)**
Window 1	Single glazed	Iron	5.6
Window 2	Double framed/single glazed	Wooden	4.8
Window 3	Double glazed	Wooden	2.6
Window 4	Double glazed	PVC	2.5
Window 5	Double glazed with Low-E	PVC	1.5

5.6.2 Shape factor

The shape factor of a building is a measure of the building’s compactness and expresses the ratio between the building’s thermal envelope area and its volume (Itai D., Morgan F., Anna, J., *2018*). The component of the building shape factor represents the approach of the designers during different period of building construction in one hand and the effect of the factor towards energy loss and potential for energy efficiency of each building type of the residential sector (Table 5.6).

Table 5.6 Calculation of the shape factor of referent buildings

Referent building		Referent building envelope surface m^2	Referent building volume m^3	Ref. building shape factor (S/V) f_o m^{-1}
ReEx 1.1	***<1960***	290.5	210.6	**1.379**
ReEx 2.1		302.7	280	**1.08**
ReEx 3.1		818.1	2236	**0.365**
ReEx 1.2	***1960-1969***	318.21	238.21	**1.335**
ReEx 2.2		245.2	152.88	**1.60**
ReEx 3.2		668.4	754	**0.886**
ReEx 4.2		1019.4	2667.6	**0.382**
ReEx 1.3	***1970-1979***	490.9	598	**0.824**
ReEx 2.3		504.3	893.58	**0.564**
ReEx 3.3		2833.05	3926.81	**0.721**
ReEx 4.3		2182.6	5574.44	**0.391**
ReEx 1.4	***1980-1999***	379.6	412.36	**0.92**
ReEx 2.4		573.9	1033.5	**0.555**
ReEx 3.4		818.0	1790.23	**0.456**
ReEx 4.4		2515.8	4276.08	**0.588**

ReEx 1.5	*After 2000*	733.3	834.75	**0.878**
ReEx 2.5		383.4	291.5	**1.31**
ReEx 3.5		1802.6	4142.88	**0.435**
ReEx 4.5		5456	16149.1	**0.337**

5.6.3 Window (non-opaque) to wall (opaque) ratio (WWR) of referent buildings

Table 5. 7 Calculation of the WWR relation of the referent buildings

Referent building	Referent building opaque surface m^2	Referent building opening surface m^2	Opaque surface share %	Opening surface share %
ReEx 1.1	95.9	11.7	**89.1%**	**11%**
ReEx 2.1	161.9	19.7	**89.2%**	**10.8%**
ReEx 3.1	323.5	64.3	**83.4%**	**16.6%**
ReEx 1.2	101.96	11.5	**89.9%**	**10.1%**
ReEx 2.2	91.0	8.4	**91.5%**	**8.5%**
ReEx 3.2	324.7	52.2	**86.4%**	**13.8%**
ReEx 4.2	381.0	205.0	**65.0%**	**35.0%**
ReEx 1.3	194.0	36.9	**84.0%**	**16.0%**
ReEx 2.3	260.0	47.4	**84.6%**	**15.4%**
ReEx 3.3	1511.0	240.2	**86.3%**	**13.7%**
ReEx 4.3	983.9	389.6	**71.6%**	**28.4%**
ReEx 1.4	195.4	22.7	**89.6%**	**10.4%**
vReEx 2.4	245.3	35.3	**87.4%**	**12.6%**
ReEx 3.4	329.8	98.2	**77.1%**	**22.9%**
ReEx 4.4	1642.5	200.4	**89.1%**	**10.9%**
ReEx 1.5	437.5	36.6	**82.3%**	**7.7%**
ReEx 2.5	135.0	18.4	**88.0%**	**12.0%**
ReEx 3.5	755.0	173.1	**81.3%**	**18.7%**
ReEx 4.5	3439.9	1090	**75.9%**	**24.1%**

5.6.4 Total heat loss through transmission of referent buildings

To generate the total heat loss through transmission, all relevant components have been included in the calculations. For the calculation of the total heat loss of each referent building the TABULA web tool has been used. Based on the building envelope data gathered from the layout/design descriptions and on field analysis, structured and presented within this chapter, it has been possible to generate the annual energy demand for heating related to the heated area of the building.

According to the calculations it has been possible to generate the results of total heat transfer by transmission and the heat transfer per square meter (m^2) for each referent building and generate the energy need for heating.

Table 5.8 Current heating energy demand of referent buildings

Building typology				
	Single Family Houses	**Terraced Houses**	**Multi-Family Houses**	**Apartment Blocks**
Construction period	**Annual heat demand related to $A_{C,Ref}$ [kWh/m²a]**			
Before1960	314.83	223.54	168.47	n/a
1960-1969	300.86	282.06	279.76	148.82
1970-1979	251.10	156.18	158.27	95.15
1980-1999	220.82	124.96	153.94	110.04
After 2000	72.80	100.07	95	49.95

5.7 Summary

As a summary of this chapter, after all detailed analysis of generated data, statistical and technical, it has been possible to create a wider and more detailed overview of the current state of the RBS in city of Prishtina and also more detailed structuring of all relevant technical data for further findings of this study. All the findings presented on this chapter subserved the study by identifying and understanding the current state of each building typology which has been considered crucial and basis for further steps of the study. It is notable that the usage of materials has evolved during different periods which in one way contributed on decrement of the energy loss. Also the windows and building shape factor evolved in terms of materials and the geometry of the building, respectively. On the other side the WWR remained mostly unchanged with some exclusion by keeping the relation between opaque and transparent surfaces of the envelope mostly unchanged.

Structuring of all generated statistical and technical data generated a fundamental matrix with a specific approach related to the focus of this study (Appendix 2). The matrix will now on be the main database of the study but may be also used for any other study related to RBS as a reliable source of technical information even for official use by the public institutions such as Prishtina Municipality and Ministry of Environment and Spatial Planning of Kosovo.

CHAPTER SIX

6 RENOVATION INTERVENSIONS AS A MEASURE FOR ENERGY SAVING

6.1 Introduction

The previous chapter was focused of current situation of the residential building stock and offered measurable data for each specific building type based on referent building. On the other hand this chapter presents the potential standardized measures that can be taken for decreasing the heating energy loss in residential building stock. The same measures may be used also as a guideline for future constructed buildings.

Considering the fact that building standards nowadays and in perspective tempts to improve in terms of quality with a specific focus on energy saving and decrement of CO_2 emission, the proposed measures are categorized in two different categories. First category "standard measures" attempts to offer an optimal solution and the second category "advanced measures" attempts to offer an advanced solution.

The collected set of real buildings serve as showcase examples to demonstrate the effect of refurbishment measures. There are three variants of each building:

- "Existing State":
  Typical state of a non-refurbished building
- "Usual Refurbishment":
  Package of measures for upgrading the thermal envelope which are commonly realized during renovation;
- "Advanced Refurbishment":
  Package of measures for upgrading the thermal envelope which are usually only realized in very ambitious renovations or research projects. (TABULA Project Team, 2012, p. 9)

6.2 Standard/Optimal measures

It is evident that currently state of the majority of RSB consists of buildings with bad conditions in terms of heating energy conservation as a result of absence of correct thermal solutions or used materials. To change the current situation it is crucial to design a standardized solution which would increase the heating energy savings by decreasing heating energy loss through the building envelope.

The “Standard measure” would be the first solution that would meet minimum standards determined by the current Technical Regulation on Thermal Saving and Thermal Protection in Buildings (TRTSTPB). The TRTSTPB determines various components of the building as measures for energy saving in buildings, including residential buildings. According to the TRTSTPB main building envelope components such as walls, roofs, floors and windows have the obligatory maximum allowed heating transmission which has to be applied on new buildings. However the existing RBS does not meet the obligatory determined standard according to TRTSTPB.

The proposed “Standard measure” for the existing building refurbishment tends to improve the building state in a level of minimum requirements determined by the TRTSTPB. According to the TRTSTPB, for exterior walls the heat transmission should not exceed 0.35 W/m^2K and roofs should not exceed 0.30 W/m^2K. Windows in cases when the building will be heated 18ºC or higher than the heat release U [W/(m2·K)] should not exceed 1.8 W/m^2K. In buildings with heating temperature higher than 12ºC, the heat release coefficient U [W/(m2·K)] of external doors and non-translucent door side, full doors, shall not be higher than ≤ 2.90 $W/(m^2 \cdot K)$ (Technical regulation on thermal energy saving and thermal protection in buildings, 2009. In this case, the majority of the existing buildings do not meet the criteria, which means that most of the existing building must go through a refurbishment process.

Considering the TRTSTPB as the only current regulation in Kosovo which determines the maximum heating transmission on building elements, the same definitions has been respected in this study’s recommended measures by applying insulation measures to decrease the heat transmission value U [W/(m2·K)] according to the regulation. Each building based on type and construction period has been treated separately by generating new transmission value U [W/(m2·K)] (APENDIX 3).

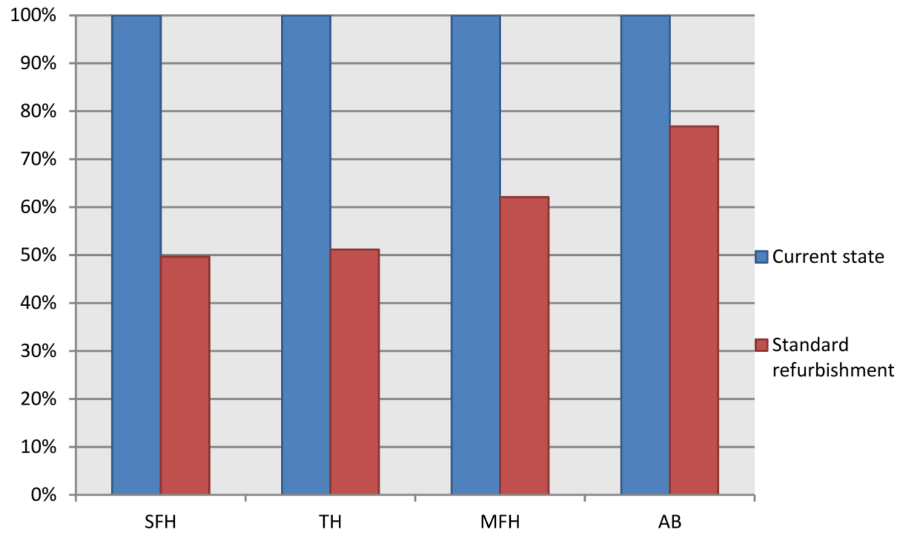
The same has been applied for floors and roofs by respecting the TRTSTPB (APENDIX 3)

In case of windows and entrance doors has been appropriated lower values that determined by the TRTSTPB. Windows has been appropriated with 1.6 W/m^2K instead of 1.8 W/m^2K and for entrance doors 2.6 W/m^2K instead of 2.9 W/m^2K (APENDIX 3)

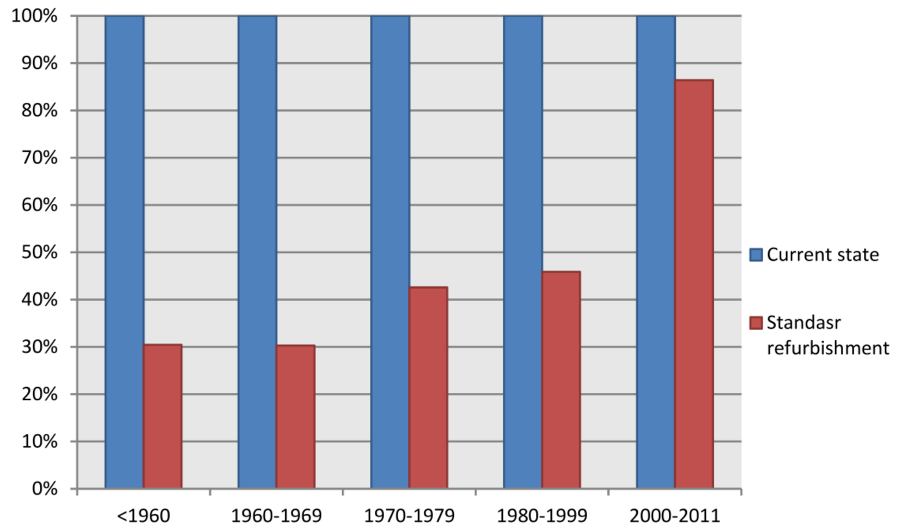
By implementing the standard refurbishment measures it was possible to meet the criteria set by the TRTSTPB for each building element of each building type and construction period. In this way it has been possible to conceive a correlation between current state of the heating loss and the potential of energy savings by implementing the “Standard refurbishment” measures.

6.2.1 Potential savings after implementation of the “Standard refurbishment” measures

The current state of the RBS in majority doesn’t comply with TRTSTPB criteria for heating transmission through building envelope. By applying the “Standard refurbishment” measures to the existing buildings of the RBS it is evident that calculations represent emphatic results. Implementation of current mandatory criteria of the TRTSTPB it has been possible to decrease the energy consumption for heating as a result of refurbishment of thermal envelope. In this case it has been possible to decrease the total energy consumption by 26.73% of the overall energy consumption used for heating, including the entire RBS. Based on building typology the decrement varies as a result of building type diversity where for SFH the potential of energy saving reaches 51.34%, TH 48.84%, MFH 37.92% and AB 23.14% (Graphic 6.1). On the other hand the energy saving s based on construction period logically starts with considerable savings in old buildings and less in new buildings with 69.56% buildings constructed before 1960, 69.72% for buildings constructed between 1960-1969, 57.38% for buildings constructed between 1970-1979, 54.11% for buildings constructed between 1980-1999 and 13.59% for buildings constructed between after 2000 (Graphic 6.2).



Graphic 6.1 Potential savings after implementation of "Standard refurbishment" measures based on building typology



Graphic 6.2 Potential savings after implementation of "Standard refurbishment" measures based construction period

Furthermore, a more detailed analysis of improvement results is possible, based onbuilding type and construction period. In this way it is possible to present measurable results of improvements for each referent building and the potential of energy saivings (Table 6.1, Table 6.2, Table 6.3, and Table 6.4).

Table 6.1 Improvements of energy demand after implementation of "Standard refurbishment" measures, Single family houses.

SINGLE FAMILY HOUSES							
		Total heat transmission through transmission kWh/a	Solar and internal heat gains	Total energy need for heating kWh/a	Referent area m²	Heating energy demand kWh/m²a	Improvements %
<1960	Current state	27338.00	1952.00	25501.10	81.00	314.83	0%
	Standard refurbishment	8442.52	1952.00	6618.81	81.00	81.71	-74%
1960-1969	Current state	29544.10	2105.10	27558.70	91.60	300.86	0%
	Standard refurbishment	8697.7	2105.10	6721.3	91.60	73.38	-76%
1970-1979	Current state	58061.00	5153.90	53233.40	212.00	251.10	0%
	Standard refurbishment	19235.8	5153.90	14428.4	212.00	68.06	-73%
1980-1999	Current state	38688.80	3920.00	35044.80	158.70	220.82	0%
	Standard refurbishment	13444.7	3920.00	9814.1	158.70	61.84	-72%
After 2000	Current state	35383.00	9191.60	26827.90	368.50	72.80	0%
	Standard refurbishment	32072.9	9191.60	23527.8	368.50	63.85	-12%

Table 6.2 Improvements of energy demand after implementation of "Standard refurbishment" measures, Terraced houses.

TERRACED HOUSES							
		Total heat transmission through transmission kWh/a	Solar and internal heat gains	Total energy need for heating kWh/a	Referent area m²	Heating energy demand kWh/m²a	Improvements %
<1960	Current state	29467.60	3184.40	26512.20	118.60	223.54	0%
	Standard refurbishment	10316.5	3184.40	7383.1	118.60	62.25	-72%
1960-1969	Current state	18007.65	1490.60	16585.06	58.80	282.06	0%
	Standard refurbishment	6877.18	1490.60	5465.372	58.80	92.95	-67%
1970-1979	Current state	63048.60	7736.90	55757.40	357.00	156.18	0%
	Standard refurbishment	26486.7	7736.90	19192.9	357.00	53.76	-66%
1980-1999	Current state	49121.00	7010.90	42486.80	340.00	124.96	0%
	Standard refurbishment	28053	7010.90	21408.1	340.00	62.97	-50%
After 2000	Current state	13858.80	2999.90	11088.30	110.80	100.07	0%
	Standard refurbishment	12257.5	2999.90	9489.1	110.80	85.64	-14%

Table 6.3 Improvements of energy demand after implementation of “Standard refurbishment” measures, Multi-family houses

MULTI-FAMILY HOUSES							
		Total heat tranfes through transmission kWh/a	Solar and internal heat gains	Total energy need for heating kWh/a	Referent area m²	Heating energy demand kWh/m²a	Improvements %
<1960	Current state	98697.10	11466.80	87858.80	521.50	168.47	0%
	Standard refurbishment	47959.6	11466.80	37099.2	521.50	71.14	-58%
1960-1969	Current state	102949.70	8325.60	95117.80	340.00	279.76	0%
	Standard refurbishment	30013.4	8325.60	22213.60	340.00	65.33	-77%
1970-1979	Current state	260566.60	35663.60	227162.60	1435.30	158.27	0%
	Standard refurbishment	141580.4	35663.60	108189.20	1435.30	75.38	-52%
1980-1999	Current state	91289.40	13573.40	78646.60	510.90	153.94	0%
	Standard refurbishment	48638.4	13573.40	36027.90	510.90	70.52	-54%
After 2000	Current state	174562.90	32207.50	143994.60	1510.90	95.30	0%
	Standard refurbishment	129647	32207.50	99064.20	1510.90	65.57	-31%

Table 6.4 Improvements of energy demand after implementation of “Standard refurbishment” measures, Apartment blocks

APARTMENT BLOCKS							
		Total heat transmission through transmission kWh/a	Solar and internal heat gains	Total energy need for heating kWh/a	Referent area m²	Heating energy demand kWh/m²a	Improvements %
1960-1969	Current state	169218.20	27296.10	143935.50	967.20	148.82	0%
	Standard refurbishment	70112.9	27296.10	45097.9	967.20	46.63	-69%
1970-1979	Current state	256153.90	55950.00	204002.50	2144.00	95.15	0%
	Standard refurbishment	144304.3	55950.00	92536.8	2144.00	43.16	-55%
1980-1999	Current state	215101.60	36061.60	180970.10	1644.60	110.04	0%
	Standard refurbishment	124378.7	36061.60	90244.4	1644.60	54.87	-50%
After 2000	Current state	403881.40	145229.80	269728.80	5400.00	49.95	0%
	Standard refurbishment	370811.8	145229.80	236958.4	5400.00	43.88	-12%

6.2.2 Increment of internal surfaces temperatures and living commodity

Application of standard refurbishment measures of the thermal envelope and replacement of windows has an impact not only in decrement of energy loss through transmission but also in decrement of temperature of internal surfaces of building shell. The results show that the living commodity can be decreased by applying the additional or replacement of thermal insulation on external walls, roof and floors, by increasing the temperature of the surface with different values depending on the typology of the building and building element respectively.

By applying standard refurbishment measures it is evident that in specific cases significant decrements of the interior surfaces has been achieved by weighted average impact of the internal surfaces temperature of walls by applying standard measures is 11%, for roofs 18% and floors 10%. The temperature difference between internal surface of the shell temperature and internal air temperature with maximum of 0.97°C and minimum 0.71°C for roofs (Table 6.5), maximum of 1.36 °C and minimum 0.86°C for walls (Table 6.6) and maximum of 1.55°C and minimum 0.52°C for floors (Table 6.7). The increment of internal surface temperature T_{si} shows the potential of increasing the living commodity within the dwellings by transforming the living spaces into more healthy environments and preventing any possible condensation and creation of the mold within interior surfaces.

Table 6.5 Increment of internal surface temperature of roof after implementation of “Standard refurbishment” measures

	Surface temperature Tsi [°C] Current state	Surface temperature Tsi [°C] Standard measures	Improvements [%]
Roof 1	13.98	20.29	31%
Roof 2	8.19	20.04	59%
Roof 3	15.30	20.03	24%
Roof 4	19.88	20.05	1%
Roof 5	19.26	20.05	4%
Roof 6	19.27	20.12	4%
Roof 7	19.87	20.27	2%

Table 6.6 Increment of internal surface temperature of external walls after implementation of "Standard refurbishment" measures

	Surface temperature Tsi [°C] Current state	Surface temperature Tsi [°C] Standard measures	Improvements [%]
Wall 1	16.40	19.81	17%
Wall 2	14.99	19.73	24%
Wall 3	14.08	19.69	28%
Wall 4	15.88	19.77	20%
Wall 5	18.61	20.14	8%
Wall 6	18.26	19.64	7%
Wall 7	17.66	19.74	11%
Wall 8	18.22	19.83	8%
Wall 9	18.80	19.69	5%
Wall 10	19.15	19.82	3%
Wall 11	18.37	19.67	7%
Wall 12	19.75	19.75	n/a
Wall 13	18.96	19.75	4%

Table 6.7 Increment of internal surface temperature of floors after implementation of "Standard refurbishment" measures

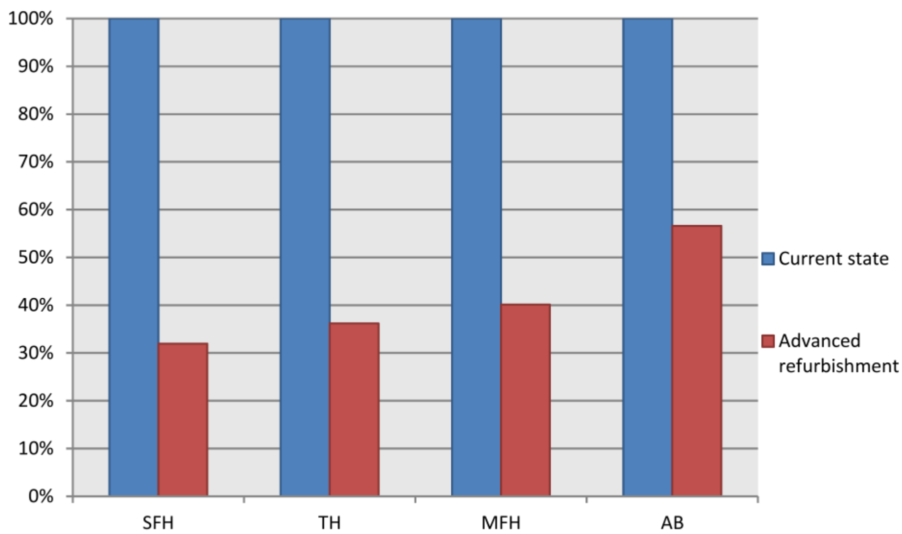
	Surface temperature Tsi [°C] Current state	Surface temperature Tsi [°C] Standard measures	Improvements [%]
Floor 1	15.86	19.73	20%
Floor 2	17.66	19.70	10%
Floor 3	15.23	19.70	23%
Floor 4	18.74	20.39	8%
Floor 5	15.87	19.73	20%
Floor 6	19.45	19.45	0%
Floor 7	18.01	19.92	10%
Floor 8	17.28	19.84	13%
Floor 9	19.63	20.48	4%
Floor 10	19.25	20.43	6%
Floor 11	19.99	19.99	0%

6.3 Advanced measures

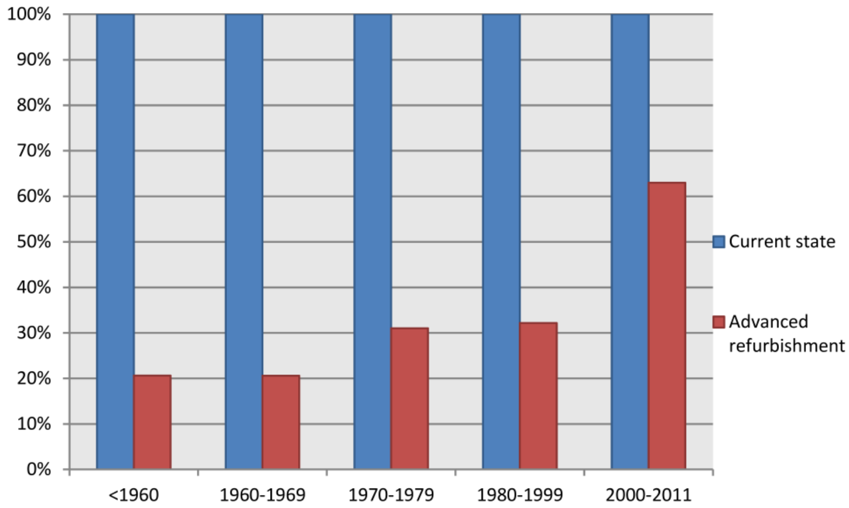
Considering the perspective of building sustainability and nearly zero energy buildings (NZEB) as one of the objectives of the EU by setting minimum energy consumption, it is important that we set also high standard criteria for building insulation which can be considered as a second scenario for residential building stock refurbishments aside the new buildings. In this case based on calculations for current state of the residential building stock and "Standard measures", it is also possible to design "Advanced refurbishment" measures which would offer a higher efficiency scenario for city of Prishtina. In this case measured that has been applied as part of “Advanced refurbishment” aim to lower the transmission values of heat loss through building envelope elements by setting the limits for exterior walls heat transmission value U ≤ 0.180 W/m’K, for roofs U ≤ 0.180 W/m’K, floors U ≤ 3.50 W/m’K, windows U ≤ 0.10 W/m’K and entrance doors U ≤ 0.15 W/m’K (APENDIX 3).

6.3.1 Potential savings after implementation of the “Advanced refurbishment” measures

By applying the “Advanced refurbishment” measures it is possible to decrease the energy consumption for heating as a result of refurbishment of thermal envelope and window replacement. In this case it is possible to decrease the total energy consumption by 46.84% of the overall energy consumption used for heating, including the entire RBS. Based on building typology the decrement varies as a result of building type diversity where for SFH the potential of energy saving reaches 68.04%, TH 63.81%, MFH 59.89% and AB 43.40% (Graphic 6.3). On the other hand the energy saving s based on construction period logically starts with considerable savings in old buildings and less in new buildings with 79.39% buildings constructed before 1960, 79.43% for buildings constructed between 1960-1969, 69.00% for buildings constructed between 1970-1979, 67.82% for buildings constructed between 1980-1999 and 37.00% for buildings constructed between after 2000 (Graphic 6.4)..



Graphic 6 3 Potential savings after implementation of “Advanced refurbishment” measures based on building typology



Graphic 6 4 Potential savings after implementation of “Advanced refurbishment” measures based construction period

For more accurate analysis of the improvement results after implementation of the “Advanced refurbishment” measures, each referent building results has been generated (Table 6.8, Table 6.9, Table 6.10 and Table 6.11). In this way it is possible to conduct separate analysis for each referent building for further studies.

Table 6.8 Improvements of energy demand after implementation of “Advanced refurbishment” measures, Single family houses.

SINGLE FAMILY HOUSES							
		Total heat transmission through transmission kWh/a	Solar and internal heat gains	Total energy need for heating kWh/a	Referent area m²	Heating energy demand kWh/m²a	Improvements %
<1960	Current state	27338.00	1952.00	25501.10	81.00	314.83	0%
	Advanced refurbishment	6089	1952.00	4270.7	81.00	52.72	-83%
1960-1969	Current state	29544.10	2105.10	27558.70	91.60	300.86	0%
	Advanced refurbishment	6449.7	2105.10	4478.9	91.60	48.90	-84%
1970-1979	Current state	58061.00	5153.90	53233.40	212.00	251.10	0%
	Advanced refurbishment	13594.10	5153.90	8813.5	212.00	41.57	-83%
1980-1999	Current state	38688.80	3920.00	35044.80	158.70	220.82	0%
	Advanced refurbishment	10354.60	3920.00	6741	158.70	42.48	-81%
After 2000	Current state	35383.00	9191.60	26827.90	368.50	72.80	0%
	Advanced refurbishment	23436.70	9191.60	14943.6	368.50	40.55	-44%

Table 6.9 Improvements of energy demand after implementation of “Advanced refurbishment” measures, Terraced houses.

TERRACED HOUSES							
		Total heat transmission through transmission kWh/a	Solar and internal heat gains	Total energy need for heating kWh/a	Referent area m²	Heating energy demand kWh/m²a	Improvements %
<1960	Current state	29467.60	3184.40	26512.20	118.60	223.54	0%
	Advanced refurbishment	7654.2	3184.40	3184.4	118.60	26.85	-88%
1960-1969	Current state	18007.65	1490.60	16585.06	58.80	282.06	0%
	Advanced refurbishment	4818.43	1490.60	3436.477	58.80	58.44	-79%
1970-1979	Current state	63048.60	7736.90	55757.40	357.00	156.18	0%
	Advanced refurbishment	22627.30	7736.90	15345.9	357.00	42.99	-72%
1980-1999	Current state	49121.00	7010.90	42486.80	340.00	124.96	0%
	Advanced refurbishment	22290.80	7010.90	15654.2	340.00	46.04	-63%
After 2000	Current state	13858.80	2999.90	11088.30	110.80	100.07	0%
	Advanced refurbishment	8588.20	2999.90	5835.1	110.80	52.66	-47%

Table 6.10 Improvements of energy demand after implementation of “Advanced refurbishment” measures, Multi-family houses

MULTI-FAMILY HOUSES							
		Total heat transmission through transmission kWh/a	Solar and internal heat gains	Total energy need for heating kWh/a	Referent area m²	Heating energy demand kWh/m²a	Improvements %
<1960	Current state	98697.10	11466.80	87858.80	521.50	168.47	0%
	Advanced refurbishment	40546.7	11466.80	29693.5	521.50	56.94	-66%
1960-1969	Current state	102949.70	8325.60	95117.80	340.00	279.76	0%
	Advanced refurbishment	23550.7	8325.60	15775.80	340.00	46.40	-83%
1970-1979	Current state	260566.60	35663.60	227162.60	1435.30	158.27	0%
	Advanced refurbishment	116398.4	35663.60	83072.20	1435.30	57.88	-63%
1980-1999	Current state	91289.40	13573.40	78646.60	510.90	153.94	0%
	Advanced refurbishment	39037.5	13573.40	26472.50	510.90	51.82	-66%
After 2000	Current state	174562.90	32207.50	143994.60	1510.90	95.30	0%
	Advanced refurbishment	91511.9	32207.50	60999.00	1510.90	40.37	-58%

Table 6.11 Improvements of energy demand after implementation of "Advanced refurbishment" measures, Apartment blocks

APARTMENT BLOCKS							
		Total heat transmission through transmission kWh/a	Solar and internal heat gains	Total energy need for heating kWh/a	Referent area m²	Heating energy demand kWh/m²a	Improvements %
1960-1969	Current state	169218.20	27296.10	143935.50	967.20	148.82	0%
	Advanced refurbishment	55277.7	27296.10	30510.4	967.20	31.55	-79%
1970-1979	Current state	256153.90	55950.00	204002.50	2144.00	95.15	0%
	Advanced refurbishment	119295.9	55950.00	67872.2	2144.00	31.66	-67%
1980-1999	Current state	215101.60	36061.60	180970.10	1644.60	110.04	0%
	Advanced refurbishment	97114.2	36061.60	63072.8	1644.60	38.35	-65%
1999-2018	Current state	403881.40	145229.80	269728.80	5400.00	49.95	0%
	Advanced refurbishment	2919.2	145229.80	175702.6	5400.00	32.54	-35%

Based on the data generated after implementing advanced measures, it is possible to decrease the energy need for heating between 35% - 88%, depending on building type and year of construction. There results show a significant decrement of the energy needs for heating by reaching the low energy building standards by applying only refurbishment measures on the building envelope and windows. The results show that low-energy residential construction is a rational investment choice, even at higher initial cost (Jonsson A. Z., 2011, p.17). The best low energy designs not only produce reductions in energy costs but also offer occupants the potential for higher quality environments and more stable and controlled levels of thermal comfort. (Pitts A., 2017, p. 22)

6.3.2 Increment of internal surfaces temperatures and living commodity

Application of advanced refurbishment measures of the thermal envelope had a slightly higher impact on increment of internal surfaces temperatures compared to the standard refurbishment measures. Although the advanced measures resulted with creation of higher living commodity by leaving a slight temperature difference between internal surface of the shell temperature and internal air temperature with maximum of 0.60°C and minimum 0.56°C for roofs (Table 6.12), maximum of 0.77 °C and minimum 0.65°C for walls (Table 6.13) , and maximum of 0.73 °C and minimum 0.32°C for floors (Table 6.14).

The temperature differences achieved by applying the advanced refurbishment measures insures a high quality living spaces within dwellings by minimize the temperature differences bellow 1°C between internal surface of the building envelope and internal air when external temperatures are -10°C.

Table 6.12 Increment of internal surface temperature of roof after implementation of "Advanced refurbishment" measures

	Surface temperature Tsi [°C] Current state	Surface temperature Tsi [°C] Advanced measures	Improvements [%]
Roof 1	13.98	20.42	32%
Roof 2	8.19	20.41	60%
Roof 3	15.30	20.40	25%
Roof 4	19.88	20.41	3%
Roof 5	19.26	20.41	6%
Roof 6	19.27	20.44	6%
Roof 7	19.87	20.41	3%

Table 6.13 Increment of internal surface temperature of external walls after implementation of "Advanced refurbishment" measures

	Surface temperature Tsi [°C] Current state	Surface temperature Tsi [°C] Advanced measures	Improvements [%]
Wall 1	16.40	20.31	19%
Wall 2	14.99	20.29	26%
Wall 3	14.08	20.28	31%
Wall 4	15.88	20.30	22%
Wall 5	18.61	20.35	9%
Wall 6	18.26	20.26	10%
Wall 7	17.66	20.23	13%
Wall 8	18.22	20.32	10%
Wall 9	18.80	20.28	7%
Wall 10	19.15	20.32	6%
Wall 11	18.37	20.24	9%
Wall 12	19.75	20.30	3%
Wall 13	18.96	20.30	7%

Table 6.14 Increment of internal surface temperature of floors after implementation of "Advanced refurbishment" measures

	Surface temperature Tsi [°C] Current state	Surface temperature Tsi [°C] Advanced measures	Improvements [%]
Floor 1	15.86	20.28	22%
Floor 2	17.66	20.61	14%
Floor 3	15.23	20.27	25%
Floor 4	18.74	20.65	9%
Floor 5	15.87	20.28	22%
Floor 6	19.45	20.46	5%
Floor 7	18.01	20.34	11%
Floor 8	17.28	20.31	15%
Floor 9	19.63	20.68	5%
Floor 10	19.25	20.66	7%
Floor 11	19.99	20.54	3%

6.4 Increment of passive energy gaining by resizing the openings

Besides the conservation of the thermal energy as a crucial measure for achievement of energy efficiency, increment of passive solar energy gaining could be an additional step towards decrement of energy need for space heating. Considering the fact that any radical physical modification of existing buildings for lowering the heat loss through transmission is almost not possible or feasible, the resizing of specific openings in specific orientation of the building could be a way of increasing the heat gain through increment of the solar irradiation of the interior space of the building through glazing. Enlargement of openings in specific orientation such as south, east and west, by changing the WWR by increasing the share of the transparent surfaces within the thermal envelope area resulted to contribute towards energy gaining and lowering the heating energy needs (Table 6.15). The energy gaining increment showed different values depending on the orientation of the openings of each referent building and the possibility of applying the opening resizing. Different building types showed different potentials for solar energy gains, i.e. ReEx 2.4 showed the lowest potential by 7% of increment of solar energy gain by lowering the energy need for heating by 3.0% and the highest potential of increment of solar energy gain by ReEx 4.2 with 46.4% and the highest potential of decrement of the energy need for heating by 11.7% at ReEx 4.3 (Table 6.16).

Table 6.15 WWR of the current state and after resizing of the openings

Build. Type	Current					Modified			
	Wall		Winow			Wall		Winow	
	m²	%	m²	%		m²	%	m²	%
ReEx 1.1	95.9	89%	11.7	11%		92.34	86%	15.257	14%
ReEx 1.2	101.96	90%	11.5	10%		98.55	87%	14.91	13%
ReEx 1.3	194	84%	36.9	16%		193	82%	42	18%
ReEx 1.4	195.4	90%	22.7	10%		188.09	88%	25.91	12%
ReEx 1.5	437.5	92%	36.6	8%		428.34	88%	59.96	12%
ReEx 2.1	161.9	89%	19.7	11%		157.73	87%	23.866	13%
ReEx 2.2	91	92%	8.4	8%		47.95	81%	11.45	19%
ReEx 2.3	260	85%	47.4	15%		246.9	80%	60.5	20%
ReEx 2.4	245.3	87%	35.3	13%		237.6	85%	42.301	15%
ReEx 2.5	135	88%	18.4	12%		130.62	85%	22.777	15%
ReEx 3.1	323.5	83%	64.3	17%		304.77	79%	83.029	21%
ReEx 3.2	324.7	86%	52.2	14%		314.24	83%	62.658	17%
ReEx 3.3	1511	86%	240.1	14%		1473.53	84%	277.57	16%
ReEx 3.4	329.8	77%	98.2	23%		316.46	74%	111.544	26%
ReEx 3.5	755	81%	173.1	19%		724.81	78%	203.292	22%
ReEx 4.2	381	65%	205	35%		334.4	57%	251.6	43%
ReEx 4.3	983.9	72%	389.6	28%		1042.682	67%	519.819	33%
ReEx 4.4	1642.5	89%	200.4	11%		1593.67	86%	249.232	14%
ReEx 4.5	3439.9	76%	1090	24%		2986.5	69%	1353.5	31%

Table 6.16 Resizing of building openings in three different orientations, increment of solar heat gain and decrement of energy need for heating

	East openings			South openings			West openings			Solar gains			Energy need for heating		
Build. Type	Current	Enlarged	**Enlarged**	Current	Enlarged	**Enlarged**	Current	Enlarged	**Enlarged**	Scenario 2	Increased	**Increment**	Scenario 2	Decreased	**Decrement**
	m²	m²	**%**	m²	m²	**%**	m²	m²	**%**	kWh/a	kWh/a	**%**	kWh/a	kWh/a	**%**
SFH 01	2.9	3.857	**+33.0%**	5.40	8.00	**+48.1%**				1951.87	2287.46	**+17.2%**	4270.68	3974.38	**-6.9%**
SFH 02	2.7	3.51	**+30.0%**	5.40	8.00	**+48.1%**				2105.49	2430.75	**+15.4%**	4478.93	4188.56	**-6.5%**
SFH 03				2.20	3.20	**+45.5%**				5153.76	5545.21	**+7.6%**	8813.53	8497.27	**-3.6%**
SFH 04	12.40	16.50	**+33.1%**	10.70	13.91	**+30.0%**				3900.18	4231.43	**+8.5%**	6740.96	6419.45	**-4.8%**
SFH 05				22.90	32.06	**+40.0%**				9191.99	10137.25	**+10.3%**	14943.60	14118.13	**-5.5%**
TH 01	10.10	12.22	**+21.0%**	6.70	8.75	**+30.5%**				3184.57	3544.72	**+11.3%**	4743.96	4441.18	**-6.4%**
TH 02	2.60	3.25	**+25.0%**	4.50	6.90	**+53.3%**				1490.83	1815.16	**+21.8%**	3411.47	3156.27	**-7.5%**
TH03	33.60	46.70	**+39.0%**							7737.09	8658.13	**+11.9%**	15345.90	14438.64	**-5.9%**
TH 04	20.60	24.51	**+19.0%**				14.00	17.79	**+27.1%**	7010.67	7502.90	**+7.0%**	15654.16	15136.09	**-3.3%**
TH 05				7.00	9.10	**+30.0%**	9.90	12.18	**+23.0%**	2999.73	3376.52	**+12.6%**	5835.05	5499.68	**-5.7%**
MFH 01	34.20	44.80	**+31.0%**				30.10	38.23	**+27.0%**	11467.18	12783.98	**+11.5%**	29693.54	28352.29	**-4.5%**
MFH 02				24.90	35.36	**+42.0%**				8325.43	9404.63	**+13.0%**	15775.77	14785.62	**-6.3%**
MFH 03	55.50	66.05	**+19.0%**	59.30	75.31	**+27.0%**	64.20	75.11	**+17.0%**	35663.40	38824.38	**+8.9%**	83072.20	79769.47	**-4.0%**
MFH 04	10.40	11.65	**+12.0%**	44.80	56.90	**+27.0%**				13573.26	14909.24	**+9.8%**	26472.53	25211.59	**-4.8%**
MFH 05	53.80	66.71	**+24.0%**	33.60	37.97	**+13.0%**	53.80	66.71	**+24.0%**	32207.11	34473.50	**+7.0%**	55008.45	52860.39	**-3.9%**
AB 02	125.00	150.00	**+20.0%**				80.00	101.60	**+27.0%**	20880.64	30572.60	**+46.4%**	30510.37	27769.45	**-9.0%**
AB 03	191.50	264.27	**+38.0%**				198.10	255.55	**+29.0%**	55950.29	65105.73	**+16.4%**	67872.19	59962.38	**-11.7%**
AB 04	80.40	103.72	**+29.0%**	22.00	24.20	**+10.0%**	80.40	103.72	**+29.0%**	36061.30	39566.93	**+9.7%**	62286.44	58924.58	**-5.4%**
AB 05	275.00	376.75	**+37.0%**	240.00	300.00	**+25.0%**	275.00	376.75	**+37.0%**	145229.76	165729.08	**+14.1%**	175702.58	158428.68	**-9.8%**

6.5 Summary

As a summary of this chapter it has been able to analyze the results of three different states of the RBS of city of Prishtina. Based on current state of buildings two additional scenarios has been developed which are in accordance with current Technical Regulation on Thermal Saving and Thermal Protection in Buildings and EU practices towards NZEB respectively. In this chapter has been possible to ascertain that potentials for energy saving in residential sector by implementing refurbishment measures it is possible to achieve 26.73% to 46.84% decrement of energy consumption as a result of heat loss. Depending on building typology and construction period by implement these measures it is possible to achieve 13.59% to 79.39 or 23.14% to 68.04% respectively. Furthermore the results have been combined to generate separate improvement for each referent building by enabling further potential analysis for a specific building and construction period apart severally. At the same time develop specific tables with all relevant detailed improvements applied for each building envelope element/window for each referent building (Appendix 3). As an additional measure, the resizing of the building openings showed that there is a real potential to increase the solar energy gains which could decrease the energy heat for heating. As a an output, this chapter presents the real potential of improvement of energy use and living commodity of RBS by adding and replacing the old building envelope elements with new material without any geometrical changes of the building construction or any substantial change of the building structure.

CHAPTER SEVEN

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 Introduction

The aim of this chapter is to present the summarized findings of the research and articulating the conclusions as a derivate of results generated from concrete calculations and analysis. As an enclose of this study which aims to contribute with measurable and concrete results to the field of residential sector and building community and empower the developments towards sustainability, it has been possible to reis the conclusions and based on this to offer the recommendations for future steps.

7.2 Summary of the study and the research constraints

Existing residential buildings as the largest share of the building sector in city of Prishtina in evidenced as the largest consumer of energy. Generally it is known that the high demand for energy is being used for space heating and hot domestic water. The high demand for heating energy derives from the high heat loss through building envelope and windows which in the majority are of low quality uninsulated and in some cases degraded.

Very little has been done by the official local or central authorities regarding the improvement of the current situation of energy loss and inefficient use of energy for space heating of the residential sector. The only improvements that have been conducted during last two decades are the exceptional cases of individual and private initiatives of inhabitants to improve the quality of building envelope and their living commodity.

For the above mentioned reasons this study has been conducted by raising concrete questions regarding this specific field and has taken into consideration all relevant components, data legislation and technical information to generate sufficient results and findings which could lead to concrete conclusions and recommendations towards future developments. In this way the study has been structured carefully to comprehend all usable and important sources.

Chapter 1 of the study introduces the aim of the study by including the objectives and the research questions of the study.

Chapter 2 is focused on creating the idea of context of the study by considering the main elated components to the subject of the study.

Chapter 3 focuses on literature review by analyzing local and foreign developments of the field. This chapter is considered as the pillar chapter which facilitated the following chapters by offering sufficient sources and information on establishing the conceptual framework of the study.

Chapter 4 presents the methodical approach of the study towards findings and generation of results. This chapter has been based on previous chapter by foreign practices of similar studies.

Chapter 5 presents the findings and all the results and findings regarding the current state of the building sector in general and specific building types and ages. The importance of this chapter is the creation of the planform of the current state upon which it has been possible to develop future recommendations for improvements.

Chapter 6 offers the scenarios for improvements of the residential building stock. In this chapter the main aim was to find the improvement effects by generating concrete and measurable results based on concrete calculations.

Even though this study offers reliable results, concrete measures and correlations between different results, it offers technical solutions by excluding the effect of any improvements in heating systems and doesn't consider the financial impact of the proposed measures. Improvement potentials of heating systems would be a step forward on achieving higher standards on energy efficiency of the RBS. Also the financial impact of the improvement measures would be a crucial instrument for assessment and determination of the most cost optimal and cost effective solutions.

Furthermore the architectural impact of the building appearance before and after the refurbishment measures may inflict the identity of a specific architectural style. This might induce discontentment if the refurbishment measures do not consider the possibility to accommodate a specific architectural style of existing buildings.

7.3 Conclusions and Thesis Statements

During the period between 1960's to nowadays when the residential sector has developed and had an exponential growth which still continues, created the largest building stock in city of Prishtina. The building stock's physical state in general was neglected and not taken to a consideration as the main energy consumer and as a potential subject of study for improvement of energy consumption and pollution in city of Prithina. Accordingly, the main focus of the study has been the identification of the current state of the RBS by identifying the number of buildings, energy source used for heating, specific building types by structuring the data in a specific order that could facilitate the following stages of the study. Furthermore, the study, based on the structured data, identified the current state in terms of heat energy demand and developed scenarios of building refurbishments and potentials of heating energy demand decrement.

Considering all the findings of the study, based on statistical and technical data gathered, results generated by the calculations and comparative process of final processed data, it has been possible to emerge the following:

1. *Creation and utilization of the matrix based database for Residential Building Stock and Typology for city of Prishtina is a key instrument for any future developments and interventions toward building stock, towards energy savings and living commodity, in local level and level of the country.*

   I have created and developed a matrix based database of statistical and technical data of Residential Building Stock referent buildings which contains all relevant and necessary technical data, material descriptions and U values for each referent buildings of four building types and five construction periods. The database matrix confirms that for any conduction of investigation towards residential building stock related to building renovation, energy efficiency and living commodity the need of structured and descriptive technical database is a key instrument by offering sufficient relevant technical data. Renovation of Residential Building Stock i city of Prishtina of any investigation towards decrement of energy loss through building envelope is considered crucial and urgent. Development of a structured statistical and technical database matrix establishes a platform upon which it is than possible to conduct necessary investigations, designs of any measure regarding the existing residential buildings sustainability, energy efficiency and living commodity within dwellings.

2. *Findings of the research show that the majority of Residential Building Stock in the city of Pristina does not meet the minimum requirements of energy conservation through building envelope envisaged by Technical Regulation on Thermal Saving and Thermal Protection in Buildings of Kosovo.*

   I have proven by applying specific calculations based on EN ISO 15316 for finding the heat loss through transmission of building envelope and windows based on all gathered technical data that the majority of the Residential Building Stock does not fulfill the minimum requirements of the Technical Regulation on Thermal Saving and Thermal Protection in Buildings of Kosovo. The buildings built after year 2000 Buildings constructed after the year 2000 have a tendency to fulfill the minimum requirements according to the Technical Regulation on Thermal Saving and Thermal Protection in Buildings of Kosovo and in some components outreach the current regulations by achieving higher standards. This has been proved by generating concrete results of heating energy loss through transmission and the final energy need for space heating. Concrete renovation propositions for Residential Building Stock towards decrement of energy loss through building envelope require precise calculated technical results of the current state of buildings. By identifying the currents state of the buildings by this research, complete renovation measures of the building envelope components have to be conducted. In case of buildings built after year 2000, renovation measures should be applied partially in specific components depending on specific cases included in this research.

3 *The current overall energy demand for heating by the Residential Building Stock can be decreased with 26.74% only by applying the minimum requirements of the Technical Regulation on Thermal Saving and Thermal Protection in Buildings of Kosovo.*

I have proven by applying specific calculations based on EN ISO 15316 and by applying technical measures of additional thermal insulation, window replacements and specific calculation for generating measurable results of energy savings and energy need for heating that the realistic potential of energy saving in Residential Building Stock only by applying the minimum requirements for heat transmission of the building envelope components envisaged by the Technical Regulation on Thermal Saving and Thermal Protection in Buildings of Kosovo is 26.74%.

Application of renovation measures of the building envelope components such as walls, roofs and floors and replacement of the existing windows according to the minimum requirements of the Technical Regulation on Thermal Saving and Thermal Protection in Buildings of Kosovo can decrease the heat loss through transmission of the building by 26.74%. Application of all recommended renovation measures and generated results within this study research will assure the decrement of energy loss to 26.74% and increment of living commodity within Residential Building Stock in city of Prishtina.

4 *The current overall energy demand for heating by the Residential Building Stock can be decreased with 46.85% only by applying high standard of building quality equal to Nearly Zero Energy Buildings.*

I have proven that the Residential Building Stock has a higher potential of savings if the higher standards of renovation measures are applied. By applying technical measures of additional thermal insulation, window replacements that comply with Nearly Zero Energy Buildings the potential of energy saving in Residential Building Stock will is 46.85%.

Developments for perspective of energy savings in Kosovo should focus in higher energy efficiency standard and living commodity. Recommended renovation measures by this research study and calculations in compliance with Nearly Zero Energy Buildings standards will assure the potential energy savings by 46.85% and increment of living commodity within Residential Building Stock by lowering the heat loss through transmission to 0.18 W/m2K for envelope components and 1.0 W/m2K for windows.

5 *Application of standard refurbishment measures make a significant increment of internal surface of building shell elements temperature by increasing the weighted average temperature by 11% for walls, 18% for roofs and 10% for floor, when the external air temperature is -10°C.*

By applying specific calculations I have proven that current differences of the temperatures between internal surfaces of the building shell elements and internal air when the external temperature is -10°C, can be significantly decrease. The weighted differences of temperatures between internal designed air of 21°C and current surface of wall of 3.37°C can be decreased to 1.23°C, for roof from 4.47°C to 0.88°C and floors from 3.09°Cto 1.06°C. The temperature difference between air temperature and internal surface of the building envelope is an important component of the living commodity. This component has been positively altered after standard renovation recommended measures by increasing the potential living commodity during the heating season.

6 *Application of advanced refurbishment measures achieve increment of internal surface of building envelope temperature and decrease the temperature difference between surrounding internal surfaces and internal air to less than 1°C.*

By applying specific calculations I have proven that by applying advanced refurbishment measures it is possible to achieve a difference of temperatures between internal air temperature 21°C and internal surfaces of the building envelope elements to less than 1°C, when the external air temperature is -10°C.

The difference between the internal air temperature and internal surfaces of the building envelope under 1°C insures the elimination of the temperature difference sensing by the building users which contributes directly in the living commodity within dwellings. Achievement of such low temperature differences between internal surfaces and internal air temperature when the outside temperature is -10°C not only creates a higher living commodity but also eliminates the possibility of appearance of condensation in building components. The results of the calculations resulted that such a difference can be achieved by applying advanced measures in compliance with Nearly Zero energy Buildings standard.

7 *Resizing of the windows oriented in East South and West, showed that the solar heat gains can be increased by average weighted of 13.7% and as a result impact in reduction of the energy needs for space heating by average weighted of 6.1%.*

I have proven, based on calculations that enlargement of specific openings oriented on the East, South and West, respectively can increase the passive solar heat gains for each referent building by increasing the passive heat gains in a range of lowest of 7.0% to highest of 46.4% for respective referent buildings, by increasing the share of transparent surface in relation with opaque surfaces. As a result the energy needs for space heating decreased in a range of lowest of 3.3% to highest of 11.7% for respective referent buildings.

The energy efficiency of the building is not achieved only by energy conservation but also by passive energy gaining. Resizing of building openings is the potential of increasing the weighted average solar energy gaining by 13.7% which directly decreases the weighted average energy need for heating by 6.07% of the Residential Building

Stock. Changing of the wall to window by leaving the construction system intact, is a practical measure that will contribute in achievement of energy efficiency in Residential Sector in city of Prishtina

As an initial attainment of the study has been the development of the RBS database matrix, which showed that it is has been a crucial instrument for the research and is an ineluctable instrument for any research or study regarding residential sector which implies building stock. On the other hand it has been possible to conduct practical calculations and identify the potential energy demand for space heating of the residential sector with the current physical state. According to the results gathered, it has been identified that majority of existing residential building do not minimum requirements of energy conservation through building envelope envisaged by the TRTSTPB. Furthermore based on findings regarding the current state and potential energy demand of the RBS, it has been possible to develop two different scenarios towards energy efficiency of RBS which could decrease the energy demand for space heating for nearly 30% and nearly 50%, respectively, by applying current official mandatory minimum requirements in Kosovo and low energy standards as an ambitious measure. Furthermore the resizing of the building envelope openings has been considered as a potential of passive heat gains by increasing the solar heat gains with average weighted of 13.7% which directly impacted the energy need for heating by decrease the needs for each referent building for average weighted of 6.1%.

Based on all findings, results generated during the calculations and comparison of scenarios results it is evident that there is an ineluctable potential for considerable energy savings through RBS refurbishments by offering practical technical interventions for building refurbishment excluding the replacement of heating systems which represent an additional improvement of the current situation.

Based on the findings of the study it is evident that there are deficiencies in specific areas and official documentations which may be complemented in future. The main but not only subject that could contribute in enhancement of this field is the Ministry for Environment and Spatial Planning of Kosovo by drafting additional technical platforms which could comprise sufficient technical data related to the building stock by supporting any concrete intervention towards existing buildings in Prishtina and Kosovo in general and foresees future results and developments based on current data. This could also standardize the refurbishment measures for RBS by preventing individual irregular interventions that do not meet the minimum requirements

7.4 Recommendations for further research

Considering the fact that this study had the main focus of physical properties of the building envelope as one of the components with a significant influence in energy demand of a building, it is obvious that additional complementary studies should be conducted to enclose the overall study by including other disciplines.

Recommendations for further research should be focused on deficiencies of this research:

1. Financial impact of proposed measures should be an imperative research study which should offer the most optimal and economical solutions.

2. Study with a focus on the potential of energy savings by implementing replacement measures for heating carriers and systems in residential sector.

3. A further analysis towards minimization of architectural impact of the refurbishment measures onto specific building styles by considering the use of specific materials which would imitate the elements and constructive details which represent a respective architectural period or style.

Generation of reliable data regarding heating systems and financial implication could contribute to final and complementary solutions with midterm and long term influence for Prishtina and Kosovo in general.

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APENDIX 1

Questionnaire for identifying the heating energy consumption from the residential sector in the city of Prishtina

This survey is part of my research within the Ph.D. studies and dissertation, which is being developed within the Department of Energy Design / Faculty of Engineering and Computer Science / University of Pécs / Hungary. Subject of this research is the heating energy consumption by the residential sector in city of Pristina and future steps towards energy efficiency.

The target of this survey is to collect data, which will be essential and will help extract the real results of the current state of energy consumption for heating dwelling in city of Pristina, from which will be built the relevant design standards of residential buildings with high efficiency in energy consumption for heating.

Data collected will be treated only in scientific terms rather than subjective and as a result, all entries will be anonymous.

Your contribution to the correct answers to the questions of this survey is essential, without which research cannot be considered finalized and therefore will not be able to defend the dissertation. Achieving the results through this research could have a positive impact on the residential sector at the municipal level within the city of Prishtina.

Hoping for your positive response to this survey, I personally thank you!

Ark. Petrit Ahmeti, Ph.D. candidate.

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1. In which part of Prishtina do you live in?

a) New Pristina (Veternik) -Hajvali

b) Kalabria

c) Mati 1

d) Matiqan

e) Dardani-Lakrishte

f) Ulpianë

g) Kodra e Diellit

h) Velani

i) Qender-Pejton-Qafa

j) Arbëri-Përroi i njelmët

k) Taslixhe-Sofali

l) Dodona Muhaxherëve-Aktash

m) Kodra e trimave -Tophane

n) Vellusha-Vreshta

o) Madrasa-Çamëri-Galap-Kolovicë

---

2) What is the exact address? (This question is intended to create a correct energy consumption heating map in the city of Pristina)

………………………………………………………………………………………………………
……

---

3) What type of building do you live in?

a) Individual homes (singles)

b) Semi-detached/terraced - The following responses must be for one dwelling only

c) Multi-story building

---

4) What is the number of levels/floors of the building where you live? (Include only residential floors, not business ones)

a) 1-3 floors

b) 4-5 floors

c) 6 +

---

5) In what year was the house / apartment built?

Before the 60s

a) 60's

b) 70's

c) 80's

d) 90s

e) After 99

The exact year, if known

…………………………

---

6) What is the total usable area of the living space (m2)? (excluding balconies, terraces and lounges)

……………………m2

---

7) How many people live in the above mentioned space?

……………………People

---

8) Is the building where you live thermally insulated?

a) Yes, the walls are insulated

b) Yes, the walls and the ceiling are insulated

c) No

---

9) If the building is thermally insulated, then what is the type of insulating material and its thickness (if known)?

Walls ……………………………………………………………………….

Ceiling………………………………………………………………………

---

10) What is the orientation or what are the orientations of your apartment? (this question does not apply to cases of individual homes)

a) North

b) Northeast

c) East

d) Southeast

e) South

f) Southwest

g) West

h) Northwest

---

11) What is the type of windows installed in your home / apartment where you live?

a) Wooden frame with a glass

b) Wooden window frame with two glasses

c) Wood-framed wooden frame with Low-E foil

d) Wooden frame with three glasses

e) Wood-framed wooden frame with Low-E foil

f) PVC (plastic) frame with two glasses

g) PVC (plastic) frame with low-E glass

h) PVC (plastic) frame with three glasses

i) PVC (plastic) frame with three Low-E foil glasses

j) Aluminum window with two glasses

k) Aluminum Double Frame with Low-E Folk Glass

l) Aluminum frame with three glasses

m) Aluminum Frame with Three Low-E Folk Glass

n) Other (please specify)

12) What is the source of energy that you use for heating of your dwelling?

a) Electrical energy

b) District heating

c) Wood

d) Coal

e) Pellet / briquette

f) Oil

g) LPG

h) Other (please specify)

13) What kind of heating units do you have in your dwelling?

a) Radiators

b) Floor heating

c) Common stove (without central system).

d) Mobile electric unit (termo, electric radiator, other electrical equipment).

e) Fixed electric unit (Climate)

f) Fireplace (without central system)

g) Other (please specify)

---

14) What type of heating system is available in the dwelling you live?

a) Central system

b) Separate heating units (non-centrally system)

c) District heating

---

15) For heating cases from District heating, wood, coal, pellet, briquette, oil, gas, how much is the heating cost per year or the heating season, the average over the last three years?

………………………………€

---

16) How much is the amount of fuel consumed per year or the heating season, averaged per year over the last three years?

a) Wood (m^3)

b) Coal (ton)

c) Pellets / Briquettes (ton)

d) Oil (liters)

e) LPG (liters)

f) Other (please specify)

---

17) In case of electricity as a heat energy source, how much is the cost of heating during a year or season of heating? Enter the cost of energy consumption for the 6 months without heating (May-October) and 6 months with heating (November-April), the average within the last 3 years?

May - October ……………………..(€)

November - April ……………………..(€)

---

18) Please specify what is the percentage (%) of the area (house / dwelling space) that you heat during the heating season?

………………………………………..% heated by the total surface of the dwelling.

---

19) How satisfied are you with the heat quality / room temperature?

a) Not at all pleased

b) Dissatisfied

c) Average

d) Satisfied

e) Very satisfied

20) Do you have an AC unit installed in your dwelling?

a) Yes

b) Not

21) If you have an AC unit installed in your dwelling, how many is it?

a) 1

b) 2

c) 3

More (please specify)……………………..

APENDIX 2

Referent buildings database matrix based on building typology and construction period

(Attached as a separate document in A3 format)

(Attached as a separate document in A3 format)

(Attached as a separate document in A3 format)

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(Attached as a separate document in A3 format)

APENDIX 3

Table of U values for building envelope elements

Walls

< 1960							
B. Type		**Wall 1**		**Wall 2**		**Wall 3**	
SFH	**Current state**	Current state	U = 1.135 W/m²K	n/a	n/a	n/a	n/a
	Standard measures	Adding 10 cm thermal insulation with max 0.04 W/m'K	U = 0.296 W/m²K	n/a	n/a	n/a	n/a
	Advanced measures	Adding 20 cm thermal insulation with max. 0.04 W/m'K	U = 0.170 W/m²K	n/a	n/a	n/a	n/a
TH	**Current state**	Current state	U = 1.135 W/m²K	Current state	U = 1.45 W/m²K	n/a	n/a
	Standard measures	Adding 10 cm thermal insulation with max 0.04 W/m'K	U = 0.296 W/m²K	Adding 10 cm thermal insulation with max 0.04 W/m'K	U = 0.313 W/m²K	n/a	n/a
	Advanced measures	Adding 20 cm thermal insulation with max. 0.04 W/m'K	U = 0.170 W/m²K	Adding 20 cm thermal insulation with max. 0.04 W/m'K	U = 0.176 W/m²K	n/a	n/a
MFH	**Current state**	Current state	U = 1.135 W/m²K	Current state	U = 1.45 W/m²K	n/a	n/a
	Standard measures	Adding 10 cm thermal insulation with max 0.04 W/m'K	U = 0.296 W/m²K	Adding 10 cm thermal insulation with max 0.04 W/m'K	U = 0.313 W/m²K	n/a	n/a
	Advanced measures	Adding 20 cm thermal insulation with max. 0.04 W/m'K	U = 0.170 W/m²K	Adding 20 cm thermal insulation with max. 0.04 W/m'K	U = 0.176 W/m²K	n/a	n/a

1960-1969							
B. Type		**Wall 1**		**Wall 2**		**Wall 3**	
SFH	**Current state**	Current state	U = 1.45 W/m²K	Current state	U = 0.865 W/m²K	n/a	n/a
	Standard measures	Adding 10 cm thermal insulation with max 0.04 W/m'K	U = 0.313 W/m²K	No improvements	U = 0.865 W/m²K	n/a	n/a
	Advanced measures	Adding 20 cm thermal insulation with max. 0.04	U = 0.176 W/m²K	No improvements	U = 0.865 W/m²K	n/a	n/a

		W/m'K					
TH	**Current state**	Current state	U = 1.45 W/m²K	n/a	n/a	n/a	n/a
	Standard measures	Adding 10 cm thermal insulation with max 0.04 W/m'K	U = 0.313 W/m²K	n/a	n/a	n/a	n/a
	Advanced measures	Adding 20 cm thermal insulation with max. 0.04 W/m'K	U = 0.176 W/m²K	n/a	n/a	n/a	n/a
MFH	**Current state**	Current state	U = 1.45 W/m²K	n/a	n/a	n/a	n/a
	Standard measures	Adding 10 cm thermal insulation with max 0.04 W/m'K	U = 0.313 W/m²K	n/a	n/a	n/a	n/a
	Advanced measures	Adding 20 cm thermal insulation with max. 0.04 W/m'K	U = 0.176 W/m²K	n/a	n/a	n/a	n/a
AB	**Current state**	Current state	U = 1.352 W/m²K	n/a	n/a	n/a	n/a
	Standard measures	Adding 10 cm thermal insulation with max 0.04 W/m'K	U = 0.309 W/m2K	n/a	n/a	n/a	n/a
	Advanced measures	Adding 20 cm thermal insulation with max. 0.04 W/m'K	U = 0.174 W/m²K	n/a	n/a	n/a	n/a
1970-1979							
B. Type		**Wall 1**		**Wall 2**		**Wall 3**	
SFH	**Current state**	Current state	U = 1.577 W/m²K	Current state	U = 1.536 W/m²K	n/a	n/a
	Standard measures	Adding 10 cm thermal insulation with max 0.04 W/m'K	U = 0.319 W/m²K	Adding 10 cm thermal insulation with max 0.04 W/m'K	U = 0.314 W/m²K	n/a	n/a
	Advanced measures	Adding 20 cm thermal insulation with max. 0.04 W/m'K	U = 0.177 W/m²K	Adding 20 cm thermal insulation with max. 0.04 W/m'K	U = 0.177 W/m²K	n/a	n/a
TH	**Current state**	Current state	U = 1.577 W/m²K	Current state	U = 0.785 W/m²K	n/a	n/a
	Standard measures	Adding 10 cm thermal insulation with max 0.04 W/m'K	U = 0.319 W/m²K	No improvements	U = 0.785 W/m²K	n/a	n/a

	Advanced measures	Adding 20 cm thermal insulation with max. 0.04 W/m'K	U = 0.177 W/m²K	No improvements	U = 0.785 W/m²K	n/a	n/a
MFH	**Current state**	Current state	U = 0.737 W/m²K	Current state	U = 1.754 W/m²K	n/a	n/a
	Standard measures	Adding 8 cm thermal insulation with max 0.04 W/m'K	U = 0.298 W/m²K	Adding 10 cm thermal insulation with max 0.04 W/m'K	U = 0.326 W/m²K	n/a	n/a
	Advanced measures	Adding 18 cm thermal insulation with max. 0.04 W/m'K	U = 0.176 W/m²K	Adding 20 cm thermal insulation with max. 0.04 W/m'K	U = 0.18 W/m²K	n/a	n/a
AB	**Current state**	Current state	U = 0.677 W/m²K	Current state	U = 0.906 W/m²K	Current state	U = 1.01 W/m2K
	Standard measures	Adding 6 cm thermal insulation with max 0.04 W/m'K	U = 0.318 W/m²K	Adding 8 cm thermal insulation with max 0.04 W/m'K	U = 0.301 W/m²K	Adding 8 cm thermal insulation with max 0.04 W/m'K	U = 0.312 W/m²K
	Advanced measures	Adding 16 cm thermal insulation with max. 0.04 W/m'K	U = 0.169 W/m²K	Adding 16 cm thermal insulation with max. 0.04 W/m'K	U = 0.169 W/m²K	Adding 18 cm thermal insulation with max. 0.04 W/m'K	U = 0.167 W/m²K
1980-1999							
B. Type		**Wall 1**		**Wall 2**		**Wall 3**	
SFH	**Current state**	Current state	U = 1.31 W/m²K	n/a	n/a	n/a	n/a
	Standard measures	Adding 10 cm thermal insulation with max 0.04 W/m'K	U = 0.306 W/m²K	n/a	n/a	n/a	n/a
	Advanced measures	Adding 20 cm thermal insulation with max. 0.04 W/m'K	U = 0.174 W/m²K	n/a	n/a	n/a	n/a
TH	**Current state**	Current state	U = 0.476 W/m²K	Current state	U = 0.785 W/m²K	n/a	n/a
	Standard measures	Adding 5 cm thermal insulation with max 0.04 W/m'K	U = 0.298 W/m²K	No improvements	U = 0.785 W/m²K	n/a	n/a
	Advanced measures	Adding 15 cm thermal insulation with max. 0.04 W/m'K	U = 0.171 W/m²K	No improvements	U = 0.785 W/m²K	n/a	n/a
MFH	**Current state**	Current state	U = 1.47 W/m²K	Current state	U = 0.479 W/m²K	n/a	n/a

	Standard measures	Adding 10 cm thermal insulation with max 0.04 W/m'K	U = 0.309 W/m²K	Adding 5 cm thermal insulation with max 0.04 W/m'K	U = 0.294 W/m²K	n/a	n/a
	Advanced measures	Adding 20 cm thermal insulation with max. 0.04 W/m'K	U = 0.174 W/m²K	Adding 15 cm thermal insulation with max. 0.04 W/m'K	U = 0.176 W/m²K	n/a	n/a
AB	**Current state**	Current state	U = 0.648 W/m²K	Current state	U = 2.0 W/m²K	n/a	n/a
	Standard measures	Adding 6 cm thermal insulation with max 0.04 W/m'K	U = 0.329 W/m²K	No improvements	U = 2.0 W/m²K	n/a	n/a
	Advanced measures	Adding 15 cm thermal insulation with max. 0.04 W/m'K	U = 0.180 W/m²K	Adding 5 cm thermal insulation with max. 0.04 W/m'K	U = 0.55 W/m²K	n/a	n/a
After 2000							
B. Type		**Wall 1**		**Wall 2**		**Wall 3**	
SFH	**Current state**	Current state	U = 0.306 W/m²K	n/a	n/a	n/a	n/a
	Standard measures	No improvements	U = 0.306 W/m²K	n/a	n/a	n/a	n/a
	Advanced measures	Adding 10 cm thermal insulation with max. 0.04 W/m'K	U = 0.177 W/m²K	n/a	n/a	n/a	n/a
TH	**Current state**	Current state	U = 0.306 W/m²K	Current state	U = 0.396 W/m²K	Current state	0
	Standard measures	No improvements	U = 0.306 W/m²K	No improvements	U = 0.396 W/m²K	No improvements	0
	Advanced measures	Adding 10 cm thermal insulation with max. 0.04 W/m'K	U = 0.177 W/m²K	No improvements	U = 0.396 W/m²K	Add 5 cm thermal insulation with max 0.04 W/m'K	0
MFH	**Current state**	Current state	U = 0.57 W/m²K	Current state	U = 0.479 W/m²K	n/a	n/a
	Standard measures	Replace with 10 cm thermal insulation with max 0.04 W/m'K	U = 0.275 W/m²K	Adding 5 cm thermal insulation with max 0.04 W/m'K	U = 0.294 W/m²K	n/a	n/a
	Advanced measures	Replace with 20 cm thermal insulation with max. 0.04 W/m'K	U = 0.156 W/m²K	Adding 15 cm thermal insulation with max. 0.04 W/m'K	U = 0.176 W/m²K	n/a	n/a
AB	**Current state**	Current state	U = 0.319 W/m²K	Current state	U = 0.396 W/m²K	n/a	n/a

	Standard measures	Adding 6 cm thermal insulation with max 0.04 W/m'K	U = 0.319 W/m²K	No improvements	U = 0.396 W/m²K	n/a	n/a
	Advanced measures	Adding 15 cm thermal insulation with max. 0.04 W/m'K	U = 0.177 W/m²K	No improvements	U = 0.396 W/m²K	n/a	n/a

Floors and roofs

< 1960					
B. Type		**Floor 1**		**Roof 1**	
SFH	**Current state**	Current state	U = 2.09 W/m²K	Current state	U = 1.61 W/m²K
	Standard measures	Adding 5 cm thermal insulation with max 0.04 W/m'K	U = 0.589 W/m²K	Adding 16 cm thermal insulation with max 0.04 W/m'K	U = 0.211W/m2K
	Advanced measures	Adding 10 cm thermal insulation with max. 0.04 W/m'K	U = 0.277 W/m²K	Adding 20 cm thermal insulation with max 0.04 W/m'K	U = 0.181 W/m²K
TH	**Current state**	Current state	U = 2.09 W/m²K	Current state	U = 1.61 W/m²K
	Standard measures	Adding 5 cm thermal insulation with max 0.04 W/m'K	U = 0.589 W/m²K	Adding 16 cm thermal insulation with max 0.04 W/m'K	U = 0.211W/m2K
	Advanced measures	Adding 10 cm thermal insulation with max. 0.04 W/m'K	U = 0.277 W/m²K	Adding 20 cm thermal insulation with max 0.04 W/m'K	U = 0.181 W/m²K
MFH	**Current state**	Current state	U = 2.09 W/m²K	Current state	U = 1.61 W/m²K
	Standard measures	Adding 5 cm thermal insulation with max 0.04 W/m'K	U = 0.589 W/m²K	Adding 12 cm thermal insulation with max 0.04 W/m'K	U = 0.284W/m2K
	Advanced measures	Adding 10 cm thermal insulation with max. 0.04 W/m'K	U = 0.339 W/m²K	Adding 20 cm thermal insulation with max 0.04 W/m'K	U = 0.180 W/m²K
1960-1969					
B. Type		**Floor 1**		**Roof 1**	
SFH	**Current state**	Current state	U = 1.36W/m2K	Current state	U = 1.61 W/m²K
	Standard measures	Adding 10 cm thermal insulation with max 0.04 W/m'K	U = 0.336W/m2K	Adding 12 cm thermal insulation with max 0.04 W/m'K	U = 0.284W/m2K
	Advanced measures	Adding 20 cm thermal insulation with max. 0.04 W/m'K	U = 0.174 W/m²K	Adding 12+8 cm thermal insulation with max 0.04 W/m'K	U = 0.180 W/m²K
TH	**Current state**	Current state	U = 2.105 W/m²K	Current state	U = 1.61 W/m²K

	Standard measures	Adding 5 cm thermal insulation with max 0.04 W/m'K	U = 0.580 W/m²K	Adding 12 cm thermal insulation with max 0.04 W/m'K	U = 0.284 W/m²K
	Advanced measures	Adding 10 cm thermal insulation with max. 0.04 W/m'K	U = 0.336 W/m²K	Adding 12+8 cm thermal insulation with max 0.04 W/m'K	U = 0.180 W/m²K
MFH	**Current state**	Current state	U = 2.561 W/m²K	Current state	U = 4.073 W/m²K
	Standard measures	Adding 5 cm thermal insulation with max 0.04 W/m'K	U = 0.610 W/m²K	Adding 12 cm thermal insulation with max 0.04 W/m'K	U = 0.294 W/m²K
	Advanced measures	Adding 10 cm thermal insulation with max. 0.04 W/m'K	U = 0.346 W/m²K	Adding 20 cm thermal insulation with max 0.04 W/m'K	U = 0.180 W/m²K
AB	**Current state**	Current state	U = 1.357 W/m²K	Current state	U = 4.073 W/m²K
	Standard measures	Adding 10 cm thermal insulation with max 0.04 W/m'K	U = 0.285 W/m²K	Adding 12 cm thermal insulation with max 0.04 W/m'K	U = 0.294 W/m²K
	Advanced measures	Adding 20 cm thermal insulation with max. 0.04 W/m'K	U = 0.170 W/m²K	Adding 20 cm thermal insulation with max 0.04 W/m'K	U = 0.180 W/m²K
1970-1979					
B. Typ		**Floor 1**		**Roof 1**	
SFH	**Current state**	Current state	U = 1.73 W/m²K	Current state	U = 1.919 W/m²K
	Standard measures	Adding 5 cm thermal insulation with max 0.04 W/m'K	U = 0.547 W/m²K	Adding 12 cm thermal insulation with max 0.04 W/m'K	U = 0.282 W/m²K
	Advanced measures	Adding 10 cm thermal insulation with max. 0.04 W/m'K	U = 0.316 W/m²K	Adding 20 cm thermal insulation with max. 0.04 W/m'K	U = 0.180 W/m²K
TH	**Current state**	Current state	U = 1.818 W/m²K	Current state	U = 1.919 W/m²K
	Standard measures	Adding 5 cm thermal insulation with max 0.04 W/m'K	U = 0.556 W/m²K	Adding 12 cm thermal insulation with max 0.04 W/m'K	U = 0.284 W/m²K
	Advanced measures	Adding 10 cm thermal insulation with max. 0.04 W/m'K	U = 0.328 W/m²K	Adding 20 cm thermal insulation with max. 0.04 W/m'K	U = 0.180 W/m²K
MFH	**Current state**	Current state	U = 0.706 W/m²K	Current state	U = 0.632 W/m²K
	Standard measures	No improvements	U = 0.706 W/m²K	Replace with 12 cm thermal insulation with max 0.04 W/m'K	U = 0.30 W/m²K
	Advanced measures	Adding 10 cm thermal insulation with max. 0.04 W/m'K	U = 0.343 W/m²K	Adding 20 cm thermal insulation with max. 0.04 W/m'K	U = 0.180W/m2K
AB	**Current state**	Current state	U = 0.90 W/m²K	Current state	U = 0.763 W/m²K
	Standard	Adding 10 cm thermal	U = 0.344 W/m²K	Adding 12cm thermal	U = 0.293 W/m²K

	measures	insulation with max 0.04 W/m'K		insulation with max 0.04 W/m'K	
	Advanced measures	Adding 20 cm thermal insulation with max. 0.04 W/m'K	U = 0.185 W/m²K	Adding 20 cm thermal insulation with max. 0.04 W/m'K	U = 0.176 W/m²K
		1980-1999			
B. Typ		**Floor 1**		**Roof 1**	
SFH	**Current state**	Current state	U = 3.27 W/m²K	Current state	U = 1.919 W/m²K
	Standard measures	Adding 5 cm thermal insulation with max 0.04 W/m'K	U = 0.531 W/m²K	Adding 12 cm thermal insulation with max 0.04 W/m'K	U = 0.282 W/m²K
	Advanced measures	Adding 10 cm thermal insulation with max. 0.04 W/m'K	U = 0.316 W/m²K	Adding 20 cm thermal insulation with max. 0.04 W/m'K	U = 0.180 W/m²K
TH	**Current state**	Current state	U = 1.68 W/m²K	Current state	U = 1.919 W/m²K
	Standard measures	Adding 5 cm thermal insulation with max 0.04 W/m'K	U = 0.542W/m2K	Adding 12 cm thermal insulation with max 0.04 W/m'K	U = 0.282 W/m²K
	Advanced measures	Adding 10 cm thermal insulation with max. 0.04 W/m'K	U = 0.323 W/m²K	Adding 20 cm thermal insulation with max. 0.04 W/m'K	U = 0.180 W/m²K
MFH	**Current state**	Current state	U = 0.588 W/m²K	Current state	U =0.624 W/m²K
	Standard measures	Adding 10 cm thermal insulation with max 0.04 W/m'K	U = 0.310 W/m²K	Replace with 12 cm thermal insulation with max 0.04 W/m'K	U =0.298 W/m²K
	Advanced measures	Adding 14 cm thermal insulation with max. 0.04 W/m'K	U = 0.177 W/m²K	Replace with 20 cm thermal insulation with max. 0.04 W/m'K	U =0.178 W/m²K
AB	**Current state**	Current state	U = 1.02 W/m²K	Current state	U = 0.58 W/m²K
	Standard measures	Adding 10 cm thermal insulation with max 0.04 W/m'K	U = 0.288 W/m²K	R 12 cm thermal insulation with max. 0.04 W/m'K	U = 0.287 W/m²K
	Advanced measures	Adding 20 cm thermal insulation with max. 0.04 W/m'K	U = 0.167 W/m²K	Adding 20 cm thermal insulation with max. 0.04 W/m'K	U = 0.179 W/m²K
		After 2000			
B. Type		**Floor 1**		**Roof 1**	
SFH	**Current state**	Current state	U = 0.338 W/m²K	Current state	U =0.364 W/m²K
	Standard measures	No improvements	U = 0.338 W/m²K	No improvements	U =0.364 W/m²K
	Advanced measures	No improvements	U = 0.338 W/m²K	Adding 10 cm thermal insulation with max. 0.04 W/m'K	U =0.180 W/m²K
TH	**Current state**	Current state	U = 0.556 W/m²K	Current state	U =0.347 W/m²K
	Standard measures	No improvements	U = 0.556 W/m²K	No improvements	U =0.347 W/m²K

	Advanced measures	Adding 10 cm thermal insulation with max. 0.04 W/m'K	U = 0.328 W/m²K	Replace with 20 cm thermal insulation with max. 0.04 W/m'K	U =0.180 W/m²K
MFH	**Current state**	Current state	U =0.590 W/m²K	Current state	U =0.624 W/m²K
	Standard measures	No improvements	U =0.590 W/m²K	Replace with 12 cm thermal insulation with max. 0.04 W/m'K	U =0.298 W/m²K
	Advanced measures	Adding 10 cm thermal insulation with max. 0.04 W/m'K	U =0.255 W/m²K	Replace with 20 cm thermal insulation with max. 0.04 W/m'K	U =0.178 W/m²K
AB	**Current state**	Current state	U = 0.312 W/m²K	Current state	U =0.351 W/m²K
	Standard measures	No improvements	U = 0.312 W/m²K	No improvements	U =0.351 W/m²K
	Advanced measures	No improvements	U = 0.167 W/m²K	Adding 10 cm thermal insulation with max. 0.04 W/m'K	U =0.180 W/m²K

Windows and entrance doors

< 1960					
B. Type		**Windows**		**Doors**	
SFH	**Current state**	Current	U = 4.80 W/m²K	Current	U =3.50 W/m²K
	Standard measures	Replaced with PVC double glazing windows.	U = 1.60 W/m²K	Replaced with a higher quality door	U = 2.60 W/m²K
	Advanced measures	Replaced with PVC triple glazing Low-E windows.	U = 1.0 W/m²K	Replaced with high thermally insulated door	U = 1.50 W/m²K
TH	**Current state**	Current	U = 4.8 W/m²K	Current	U =3.50 W/m²K
	Standard measures	Replaced with PVC double glazing windows.	U = 1.60 W/m²K	Replaced with a higher quality door	U = 2.60 W/m²K
	Advanced measures	Replaced with PVC triple glazing Low-E windows.	U = 1.0 W/m²K	Replaced with a thermally insulated door	U = 1.50 W/m²K
MFH	**Current state**	Current	U = 4.80 W/m²K	Current	U =3.50 W/m²K
	Standard measures	Replaced with PVC double glazing windows.	U = 1.60 W/m²K	Replaced with a higher quality door	U = 2.60 W/m²K
	Advanced measures	Replaced with PVC triple glazing Low-E windows.	U = 1.0 W/m²K	Replaced with high thermally insulated door	U = 1.50 W/m²K
1960-1969					
B. Type		**Wall 1**		**Wall 2**	

SFH	Current state	Current	U = 4.80 W/m²K	Current	U =3.50 W/m²K
	Standard measures	Replaced with PVC double glazing windows.	U = 1.60 W/m²K	Replaced with a higher quality door	U = 2.60 W/m²K
	Advanced measures	Replaced with PVC triple glazing Low-E windows.	U = 1.0 W/m²K	Replaced with high thermally insulated door	U = 1.50 W/m²K
TH	Current state	Current	U = 4.80 W/m²K	Current	U =3.50 W/m²K
	Standard measures	Replaced with PVC double glazing windows.	U = 1.60 W/m²K	Replaced with a higher quality door	U = 2.60 W/m²K
	Advanced measures	Replaced with PVC triple glazing Low-E windows.	U = 1.00 W/m²K	Replaced with high thermally insulated door	U = 1.50 W/m²K
MFH	Current state	Current	U = 4.80 W/m²K	Current	U =3.50 W/m²K
	Standard measures	Replaced with PVC double glazing windows.	U = 1.60	Replaced with a higher quality door	U = 2.60 W/m²K
	Advanced measures	Replaced with PVC triple glazing Low-E windows.	U = 1.00 W/m²K	Replaced with high thermally insulated door	U = 1.50 W/m²K
AB	Current state	Current	U = 4.80 W/m²K	Current	U =5.60 W/m²K
	Standard measures	Replaced with PVC double glazing windows.	U = 1.60 W/m²K	Replaced with a higher quality door	U = 2.60 W/m²K
	Advanced measures	Replaced with PVC triple glazing Low-E windows.	U = 1.00 W/m²K	Replaced with high thermally insulated door	U = 1.50 W/m²K
1970-1979					
B. Type		**Wall 1**		**Wall 2**	
SFH	Current state	Current	U = 4.80 W/m²K	Current	U =3.50 W/m²K
	Standard measures	Replaced with PVC double glazing windows.	U = 1.60 W/m²K	Replaced with a higher quality door	U = 2.60 W/m²K
	Advanced measures	Replaced with PVC triple glazing Low-E windows.	U = 1.00 W/m²K	Replaced with high thermally insulated door	U = 1.50 W/m²K
TH	Current state	Current	U = 4.80 W/m²K	Current	U =3.50 W/m²K
	Standard measures	Replaced with PVC double glazing windows.	U = 1.60 W/m²K	Replaced with a higher quality door	U = 2.60 W/m²K
	Advanced measures	Replaced with PVC triple glazing Low-E windows.	U = 1.0 W/m²K	Replaced with high thermally insulated door	U = 1.50 W/m²K
MFH	Current state	Current	U = 2.60 W/m²K	Current	U = 5.60 W/m²K

	Standard measures	Replaced with PVC double glazing windows.	U = 1.60 W/m²K	Replaced with a higher quality door	U = 2.60 W/m²K
	Advanced measures	Replaced with PVC triple glazing Low-E windows.	U = 1.0 W/m²K	Replaced with high thermally insulated door	U = 1.50 W/m²K
AB	**Current state**	Current	U = 2.60 W/m²K	Current	U = 5.60 W/m²K
	Standard measures	Replaced with PVC double glazing windows.	U = 1.60 W/m²K	Replaced with a higher quality door	U = 2.60 W/m²K
	Advanced measures	Replaced with PVC triple glazing Low-E windows.	U = 1.0 W/m²K	Replaced with high thermally insulated door	U = 1.50 W/m²K

1980-1999					
B. Type		**Wall 1**		**Wall 2**	
SFH	**Current state**	Current	U = 2.6 W/m²K	Current	U = 3.50 W/m²K
	Standard measures	Replaced with PVC double glazing windows.	U = 1.60 W/m²K	Replaced with a higher quality door	U = 2.60 W/m²K
	Advanced measures	Replaced with PVC triple glazing Low-E windows.	U = 1.0 W/m²K	Replaced with high thermally insulated door	U = 1.50 W/m²K
TH	**Current state**	Current	U = 2.60 W/m²K	Current	U = 3.50 W/m²K
	Standard measures	Replaced with PVC double glazing windows.	U = 1.60 W/m²K	Replaced with a higher quality door	U = 2.60 W/m²K
	Advanced measures	Replaced with PVC triple glazing Low-E windows.	U = 1.0 W/m²K	Replaced with high thermally insulated door	U = 1.50 W/m²K
MFH	**Current state**	Current	U = 2.60 W/m²K	Current	U = 5.60 W/m²K
	Standard measures	Replaced with PVC double glazing windows.	U = 1.60 W/m²K	Replaced with a higher quality door	U = 2.60 W/m²K
	Advanced measures	Replaced with PVC triple glazing Low-E windows.	U = 1.0 W/m²K	Replaced with a thermally insulated door	U = 1.50 W/m²K
AB	**Current state**	Current	U = 2.60 W/m²K	Current	U = 5.60 W/m²K
	Standard measures	Replaced with PVC double glazing windows.	U = 1.60 W/m²K	Replaced with a higher quality door	U = 2.60 W/m²K
	Advanced measures	Replaced with PVC triple glazing Low-E windows.	U = 1.0 W/m²K	Replaced with high thermally insulated door	U = 1.50 W/m²K

1980-1999					
B. Type		**Wall 1**		**Wall 2**	
SFH	**Current state**	Current	U =2.50 W/m²K	Current	U = 2.60 W/m²K
	Standard measures	Replaced with PVC double glazing windows.	U = 1.60 W/m²K	No improvements	U = 2.60 W/m²K
	Advanced measures	Replaced with PVC triple glazing Low-E windows.	U = 1.00 W/m²K	Replaced with high thermally insulated door	U = 1.50 W/m²K
TH	**Current state**	Current	U =2.50 W/m²K	Current	U = 2.60 W/m²K
	Standard measures	Replaced with PVC double glazing windows.	U =1.60 W/m²K	No improvements	U = 2.60 W/m²K
	Advanced measures	Replaced with PVC triple glazing Low-E windows.	U =1.00 W/m²K	Replaced with high thermally insulated door	U = 1.50 W/m²K
MFH	**Current state**	Current	U =2.60 W/m²K	Current	U = 2.60 W/m²K
	Standard measures	Replaced with PVC double glazing windows.	U =1.60 W/m²K	No improvements	U = 2.60 W/m²K
	Advanced measures	Replaced with PVC triple glazing Low-E windows.	U =1.00 W/m²K	Replaced with high thermally insulated door	U = 1.50 W/m²K
AB	**Current state**	Current	U = 1.50 W/m²K	Current	U = 2.60 W/m²K
	Standard measures	No improvements	U = 1.50 W/m²K	No improvements	U = 2.60 W/m²K
	Advanced measures	Replaced with PVC triple glazing Low-E windows.	U = 1.00 W/m²K	Replaced with high thermally insulated door	U = 1.50 W/m²K