RETROFIT STRATEGIES FOR ENERGY EFFICIENCY IN HISTORIC URBAN FABRIC: A CASE STUDY IN BASMANE DISTRICT, İZMİR

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ABSTRACT

RETROFIT STRATEGIES FOR ENERGY EFFICIENCY IN HISTORIC URBAN FABRIC: A CASE STUDY IN BASMANE DISTRICT, İZMİR

Energy efficient retrofit of historic urban stock requires a methodical approach, comprehensive analysis and case-specific solutions. In large scale rehabilitation projects, the retrofit strategy should be developed on how to decide solutions for buildings providing the most energy saving in a short time. This paper presents a pilot study conducted at the neighborhood scale, consisting of 22 pre- and early-republican residential and contemporary buildings in a historic urban fabric of İzmir, Turkey. It aims to develop an integrated approach to identify case-specific energy efficient solutions for retrofit strategy of larger scale historic district. It utilizes building performance simulation (BPS) model, created through the documentation and quick field survey. All case buildings are grouped under three main categories considering their heritage value and building characteristics. Two retrofit packages and three individual operational solutions are constituted by considering five-leveled retrofit impact assessment of the CEN EN 16883:2017 Standard. Within the integrated approach, energy classes of the buildings are calculated regarding Building Energy Regulation of Turkey. Most-related two design parameters, S/V and ground floor area to conditioned volume ratio, on annual energy consumption of the buildings in current cases are identified by Pearson correlation analysis. The simulation results indicated that, three buildings including Building 8, 11 and 21 representing each group can initially be retrofitted. Building 11 has the most energy saving potential through Package 2 in its own group. For all buildings, while maximum energy saving was provided by Package 2 with 48,57%, minimum energy saving obtained from Package 1 with 19,8%.

ÖZET

TARİHİ KENTSEL DOKUDA ENERJİ-ETKİN İYİLEŞTİRME STRATEJİLERİ: İZMİR, BASMANE SEMTİNDE ALAN ÇALIŞMASI

Tarihi kentsel dokunun enerji etkin yenilemesi yöntemsel yaklaşım, kapsamlı analiz ve yere özel çözümler gerektirmektedir. Büyük ölçekli iyileştirme projelerinde, en fazla enerji korunumu sağlayacak yenileme kararlarının hangi binalarda, nasıl verileceği konusunda kısa zamanda yenileme stratejisi geliştirilmesi gerekmektedir. Bu tez, İzmir'in tarihi bir semtindeki Cumhuriyet öncesi, erken Cumhuriyet dönemi ve günümüz yapılarından 22 binayı kapsayan, komşuluk ölçeğindeki bir pilot çalışmadır. Bu çalışma, daha büyük ölçekteki tarihi bölgelerin retrofit stratejileri için alana özgü enerji etkin çözümleri belirlemede bütünleşik bir yaklaşım geliştirmeyi amaçlamaktadır. Çalışma, dokümantasyon ve hızlı saha araştırması ile oluşturulan bina enerji simulasyon (BES) modelinden faydalanmaktadır. Tüm çalışma binaları, yapıların karakter özellikleri ve mirasi değerleri düşünülerek üç ana grupta toplanmıştır. Toplam iki iyileştirme paketi ve üç bireysel operasyonel çözüm, CEN EN 16883:2017 standardının tarihi binalar için hazırladığı beş aşamalı iyileştirme etki değerlendirmesi dikkate alınarak oluşturulmuştur. Bütünleşik yaklaşım kapsamında, binaların energy sınıfları Türkiye'nin Bina Enerji Performansı Yönetmeliğine göre hesaplanmıştır. Binaların mevcut durumlarının enerji tüketimiyle en ilişkili olan iki parametre, A/V ve zemin taban alanının ısıtılan hacme oranı, Pearson katsayı analizi ile tanımlanmıştır. Simulasyon sonuçları her bir yapı grubunu temsil eden Bina 21, 8 ve 11'in öncelikli olarak iyileştirilebileceğini göstermiştir. Paket 2 ile Bina 11, kendi grubu içerisinde en yüksek enerji tasarrufu potansiyeline sahiptir. Tüm binalar için maksimum enerji tasaruffu ile %48,57 ile Paket 2 ile sağlanırken, minimum enerji tasarrufu %19,8 ile Paket 1'den elde edilmiştir.

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LIST OF ABBREVIATIONS

2D	: Two Dimensional
3D	: Three Dimensional
ASHRAE	: The American Society of Heating, Refrigerating and Air Conditioning Engineers
BES	: Building Energy Simulation
BPIE	: Building Performance Institute Europe
BPS	: Building Performance Simulation
CAD	: Computer Aided Design
CEN	: European Committee for Standardization
EED	: Energy Efficiency Directive
EPBD	: Energy Performance Building Directive
ESM	: Energy Saving Measures
EU	: European Union
GIS	: Geographical Information Systems
HVAC	: Heating, Ventilating and Air Conditioning
IEA	: International Energy Agency
MENR	: Ministry of Environment and Natural Resources
MEU	: Ministry of Environment and Urbanisation
MFA	: Ministry of Foreign Affairs
NEEAP	: National Energy Efficiency Action Plans
NGO	: Non-governmental Organizations
OPEC	: Organization of Petroleum Exporting Countries
S/V	: Surface Area to Volume Ratio
TPES	: Total Primary Energy Supply
TS	: Turkish Standard
TSE	: Turkish Standard Institute
UNFCCC	: United Nations Framework on Convention on Climate Change
U-value	: Heat Transfer Coefficient
WEC	: World Energy Council

CHAPTER 1

INTRODUCTION

1.1. Problem Statement

Many countries throughout world have implemented numerous policy measures and strategies about energy efficiency depending on national circumstances and political goals associated with the risks of climate change and global warming, increasing energy demand/consumption and rapidly wasting natural resources (World Energy Council, 2013). Energy-oriented solutions within buildings have become substantial for pursuing energy supply policies since the highest energy saving potential lies on building sector (Figure 1.1).

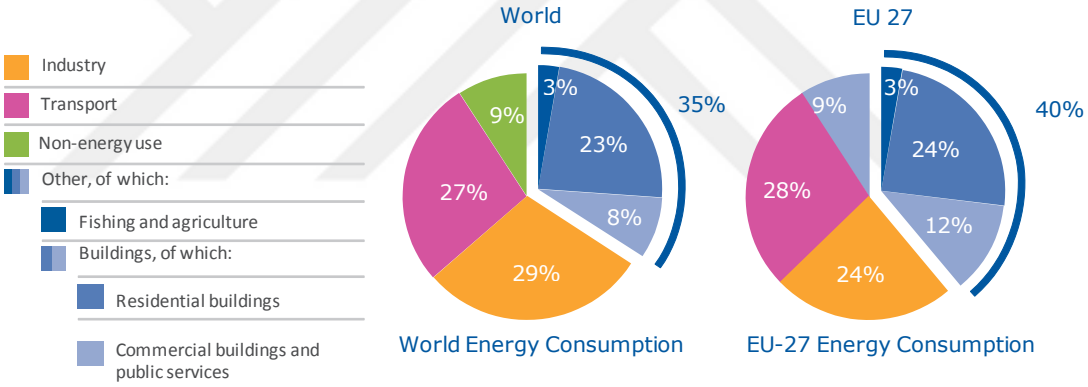


Figure 1.1. Final energy consumption by sector in the EU-27 countries and the world (Source: Adapted from Blok, Hofheinz and Kerkhoven, 2015)

It is the fact that the building sector is the highest energy-consumer by 31% at global level and 36% in the EU-27 countries in terms of total energy consumption in 2015. In particular, residential buildings account for 24% and 23% of total energy consumption in the EU-27 countries and all around the world, respectively (Blok et al., 2015). In Turkey, Environmental Indicators of Turkey 2016 published by the Ministry of Environment and Urbanisation [MEU] indicated that household-trade and service sector has the highest share with 24.5% in total energy consumption, followed by energy and conversion (23,3%), transport (19,7%), non-energy (5,1%) and agriculture

and livestock sector (3%) in 2016 (Ministry of Environment and Urbanisation [MEU], 2018) (Figure 1.2).

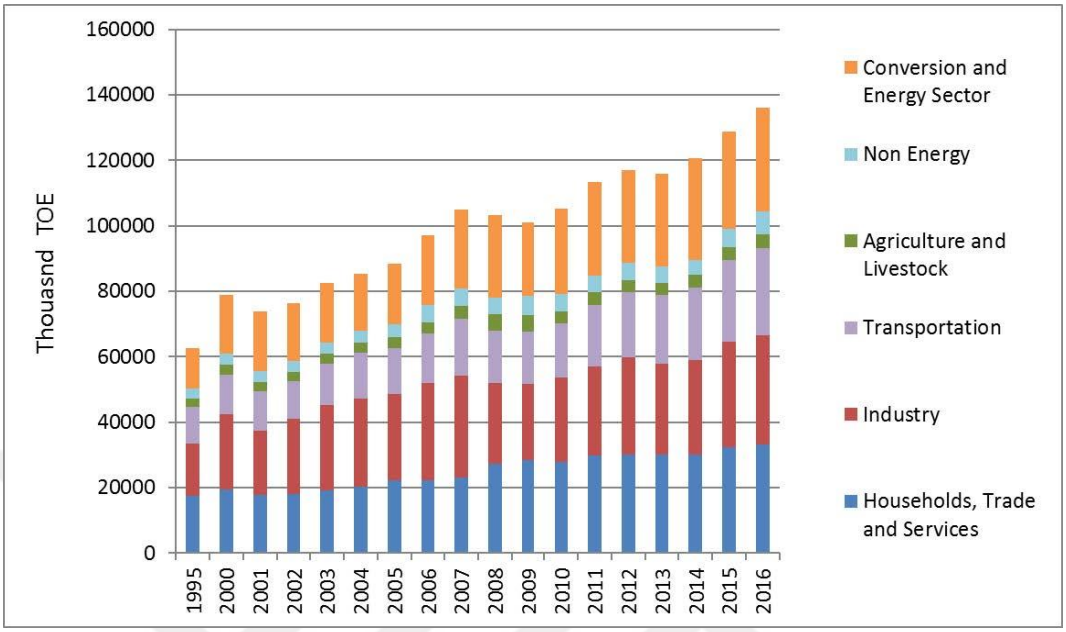


Figure 1.2. Total energy consumption by sectors in the year 2016 in Turkey (Source: MEU, 2018)

European Commission (EC) has attempted a series of policies and regulations on new and existing buildings to promote the improvement of buildings' energy performance, reduce CO_2 emissions and minimize the effect of climate change in the EU countries (European Union, 2002; European Union, 2010; European Union, 2012). It initially entailed three key targets; to reduce Greenhouse gas (GHG) emissions by at least 20%, increase the share of renewable energy sources by 20% in energy consumption and achieve energy savings of 20% by 2020 (European Commission, 2010). Furthermore, by 2050 towards the initiatives for low-carbon development, energy and resource efficiency of the EU countries, the EU has determined a long-term strategy for reducing GHG emissions by 80-95% in comparison to 1990 levels (European Commission, 2011a). When the EU strategies are taken into consideration, building sector has a key role not only constructing new buildings to be low or zero energy, but also encouraging the renovation of existing building stock to make them more energy-efficient.

As a candidate country for the EU, Turkey upgrades its legal efforts in a way to compatible with the EU's legal process. Initially, TS 825-Thermal Insulation Requirements for Buildings came into force at 1998, has been in use as the national

legislation since 2000, and so was revised in 2008 (TSE, 2008). Then, The Energy Efficiency Law in 2007 was adopted by the Ministry of Public Works and Settlement, currently changed as MEU to increase energy efficiency, avoid energy waste, minimize the burden of energy costs on the economy and ensure efficient use of energy and energy sources. Then, in 2008, Energy Performance Regulation on Buildings was published in line with the requirements of the Energy Efficiency Law. The regulation was prepared based on the Energy Performance Building Directive (EPBD) 2002/91/EC. It stipulated new and existing buildings to receive the energy certificate by 2017 and the determination of minimum energy performance requirements for buildings which undergo the renovation, as well as the energy classification of the buildings (Bayındırlık ve İskân Bakanlığı, 2008). More recently, in 2012, Turkey announced the Energy Efficiency Strategy Paper (2012-2023) which presents a comprehensive framework on energy efficiency actions, specifically closely associated with existing building renovation. It is envisaged that at least one fourth of the building stock in 2010 will be sustainable building by the year 2023 (Ministry of Energy and Natural Resources [MENR], 2012).

Historic buildings constitute a substantial part of existing building stock. Historic buildings constitute over 25% of total buildings (Moran, Blight, Natarajan and Shea, 2014) and more than 40% of the residential ones were built before 1960s in Europe (Building Performance Institute Europe [BPIE], 2011). In Turkey, the ratio of historic buildings built before 1945 is 6.1% (EFFESUS, 2013). According to the statistics of General Directorate of Cultural Heritage and Museums, residential buildings representing civil architecture examples have a great share of 53,4% within legally protected immovable cultural properties of Turkey by the end of year 2017 (Kültür Varlıkları ve Müzeler Genel Müdürlüğü, 2017) (Figure 1.3).

Historic buildings were designed in accordance with the period of time in which they are in. They present inherently sustainable building characteristics in terms of construction type, material and land use, and topographic conditions. The careful adaptation and re-use of historic buildings and allowing their thermal ugrading can show favourable results compatible with conservation principles and sustainability (English Heritage, 2012).

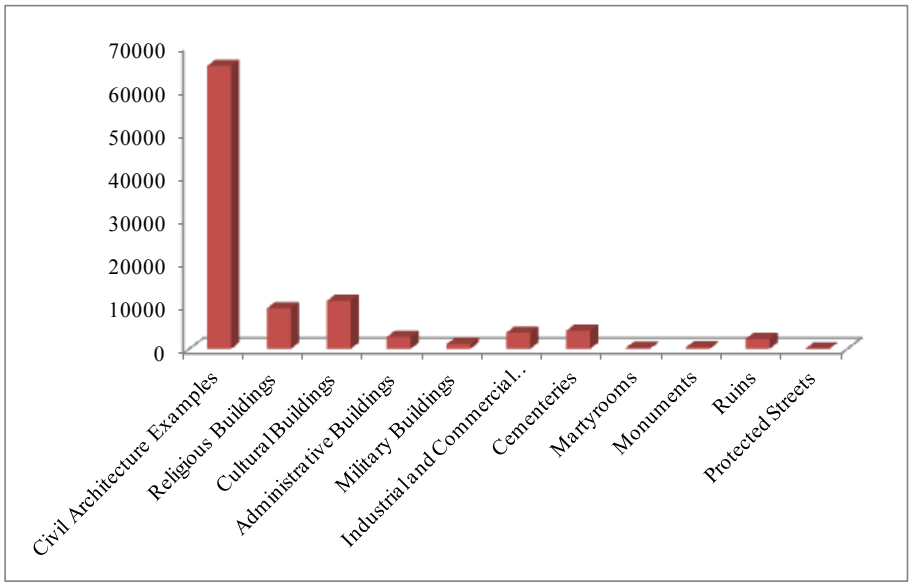


Figure 1.3. Distribution of legally protected immovable cultural properties in Turkey (Source: Adapted from Kültür Varlıkları ve Müzeler Genel Müdürlüğü, 2017)

Historic buildings differ from other existing buildings not only with their distinctive architectural and aesthetical characteristics but also with having less tangible elements such as associations of historic people, events, aspects of social history and other assets within the heritage values. The heritage value of buildings encompasses evidential, historical, aesthetic and communal values (English Heritage, 2012). It should be well acknowledged that historic buildings require a special interest for protecting and maintaining the heritage values when they are subject of energy-efficient retrofit activities. This issue should be also addressed in an interdisciplinary approach so as to bridge the gaps between conservation principles and improvement of energy-efficiency of historic buildings.

Considering energy-efficient retrofit of historic buildings from a legal perspective, historic buildings were brought to agenda as a subject of sustainability in various conferences before the first EPBD was entered into force in 2002 in Europe. Although they raised awareness, they could not be effectively integrated into the first EPBD (Litti, Audenaert, and Braet, 2013). The first EPBD in its article 4 pointed out that "Member States may decide not to set or apply the requirements" referred to this building category: "Buildings and monuments officially registered as part of a designated environment or because of their special architectural or historical merit, in so far as compliance with certain minimum energy performance requirements would unacceptably alter their character or appearance" (European Union, 2002). Then, the

following directives revised and rearticulated the above-referred statement in their articles (European Union, 2010; European Union, 2012). The recent EPBD points out that the testing of new solutions for improving the energy performance of historical buildings and sites should be encouraged while safeguarding and preserving heritage values (European Union, 2018).

One concern is that the EU gives initiative to its Member States about deciding whether to apply minimum energy performance requirements to historic buildings. However, there is no protocol on how to improve historic buildings in an energy-efficient way (Mazzerella, 2015). Another concern is how to treat historic but not 'officially registered' buildings. The European Building Directives do not establish any legal barriers to prevent the application of minimum energy performance requirements in such buildings. Even if the buildings do not have such a denotation, non-officially registered buildings require particular attention regarding conservation, aesthetical, structural and building physics-related issues (Troi, 2011). Minor and moderate energy efficiency measures may often be feasible for the heritage buildings, even though they do not undergo the total renovation (BPIE, 2011).

In the energy performance regulation of Turkey, there is no clear definition about historic building retrofit. It refers to a similar statement as specified in the EPBDs (Bayındırlık ve İskân Bakanlığı, 2008). The following initiatives about building energy retrofit do not include historic buildings within existing building category in Turkey (MENR, 2012).

Due to lack of the legislative efforts at EU level, many European countries have set a course for improving energy efficiency of their historic environments while sustaining the heritage values. Guidelines, research projects and scientific studies are essential initiatives on this issue. Furthermore, the EU generated a new standard BS EN 16883:2017, Guidelines for improving the energy performance of historic buildings in behalf of increasing energy efficiency of historic buildings in Europe (BSI Standards Development, 2017).

There is a limited effort on historic building retrofit at national level except for a limited number of scientific studies (Şahin, 2013; Şahin, Arsan, Tuncoku, Broström and Akkurt, 2015) and only a research project (EFFESUS, 2016a). Moreover, it is required to conduct further studies to broaden energy efficiency viewpoint on historic buildings specifically for residential ones in Turkey.

In terms of energy-efficient retrofit impovements, larger scale case studies require a retrofit strategy differently from the studies conducted at individual scale. In this scope, it is significant to find which buildings are providing the most energy saving in a short time while deciding retrofit solutions. The need of developing an integrated approach is essential to identify energy-efficient solutions for retrofit strategy of larger scale case studies.

1.2. Aim and Objectives of the Study

In large scale rehabilitation projects, the requirement of developing a retrofit strategy is crucial about how to decide solutions to which buildings can initially be retrofitted. In historic urban fabrics of Turkey, generally, street and/or façade rehabilitation projects are conducted at neighbourhood scale. These studies are limited to various efforts such as improving the physical appearances of buildings and façade components, painting of buildings' façades and fixing street furnitures and decoration elements by protecting the fabric and distinctive characteristics of the buildings and streets. İzmir Metropolitan Municipality has prepared for a façade rehabilitation project for the determined case area. This thesis aims at broadening this approach from the energy efficient point of view. Thus improving energy performance of 22 historic and contemporary buildings at neighbourhood scale in historic urban fabric of Basmane, İzmir is proposed with by proposing a range of energy-efficient retrofit solutions.

The objectives to accomplish the aim of thesis are stated as follows:

- Developing an integrated approach to identify case-specific energy efficient solutions for retrofit strategy of larger scale historic district
- Proposing retrofit solutions for a residential area in historic urban fabric consisting of both historic and contemporary buildings, and identifying the most appropriate retrofit solutions eliminating inappropriate ones
- Saving energy as much as possible for historic buildings considering the heritage value of the buildings
- Conducting a quick survey analysis for buildings to identify the possible retrofit solutions in a short time and prioritizing buildings are of top priority to which these solutions need to be implemented

- Classifying and characterizing case buildings with different features under groups and identifying the appropriate retrofit solutions for each group
- Discussing the current status of case buildings in terms of energy performance and presenting the comparisons between building groups after the retrofit process
- Analyzing the significance of building performance simulations in retrofitting process
- Investigating the relationship between buildings' design parameters and energy performance of buildings
- Displaying an energy-efficient approach to buildings at neighbourhood scale rather than an individual building scale
- Expanding the studies on energy-efficient approach to historic buildings in Turkey in addition to conservation-related studies

1.3. Limitations and Assumptions

During the study, there have been some limitations and assumptions arising from several sections of the overall method of the thesis. The limitations are stated as follows:

- The detailed and required information about the case buildings have not been reached during the field survey since most of the buildings fell into disuse or risk of collapse.
- Any information, i.e. documentation, scientific studies and thesis, have not been reached about the buildings' pysical characteristics, i.e., plan schemes, sections, construction types and materials, except for Buildings 12, 19 and 20.
- The insecure and temporary use of the case buildings and mostly renting of these buildings make it difficult to collect information about the buildings and the case area.
- Observations about the case area have been conducted in 20th and 25th of June 2014. Then, the data collected from the case area was checked and revised between the 10th and 15th of February 2016. Within this time

period, Building 5 was emptied and Building 20 was in danger of collapse.

- Short interviews could be conducted only for Building 3, 7, 21 and 22, because there is not continuous use of most case buildings.

The assumptions are stated as follows:

- Assumptions about the physical characteristics of buildings' envelopes have been utilized on-site measurements, personal observations and short interviews with the occupants (for detailed assumptions and limitations about the geometry of the case buildings see Section 5.2.2).
- Kumrulu Masjid, adjacent to Building 20, is out of scope of this study since the building is a religious building and was recently restored.

1.4. Thesis Outline

This thesis comprises of seven chapters of which the first one starts with an introduction. In this chapter, the general framework of the thesis is mentioned. Significance of energy performance and retrofitting of existing buildings is presented. The legislative efforts on energy efficiency of buildings covering both historic and contemporary ones in the EU and Turkey are briefly explained. Then, aim, scope and objectives of the research are enlightened.

The second chapter presents the background of the study. It includes an overview about energy efficiency and energy-efficient retrofit, previous and current policies and more recent activities about building energy performance in the EU and Turkey. Following, scientific studies on existing building retrofit conducted in European countries are presented.

The third chapter specifically focuses on historic buildings from energy efficiency and retrofit point of view. It draws attention to the importance and characteristics of historic buildings that distinguish them from other existing ones, as well as current status in existing residential building stock in Europe and Turkey. It also demonstrates legal approaches and other initiatives including research projects, guidelines and standards and then limitations and problems about retrofitting of historic buildings. Finally the state-of-the-art of survey on energy-efficient retrofit of historic

residential buildings based on many scientific studies published in European countries and Turkey is presented.

In the fourth chapter named ‘Basmane District: 1273 Street’, 1273 Street selected for the case area is presented. After describing Basmane District and its residential fabric in terms of their historical development, significance and the projects conducted within it, the study has mainly concentrated on the case area. Buildings located in the street are characterized and their structural components are explained.

In the fifth chapter, material and method used in the study are clarified. The chapter prefaces with data collection, short interviews and on-site measurements conducted in the case area. Then, the dynamic simulation modelling of buildings is created for analyzing energy performance. The prevailing design parameters affecting energy consumption of buildings are presented through numerical analysis in order to prioritize buildings for identifying the retrofit solutions. Finally, an energy-efficient retrofit strategy is presented to categorize case buildings and find the most appropriate retrofit solutions for each building group.

The results of total energy consumption for each building group before and after retrofit process are presented in the sixth chapter. The comparisons of the simulation results of building groups with each other and the overall evaluation of results of all building groups are discussed.

The seventh chapter encapsulates the obtained conclusions from this research and possible further studies as well as recommendations for future problems in the research area.

CHAPTER 2

LITERATURE REVIEW

In this chapter, a survey of literature about the studies related to the research area was conducted. This chapter generally presents the scientific studies and the legislative efforts on increasing energy efficiency of the existing buildings via retrofitting way. The main objective of this chapter is to highlight the related studies in the literature, and make them the source of inspiration for the framework of the thesis.

Literature survey was conducted under two main categories: energy-efficient retrofitting of the existing and historic buildings. The first section of the literature review starts with an overview about energy efficiency, building energy performance assessment and energy efficient retrofitting. This section focuses on the background and current policies including action plans, directives, climate and energy strategies primarily related to building energy performance, energy efficiency and energy-efficient retrofitting throughout the Europe. Later, it goes forward with Turkey's policy progress in similar direction. The last part also reveals the process of adaptation of Turkey to the EU related to buildings' energy performance.

The next section of literature review on historic buildings was grouped under two sub-categories as single historic buildings and historic districts when considered from energy efficient point of view. In this section, primarily researches on considering the heritage value are the most important criterion when reviewing the literature. This section includes the publications, guidelines, standards and nationally and internationally conducted research projects connected to the research area. Especially with the section concerned on research and regulative activities for the European countries and particularly Turkey make explicit contribution to the problem statement of the thesis. A broad range of publications and the research projects on energy-efficient retrofitting historic buildings and districts were carefully investigated by tabularizing them.

2.1. Energy Efficiency and Energy-efficient Retrofit in Buildings

When the energy saving and efficiency issues occurred, most professionals and researchers encounter with the questions of how to define degree of energy efficiency and how to assesses energy performance of buildings? Energy efficiency can be identified as using less energy without compromising the building performance and human comfort, or avoiding unnecessary energy consumption. Energy performance assessment is substantial in establishing efficient energy use in buildings, by which it supplies understandable information to owners or occupants concerning how much energy being consumed and how much performance are achieved in comparison with energy benchmarks in use. It supplies understandable information to building owners or occupants concerning how much energy being consumed and how the performance is assessed in comparison with current energy benchmarks. Correspondingly, it is a necessary initiative to determine cost-effective energy saving potentials if buildings have lower energy performance. Building energy performance assessment also contributes to reduce operation and maintenance costs of any action taken for the minimization of energy consumption (Wang, Yan and Xiao, 2012).

As a term, 'retrofit' means "providing something with a component or feature not fitted during manufacture or adding something that it did not have when first constructed" (Eames et al., 2014, p. 2). Retrofit can be defined for buildings that "making changes to the systems inside the building or even the structure itself at some point after its initial construction and occupation" (Mazzarella, 2015, p. 30). In a sense, retrofitting is more related to the installation of new systems, but also refers to modify a building fabric like addition of insulation to the walls and improvement of the glazing system with the aim of enhancing energy efficiency of buildings. On the other hand, the literature on retrofitting of existing buildings frequently addresses the terms such as 'refurbishment' and 'renovation' similar to 'retrofit.' Refurbishment implies a broad process of improvements by repairing, renovating and modifying so as to meet economic and/or functional, criteria of a building. 'Renovation' and 'refurbishment' terms have a similar meaning and they are sometimes used as if they are interchangeable. However, 'renovation' differs from 'refurbishment' in some way. Renovation is appropriate particularly for buildings. 'Renovation' mostly concentrates on aesthetics and occupants facilities, as well as it may include the installation of building systems and energy efficient measures (Mazzarella, 2015). In the scope of this

thesis, as a term, retrofit has been selected since it highly concerns about the alterations on the buildings' fabric and systems. Accordingly, the thesis focuses on making improvements on the components of the buildings' envelope such walls, floors, roofs and openings so as to increase energy efficiency.

Building Performance Institute Europe. (BPIE, 2013) summarizes the following major benefits of sustainable energy renovation of the buildings (Table 2.1):

Table 2.1. The multiple benefits of energy renovation of the buildings
(Source: Adapted from BPIE, 2013)

Economic Benefits	**Societal Benefits**	**Environmental Benefits**	**Energy System Benefits**
Providing energy cost saving	Reducing fuel poverty	Reducing CO_2 emissions	Increasing energy security
Economic stimulus	Health benefits	Reducing air pollution	Avoiding new generation capacity
Positive impact on gross domestic products (GDP)	Increasing occupant comfort and productivity		Reducing energy demand
Increasing property values			
Promoting research&development, industrial competitiveness, export opportunities			
Positive impact on public finances			
Reducing energy import bills			

In the process of the retrofitting existing buildings, it is important to decide and apply cost-effective solutions while enhancing energy performance, as well as maintaining efficient service levels, convenient indoor thermal comfort under the such constraints as climate conditions, building information, human requirements and behavior, financial conditions, retrofit technologies, services equipments, energy sources, government policies and regulations (Ma, Cooper, Daly, and Ledo, 2012).

The other important issue is to determine the most appropriate energy saving measures (ESM) in the building renovation process to realize retrofit targets and to obtain more effective and more reliable results over the long term. According to Terés-Zubiagaa, Campos-Celador, González-Pinoa and Escudero-Revilla (2015), ESMs for

existing buildings can be mainly identified in three different ways including energy savings related to thermal performance of the building envelope, energy savings by upgrading heating systems and energy savings based on partly or fully supplying from energy demand by renewable sources.

2.1.1. The Major Phases in Building Retrofit

The process of sustainable building retrofit requires major phases for defining, determining and applying the optimal retrofit measures. Respectively, these are building energy audit, energy performance assessment, quantifying potential energy savings and evaluating the performance of energy benefits. Initially, it is required to identify scope of the work and set the project objectives before starting to the retrofit process. Besides, conducting a pre-retrofit survey helps to better understand building operational problems and occupants matters (Ma et al., 2012).

Energy audit is a process that investigates energy use and its optimization in existing buildings. It has an important role on determining operating problems, increasing human comfort, and evaluating potentials for energy conservation. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) classify energy audit in 3 levels as: Walk through assessment, energy survey and analysis and detailed energy analysis. Convenient energy audit level can be chosen taking into account of project objectives, project details, scope of work, and so time frame and budget (Alajmi, 2012).

Energy performance assessment and diagnosis are another phases which are used for benchmarking energy use to sustain building retrofit. Energy diagnosis detects inadequate equipment, inappropriate control schemes and building operation problems (Ascione, Bianco, De Masi, De'Rossi, and Vanoli, 2015). It can be called as performance auditing tool that specifies poor energy performance zones and gives proper data to repair these zones. Diagnosis methodology investigates whole building energy consumption including HVAC systems, lighting and office equipments and subsystems such as lifts, fire and security systems (Yan, Wang, Xiao, and Gao, 2015).

Quantification of energy savings is a substantial step to determine optimal saving measures in the sustainable building retrofit process. Various energy simulation packages, energy simulation models and also Building Information Modeling (BIM) are

generally used to evaluate energy performance of different retrofit measures. Some of energy simulation programs can be used to simulate the thermodynamic characteristics and energy performance of different retrofit measures. To select correct programs and to generate its parameters help to reach reliable results. After the determination of potential energy savings, prioritizing retrofit measures and eliminating inappropriate ones should be necessary to obtain better economical, energy-efficient and environmental solutions. Economic analysis and risk assessment methods are commonly used to evaluate the performance of retrofit measures. Economic analysis deliberates over whether the retrofit measures are energy efficient and cost effective comparing among retrofit alternatives. On the other hand, risk assessment assesses quantitative or qualitative value of potential risks, as well as gives information decision makers about risk exposure (Ma et al., 2012).

2.1.2. Energy Efficiency and Building Retrofit in European Policy

Energy efficiency issues have long been an integral component of the European Union's common policy. The EU has had increasingly more ambitious energy policies and programmes since the early 1970's oil crisis resulted from heavily dependency on fuel imports. After the crisis, European countries have diversified supplies, reduced dependence on OPEC (Organization of Petroleum Exporting Countries), developed an extensive mix of energy sources and maximized domestic energy sources including renewable energy. Accordingly, improving efficiency to reduce energy demand at all phases of the energy cycle has been the center of attention of the European policy (EuroACE, 2004).

From the 1980's, environmental concerns has began to affect the design of energy policy. Initially, acid rain and then global warming have brought to the agenda. European governments have approved targets toward GHG emissions (Helm, 2002).

In 1992, countries took part in the international environmental treaty, the United Nations Framework on Convention on Climate Change (UNFCCC) adopted in the Rio Earth Summit, to consider what they could do to limit the increasing greenhouse gas in the atmosphere at a certain level and the resulting climate change and to overcome its harmful effects (United Nations, 1992). Therewith, the Kyoto Protocol as a substantial extension to the Convention proposed legally binding measures so as to limit and to

reduce GHGs by setting national objectives, in 1997. After the Kyoto protocol came into force in 2005, industrialized countries have committed to reduce their overall emissions by at least 5% below 1990 levels in the first Kyoto period 2008 to 2012 (United Nations, 1998). While this commitment under the Protocol varies from nation to nation, the EU introduced the deepest GHGs cuts and approved the highest reduction target by 8% among all the major industrialized countries (Oberthür and Kelly, 2008).

Energy efficiency has gained acceleration in policy direction of the EU through action plans and directives on energy efficiency particularly since 2000. In April 2000, an Action Plan for Improving Energy Efficiency emerged on the invitation of the Council in 7 December 1998 regarding the necessity of promoting energy efficiency vigorously in the European Community. In the Action Plan, proposed actions to the removal of barriers for energy efficiency were included in three mechanism groups; the integration of energy efficiency into non-energy policies and programmes; strengthening existing policies and measures; and new policies and measures. Moreover, these actions were planned to implement in the areas of transport, industry, buildings, household appliances, commercial and other end-use equipment, research and technology. As regards to the buildings, it was required to special interest to the building sector. Accordingly, proposed key actions in this sector covered the insulating new buildings; energy efficiency standards; programmes or incentives for improving insulation of existing buildings, energy certification and training, regular inspection of boilers, heating, air conditioning and hot water systems. Among the many initiatives, the Community also launched the EU Green Light program to promote efficient lighting in commercial and public buildings (Commission of the European Communities, 2000).

Energy Performance of Building Directive (2002/91/EC): The main regulatory framework in energy efficiency policy directly influencing the building sector is the Energy Performance of Building Directive (EPBD) (2002/91/EC). The directive entered into forced on 4 January 2003. After the directive became obligatory, it allowed for a process of adaptation in order for the EU member states to implement the EPBD measures by 4 January 2006 at the latest. The EPBD was legislated by EC so as to promote the improvement of the building energy performance and to achieve carbon emissions targets for environmental protection under the Kyoto commitment. This directive contains all aspects of energy efficiency in buildings in an attempt to establish a truly integrated approach (European Union, 2002). Article 1 refers to the key objectives in the Directive:

- A methodology framework for calculating the integrated energy performance of buildings
- Establishing minimum energy performance requirements on the energy performance of new buildings and large existing buildings that are subject to major renovation
- Energy certification system for buildings
- Regular inspection of boilers and of air-conditioning systems in buildings, and an assessment of the heating installation in which the boilers are more than 15 years-old (European Union, 2002).

In the line with the findings of the Green Paper on Energy Efficiency or Doing More with Less, still-continuing energy challenges derived from the dependency on energy import, concerns about supplies of fossil fuels and the effects of climate change caused to launch a new energy efficiency effort. The Green Paper envisaged that the EU holds a potential to achieve a reduction of the energy consumption by 20 % compared to the projections for 2020 in a cost effective way (Commission of the European Communities, 2005). Consequently, the EU took a remarkable step within the 2006 Action Plan for Energy Efficiency (2007-2012) aimed at reaching the 20% primary energy savings by 2020. The Action Plan covered a wide range of cost-effective initiatives to make more energy efficient of energy services, energy generation, transport and buildings. As a priority, the focus was the building sector because of having the largest cost-effective energy saving potential among all sectors, with the estimation of the saving potential around at 27% and 30%, respectively in residential and commercial buildings. Additionally, it represented that retrofitted walls and insulated roofs represent a great opportunity for energy saving in residential buildings, while improved energy management systems are significant for commercial buildings. The Action Plan was also interested in adopting minimum energy performance requirements for new and renovated buildings and developing a strategy for low energy or passive buildings (Commission of the European Communities, 2000).

Energy Performance of Building Directive (2010/31/EU): On 19 may 2010, the EPBD 2010/31/EU, called as the recast EPBD, was enacted with more ambitious targets so as to consolidate the energy performance requirements and to clarify and regulate some of the provisions from the first EPBD and considering a large number of energy efficiency measures of the 2006 Action Plan. By 9 July 2012, the Member States

should adopt and publish their national rules implementing the articles of the recast EPBD. Differently from the first EPBD, the recast EPBD introduces the following principal novelties addressing building sector: all new buildings must be nearly zero-energy buildings by 2020 and for public buildings by 2018; extension of minimum energy performance requirements to all new and existing buildings, regardless of their size, including building systems, components of building envelope and renovated buildings or renovated parts; a comparative calculation methodology for minimum energy performance requirements towards a cost-optimal level; and a more detailed procedure for energy performance certificates within controls on a regular basis (European Union, 2010). As for building retrofit, the Directive gives more importance to the major renovation of existing buildings about providing an opportunity to take cost-effective measures. However, there was no specific target for renovation, but the necessity for Member States to set their objectives toward existing buildings was stressed in order to stimulate the transformation of refurbished buildings into nearly-zero energy and to inform the Commission about their national plans and targets (European Union, 2010).

Although there are the ambitious developments on energy efficiency, nevertheless, the EU was on course to achieve only half of the 20% objective according to the estimation of the Commission. In 8 March 2011, the EC has therefore developed a new Energy Efficiency Plan 2011 toward putting 20% targets on the right track. This plan forms a part of the EU's 20% targets and 2020 Energy Strategy. It principally concentrates on buildings and transport, product and processes due to their higher energy saving potential. The plan rightly acknowledges that the greatest potential for energy saving lies in buildings. The action plan proposes measures for buildings to stimulate the renovation process for public and private buildings and to improve energy performance of buildings, services and products (European Commission, 2011a).

Energy Efficiency Directive (EED) (2012/27/EU): The directive is the EU's last framework in the scope of energy efficiency, which was adopted on 25 October 2012, as a legally extended result of the Energy Efficiency Plan 2011. The EED is crucial for energy efficiency target of saving 20% in the EU's primary energy consumption by 2020 and for further energy efficiency improvements after 2020, especially for the EU's 2050 roadmap. The EED places emphasis on building stock of the EU countries. It comprises a basis for making the buildings more energy-efficient and necessitates the EU countries to establish long-term national strategies towards

renovating building stock. Correspondingly, it obligates for Member States to establish National Energy Efficiency Action Plans (NEEAPs) by 30 April 2014 and updates every three years thereafter. NEEAPs set out energy efficient improvement measures, expected and/or achieved energy savings and estimated energy consumption. Moreover, Member States are required to transpose the laws, regulations and provisions into their national laws by June 2014 (European Union, 2012). Under the Directive, the following eight articles concerning the buildings and building renovation:

- Article 4 points out establishing long-term strategy for mobilising investment in the renovation of the national stock of residential and commercial buildings, both public and private. This article also focuses on providing an overview of national building stock on statistical, stimulating cost-effective deep renovation of buildings and estimating expected energy savings and wider benefits that will results from renovations.
- Article 5 concerns public bodies' buildings on providing an exemplary role by each year renovating 3% of floor space in buildings of central governments, aiming to meet minimum energy performance requirements.
- Article 6 is related to the encouragement of central governments to purchase only products, services and buildings with high energy-efficiency performance.
- The focus of Article 7 is to achieve 1.5% yearly efficiency improvements between the period 2014 and 2020, within national energy efficiency obligation schemes. This obligation can be used to support and finance building renovation.
- The article of number 8 proposes the high quality energy audits and energy management systems in cost-effective and an independent manner and the necessity of raising awareness among households about the benefits of audits.
- Article 9 refers to the supplement of individual meters for electricity, natural gas, district heating, district cooling and domestic hot water to final customers providing information about energy consumption and actual time

of use. Such meters must be provided when a new connection is made in a new building or a building undergoes major renovation.

- Article 16 includes certification, accreditation and equivalent qualification schemes for providers of energy services, energy audits, energy managers and installers of energy-related building.
- The article of number 18 emphasizes the necessity of encouraging energy services market and supporting the public sector in taking up energy services offers, particularly for building refurbishment (European Union, 2012).

Energy Performance of Building Directive (EPBD) (2018/844/EU): The 2rd revised Energy Performance of Building Directive (EPBD) was published by the Council of the European Union on 19 June 2018. The revised provisions entered into force on 9 July 2018. EU countries will have to transpose the provisions of the legislation into national law by 10 March 2020 (European Union, 2018).

The 2rd recast directive is committed to developing sustainable, competitive, secure and decarbonised energy systems. It presents key requirements for the building sector. It is intended to accelerate building renovation toward energy-efficient systems, strengthen the energy performance of new buildings, making them smarter. The key measures include (European Union, 2018):

- Establishing a long-term renovation strategy for Member States to achieve an energy-efficient and decarbonised European building stock by 2050
- Ensuring new buildings to take necessary measures in order to meet minimum energy performance requirements and encouraging buildings undergoing major renovation high-efficiency alternative systems in so far as this is technically, functionally and economically feasible, and addressing the issues of healthy indoor climate conditions, fire safety and risks related to intense seismic activity
- Ensuring new buildings, where technically and economically feasible, to be equipped with selfregulating devices for the separate regulation of the temperature in each room or, where justified, in a designated heated zone of the building unit

- Strengthening measures to establish regular inspection of heating, ventilation and air-conditioning systems and presenting a feasibility study about the inspection of stand-alone ventilation systems, and an optional building renovation passport that is complementary to the energy performance certificates
- Establishing of a voluntary Smart Readiness Indicator (SRI) promoting digitalisation and smart Technologies

2.2. Energy and Climate Strategies of the EU

The energy efficiency activities are closely linked to environmental policy, particularly climate change. At UNFCCC Conference in Montreal in 2005, countries negotiated about deeper cuts in GHG emissions for post-period of the Kyoto Protocol due to its expiration in 2012 (Capros, 2011).

The EU has been at the forefront of international efforts to tackle global climate change. Accordingly, the EU took ambitious energy and climate change targets for 2020. The European Council proposed that the EU and its Member States pursue a 30% reduction in GHGs by all developed countries by 2020 as a part of the international agreement aimed at limiting global climate change to less than 2°C above pre-industrial levels. In addition, the EU has already planned its independent commitment to succeed in the objective of at least a 20% reduction of GHG emissions by 2020 compared to 1990 levels. In January 2007, these emissions targets were underpinned by the following energy-related objectives for 2020 (Commission of the European Communities, 2007):

- A 20% improvement in EU's energy efficiency
- A 20% share of energy consumption supplied from renewable energy sources

2.2.1. The Europe 2020 Strategy

The Europe 2020 Strategy is a ten-year job and growth strategy launched on 3 March 2010 by the EC. The strategy lays down three priorities: "smart growth-developing an economy based on knowledge and innovation, sustainable growth-

promoting a more resource-efficient, greener and more competitive economy, and inclusive growth - fostering a high-employment economy delivering economic, social and territorial cohesion" (European Commission, 2010, p. 10). To make realize these priorities, the European Commission proposed five headline objectives to be achieved by 2020 and to be translated into national targets in the fields of employment, innovation, education, social inclusion and climate change and energy. The Commission also introduced seven flagship initiatives to facilitate progress under each priority theme. The flagship initiative, 'Resource Efficient Europe' represents energy efficiency as a major element in providing the sustainability of the use of energy resources. The five headline objectives of the Europe 2020 Strategy are described as the following:

- The employment rate of the population aged 20-64 should increase from the current 69% to at least 75%, including through the greater involvement of women, older workers and the better integration of migrants in the work force;
- The EU currently has a target of investing 3% of GDP in R&D. The target has succeeded in focusing attention on the need for both the public and private sectors to invest in R&D but it focuses on input rather than impact. There is a clear need to improve the conditions for private R&D in the EU and many of the measures proposed in this strategy will do this. It is also clear that by looking at R&D and innovation together we would get a broader range of expenditure which would be more relevant for business operations and for productivity drivers. The Commission proposes to keep the 3% target while developing an indicator which would reflect R&D and innovation intensity;
- Reduce greenhouse gas emissions by at least 20% compared to 1990 levels or by 30%, if the conditions are right; increase the share of renewable energy sources in our final energy consumption to 20%; and a 20% increase in energy efficiency;
- A target on educational attainment which tackles the problem of early school leavers by reducing the drop out rate to 10% from the current 15%, whilst increasing the share of the population aged 30-34 having completed tertiary education from 31% to at least 40% in 2020;
- The number of Europeans living below the national poverty lines should be reduced by 25%, lifting over 20 million people out of poverty (European Commission, 2010, pp 10-11).

2.2.2. Europe 2050 Roadmaps

The EU is committed longer-term strategies to decreasing GHG emissions to 80 to 95% compared to 1990 levels by 2050 which is linked to the objective of ensuring global warming does not exceed 2℃ above pre-industrial levels. Emphasizing the way to achieve these objectives, the European Commission has adopted roadmaps on low-carbon development, energy and resource efficiency.

The Low-Carbon Economy 2050 Roadmap: On 8 March 2011, the European Commission launched 'A roadmap for moving to a competitive low carbon economy in

2050' under the Resource Efficiency Flagship Initiative. Through domestic actions alone, the roadmap sets out milestones to reach the 2050 goal in a cost-effective way, a 40% reduction in emissions by 2030 and a 60% reduction by 2040, as well as a 25% reduction by 2020. In this sense, energy efficiency is crucial for the successful transition to low-carbon economy. If the EU meets 20% energy efficiency improvement target and the energy-efficient actions are fully implemented, it will outperform its 2020 target and provide a 25% reduction. Among various sectors, built environment facilitate low-cost and short-term opportunities by improving of building energy performance. The roadmap analysis shows that emissions can be cut in this area by around 90% by 2050 if the climate change targets are to be met. Priorities under the building sector cover the new buildings to be low or zero energy, the refurbishment of the existing building stock and the use of low-carbon electricity and renewable energies by moving away from the fossil fuels (European Commission, 2011b).

The Energy Roadmap 2050: On the basis of the low-carbon roadmap for 2050, the energy roadmap was issued on 15 December 2011 by the European Commission. The roadmap investigates some pathways for the transition of the energy systems in a way to compatible with the 2050 target, while ensuring competitiveness and security of supply. It also forms a basis for developing the 2030 policy framework. The roadmap proposes scenarios to illustrate potential future developments of the EU's energy systems by analyzing and combining in different ways. According to the Energy Roadmap, improving energy efficiency is a key driver in all decarbonisation scenarios. To do this, it is necessary to the rigorous implementation of the current initiatives. The energy efficiency scenario assumes a political commitment, notably in the building sector, in order to get high primary energy savings, leading to a 41% cut in energy demand by 2050 in comparison with 2005 levels (European Commission, 2011c).

2.2.3. The 2030 Climate and Energy Framework

The EU has already formed a clear framework for 2020 targets and the EU has been getting ahead in meeting these targets. However, it is a matter of uncertainty about whether and how these targets will be continued after the period of the 2020. Therefore, in January 2014, 'A policy framework for climate and energy in the period from 2020 to 2030' was proposed by the European Commission to make the EU's economy and

energy systems a more competitive, secure and sustainable. GHG emissions, renewable energy and energy efficiency are the key pillars of this framework in common with the 2020 targets. The European Council reached an agreement on the EU-wide energy and climate framework for 2030 and then the triple key objectives which build on full implementation of the 2020 targets were approved on October 2014 (European Council, 2014):

- A binding target of an at least 40% cuts in GHG emissions (below 1990 levels) for the all member states in a most cost-effective manner
- A binding target of an at least 27% share for renewable energy
- An indicative target of an at least 27% improvement in energy efficiency. This target will be reviewed by 2020, considering the increase to 30%.

The proposed 2030 framework brings multiple benefits including reduces on highly imported energy dependency, greater innovation, job creation, economic growth and increase on competitiveness. It is also a strong action to fight against climate change. It sets out an ambitious target towards to meeting further developments for the 2050 Roadmaps. The target also set an exemplary commitment of the EU as a part of negotiations on the new global climate agreement for the Paris Conference in December 2015. The EU's efforts play a decisive role but also for the non-European countries. The Framework emphasizes that the EU should concentrate on strengthening EU–wide energy efficiency standards for appliances, equipments, buildings and CO2 standards for vehicles on behalf of accelerating the current efforts (European Council, 2014).

2.2.4. The Recent International Actions

On 12 December 2015, a new legally binding framework for internationally coordinated efforts to tackle climate change was issued at 21st Conference of Parties (COP21) to the UNFCCC in Paris. The agreement was opened for the signature from 22 April 2016 to 21 April 2017. It entered in force 4 November 2016. The Paris Agreement brings all nations into common but differentiated responsibilities to take ambitious efforts on climate change. The agreement was aimed to strengthen the national efforts and to support sustainable development by confirming the long-term objective of keeping the global temperature increase below 2℃ and pursuing efforts to limit the

temperature increase to 1.5℃ above pre-industrial levels. In order to achieve this objective, the global GHG emissions should peak at the soonest time possible and balance human-related emissions and eliminate GHGs in the second half of the century (United Nations, 2015).

2.3. Energy Efficiency and Building Retrofit in Turkey's Policy

Turkey has become one of the largest emerging markets, especially in energy, around the world with its rapid economic growth and relatively young and rapidly-increasing population. Energy demand has risen in accordance with increases in growing economy and there is also that Turkey has become heavily dependent on imported energy sources, primarily gas and fuel, due to its limited domestic energy resources. Nowadays, nearly 25% of the Turkey's total energy demand is met from domestic resources, while the remaining is supplied from the imported ones (Republic of Turkey Ministry for EU Affairs [MFA], 2014). Figure 2.1 indicates that appreciable increase of total primary energy supply (TPES) of Turkey from 24.4 million tonnes in 1973 to 114.1 Mtoe in 2011 at a compound annual growth rate 4%. It is foreseen that a compound annual growth rate of TPES around 4.5% from 2015 to 2030 with increasing to over 237 Mtoe (International Energy Agency [IEA], 2013).

Reducing foreign dependence on resources and by extension, supplying energy security are the matter of urgency for Turkey's energy policy 'while realizing economic growth and supporting social development by maintaining a steady flow of reliable, cost-effective and environmentally friendly forms of energy resources'. In this scope, Turkey's energy policy principally aims at (Republic of Turkey Ministry for EU Affairs [MFA], 2016):

- Making energy available for the consumers from the point of cost, time and amount
- Actuating public and private facilities as part of free market practices
- Enhancing independency on imports
- Increasing Turkey's influence on the energy field regionally and globally
- Ensuring the availability of varied routes, technology and resources
- Ensuring maximum renewable energy resources

- Increasing energy efficiency
- Reducing negative environmental impact while producing and using of energy

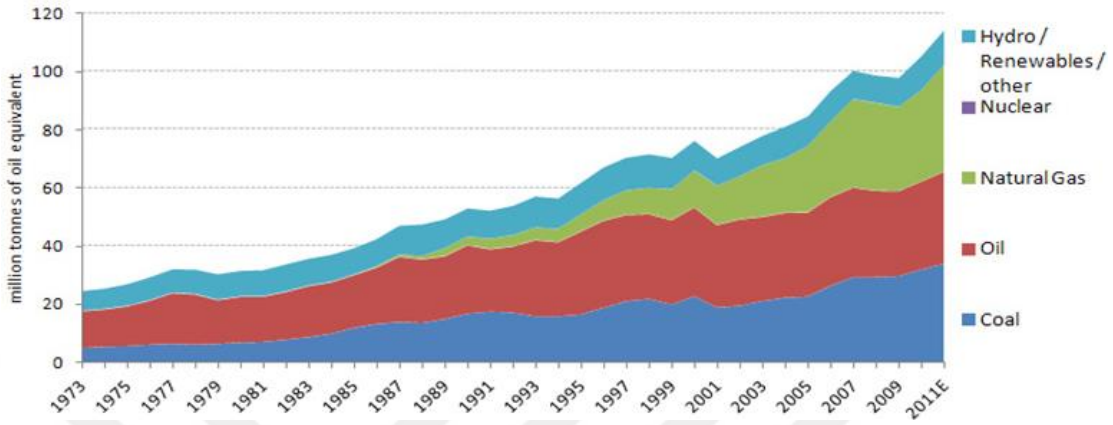


Figure 2.1. Total primary energy supply of Turkey
(Source: IEA, 2013)

2.3.1. Regulations on Energy Efficiency and Buildings in Turkey

Energy efficiency is one of the substantial components of national energy strategies and energy policies of Turkey. It is an effective route to enhance Turkey's energy security. Turkey has come a long way in forming the regulatory and institutional framework so as to increase energy efficiency. As a candidate country for the EU, Turkey is expected to fulfill the requirements in the adaptation to the EU's legal process. That's why, the legislative efforts have been also upgrading to compatible with the policies of the EU and its Member States. MENR and MEU are prominent institutions regarding energy efficiency and buildings activities in ongoing the process of Turkey particularly since 2000. There are a range of regulations in Turkey as follows:

2.3.2. TS 825- Thermal Insulation Requirements for Buildings

Heating and cooling requirements for buildings have a considerable share in energy use in Turkey. Turkey principally focuses on minimizing heat loss particularly in its cold regions by using thermal insulation. TS 825 'Thermal Insulation Requirements

for Buildings' establishes the rules for thermal insulation in buildings of Turkey. It came into force at 1998 and it has been in use as a compulsory since 2000. The TS 825 standard was revised in 2008. The main objective of the standard is to improve energy saving by limiting heating energy demand according to exposed area to A/V ratio. TS 825 standard divides the country into four climatic regions in terms of determined degree-day values. The standard includes a calculation procedure to determine heating energy demand of buildings. In the design phase of new buildings, by using the calculation method, building energy demand should be calculated not to exceed the limit values given in the standard and a thermal insulation project which includes material selection, sizing of building elements and detailed solutions should be prepared. For existing buildings, U-values of renovated parts should comply with values stated in the standard (Türk Standartları Enstitüsü, 2008).

2.3.3. Energy Efficiency Law and Building Energy Performance Regulation

Turkey adopted the Energy Efficiency Law in 2007 aiming at increasing efficiency, avoiding energy waste, minimizing the burden of energy costs on the economy and ensuring efficient use of energy and energy sources for protecting the environment. Moreover, it encourages the use of renewable energy and raises awareness of society about the energy issues. The Energy Efficiency Law addresses production, transmission, distribution and consumption phases of energy, buildings, electrical energy generation plants, industrial enterprises, transmission and distribution networks and transportation (Enerji ve Tabii Kaynaklar Bakanlığı [ETKB], 2007).

According to the requirements of the Energy Efficiency Law, Energy Performance Regulation on Buildings which published on 5 December 2008 by the Ministry of Public Works and Settlement, currently named as the MEU, has been a substantial step towards efficient use of energy in buildings of Turkey. The regulation was designed in accordance with the EPBD 2002 of the EU. It was regulated for new and existing buildings including residences, commercial and services buildings. The regulation pursues main objectives (ETKB, 2007):

- Determining calculation procedures for overall energy assessment of buildings

- Classifying the buildings with regard to primary energy use and CO_2 emissions
- Determining minimum energy performance requirements for new and existing buildings that undergo major renovation
- Evaluating the applicability of renewable energy use
- Inspecting regularly heating and cooling systems

Energy Efficiency Law and the Building Energy Performance Regulation stipulates for preparing a 'Building Energy Certificate (Enerji Kimlik Belgesi)' that includes data about minimum energy requirements of the building, classification of energy performance varying between A (the best) and G (the worst), insulation properties and efficiency of heating-cooling systems, as well as general information about the building. The building energy certificate has been valid for ten years. The obligation of certification covers new buildings and existing buildings having the total area of use over $1000m^2$. The existing buildings should take an energy performance certificate within ten years from the date of publication of the Energy Efficiency Law, in other words until 2 May 2017. For the new buildings, the certificate has been mandatory since January 2011 (ETKB, 2007).

Energy efficiency actions have accelerated with the update of the regulation in 2011 to bring into alignment with the EU regulations, especially the recast EPBD. Concomitantly a national internet based software named as BEP-TR has been developed by MENR. BEP-TR has been used for preparing energy performance certificate. According to the BEP-TR, the new buildings are required to have class-C or more in the sense of energy consumption and CO_2 emissions. There is no such requirement for the existing buildings (ETKB, 2007).

2.3.4. Energy Efficiency Strategy Paper 2012-2023

Published on February 2012, the Energy Efficiency Strategy Paper (2012-2023) draws a current and comprehensive outline for detailing energy efficiency actions of the Turkey by 2023 bringing together public, private sectors and non-governmental organizations (NGOs) in close collaboration. The Energy Efficiency Strategy Paper mainly underlines the aim to reduce at least 20% of energy intensity (the amount of energy consumed per unit of GDP) by the year 2023 in comparison to 2011 level. The

other strategically purposes of the Energy Efficiency Strategy Paper are as the following (MENR, 2012):

- To reduce energy intensity and energy losses in industry and services sectors
- To decrease energy demand and carbon emissions of the buildings; to promote sustainable environment friendly buildings using renewable energy sources
- To provide market transformation of energy efficient products
- To increase efficiency in production, transmission and distribution of electricity, to decrease energy losses and harmful environment emissions
- To reduce unit fossil fuel consumption of motorized vehicles, to increase share of public transportation in highway, sea road and railroad and to prevent unnecessary fuel consumption in urban transportation
- To use energy effectively and efficiently in public sector
- To strengthen institutional capacities and collaborations, to increase use of state of the art technology and awareness activities, to develop financial mechanisms except public financial institutions (p. 8).

One of the focuses of the strategy is the building sector to make realize the objective on the subject of energy intensity. The strategy mainly aims to ensure at least one fourth of the building stock in 2010 to be sustainable building by the year 2023 (MENR, 2012).

2.3.5. Projects on Building Energy Efficiency and Retrofitting in Turkey

Turkey has been in various international cooperative projects on energy efficiency over the last decades, alongside of the legislative regulations. Some of them are directly related to improving energy efficiency in buildings.

In the period of 2002- 2005, a project of **Promotion of Energy Efficiency in Buildings** was carried out within the framework of technical cooperation Turkey and Germany with the participation of Electric Power Resources Survey and Development Administration (EIE)/National Energy Conservation Centre (NECC), the German Technical Cooperation (GTZ) and the Erzurum Municipality. Erzurum was decided as a pilot city and three demonstration buildings were determined to be implemented of this project. The objectives of this project are to propose energy saving measures for reducing energy use in buildings, serve as basis for a strategy of implementation moving beyond Erzurum and stimulate the other municipalities of Turkey and to develop training schemes for energy managers and foundations to be extended national level. Moreover, an energy consultation center was founded in Erzurum to give

recommendations about energy efficiency to users of buildings and to raise public awareness for promoting energy efficiency (CEval - Center for Evaluation, 2008).

Promoting Energy Efficiency in Buildings (UNDP/GEF) is a project financially supported by Global Environment Facility (GEF) and it was conducted in cooperation with General Directorate of Renewable Energy (YEGM) of MENR, MEU, Ministry of National Education and United Nations Development Programme (UNDP) as an implementing agency between the years of 2011 and 2015. The project principally aims at decreasing energy consumption and associated GHG emissions in new and existing buildings of Turkey. In line with this objective, this project put excessive emphasizes on revising and improving the current energy performance standards and building codes, enhancing building energy management standards and introducing the integrated building design approach and demonstrating its implementations in case studies. Furthermore, it is point out that the retrofitting of existing buildings is an important step to be achieved the principal aim (Promoting Energy Efficiency in Buildings Project Brochure, 2013).

Technical Assistance for Improving Energy Efficiency in Buildings is a project which was started on 13 April 2015 and ended on 12 May 2017 and co-financed by the EU and Government of the Republic of Turkey. Public and residential buildings take part in the scope of this project. The project aspires to provide technical assistance to improve energy efficiency in buildings by analyzing the current situation of buildings, to design new buildings in a sustainable and energy-efficient manner and to establish the retrofitting principles for existing buildings through analyses of the necessities and typologies of the existing buildings. The project discusses gaps and requirements regarding the current legislation and institutional framework for new and existing buildings in Turkey and legislative harmonization with the related EU regulations, specifically the EPBD. Furthermore, the project works at increasing awareness and informing stakeholders about energy efficiency in buildings at central and local level and developing a simple energy performance simulation tool to assess life time economic energy performance of buildings and creating a data inventory about buildings in Turkey (Ministry of Environment and Urbanisation [MEU], 2016).

2.4. Publications on Energy efficient Retrofit in Existing Residential Buildings

In the literature, there are numerous studies about energy efficient retrofit in existing residential buildings. Stazi, Vegliò, Di Perna and Munafò (2012) demonstrated an analytic and experimental study aiming at identifying appropriate retrofit solutions with regard to energy consumption, environmental impact and comfort conditions of multi storey residential buildings in Italy. Initially, five case buildings were selected from among 70 buildings through typological analysis and then, a preliminary energy analysis was performed to investigate different retrofit solutions for the case studies to determine one typical building. This study also covered monitoring summer and winter conditions of the typical building, thermal simulation model of the building by using EnergyPlus software and calibration of the model to obtain more reliable results. Retrofitting solutions were suggested for the external horizontal and vertical building envelopes including insulation of walls, insulation of floors and roofs, thermal glazing and their different combinations. The study demonstrated that external vertical insulation is the most effective strategy. Finally, when analyzing the retrofit solutions, the position of the insulation layers on building envelope, types of insulation on external wall and optimal retrofit for external wall in point of environmental impact and energy use were considered.

Similarly, in Bologna, Italy, energy-efficient retrofitting scenarios of a residential building were investigated in the study of Zanchini, Naldi, Lazzari and Morini (2015). Each retrofit scenario was evaluated in the sense of annual primary energy use, CO2 emissions, thermal comfort conditions, as well as economic analysis. A simulation model was generated through TRNSYS 17 dynamic simulation tool and the heat pump system with thermal storage has been simulated by own MATLAB codes. Thereafter, a pre-retrofit monitoring was conducted in order to validate the simulation code in the present state scenario. Five simulation scenarios have been created including different combinations of retrofit solutions. These solutions consisted of thermal insulation of walls and floors, replacing windows, installation of an air-to-water heat pump for heating and DHW supply, installation of LED lighting and PV collectors. According to the evaluation of scenarios, the proposed scenario which had all measures provided an 86.5 % reduction of the use of primary energy, an 86.3% reduction of CO_2 emission, and a relevant improvement of the thermal comfort.

In another study, Noris, Delpa, Vermeer, Adamkiewicz, Singer, and Fisk (2013) developed a point-based protocol for selecting retrofitting solutions depending on energy savings, improvement of indoor environmental quality (IEQ), retrofit costs and comfort. 17 apartments in three buildings in two different climate of California were determined for implementing this protocol. The study involves data obtained from interviews, inspections and measurements for retrofit selection, the selected retrofits and their costs, targeted energy savings and the results of diagnostic measurements before and after retrofits. In addition to a low-cost and beneficial priori retrofit measures for upgrading air sealing with the application of energy efficient ventilation equipment, a list of candidate retrofit measures such as replacement of heating and cooling systems, duct sealing, insulating walls and attics, replacing windows or doors, installation air filtration systems was generated. After the implementation of retrofits, the diagnostic measurements indicated substantial improvements in apartment performance and occupant's satisfaction. Moreover, anticipated energy savings within three buildings varied between 17 and 27%, with simultaneous substantial predicted improvements in thermal comfort and indoor air pollutant levels.

Liu, Rohdin and Moshfegh (2015) aimed to investigate both indoor environment and energy use of two retrofitted building in comparison to a non-retrofitted multi-family building from the same area in Sweden in their study. The study covered methods including a standardized indoor environment questionnaire, building energy simulations (BES) and on-site measurements. The measurements were done to specify indoor air temperature, humidity, the electricity use of household appliances. On the other hand, the simulation model was carried out to predict energy use, average indoor temperature and surface temperatures on the inside of the building. External insulation, adding a barrier layer to internal wall for infiltration and moisture, replacing double-glazing chancing windows and roof insulation were among the energy efficient retrofit measures. According to the validated simulation results, the retrofitted building had potential to decrease space heating by 39%. Moreover, the study indicated that occupants have more satisfied with the indoor air quality compared to the non-retrofitting building.

In the study of Hens (2010), a step-by-step retrofitting of two-storey house which was built in Belgium in 1957 was discussed by insulating roof, ground floor and walls, changing windows with high-technologic ones, installing a ventilation system and upgrading the central heating system. Measurements and a calculation methodology

were conducted to determine and predict annual energy for space heating, lighting and appliances, domestic hot water use, as well as primary energy use. After the comparison of measured and predicted data, the measurements showed a net decrease for annual energy for space heating, consistently underscore predictions. Besides, it was stated that the benefits of using better insulation, energy efficient windows, better air-tightness, upgraded ventilation and central heating are maximal in comparison with the using solar boiler and Photo Voltaic panels.

In other study, Çetiner and İdis (2014) evaluated retrofit alternatives of existing detached residential buildings in terms of decreasing space conditioning energy consumption, without structural and service systems. To define optimum retrofit alternatives, overall performance as environmentally (energy consumption and resulting emissions, effects of material production, construction processes) and economically (costs regarding construction, maintenance operations and space conditioning) was evaluated separately via life cycle assessment (LCA) method. In Qatar as an example of hot climate, a study about the effect of different retrofit measures for decreasing cooling load of a residential house was conducted by Kharseh and Al-Khawaja (2016). The examined retrofit measures contained indoor temperature, lighting efficiency, total heat transfer coefficient of the external shell and the color of external shell. Hourly analysis program (HAP) model was used to simulate the cooling requirements and an economical analysis was performed by current price in Qatar. Afterwards, the cooling load of the case building was estimated for all possible combinations among measures in retrofitting scenarios. The results stated that 53% reduction in the cooling load can be obtained by implementing all measures. From economical approach, the payback period of the examined retrofit measures depending on the current price changed between 0.5 and 4 years. In case of implementing all measures, the period would be about 1.5 years.

Asadi, Da Silva, Antunes and Dias (2012) approached the retrofitting action from the point of a multi-objective optimization problem. The generated optimization problem was adapted into a real semi-detached house which constructed in 1945 in Portugal. Alternative retrofit actions and their combinations regarding windows, external wall insulation material, roof insulation material and installation of solar collector represented aiming at improving enegy saving, reducing costs and energy consumption. Each retrofit solution brought about different retrofit costs, energy saving trade-offs, as well as energy classification. Accordingly, corresponding retrofit actions were indicated by optimizing each objective function after the energy analysis. For this

case building, an increment of energy classification by one level was performed within a slightly increase of cost investment.

In the study of Terés-Zubiaga et al. (2014), the principal focus was to the implementation of building envelope ESMs in the building renovation. A representative building of the 50s-60s periods in Spain was determined as a case study. This study covered a TRNSYS simulation model and a detailed experimental measurement in order to validate and calibrate this simulation model. Four retrofit scenarios were developed regarding ESMs in façades, windows, roof and their combinations and they were prioritized based on improvement level. Furthermore, an energy and economical assessment of different ESM simulation combinations was conducted under the thermal requirements of the Spanish regulations. The results indicated that thermal energy improvement of roof and façades is profitable in terms of energy, environmental, as well as economical approach for this case study.

CHAPTER 3

ISSUES OF ENERGY EFFICIENCY AND RETROFIT IN HISTORIC BUILDINGS

Historic buildings symbolize identity and culture as an important constituent of existing building stock and form a distinctive character of many urban centers. They create a link with the past enlightening on the changes of places over time (Troi and Bastian, 2014). To consider a building as a 'historic', it must hold crucial features including: a sufficient age to have been studied by historians, architectural historians or archaeologists, a high historic physical integrity relatively unchanged and above all else, historical significance by either representing distinctive physical and spatial characteristics of an architectural style or building type, structure, landscape or construction method or having the makings of important information about our understanding of the past via investigation and analysis (Georgia Department of Natural Resources – Historic Preservation Division, 2014).

In this context, the meaning and significance of a historic building not only lie on its architectural value, but also they lead to its cultural significance values. "The term, cultural significance, is synonymous with heritage significance and cultural heritage value". It refers to "aesthetic, historic, scientific, social or spiritual value for past, present or future generations. Cultural significance is embodied in the place itself, its fabric, setting, use, associations, meanings, records, related places and related object (ICOMOS, 1999, p. 2)". Conservation of the cultural heritage places is an essential requirement for present and future generations, because these places enhance people's lives and establish a deep and inspirational sense of connection to community, to the past and to lived experiences.

Historic buildings mostly commune with bioclimatic design. They present often resilient architectural structures and durable construction materials and accordingly they introduce inherently sustainable characteristics (Todorović, Ećim-Đurić, Nikolić, Ristić and Polić-Radovanović, 2015) and historic neighbourhoods are usually described by density, short distances and mixed uses which turn them into a relatively efficient model for sustainable development in local communities (3ENCULT, 2014).

Differently from modern buildings, construction of historic buildings has ability to breathe because of using generally permeable materials within building envelope. This feature allows making buildings more porous and naturally ventilated. In historic buildings, solid walls having high thermal mass keep heat better in comparison to modern cavity walls and they help to regulate air temperature inside according to seasonal conditions. However, historic buildings can typically be draughty and can leak heat due to breathable fabric, larger window size, a predominance of sash and case windows and therefore, low-efficiency glazing. They are deprive of insulation since they were built before modern construction standards, accordingly, they present thermal inefficiency allied with greater heat loss. Older heating systems generally allow to more energy use and less heat generation in comparison to modern systems (Change Works, 2008). Furthermore, these poor systems for heating contribute adversely to increase considerable amount of GHG emissions derived from the using a high level of fossil fuels.

In most cases, historic buildings have fallen short of the modern-day expectations with the passing of time. They move away from the image of city and damage cultural heritage values. As a consequence, they are getting less desirable, unusable and so they can be decayed. It is important to ensure continuous and proper re-use of historic buildings by adapting to modern-day conditions and meeting requirements for present and future generations (URBACT II, 2013). The process of careful adaptation and re-use can produce buildings as if it is newly built and create spaces with a high architectural quality through conservation.

Building conservation and energy efficiency are both key aspects of sustainable development which covers social, economic and environmental requirements and places them into harmony. It is possible to improve energy efficiency in historic buildings without compromising their character and fabric (Change Works, 2008). In fact, there is no inherent conflict between the retention of historic buildings and sustainability (English Heritage, 2012). Finding solutions in accordance with conservation principles provide to retain historic buildings and they bring them in a sustainable future.

Historic buildings are finite and precious resource which once lost cannot be replaced with the new one. The process of adaptation or conversion of those buildings carries a risk of losing of the character and historic fabric, as well as it can dramatically affect the building's performance (Godwin, 2011). This situation brings with it a problem about how to be treated historic buildings in an energy-efficient way and

simultaneously protecting them. It is required to be well-understood of buildings' character and fabric in order to know how to improve their energy efficiency.

Energy-efficient retrofit of historic buildings is considered as a 'new challenger' of research due to having major benefits to reduce energy consumption. On the other hand, this is the matter which is dependent on preservation of historic buildings; otherwise it may cease to be a priority (Fabbri, 2013; Litti et al., 2013).

Energy–efficient retrofit in historic buildings is a prominent need not only for reducing energy consumption, but also for the maintenance the value of the property and its physical integrity, increasing of comfort conditions and life quality of the occupants, prolonging the building's life, avoiding demolition and new construction waste and promoting the sustainability of wider historic environment in urban centers.

According to Power (2008), refurbishment of old and inefficient buildings have a great variety of benefits from the social, economic and environmental points of view. These benefits comprise of preserving basic structure of the property and existing infrastructure in existing environment, encouraging neighbourhood renewal and reinvestment, having positive effects on street condition, social mixing, service quality by giving value and attractiveness of the area, having a shorter and a continuous building process, reducing costs, increasing reuse of materials and developing local economy. Refurbishment is also socially more acceptable, cheaper and more environmental-friendly, while decreasing fuel property compared to demolition and replacement of buildings. It considerably reduces energy use in buildings over the short and long term.

Before implementation of the energy-efficient retrofit measures, existing character-defining elements of historic buildings should be identified to evaluate their environmental potential. These elements comprise of the materials, form, location, spatial configurations, uses, cultural associations or meanings that provide to retain the heritage value and extend the building's physical life. They have an important role on how buildings perform. Comprehension of the past and present environmental characteristics and performance of a historic building allow for getting the most appropriate retrofit solutions. When making decisions on treatments, any solution to further improve energy efficiency should utilize the historic building's inherently sustainable features like durability and adaptability. A successful retrofit process is possible with the conservation of character-defining elements and the heritage value (Canada's Historic Places, 2010).

In the phase of the retrofit, all possible measures should take into consideration with a great sensitivity. A thorough understanding of retrofit implications becomes important. Moreover, retrofit measures ought to be preferred within conservation principles. According to the English Heritage (2012), these principles are conservative repair, minimum intervention, compatibility, reversibility and authenticity:

- A new repairing operation, as closely as possible to the originals, should be conducted in a way to increase the performance and durability of the building.
- Interventions should be kept in minimum level for all retrofitting scales in order to preserve maximum historic fabric.
- Using materials and techniques should be preferred as compatible as possible to the state of original ones.
- Changes on building fabric should be reversible, because they may not show great performance as expected. The historic fabric should be returned to the original status without damage after the changes have completed their life.
- Alterations should be considered within the authenticity concept by respecting and clearly understanding the history and fabric of a building.

This is a fact that improving energy efficiency of historic buildings is a delicate matter. Retrofit of historic buildings requires different process in comparison with interventions which are performed in the other existing buildings. All retrofit works on historic buildings are specific in their context. Furthermore, the assessment of energy performance of historic buildings requires an interdisciplinary perspective so as to reach the best retrofit solutions.

It is significant to maintain the convenient balance between modern performance standards and sustainability requirements when improving buildings or else, heritage value of buildings suffers from lasting damage and its declines in importance. It is possible to adapt or convert historic buildings in sustainable manner as long as the local distinctiveness and individual character are taken into consideration (Godwin, 2011).

3.1. Historic Building Stock of Europe and Turkey

European building stock possesses a richness of mix with respect to both historic and modern architecture. European countries such as United Kingdom, Denmark, Sweden, France, Czech Republic and Bulgaria have a major historic building stock. In fact, a substantial share of existing European building stock is older than 50 years with many buildings which are hundred years old in use today. More than 40% of total residential buildings were built before the 1960s when energy regulations of existing buildings were insufficient and only a minor part of these buildings have undergone major energy retrofits (BPIE, 2011). Figure 3.1 illustrates the categorization of European housing stock by age.

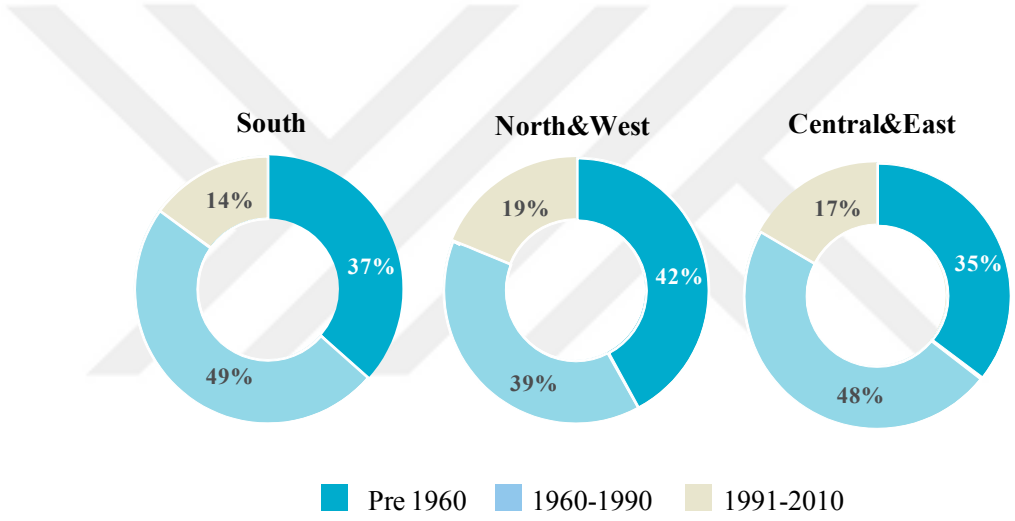


Figure 3.1. Categorization of housing stock by age in Europe
(Source: BPIE, 2011)

Furthermore, according to BPIE (2011) data, heat consumption level of existing building stock by age indicates that older building stock have the major opportunity for energy savings. This is because the U-value data of older buildings represents the deficiencies of insulation of the building envelope within insulation standards in those construction years were limited. For this reason, retrofitting historic building stock of Europe takes special importance in order to reduce energy consumption. According to the housing stock analysis of EFFESUS project[1], EU-28 countries, Norway, Switzerland

[1] EFFESUS is a research project which was conducted between the years 2012 and 2016 with the aim of improving energy efficiency of historic buildings and district in European countries. More detailed information about this project is given in the following section.

and also including Turkey has been considered in detailed survey (EFFESUS, 2013) (Table 3.1).

Table 3.1. Age distribution of housing stock in European countries (Adapted from EFFESUS, 2013)

Country	Year	< 1919	1919 - 1945	1946 - 1970	1971 - 1980	1981 - 1990	1990 - 2000	> 2000
Austria	2009	15,2	8,2	28	15,2	11,5	13,6	8,3
Belgium	2009	17,1	24,2	24,2	13,7	20,8	-	-
Bulgaria	2009	3,9	17,3	45,7	14,7	12,3	5,4	0,8
Croatia	2001	9,1	7,3	31	23,1	17,2	8,4	-
Cyprus	2001	-	7,4	16,9	20,7	27,4	27,1	-
Czech Republic	2005	10,5	14,2	25,4	21,8	15,8	7,9	3,4
Denmark	2009	19,7	16,1	26,4	16,6	9,1	5,4	6,7
Estonia	2009	9,4	14,2	30	21,5	19,6	2	3,3
Finland	2009	1,5	8,1	27,6	21,5	18,5	11,5	9,8
France	2006	17	13,2	17,4	25,2	10,2	8,5	8,4
Germany	2006	14,4	13,6	46,3	13,2	9,2	3,3	-
	2010	14,3	12,9	46,5	10,5	2,8	8,2	4,9
Greece	2001	3,1	7,2	31,8	24,5	19,1	14,4	na
Hungary	2005	-	20,8	27,2	23,1	17,8	7,9	3,2
Ireland	2002	9,4	8	15,9	14,2	13,2	19,5	19,8
Italy	2001	14,2	9,9	36,8	18,8	12,2	7,9	-
Latvia	2008	13,8	13,1	22,1	19,4	20,2	7	4,4
Lithuania	2002	6,2	23,3	33,1	17,6	13,5	6,3	-
Luxembourg	2008	21,8	25,6	29,2	11,6	5,1	4,5	2,2
Malta	2005	12,2	10	22,1	16,2	19,1	17	3,4
Netherlands	2009	6,9	13,9	27	17	15,4	12	7,9
Norway	2011	8,3	6,7	25,2	15,7	13,8	9,7	12,2
Poland	2002	10,1	13,1	26,9	18,3	18,7	12,9	-
Portugal	2008	7,4	10	21,9	16,1	18,8	17,7	8,1
Romania	2002	3,9	11,5	37,3	23,8	14,8	7,3	1,4
Slovak Republic	2001	3,4	6,6	35,1	25,6	21	6,2	0,6
Slovenia	2004	15,1	7,8	27,7	23,2	16	6,9	3,4
Spain	2001	8,9	4,2	33,5	24,1	13,6	15,7	-
Sweden	2008	12,1	14,7	37	16,8	9,4	5,5	4,6
Switzerland	2000	22,4	13,2	25	13,4	14	12,1	-
Turkey	**2000**	**2,2**	**3,9**	**15,6**	**20**	**27,2**	**30,1**	-
United Kingdom	2004-5	17	17	21	21,8	20	-	-
EU-28		10,63	13,34	30,39	19,64	15,80	9,64	na

The analysis of EFFESUS project shows that Turkey's building stock ratio was 6.1% before 1945. This ratio of building stock reached to 15.6% with an 11.7% increase in 1970 from 1945. By the year 2000, Turkey has generally high percentages between the other European countries (Table 3.1). As stated previously, Turkey's existing building stock which was constructed before 2000 has high energy efficiency potential due to lack of thermal insulation and energy performance standards.

3.2. Retrofit Issues in Historic Buildings of the European and Turkey Regulations

The EU Directives include the major aspects on renovation of existing building stock and the technical elements and systems of retrofitting and more particularly they have been accelerated after the recast EPBD from the point of cost effectiveness (European Union, 2002; European Union, 2010; European Union, 2012). On the other hand, developments about sustainability perspective in historic buildings in the past could not be effectively integrated into the first EPBD, even though they created awareness (Litti et al., 2013).

The first EPBD (European Union, 2002) in point 1 of article 4 underlines that "Member States may decide not to set or apply the requirements" referred to the following building categories: "Buildings and monuments officially registered as part of a designated environment or because of their special architectural or historical merit, in so far as compliance with certain minimum energy performance requirements would unacceptably alter their character or appearance" and "buildings used as places of worship and for religious activities". Then, the following directives revised and rearticulated the statement (European Union, 2010; European Union, 2012)". Consequently, the directives do not have a clear statement about retrofitting historic building stock. In brief, a protocol about energy retrofit of historic buildings has been neglected in European legislations. There is no mention about how to improve energy efficiency while preserving their function, quality or character of a building. Moreover, another concern is the lack of any protection procedure covering historic buildings even if not legally protected. This situation poses a risk when it comes to alteration for those buildings which are large part of European historic centers (Mazzarella, 2015).

In the scope of the building regulation of Turkey, there is no clear definition about historic building retrofit. Bayındırlık ve İskân Bakanlığı (2008) refers to a similar statement as specified in the first EPBD. Article 2 (ç) in the regulation indicates that energy efficient interventions on the buildings that are officially registered as cultural asset should be conducted by receiving consultancy of competent authorities in a way to not affect building fabric and appearance. In 2023 projections, Turkey points out the necessity of encouraging rehabilitation of the existing buildings to decrease energy demand and CO_2 emissions and to make them sustainable, however there is no distinctive expression covering historic buildings (MENR, 2012).

Due to the legal uncertainty on energy efficient retrofit of historic buildings, European countries have been in a struggle for improving energy efficiency in their historic environments by protecting the heritage values. These efforts are composed of guidelines, standards and nationally or internationally conducted research projects.

3.2.1. Guidelines

England, Scotland, Wales, Ireland and Italy are leading countries in developing their own guidelines for their historic environments. England introduced useful advices and publications on energy performance certificates for historic buildings and a range of energy-efficient solutions regarding to building envelope for improving historic buildings while preventing conflicts between energy efficiency and conservation of these buildings (English Heritage, 2012). Ireland proposes a number of energy-efficient solutions by laying a bridge between building conservation and sustainability with a good understanding of the characters of traditional buildings in the country. It also explains how the energy-efficient solutions can be implemented without negatively affecting on the historic buildings' character by demonstrating various case studies (Advice Series Energy Efficiency in Traditional Buildings, 2010).

Scotland presents a series of practical solutions for improving energy efficiency of traditional and historic buildings through specific intervention measures on the fabric of buildings. The guideline points out key principles while implementing these measures so as to ensure the health of building and occupants, to retain historic character and to minimize the visual impact of the interventions (Historic Scotland, 2013). On February 2014, AICARR (The Italian Association of Air Conditioning and Heating) published a guideline to support designers and technicians of the superintendence in conducting energy retrofit actions in historic buildings. The guideline gives useful information about how to assess and how to improve the energy performance of historic buildings in Italy. Furthermore, the guideline aims to enlighten the relationship between restoration and installations in historic buildings. It presents energy efficiency procedure covering preliminary actions, energy performance evaluation and the improvement of energy efficiency for historic buildings. This procedure can be also used for new buildings (Santoli, 2015).

Since the year 2012, ASHRAE has been studying on a guideline that provides direction on making historic buildings more energy-efficient and energy conserving in an internationally applicable manner. ASHRAE Guideline, 'Energy Guideline for Historic Buildings', prİmarily aims at preserving buildings having historic character, characteristics and materials through reversible improvements and decreasing energy use and harmful effects to the environment. The guideline addresses energy efficient operation and maintenance, building systems and equipments, building envelopes and lighting (Means, 2016).

3.2.2. Standards

The technical committee of the CEN (European Committee of Standardization), 'CEN TC 346 - Conservation of Cultural Heritage', brought a group of European experts together called as 'Working Group 8' to develop a new European standard focuses on energy efficiency of historic buildings. This group has prepared a standard named as 'Guidelines for improving the energy performance of historic buildings'. This CEN standard covers historically, architecturally or culturally valuable buildings regardless of whether the buildings are officially registered, but containing a range of building types and ages. The standard considers the improvement of building envelope and technical systems. It includes a systematic procedure about the identification of the objectives for refurbishment according to the assessment categories such as energy saving, heritage significance, economic viability, compatibility, selecting and evaluating interventions and deciding on the most appropriate ones while respecting heritage significance of buildings (BSI Committee B/560, 2015). BSI (British Standard Institution) launched the standard EN 16883:2017 entitled as 'Conservation of cultural heritage-guidelines for improving the energy performance of historic buildings' on 26 June 2017 (BSI Standards Development, 2017).

3.2.3. Research Projects

There are a growing number of nationally and internationally conducted projects on improving energy efficiency via retrofitting in historic buildings and sustaining historic neighbourhoods and districts aimed at developing holistic and multidisciplinary

approach that helps professionals decide on optimal retrofit solutions, throughout European countries within different climate and cultural conditions.

Information is obtained from the literature about the completed or ongoing projects dealing with energy-efficient retrofitting of historic buildings. A number of projects are gathered under various topics including the duration of the projects, participating countries, objectives of the projects and proposed energy-efficient retrofit measures within the projects and they are illustrated in Table 3.2. The common aim of the projects was to integrate the energy-efficient technologies and materials into historic buildings with intent to obtain energy saving, meet today's requirements, make them sustainable for the future generations and conserve the historic buildings by understanding the impact of energy-efficient measures on their identity and heritage values.

Some of the above mentioned projects and an additional research project which help to better enlighten the framework of the thesis are chosen and then, a general overview about the selected projects was presented as follows:

3ENCULT - Efficient Energy for EU Cultural Heritage: 3ENCULT was conducted between the periods 2010 and 2014 with the participating 22 partners from 10 countries. 3ENCULT was mainly aimed to bridge historic building conservation and climate protection in an interdisciplinary discussion. From Italy, Denmark, Germany, Austria, Spain and Switzerland, different eight case studies were determined to demonstrate and assess the developed solutions which are applicable to European built heritage. 3ENCULT consists of different work packages which reflect the project approach. The project covers the development of active and passive energy-efficient solutions for refurbishment of historic buildings. Based on the developed solutions, the project proposes new or enhanced products covering interior insulation, windows, lighting, ventilation and solar integration and also intelligent monitoring and control systems. 3ENCULT presented a handbook with design guidelines and a pool of technical solutions for planners and guides for local governments as the other deliverables of the project. Moreover, the project developed the position papers which suggest possible integrations of the present regulation, especially related to the EPBD, for improving energy efficiency of historic buildings in urban areas and supported the development of the CEN standard on energy performance of historic buildings (3ENCULT, 2016).

EFFESUS - Energy Efficiency of European Historic Urban Districts: EFFESUS is a research project funded by EC between the years 2012 and 2016 with the participation and cooperation of 13 countries from Europe. The EFFESUS describes historic districts as a grouping of significant old buildings built before 1945, regardless of protected by heritage legislation within its context. The overall objective of the EFFESUS project is to develop a methodology to select and prioritize energy efficiency interventions through existing and new, cost-effective technologies in compatible with the heritage values. The four main aims of the project as the following (EFFESUS, 2016b):

- Developing a data model to categorization of European historic districts
- Developing and implementing cost-effective systems and technologies to improve energy efficiency in historic districts
- Evaluating energy retrofitting interventions through a methodology and a software tool
- Achieving technical and nontechnical barriers when implementing of the project results

From the participating countries such as Spain, Sweden, Budapest, Turkey, Italy, Germany and UK, the seven case buildings belonging to different historic periods, constructed with different materials, different architectural and urban patterns and different heritage protection level were chosen to implement the methodology and to demonstrate the project process at real scale. Three types of interventions were carried out in these different case studies: implementation of new and existing technologies at urban level (smart grids, photovoltaic, lighting, energy storage, district heating); application of new and existing products and systems at building level (insulating mortars and coatings, aerogel insulation, traditional passive solutions, improved indoor climate control systems, secondary glazing); and study containing the analysis of the existing municipal documents and data to prepare a building stock (EFFESUS, 2016).

Table 3.2. European Projects on Energy Efficiency and Retrofitting of Historic Buildings and Neighbourhoods (Sources: Vieites, Vassileva and Arias, 2015; Co_2olBricks, 2013; SECHURBA guide, 2011; Climate for Culture, 2016; HELTH, 2017; Co2olBricks, 2016; 3ENCULT, 2016; Lopez et al., 2012; EASEE, 2016; EFFESUS, 2016; ReFoMo, 2016; RIBuild, 2016)

Project name	Project Duration	Participating countries	Focus of the project	Objectives of the project	Scope of energy-efficient retrofitting measures
NEW4OLD (Vieites et al., 2015)	2007-2010	Belgium, Austria, Germany, Greece and Ireland	Heritage buildings	To integrate renewable energy and energy efficiency technologies into historic buildings	Insulation of building façade and roof, improvement of windows, lighting and HVAC systems
AlpHouse (Co_2olBricks, 2013)	2007-2013	Austria, Italy, Germany and France	Traditional Alpine buildings and settlements	To understand the principles of traditional alpine architecture, integrate them in present-day construction, and develop them further.	Building façade-construction and insulation, moisture control and optimization of windows
SECHURBA (SECHURBA guide, 2011)	2008-2011	United Kingdom, Bulgaria, Denmark, Greece, Hungary, Ireland and Italy	Historic buildings and urban areas	To understand historic buildings and highlight their important roles in modern lifestyles and reduce carbon emissions and make them sustainable while respecting the heritage value	Insulation of internal walls, roof, floors and non-heated areas, draught-proofing of doors and openings, repairing/replacing windows, improvement of heating, cooling and lighting systems, upgrading internal environment and integration of the renewable energy systems
Climate for Culture (Climate for Culture, 2016)	2009-2014	Germany, Czech Rebuplic, Italy, Crotia, Greece, Netherlands, Slovenia, Sweden, Poland, Austria, Spain, Eygpt, UK and Romania	Historic buildings in Europe and Mediterranean	To analyze the damage potential of climate change on cultural heritage and the possible socio-economic impact of climate change and encourage climate change mitigation strategies	Improvement of historic heating and air circulation systems, enhancement of passive climatisation for microclimate control and promotion of the renewable energy use
HELTH (HELTH, 2017)	2010-2013	Estonia, Sweden and Finland	Traditional rural houses which are built before 1940	To identify the conditions and main problems of traditional houses, to improve energy efficiency and indoor climate and to reduce emissions by renovating the houses	Insulation of walls and floors, improvement of windows, heating and ventilation systems, solar collectors, PV panels
CO_2olBricks (CO_2olBricks, 2016)	2010-2013	Denmark, Germany, Sweden, Finland, Estonia, Latvia, Lithuania, Poland, Belarus and Russian Federation	Historical buildings in Baltic Sea Region (BSR)	To provide the balance between climate protection and heritage conservation and reduce energy consumption of historical buildings without destroying their cultural value and identity	Internal insulation and limited number of external insulation of outer walls, insulation of floors, roofs, attics and cellars, replacing windows and doors, upgrading HVAC systems, installation of energy-efficient lighting and electrical equipments, HVAC system automation and smart control and integration of the renewable energy systems
3ENCULT (3ENCULT, 2016)	2010-2014	Italy, Austria, Belgium, Czech Republic, Denmark, France, Germany, Netherlands, Spain and United Kingdom	Historic buildings in Europe and mostly Mediterranean countries	To bridge historic building conservation and climate protection in an interdisciplinary discussion	Interior insulation, windows, lighting, ventilation and solar integration and also intelligent monitoring and control systems
RENERPATH (Vieites et al., 2015)	2011-2012	Spain and Portugal	Heritage buildings	To develop a methodology for assessing energy efficiency of historic buildings via non-invasive techniques	Solar tyles and ceramic masonry blocks
ENBAU - Energie und Baudenkmal (Lopez et al., 2012)	2011-2012	Switzerland	Historic heritage buildings	To identify appropriate interventions to reduce energy requirements and improve level of interior comfort, to assess the possibility of integrating solar systems and to develop uniform and re-applicable methodolgy for the other protected buildings	The photovoltaic and solar thermal systems, replacing windows, improving shutters, insulation of internal and external walls, floors and roofs and improving building systems
EASEE (EASEE, 2016)	2012-2016	Italy, Greece, Switzerland, Germany, Poland, Scotland, Spain and Belgium	Multi-storey residential buildings were built between 1925 and 1975	To reduce energy demand and minimize impact on occupants by developing a toolkit for energy-efficient envelope retrofitting whilst preserving buildings appearance	Improvement of the outer façade, the internal envelope and the cavity walls
EFFESUS (EFFESUS, 2016)	2012-2016	Spain, Germany, Italy, Greece, Norway, Turkey, Sweden, Ireland, United Kingdom, Netherlands, Hungary, France and Portugal	Historic districts as a grouping of significant old buildings built before 1945	To develop a methodology to select and prioritize energy efficiency interventions through existing and new, cost-effective technologies in compatible with the heritage values.	Smart grids, photovoltaic, lighting, energy storage, district heating in urban level and insulating mortars and coatings, aerogel insulation, traditional passive solutions, improved indoor climate control systems, secondary glazing in building level
ReFoMo (ReFoMo, 2016)	2013-2015	The Netherlands, Italy, Spain and Hungary	Heritage buildings (listed buildings built before 1945)	To reduce the footprint of heritage buildings by bridging the gap between the building energy performance and the potential energy savings and develop climate-proof refurbishment	Insulation of walls, roofs, and floors, draught proofing doors and windows, replacement of windows, adding secondary glazing, upgrading electrical appliances, heating and lighting systems, integration of renewable energy systems
RIBuild (RIBuild, 2016)	2015-2019	Danmark, Latvia, Germany, Belgium, Italy, Sweden and Switzerland	Historic buildings across the Europe	To reduce energy consumption in historic buildings to fulfill the 2020 energy and climate targets and develop guidelines on how to install internal thermal insulation without compromising the heritage value	Insulation of internal walls

FASUDIR - Friendly Affordably Sustainable Urban Districts Retrofitting: The FASUDIR is a research project funded by the European Commission between the years of 2013 and 2016 with the participation of five countries from Europe. The project was approved to support the necessary building retrofitting market mobilization towards achieving the European 2020 and 2050 targets. The FASUDIR project was mainly aimed at developing a new decision making methodology to determine and prioritize the best energy retrofit solutions for the sustainability of urban districts. The FASUDIR project not only focuses on new urban areas but also historic centers and districts (FASUDIR, 2016).

Three different case studies were specified as the representative of different European district typologies including a cultural heritage district from Spain, a communist era district from Hungary and residential districts built up on the 1970's decade in Germany. The project also includes technologies, systems and solutions for energy retrofitting at building and district level and implementation, demonstration and evaluation of them in real case studies (FASUDIR, 2016).

3.3. Publications and State-of-the-Art on Energy-efficient Retrofit of Historic Residential Buildings

In this section, scientific studies which mainly concentrate on energy-efficient retrofit of historic buildings and environments are presented. This section is composed of various information sources such as articles, dissertations and proceedings from the European countries and Turkey published between the years of 2000 and 2016. The literature survey was restricted with historic buildings which have residential use, because they constitute a significant part of historic building stock. Totally 52 studies, 10 of which are from Turkey, including 40 papers, three thesis and nine proceedings were investigated.

The course of studies was discussed in terms of diversity of the research topics rather than chronological change. These topics are grouped as five sub-topics consisting of energy efficiency, thermal comfort, environmental impact, economic impact and the heritage value. Improving energy efficiency and considering heritage value are common points among the publications. Additionally, energy-efficient retrofit solutions addressing building systems, equipments and building envelope such as walls, floors,

roofs, windows, doors and shutters are categorized in surveyed retrofit-related publications. Table 3.3 presents an overview of 31 publications related directly to energy-efficient retrofit approaches and the research topics; the rest 21 publications were discussed within the paper below.

The research cases are grouped into two categories including single historic buildings and historic building stock. Initially, the former category prefaces with the research on single historic buildings and its evaluation. It comprises of 16 studies from both urban and rural areas. Latter category which continues with the building stock retrofit in urban areas possesses 15 studies. Although there is no overall the building stock retrofit, a number of studies are included in latter category since they assess representative buildings which characterize building stock in determined urban areas (Arumägi and Kalamees, 2014; Alev et al., 2014; Tadeu, Rodrigues, Tadeu, Freire and Simões, 2015).; Arumägi, Mändel, and Kalamees, 2015). The rest presents an extensive building stock retrofit.

Conserving the heritage value is a significant matter to be considered in all disciplines about historic buildings. Since historic buildings, which are integral part of the history and communities, characterize and enrich the environment they are in. Energy upgrading of historic buildings is an agenda topic in recent years. Accordingly, historic buildings and their heritage values has been considered while deciding on energy-efficient measures in retrofit actions. A variety of studies have been a struggle for providing proper and continuous use of historic buildings, while improving energy performance and bringing them up satisfactory comfort levels as indicated in Table 3.3.

Existing buildings allow diversify in terms of energy-efficient measures and their application areas. However, historic buildings cannot be treated in the same way as such in other buildings. Each measure should be meticulously scrutinized under any circumstances. It is notably expected energy-efficient interventions to be preferred as compatible and reversible alongside of being responsive to the energy requirements, and their impact on the heritage value should be as minimal as possible (Grytli, 2011, Grytli, Kværness, Rokseth, and Ygre, 2012; Moschella, Salemi, Sanfilippo, Detommaso, and Privitera, 2013; López and Frontini, 2014).

Table 3.3. Categorization and main characteristics of the retrofit-related publications by a systematically reviewed literature

Level of retrofit	References	Publication Date	Country	Type	Research topics					Energy-efficient retrofit solutions											
					EE	TC	ENI	ECI	HV	EIW	IIW	CWI	IF	IR	IAF	WS	RRWD	IS	IHVAC	IEA	IRES
SINGLE BUILDING LEVEL	Grytli	2011	Norway	Proceeding	●		●		●				✓	✓		✓	✓		✓		
	Grytli et al.	2012	Norway	Paper	●		●		●	✓	✓		✓	✓	✓	✓	✓		✓		✓
	Morelli et al.	2012	Denmark	Paper	●			●	●		✓						✓		✓		
	Aste et al.	2012	Italy	Paper	●				●	✓	✓						✓	✓	✓		
	Garrecht and Reeb	2013	Switzerland	Paper	●	●			●		✓				✓		✓				
	Moschella et al.	2013	Italy	Paper	●				●												✓
	Şahin	2013	Turkey	Master Thesis	●			●	●		✓		✓	✓	✓	✓	✓		✓		
	Taranto and Kacel	2013	The UK	Paper	●	●			●		✓			✓			✓				
	Almeida	2014	Spain	Master Thesis	●				●	✓	✓			✓			✓	✓	✓	✓	✓
	López and Frontini	2014	Switzerland	Paper	●	●			●												✓
	Zagorskas et al.	2014	Latvia	Paper	●			●	●		✓										
	Ben and Steemers	2014	The UK	Paper	●				●			✓		✓		✓	✓		✓		
	Şahin et al.	2015	Turkey	Paper	●			●	●		✓		✓	✓	✓	✓	✓		✓		
	Dalla Mora et al.	2015	Italy	Paper	●	●	●	●	●		✓			✓					✓		✓
	Milone et al.	2015	Italy	Paper	●			●	●	✓							✓	✓			
	Cornaro et al.	2016	Italy	Paper	●				●	✓			✓				✓		✓		
DISRICT LEVEL	Boarin and Davoli	2013	Italy	Proceeding	●		●		●	✓	✓		✓	✓			✓				
	Flores	2013	Portugal	Dissertation	●	●	●	●	●		✓		✓	✓		✓	✓	✓	✓	✓	✓
	De Berardinis et al.	2014	Italy	Paper	●	●		●	●	✓	✓						✓				
	Arumägi and Kalamees	2014	Estonia	Paper	●	●		●	●	✓	✓		✓		✓		✓		✓		
	Alev et al.	2014	Estonia, Finland	Paper	●	●			●	✓			✓		✓		✓		✓	✓	
	Bonomo and Benardinis	2014	Italy	Paper	●			●	●												✓
	Broström et al.	2014	Sweden	Paper	●	●		●	●	✓	✓				✓	✓	✓		✓		
	Eriksson et. al	2014	Sweden	Paper					●	✓											
	Lucchi et al.	2014	Spain	Proceeding	●				●												✓
	Stahl et al.	2014	Sweden	Proceeding	●			●	●	✓	✓		✓		✓	✓	✓		✓		
	Giombini and Pinchi	2015	Italy	Paper	●				●	✓	✓			✓			✓				
	Tadeu et al.	2015	Portugal	Paper	●		●	●	●	✓			✓	✓			✓		✓		
	Egusquiza et al.	2015	Spain	Paper	●			●	●		✓			✓					✓	✓	
	Arumägi et al.	2015	Estonia	Paper	●	●			●	✓			✓	✓			✓				
	Fatiguso et al.	2015	Italy	Paper	●				●		✓		✓	✓							

Abbreviations: EE, energy efficiency; TC, thermal comfort; ENI, environmental impact; ECI, economic impact; HV, heritage value; EIW, external insulation of walls; IIW, internal insulation of walls; CWI, cavity wall insulation; IF, insulation of floors; IR, insulation of roofs; IAF, insulation of attic floors; WS, weather stripping, RRWD, repairing or replacing of windows and doors; IS, improving shutters; IHVAC, improving HVAC systems; IEA, improving of the electrical appliances and IRES, integration of the renewable energy systems.

When the subject is alterations on historic buildings, restoration as a highly specialized operation comes into prominence. It mainly aims at preserving and revealing the aesthetic and historic values whilst respecting for original material and authentic documents (Charter, 1964). In last few years, energy-efficient approach has played a part in the restoration discipline. Some studies reveal that efforts on improving energy efficiency of historic buildings that undergo restoration process make a significant contribution to sustainability and maintaining the heritage value (Maahsen-Milan and Fabbri, 2013; Gálvez, De Hita, Martín, Conde, and Liñán, 2013; Gagliano, Nocera, Patania, Detomaso and Sapienza, 2014; Ivanović-Šekularac, Čikić-Tovarović, and Šekularac, 2016).

The restoration actions can be examined in the line with meeting the requirements of historic buildings from numerous aspects such as repairs to guarantee safety of buildings, improving energy performance, indoor climate, air quality, thermal comfort, architectural planning, visual quality, living quality, additional comfort, environmental impact reduction and cost saving (Arumägi et al., 2015; Tadeu et al., 2015).

Several researchers focus on legislative restrictions on improving energy efficiency of officially registered historic buildings which are subject to any retrofit action (Litti et al., 2013; Mazzarella, 2015). Thus, each country sets local strategies for historic buildings and environments in accordance with its own legislative framework and regulatory constraints. However, there is limited number of national-level initiatives on energy efficiency of historic buildings among European countries (Energy Efficiency in Traditional Buildings, 2010; English Heritage, 2012; Historic Scotland, 2013; Santoli, 2015).

Some of the studies (Garrecht and Reeb, 2013; Alev et al., 2014; Zagorskas et al., 2014; Lopez and Frontini, 2014; Lucchi, Garegnani, Maturi and Moser, 2014; Eriksson, Hermann, Hrabovszky-Horváth and Rodwell, 2014; Broström et al., 2014; Egusquiza, Brostrom, Pagliula, Hermann, and Rodwell, 2015; Genova, Fatta, and Broström, 2015) were emerged as a significant part of the outcomes of various cooperative research projects (3ENCULT, 2016; HELTH, 2017; Co2olBricks, 2016; Lopez et al., 2012; EFFESUS, 2016) within European countries. Accordingly, research projects make a significant contribution to increase the publications in this research area.

Moreover, various studies on historic residential buildings have been addressing different climatic regions and countries including Italy, the UK, Estonia, Sweden, Portugal, Spain, Switzerland, Latvia, Denmark, Norway and Finland. Considering warmer climates, Italy is the prominent country in terms of the number of the studies, because it has a major built heritage, mainly residential. On the other hand, studies in cold climates mostly cover the countries around Baltic Sea Region.

In Turkey, the studies related to the research area deal with traditional buildings in mostly hot-dry regions, however there is lack of studies for the residential areas in hot-humid regions of the country. Many of studies have been discussing ecological design parameters, architectural characteristics and the relation of the traditional buildings with the environmental conditions (İpekoğlu, Böke, and Çizer, 2007; Şerefhanoğlu Sözen and Gedik, 2007, Manioğlu and Yılmaz, 2008; Esin and Yüksek, 2008; Baran, Yıldırım, and Yılmaz, 2011; Gezer, 2013; Kocagil and Koçlar Oral, 2015), their energy performance comparisons with modern buildings (Manioğlu and Yılmaz, 2008) and thermal comfort analysis (Ulukavak Harputlugil and Çetintürk, 2005). On the other hand, there are a very limited number of studies interested in energy performance improvements of historic buildings via the retrofitting way in Turkey (Şahin, 2013; Şahin et al., 2015). Şahin (2013) adopted a transdisciplinary approach while improving energy efficiency of a historic residential building in the Aegean region of Turkey. Nevertheless, there is no extensive retrofitting approach on historic building stock in Turkey.

Improving energy efficiency of historic residential buildings is a common topic of most studies in the literature (Table 3.3). In addition to energy efficiency, some studies aimed at improving thermal comfort (Taranto and Kacel, 2013; Garrecht and Reeb, 2013; Flores, 2013; Alev et al., 2014; López and Frontini, 2014; Arumägi and Kalamees, 2014; De Benardinis et al., 2014; Broström et al., 2014; Dalla Mora, Cappelletti, Peron, Romagnoni, and Bauman, 2015; Arumägi et al., 2015), achieving carbon emissions reductions and assessing the energy-efficient measures in terms of environmental performance via life-cycle approach (Grytli, 2011; Grytli et al., 2012; Tadeu et al., 2015) and the economic performance with regard cost-effectiveness (Aste, Adhikari and Buzzetti, 2012; Morelli, et al., 2012; Şahin, 2013; De Benardinis et al., 2014; Broström et al., 2014; Ben and Steemers, 2014; Milone, Peri, Pitruzzella, and Rizzo, 2015; Tadeu et al., 2015, Şahin et al., 2015).

At district level studies, a number of researchers give place energy performance investigations of historic districts based on a database which covers different parameters such as ages, numbers and characteristics of the residential buildings via statistical approach rather than the extensive energy-efficient retrofit objectives (Moran, Natarajan and Nikolopoulou, 2012; Fabbri et al., 2012; Ascione et al., 2013; Buratti, Asdrubali, Palladino and Rotili, 2015). Furthermore, some of the studies introduce energy maps by visually identifying energy performance of the case districts. The maps present energy quality and facilitate the evaluation of potential retrofit measures concerning whole districts and beyond the single building (Fabbri et al., 2012; Ascione et al., 2013).

When retrofit actions are considered, energy-efficient retrofitting studies can be categorized in two strategies: studies with single retrofit scenario and studies with multiple retrofit scenarios. Several researchers more concentrate on single retrofit solutions in their studies. For instance, Moschella et al. (2013) and López and Frontini (2014) debate over the integration of solar energy technology systems into historic buildings while Zagorskas et al. (2014) discusses on internal insulation alternatives of the walls of the case building. The other researchers take closely notice of multiple retrofit packages (Grytli, 2011; Aste et al., 2012; Grytli et. al, 2012; Morelli et al., 2012; Taranto and Kacel, 2013; Almeida, 2014; Flores, 2013; Şahin, 2013; De Benardinis, 2014; Broström et al., 2014; Ben and Steemers, 2014; Ståhl et al., 2014; Milone et al., 2015; Tadeu et al., 2015; Alev, et al., 2014; Şahin et al., 2015; Egusquiza et al., 2015; Dalla Mora, 2015; Cornaro et al., 2016). The advantage of generating retrofit packages serves the purpose of revealing which solutions are the most appropriate toward the targets by evaluating and comparing different retrofit scenarios with each other and the base case.

It has been obviously seen in the retrofitting studies that energy-efficient solutions mostly concentrate on building envelope like walls, floors, roofs, windows and doors. Insulation applications and repairing or replacing door and window systems are the common retrofitting solutions. Accordingly, interior insulation of the external walls and improving windows prevail in the studies within the literature. It was followed by improvements of the HVAC systems and equipments while the integration of renewable energy systems has been in the minority due to respecting building appearance and the heritage value. Moreover, the using of weather stripping is the cheapest but effective way to improve energy performance of the buildings among the

studies. All the energy-efficient solutions which used in the studies were classified and indicated in Table 3.3.

Moreover, some of the studies at district scale present various energy-efficient measures which range from directly concerned single building level to neighbourhood, district or wider scale within the multiscale approach. For instance, Bonomo and Benardinis (2014) discussed the integration of solar PV technologies into building, urban and landscape scale in a historical settlement in Italy. Installation of district heating systems is among the district level solutions in the study of Broström et al. (2014). Single building level solutions of the studies at district scale were presented in Table 3.3.

Researchers follow different methods in the line with their objectives. These are generally comprised of calculations, in-situ surveys, measurements, simulations, and their combinations. It has been seen in the recent literature that there is a rapid increase in using the building energy simulation (BES) tools not only for assessing building energy performance but also in determining and evaluating the energy-efficient measures in historic buildings (Şahin, 2013; Moschella et al., 2013; Taranto and Kacel, 2013; Flores, 2013; Alev et al., 2014; Arumägi and Kalamees, 2014; Ben and Steemers, 2014; Milone et al., 2015; Arumägi et al., 2015). Moreover, some studies showed that using dynamic simulation tools gives good results in assessing energy performance (Adhikari et al., 2013) and the refurbishment solutions in historic buildings (Cornaro et al., 2016). However, while a variety of studies mostly use the BES tools abroad, very few studies utilize the BES tools in Turkey (Şahin. 2013, Şahin et. al; 2015).

In the literature review, researchers have concentrated on the energy-efficient retrofitting studies conducted at wider scale when taking into account of the energy saving potentials lying on historic buildings. Accordingly, the studies at neighbourhood or district scale show different methodological approaches to historic building stock. The determination of retrofit strategies vary as the larger scale energy saving profit in compared to single building retrofits'. In some of the studies, the researchers illustrate their retrofit works on one or more representative buildings that characterize a determined building stock in historic urban areas. Accordingly, they evaluate the outcomes of their studies on the representative case buildings by extrapolating to investigated wider scale. In addition to this, a number of these studies explicitly present a categorization method considering various criteria so as to decide representative buildings within the building stock or districts (Flores, 2013; Egusquiza et al., 2015,

Broström et al., 2014; Giombini and Pinchi, 2015; Genova et al., 2015; Fatiguso, De Fino, Cantatore, Scioti and De Tommasi, 2015). These criteria which are necessary for categorization can be listed as type of building, type of use, building size, construction year, building envelope, heating/cooling systems, construction techniques, heritage values, fabric compatibility, number of floors, adjoining walls, gross floor area and gross building volume (Brostrom et al., 2013; Lucchi et al., 2014; Egusquiza et al., 2015; Genova et al., 2015; Fatiguso et al., 2015).

Additionally, various studies covers large scale in-situ surveys and energy audit to identify the building stock characteristics, energy behaviour and energy potential (Boarin and Davoli, 2013; Ascione et al., 2013) and statistical analysis (Fabbri et al., 2012; Moran et al., 2012; Ascione et al., 2013). On the other hand, the use of the Geographical Information Systems (GIS) has been come into prominence in recent studies. Because, the GIS is a useful tool to create a platform bringing together documentation, analysis and evaluation processes where different kind of data which were aggregated. The GIS allow for the spatial representations of urban districts by generating digital maps (Fabbri et al., 2013). Many of researchers address the use of the GIS in their studies (Lucchi et al., 2014; Fatiguso et al., 2015; Fabbri et al., 2012; Ascione et al., 2013).

In conclusion, energy efficiency issues for historic environments have become significant in the last decade as the evidence of the studies covering publications such as articles, proceedings and dissertations conducted in the European countries. Therefore, a range of studies have been systematically surveyed. The state-of-the-art on the recent literature affirms that the number of publications has accelerated after 2010. All the studies for all categories were discussed in a way to have energy-efficient approaches. The retrofit-oriented studies come to the forefront as a more recent issue when compared to the other energy-related studies in the literature. Moreover, Italian historic buildings and districts are leading in terms of the number of the conducted studies and research projects on the research area. Because of the limited number of the studies, more academic research and publication are required on energy-efficient developments in historic residential buildings of Turkey. Even if energy-efficient retrofitting is a challenge for historic buildings and urban areas, proper energy-efficient retrofit of historic residential buildings provides to improve energy efficiency, ensure living conditions and promote the sustainability for future generations while maintaining the heritage value and the character of the historic environment.

3.4. Retrofit Solutions for Historic Building Envelope

This section includes a range of possible retrofit solutions for historic building envelope. Retrofit solutions are critized under 12 subtitles considering the significant chacteristics of historic buildings' envelope based on a number of the studies including articles, proceedings and guidances for historic building retrofit of some countries in the literature survey.

Draught-proofing/Weather Stripping: Draughts are responsible for heat loss rate of 15% (ChangeWorks, 2008). Windows, doors and floors can generally cause draughts. They can be decreased by simple repairs and draught-proofing. Draught proofing is cost effective and least intrusive solution therefore it has a minimum impact on buildings' appearance. It improves occupants' comfort and reduces energy use for heating and air filtration rate and provides sound insulation (English Heritage Guidance, 2012a). However, the need of sufficient ventilation of building should not be ignored so as to avoid reduced air quality due to lower air exchange rate and potential moisture risk (Stahl, 2011).

External insulation of walls: Walls substantially contribute energy consumption with the highest rate of heat loss with 35% (ChangeWorks, 2008). Exterior insulation of walls can be preferable with the aim of reducing hygrothermal risks, decreasing moisture damage and thermal bridging risks, while providing thermal comfort. Building envelope will be more airtight with insulation, if there is air leakage arising from the exterior walls. It is also significant to use the insulation materials that allow moisture movement through the building envelope (Stahl, 2011).

However, exterior insulation may have negative effect on façade regarding the heritage value of historic buildings (Stahl, 2011). Furthermore, architectural constraints and application difficulties, i.e. high quality ashlar work, visually attractive façades, window and door reveals, are the reasons why exterior insulation is not preferred (Historic Scotland, 2013). In some situations, this type of insulation can be applied to the external surface such as less visible façades.

Internal insulation of walls: Interior insulation has several advantages and disadvantages. It provides thermal protection and keeps building appearance since there is no change on the exterior surface of a building. It does not require additional protection from external impacts such as variable temperature, humidity and wind. On the other hand, it decreases room area because of increasing wall thickness (Murgul and

Pukhkal, 2015). Moreover, it is required to point out the details on interior surfaces when installing any insulation system. A thorough and careful design for the details is essential. Another problem is moisture risk. Because, exterior side of wall will become much colder after the implementation of internal insulation layer, it may results in condensation of water vapour. Vapour-impermeable and vapour-permeable, capillary-active insulation systems can be used to prevent moisture (Troi and Bastian, 2014). Insulating walls from interior is a viable option for historic buildings under conservation principles.

Insulation of ground floor: Ground level floors cause the heat loss with the rate of 15% (ChangeWorks, 2008). The type of floor construction should be well-understood before making interventions, therefore it can be solid ground floor or suspended timber floor built by a traditional technique. Since solid floors have physical characteristics differently from modern solid concrete floors, they generally allow the movement of the moisture. Breathable materials should be used for insulation in order to avoiding moisture risk. Moreover, it is difficult to add insulation beneath the solid ground floor, because it normally bedded directly on the earth or on permeable fills and mortars without damp proof membrane for hygrothermal risks. The excavation and replacement of solid ground floors should be avoided unless it is necessary to enhance a destructive defect (English Heritage Guidance, 2012b). In some situations, an insulation layer can be placed on the top of existing floor or the solid ground floor can be lifted by excavating and an insulation layer can be placed in case of loss of original features and having more contemporary concrete floor (Historic Scotland, 2013).

Regarding suspended timber floors, this construction is basically composed of one set of timber joists and floorboards. Timber joists are physically separated from the earth. The ventilation of sub-floor void protects timber from the source of moisture. However, gaps between floorboards that generate draughts can be lead to heat loss. Heat loss can be preventing by heat insulation or draught proofing. Insulation applications decrease heat loss and ignore draughts from unheated and ventilated void below. Insulation can be fitted in two ways including from below and from above. If access is possible from below, the application can be performed without the necessity of removing floorboards. If the insulation level is fitting from above, the boards should be lifted and replaced carefully without damage. Insulation should be supported by using netting, a breather membrane or proprietary fixing depending on the kind of insulation material. Breathable natural fibres can be preferred such as sheep's wool, hemp fibre,

cellulose (fibres derived from recycled newsprint) and wood fibre (English Heritage Guidance, 2012c).

Insulation of the attic floor: This type of insulation decreases heat loss, but attic floor encounters moisture problem if air leakage coming from interior space exists. After the insulation, the relative humidity will have at high level due to moisture during winter and this level will gradually increase in autumn and spring. It is required to prevent air leakage via attic floor, to seal the ceiling penetration, and ventilate the attic floor to so as to solve this problem (Ståhl, 2011). Installing insulation at attic floor from below has generally no unfavorable influence on historical significance while adding insulation from above is more preferable option since it does not change buildings' interior appearance.

Insulation of the roof at rafter level: Roofs have a share of about 25% of heat loss (ChangeWorks, 2008). Therefore it is possible to reduce excessive heat loss and solar gain and air filtration with well-detailed insulation at rafter level. Moreover, this type of insulation is suitable for creating a warm roof space. There are three types of insulation for roofs at rafter level in terms of the position of the insulation including insulation above the rafters, between the rafters and below the rafters (English Heritage Guidance, 2012d).

Firstly, insulation above the rafters can be implemented on top of the rafters and beneath the battens and roof coverings. It has some advantages such as reducing air filtration, the risk of condensation on timbers and overheating of the internal environment from solar gain and improving the performance of insulation layer. On the other hand, it increases cost, because scaffolding and temporary roofing are necessary to install sarking boards. The installation of sarking boards necessitates the height of the roof to be raised. This situation increases the height of the roof and it can affect building appearance and historical character. Insulation between the rafters more economical and the height of the roof does not visibly increase. However, it is required to a high level of workmanship to be filled the gaps between the rafters, otherwise it results in air filtration. Moreover, the top face of the rafters more likely to has a potential thermal bridge if there is no sarking insulation. Lastly, insulation below the rafters is a good option, if there is an enough internal space. It does not visibly affect the height of the roof. It also does not create air leakages because of continuous implementation. In other respects, it may change appearance and proportion if there are internal spaces that are

used and any historic details on ceilings. This situation may cause the damage on historic significance (English Heritage Guidance, 2012d).

Insulation flat roofs For flat roofs, insulating flat roofs is not generally harmful for the heritage value of a historic building (Pilzer, 2016). Insulation can be installed either both below the decking and above the ceiling, named as 'cold deck system' or above the decking and below the waterproof layer, named as 'warm deck system'. Cold deck system is typically used in historical buildings, but using both cold and warm deck systems are the most convenient and desirable solution. After insulation, potential condensation problems within construction, rot problems in metal roof coverings and corrosion in timber due to add insulation below an impermeable roof are taken into consideration (English Heritage Guidance, 2012e).

Solutions for windows: Windows are responsible for heat loss rate of 10% (ChangeWorks, 2008). Therefore, historic buildings have a considerable heat loss derived from low thermal resistance and air leakage through old windows. There are a range of solutions which do not intervene in historic windows of a building. First of all, draught proofing or weather stripping is a simple, effective and non-destructive solution that can be implemented without causing considerable heat loss and damaging historical character of buildings (Ståhl, 2011). This solution can also decrease air leakage by 80% and it allows for using the windows with full capacity in terms of opening and closing though it does not improve the U-value (Historic Scotland, 2013).

As an another solution, adding a secondary glazing provides an effective insulation and noise control as well as reduces the draughts caused by windows (English Heritage, 2012). It is composed of a second window that is installed to existing original window from inside without disturbing the appearance. Therefore, it has minimal impact on original window and historic building fabric as long as the improvement work is not damaging. However, it can cause to some intrusion into the room, loss of usable window ledge space and use of internal shutters, and a double reflection visible from outside (ChangeWorks, 2008).

Adding a film layer on existing glazing can be applied so as to reduce solar heat gain and air conditioning load. It blocks ultraviolet light which causes to fade paintings, furniture and collections in historic buildings (ASHRAE, 2016). It is also a low-cost solution and easy to implement. But, applying a film layer on glazing may affect the visual integrity of the building therefore, it brings damage on the heritage value (Flores, 2013).

Changing windows with double glazing windows is a favorable option for historic windows. Double glazing windows consist of two panes of glass with an air gap (typically 12-18 mm) between them. It provides thermal insulation and significantly reduces carbon emissions and draughts, if the glass is coated and the air gap is filled with an inert gas. On the other hand, this solution causes to lead changing building appearance thereby it has a considerably negative influence on historic fabric and heritage value of a building. Adding a secondary glazing is more preferable option in comparison to replacing windows with double glasses (English Heritage Guidance, 2012f). Moreover, changing windows may be acceptable solution in some situations. For instance, slim-profile double glazing system can be used for listed buildings where the original glazing is no longer in place. This system allows either retention of the existing frame or a new frame with the original dimensions (ChangeWorks, 2010).

Solutions for doors: Draught proofing around the door and insulating the fabric of the door itself are the solutions that can be used to reduce heat loss caused by doors in historic buildings. Even if draught proofing significantly reduces heat loss, it is not always suitable for doors which have the heritage value (Historic Scotland, 2013).

Solutions for shutters: Shutters mostly serve a part of historic elements of windows and buildings' heritage. Changing shutters influence adversely the façade and historic character of a building. Instead of this, repairing shutters is a more appropriate option.

Using shutters is a traditional, simple and cheaper solution among the methods of reducing heat loss for windows (Baker, Curtis, Kennedy and Wood, 2008). They contribute to regulate sunlight and heat flow. They provide noise insulation. Moreover, in some situations, it is significant to activate passive systems such as operable shutters and operable windows in order to reduce dependency on mechanical systems for heating, cooling and ventilation. Using shutters during night blocks solar overheating as well as provides solar protection (ASHRAE, 2016).

Nighttime ventilation: Nighttime ventilation is a ventilation strategy which is applying for cooling of the building interior by precooling the thermal mass or a thermal storage system with cool nighttime outdoor air. It decreases the peak air temperature, structural temperature and creates a time lag of the peak temperature (Yao, Li, Steemers and Short, 2009). This strategy can be used as an alternative option to air conditioning so as to mitigate summer overheating (Roucoult, Douzane, and Langlet, 1999). Nightime ventilation is more effective in comparison to daytime ventilation since the

temperature at nighttime is mostly low to enhance thermal comfort (Liping and Hien, 2007). However, this strategy is not always suitable because of the reasons such as security problems especially for floors close to ground level, air and noise pollution.

The use of oriels as sun space: Oriels are significant façade constituents of historic buildings which establish strong relation of the buildings with street in the upper floors as well as meet space requirement expanding toward the street. They also make the interior more spacious, widen buildings' surface area and create semi-open spaces at the entrance. In Levantine houses, they have been unified with the space which is togetherly used while they act a separate and independent space separated by a door from the space (Akyüz, 1993).

Oriels are not covered with solar control elements like shutters and they receive directly sunlight specifically for façades facing with south. Therefore, they can be used as a glass house to maximize solar effect in winter and minimize this effect in summer by opening the windows (Terim, 2011). Moreover, they lift effectiveness solar gain thanks to their multi-sided design (mostly three-sided in Levantine houses) and wide glazing surfaces.

CHAPTER 4

BASMANE DISTRICT: 1273 STREET

This study has been carried out in the case area located in Basmane District in İzmir, Turkey. Initially, the chapter prefaces with a brief description about the location and climatic conditions of İzmir.It continues with general information on the position, historic development and importance of Basmane District within the city of İzmir. Then, information about the recent plans, projects and initiatives related to Basmane within the Kemeraltı Urban Historical Site is presented. Following this, the general characteristics of residential areas in Basmane are explained. Finally, the chapter focuses on the selected case area, 1273 Street within the boundaries of Basmane District, under investigation.

İzmir is the third largest city of Turkey with the annual population growth rate of 13.1% in 2016 (Turkish Statistical Institute, 2016). İzmir is situated in the west coast of the country next to the Aegean Sea (Figure 4.1). The climate of İzmir is classified as Mediterranean; summers are hot and humid, while winters are mild and rainy. Average maximum temperature is around 33.1°C in July and average minimum temperature is around 5.7°C in January in long period in İzmir. The mean temperature is 8.8°C. Moreover, the average relative humidity (RH) is around 65% (Turkish State Meteorological Service, 2017).

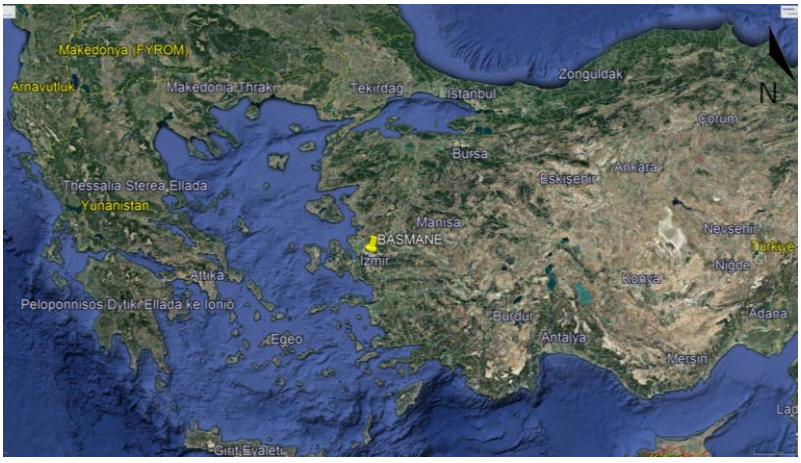


Figure 4.1. Location of İzmir
(Source: Google Earth, 2017)

4.1. General Information about İzmir and Basmane District

Basmane District is located in Konak county, İzmir. Basmane District is situated on the north of Çorakkapı District, on the east of Çankaya District, on the south of Kültürpark Fairground and Kahramanlar neighbourhood and on the west of Kemer and Kapılar District. Basmane includes a number of important transportation axes: it is bordered by FevziPaşa Boulevard and Gaziler Street in the north and Eşref Paşa Street in the west. Moreover, Ancient Theatre and Kadifekale archeological areas are located in the south of the region. Basmane Train Station, Agora and Altınpark archeological areas which are significant historic, cultural and heritage values for İzmir are located within the boundaries of Basmane (Figure 4.2).

Figure 4.2. Location of Basmane and important historic places within the district (Source: Google Earth, 2017)

As one of the oldest districts of İzmir, Basmane District gained a key position together with the construction of İzmir-Kasaba (Turgutlu) railway and Basmane Train Station in 19th century. Basmane Station has been a major part of the urban transportation system that links the İzmir port to inner regions during the period of social and economic development of the city. It substantially affected its immediate environment within the places used for the purpose of commercial, social, residential

and accommodation. After the Basmane Station was opened in 1866, inns commonly used for accommodation in long-distance caravan transport fell into a decline and gave place to the hotels (Sürgevil, 2011). Within this period, many dwellings were converted into hotels in addition to construction of new ones. Dibek Street, where accommodation activities were performed intensely in began to be mentioned as 'Hotels Street' in the district. After a considerable part of historical hotels in the coastal line were destroyed by the İzmir Fire in 1922 and historical hotels close by the government office on Anafartalar Street at Kemeraltı were damaged, Basmane District came into more prominence thanks to the hotels (Kayın, 2010).

While İzmir was in an effort of creating a new-modern city in the early Republican Period after the Great Fire, the opening of International İzmir Fair and Kültürpark where positioned nearby the station offered a great opportunity for urban life in terms of socio-economic, ideological, cultural and spatial parameters (Kayın, 2016).With emphasis on the change of physical environment of Basmane and its vicinity in the late 1930's, 9 Eylül (Basmane) Square and 9 Eylül (Basmane) Gate of Kültürpark became the significative components of Basmane District within the urban fabric. In those years, Basmane District was in a peak period due to the train station, Kültürpark and accordingly the hotel functions (Sürgevil, 2011).

In addition to Basmane Station and Kemeraltı, Kültürpark has ensured the hotel functions' continuity in the area as from the year 1936. However, while an increase in migration phenomenon altered the socio-economic structure of the region after 1950's, historic fabric fell into a decline. Moreover, the erosion of International İzmir Fair and Kültürpark after 1980 has triggered this situation. In recently, Basmane Region has mostly received refugees and residential areas have become temporary residences of refugees (Kayın, 2010).

4.2. Plans, Projects and Initiatives related to Basmane District

Basmane District constitutes a considerable part of 'Kemeraltı Urban Historical Site' within the historic urban texture. Kemeraltı and its vicinity has been a major traditional city center of İzmir that is still actively used today. As well as being Urban Historical Site, Kemeraltı region was completely determined as 3rd Degree Archeological Site. It also contains 1st Degree Archeological Sites and Natural Site

Areas. Therefore, a range of studies and projects about Kemeraltı Urban Historical Site0 has been put into practice by İzmir-Konak Municipality. 'Kemeraltı Conservation Master Plan' was initially approved in 1984. Then, it was decided to revise in order to adopt a more sensitive and conservative approach. In parallel with this, 'The Conservation Master Development Plan' at 1/5000 scale for the area was prepared by İzmir Metropolitan Municipality (İzmir Konak Belediyesi, 2002).

The entire study was divided into two stages due to the size of area and natural/artificial distinctions. First of all, 'Kemeraltı I. Stage Revision Conservation Master Plan' was prepared by Dokuz Eylül University, Department of City and Regional Planning in 2004 (Kemeraltı II. Etap I. Bölge Koruma Amaçlı Revizyon İmar Planı, Plan Raporu, 2009). The first stage covers the area bounded by İzmir Girls High School, Bayram Yeri, İkiçeşmelik Avenue, Fevzi Paşa Boulevard, Gümrük and Konak Square (Figure 4.3). Together with the holistic plan framework, site investigations in detail were conducted and the data were updated, as well as upper scale general land use decisions within 1/5000 scale were taken. In subscale studies of the first stage of the plan, strategies for transportation, green spaces, social reinforcement and service areas, infrastructure, land use etc. were developed. Moreover, conserving the harmonious spatial integrity and the architectural characteristics of the historic urban texture and ensuring its sustainability were primarily considered (İzmir Konak Belediyesi, 2002). As components of 'Kemeraltı I. Stage Revision Conservation Master Plan', plan notes, urban design projects and urban design guide were prepared. They provide guidance towards the implementations within Kemeraltı Urban Historical Site.

In the direction of the studies for the first stage of the plan, as an implementation model, Ali Paşa Square in Kemeraltı was initially improved. The interventions continued with Hotels Street in Basmane District so as to revitalize and regain its significance. Konak Municipality has a series of tasks both for the buildings and across the street. Infrastructure and street pavement works were conducted and street lighting equipments were improved. The areas for planting and landscape design were created. Additionally, property owners renewed the buildings' façade according to the projects and alterations which were suggested by Konak Municipality (Konak Belediyesi AR-GE Müdürlüğü, 2004).

As from the year 2004, the studies have been initiated on 'Kemeraltı II. Stage Revision Conservation Master Plan'. The area for second stage is bounded by Gaziler Street and Fevzi Paşa Boulevard in the north, İkiçeşmelik Avenue in the west and 1282.

Street in the east. The area extends over Kadifekale in the south, as well (Kemeraltı II. Etap I. Bölge Koruma Amaçlı Revizyon İmar Planı Plan Raporu, 2009) (Figure 4.3).

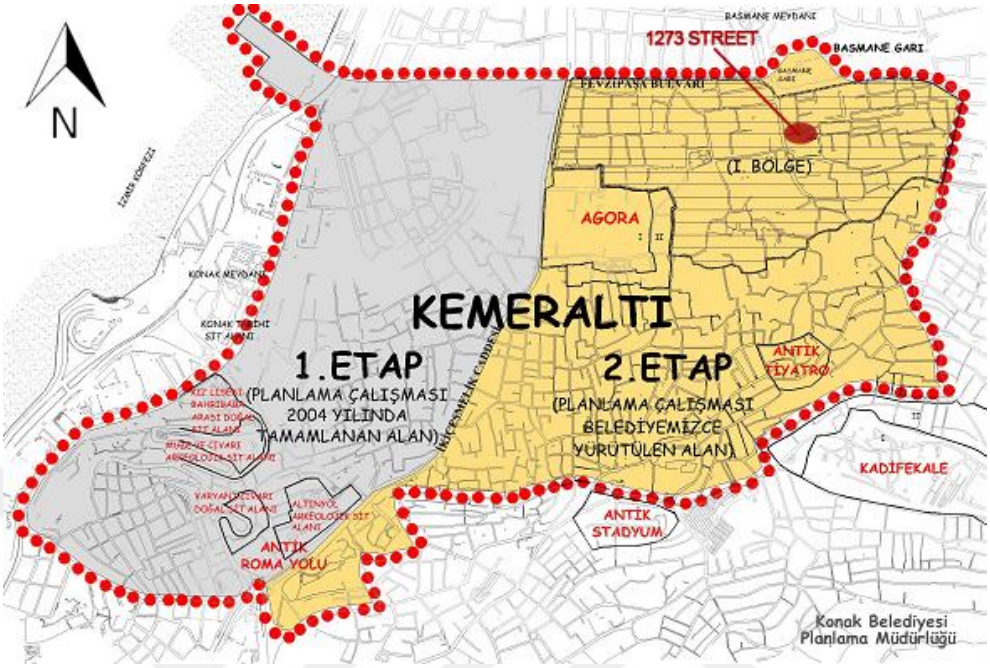
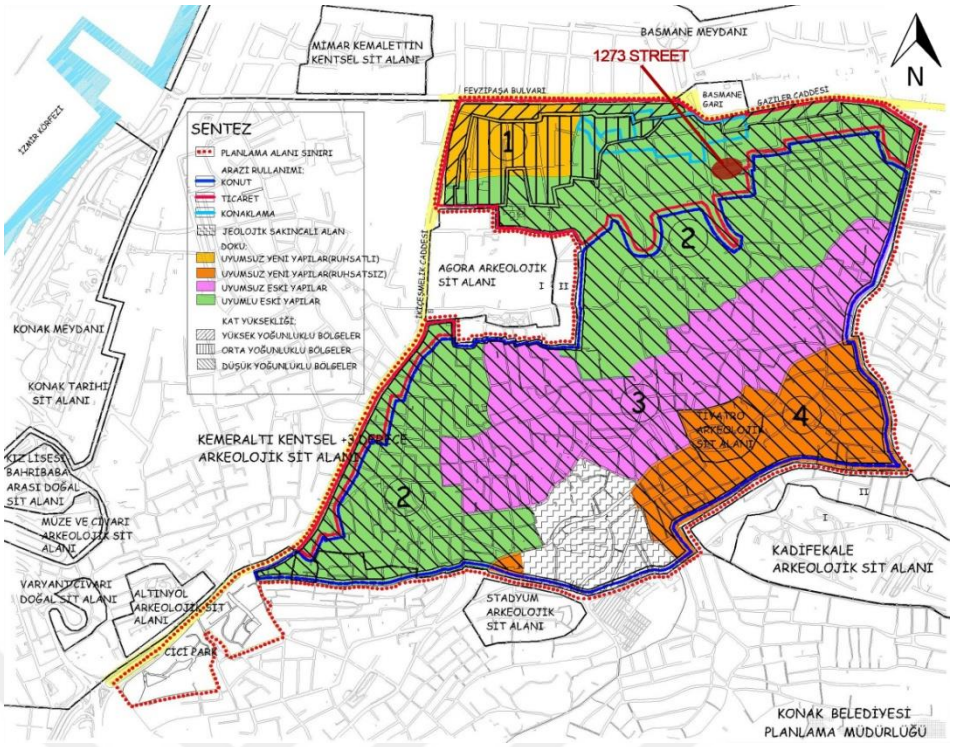
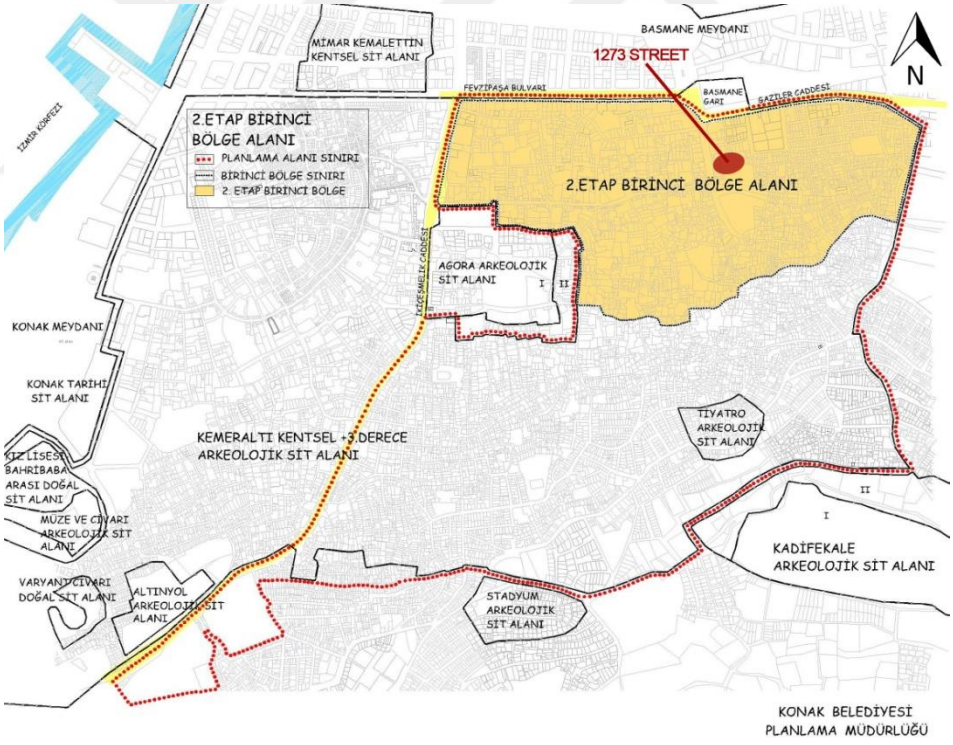


Figure 4.3. Plan Regions within Kemeraltı Revision Conservation Master Plan (Source: Adapted from Kemeraltı II. Etap I. Bölge Koruma Amaçlı Revizyon İmar Planı Plan Raporu, 2009)

A certain number of analyses and studies were carried out in second stage revision plan as such in first stage revision plan. It was observed that the study area was composed of four different zones when all area was categorized and superposed according to the analyses obtained from texture, land use and storey height (Figure 4.4a). First zone is an area where multi-layered settlement and deterioration have increased due to the implementations and the proximity to Fevzipaşa Boulevard together with having intensive commercial activities. Also, the area partly includes qualified buildings. Second zone contains both commercial and residential areas which carry the traces of Turks and Rums' neighborhoods. The area has a low density but, the density has been increasing within the part used for the commercial purpose (Kemeraltı II. Etap I. Bölge Koruma Amaçlı Revizyon İmar Planı Plan Raporu, 2009).



(a)



(b)

Figure 4.4. (a) Planning zones and (b) Kemeraltı II. Stage I. Region within Kemeraltı II. Stage Revision Conservation Master Plan (Source: Adapted from Kemeraltı II. Etap I. Bölge Koruma Amaçlı Revizyon İmar Planı Plan Raporu, 2009).

The first zone and a significant part of the second zone were determined as the priority study areas, because these zones ideally represent historical process and they have a considerable amount of cultural properties that need to be protected. These zones have a high probability of deterioration owing to the proximity of the center. Therefore, Kemeraltı II. Stage I. Region Revision Conservation Master Plan was generated in 2009 (Kemeraltı II. Etap I. Bölge Koruma Amaçlı Revizyon İmar Planı Plan Raporu, 2009) (Figure 4.4b).

In addition to the general studies about the entire area in the second stage, site analyses were carried out specific to the first region. 1/1000 scale Kemeraltı II. Stage I. Region Revision Conservation Master Plan including main decisions and 1/500 scale layout plan in detail were generated. The plan was divided into the sub-zones and the sub-targets which were determined according to the characteristics of sub-zones and plan integrity.

Moreover, 'Priority Implementation Areas'[2] and 'Special Project Areas'[3] were decided within the boundaries of the planning area. Plan notes and urban design guide were prepared and building typologies were analyzed. Furthermore, façade and urban design projects were prepared for a number of areas that need to be studied at the urban design scale (Kemeraltı II. Etap I. Bölge Koruma Amaçlı Revizyon İmar Planı Plan Raporu, 2009).

Following a number of the ongoing planning studies, in 2013, İzmir Metropolitan Municipality initiated a long-term project entitled 'İzmir History Project' in order to strengthen the relations of the residents with the history of İzmir and to prevent the emergence of the urban decline areas and to reverse them. The project has a participatory and multidisciplinary approach: local administrations, public institutions, private sector, funders and other participants such as dwellers, users and volunteers play an important role in achieving this project (Tekeli, 2015).

[2] As a result of the analyses towards Kemeraltı II. Stage, the limited number of areas, which reached into the present day with their historical and architectural values and/or entered into a process of extinction, were determined as Priority Implementation Areas (Kemeraltı II. Etap I. Bölge Koruma Amaçlı Revizyon Imar Planı Plan Raporu, 2009).

[3] As a result of the analyses towards Kemeraltı II. Stage, various areas have been designated as Special Project Areas in order to accelerate the implementation of plan (Kemeraltı II. Etap I. Bölge Koruma Amaçlı Revizyon Imar Planı Plan Raporu, 2009).

İzmir History Project covers the area bordered by FevziPaşa Boulevard and Gaziler Street in the north and it includes Kemeraltı Urban Historical Site and Kadifekale Urban Redevelopment Area. The project area was divided into nineteen sub-regions and each sub-region has substantial archeological cultural properties and historic building stock (Figure 4.5). Operation plans were prepared by encouraging participation from various sectors for the development of the implementation programmes that will revitalize the social and economic life while preserving the heritage value within the area (Tekeli, 2015). There are a range of works and studies conducted within the boundaries of the project area (Table 4.1). Some of them were conducted before İzmir History Project was launched; others are the ongoing and planned studies while İzmir History Project is in process.

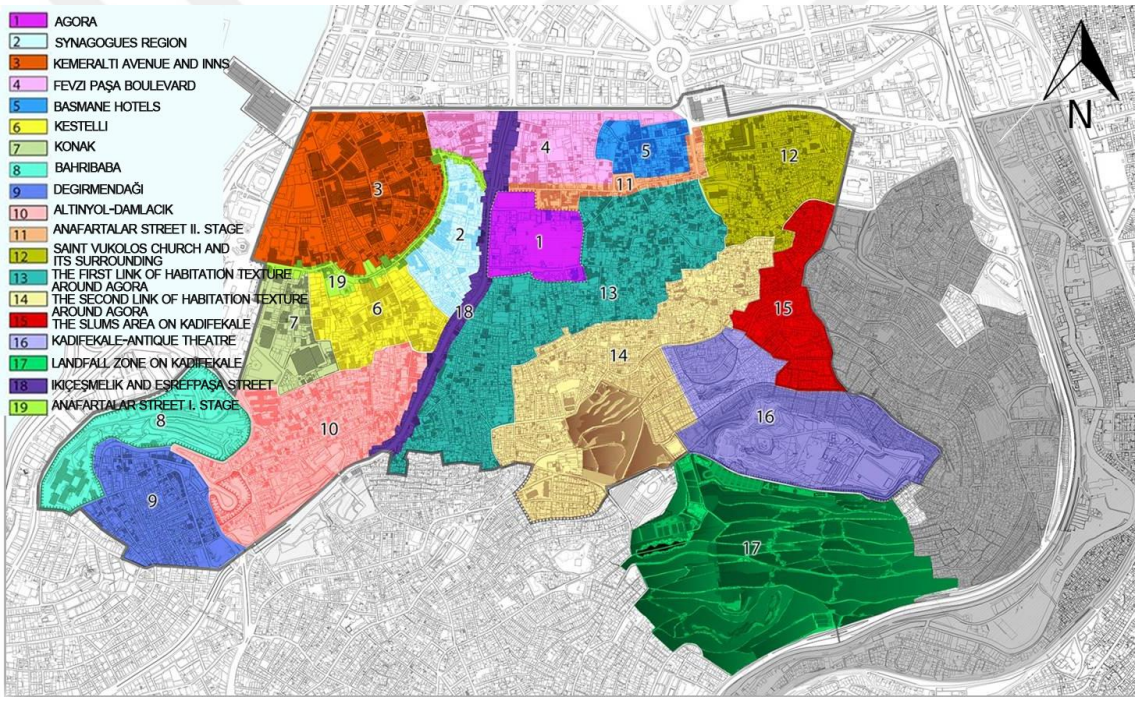


Figure 4.5. The nineteen sub-regions of İzmir History Project
(Source: Adapted from Tekeli, 2015)

Table 4.1. Completed, ongoing and planned studies and works in all sub-regions (Source: Tekeli, 2015)

Projects for All Sub-regions	Completed	Ongoing	Planned
1. Sub-region: Agora	Agora Security Wall Project Agora Excavation House Restoration Simple Maintenance and Repair of Walls Resulting from Expropriation and Demolition Studies in the Agora Excavation Area	Agora Museum and Exhibition House Restoration Agora Entrance Hall Support for Acheological Excavation Namazgah Bath	
2. Sub-region: Havra District	Beint-Hillel Sinagog Restoration 926 Street Rehabilitation Project	Congregation Archieve Project	
3. Sub-region: Kemeraltı Street and Khan Region	Kemeraltı Historical Şükran Hotel Entrance Door and Fountain Restoration Abacıoğlu Khan	Fisherman Square Project Demir Khan, Mirkelamoğlu Khan and Selvili Khan Restoration Dalan Soap Museum	Çakaloğlu Khan Restoration
4. Sub-region: Fevzi Paşa Boulevard	Kavaflar Passage Restoration		
5. Sub-region: Hotels Region	Basmane Woman Museum Restoration Hotels Street Façade Renovation Basmane Neighbourhood Centre Restoration Fettah Mosque Restoration		
6. Sub-region: Kestelli			
7. Sub-region: Konak	Ahmet Ağa Mansion Restoration Kızılay Building Restoration		Tekel and Kızılay Building Restoration Milli Kütüphane Street Revitalization
8. Sub-region: Bahribaba	Şato Restaurant Restoration Konak Tunnel		
9. Sub-region: Değirmendağı			
10. Sub-region: Altınyol-Damlacık	Toy Museum Saadet Mirci Neighbourhood Centre Restoration Ayla Ökmen House Restoration Kılcı Mescid Restoration	442. and 834. Street Renovation Project	Akevler Mansion Restoration
11. Sub-region: Anafartalar Street 2. Stage		960. Street Rehabilitation Project	Akhisar Hotel Restoration Historical Coffee House Restoration nearby Altınpark
12. Sub-region: Agios Voukolos Church and its Surrounding	Agios Voukolos Church Restoration	Altınpark Excavation Area Top Covering for Protection Agios Voukolos Church Landscape Project Kumrulu Mescit Restoration 1273. and 1276. Street Rehabilitation	Bıçakçı Khan Restoration
13. Sub-region: First Housing Fabric	Emir Sultan Tomb Restoration Çokov Foundation Building Restoration Altınordu Sports Club Restoration Radio and Democracy Museum Project	Kadifekale-Agora Lighting Master Plan Carfi Mansion Kadifekale-Agora-Kemeraltı Transportation Master Plan	Crimerian Turks House Restoration Kapanizade House Restoration
14. Sub-region: Second Housing Fabric		Rehabilitation of Jeologically Inconvenient Area	
15. Sub-region: North Slope Slum Areas			
16. Sub-region: Kadifekale-Ancient Theatre	Kadifekale Walls Restoration	Chapel and Cistern Restoration Project Mescid Restoration Project Alanyalı Mansion Restoration Aegean Civilization Archeology and History Park	Kadifekale-Ancient Theatre Land Arregement Area
17. Sub-region: South Slope Lanslide Area		Rehabilitation of Jeologically Inconvenient Area	
18. Sub-region: Ikiçeşmelik-Eşrefpaşa Street	Police Memory House Ikiçeşmelik Street Façade Renovation Project		
19. Sub-region: Anafartalar Street I. Stage	Kemeraltı - Anafartalar Street Façade Renovation Project	Kemeraltı - Anafartalar Street Façade Renovation Project V. Stage Kemeraltı Bazaar Top Covering and Urban Furnishings	

4.3. General Characteristics of Historic Residential Areas of İzmir and Basmane District

İzmir has been a prominent center where commercial, cultural and artistic activities are performed together due to its geographical position down the ages. It has rapidly developed from the beginning of 15th century under the sway of Turks, and became one of the foremost industrial ports of Anatolia and the eastern Mediterrenean in 17th century. Accordingly, its urban life was affected by the arrival of travelers and merchants from all-around world. Moreover, the European Christians known as Levantines, i.e. Franks, have a significant contribution to the domestic architecture of the city, although they had not a large population. Thereby, Levantine architecture has emerged (Akyüz, 1996).

After 18th century, ethnic groups including Muslims, Rums, Armenians, Jews and Levantines have reached a considerable population all around city. Residential areas of these ethnic groups have become clear at the beginning of the 20th century and therefore, the city was divided into four neighbourhoods. There were Muslims-Turks in ArapFırını, Kestelli Street, Basmane, Keçeciler, Mezarlıkbaşı, Namazgah, Tilkilik and İkiçeşmelik District and Kadifekale and Değirmentepe Neighbourhoods in the south and east, Rums in the Kültürpark Fairground and Alsancak (Punta), Armenians in the region that extends from Basmane to the rear of Alsancak and Jews in Mezarlıkbaşı, Karataş and around of Havra Street (Akyüz, 1996). The differences in the lifestyles of the ethnic groups could be observed in their neighbourhoods and the typologies of their houses. Levantines whose houses were located along the coastline were an affluent society in contrast with their low population. Rums and Armenians were in the immediate neighbourhoods of the Levantines and Jews and Turks lived on the slopes of Kadifekale expanding towards the gulf. In this case, the coastline region reflected the modern view, while it left its place to the oriental texture towards the rear of the city (Ballice, 2004).

Turkish neighborhoods in İzmir have sloping streets due to topographic conditions where their houses are located in. Their streets are in organic form which is expanding and narrowing. Turkish neighbourhoods also reflect a self-enclosed life-style which has an impact upon their housing characteristics. Armenian neighborhoods have streets which were positioned to cut each other at right angles. Their streets are clean, wide and well-arranged compared to the other neighbourhoods within the city. Therefore, their neighbourhoods draw attention with the architectural characteristics of

their houses all around the city. The streets of Rum neighbourhoods gather in an irregular composition and Rum houses located around the streets do not form integrity in terms of height, size and construction system of buildings (Beyru, 2011).

Basmane-Tilkilik region serves as a transitional zone where various cultural interactions, commercial activities, accommodation and residential areas exist together concerning social allocation of the city. Within the scope of housing architecture, Basmane-Tilkilik region has many historic dwellings which reflect architecture of interaction arising from multi-cultured social structure of the city. The residential architecture has developed as the synthesis of different cultures within the city and partially in eclectic approach (İzmir Architectural Guide, 2005).

Basmane-Tilkilik region presents typical two-storied houses which have protrusions, mostly central sofas and relatively limited number of side sofas and oriels as a reflection of the character of the Aegean traditional coastal architecture. The houses have a basement floor which is ventilated by small windows and entrance doors designed as a niche and sheltered backyards. The region also includes houses with mezzanine floors or single-storied buildings constructed over the basements. The residential architecture of the region has been shaped as hybrid architecture of interaction presenting characteristics of both traditional Ottoman-Turkish houses in Kadifekale-Namazgah Districts and the coastal Levantine houses (İzmir Architectural Guide, 2005).

It is seen that İzmir houses which remain still standing belong to the last periods of the 19th century (Beyru, 2011). According to Akyüz (1994), the housing examples of İzmir could be considered in three main groups: these are Traditional Turkish Houses, Levantine and Greek Houses and Interaction Houses.

4.3.1. Traditional Turkish Houses

Traditional Turkish Houses are mostly located in Turkish neigbourhoods, while they rarely exist in Bornova and Buca District. They have generally exterior sofas and they leave a plastic impression with their oriels. Turkish houses are generally double-storied. Their first floor has masonry system and upper floor which is constructed with the wooden frame technique. The relation of the houses with the street is provided with windows and oriel windows in the upper floor. The spaces of the upper floor are

converted into rectangular shapes, because the houses are situated in the organic street composition and plot form. Although Turkish houses have generally self-contained rooms, there is a transition between the rooms in Turkish houses of İzmir. They are virtually self-closed and generally have a garden. Minimum connection with the outer spaces in ground floor and lattice windows symbolize privacy based on ethnic and cultural conditions of Turkish society (Akyüz, 1994).Water wells, fountains and pools are among water elements located in the gardens of Turkish Houses. Moreover, there are cupboards and bathing cubicles in rooms, while annexes take place in the garden independently from the main building (Akyüz, 1996).

The entrance to the building is generally provided by the front garden in Turkish houses of İzmir. The garden area has high walls in order to detach the building from the street. As main constituents, rooms are mostly rectangular and they are shaped around a hall. The halls not only provide a connection between the rooms but also they act as meeting places. They are also used for household activities. Rooms generally include various furnishings such as a cupboard, a drawer and a small bathroom (Akyüz, 1997).

Regarding structural system, Turkish houses are generally built by wooden and rough stone. Their walls are covered with plaster. The houses have protrusions supported by wooden corbels. Façade of the houses is made of wooden and stone. Stone is used as a filling material in massive sections. When constructing the floor of pavements of halls and garden, it is utilized marble. Additionally, roofs have a wooden construction and wide eaves and they are covered with tiles. The underside of the eaves decorated with geometrical design by using long and narrow wood strips. The entrance door of the houses is made of wooden with one or two leaves while windows are encircled with lattices made up of wooden strips or perpendicular to each other to prevent appearance of the interior spaces from outside. Apart from this, as traditional architectural construction system, ‘baghdadi system’ that is covered with wooden frame mortar has been applied so that the reflection of the effect of modular façade character has been preserved (Akyüz, 1997).

4.3.2. Levantine and Greek Houses

In İzmir, Levantine and Greek houses are located in Alsancak, Karşıyaka, Buca and Bornova and in perpendicular and parallel of Mithatpaşa Street. Apart from this,

these houses appeared in coastal cities such as Çanakkale and Thessaloniki 100-120 years ago (Akyüz, 1996). Although Levantine settlements in Bornova and Buca districts show an expansion differently from each other, Levantine settlements in both districts have been privileged and differentiated within the entire city. They contain large-scale Levantine houses in wide plots developing based on social status and economic potential of the wealthy dwellers. These houses exhibit distinctive façade arrangement, interior space and landscape organizations differently from the local architecture of the city (Akkurt, 2004).

Levantine and Greek Houses resemble each other in terms of plan and façade organizations. They are generally two-storied, adjacently arranged and have narrow façades. They reflect Western culture because of the multi-cultured social structure of İzmir. Though, there is no Greek house anywhere in Anatolia and Rumelia, Greek houses in Aegean Region differ from Turkish houses. Greek houses are generally one or two storied with an oriel. They have a masonry construction in ground floor while Baghdadi system is used in first floor. They have also various decorations on their façades which represent neoclassical period (Akyüz, 1996).

There are also described as 'Chios type houses' among the Levantine houses. These houses are similar with the houses in Chios in terms of façades elements rather than the plan or façade scheme. These similarities are regarded as stone cladding façades, stone carving and moldings, horizontal and vertical protrusions as well as triangle pediments and portals. Moreover, the similarities are resulted from construction materials supplied from same place and same construction foreman working in the islands, İzmir and Western Anatolia (Akyüz, 1994).

Levantine houses in adjacent order can be classified as the ones having side hall and the ones having center hall within their frontal characteristics. The houses having side hall prevail among the all types. These two type houses can be sub-grouped depending on the number of floors and their properties, as well. The number of floors ranges from single storey to two-storied ones. Apart from these, there are a limited number of Levantine houses with triple storied in İzmir. Moreover, Levantine houses can be classified by their spatial characteristics ranging from open to closed spaces and from private to public spaces. In these houses, the entrance from the street is provided by a semi-public semi-open space and then, there is a semi-private closed hall space. The doors and the garden are reached from the hall and the garden is situated on the rear

side because of avoiding visual connection of the interior spaces with street. The service spaces have contact with the hall and the garden (Akyüz, 1997).

Majority of the Levantine houses have basement floors. While some of them are lower heights compared to typical floor, some are kept high as an independent unit. On the other hand, a number of houses have only ground and first floor without basement floor. The stairs of the houses are located on side to avoid the space loss. The entrance of the Levantine houses is generally separated from the street level with several stairs and the entrance doors are mostly iron, and barely wooden with double-leaf. There are also transom-topped windows with iron frame, the other windows in upper floors have wooden frame (Akyüz, 1997).

Considering the construction system, Levantine houses are generally masonry in ground floor and the upper floor is of Baghdadi system. There are also houses with single and double-storied which have totally wooden frame type. Stone covered façades are distinguishing characteristics of the Levantine houses, while some of examples have pressed brick façades. Façade materials of the houses are stone, brick and wooden. The stone is used in polygonal and sedimentary forms in masonry type, while cut-stones are used with reliefs on covered façades. It is usually in dark green or soil color. Furthermore, wooden is used in joinery work covering windows, doors, floor surfaces of rooms, wall structure of the upper story and interior stairs (Akyüz, 1997).

4.3.3. Interaction Houses

Interaction houses reflect the characteristics of both types of the houses in İzmir as a result of architecture of east-west interaction. They are found at Arapfırını, Tilkilik, Dönertaş, İkiçeşmelik, Karantina, Alsancak, Kemeraltı, Mezarlıkbaşı, Keçeciler, Karataş and Basmane District (Akyüz, 1997). These houses are generally double-storied with rectangular plan scheme. In these houses which directly enter into the interior spaces, rooms and stairs open to the hall. Oriel window in upper story is unified with the hall or the room (Akyüz, 1994).

Interaction houses are generally adjacently arranged. These types of houses are classified as the ones with side-halls and the ones with center hall in common with the Levantine houses. They are also grouped according to the number of floors. Rooms are not independent unit; there are passages in between the rooms next to each other. The

rooms on the front side of the hall are connected with the street, while other rooms on rear side are related to the courtyard. In their rooms, there are a small bathroom and a cupboard in common with Turkish houses. Oriel windows which are integrated with the hall on the upper floor and they have a lower height than the rooms. The stairs is connected with the hall. Services spaces are located near the hall and the stair. In addition, the story height of service spaces is kept lower than the other spaces (Akyüz, 1997).

Interaction houses are similar with the western-influenced houses in terms of spatial characteristics. Plan scheme of the stories are almost same. There are not too much semi-open spaces and as an open space of the building, the garden is located on the rear side. The structure system of the interaction houses shows also similarities with the Levantine Houses. However, the façades are mostly plastered instead of stone covering. Moreover, basement portion of the façade have a cut-stone look by way of a plaster technique. Floors and ceiling covers are made of wooden and the floor of the hall in some samples is covered by black and white marble with 50/50 cm. Consequently, interaction houses represent the characteristics of both housing types in İzmir. They are in harmony with the plan arrangement of a Turkish house and the façade elements of the Levantine houses (Akyüz, 1997).

Housing architecture of İzmir belonging to the last centuries was affected by the different cultural interactions and housing types in İzmir. However, it is not a matter to mention about the continuous and particular development of any type of houses in İzmir (Akyüz, 1994).

Throughout 19th century, a new housing texture specific to İzmir has been developed. In this direction, Çıkış (2009) defines İzmir houses which have come to exist in the last quarter of 19th century as '19th century İzmir houses'. These houses were built in order to meet the different requirements of a particular housing typology in İzmir. İzmir houses are mostly adjacently arranged, two storied and they have oriels and asymmetrical façades. The first examples of these houses are encountered in Punta (Alsancak). Accordingly, these houses set an example for the houses which have been built over time in other regions of the city.

4.3.4. Analysis of Building Envelope of Historic İzmir Houses

In İzmir houses, building envelope covering walls, floors, roofs, windows and doors can be briefly summarized considering their materials and construction techniques as follows:

Walls: There are three types walls used in İzmir houses. These are massive walls, half-infill walls and infill and cladding walls. Massive walls are composed of rubble stone or brick or both of them. Rubble stone walls are generally plastered with lime. While they are strengthened with wooden beams in Turkish houses, reinforced concrete is used in Levantine houses. Half-infill walls consist of wooden frame and massive walls with 55-65 cm thickness. Infill and cladding walls are used for first level story interior walls in double storied houses. They are filled with brick and plastered or the both side of the walls coated with Baghdadi wooden strips, then plastered (Akyüz, 1997).

Floors: The floors in İzmir houses are gathered in three groups. They can be counted as those being laid on the ground, those having wooden joists and those tacking ones. The halls, service spaces and gardens have stone floors on the ground. White and black marble cover also used for the halls in Levantine houses over the concrete based ground. Rooms of the upper story have floors that consist of wooden joists. There are also ground storied houses coated with wooden, because they have a basement floor. Apart from these, it is observed that brick arch floors are used in the floors of service spaces and the terraces in some spaces (Akyüz, 1997).

Roofs: Roofs are generally made of wooden and covered with tiles in Turkish style. They have either wide or narrow eaves or without any eave. Roofs with wide eaves have width of 55-65 cm especially in old Turkish quarters and narrow eaves have width of 20-30 cm in houses from various regions of the city. The protrusions of the Turkish houses are unified with the main body as an extension of roof while there are separate oriel windows which were inclined and metal-covered in Levantine houses (Akyüz, 1997).

Windows, shutters and external doors: The windows of İzmir houses vary by the types of the houses and the storey they are in. They can be classified according to the frame type and their balustrade and shutter position. The basement windows in İzmir houses have generally squire-like dimensions while the windows on upper façades

have rectangular shapes. Their jambs are stone or rarely brick. The windows in ground floor have generally iron shutters and the upper floor have wooden shutters and sometimes all windows have totally wooden or iron shutters in some houses examples (Akyüz, 1997).

External doors consist of garden and entrance doors in İzmir houses. The entrance to the building is provided by garden door to the garden, from there to the houses. Garden doors are generally made of wood or iron and have double wings. External doors are classified by their materials. They can be iron or wooden. External doors are also grouped as massive by nature, massive at bottom, semi translucent on top and completely semi translucent (Akyüz, 1997).

4.4. Description of the Case Area: 1273 Street in Basmane District

1273 Street has been determined as the case area within the scope of this thesis. The case area lies on the east-west direction in Basmane District, İzmir with 38.25°N latitude, 27.08°E longitude and 12 m elevation above sea level. It was situated in the south of Basmane Train Station and in the northern border of Altınpark Excavation Area (Figure 4.6).

Figure 4.6. Aerial view of 1273 Street and its surrounding
(Source: Google Earth, 2017)

The west of the street faces to the street named as Anafartalar. In the east, 1273 Street ends with Kumrulu Masjid and it is connected with the street numbered as 1270 Street which opens to the main entrance of Saint Vukolos Church. Moreover, Bıçakçı Inn is located in the northern border of the 1270 Street. The street view is indicated from the east and west direction below (Figure 4.7).

(a) (b)

Figure 4.7. The view of 1273 Street from (a) east and (b) west direction

Altınpark Excavation Area, Bıçakçı Inn and Saint Vukolos Church are among the special project areas which are evaluated in urban design scale within Kemeraltı II. Stage I. Region Revision Conservation Master Plan. It was aimed to include socio-cultural facilities and public uses in these areas and the special project areas where archeological excavation works have been carried out were allowed to be assessed according to the decisions of the Conservation Regional Board. Moreover, it was envisaged that projects for these areas will be prepared by public or private institutions and organizations with plan notes, thus it was targeted to actualize the plan by accelerating the implementation process in these areas (Kemeraltı II. Etap I. Bölge Koruma Amaçlı Revizyon İmar Planı Plan Raporu, 2009).

In this direction, a proposal urban design project for Saint Vukolos Church and Bıçakçı Inn and their surroundings was prepared. The existing and proposal façade projects for 1270, 1273 and 1274 Street were generated (Kemeraltı II. Etap I. Bölge Koruma Amaçlı Revizyon İmar Planı Plan Raporu, 2009). Furthermore, 1273 Street is

included in İzmir-History Project as a part of Saint Vukolos Church and its surrounding which is twelfth sub-region. A range of works were completed when some have been in process and some have been planned to be put into practice for the sub-region in the scope of İzmir-History Project as stated in Table 4.1 (Tekeli, 2015).

1273 Street is located in a residential zone which hosts mostly qualified and historic buildings within Basmane District. Moreover, it has a key position due to close proximity to the special project areas and accordingly existence of implementation-oriented studies conducted by local authorities in the street and its immediate vicinity. Taking into account of these, it was the reason of selecting 1273 Street as the case area.

4.4.1. Characterization of the Buildings

Within the scope of the thesis, 22 buildings covering historic and contemporary buildings which lie on 1273 street are investigated. There are 11 buildings on the northern border of the street while the other half of the buildings forms the southern border of the street. The buildings in both directions are positioned as adjoining ordinances along the street. The main entrances of the buildings are provided through 1273 street (Figure 4.8).

In this part, the buildings are firstly described by being classified under a range of building related parameters. Then, the structural features of the buildings based on the components of buildings' envelope are explained in the case area. The descriptions about the buildings are investigated by coding and categorizing them since there are investigated 22 buildings having different characteristics. Accordingly, each building is assigned a number, i.e. Building 1 and Building 2, in order to facilitate the description of specifications on the buildings in the case area (Figure 4.8).

Function of buildings: 1273 Street includes three different types of buildings. The buildings mostly consist of residential uses. The ground floors of some buildings among the residential ones are arranged for commercial use, while upper floors are for housing units. There are some buildings having completely commercial use. Commercial buildings in the case area have various functions such as coffeehouse, food sales unit, manufacturing shop and storage place. There are four buildings with completely commercial use while the ground floors of three of 18 residential buildings have commercial use in the case area (Figure 4.9).

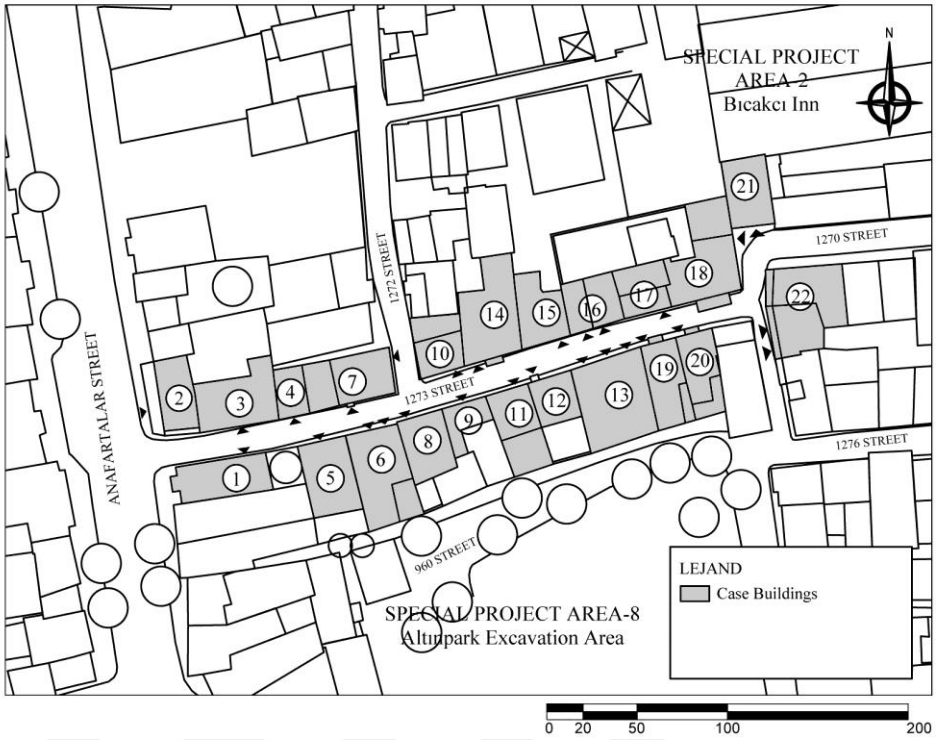


Figure 4.8. Numbered case buildings in 1273 Street

Additionally, there is one religious building named as Kumrulu Masjid (Abdurrahman Masjid) at the corner of the 1273 Street which is connected with 1276 Street. Kumrulu Masjid was built in 1756-1757. The masjid includes a sanctuary with a rectangular shape and a narthex in the north of the sanctuary. The ground floor is tomb while the upper floor is used as masjid (Kemeraltı II. Etap I. Bölge Koruma Amaçlı Revizyon İmar Planı Plan Raporu, 2009) (Figure 4.9).

Type of buildings: Historic and contemporary buildings coexist in the street where the buildings are situated in adjacently order. There are 13 historic buildings in total. According to the decisions of dated 1981 and 1992 İzmir No 1 Cultural and Natural Heritage Conservation Regional Board, 11 historic buildings were officially registered within the case area.[4] (Kemeraltı II. Etap I. Bölge Koruma Amaçlı Revizyon İmar Planı Plan Raporu, 2009). The other two buildings are determined as non-registered historic buildings in this study. Moreover, nine buildings are introduced as contemporary buildings in the case area within this thesis (Figure 4.10).

[4] Inventory forms of the officially registered buildings in the case area are provided from İzmir Metropolitan Municipality Directorate of Historic Environment and Cultural Properties.

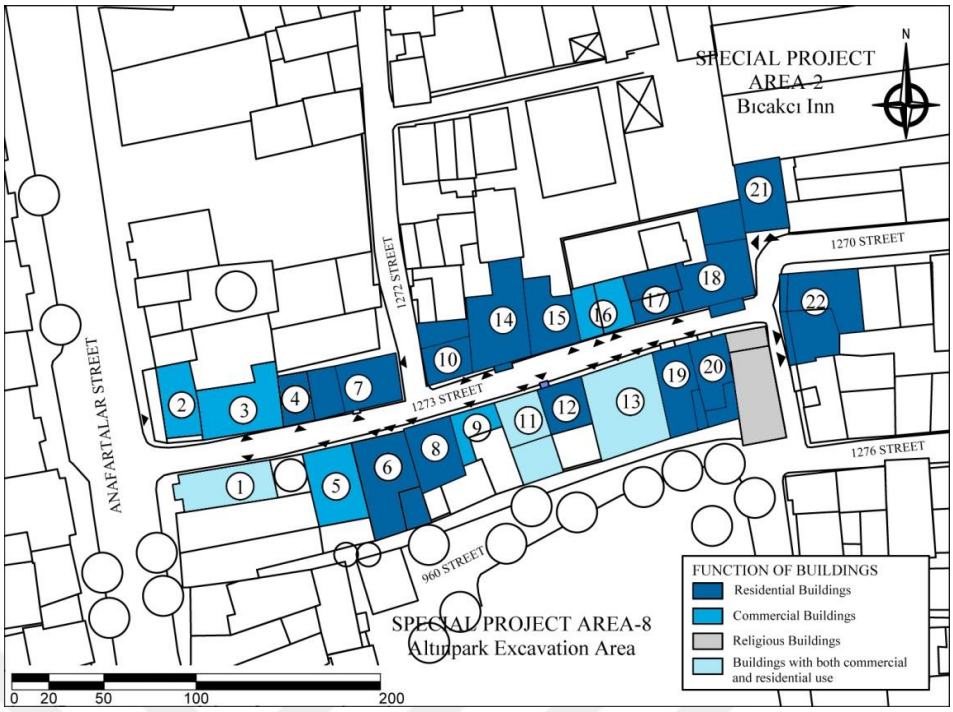


Figure 4.9. Function of case buildings

Figure 4.10. Type of case buildings

According to Kemeraltı II. Etap I. Bölge Koruma Amaçlı Revizyon İmar Planı Plan Raporu (2009), 11 historic buildings are specified as Greek and Levantine houses in the case area (Figure 4.11). There is no Turkish house in the case area. However,

some Greek and Levantine houses have not been able to preserve their individual characteristics by changing hands and they have been functionally altered by changing the proportions of windows and doors. These examples are regarded as 'Rum and Levantine houses which lost their original quality'. Therefore, there is one historic building specified as 'Rum and Levantine house which lost their original quality' in the case area (Kemeraltı II. Etap I. Bölge Koruma Amaçlı Revizyon İmar Planı Plan Raporu, 2009) (Figure 4.11).

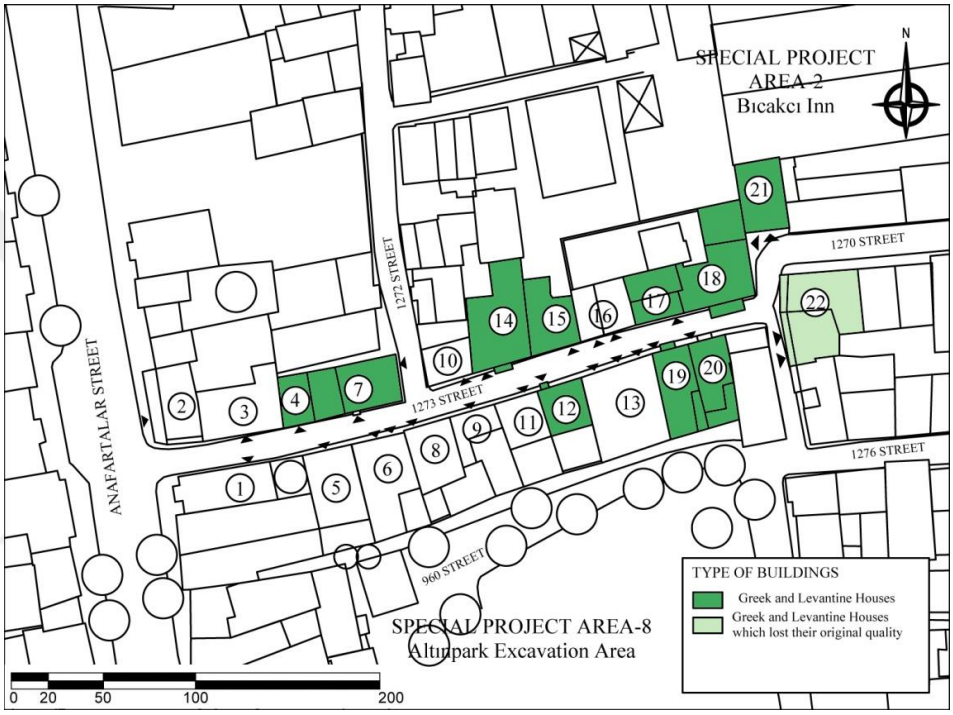


Figure 4.11. Type of historic case buildings

Number of floors: Number of floors of buildings varies between one and three in area. Greek and Levantine buildings are generally two storied and there is only one Greek and Levantine building with three-storied. The number of floors of contemporary buildings range from one to three in the area (Figure 4.12). Additionally, it is possible to classify buildings whether they have a basement floor or not. There are nine buildings which have basement floor, while 13 buildings are without basement floor. The basement floors of the buildings are not continuously used except for some basement floors used as storage.

Figure 4.12. Number of floors of case buildings

Construction Period of Buildings: It is known that a large majority of extant historic buildings were built in 19th century and the first quarter of 20th century within the scope of a study conducted in Kemeraltı II. Stage I. Region (Uçar H. and Uçar A., 2013).

Construction Types of Buildings: 20 buildings were built with a masonry system in the case area. There are two buildings which were constructed with reinforced concrete system (Figure 4.13). Considering Greek and Levantine buildings, they are generally masonry in ground floor and the upper floor is of Baghdadi system. Moreover, for buildings with oriels, the oriels were made of wood while one of them was made of iron in the case area.

Occupancy status of buildings: The site investigations on the case area have been conducted in two separate time periods including between the 20th and 25th of June 2014 and between the 10th and 15th of February 2016. In this period, most of case buildings have hosted refugees. For this reason, these buildings have not been continuously used. A small number of dwellers live in their own houses (Building 4, 7, 21, and 22).

Figure 4.13. Construction types of case buildings

Plan and Façade Organization of Buildings: Contemporary buildings have not a specific plan and façade scheme in the case area. Regarding Rum and Levantine Houses, buildings with narrow façades facing the street predominate in the area while there is limited number of buildings with long façades facing the street. As a result of this, the buildings with narrow façades have a side hall and plan scheme. While the ground floors are used for functions such as kitchen, storage, cellar and living room, the upper floor is arranged for the bedrooms. The hall is the common area which links service spaces, living room and a stair for upper floor. The plan of living room has mostly square shape and has generally two windows. The main entrance of most buildings is separated from the street with a few stairs (Kemeraltı II. Etap I. Bölge Koruma Amaçlı Revizyon İmar Planı Plan Raporu, 2009).

In the case area, most of Rum and Levantine houses with two storied have generally oriels in their second floors. Oriels are designed as a protrusion with three-partitioned and wooden or iron structure. They are mostly supported by cast iron corbels. There is a partition between the oriel and room which is connected to the oriel in the second floor. Moreover, the roof of oriels is separated from the main buildings' roof. Windows have mostly rectangular shape. Besides, if buildings have a basement floor, there are windows on the façade surface at basement level. The windows have

generally stone jambs. Most of windows have also iron shutters and external doors have one wing or double iron wings.

Building Form and Parcel Typology: Case buildings have mostly rectangular shape because of narrow and rectangular shaped parcels. A limited number of buildings have geometry close to square.

As for typology of parcels, 10 different groups were generated by examining the position of all officially registered buildings within parcels and wards specific to Kemeraltı II. Stage I. Region (Kemeraltı II. Etap I. Bölge Koruma Amaçlı Revizyon İmar Planı Plan Raporu, 2009). These groups are indicated in Figure 4.14.

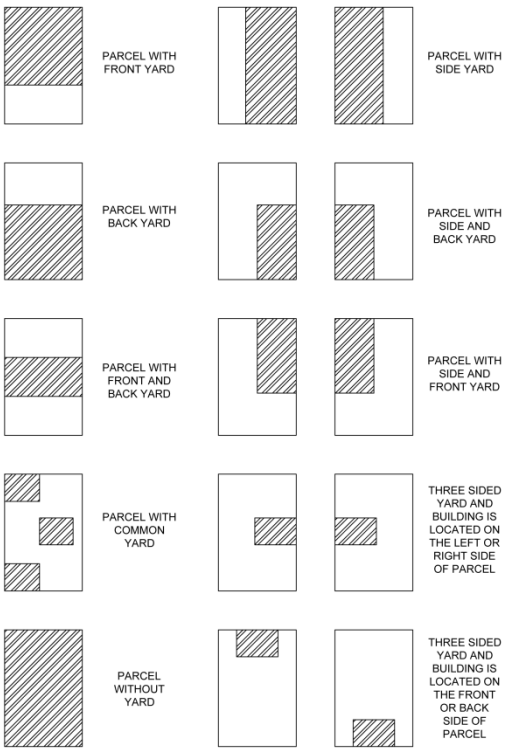


Figure 4.14. Parcel typologies of officially registered historic buildings (Source: Kemeraltı II. Etap I. Bölge Koruma Amaçlı Revizyon İmar Planı Plan Raporu, 2009)

The case area includes historic buildings having different positions within the parcels based on the typologies as stated in Figure 4.14. In the case area, there are five buildings which were determined as number two. These buildings have a rear garden and they are located in the front of the parcels. Besides, two buildings belong to number four. They have a common garden. Additionally, the case area contains one building

with a side garden. Apart from these, two buildings pertain to number five and accordingly they have no garden.

Façade Typology of Buildings: Within the boundaries of Kemeraltı Urban and 3rd Degree Archeological Site II. Stage I. Region, a typology study about Greek and Levantine houses was carried out taking into account of the number of floors and façade characteristics. In the typology study, main groups and sub-groups belonging to these main groups were generated. In the region, the housing type with two storied, a basement floor, a side hall and also an oriel is a prevalent in comparison to the other types (Kemeraltı II. Etap I. Bölge Koruma Amaçlı Revizyon İmar Planı Plan Raporu, 2009). Regarding Greek and Levantine houses in the case area, five buildings belong to this common housing type. But, all Greek and Levantine houses show different characteristics under sub-groups. Greek and Levantine houses in the case area are evaluated according to the façade characteristics and the number of floors as follows:

Considering the position of the oriels of buildings with two storied and a basement floor, with an oriel and a side hall in the area, there are two buildings including Building 19 and 20 with an oriel which is located in the middle of the façade (Figure 4.15 (a) (b)). Building 20, indicated in Figure 4.15 (b), was included in the category of buildings with oriels, because it previously had an oriel instead of a balcony.

Apart from these, Building 12 has an oriel which is located in the same axis with the main entrance of building (Figure 4.15 (c)). Building 17-18 has an oriel which is located on the right of the façade (Figure 4.15 (d)).

Building 19 (a) Building 20 (b) Building 12 (c) Building 17-18 (d)

Figure 4.15. Examples of historic houses according to the position of the oriels

With regard to both the position of oriels and the number of floors of buildings with an oriel, a side hall and but without a basement floor, there is only one building (Building 7) with two storied. Its oriel is situated in the same axis with the main entrance of building (Figure 4.16 (a)). Except from this, Building 14 is three storied and it has an oriel which is located in the middle of the façade (Figure 4.16 (b)).

Building 7 Building 14
(a) (b)

Figure 4.16. Examples of historic houses without a basement floor according to the position of oriels and the number of floors

When historic buildings without an oriel are considered, there are totally three historic buildings in the case area. They are also sub-grouped as to whether they have a basement floor or not. There are two buildings with two storied, a side hall and without a basement floor (Figure 4.17 (a) (b)). These are Building 4 and 15. On the other hand, Building 21 is two storied and it has a side hall and a basement floor (Figure 4.17 (c)).

Building 4 Building 15 Building 21
(a) (b) (c)

Figure 4.17. Examples of historic houses without oriels

4.4.2. The Structural Components of the Buildings

In this section, the present physical situation of the components of the buildings located in 1273 Street is described. Envelope of the buildings covering external walls, oriels, basement floors (if available), ground floors, attic floors, roofs, windows, shutters and external doors are examined. Interior spaces and the components of the buildings such as partition walls, intermediate floors and stairs are out of scope within this study.

4.4.2.1. External Walls and Oriels

The characteristics of all façades vary by buildings in the case area. Thereby, there are different types of external walls belonging to the each building. The construction materials belonging to the external walls consist of both traditional and contemporary materials, because the case area hosts both historic and new buildings. Information about the construction materials of each external wall are obtained from field investigations. In this direction, traditional materials were determined as stone named as andesite and solid brick while contemporary materials include hollow brick. Solid brick (Figure 4.18 (a)) and stone (Figure 4.18 (b)) samples were collected from immediate environment of the case buildings so as to perform measurements on their thermal properties. Thermal conductivity of the samples was measured by Geothermal Research and Application Center of İzmir Institute of Technology.

External walls differ from building to building when their components, thickness and thermal properties are considered. Most of the case buildings have a masonry construction system in the case area. External walls of the buildings are built by only stone or only solid brick (Figure 4.19 (a)) or both solid brick and stone (Figure 4.19 (b)). Each component is not evenly distributed within the external walls consist of both solid brick and stone mixture. Therefore, the percentage of the use of solid brick within this type of external walls is accepted as 10% as measured from the façade of a case building.

Masonry buildings with external stone wall constitute the majority in the case area. Thicknesses of all masonry external walls vary between 15 and 60 centimeters.

Apart from these, several buildings were built by reinforced concrete system which is covered by hollow brick external walls with 20 cm wall thickness.

(a)

(b)

Figure 4.18. Solid brick and (a) stone (b) samples collected from the immediate environment of the case buildings

Building 21 (a) Building 6 (b)

Figure 4.19. External wall examples made of both solid brick and stone (a) and only solid brick (b)

External walls also vary by number and position of the layers. They consist of minimum two and maximum five layers. They are mostly plastered with lime or cement from both interior and exterior while some of them are without plaster (Figure 4.20 (a)). Moreover, for the external walls belonging to basement floor, it was determined 2 types of external walls including below-grade and above-grade walls. Apart from these, front façades of some historic buildings have solid brick (Figure 4.20 (b)) or face stone (Figure 4.20 (c)) cladding.

Building 17-18 (a) Building 19 (b) Building 14 (c)

Figure 4.20. External wall examples (a) without external plaster and (b) with solid brick and (c) face stone cladding

1273 Street have present six historic buildings with oriel positioned on their front façades. There are three types of oriels which were built by different materials. These materials consist of solid brick, wooden and iron. Oriels are generally supported by mostly iron brackets from beneath. There are four buildings have wooden oriels (Figure 4.21 (a)) while one has an oriel which is made of iron (Figure 4.21 (b)) and the rest is solid brick (Figure 4.21 (c)). Their thickness vary between 0.2 mm and 4 cm.

In this direction, a broad range of external wall and oriel types including 37 types were generated. Each type of external wall and oriel was assigned a number so as to clarify specifications on entire types. For instance, the wall type numbered 1 was labeled as B_W1. If a wall type is used in more than one building, it is called with the same label in those buildings. On the other hand, a level of floor of the buildings may contain more than one wall type while some of wall types wrap up the whole floor. Specifications about the external walls and oriels including which wall types are on

which level of floor, description of the external wall and oriel types and also simple drawings of buildings' envelope are indicated in Table 4.2. Following this, the thermo-physical properties and cross-section of external wall and oriel types are presented in Table 4.3 and Table 4.4, respectively.

Building 12 (a) Building 14 (b) Building 1 (c)

Figure 4.21. Examples of (a) wooden, (b) iron and (c) solid brick oriels

4.4.2.2. Floors

The case buildings show different floor characteristics from level to level. The descriptions on floors were grouped under five floor types including basement, ground, attic floors, floors of the oriels and external floors above the entrance of buildings. The intermediate level of floors is excluded from the scope of this study. Total 21 floor types were generated and each type of floor was denominated as such in describing the external walls and oriels. To exemplify, floor type 1 was entitled as B_F1.

Name of floors and buildings and specifications about construction materials and total thicknesses of all floor types are illustrated in Table 4.5. Table 4.6 presents the thermo-physical properties and cross-sections of the all floor types.

Basement Floors: There are 12 buildings with basement floor. Two different types of basement floor (B_F1 and B_F8) were specified. While the first type is accepted for contemporary buildings, the second one is assumed for historic buildings. The first type is composed of three layers with 35 cm thickness in total. These layers are lean concrete, sand and gravel and gravel based earth, from top to bottom, respectively. The other type is simply considered as gravel based earth with 50 cm thickness.

Table 4.2. Specifications about external wall types and oriels belonging to the case buildings

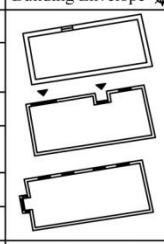
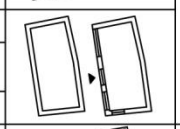
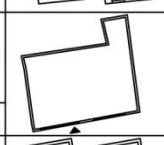
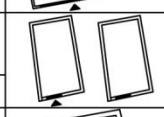
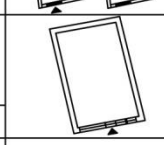
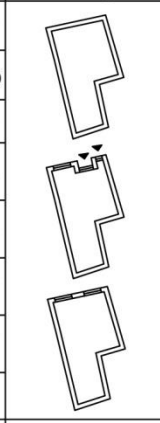
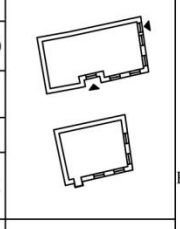
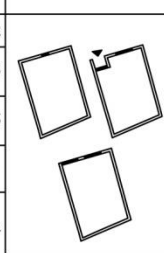
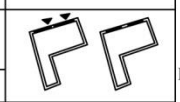
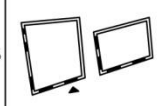
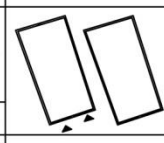
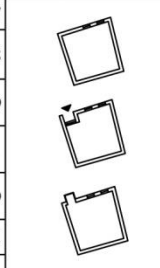
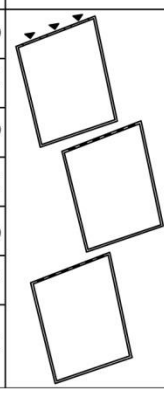
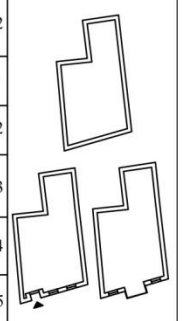
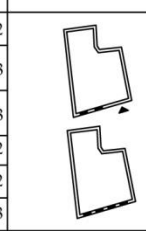
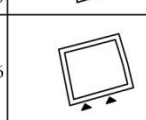
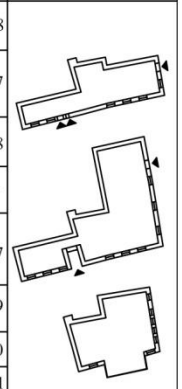
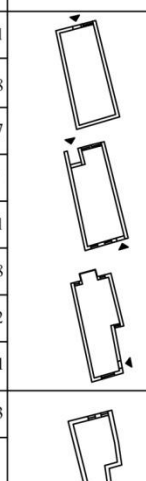
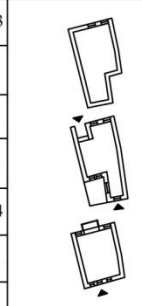
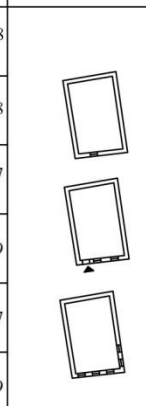
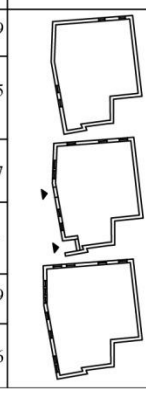
Building Name	Floor Name	Wall Description	Total Thickness (cm)	Wall Type	Drawing of Building Envelope
Building 1	Basement	Stone wall with plaster	50	B_W1	
		Below-grade stone wall without external plaster	50	B_W2	
	Ground	Solid brick wall with plaster	30	B_W3	
		Solid brick wall with plaster (with external door)	15	B_W4	
	First	Solid brick wall with plaster	30	B_W4	
		Solid brick oriel	15	B_W3	
Building 2	Basement	Stone wall with plaster	50	B_W1	
		Below-grade stone wall without external plaster	50	B_W2	
	Ground	Stone wall with plaster	50	B_W1	
Building 3	Ground	Hollow brick wall with plaster	20	B_W6	
	Roof	Gable wall with plaster	20	B_W6	
Building 4	Ground / first	Solid brick wall with plaster	30	B_W3	
	Roof	Gable wall with plaster	15	B_W5	
Building 5	Ground	Stone wall with plaster	50	B_W1	
	Roof	Gable wall with plaster	50	B_W1	
Building 6	Basement	Stone wall with plaster	55	B_W9	
		Below-grade stone wall without external plaster	55	B_W10	
	Ground	Solid brick wall with plaster	55	B_W7	
		Below-grade solid brick wall without external plaster	55	B_W8	
		Solid brick wall with plaster (with external door)	15	B_W4	
	First	Solid brick wall with plaster	55	B_W7	
	Second	Solid brick wall with plaster	55	B_W7	
	Roof	Gable wall with plaster	15	B_W5	
Building 7	Ground	Stone wall with plaster	55	B_W9	
		Below-grade stone wall without external plaster	55	B_W10	
		Solid brick wall with plaster (with external door)	15	B_W4	
	First	Stone wall with plaster	55	B_W9	
		Wooden oriel	4	B_W11	
Building 8	Basement	Stone wall with plaster	35	B_W12	
		Below-grade stone wall without external plaster	35	B_W13	
	Ground	Below-grade stone and solid brick wall without ext.plaster	35	B_W15	
		Solid brick wall with plaster (with external door)	15	B_W4	
	Ground/ First	Stone and solid brick wall with plaster	35	B_W14	
Building 9	Ground/ first	Solid brick wall with plaster	30	B_W3	
	Roof	Gable wall with plaster	30	B_W3	
Building 10	Ground/ first	Solid brick wall with plaster	35	B_W16	
Building 11	Ground/ first/second	Hollow brick wall with plaster	20	B_W6	
	Roof	Gable wall with plaster	20	B_W6	
Building 12	Basement	Stone wall with plaster	40	B_W17	
		Below-grade stone wall without external plaster	40	B_W18	
	Ground	Stone and solid brick wall with plaster	40	B_W19	
		Solid brick wall with plaster (with external door)	15	B_W4	
	First	Stone and solid brick wall with plaster	40	B_W19	
		Wooden oriel	4	B_W11	
	Roof	Gable wall with plaster	15	B_W5	
Building 13	Ground	Hollow brick wall with plaster	25	B_W20	
		Below-grade stone wall without external plaster	25	B_W21	
	First	Hollow brick wall with plaster (north and south)	25	B_W20	
		Hollow brick wall without ext. plaster (east and west)	25	B_W21	
	Second	Hollow brick wall with plaster (north and south)	25	B_W20	
		Hollow brick wall without ext. plaster (east and west)	25	B_W21	
	Roof	Gable hollow brick wall without external plaster	25	B_W21	
Building 14	Ground	Stone and solid brick wall with face stone (on the both side of the external door)	50	B_W22	
		Solid brick wall with plaster (with external door)	15	B_W4	
	Ground/ first/ second	Stone and solid brick wall with face stone (south)	50	B_W22	
		Stone and solid brick wall without external plaster (east and west)	50	B_W23	
		Stone and solid brick wall with plaster (north)	50	B_W24	
	Second	Iron oriel	0.2	B_W25	
Building 15	Basement	Stone wall with plaster	35	B_W12	
		Below-grade stone wall without external plaster	35	B_W13	
	Ground/ first	Stone wall without external plaster (west)	35	B_W13	
		Stone wall with plaster	35	B_W12	
	Roof	Gable wall with plaster(east)	35	B_W12	
		Gable wall with plaster(west)	35	B_W13	
Building 16	Ground	Stone wall with plaster	60	B_W26	
Building 17-18	Basement	Stone and brick below grade wall without external plaster	50	B_W28	
		Stone and brick wall with scraped rendering (south and east)	50	B_W27	
		Stone and brick wall without ext. plaster (west and north)	50	B_W28	
	Ground	Solid brick wall with plaster (with external door)	15	B_W4	
		Stone and solid brick wall with marble covering (on both side of the front door)	50	B_W37	
	Ground/ first	Stone and brick wall without external plaster	50	B_W29	
	First	Brick wall with plaster(west)	50	B_W30	
		Wooden oriel	4	B_W11	
Building 19	Basement	Stone wall with solid brick cladding	40	B_W31	
		Below-grade stone wall without external plaster	40	B_W18	
	Ground	Stone wall with plaster (on both side of the front door)	40	B_W17	
		Solid brick wall with plaster (with external door)	15	B_W4	
	Ground/ first	Stone wall with solid brick cladding (north)	40	B_W31	
		Stone wall without external plaster (east and west)	40	B_W18	
		Solid brick wall with plaster (south)	40	B_W32	
	First	Wooden oriel	4	B_W11	
Building 20	Basement	Stone wall with scraped rendering	50	B_W33	
		Below-grade stone wall without external plaster	50	B_W1	
	Ground	Stone wall with plaster (on both side of the front door)	50	B_W2	
		Solid brick wall with plaster (with external door)	15	B_W4	
	Ground/ first	Stone wall with solid brick cladding (north)	50	B_W34	
		Stone wall without external plaster (east and south)	50	B_W2	
		Stone wall with plaster (west)	50	B_W1	
Building 21	Basement	Stone and brick wall without external plaster	50	B_W28	
		Stone and brick below grade wall without external plaster	50	B_W28	
	Ground	Stone and brick wall with scraped rendering (south)	50	B_W27	
		Stone and brick wall without external plaster	50	B_W29	
	First	Stone and brick wall with scraped rendering (south)	50	B_W27	
		Stone and brick wall without external plaster	50	B_W29	
Building 22	Basement	Stone and solid brick wall with plaster	40	B_W19	
		Stone and solid brick below grade wall without external plaster	40	B_W35	
	Ground	Stone wall with plaster	40	B_W17	
		Solid brick wall with plaster (with external door)	15	B_W4	
	First	Stone and solid brick wall with plaster	40	B_W19	
		Wooden wall filled with mortared rubble (hımış system) (west)	20	B_W36	

Table 4.3. Thermo-physical properties of the external wall types

External wall type	Position	Layer name	Thickness (cm)	Conductivity (W/m.K)	Specific Heat (J/Kg.K)	Density (Kg/m^3)	U-value ($W/m^2.K$)
B_W1	Outermost	Andesite	48	1.656	840	2110	2.109
	Innermost	Cement plaster	2	1.4	840	2000	
B_W2	Outermost	Cement plaster	3	1.4	840	2000	2.094
		Andesite	45	1.656	840	2110	
	Innermost	Cement plaster	2	1.4	840	2000	
B_W3	Outermost	Lime plaster	3	1	840	1800	1.07
		Solid brick	25	0.35	900	2000	
	Innermost	Lime plaster	2	1	840	1800	
B_W4	Outermost	Lime plaster	3	1	840	1800	1.977
		Solid brick	10	0.35	900	2000	
	Innermost	Lime plaster	2	1	840	1800	
B_W5	Outermost	Lime plaster	3	1	840	1800	2.059
	Innermost	Solid brick	10	0.35	900	2000	
B_W6	Outermost	Cement plaster	3	1.4	840	2000	1.855
		Hollow brick	15	0.45	850	1000	
	Innermost	Cement plaster	2	1.4	840	2000	
B_W7	Outermost	Cement plaster	3	1.4	840	2000	0.612
		Solid brick	50	0.35	900	2000	
	Innermost	Cement plaster	2	1.4	840	2000	
B_W8	Outermost	Solid brick	53	0.35	900	2000	0.589
	Innermost	Cement plaster	2	1.4	840	2000	
B_W9	Outermost	Lime plaster	3	1	840	1800	1.916
		Andesite	50	1.656	840	2110	
	Innermost	Lime plaster	2	1	840	1800	
B_W10	Outermost	Andesite	53	1.656	840	2110	1.961
	Innermost	Lime plaster	2	1	840	1800	
B_W11	Oriel	Pinewood	4	0.13	2720	600	2.093
B_W12	Outermost	Lime plaster	3	1	840	1800	2.493
		Andesite	30	1.656	840	2110	
	Innermost	Lime plaster	2	1	840	1800	
B_W13	Outermost	Andesite	33	1.656	840	2110	2.569
	Innermost	Lime plaster	2	1	840	1800	
B_W14	Outermost	Lime plaster	3	1	840	1800	2.368
		Andesite with solid brick (%10)	30				
	Innermost	Lime plaster	2	1	840	1800	
B_W15	Outermost	Andesite with solid brick (%10)	33				2.43
	Innermost	Lime plaster	2	1	840	1800	

(cont. on next page)

Table 4.3. (cont.)

B_W16	Outermost	Lime plaster	3	1	840	1800	0,928
		Solid brick	30	0,35	900	2000	
	Innermost	Lime plaster	2	1	840	1800	
B_W17	Outermost	Lime plaster	3	1	840	1800	2,318
		Andesite	35	1,656	840	2110	
	Innermost	Lime plaster	2	1	840	1800	
B_W18	Outermost	Andesite	38	1,656	840	2110	2,384
	Innermost	Lime plaster	2	1	840	1800	
B_W19	Outermost	Lime plaster	3	1	840	1800	2,196
		Andesite with solid brick (%10)	35				
	Innermost	Lime plaster	2	1	840	1800	
B_W20	Outermost	Cement plaster	3	1,4	840	2000	1,538
		Hollow brick	20	0,45	850	1000	
	Innermost	Cement plaster	2	1,4	840	2000	
B_W21	Outermost	Hollow brick	23	0,45	850	1000	1,438
	Innermost	Cement plaster	2	1,4	840	2000	
B_W22	Outermost	Face stone (andesite)	13	1,656	840	2110	1,981
		Andesite with solid brick (%10)	25				
	Innermost	Lime plaster	2	1	840	1800	
B_W23	Outermost	Andesite with solid brick (%10)	38				1,976
		Andesite	10	1,656	840	2110	
	Innermost	Lime plaster	2	1	840	1800	
B_W24	Outermost	Lime plaster	3	1	840	1800	1,935
		Andesite with solid brick (%10)	35				
		Andesite	10	1,656	840	2110	
	Innermost	Lime plaster	2	1	840	1800	
B_W25	Oriel	Iron	0,2	56	540	7500	5,881
B_W26	Outermost	Lime plaster	3	1	840	1800	1,811
		Andesite	55	1,656	840	2110	
	Innermost	Lime plaster	2	1	840	1800	
B_W27	Outermost	Scraped rendering with gravel aggregate	4	0,82	840	1680	1,874
		Andesite with solid brick (%10)	44				
	Innermost	Lime plaster	2	1	840	1800	

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Table 4.3. (cont.)

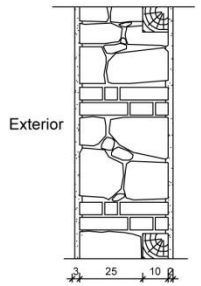
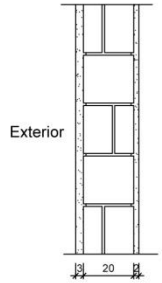
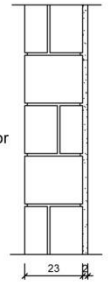
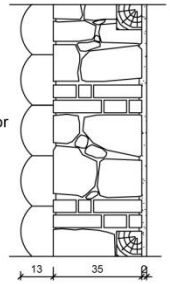
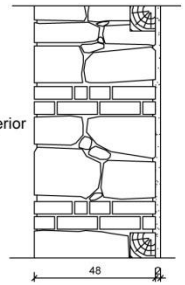
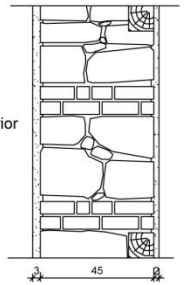
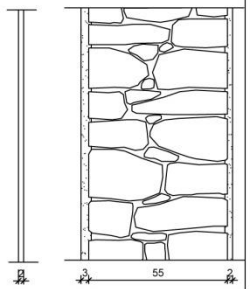
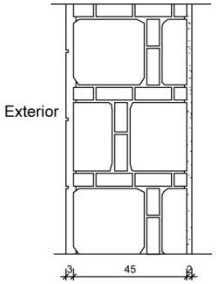
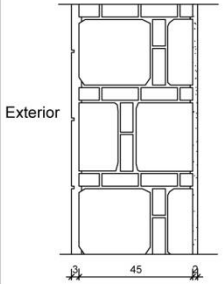
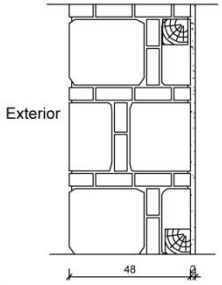
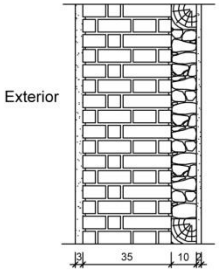
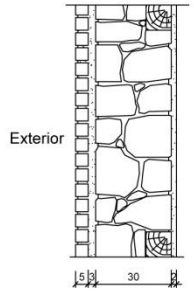
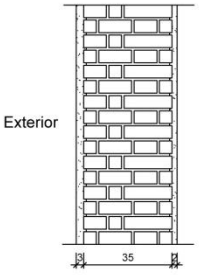
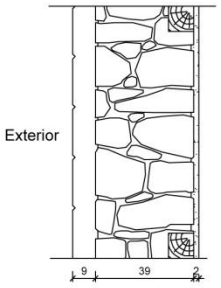
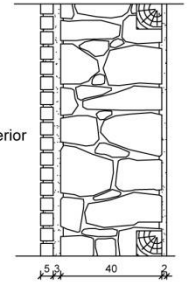
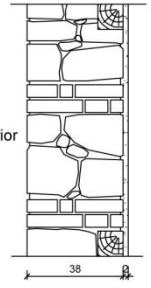
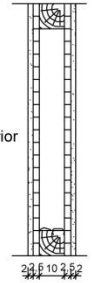
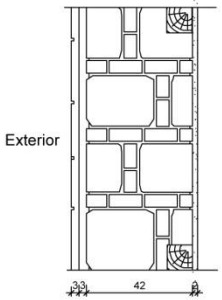
B_W28	Outermost	Green andesite with solid brick (%10)	48				1,96
	Innermost	Lime plaster	2	1	840	1800	
B_W29	Outermost	Andesite with solid brick (%10)	38				1,976
		Rubble stone (Andesite)	10	1,656	840	2110	
	Innermost	Lime plaster	2	1	840	1800	
B_W30	Outermost	Lime plaster	3	1	840	1800	0,781
		Solid brick	35	0,35	900	2000	
		Rubble stone (Andesite)	10	1,656	840	2110	
	Innermost	Lime plaster	2	1	840	1800	
B_W31	Outermost	Solid brick cladding	5	0,35	900	2000	1,838
		Lime mortar	3	1	840	1800	
		Andesite	30	1,656	840	2110	
	Innermost	Lime plaster	2	1	840	1800	
B_W32	Outermost	Cement plaster	3	1,4	840	2000	0,816
		Solid brick	35	0,35	900	2000	
	Innermost	Cement plaster	2	1,4	840	2000	
B_W33	Outermost	Andesite	9	1,656	840	2110	2,034
		Lime mortar	3	1	840	1800	
		Andesite	36	1,656	840	2110	
	Innermost	Lime plaster	2	1	840	1800	
B_W34	Outermost	Solid brick cladding	5	0,35	900	2000	1,655
		Lime mortar	3	1	840	1800	
		Andesite	40	1,656	840	2110	
	Innermost	Lime plaster	2	1	840	1800	
B_W35	Outermost	Andesite with solid brick (%10)					2,25
	Innermost	Lime plaster	2	1	840	1800	
B_W36	Outermost	Lime plaster	3	1	840	1800	1,504
		Pinewood	2,5	0,13	2720	600	
		Rubble stone (Andesite)	10	1,656	840	2110	
		Pinewood	2,5	0,13	2720	600	
	Innermost	Lime plaster	2	1	840	1800	
B_W37	Outermost	Marble	3	2,77	802	2600	1,951
		Lime mortar	3	1	840	1800	
		Andesite with solid brick (%10)	42				
	Innermost	Lime plaster	2	1	840	1800	

Table 4.4. Cross-sections of the external wall types

B_W1	B_W2	B_W3	B_W4	B_W5	B_W6
B_W7	**B_W8**	**B_W9**	**B_W10**	**B_W11**	**B_W12**
B_W13	**B_W14**	**B_W15**	**B_W16**	**B_W17**	**B_W18**

(Cont. on next page)

Table 4.4. (cont.)

B_W19	B_W20	B_W21	B_W22	B_W23	B_W24
					
B_W25 B_W26	**B_W27**	**B_W28**	**B_W29**	**B_W30**	**B_W31**
					
B_W32	**B_W33**	**B_W34**	**B_W35**	**B_W36**	**B_W37**
					

Ground Floors: Actually, ground floors of the case buildings may show different patterns throughout the level. It is accepted a single pattern for the ground floor of each case building in itself within the scope of the study. There are totally nine different ground floor types. The components of the ground floor types were initially assumed based on the construction types of buildings. They also show differences depending on whether the buildings are historic or not. For contemporary buildings with basement floor, it was accepted that the most common ground floor type consists of three layers, from top to bottom, cement tile (karosiman), cement mortar and reinforced concrete with totally 16 cm thickness (B_F2). As a component of this ground floor type, cement tile has been commonly used in the decoration both of the floors and the façades of İzmir houses in the late 19th century and the beginning of 20th century (Uçar, 2014). The use of cement tile in Building 21 can be seen on Figure 4.22.

Among historic buildings with basement floor, the floor type (B_F7) which is composed of timber beams and pinewood planks nailed on timber beams was specified as the most common type. In fact, it is estimated that timber beams are placed with the approximate distances of 50 cm. Within this floor type, the layer of timber beams refers to air gap, because the air gap constitutes majority of the layer composition. Therefore, this layer is accepted as air gap.

Figure 4.22. The use of cement tile (karosiman) in the floor of Building 21

Attic Floors: Attic floors of the case buildings comprise of four different types. For reinforced concrete buildings, the most common attic floor type consists of two layers with totally 12 cm thicknesses (B_F3). These layers are reinforced concrete and cement plaster from top to bottom. For masonry buildings, the floor type composed of,

from top to bottom, pinewood floor planks, timber beams and pinewood ceiling cover is commonly used and the floor thickness is totally 14 cm (B_F4). As stated earlier, timber beams are considered as air gap, because the majority of the layer occupied by the air.

The other two types of attic floors have simply two layers. One of them consists of PVC ceiling panel and steel beams (B_F5) while the other is composed of pinewood planks and timber beams (B_F7), from top to bottom. Timber and steel beams are also assumed as air gap. Figure 4.23 presents the attic floor type named as B_F7.

Figure 4.23. Attic floor type (B_F7) of Building 5

Floors of Oriels: Floors of oriels can be examined in two types, ground and ceiling. Ground floor types of oriels are basically constructed with pinewood and reinforced concrete in the case area. There is just an oriel which has a reinforced concrete floor supported by reinforced concrete braces from below. This type of floor consists of three layers, from top to bottom, cement tile, cement mortar and reinforced concrete with totally 16 cm thickness. It is also an extension of the intermediate floor of the building. Apart from this, the ground floors of the other oriels are arranged with pinewood planks and underpinned by iron braces. They are not plastered but painted. Moreover, the braces of the oriels are not regarded as a component of the floor type.

When the oriels which are unified with the main building as an extension of roof was considered, the ceilings of these oriels were assumed to be the same as the main buildings' attic floor. There are three oriels belonging to this type. Furthermore, there are two oriels that have a lower ceiling level. While one of them has a reinforced concrete layer with 5 cm thickness, the other has pinewood planks with 3 cm thickness.

External Floors above the Entrance of Buildings: Entrances were designed as a niche in eight case buildings. The entrance from the street is provided by a semi-

public semi-open space and separated from the street with a few stairs. Therefore, the external floors above the entrance of the buildings were accepted as a separate floor type. There are nine buildings which have an entrance designed as a niche and accordingly five external floor types were generated.

One of the floor types is composed of three layers including timber beams, pinewood ceiling cover and lime plaster with totally 3 cm thickness, from top to bottom (B_F17). There are three historic buildings which have this floor type. Other two historic buildings have a floor type that contains pinewood planks, timber beams, pinewood ceiling cover and lime plaster, from top to bottom (B_F18). Floor thickness is 16 cm. Another historic building shows similarities with the floor type named as B_F18. The difference is that the air gap is replaced by andesite rubble. This floor type has totally 10 cm thickness (B_F14). Apart from these, a contemporary building has a floor type as an extension of the intermediate floor of the building. It consists of, from top to bottom, cement tile, cement mortar, reinforced concrete and cement plaster with totally 19 cm thickness (B_F16). Moreover, two contemporary buildings have an external floor type which consists of reinforced concrete and cement plaster from top to bottom (B_F12).

4.4.2.3. Roofs

Roofs of the case buildings vary depending on the four different types, namely flat, gable, pent and pitched roof considering form of roofs. The fact remains that while some buildings have a uniform roof, some have more than one type in their different level of floors. Eight buildings have pitched roof, four buildings have gable roof and one building has a flat roof. Moreover, there are nine buildings with pent roof and three of these buildings have also flat roof in the case area.

Totally 17 case buildings have a traditional tiled roof regarding construction materials of roof. Besides, all historic buildings excluding one have the traditional tiled roof. Type of roofs of all buildings and specifications about the components and total thicknesses of these roof types are illustrated in Table 4.7. Table 4.8 shows thermo-physical properties of the roof types. Moreover, the cross-sections of the three roof types are illustrated in Table 4.9.

Table 4.5. Specifications about floor types belonging to the case buildings

Building name	Floor name	Floor type	Total Thickness (cm)	Building name	Floor name	Floor type	Total Thickness (cm)
Building 1	Basement	B_F1	35	Building 7	Ground	B_F13	56
	Ground	B_F2	16		External floor (below the oriel)	B_F9	3
	External floor (above the entrance)	B_F12	13		External floor (above the entrance)	B_F14	10
	Attic	B_F3	12		External floor (above the oriel)	B_F15	5
					Attic	B_F4	14
Building 2	Basement	B_F1	35	Building 8	Basement	B_F1	35
					Ground	B_F2	16
	Ground	B_F21	13,8		External floor (above the entrance)	B_F16	19
	Attic	B_F4	14		Attic	B_F3	12
Building 3	Ground	B_F20	38,8	Building 9	Ground	B_F20	38,8
	Attic	B_F5	2,5		Attic	B_F3	12
Building 4	Ground	B_F6	41	Building 10	Ground	B_F6	41
	Attic	B_F4	14		Attic	B_F3	12
Building 5	Ground	B_F1	35	Building 11	Ground	B_F20	38,8
	Attic	B_F7	3		Attic	B_F3	12
Building 6	Basement	B_F1	35	Building 12	Basement	B_F8	50
	Ground	B_F2	16		Ground	B_F7	3
	External floor (above the entrance)	B_F12	13		External floor (below the oriel)	B_F9	3
					External floor (above the entrance)	B_F17	3
	Attic	B_F3	12		Attic	B_F4	14

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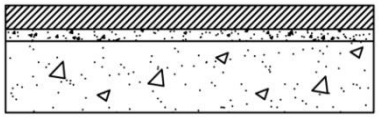
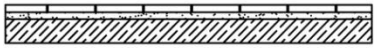
Table 4.5. (cont.)

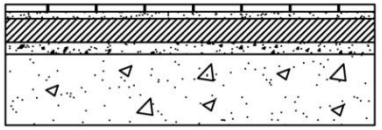
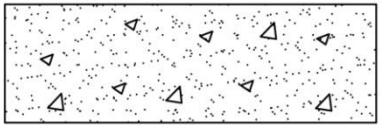
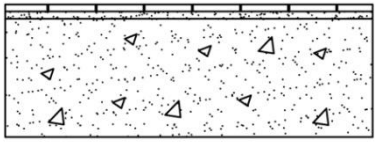
Building name	Floor name	Floor type	Total Thickness (cm)	Building name	Floor name	Floor type	Total Thickness (cm)
Building 13	Ground	B_F20	38,8	Building 19	Basement	B_F8	50
					Ground	B_F7	3
					External floor (above the entrance)	B_F17	3
	Attic	B_F3	12		External floor (below the oriel)	B_F9	3
					Attic	B_F4	14
Building 14	Ground	B_F6	41	Building 20	Basement	B_F8	50
	External floor (below the oriel)	B_F10	16		Ground	B_F7	3
	External floor (above the entrance)	B_F18	16		External floor (above the entrance)	B_F17	3
	Attic	B_F4	14		Attic	B_F4	14
Building 15	Basement	B_F8	50	Building 21	Basement	B_F8	50
	Ground	B_F7	3		Ground	B_F19	16,8
	Attic	B_F4	14		Attic	B_F4	14
Building 16	Ground	B_F1	35				
	Attic/roof	B_F3	12				
Building 17-18	Basement	B_F8	50	Building 22	Basement	B_F8	50
	Ground 1	B_F7	3		Ground	B_F7	3
	Ground 2	B_F11	56				
	External floor (below the oriel)	B_F9	3		First	B_F4	14
	External floor (above the entrance)	B_F18	16		Attic	B_F4	14
	Attic	B_F4	14				

Table 4.6. Thermo-physical properties and cross sections of all floor types

Floor type	Position	Layer name	Thickness (cm)	Conductivity (W/m.K)	Specific Heat (J/Kg.K)	Density (Kg/m^3)	U-value ($W/m^2.K$)	Cross section of the floor type
B_F1	Outermost	Gravel based earth	20	0,52	180	2050	1,442	
		Sand and gravel	5	2	1045	1950		
	Innermost	Lean concrete	10	1,35	1000	1800		
B_F2	Outermost	Reinforced concrete	10	2,4	840	2100	2,821	
		Cement mortar	3	1,4	840	2000		
	Innermost	Cement tile	3	1,4	840	2000		
B_F3	Outermost	Cement plaster	2	1,4	840	2000	3,068	
	Innermost	Reinforced concrete	10	2,4	840	2100		
B_F4	Outermost	Pinewood	3	0,13	2720	600	1,356	
		Air gap	10					
	Innermost	Pinewood	1	0,13	2720	600		
B_F5	Outermost	PVC ceiling panel	2,5	0,19	1470	1200	2,49	

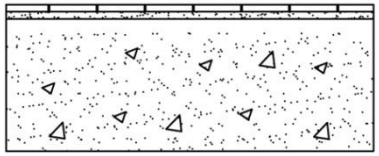
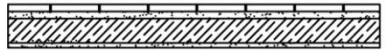
(Cont. on next page)

Table 4.6. (cont.)

B_F6	Outermost	Gravel based earth	20	0,52	180	2050	1,255	
		Sand and gravel	5	2	1045	1950		
		Lean concrete	10	1,35	1000	1800		
		Cement mortar	3	1,4	840	2000		
	Innermost	Cement tile	3	1,4	840	2000		
B_F7	Outermost	Pinewood	3	0,13	2720	600	2,269	
B_F8	Outermost	Gravel based earth	50	0,52	180	2050	0,854	
B_F9	Outermost	Pinewood	3	0,13	2720	600	1,997	
B_F10	Outermost	Reinforced concrete	10	1,35	1000	1800	2,821	
		Cement mortar	3	1,4	840	2000		
	Innermost	Cement tile	3	1,4	840	2000		
B_F11	Outermost	Gravel based earth	50	0,52	180	2050	0,823	
		Cement mortar	3	1,4	840	2000		
	Innermost	Cement tile	3	1,4	840	2000		

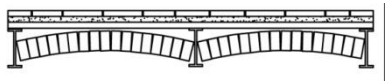
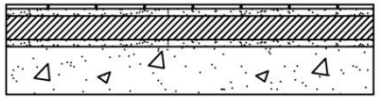
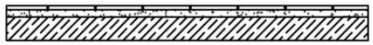
(Cont. on next page)

Table 4.6. (cont.)

B_F12	Outermost	Cement plaster	3	1,4	840	2000	3,002	
	Innermost	Reinforced concrete	10	2,4	840	2100		
B_F13	Outermost	Gravel based earth	50	0,52	180	2050	0,825	
		Lime mortar	3	1	840	1800		
	Innermost	Marble	3	2,77	802	2600		
B_F14	Outermost	Lime plaster	2	1	840	1800	1,78	
		Pinewood	1	0,13	2720	600		
		Andesite rubble	4	1,656	840	2110		
	Innermost	Pinewood	3	0,13	2720	600		
B_F15	Outermost	Reinforced concrete	5	2,4	840	2100	3,438	
B_F16	Outermost	Cement plaster	2	1,4	840	2000	2,711	
		Reinforced concrete	10	2,4	840	2100		
		Cement mortar	3	1,4	840	2000		
	Innermost	Cement tile	3	1,4	840	2000		
B_F17	Outermost	Lime plaster	2	1	840	1800	3,258	
	Innermost	Pinewood	1	0,13	2720	600		

(Cont. on next page)

Table 4.6. (cont.)

B_F18	Outermost	Lime plaster	2	1	840	1800	1,32	
		Pinewood	1	0,13	2720	600		
		Air gap	10					
	Innermost	Pinewood	3	0,13	2720	600		
B_F19	Outermost	Solid brick	10	0,35	900	2000	1,71	
		Gravel based earth	3	0,52	180	2050		
		Cement mortar	3	1,4	840	2000		
	Innermost	Ceramic tile	0,8	0,8	850	1700		
B_F20	Outermost	Gravel based earth	20	0,52	180	2050	1,379	
		Sand and gravel	5	2	1045	1950		
		Lean concrete	10	1,35	1000	1800		
		Cement mortar	3	1,4	840	2000		
	Innermost	Ceramic tile	0,8	0,8	850	1700		
B_F21	Outermost	Reinforced concrete	10	2,4	840	2100	2,915	
		Cement mortar	3	1,4	840	2000		
	Innermost	Ceramic tile	0,8	0,8	850	1700		

Totally six roof types are identified for the case buildings. First type is entitled as B_R1. Constructional composition of this type is clay roofing tile, pinewood roof boards nailed on timber rafters from outermost to innermost (Figure 4.24 (a)). Total thickness of the type is 6 cm. Most of the buildings' roofs belong to this type in the case area.

The second type, from top to bottom, is simply composed of a corrugated polycarbonate translucent roofing sheet and metal rafters with totally 0.2 cm thickness (B_R2) (Figure 4.24 (b)). There is one building which has this type. The third type has a similar layer order with the second roof type. It consists of a corrugated galvanized metal roofing sheet and metal rafters from top to bottom (B_R3) (Figure 4.24 (c)). Total thickness of the type is 0.2 cm. Five buildings belong to this roof type. Regarding the second and third type, metal rafters are considered as air gap since the majority of the layer occupied by the air.

Furthermore, the remaining three types were identified for flat roofs but they are named as floor type. Table 4.7 illustrates which buildings have flat roofs. Besides, all specifications about flat roof types were explained in Table 4.5 and 4.6 in the previous part. First type is composed of four layers. These layers are, from innermost to outermost, cement tile, cement mortar, reinforced concrete and cement plaster with totally 18 cm thickness (B_F16). The second flat roof type (B_F19) is called as jack arch floor (volta döşeme). This floor type is basically composed of bricks which are laying in arch shape between steel I beams. There are two more layers on the layer of brick including compacted earth and ceramic tile as a floor covering, respectively. This type has 16.8 cm thickness. The last type is identified for the flat roofs of two buildings. It has two layers covering reinforced concrete and cement plaster, from top to bottom with total 12 cm thickness (F_F3).

Building 15 (a) Building 3 (b) Building 14 (c)

Figure 4.24. Examples of roof types of the case buildings

Table 4.7. Specifications about the roof types belonging to the case buildings

Building name	Roof Type	Total Thickness (cm)	Building name	Roof Type	Total Thickness (cm)
Building 1	B_R1	6	Building 13	B_R1	6
Building 2	B_R1	6	Building 14	B_R3	0,2
Building 3	B_R2	0,2	Building 15	B_R1	6
Building 4	B_R1	6	Building 16	B_F3	12
Building 5	B_R1	6	Building 17	B_R1	6
Building 6	B_R1 B_F21	6 13,8	Building 18	B_R1	6
Building 7	B_R1 B_F19	6 16,8	Building 19	B_R1 B_F16 B_R3	6 18 0,2
Building 8	B_R1	6			
Building 9	B_R3	0,2	Building 20	B_F19 B_F3 B_R3 B_R1	16,8 12 0,2 6
Building 10	B_R1 B_F16	0,6 18			
Building 11	B_R3	0,2	Building 21	B_R1	6
Building 12	B_R1	6	Building 22	B_R1	6

Table 4.8. Thermo-physical properties of the roof types belonging to the case buildings

Roof type	Position	Layer name	Thickness (cm)	Conductivity (W/m.K)	Specific Heat (J/Kg.K)	Density (Kg/m^3)	U-value ($W/m^2.K$)
B_R1	Outermost	Clay tile	3	0,84	800	1900	2,46
	Innermost	Pine wood roof board	3	0,13	2720	600	
B_R2	Outermost	PVC	0,2	0,2	1200	1200	6,667
B_R3	Outermost	Corrugated galvanized metal roofing sheet	0,2	45,28	500	7824	7,141

Table 4.9. Cross-sections of roof types belonging to the case buildings

B_R1	
B_R2	
B_R2	

4.4.2.4. Windows, External Doors and Shutters

Windows: There exists a range of window types belonging to the buildings in their different floor levels. The windows on ground or upper floors are generally horizontally positioned rectangular and some of have square-like shape. Basement windows on ground level are generally square. They are smaller than ones on the upper floor level. There are also transom-topped windows on their entrance doors of some buildings. Moreover, windows have generally vertical and horizontal dividers. They open in vertical direction in order to provide air transfer from outside to inside.

Windows are among significant façade components of historic buildings. Considering some historic buildings in the case area, windows are mostly covered by stone jambs and sometimes their jambs are decorated with motifs. Besides, some windows have iron balustrades. Some window examples belonging to some historic and contemporary buildings in the case area are indicated in Figure 4.25 and Figure 4.26, respectively.

Therefore, four window types were observed in the case area. The window types are evaluated in two ways, taking into account the materials of glazing and frame. First type of window consists of pinewood frame with 4 cm thickness and simply single glass with 3 mm thickness. It was named as B_G2. The overall heat transfer coefficient of this type is calculated as 2.093 W/m^2K. Moreover, it was observed that this type of window predominates in the case area.

Building 15 Building 17-18 Building 19

Figure 4.25. Window examples of some historic buildings located in the case area

Building 9 Building 10 Building 13

Figure 4.26. Window examples in some contemporary buildings located in the case area

Second type has aluminum frame and single glass with 3 mm thickness. In this type of window, the aluminum frame is simply considered as a box profile. Therefore, the frame is composed of double aluminum pane with 1.5 mm thickness with 3.7 mm air gap. It was entitled as B_G3. The overall heat transfer coefficient of the second type is calculated as 2.857 W/m^2K.

The rest two types have similar layer order and their frames are considered as box profile. Third type of window is named as B_G1. It comprises of three layers including 1.5 mm double iron pane with 3.7 mm air. The overall heat transfer coefficient of the second type is calculated as 2.857 W/m^2K. The last type has PVC joinery. PVC frame is composed of 1.5 mm double PVC pane with 5.7 cm air gap. The glazing units of this type consist of 3 mm clear double-pane glasses with a 13 mm air gap. The overall heat transfer coefficient of the second type is calculated as 1.779 W/m^2K.

Window components and their thermo-physical properties were selected from the library of DesignBuilder energy simulation software. Types of windows of all buildings and specifications about the position of the windows on the façade and the number of windows belonging to the floor type are illustrated in Table 4.10. Following this, the construction material and the overall heat transfer coefficient of the windows are presented in the Table 4.11.

Table 4.10. Specifications about the window types belonging to the case buildings

Building name	Floor name	Window Type	Façade	Number of windows
Building 1	Basement	B_G1	north	1
	Ground	B_G2	north	1
			west	1
	First	B_G2	north	4
			west	6
			east	3
Building 2	Ground	B_G3	south	1
			west	2
Building 3	Ground	B_G3	south	2
Building 4	First	B_G2	south	1
Building 5	Ground	B_G1	north	3
Building 6	Ground	B_G2	north	1
		B_G1	north	1
		B_G2	south	4
		B_G1	south	2
	First	B_G2	north	2
	Second	B_G2	north	2
			west	2
Building 7	Ground	B_G1	south	1
		B_G2	south	2
			east	2
	First	B_G2	south	6
			east	2
			west	6
Building 8	Basement	B_G1	north	1
	Ground	B_G2	north	1
	First		north	2
Building 9	Ground	B_G1	north	2
	First	B_G3	north	2
Building 10	Ground	B_G3	south	1
			west	1
		B_G1	west	2
	First	B_G3	south	2
			west	2
Building 11	Ground	B_G2	south	1
	First		north	1
		B_G3	north	1
	Second	B_G3	north	1
Building 12	Basement	B_G1	north	2
	Ground	B_G2	north	2
	First		north	6

Building name	Floor name	Window Type	Façade	Number of windows
Building 13	Ground	B_G1	south	3
	First	B_G1	north	6
		B_G1	south	4
	Second	B_G1	north	6
Building 14	Ground	B_G1	south	3
	First	B_G2	south	3
	Second	B_G2	south	2
		B_G1	south	3
Building 15	Ground	B_G2	south	2
		B_G1	south	1
	First	B_G2	south	4
Building 16	Ground	no windows		
Building 17-18	Basement	B_G2	south	6
			east	1
	Ground	B_G2	south	6
			east	3
	First	B_G2	south	8
			east	7
Building 19	Basement	B_G2	north	2
	Ground	B_G2	north	2
			south	2
	First	B_G2	north	6
		B_G1	south	1
		B_G2	south	3
Building 20	Basement	B_G1	north	1
	Ground	B_G2	north	2
			south	1
	First	B_G2	north	3
		B_G4	south	1
			west	1
	Roof	B_G2	south	2
		B_G4	south	1
		B_G2	south	2
Building 21	Basement	B_G1	south	1
	Ground	B_G3	south	2
	First	B_G3	south	3
		B_G2	east	2
Building 22	Basement	B_G1	west	1
			north	1
	Ground	B_G2	west	1
		B_G3	west	4
		B_G2	north	3
	First	B_G3	west	4
		B_G2	west	3
			north	4

Table 4.11. Thermo-physical properties of the window types belonging to the case buildings

Window type	Position	Glazing			Frame		
		Layer name	Thickness (cm)	U-value ($W/m^2.K$)	Layer name	Thickness (cm)	U-value ($W/m^2.K$)
B_G1	outermost	single clear	0.3	5.894	iron	0.15	2.857
					air gap	3.7	
	innermost				iron	0.15	
B_G2		single clear	0.3	5.894	pinewood	4	2.093
B_G3	outermost	single clear	0.3	5.894	aluminium	0.15	2.857
					air gap	3.7	
	innermost				aluminium	0.15	
B_G4	outermost	clear	0.3	2.716	PVC	0.15	1.779
		air gap	1.3		air gap	5.7	
	innermost	clear	0.3		PVC	0.15	

External Doors: In the case buildings, it was observed that the external doors are positioned in different floor levels covering basement, ground and first and roof floor. In the ground floor level, the entry of some buildings is separated from the street by a few of stair (Figure 4.27) while there are some samples in which the building on the same bottom level of the street. Moreover, there are external doors which are positioned on the first or second floor level of the buildings with a terrace or a balcony. Apart from this, some historic buildings have basement doors which provide directly entrance from the street level (Figure 4.28).

Building 12 Building 20

Figure 4.27. Examples of the entrance heightened with a few stairs

Building 19 Building 17-18

Figure 4.28. Basement door examples belonging to the historic buildings

The external doors can be classified by their materials and their surface properties. There are four different materials used for the doors including iron, aluminum, wooden and PVC. Besides, the surfaces of external doors are completely massive or transparent or semi-translucent. There are mostly the external doors with semi-translucent surfaces and the external doors are made of iron in the case area.

The external doors have single or double wings and there are generally iron railings on wings. The external doors carry importance for façades of historic buildings. Historic buildings have completely iron doors. There exist motifs on the railings and massive sections of the wings in some historic buildings. Figure 4.29 and Figure 4.30 show the examples of the external doors belonging to various historic and contemporary buildings, respectively.

Building 7 Building 14 Building 15 Building 19

Figure 4.29. External door examples belonging to the historic buildings

Building 3 Building 6

Figure 4.30. External door examples belonging to the new buildings

It was determined four types of external door in the case buildings. On the other hand, the external doors which have completely transparent surfaces are included in the window types as stated in Table 4.13. First type is made of iron with 3 mm thickness. The overall heat transfer coefficient of the first type is calculated as 5.88 W/m^{2}K. This is the most common type in the case area. Second type has an aluminum surface with 1.5 mm thickness. This type has overall heat transfer coefficient 5.882 W/m^{2}K. The third type is made of pinewood with 4 cm thickness. The overall heat transfer coefficient of the first type is calculated as 2.093 W/m^{2}K. The last type is made of PVC. The thickness of this type was determined as 2.5 mm. This type has overall heat transfer coefficient 5.387 W/m^{2}K.

The external doors' components and their thermo-physical properties were selected from the library of DesignBuilder energy simulation software. Types of the external doors of all buildings and specifications about the position of the doors on the façade are illustrated in Table 4.12. Following this, the construction material and the overall heat transfer coefficient of the external doors are presented in the Table 4.13.

Shutters: It is observed that the shutters are mostly on historic buildings' façades in the case area. Windows of new buildings have generally without shutters. There are two types of shutters which made of iron and wooden. Iron shutters are mostly prevailing in the case area. The shutters are located in the ground or upper floors of the buildings. In historic buildings, the windows on ground floor level have iron shutters (Figure 4.31 (a) (b)) while upper floors have wooden shutters (Figure 4.31 (c)) due to concerns on security.

Table 4.12. Specifications about the external door types belonging to the case buildings

Building name	Floor name	External door Type	Façade	Building name	Floor name	External door Type	Façade
Building 1	Ground	B_D1	north	Building 16	Ground	B_D1	South
Building 2	Ground	B_G3	west	Building 17-18	Basement	B_D1	South
Building 3	Ground	B_D2	south				East
Building 4	Ground	B_D1	south		Ground	B_D1	South
Building 5	Ground	B_G1	north				East
Building 6	Ground	B_D1	north	Building 19	Basement	B_D1	North
Building 7	Ground	B_D1	south		Ground	B_D1	North
			east				South
Building 8	Ground	B_D1	north		First (terrace)	B_D3	East
Building 9	Ground	B_D1	north	Building 20	Basement	B_D1	North
Building 10	Ground	B_D1	south		Ground	B_D1	North
Building 11	Ground	B_G3	north				South
Building 12	Ground	B_D1	north		First (balcony)	B_D3	North
Building 13	Ground	B_D1	north		Roof	B_D4	South
			south	Building 21	Ground	B_D1	South
Building 14	Ground	B_D1	south	Building 22	Basement	B_D1	West
Building 15	Ground	B_D1	south		Ground		

Table 4.13. Thermo-physical properties of the external door types belonging to the case buildings

External door type	Layer name	Thickness (cm)	Conductivity (W/m.K)	Specific Heat (J/Kg.K)	Density (Kg/m^3)	U-value ($W/m^2.K$)
B_D1	iron	0,3	56	740	5400	5,88
B_D2	aluminium	0,15	160	880	2800	5,882
B_D3	pinewood	4	0,13	2720	600	2,093
B_D4	PVC	0,25	0,16	1000	1380	5,387

Building 14 (a) | Building 8 (b) | Building 19 (c)

Figure 4.31. Shutter examples belonging to the case buildings

4.4.2.5. HVAC Systems

There is not any district heating and cooling system in the case area. Moreover, there is limited number of the case buildings in continuous use. Therefore, most of buildings are not continuously heated and cooled because of occupancy status. Heating is provided by stoves in residential buildings while buildings with commercial use electricity for heating and cooling. Some buildings have an air-conditioning system (Building 2, 11 and 13).

CHAPTER 5

METHOD

The main objective of this chapter is to introduce the framework of the research process and discuss the method. The chapter proposes a method to develope retrofit strategies about energy efficiency of existing buildings in historic urban district including both historic and new ones via appropriate solutions for the buildings' envelopes. The retrofit strategy considers the impact assessment criteria and scale of retrofit measures for historic buildings, presented by fivel-leveled assessment scale of CEN EN 16883:2017. Moreover, this chapter has the intention of proposing a process including data collecting, modelling, simulating, assessing and analyzing. This study concentrates on the application of the process through the case study.

The process of the method will be presented step by step. The method is composed of six main stages. Table 5.1, below, illustrates the flow diagram of identification process of energy-efficient solutions. The method starts with the quick field survey, called as data collection that has been conducted in several levels. First of all, documents about the case area were obtained from İzmir Metropolitan Municipality and Konak Municipality to get preliminary information and the data sheets were created in order to characterize of the buildings in the case area. Then, on-site measurements on the buildings' envelope were carried out through data sheets. Additionally, it was attempted to get information about the buildings in use from the users of buildings.

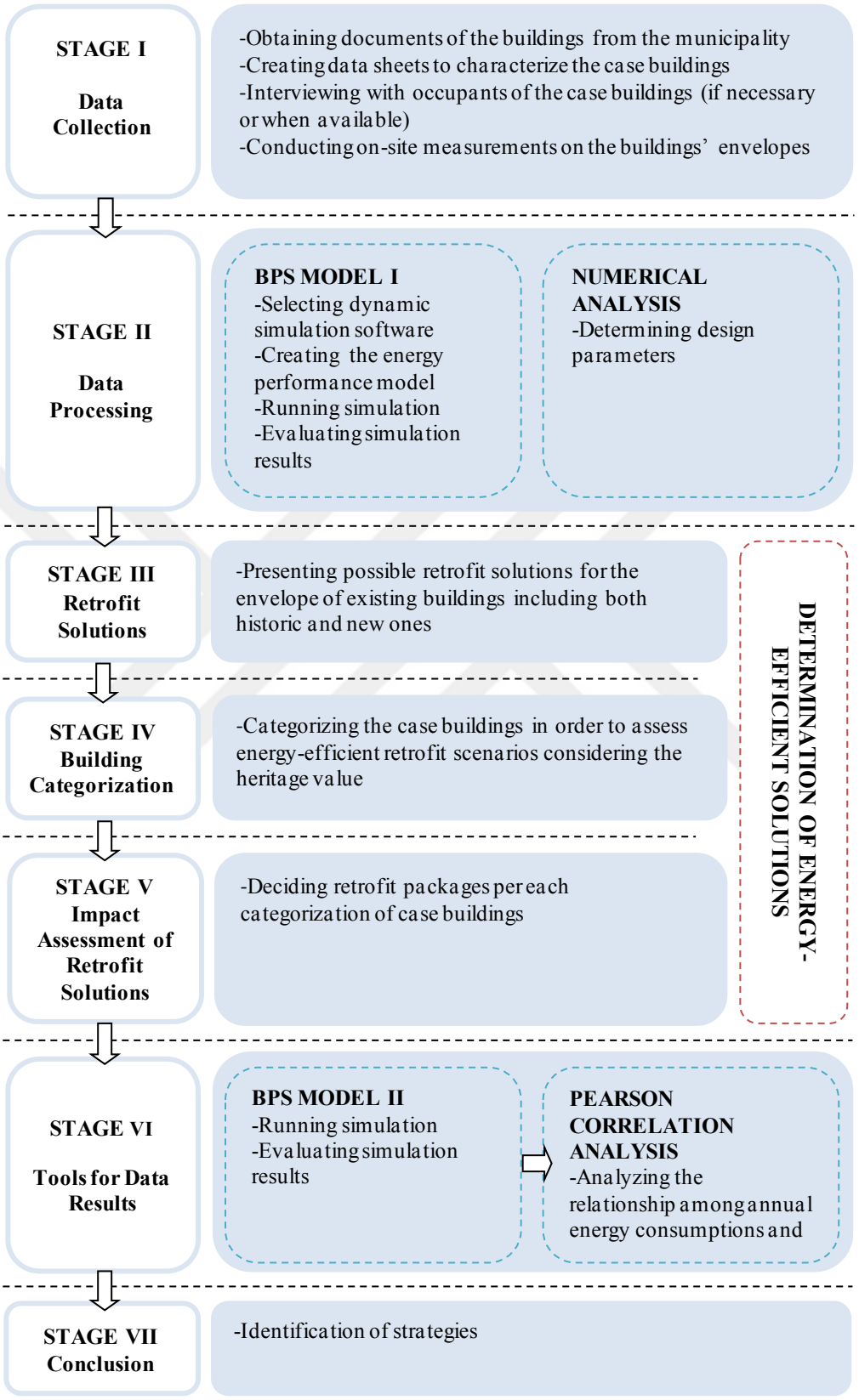
The second stage continues with the characterization of the tool selected to put in process of the method and explanation on how they work. The case area was modelled in dynamic simulation software to calculate the energy consumption of the case buildings in existing conditions. This building performance simulation (BPS) model represents the base model of case buildings. The next three stages lay emphasis on the energy-efficient retrofit strategy for the case buildings. Accordingly, third stage discusses and presents possible energy-efficient solutions for retrofit of existing buildings covering new and historic ones. It primarily concerned with the retrofit solutions about the components of the buildings' envelope including external walls, floors, roofs, oriels, windows and doors. The fourth stage goes forward with the categorization of the case buildings considering the heritage value.

The fifth stage aims at deciding possible packages of retrofit solutions so as to provide energy savings. It presents the most appropriate solutions and eliminates the inappropriate ones for the categorized case buildings. Therefore, five-levelled impact assessment scale for retrofit solutions is investigated for historic buildings. In the sixth stage, new energy performance models for retrofit solutions are created and simulated for each retrofit package. After a comparative study between the base case simulation results and retrofitted ones, the relationship among annual energy consumptions and design parameters.

5.1. Data Collection

Data collection is a significant starting point in terms of ensuring the workflow of the method. It is composed of several steps, i.e. prestudy and field survey. These steps mainly aim at collecting the required, adequate, and reliable information about buildings' envelope through a quick survey. The prestudy includes the collection of any research about case area and buildings, and official documents. The steps are mainly grouped under site investigations cover creating data sheets and then on-site measurements on the components of buildings' envelope through the data sheets. Moreover, during the site investigations, interviews have been held with the buildings' users in order to get information about the use of buildings, the number of person lived/used in the buildings and the type of fuel used etc.. Moreover, during the data collection about the case buildings, İzmir 3D City Guide has been used during the data collection (İzmir City Guide, 2016). Collected data through the data sheets, on-site measurements, the information obtained from İzmir city guide, as well as interviews with the occupants have contributed the process of creating the model and simulation by utilizing both quantitative and qualitative information on the case buildings. Data collection has been conducted in two separate time periods including between the 20th and 25th of June 2014 and between the 10th and 15th of February 2016.

Table 5.1. Flowchart of the identification process of energy-efficient solutions



5.1.1. Prestudy: Documentation

The documented data about the case area and its surrounding have taken from İzmir Konak Municipality. 2D architectural drawings covering implementary development plan, cadastral plan and base map which include necessary information about the position, orientation, the footprints of buildings within the parcels, space usage, distances between buildings, number of floors, roads, and their elevations were obtained from the documented data. North and south façade drawings of buildings located in 1273 and 1276 street, which were prepared in the scope of street rehabilitation project, were taken from Konak Municipality. However, this project has not been put into practice yet.

Furthermore, in 2013, a street rehabilitation and urban design project was prepared for 960 street located on the south parallel of 1273 street and bordered by Altınpark excavation area. Measured drawings covering plans, sections and elevations of the officially registered buildings numbered as Building 12, 19 and 20 in the thesis were prepared within this street rehabilitation and urban design project. These drawings, which were prepared in 2013, were obtained from Konak Municipality. However, the street rehabilitation and urban design project were not put into practice.

Except for three case buildings including Building 12, 19 and 20, the architectural drawings such as the floor plans and sections of the buildings in the case area have not been reached during the site investigations. Particularly for historic buildings, inventory forms of eleven officially registered buildings (Building 4, 7, 12, 14, 15, 17-18, 19, 20, 21 and 22) in the case area are provided from İzmir Metropolitan Municipality Directorate of Historic Environment and Cultural Properties. These forms inform about the degree of protection status of historic buildings; they do not include any construction drawings and details. They cover general information about the buildings including the location, type of use for past and present and recommended use, photograph from the main façade, and observations on the buildings' components, repairs and maintenance conducted for the buildings.

5.1.2. Data Sheets [5]

The aim of preparing data sheets is to characterize the current status of the case buildings, e.g. physical (envelope) characteristics, construction details, climatization and surrounding features. Type of data about building envelope and surrounding required by BPS model are determined. Alongside of the abovementioned data, the sheets named as 'data sheets' were formed by the author in 2014 to reach further information about the case buildings. Then, the information has been noted on the data sheets during site investigations conducted in totally 10 days between the 20th and 25th of June 2014 and between the 10th and 15th of February 2016. Data sheets, composed of a double-sided page in A4 format, are prepared for each building in the case area. It covers a number of titles so as to get general information about the architectural and historic characteristics of the buildings and their components. Observation, measurements and photography techniques have been used in collecting required data for the data sheets. Front page of the data sheet consists of (Table 5.2):

Door Number: The door number of building is given.

Street: The street name where the building located in is described.

Number of Floors: It informs about the number of floors of the building. Moreover, it specifies whether the building has a basement floor or not.

Height: The height of building is described.

Building Plot: It informs about the position of building in the plot.

Photograph: Each building is photographed from the main façade.

Location: The location of building is signed on the map.

Plan Scheme: Information about the plan scheme is noted for the building which is entered.

External Walls: The features of external walls covering thickness and material for each level of floor, if possible, are described. Moreover, this part includes a simple drawing of the wall section.

External Doors: The features of external doors for each level of floor are described. This part also covers a simple cross-section of the doors.

Windows: The features of windows for each level of floor are described. This part also covers a simple cross-section of the windows.

[5] Prepared data sheets for all case buildings were presented in Appendix A.

Back page of the data sheet is composed of (Table 5.3):

Construction Period: Approximate construction and usage period of the building are described.

Construction Date: Approximate construction date is defined.

Courtyard / Garden: It informs whether the buildings have a courtyard or garden.

Plant on Garden: It informs whether the building has any plant, e.g. trees, bushes, on their garden.

Waterpond: It informs whether the building has a waterpond, or not.

Well: It informs whether the building has a well, or not.

Outer Color: The color of external surfaces of building is described.

Number of Flat: It informs about how many flats a whole building have.

Occupancy: It gives information about the number and status of occupants.

Roof Floor: It informs about whether the building has a roof floor, or not.

Oriels: The materials of oriels are described.

HVAC Loads: The building systems and equipments used for HVAC are described. This title is grouped under four subtitles including availability of heating type, cooling type, source of energy, and solar collector.

Ground Floor: The features of ground floor considering its thickness and materials are described. This part also covers a simple drawing of the basement floor section, if available.

Attic Floor: The features of attic floor regarding its thickness and materials are described. This part also covers a simple drawing of the attic floor section.

Roof: It introduces the type and materials of roof. It also informs about whether the roof is occupied, or not.

Shadings: The shading elements covering materials and thickness for each level of floor are described. Moreover, this part includes a simple cross-section of the shading device.

5.1.3. Short Interviews

During the site investigations, short interviews with the occupants of several buildings in the case area have been conducted. It was aimed to obtain adequate

information about the case buildings, i.e the purpose of use, number of occupants/users, user profile, construction date, how the buildings are heated and cooled and type of fuel used through short interviews. The interview was conducted with the occupants/users of only three buildings including Building 3, 7, 21 and 22. Moreover, it was entered into Building 21 and observations were made about interior spaces and a simple plan scheme was created for the buildings.

5.1.4. On-site Measurements

After creating the data sheets, on-site measurements have been conducted for five days between 20th and 25th of June 2014. It is purposed to get information about the characteristics of building components, materials used in construction and components, the thickness of materials, simple sections, elevations and plan drawings, if possible. Then, the data collected from the measurements was checked and revised for the case area between the 10th and 15th of February 2016 to specify any changes on the components of measured buildings if exists and clarify the openings on the south façades of case buildings bordered by Altınpark Excavation Area. Such data collected from the on-site measurements were used for creating the structural model of buildings in dynamic simulation tool. The measurements were carried out for the components of the buildings including external walls, floors, roofs, oriels, windows, external doors and shutters. The buildings were examined based on the numbering order of the buildings in the case area (see Figure 4.16 in Chapter 4). Dimensions of the structural components were identified via a laser distance meter and then, noted on the relevant section in data sheets. Moreover, the height and width of the surrounding buildings are measured by laser distance meter so as to identify the adiabatic surfaces of adjacent neighboring buildings and their shading effect on the case buildings. The location of trees around the case area was determined during site investigations. Through the measurements, the following specifications about the case buildings' components have been clarified and corrected:

- Width-length-height of the external walls
- Width-length of the external floors (external floor below the oriels and external floor over the entrances designed as a door niche)

- Width-length-height of the windows and their position on the external wall surfaces
- Width-length-height of external doors and their position on the external wall surfaces
- Width-length-height of the oriels
- Width-length-height of the shutters
- Width and length of the eaves of the roofs

5.2. Data Processing

This part principally focuses on the tool used for model creation, energy simulation process and analysis as well as presentation of the results of the simulation. During the model creation, it was aimed to create a building envelope-based model to calculate the amount of annual energy consumption derived from the buildings' components. Following steps including the energy simulation process and analysis and presentation of the simulation results has adhared to the building envelope-based model.

Reliable and verified tool has been used for creating and simulating model and presenting the simulation results. Model creation of the case buildings was prepared according to the recent field survey which was completed in 2016. Thus the following steps, i.e. data entry about building components for the base case model and updating these data for the retrofit process, after model creation have been conducted based on the building data of 2016. Through data processing, it was aimed to bring the model to present the appropriate retrofit stragies for case buildings.

5.2.1. Building Performance Simulation Tool

Building energy performance assessment methods vary by issues concerned, i.e. environmental and energy, their goals, i.e. energy performance diagnosis, decision making, certification and detail factor, i.e. building level, district level, multi-level. In principal, many current researches, studies and applications of energy performance assessment methods have been concerned with quantitative performance based approach. The quantification of energy use for an existing building utilizes three different approaches (Wang et al., 2012):

- Calculation-based approach (Dynamic Simulation and Steady-State Method)
- Measurement-based approach (Bill-Based Method and Monitoring-based Method)
- Hybrid method (Calibrated simulation and Dynamic Inverse Modeling)

Dynamic simulation tools are one of the quantitative energy performance assessment methods. At present time, the simulation tools have been dramatically increased and extensively used in entire phases of buildings, for example in design, construction, operation, maintenance and management. The simulation tools serve useful purposes including analyzing energy performance for design and retrofit, ensuring comfort requirements for the users of the buildings, designing the building to the requirements of local building regulations, codes or standards, supporting energy auditing to check the energy performance of the as built building as well as performing cost analysis by presenting cost-effective energy saving alternatives (Hong, Chou and Bong, 2000). Building performance simulation (BPS) tools not only are effectively used in earlier stages of a design process to make sustainable buildings but also they are powerful and essential tools in analyzing existing building performance and, evaluating alternative retrofit options to make buildings more energy-efficient (See Section 3.3 in Chapter 3).

BPS tools include mathematical and thermodynamic algorithms which are used to calculate energy performance depending on the underlying simulation model with location-specific climatic data based on long time meteorological measurements. They require input files so as to enable detailed simulations. They have a computational engine and a graphical interface that provide users to make easier data entry and analysis of output (Maile, Fischer and Bazjanac, 2007).

The input data of a simulation tool mainly comprises of weather conditions, building description, and system and component descriptions of buildings. Weather conditions contain dry bulb temperature and relative humidity, solar radiation, wind speed and direction, atmospheric pressure and cloud cover of that particular place. Building description mainly addresses coordinates of location, design and construction data, thermal zones, sources of heat internal gain, infiltration and usage profile. System description is related to heating, cooling and ventilation, i.e. HVAC system, size and types, control schedules and outdoor air requirements. Finally, component description refers to HVAC systems' plant components (Wang et al., 2012) (Figure 5.1).

Table 5.2. The front page of data sheet prepared for each case building

<table>
<tr><td>Door Number</td><td>Street</td><td>Building Plot</td><td colspan="4">Building Components</td></tr>
<tr><td rowspan="2"></td><td rowspan="2"></td><td rowspan="4"></td><td colspan="2">Plan / Façade Scheme</td><td colspan="2">Exterior Walls</td></tr>
<tr><td rowspan="3" colspan="2"></td><td>Feature</td><td>Section</td></tr>
<tr><td>Number of Floor</td><td>Height</td><td rowspan="2">Basement(cm/material):
Ground(cm/material):
First(cm/material):</td><td rowspan="2"></td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="3" rowspan="3"></td><td colspan="2">External Doors</td><td colspan="2">Windows</td></tr>
<tr><td>Feature</td><td>Section</td><td>Feature</td><td>Section</td></tr>
<tr><td colspan="3">Location:</td><td>Glass: single/double
Basement(cm/material)
Ground(cm/material)
First(cm/material)</td><td></td><td>Glass: single/double
Basement(cm/material)
Ground(cm/material)
First(cm/material)</td><td></td></tr>
</table>

Table 5.3. The back page of data sheet prepared for each case building

Construction Period	Construction Type	Courtyard Garden	Building Components			
			Ground Floor		Ceiling	
Plant on Garden	Waterpond	Well	Feature	Section	Feature	Section
Outer Color	Number of Flat	Occupancy				
Attic		Oriel				
HVAC Loads						
Heating		Cooling	Roof		Shadings	
			Feature	Section	Feature	Section
Fuel Source		Solar Panel	Roof Type:			
			Roof Material:			
Notes:			Occupied/Unoccupied:			

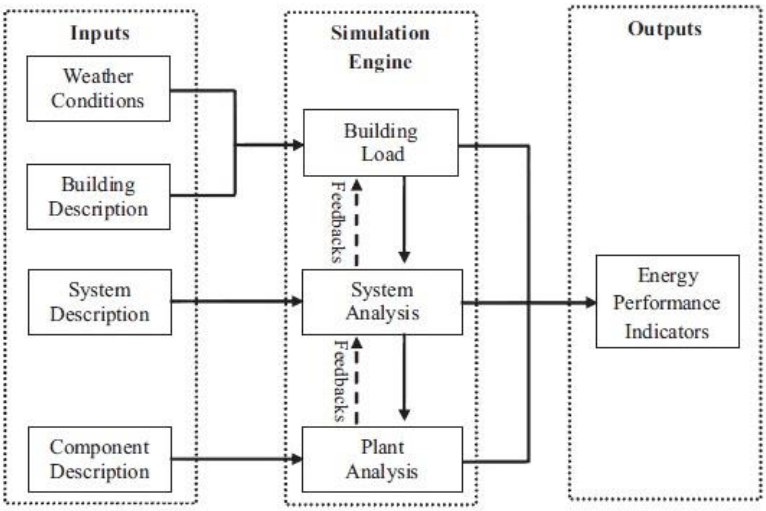


Figure 5.1. Flow diagram of a detailed simulation process
(Source: Wang et al., 2012)

Dynamic Simulation Tool-DesignBuilder: DesignBuilder dynamic simulation tool has been selected as building performance simulation software in this study. Digital modelling of the case buildings and their simulation processes have been conducted by licenced and educational version of v5.2.003 (DesignBuilder, 2018).

DesignBuilder is comprehensive dynamic simulation software which enables energy assessors, architects, engineers, academic institutions and other users to make analyses of whole building energy, lighting and thermal comfort performance, CO_2, cost, Computational Fluid Dynamics (CFD) and optimization alongside of 3D building modelling. It uses EnergyPlus, developed by the U.S. Department of Energy's (DOE) Building Technologies Office (BTO), as its simulation engine for calculating energy performance of the buildings (EnergyPlus, 2018). DesignBuilder is validated by Building Energy Simulation Test (BESTEST), well-known validation and diagnostics procedure developed by International Energy Agency (IEA) in 1995 (Melo, Cóstola, Lamberts and Hensen, 2012). DesignBuilder allow users to create the models that vary from simple to complex. It has also the ability of presenting the simulation analyses in annual, monthly, daily, hourly and sub-hourly intervals. Accordingly, the results of the analyses can be presented by using different formats such as graphs, tables and lists and they can be exported in tabular format to be demonstrated in other applications.

DesignBuilder simulation tool necessitates a number of input data so as to generate the model. First of all, it starts with selecting the location of the case building/area and proper weather data in EPW format. Then, it is possible to directly

create the model geometry by drawing tools within simulation software. The other option is that DesignBuilder is compatible with CAD interface. Therefore, one can import DXF files as footprints into the software for creating the model geometry. After the generation of the physical model, detailed templates and schedules need to be generated for the qualifications of the materials. DesignBuilder addresses a wide range of ready-made material templates in its library, as well as it allows users to create their own case-specific templates. These templates apply to thermo-physical qualifications and operation schedules for internal loads, occupancy, construction types, openings (windows and doors), lighting and HVAC systems. After the definition of all input for the model, the simulation process can be performed (Maile et al., 2007). The principal workflow of DesignBuilder dynamic simulation tool is indicated below (Figure 5.2).

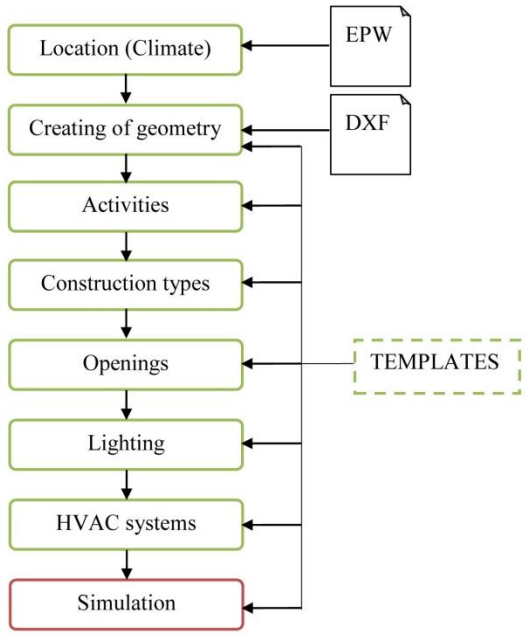


Figure 5.2. Workflow of DesignBuilder simulation software
(Source: Adapted from Maile et al., 2007)

5.2.2. Numerical Analysis

This section aims to prioritize the case buildings for determining the most appropriate energy-efficient retrofit solutions taking into account a number of design parameters affecting existing buildings' energy consumption through a numerical analysis. The section also intended for finding the relationship between the most

appropriate design parameters for all case building groups and the values of total annual energy consumption of the case buildings' envelope.

Design Parameters Affecting Buildings' Energy Consumption: There is a wide range of building design parameters that are discussed under different categories in the literature. A number of studies classified design parameters in two main categories including the parameters related to the outer environment and the parameters related to the building scale (Özler, 2003; Akgöz, 2004; Kundakçı, 2013), while some are grouped the parameters into three categories consisting of building scale design parameters, environmental parameters and user-related parameters (Soysal, 2011; Erdemir, 2014). Environmental parameters can be numbered as topography, vegetation, climate and climate-related factors such as exterior temperature, wind, solar radiation and exterior humidity. Building scale parameters mainly consist of building form, location, orientation, building distances and height, visual and thermo physical properties of building envelope, lighting, sun control, ventilation, specifications about windows and glazing, the properties of building components and systems, compactness, zoning and space organization (Akgöz, 2004; Özler, 2003; Soysal, 2008; Yasan, 2011; Kundakçı, 2013; Erdemir, 2014; Türktaş, 2014) User-related parameters age, gender, characteristics, condition and activity of the users (Soysal, 2008; Erdemir, 2014) (Table 5.4).

This study addresses a number of design parameters including building scale parameters. Therefore, it specifically focuses on the most prevailing geometric variables regarding building form in order to examine their relationship with the total energy consumption values (kWh) of case buildings' envelope. The study discusses total seven design parameters:

- Total surface area (m^2) to conditioned volume (m^3) ratio (A/V)
- Window to wall ratio (WWR)
- Window to wall ratio (WWR) for the façades face to street
- Shape factor (building length to depth)
- Usable ground floor area (m^2) to conditioned volume (m^3)
- Total usable floor area (m^2) to conditioned volume (m^3)
- Building height (m) to plan depth (m)

Table 5.4. Classified design parameters based on the literature survey (Sources: Özler, 2003; Akgöz, 2004; Soysal, 2008; Yasan, 2011; Kundakçı, 2013; Erdemir, 2014; Türktaş, 2014)

Type of Parameters	Parameter Name	References						
		Özler, 2003	Akgöz, 2004	Soysal, 2008	Yasan, 2011	Kundakçı, 2013	Erdemir, 2014	Türktaş, 2014
Building Scale Parameters	Building orientation	●	●	●	●	●	●	●
	Building form	●	●	●	●	●	●	●
	Location				●	●	●	●
	Building distances	●	●	●	●	●	●	●
	Building height			●	●	●		
	Visual and thermo-physical properties of building envelope	●	●	●	●	●	●	●
	Compactness	●						
	Zoning	●			●			
	Space organization			●	●			●
	Lighting / sun Control	●					●	●
	Building components	●						
	Windows and shading			●	●			
	Air movement /ventilation			●	●			●
	Use of sustainable materials				●			
Environmental Parameters	Climate	●	●	●	●	●	●	
	Topography	●		●	●			
	Vegetation	●		●	●			
	Built environment			●	●			
User-related Parameters	Condition, age and characteristics of users			●			●	

Pearson Correlation Analysis: Bivariate Pearson correlation coefficient analysis was selected to understand emprically the relation with the design parameters and total energy consumption of the case buildings. Since the number of variables included in the analysis, it becomes not plausible to adopt more complex methods, i.e. regression analysis (Kalaycı, 2016).

Pearson correalation analysis is a statistical method used to determine whether there is a linear relationship between two numerical variables, and if any, the degree of the relationship. In other words, this analysis looks for an answer to the question whether there is a significant relationship between two variables. The Pearson correlation coefficient is used only if there is a linear relationship between the variables. Pearson correlation coefficient is expressed in '*r*'. It can take a range of values from +1 to -1 depending on whether the relationship is positive or negative, respectively (Kalaycı, 2016).

- *r*=-1, a perfect negative linear relationship. One variable increases, the other decreases or one variable decreases while the other increases.
- *r*=1, a perfect positive linear relationship. One variable increases, the other increases or or one variable decreases while the other decreases
- *r*=0, no relationship. There is no relationship between two variables

The interpretation of the Pearson correlation coefficient between two variables is as follows:

R	Relation
0,00-0,25	Very low
0,26-0,49	Low
0,50-0,69	Medium
0,70-0,89	High
0,90-1,00	Perfect

5.2.3. BPS Model of the Buildings in 1273 Street

In this section, the digital modelling of totally 22 case buildings in 1273 Street in Basmane District, İzmir by simulation software will be presented. DesignBuilder version 5.2.003 has been used to generate 3D BPS models. Calculation of extant energy consumption of the case buildings has been conducted by using DesignBuilder version 5.2.0.156 and version 5.0.3.007 (Design Builder, 2017). By using dynamic simulation tool, it was mainly aimed to calculate seasonal energy consumption for heating and cooling, annual energy consumption and test possible retrofit solutions in order to improve energy efficiency of the buildings. Therefore, the base case models which indicate the real status of each case building and then, a large number of retrofitted case models to assess the energy-efficient retrofit solutions were prepared in this thesis.

BPS modelling involves a certain degree of abstraction. A simulation model is not a detailed representatiton of all geometry and all process in a building. Design Builder tool enables creating 3D models of the case buildings for energy and/or thermal simulation in a simplified or complex way. The complex models present more accurate results however they are time consuming due to a high level of detailed data input. Conversely, it is easier to create, analyze and modify data in a simplified model. Besides, the time to complete simulation process reduces, accordingly. Thus the model

geometry of case buildings was simplified in line with the purpose of the study: identification of strategies for energy-efficient retrofit via quick field survey. Moreover, the number of buildings to be modelled, the acceleration of simulation process and the minimization of model complexity are significant reasons for using the simplified way in the study. However, a variety of assumptions and limitations for the geometry of case buildings come to exist during the model creation process of base case:

1. Idetification of thermal zones:
    - Unheated and heated spaces are divided into separate zones
    - All floors except for basements and roofs, i.e. heated spaces, are assumed as a single/whole thermal zone regarding with its volume.
    - All intermediate level of floors are removed and accepted as a single volume
    - Unheated zones are accepted as basement floors and roofs
    - Basements and roofs are accepted as separate thermal zones.
    - Internal partitions, stairs and stairwells are excluded in all buildings.
2. Height of thermal zones:
    - The height of thermal zones is measured from the entrance level of buildings to the surface under the eaves of roofs.
    - For basement floors, the height of storey is specified as far as could be measured from the basement openings or else an average value for the height of storey is accepted.
3. The outer stairs where positioned on the entrances of the buildings are not modelled, because such details are excluded from the scope of this study.
4. Neighboring buildings, the trees, balconies and sunshades assumed as component blocks, i.e. adiabatic, but have only shading effect and thermal effect with their surface properties, in order to reduce the simulation time.
5. Shutters are not modelled in the simulation model of base case phase. They are included in the retrofit process.
6. Any decoration elements such as balustrades, reliefs, and door and window jambs on the façades of the historic buildings are not modelled, since such details are excluded from the scope of this study.

7. Openings on some façades in various buildings could not be identified during field investigations. These buildings and their façades are indicated below:
    - East façade of ground floor in Building 1
    - West façade of ground floor and south façade in Building 5
    - East façade of first floor in Building 6 (specifically, façades open to the terrace)
    - South façade of ground floor in Building 8 (specifically, façades open to the garden)
    - North façade of first floor in Building 10 (specifically, façades open to the terrace)
    - South façade of ground floor in Building 12 (specifically, façades open to the garden)
    - North façades of Building 15 and Building 16
    - West façade of Building 18
8. No specific climate data indigenous to the case area was created. Climate data as İzmir/Menderes has been obtained from DesignBuilder Library
9. Doors on the partition which seperates the oriels and interior spaces of case buildings are not modelled in base case model

5.2.2.1. Geometry of the Buildings

Considering the geometry of buildings, architectural drawings including site plan and façade drawings were obtained from Konak Municipality and through field surveys. There are certain steps conducted during the modelling of geometry of the case buildings. Initially, the model abstraction is conducted for both façades of buildings and layout plan. The drawings of footprints of buildings are revised according to the architectural drawings and revisions based on on-site measurements and observations during field surveys. Then, simple drawings of the envelope of each building and openings for each floor are identified in AutoCAD software (AutoCAD, 2016) (see Chapter 4 Table 4.2; see Appendix A). The case buildings are modelled along with their surroundings to observe the shading effects on solar gain calculations. Therefore,

neighboring and adjacent buildings, the trees and roads are included in two dimensional (2D) data (Figure 5.3).

As the roads slope up and down along 1273 street and the intersecting streets, the roads, shown as coloured white in Figure 5.3, are divided into a number of elevations according to real case elevations. Therefore, each case building, coloured dark grey in the Figure 5.3, is situated in a separate elevation in 1273 street. Moreover, Figure 5.3 illustrates neighboring buildings via light grey coloured items, while pink ones refer to adjacent buildings which are accepted as adiabatic, i.e. means that heat is not transferred across in its external surface. Green coloured areas and dots belong to green spaces and trees. The numbers on the roads, i.e. 11.20, indicate that the height from the sea level (m). The roads has been specified as asphalt surface and trees are selected as non-evergreen in winter seasons and the neighboring buildings' surfaces has been expressed in light colours with high reflectivity as in the real cases in the created model.

After the model abstractions in site level are executed, 2D drawings of the case buildings exported into DesignBuilder. First of all, ground components covering roads and gardens are created then, the case buildings are modelled as three dimensional objects. Afterwards, the adjacent and surrounding neighboring buildings and trees are modelled.

Figure 5.4 shows the case buildings and their surroundings drawn on 3D user interface of DesignBuilder from (a) south and (b) north direction, respectively. All the construction materials of external walls, basement, ground and attic floors, roofs, oriels as well as windows and doors for the buildings are selected and assigned from DesignBuilder software library, after the creation of templates taken as a reference from a number of sources and specifications of the sample materials belong to case area done, as indicated in Chapter 4 (see Section 4.4.2.1 in Chapter 4).

5.2.2.2. Base Case Schedules

DesignBuilder dynamic simulation software provides and opportunity to the users for designating time dependent variables such as occupancy density, HVAC, equipment and lighting operation and transparency of component blocks (DesignBuilder, 2018). The software presents different types of schedules including

7/12 schedules, day schedule and compact schedules. Compact schedule defines all the features of schedule components, e.g. entered in a single command. In this study, compact schedules are used to maximize the operational time needed for building energy simulation calculations. Furthermore, the simulation calculations have been conducted for one year period from 1 January to 31 December.

Occupancy Schedule: All case buildings are assumed to be unoccupied. The models of buildings include combined functions in simplified zones since this study primarily aims at calculating annual energy consumption, i.e. sum of energy for heating and cooling, based on the specifications of building envelope. Apart from this, the resident profile has mostly been composed of the refugees in recent years, therefore the case buildings are not continuously used. Besides, some of historic ones are substantially demolished, abandoned or become unusable due to lack of any repair and maintenance as well as improvements works. Hence, any occupancy schedule is not entered into the case buildings.

Figure 5.3. 2D drawings of the case buildings and their surrounding in AutoCAD

(a)

(b)

Figure 5.4. Case buildings and their surrounding from (a) south and (b) north direction in DesignBuilder dynamic software

Schedule for Heating and Cooling Equipments: Heating and cooling equipments schedules are arranged based on the function of the buildings. The purpose of the study is to determine the annual energy consumption due to the building envelope, regardless of whether the existing heating and cooling system, the heating system of residential buildings is selected as stove and their cooling system is considered as a split type air conditioning. Commercial buildings are climatized with a split type air conditioning in both summer and winter season.

Each type of building is composed of occupied and unoccupied thermal zones in terms of equipment operations. In the scope of the study, while basement floors and

roofs, accepted as a separate zone, are determined as unoccupied, the other whole zone, the total of ground and upper floors, is accepted as occupied. Therefore, there is not any heating and cooling system in unoccupied zones in both two types of buildings.

For residential buildings, heating and cooling operation schedules in the occupied zone are arranged as on 7/24 for a year. Moreover, type of fuel for heating is coal and type of fuel for cooling is electricity from grid. Commercial buildings are assumed as heated and cooled on weekdays and Saturday for a year. The heating and cooling system are switched on at 08:30 am and off at 19:00 pm. It is not active on the other time periods and Sundays and holidays. Electricity is used for both heating and cooling in commercial buildings. Moreover, the use of domestic hot water (DHW), options for mechanical and natural ventilation are not included to energy calculations. Heating and cooling equipment schedules prepared for the case buildings are illustrated in Table 5.5.

Table 5.5. Heating and cooling equipment schedules for the case buildings

<table>
<tr><td rowspan="3">Schedules</td><td colspan="3">Residential Buildings</td><td colspan="4">Commercial Buildings</td></tr>
<tr><td rowspan="2">Type of fuel</td><td>Occupied</td><td>Unoccupied</td><td rowspan="2">Type of fuel</td><td colspan="2">Occupied</td><td>Unoccupied</td></tr>
<tr><td>All days</td><td>All days</td><td>Weekdays-Saturday</td><td>Sunday-Holidays</td><td>All days</td></tr>
<tr><td>Heating</td><td>Coal</td><td rowspan="2">On 7/24</td><td rowspan="2">No heating cooling</td><td>Electricity from grid</td><td rowspan="2">8.30-19.00</td><td rowspan="2">Off</td><td rowspan="2">No heating cooling</td></tr>
<tr><td>Cooling</td><td>Electricity from grid</td><td>Electricity from grid</td></tr>
<tr><td>Mechanical ventilation</td><td>-</td><td colspan="2">Off</td><td>-</td><td colspan="3">Off</td></tr>
<tr><td>Natural ventilation</td><td>-</td><td colspan="2">Off</td><td>-</td><td colspan="3">Off</td></tr>
<tr><td>DHW</td><td>-</td><td colspan="2">Off</td><td>-</td><td colspan="3">Off</td></tr>
</table>

Schedules for Environmental Control: For all occupied zones, heating temperature is set as 21ºC with a heating setback temperature is of 18ºC. Moreover, the minimum cooling temperature is determined as 26ºC with a cooling setback temperature of 28ºC.

Operation Schedule for Electrical Devices, Lighting and Openings: The effect of occupancy on energy consumption is assumed as out of scope of this thesis therefore, the following assumptions are kept during the base case and retrofitted case models:

- Schedules for electrical devices such as computer, printer, fax machine, television, iron and hoover: off
- Lighting: no lighting
- Opening (doors and windows): always closed
- Shading: no shading

5.2.2.3. Retrofitted Case Schedules

Operation schedules for windows, doors and shutters including the strategy of use of oriels' as sunspace, nighttime ventilation and shutter control has been only conducted in retrofitted case models of all buildings (Table 5.6):

Table 5.6. Operational schedules for all retrofitted case buildings

Operational Solutions	Base Case Model	Retrofitted Model
Use of oriels as a sunspace	X	✓
Nighttime ventilation	X	✓
Shutter control	X	✓

Schedule for Use of Oriels as Sunspace: Use of oriels as a sunspace has been conducted for historic case buildings including both officially registered and officially non-registered buildings. It is aimed to heat the interior space by using the oriel as a sunspace through this strategy. In retrofitted cases, a door was added to the partition seperating the oriel and interior space of case buildings and a schedule is prepared for the door. In the scenario, the door will be open according to schedule from evening 17:00 to 18:00 in evening from 1 December to 31 March. The will be open in the summer seasons and it will be generally closed in the winter season (Table 5.7).

Table 5.7. Schedule for use of oriels as sunspace

For retrofitted cases	Schedule for Use of Oriels as Sunspace
	Start-End
Open	from 1 December to 31 March
	from 17:00 to 18:00
	in summer period
Closed	generally closed in winter period

Schedule for Nighttime Ventilation Strategy: Nighttime ventilation strategy is conducted for all windows of heated zones in all case buildings in the summer season 'over heating time'. In the scenario, the windows will be open according to schedule from night to early morning from 19:00 to 09:00 from 31 March to 30 September in one year period (Table 5.8). Windows will be closed at the other times. Moreover, if an oriel exists, the door separating the oriel and interior space will be always open.

Prerequisite for this strategy is that when the outside air temperature is lower than the inside air temperature, the strategy is conducted for windows. There is not any constant temperature value. For providing this prerequisite, Delta T limit control has been selected from operation schedule in HVAC tab in DesignBuilder (DesignBuilder, 2018). Delta T limit control limits natural ventilation operation based on the temperature difference between the indoor and outdoor air dry-bulb temperature. It allows ventilation to be stopped if the temperature outside is too warm and could potentially heat the space (DesignBuilder, 2018).

Table 5.8. Schedule for nighttime ventilation strategy

For retrofitted cases	Schedule for Nighttime Ventilation
	Start-End
Open	from 31 March to 30 September
	from 19:00 to 06:00
Closed	from 1 December to 30 March
Always open	the door seperating the oriel and interior space

Schedule for Shutter Control: The strategy of shutter control is conducted for heated zones of all case buildings. It is aimed to prevent overheating of interior spaces in summer seasons by using the strategy. Only existing shutters have been used for historic buildings while new shutters are added to all windows of contemporary

buildings in addition to the existing shutters. DesignBuilder presents a limited number of choices for shading type; therefore a blind with low reflectivity slats is selected for shutters. It is considered to be applied from the outside of case buildings. Control type is determined as day cooling and solar from the library of DesignBuilder. It means shading is off at night. Shading is on during the day when the solar radiation incident on the window exceeds SetPoint (W/m^2 or $BTU/hr\text{-}ft^2$) and if the zone cooling rate in the previous time step is non-zero (DesignBuilder, 2018).

In the scenario, the shutters will be closed according to schedule from before noon to early evening from 11:00 to 16:00 from 1 April to 31 September in one year period. Shutters will be opened at the other times in summer period and all winter period. Moreover, if an oriel exists, the door separating the oriel and interior space will be always open to conduct this strategy (Table 5.9).

Table 5.9. Schedule for shutter control

For retrofitted cases	Schedule for Shutter Control
	Start-End
Closed	from 1 April to 31 December
	from 11:00 to 16:00
Open	opened in other times in summer period
	in winter period
Always open	the door seperating the oriel and interior space

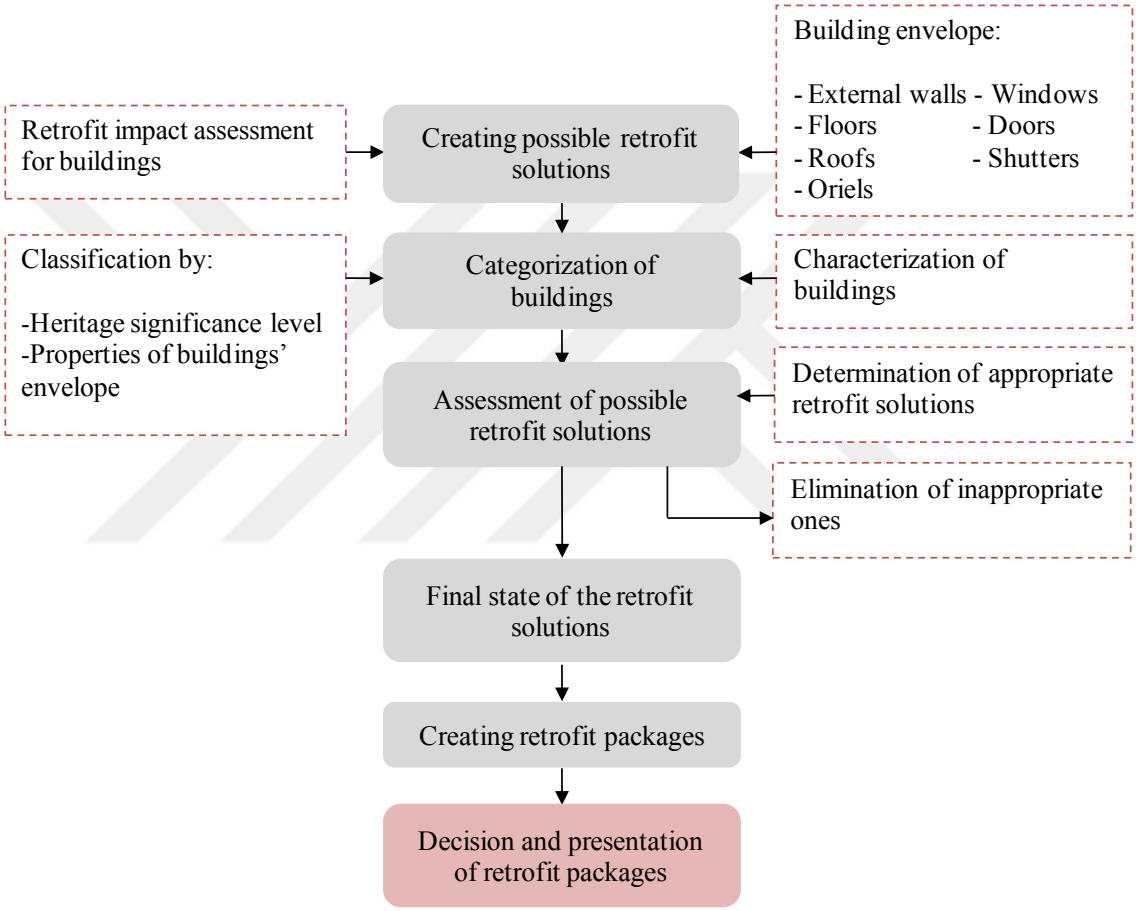
5.3. Determination of Energy-Efficient Solutions

This section principally aims to discuss the possible energy-efficient retrofit solutions for historic urban fabric, and find the most appropriate solutions for building envelope. The section starts with a preliminary analysis of the possible retrofit solutions taking account of literature survey including guidelines, standards, dissertations and publications to contribute the evaluation and decision process of the retrofit solutions for case buildings.

This section continues with the categorization step. 22 buildings are classified and characterized by number of qualitative and quantitative data. Following, a pre-assessment is conducted to find the best retrofit solutions by excluding inappropriate ones and identify a series of acceptable measures. After this process, retrofit solutions

are grouped under retrofit packages by combining the best solutions. This step serves the purpose of revealing which packages are most appropriate toward the targets of the study by evaluating and comparing different retrofit scenarios with each other and base-case. Final step is composed of the decision and presentation of retrofit packages (Table 5.10).

Table 5.10. Flowchart on determination process of energy-efficient solutions of the study



5.3.1. Retrofit Impact Assessment for Historic Buildings

This section principally aims to discuss the possible of energy-efficient retrofit solutions for the case buildings covering both historic and new ones and find the most appropriate solutions for the components of buildings' envelope. The section starts with a preliminary analysis of the possible retrofit solutions taking account of literature survey including guidelines, standards dissertations and publications to contribute the evaluation and decision process of the retrofit solutions for the case buildings. The

section utilizes the five-level assessment criteria and scale of possible retrofit measures for historic buildings which are introduced by CEN EN 16883 (BSI Committee B/560, 2015) (Figure 5.5).

A special approach should be adopted for retrofitting of historic buildings that reflects the life styles and cultures of the communities in history by reaching from the past to the present day and accordingly show distinctive characteristics in terms of architectural, aesthetical and heritage values among existing building stock. When suggesting any intervention on a historic building fabric, it is necessary to realize its construction, condition and characteristic. Implication of well-understood energy-efficient retrofit approach protects architectural, aesthetic and heritage values, reduces energy bills, and improves comfort conditions and health of occupants as well as increases the value and prolongs the life of historic buildings.

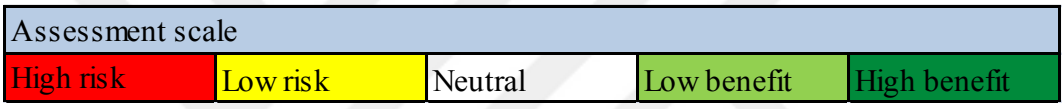


Figure 5.5. The five-level assessment scale for retrofit impact assessment (Source: BSI Committee B/560, 2015)

Historic buildings differentiate in two major ways that can affect energy retrofits in comparison with other building categories. The first one is physical characteristics such as complexity of geometry, method of construction, used materials and existence of inherently passive climate strategies. The second one is conservation principles since historic buildings are held to account for established conservation principles so as to preserve their historic fabric and distinguishing characters (Webb, 2017). In this direction, it is essential to point out that the need for providing convenient balance between building conservation principles and energy-efficient improvements.

Conservation principles have the meaning for “the lines of reasoning, methods, and tools used to meet the demands of change, theories, and diverse actions required to maintain cultural heritage” (Troi and Bastian, 2014, p. 34). Heritage significance for a historic building is embodied its fabric that means physical material covering elements, fixtures, contents and objects (The Burra Charter, 2013). Therefore, conservation of historic buildings depends on understanding and retaining the heritage significance as well as minimum intervention, compatibility, reversibility, authenticity and integrity principles on the character, significance and fabric of historic buildings (English

Heritage, 2012; Troi and Bastian, 2014). When any intervention is subject for historic buildings, it is necessary to keep intervention at minimum level. Moreover, interventions should be reversible so that it can be removed and replaced with more suitable measures and compatible with heritage values for guaranteeing durability and safety requirements (ICOMOS Charter, 2003). Besides, they should safeguard authenticity by respecting the history and fabric of a building and architectural integrity by cogitating over material and visual impact of intervention works on a historic building (Troi and Bastian, 2014).

As such in existing non-historic and contemporary buildings, it is possible to develop energy-efficient strategies for historic building envelope and building systems and equipments. However, a standardized retrofit process cannot be conducted and accordingly a method for retrofit impact assessment becomes inevitable in determining the best retrofit solutions that can be implemented to historic buildings. Therefore, energy-efficient retrofitting of historic buildings requires an interdisciplinary approach (Şahin, 2013; Troi and Bastian, 2014).

The recent literature about energy-efficient retrofit of historic buildings frequently addresses that an appropriate balance needs to be achieved between conservation principles and retrofit measures to increase energy efficiency of historic buildings. A deep qualitative assessment is required to evaluate the impact of the possible retrofit solutions on the heritage value and determine the best solutions by eliminating inappropriate ones (Şahin, 2013; Şahin et al., 2015).

The retrofit assessment has an approach based on certain criteria for each type of existing buildings. This criteria used for assessing energy-efficient retrofit solutions can be grouped under different topics such as energy, i.e. energy saving, embodied and operational energy, and economic aspect, indoor and outdoor environment and the hygrothermal performance, i.e. durability, moisture risk and thermal transmittance (Table 5.11). However, the criteria and the process of retrofit differ by conservation principles for historic buildings (Webb, 2017). Thus the heritage value protection commonly plays a leading role for assessing historic buildings (Grytli, 2011; Grytli et. al., 2012; Flores, 2013; Erikson et al, 2014; Pilzer, 2016; Broström et al., 2014; Şahin, 2013; Şahin et al., 2015, Webb, 2017) (Table 5.11).

The criteria for retrofit impact assessment specific to historic buildings can be scrutinized under specific subtopics to determine the most appropriate retrofit solutions: the retrofit effects on building envelope, i.e. visual and spatial effects from interior and

exterior, and the properties of retrofit materials, i.e. reversibility, damage potential and fabric compatibility (Grytli, 2011; Grytli et. al., 2012; Flores, 2013; Erikson et al, 2014; Pilzer, 2016) (Table 5.11).

An overview about the retrofit impact assessment of various scientific studies and guidelines were presented based on two major criteria including the heritage value protection and energy saving. The overview is of great importance in terms of enlightening the determination process of energy-efficient solutions of this thesis, although each study has a case-specific approach on historic buildings. The assessment was conducted for all building components covering walls, floors, roofs, oriels, openings and shutters and a range of retrofit solutions in accordance with these building components. Moreover, the retrofit assessment of sources was interpreted by utilizing the five-level assessment criteria introduced by CEN EN 16883 (Table 5.12).

Table 5.11. Criteria for retrofit impact assessment

Criteria for retrofit impact assessment							
				Criteria for heritage value impact assessment			
Şahin, 2013 Şahin et al., 2015	Eriksson et al., 2014	Broström et al., 2014	Webb, 2017	Grytli, 2011 Grytli et al., 2012	Flores, 2013	Eriksson et al., 2014	Pilzer, 2016
Energy saving	Indoor environment	Energy savings	Global environment	Reversibility	Impact on fabric	Visual	Impact on appearance
Cultural heritage values	Fabric compatibility	Economic	Building fabric	Visibility	Impact on visual integrity	Physical	Irreversibility risk
Durability	Heritage significance	Heritage values	Indoor environment	Effects on the interior or the exterior	Impact on site	Spatial	Damage potential
Economic return	Embodied energy	Moisture	Economics		Overall impact		
Moisture	Operational energy	Indoor environment					
Indoor environment	Economy						

According to the retrofit assessment, the most prominent results of the sources for the retrofit solutions were presented. External insulation of walls, ground floor insulation, changing/improving windows, doors and shutters predominantly resulted in high risk on the heritage value and historic building character, façade while they provide substantial energy savings. Internal insulation of walls, basement floor insulation, attic floor insulation, flat roof insulation and adding a secondary glazing on existing windows have less risk on the heritage value while they provide low benefit for energy efficiency. Implementation of weather stripping and roof insulation at rafter level have no risk on the heritage value and building apperarance as well as they present moderate

energy savings. Finally, shutter control, nighttime ventilation and use of oriels as sun space can be considered as the retrofit solutions without risk for the heritage value, because they do not cause any change on buildings' envelope.

5.3.2. The Possible Retrofit Solutions for Building Envelope[6]

This section addresses a list of possible energy-efficient solutions so as to conduct the retrofit strategies for case buildings including both historic and contemporary ones in the case area. There are a wide range of possible energy efficient retrofit solutions based on the literature survey. The section covers 17 envelope-related retrofit solutions since the energy consumption of buildings' envelope is taken into account within the scope of the study (see Section 2.4 and Section 3.4).

For all heated zones:

- Draught Proofing / Weather Stripping

Walls:

- External insulation of walls
- Internal insulation of walls

Floors:

- Insulation of basement floor
- Insulation of ground floor
- Insulation of attic floor
- Insulation of external floors
- Insulation of oriels' ground floor
- Insulation of oriels'attic floor

Roofs:

- Insulation of flat roof
- Insulation of pitched roof

Windows and doors:

- Changing windows
- Adding a secondary glazing to existing windows
- Changing doors

[6] The retrofit solutions for historic buildings are presented and evaluated in Chapter 3.4.

- Use of oriels as a sunspace
- Nighttime ventilation
- Shutter control

5.3.3. Categorization of the Case Buildings

Conservation practice for historic structures involves closely a full understanding of the structural and material characteristics (ICOMOS Charter, 2003). In order to conduct a successful retrofit work, it is also essential to understand and identify existing characteristics of historic buildings and how they function, as well as to understand their character-defining elements to ensure their preservation. Moreover, utilization of inherent sustainable features of historic buildings contributes further energy-efficient improvements beyond adding new retrofit solutions (Hensley and Aguilar, 2016).

Building components such as walls, floors, roofs and construction methods, materials and techniques can be regarded as character-defining elements of historic buildings. Character-defining elements must be retained to preserve the heritage value. Any action that cause to physical change on character-defining elements should be designed to be physically compatible, reversible as well as it should be respect and protect the heritage value (Canada's Historic Places, 2010). Thus, characterization has a major importance for deciding energy-efficient retrofit measures while retaining the heritage value of a historic building.

In this study, a categorization process has been conducted for the case buildings to assess the retrofit solutions by characterizing buildings considering their heritage values and architectural characteristics. This process aims at ensuring the most appropriate energy-efficient solutions by properly matching the retrofit packages with each building category. Criteria used in the categorization are mainly composed of two criteria including the specification of heritage value and the classification of buildings according to building components.

Table 5.12. Retrofit solutions for the building envelope based on retrofit impact assessment (Sources: (1), Grytli, 2012; (2), Grytli et al., 2012; (3), Morelli et al., 2012; (4), Aste et al., 2012; (5), Şahin, 2013; (6), Taranto and Kacel, 2013; (7), Almeida, 2014; (8), Zagorskas et al., 2014; (9), Ben and Steemers, 2014; (10), Şahin et al., 2015; (11), Flores, 2013; (12), Broström et al., 2014; (13), Stahl, 2012; (14), Stahl et al., 2014; (15), Grytli et al., 2014; (16), Historic Scotland, 2013; (17), ChangeWorks, 2008; (18), ASHRAE, 2016)

Components of Building Envelope	**Type of Retrofit**	**Sources**	**Retrofit Impact Assessment**	
			Heritage Value Protection	**Energy Saving**
All components	Weather stripping/draught proofing	1, 2, 5, 7, 9, 10, 11, 12, 13, 16, 17, 18		
External walls	External insulation	2, 4, 5, 7, 8, 10, 11, 12, 14, 15, 16, 17		
	Internal insulation	3, 4, 5, 6, 7, 8, 10, 12, 16, 17, 18		
Floors	Insulation of basement floor	2		
	Insulation of ground floor	2, 5, 7, 10, 11, 13, 16, 17		
	Insulation of attic floor	2, 5, 10, 11, 12, 13, 14, 16, 17		
Roofs	Insulation of roof at rafter level	2, 5, 6, 7, 8, 9, 10, 11, 13, 15, 16, 17		
	Insulation of flat roof	8, 17		
Windows, doors and shutters	Adding secondary glazing on existing windows	1, 3, 6, 7, 9, 11, 12, 13, 16, 17, 18		
	Changing windows with double/triple glasses	1, 3, 5, 10, 11, 12, 17		
	Changing windows with low-e double/triple glasses	3		
	Changing/improving shutters	7, 13, 16, 17, 18		
	Changing/improving doors	16		
	Shutter control			
	Nighttime ventilation			
Oriels	Use of oriels as sun space			

Categorization starts with the heritage significance level. The heritage significance level is of top priority because it is the most decisive and distinctive criteria at the first stage of categorization. The categorization process continues with characterizing the components of building envelope, i.e. walls, floors, roofs and oriels. The heritage significance level and characteristics of the buildings components affect the number and type of retrofit solutions produced for each building and how they work and are applied to the building structure. In this study, availability of basement floor and oriel in case buildings are initially selected as criteria after the selection of heritage significance level. Table 5.13 illustrates a categorization process of the case buildings.

In accordance with the categorization process, the case buildings are gathered under three main groups based on the heritage significance level of buildings. These groups are officially registered historic buildings named as Group 1 Buildings, officially non-registered historic buildings named as Group 2 Buildings and contemporary (non-historic) buildings named as Group 3 Buildings:

5.3.3.1. Group 1 Buildings (HR)

The case buildings which are officially registered historic buildings are included in Group 1 Buildings. They present a significant heritage value in terms of historic building constituents and façade characteristics, i.e. external walls, oriels, roofs, windows, doors and shutters, traditional construction type, i.e. masonry and baghdadi system and construction materials, i.e. stone, brick, wooden and lime plaster/mortar, and the rich details, i.e façade motifs and ornaments as plant and geometric designs, window and door frames and lattices, moldings, decoration elements on eaves.

Group 1 Buildings are totally composed of 11 officially registered buildings. These are Building 4, 7, 12, 14, 15, 17-18, 19, 20, 21 and 22. Group 1 Buildings were encoded as ‘historic registered (HR)’ in the categorization process (see Figure 5.3 for the position of the buildings in the 1273 Street).

5.3.3.2. Group 2 Buildings (HNR)

Group 2 Buildings are composed of Building 1 and 8 in the case area (see Figure 5.3 for the position of the buildings in the 1273 Street). Building 8 is also

identified as the building compatible with historic urban fabric and suggested to be officially registered and within the scope of plan report of Kemeraltı II. Stage I. Region Conservation Master Plan (Kemeraltı II. Etap I. Bölge Koruma amaçlı İmar Planı Plan Raporu, 2009). Additionally, the building licence of Building 1 which was taken before the year 1957 is specified in the façade rehabilitation and urban design project was prepared for 960 Street.

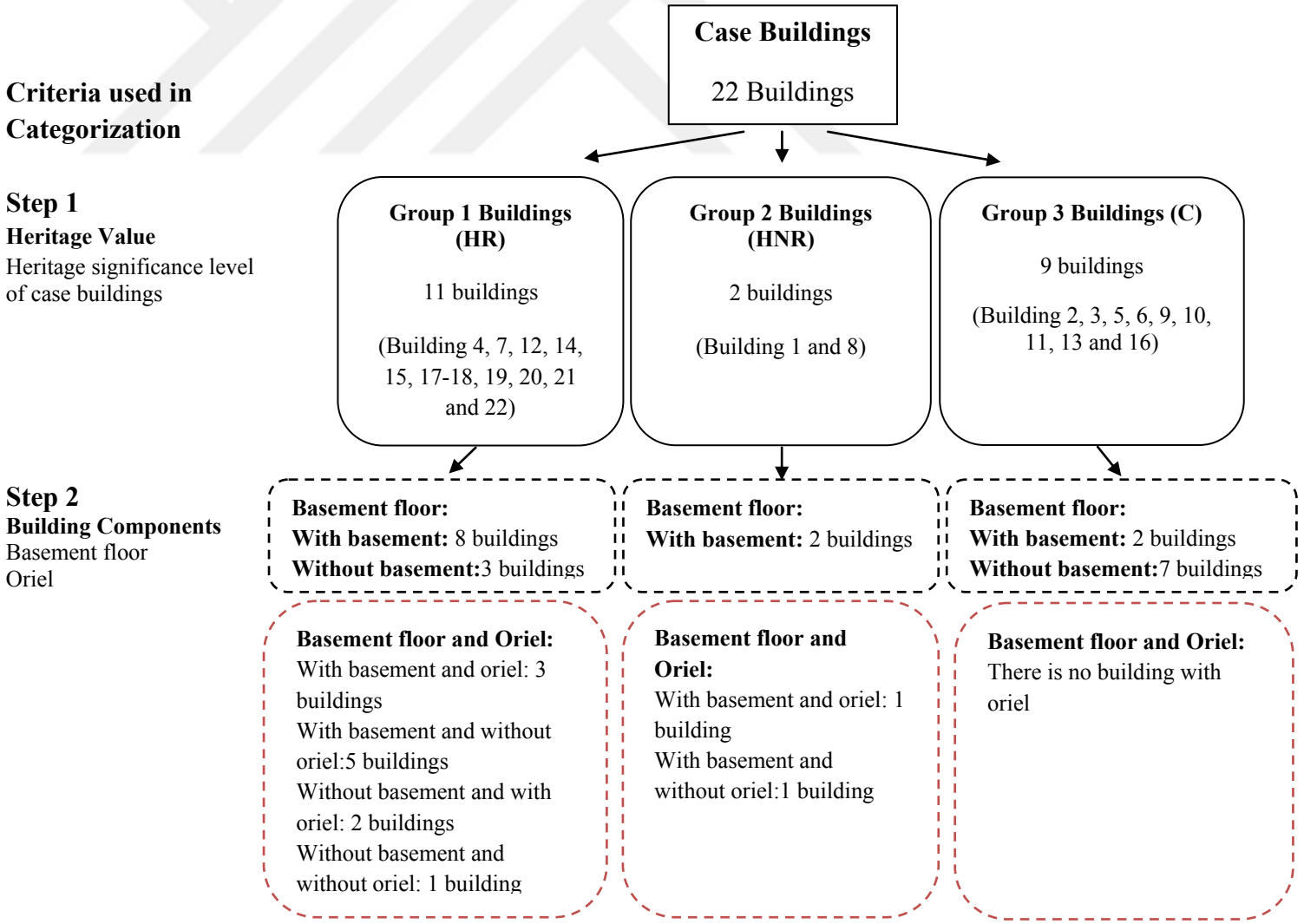
Building 1 and 8 are not officially registered buildings but they are in harmony with the officially registered historic buildings located in 1273 Street in terms of physical, visual and material characteristics of historic buildings' envelope.

Building 1 and 8 are built with a masonry system as well as traditional materials and techniques, i.e. stone, brick and wooden are used in the construction and building components. Windows and doors of the buildings are compatible with the historic building ones in terms of dimension, material and size, although they do not contain as many details as the windows and doors of historic buildings. Besides, some of windows have metal shutters. Building 1 has an oriel enclosed by a solid brick wall differently from the materials of historic buildings' oriels, while Building 8 has no oriel. Both two buildings have a basement floor. Group 2 Buildings were encoded as 'historic non-registered (HNR)' in the categorization process.

5.3.3.3. Group 3 Buildings (C)

Group 3 Buildings consist of nine buildings in the case area. They are characterized as contemporary buildings. They can be entitled as non-historic buildings, because they do not present any historic and heritage value and façade character. Building 2, 3, 5, 6, 9, 10, 11, 13 and 16 are included in this category (see Figure 5.3 for the position of the buildings in the 1273 Street). Group 3 Buildings were encoded as 'contemporary (C)' in the categorization process.

Table 5.13. Categorization of the case buildings



5.3.3.4. Impact Assessment of Possible Retrofit Solutions for Group 1 Buildings (HR)

First of all, defining the retrofit targets is of importance to properly assess the energy-efficient retrofit solutions and decide the appropriate ones for buildings. A number of targets are specified for Group 1 Buildings:

- To produce the energy-efficient retrofit solutions primarily considering the heritage value of case buildings
- To provide as much energy savings as possible while protecting the heritage value of case buildings
- To select the retrofit solutions as natural, breathable, reversible and compatible with the historic fabric, character and façade components of case buildings
- To select the insulation materials so as to meet TS 825 requirements, although there is no description about officially registered historic buildings in the building performance regulation of Turkey (Bayındırlık ve İskân Bakanlığı, 2008)

After the definition of retrofit targets, 18 possible energy-efficient retrofit solutions for Group 1 Buildings are evaluated based on the retrofit impact assessment by utilizing the five-level assessment criteria introduced by CEN EN 16883 (Table 5.14). As a result of the assessment, all retrofit solutions were gathered under three risk groups based on the heritage value: high-risk solutions, low-risk solutions and neutral solutions.

Initially, three retrofit solutions including the external insulation of external walls, changing windows and doors, red coloured boxes in Table 5.14, were specified the high-risk solutions for the heritage value after the assessment. Therefore, they are excluded from the scope of the solutions for Group 1 Buildings.

Six retrofit solutions, yellow coloured boxes in Table 5.14, are determined as the low-risk solutions after the heritage value impact assessment. These solutions are considered to have less impact on the heritage value and buildings' appearance while causing changes on buildings' construction. List of the retrofit solutions with low risk are the following:

- Internal insulation of external walls
- Internal insulation of oriel wall

- Insulation of oriels' ground floor
- Insulation of oriels' attic floor
- Insulation of the external floors (floor of protrusion and floor above entrance)
- Adding secondary glazing to existing windows

Considering the heritage value impact assessment, six retrofit solutions were determined as the neutral solutions causing the physical change on buildings' envelope, white coloured boxes in building envelope section of Table 5.14. These solutions improve energy efficiency of Group 1 Buildings without damaging the heritage value. List of the neutral retrofit solutions are the following:

- Weather stripping to improve air-tightness of the building envelope
- Insulation of ground floor
- Insulation of attic floor
- Insulation of flat roof
- Insulation of oriels' roof
- Insulation of pitched roof

The rest three retrofit solutions are the passive solutions related to building operation. They are also entitled as the neutral solutions which do not cause any physical change on the buildings' envelope, white coloured shown in building operation section of Table 5.14. List of these retrofit solutions are the following:

- Use of oriels as a sunspace
- Nighttime ventilation
- Shutter control

Table 5.14 presents the assessment of possible retrofit solutions for Group 1 Buildings based on the heritage value impact assessment. Each coloured boxes represent a risk degree of the retrofit solutions for the heritage value of the case buildings: red coloured boxes are the high-risk solutions, yellow coloured boxes are the low-risk solutions, and white coloured ones are the neutral solutions. Additionally, Grey coloured boxes show that there is no solution defined for the case buildings.

After the determination of the appropriate retrofit solutions based on the heritage value impact assessment for Group 1 Buildings, some of the retrofit solutions are grouped under the retrofit packages while some of are individually assessed. First of all,

the neutral retrofit solutions cause the physical changes on buildings' envelope are included in a package named as Package 1.

Package 1 was seperately simulated for Group 1 Buildings. Low-risk solutions for Group 1 Buildings were not been separately evaluated, since they are not a foremost option in terms of preference and application priority. Therefore, Package 2 was generated by adding the low-risk retrofit solutions to Package 1 solutions and then evaluated. Moreover, operational solutions are not grouped so as to observe their individual effects on the buildings' envelope (Table 5.14). Table 5.15 presents all retrofit solutions and packages determined for Group 1 Buildings.

Table 5.14. Heritage value impact assessment of Group 1 Buildings

	Retrofit Solutions	Numbered Case Buildings									
		B4	B7	B12	B14	B15	B 17-18	B19	B20	B21	B22
Change on building envelope	External insulation of external wall										
	Changing windows										
	Changing doors										
	Internal insulation of external wall										
	Insulation of oriel wall										
	Insulation of oriel attic floor										
	Insulation of oriel ground floor										
	Insulation of external floor										
	Adding secondary glazing										
	Insulation of flat roof										
	Insulation of oriel roof										
	Insulation of pitched roof										
	Weather stripping										
	Insulation of ground floor										
	Insulation of attic floor										
Building Operation	Use of oriels as sunspace										
	Shutter control										
	Nightime ventilation										

Eliminated Solutions
Package 2
Package 1
Operational Solutions

Specifications about Insulation Materials for Group 1 Buildings: Determination of insulation material carries importance so as to protect the heritage value and historic buildings' fabric. Therefore, the use of natural, breathable and reversible materials is beneficial for minimizing the risks, i.e. moisture, on historic building construction and components.

Table 5.15. Determined retrofit solutions and packages for Group 1 Buildings

Group 1 Buildings		
Package 1 (neutral related to building envelope)	**Package 2 (the combination of neutral and low-risk)**	**Individual Operational Solutions (neutral related to building operation)**
Weather stripping Insulation of flat roof Insulation of oriel roof Insulation of pitched roof Insulation of ground floor Insulation of attic floor	Weather stripping Internal insulation of external wall Insulation of oriel wall Insulation of oriel attic floor Insulation of oriel ground floor Insulation of external floor Adding secondary glazing Insulation of flat roof Insulation of oriel roof Insulation of pitched roof Insulation of ground floor Insulation of attic floor	Use of oriels as sunspace Shutter control Nightime ventilation

Wood fibre board and sheep wool have been selected as the insulation material for Group 1 Buildings. Wood fibre board has been used for external wall insulation and ground, external floor and flat roof insulation, while sheep wool shaped as roll has been selected for insulating attic floors. Wood fibre board is made of wooden soft fibres connected to each other through the effect of heat and pressure. It is a sustainable, homogeneous and dense but breathable material. Therefore, it helps moisture to be regulated and provides effective thermal insulation (WoodProductsFi, 2018). Sheep wool insulation is composed of sheep wool fibres. It is a natural, breathable and sustainable material. It has the ability to absorb and release moisture from the air without compromising its thermal performance. It can be produced as roll or batt due to the high elasticity of the wool fibres (SheepWoolInsulation, 2018). Thermo-phyiscal properties of wood fibre board (BISCHOFF + SCHÄFER, 2018) and sheep wool (GreenSpec, 2018) were presented as the following (Table 5.16):

Specifications about Package 1 for Group 1 Buildings: Package 1 aspires to enhance energy efficiency of Group 1 Buildings without damaging the heritage value. The package contains implementation of whether stripping to improve air-tightness of the building envelope, insulation of attic floor, insulation of flat roof, insulation of oriels' roof, insulation of pitched roof and insulation of ground floor.

Table 5.16. Thermo-physical properties of insulation materials for Group 1 Buildings

Insulation Materials for Group 1 Buildings	Thermal Conductivity W/ m.K	Specific heat J/Kg.K	Density Kg/m³
Wood fibre board	0.038	2100	50
Sheep wool	0.038	1800	23

Considering air-tightness improvements, the air exchange rate (ACH) is assumed to be improved from 0.7 h^{-1} to 0.4 h^{-1} in heated zones and from 0.9 h^{-1} to 0.7 h^{-1} in unheated zones to repair the cracks and holes on the building envelope. For floors, ground floor and attic floor insulation exist in Package 1. On the other hand, the ground floors of some buildings were decided to should not undergo a change during the retrofit interventions due to their structural composition and historic material properties. Building 4, 7 and 14 are included in this situation. Table 5.17 presents all floor types and their U-values before and after retrofit within Package 1 according to TS 825 requirement for floors.

Table 5.17. Specifications of floor types and new overall heat transfer coefficients within Package 1 for Group 1 Buildings

	Package 1 (for floors)	Ground floor type	Insulation of ground floor		Attic floor type	Insulation of attic floor		TS 825 requirements (W/m²K)
			Old U-value (W/m²K)	New U-value (W/m²K)		Old U-value (W/m²K)	New U-value (W/m²K)	
Group 1 Buildings	Building 4				B_F4	1,356	0,432	≤ 0.45
	Building 7				B_F4	1,356	0,432	
	Building 12	B_F7	2,269	0,37	B_F4	1,356	0,432	
	Building 14				B_F4	1,356	0,432	
	Building 15	B_F7	2,269	0,37	B_F4	1,356	0,432	
	Building 17-18	B_F7	2,269	0,37	B_F4	1,356	0,432	
	Building 19	B_F7	2,269	0,37	B_F4	1,356	0,432	
	Building 20	B_F7	2,269	0,37	B_F4	1,356	0,432	
	Building 21	B_F19	1,71	0,369	B_F4	1,356	0,432	
	Building 22	B_F7	2,269	0,37	B_F4	1,356	0,432	

The content of Group 1-Package 1 presents the insulation implementations for all roof types including pitched roof, flat roof and oriel roof. Within the pitched roofs, the pitched roof and the oriel roof of Building 14 were only retrofitted as such in the

original status. Thus, they were transformed into wooden roof encoded as B_R1. All roof types for Package 1 and their old and new overall heat transfer coefficients before and after retrofit are shown in Table 5.18.

Table 5.18. Specifications of all roof types and new overall heat transfer coefficients within Package 1 for Group 1 Buildings

	Package 1 (for roofs)	Pitched roof type	Old U-value ($W/m^2.K$)	New U-value ($W/m^2.K$)	Flat roof type	Old U-value ($W/m^2.K$)	New U-value ($W/m^2.K$)	Oriel roof type	Old U-value ($W/m^2.K$)	New U-value ($W/m^2.K$)	TS 825 requirements (W/m^2K)
Group 1 Buildings	Building 4	B_R1	2,46	0,398							≤ 0.45
	Building 7	B_R1	2,46	0,398	B_F19	1,71	0,369	B_R1	2,46	0,398	
	Building 12	B_R1	2,46	0,398				B_R1	2,46	0,398	
	Building 14	B_R3	7,14	2,46				B_R3	7,14	2,46	
		B_R1						B_R1			
	Building 15	B_R1	2,46	0,398							
	Building 17-18	B_R1	2,46	0,398				B_R1	2,46	0,398	
	Building 19	B_R1	2,46	0,398	B_F16	2,71	0,385	B_R1	2,46	0,398	
	Building 20	B_R1	2,46	0,398	B_F3	3,068	0,39	B_R1	2,46	0,398	
		B_R3	7,14	0,39	B_F19	1,71	0,369				
	Building 21	B_R1	2,46	0,398							
	Building 22	B_R1	2,46	0,398							

Specifications about Package 2 for Group 1 Buildings: Package 2 was intended to reveal the effects of both neutral and low risk retrofit solutions by providing as much as energy saving for Group 1 Buildings. Package 2 presents the combination of the low-risk and neutral solutions named (Package 1). Therefore, following specifications for the low-risk solutions are presented in addition to above mentioned specifications about Package 1.

The content of low-risk solutions is composed of six retrofit solutions including internal insulation of external wall, insulation of oriel wall, insulation of oriels' attic floor and oriel ground floor and roof and insulation of the external floors (floor of protrusion and floor above entrance) and adding secondary glazing to existing windows.

Considering walls, internal insulation of external wall and oriel wall were implemented for heated spaces. If there are case buildings with gable roof, gable walls were also insulated from inside. Moreover, external wall surfaces as an adiabatic were not insulated. For Building 14, oriel walls are considered to have been restored and retrofitted as such in its first state and its material was changed as wooden. Table 5.19 indicates external wall and oriel wall types and their overall heat transfer coefficients before and after retrofit in compliance with TS 825 requirements.

Table 5.19. Specifications of external wall and oriel wall types and new overall heat transfer coefficients within Low-risk solutions for Group 1 Buildings

	Low risky solutions (external walls)	External Wall type	Internal Insulation of external wall		Oriel wall type	Internal Insulation of oriel wall		TS 825 requirements (W/m²K)
			Old U-value (W/m²K)	New U-value (W/m²K)		Old U-value (W/m²K)	New U-value (W/m²K)	
Group 1 Buildings	Building 4	B_W3	1,07	0,441				≤ 0.70
		B_W5	2,059	0,549				
	Building 7	B_W5	2,059	0,549	B_W11	2,093	0,535	
		B_W9	1,916	0,538				
	Building 12	B_W4	1,977	0,543	B_W11	2,093	0,535	
		B_W17	2,318	0,566				
		B_W19	2,196	0,554				
	Building 14	B_W4	1,977	0,543	B_W25 B_W11	5,881	0,535	
		B_W22	1,981	0,541				
		B_W23	1,976	0,539				
		B_W24	1,935	0,536				
	Building 15	B_W12	2,493	0,576				
	Building 17-18	B_W4	1,977	0,543	B_W11	2,093	0,535	
		B_W27	1,874	0,53				
		B_W28	1,96	0,537				
		B_W29	1,976	0,539				
		B_W30	0,781	0,382				
		B_W37	1,951	0,537				
	Building 19	B_W4	1,977	0,543	B_W11	2,093	0,535	
		B_W17	2,318	0,566				
		B_W18	2,384	0,57				
		B_W31	1,838	0,532				
		B_W32	0,816	0,365				
	Building 20	B_W2	2,094	0,551				
		B_W2	2,094	0,497				
		B_W4	1,977	0,543				
		B_W34	1,655	0,515				
	Building 21	B_W27	1,874	0,53				
		B_W29	1,976	0,539				
	Building 22	B_W4	1,977	0,543				
		B_W17	2,318	0,566				
		B_W19	2,196	0,554				
		B_W36	1,504	0,5				

Installation of secondary glazing has been selected to provide an effective insulation for historic windows and limit draughts without changing any components of windows and damaging their character and heritage values. However, changing windows (glazing and frame) are envisaged on the façades of some Group 1 Buildings.

Because there are various annexes on the south façades of Building 19 and 20 and they have not a historic value.

All window types and their U-values with and without retrofits were shown in Table 5.20. Thus, it is obvious that the overall heat transfer coefficient targets were reached after the retrofits.

Table 5.20. Specifications of window types and their new overall heat transfer coefficients within low-risk solutions for Group 1 Buildings

Window type	Position	Layer name	Thickness (cm)	Frame	Old U-value ($W/m^2.K$)	Position	Layer name	Thickness (cm)	Frame	New U-value ($W/m^2.K$)
B_G1	outermost	single clear	0,3	iron	5,894	outermost	low-e clear	0,6	iron	1,912
							air gap	2		
	innermost					innermost	clear	0,3		
B_G2	outermost	single clear	0,3	wooden	5,894	outermost	low-e clear	0,6	wooden	1,912
							air gap	2		
	innermost					innermost	clear	0,3		
B_G4	outermost	clear	0,3	PVC	2,716	outermost	low-e clear	0,6	PVC	1,771
		air gap	1,2				air gap	2		
	innermost	clear	0,3			innermost	clear	0,6		

As for floors, ground and attic floor of the oriels and external floors such as ground floor of protrusions and the floors above the buildings' entrance are also included in low-risk solutions. Overall heat transfer coefficient targets to meet TS 825 requirements were achieved after the retrofits. Moreover, the ground floor of the oriel of Building 14 was restored as wooden floor as such in the original state during simulation process. In a similar way, the attic floor of the oriel of Building 7 was changed as wooden floor. Table 5.21 denotes all floor types for low-risk solutions and their old and new overall heat transfer coefficients before and after retrofit.

5.3.3.5. Impact Assessment of Possible Retrofit Solutions for Group 2 Buildings (HNR)

A similar retrofit impact assessment approach with Group 1 Buildings has been conducted for Group 2 Buildings, since Group 2 Buildings are the historic buildings compatible with the other officially registered historic case buildings in terms of physical, visual and material characteristics of façade constituents. Therefore, it is significant to identify the retrofit targets to determine the appropriate retrofit solutions and ensure the retrofit process for Group 2 Buildings:

- To select and evaluate the energy-efficient retrofit solutions primarily considering the historic character and façade constituents of case buildings
- To provide as much energy savings as possible without damaging the historic character and façade constituents of case buildings
- To select effective insulation materials compatible with the case buildings' character
- To meet TS 825 requirements for the components of buildings' envelope

Table 5.21. Specifications of floor types and new overall heat transfer coefficients within the low-risk solutions for Group 1 Buildings

	Low risky solutions (for floors)	Oriel ground floor type	Insulation of oriel ground floor		Oriel attic floor type	Insulation of oriel attic floor		External floor type	Insulation of external floor		TS 825 requirements (W/m²K)
			Old U-value (W/m²K)	New U-value (W/m²K)		Old U-value (W/m²K)	New U-value (W/m²K)		Old U-value (W/m²K)	New U-value (W/m²K)	
Group 1 Buildings	Building 4										≤ 0.45
	Building 7				B_F15	4,332	0,432	B_F14	1,78	0,372	
		B_F9	1,997	0,37	B_F4						
	Building 12	B_F9	1,997	0,37	B_F4	1,356	0,432	B_F17	3,258	0,409	
	Building 14	B_F10	2,821	0,37	B_F4	1,356	0,432	B_F18	1,32	0,428	
		B_F9				1,356	0,432				
	Building 15										
	Building 17-18	B_F9	1,997	0,37	B_F4	1,356	0,432	B_F18	1,32	0,428	
	Building 19	B_F9	1,997	0,37	B_F4	1,356	0,432	B_F17	3,258	0,409	
	Building 20							B_F17	3,258	0,409	
	Building 21										
	Building 22							B_F4	1,356	0,432	

After the identification of the retrofit targets of Group 2 Buildings, 17 possible energy-efficient retrofit solutions were evaluated considering the five-level assessment criteria introduced by CEN EN 16883. All retrofit solutions divided into three risk groups including high-risk solutions, low-risk solutions and neutral solutions (Table 5.22).

First of all, external insulation of external walls and changing doors were eliminated, since they carry a risk for Group 2 Buildings according to the heritage value impact assessment. Thus these solutions leave out of the scope of appropriate solutions for Group 2 Buildings.

Five retrofit solutions, yellow coloured boxes shown in Table 5.22, were specified as the low-risk solutions based on the heritage value impact assessment. They are determined as the solutions which cause less impact on the buildings' façade characters and appearance while causing change on the buildings' components. List of the retrofit solutions with low risk are the following:

- Internal insulation of external walls
- Insulation of oriel wall
- Insulation of oriels' ground floor
- Insulation of external floor
- Changing windows

Seven retrofit solutions were specified as the neutral solutions causing physical change on the buildings' envelope, but without damaging the historic character of buildings according to the heritage value impact assessment. They are illustrated in yellow coloured boxes in Table 5.22. List of the neutral retrofit solutions for Group 2 Buildings are the following:

- Weather stripping to improve air-tightness of the building envelope
- Insulation of basement floor
- Insulation of ground floor
- Insulation of attic floor
- Insulation of oriel attic floor
- Insulation of oriel roof
- Insulation of pitched roof

The rest three retrofit solutions are the passive solutions regarding building operation. They do not cause any physical change on the buildings' envelope. They were shown in white-coloured boxes of building operation section of Table 5.22. List of these retrofit solutions are the following:

- Use of oriel as a sunspace
- Nighttime ventilation
- Shutter control

Table 5.22 shows the assessment of possible retrofit solutions for Group 2 Buildings based on the heritage value impact assessment. Each coloured boxes represent a risk degree of the retrofit solutions for the historic character of the case buildings: red coloured boxes are the high-risk solutions, yellow coloured boxes are the

low-risk solutions, and white coloured ones are the neutral solutions. Additionally, Grey coloured boxes show that there is no solution specified for the case buildings.

Table 5.22. Heritage value impact assessment of Group 2 Buildings

	Possible Retrofit Solutions	Group 2 Buildings	
		B1	B8
Change on building envelope	External insulation of external wall		
	Changing doors		
	Internal insulation of external wall		
	Insulation of oriel wall		
	Insulation of oriel ground floor		
	Insulation of external floor		
	Changing windows		
	Insulation of oriel attic floor		
	Weather stripping		
	Insulation of basement floor		
	Insulation of attic floor		
	Insulation of oriel roof		
	Insulation of pitched roof		
	Insulation of ground floor		
Building Operation	Use of oriel as sunspace		
	Shutter control		
	Nightime ventilation		

Eliminated solutions

Package 2

Package 1

Operational Solutions

After the selection of appropriate retrofit solutions based on the heritage value impact assessment for Group 2 Buildings, some of the retrofit solutions are grouped under the retrofit packages while some are individually evaluated. The neutral solutions which cause the physical changes on buildings' envelope are included in a package named as Package 1. Package 1 was seperately simulated for Group 2 Buildings. Low-risk solutions for Group 2 Buildings have not been individually performed because of the similar reasons with Group 1 Buildings. Unchanged or less changed façades for this group of buildings were principally desired due to their façade characteristics. Low-risk solutions were combined and simulated with the Package 1 for Group 2 Buildings. Thus Package 2 originated from the combination of the solutions with low-risk and neutral effect on the heritage value of Group 2 Buildings. Furthermore, operational solutions

are not grouped to observe their individual effects on the buildings' envelope (Table 5.23).

Table 5.23. The determined retrofit solutions and packages for Group 2 Buildings

Group 2 Buildings		
Package 1 (neutral related to building envelope)	**Package 2 (the combination of neutral and low-risk)**	**Individual Operational Solutions (neutral related to building operation)**
Weather stripping Insulation of oriel attic floor Insulation of basement floor Insulation of attic floor Insulation of oriel roof Insulation of pitched roof Insulation of ground floor	Weather stripping Internal insulation of external wall Insulation of oriel wall Insulation of oriel ground floor Insulation of external floor Changing windows Insulation of oriel attic floor Insulation of basement floor Insulation of attic floor Insulation of oriel roof Insulation of pitched roof Insulation of ground floor	Use of oriel as sunspace Shutter control Nightime ventilation

Specifications about Insulation Materials for Group 2 Buildings: Wood fibre board and sheep wool have been used for Group 2 Buildings, because these buildings show similarity with Group 1 Buildings in terms of physical, visual and material characteristics. Thermophysical properties of the insulation materials were illustrated in Table 5.16.

Specifications about Package 1 for Group 2 Buildings: Package 1 of Group 2 Buildings consists of the energy-efficient retrofit solutions for horizontal building components and weather stripping. Regarding air-tightness improvements, the air exchange rate (ACH) is assumed to be improved from 0.7 h^{-1} to 0.4 h^{-1} in heated zones and from 0.9 h^{-1} to 0.7 h^{-1} in unheated zones to repair the cracks and holes on the building envelope. Solutions for horizontal building components cover attic floor insulation, roof insulation, oriels' floor insulation, basement floor insulation and ground floor insulation. All building components meet TS 825 requirements after the implementation of the retrofits. All floor types belonging to Group 2 Buildings and their old and new heat transfer coefficients are indicated in Table 5.24.

Table 5.24. Specifications of floor and roof types and new overall heat transfer coefficients within Package 1 for Group 2 Buildings

	Package 1 (for floors and roofs)		Floor and roof type	U-value (W/m²K)		TS 825 requirements (W/m²K)
				Old U-value (W/m²K)	New U-value (W/m²K)	
Group 2 Buildings	Building 1	Basement	B_F1	1,442	0,332	≤ 0.45
		Ground	B_F2	2,821	0,377	
		Attic	B_F3	1,442	0,332	
		Pitched roof	B_R1	2,46	0,398	
	Building 8	Basement	B_F1	1,442	0,332	
		Ground	B_F2	2,821	0,377	
		Attic	B_F3	1,442	0,332	
		Pitched roof	B_R1	2,46	0,398	

Specifications about Package 2 for Group 2 Buildings: Package 2 consists of the combination of the low-risk and neutral solutions (Package 1). Therefore, following specifications for the low-risk solutions are presented in addition to above mentioned specifications about Package 1 for Group 2 Buildings.

The low-risk solutions includes five energy-efficient solutions including internal insulation of external wall, internal insulation of oriel wall, insulation of oriel attic floor and insulation of external floor (floor of protrusion and floor above entrance) and changing windows. All building components fulfilled TS 825 requirements after the retrofit work.

For walls including external walls and oriel walls, insulation applications from inside were performed for heated spaces. External wall surfaces which are specified as adiabatic are not insulated. All wall types and their old and new overall heat transfer coefficients are illustrated in Table 5.25. Additionally, there is no expression on oriel wall type for Building 8, because Building 8 has no oriel.

Regarding floor types, the ground floor of oriels and external floors were involved in the low-risk solutions. While one type of oriel floor was defined for only Building 1, both two buildings have the external floors above their main entrances. Table 5.26 presents all floor types and their old and new U-values before and after retrofit.

Table 5.25. Specifications of wall types and new overall heat transfer coefficients within the low-risk solutions for Group 2 Buildings

Group 2 Buildings	Low-risk solutions (for walls)	External Wall type	Internal Insulation of external wall		Oriel wall type	Internal Insulation of oriel wall		TS 825 requirements (W/m²K)
			Old U-value (W/m²K)	New U-value (W/m²K)		Old U-value (W/m²K)	New U-value (W/m²K)	
	Building 1	B_W2	2,094	0,498	B_W4	1,977	0,543	≤ 0.70
		B_W3	1,07	0,537				
		B_W4	1,977	0,543				
	Building 8	B_W4	1,977	0,543				
		B_W12	2,493	0,576				
		B_W14	2,368	0,565				

Table 5.26. Specifications of floor types and new overall heat transfer coefficients within the low-risk solutions for Group 2 Buildings

Group 2 Buildings	Low-risk solutions (for floors)	Oriel ground floor type	Insulation of oriel ground floor		External floor type	Insulation of external floor		TS 825 requirements (W/m²K)
			Old U-value (W/m²K)	New U-value (W/m²K)		Old U-value (W/m²K)	New U-value (W/m²K)	
	Building 1	B_F2	2,821	0,377	B_F12	3,002	0,385	≤ 0.45
	Building 8				B_F16	2,711	0,411	

It is planned for the window types that they can be changed, because there is no restriction in terms of protection status of these buildings. Therefore, unlike Group 1 Buildings, changing both glazing and frames with new ones but similar material with the existing frames was implemented rather than adding a glazing on existing windows. All windows were changed in heated zones. Table 5.27 demonstrates the window types and their old and new heat transfer coefficients before and after retrofit.

Table 5.27. Specifications of window types and new overall heat transfer coefficients within the low-risk solutions for Group 2 Buildings

Window type	Position	Layer name	Thickness (cm)	Frame	Old U-value ($W/m^2.K$)	Position	Layer name	Thickness (cm)	Frame	New U-value ($W/m^2.K$)
B_G2	outermost	single clear	0,3	wooden	5,894	outermost	low-e clear	0,6	wooden	1,771
							air gap	1,2		
	innermost					innermost	clear	0,6		

5.3.3.6. Assessment of Possible Retrofit Solutions for Group 3 Buildings (C)

Initially, the following retrofit targets for Group 3 Buildings were determined:

- To provide as much as energy savings as possible by implementing the appropriate retrofit solutions
- To select the retrofit materials compatible with the buildings‘ envelope
- To ensure the buildings’ components meet TS 825 requirements after retrofit

The heritage value impact assessment for Group 3 Buildings has not been performed, because they consist of contemporary buildings which do not present any historic character and heritage value. Therefore, a list of 12 possible retrofit solutions was prepared. Then, the retrofit solutions were basically grouped under according to vertical and horizontal building components. Furthermore, the operational solutions were excluded from the packages as for other building groups. The solutions applied for the vertical building components, i.e. walls, windows and doors, were determined as Package 1. Package 2 consisted of the combination of the retrofit solutions applied for both the vertical and horizontal building components. Then, the operational solutions individually assessed for Group 3 buildings (Table 5.28).

Specifications about Insulation Materials for Group 3 Buildings: For Group 3 Buildings, rock wool and expanded polystyrene (EPS) have been selected as insulation materials. While stone wool was used for external wall insulation, EPS was used for insulating floor types including basement, ground, attic and external floors. Thermo-physical properties of the insulation materials were selected from the library of DesignBuilder energy simulation software (Table 5.29).

Specifications about Package 1 for Group 3 Buildings: Package 1 includes the retrofit solutions which are thought to be more preferable in terms of priority and ease of implementation. List of the solutions for Package 1 is the following:

- Weather stripping
- External insulation of external walls
- Changing windows
- Changing doors

Table 5.28. The determined retrofit solutions and packages for Group 3 Buildings

Group 3 Buildings		
Package 1 (vertical components)	**Package 2 (the combination of vertical and horizontal components)**	**Individual Operational Solutions**
Weather stripping External wall insulation changing windows Changing doors	Weather stripping External wall insulation changing windows Changing doors Insulation of attic floor Insulation of flat roof Insulation of pitched roof insulation of external floors Insulation of basement floor Insulatation of ground floor	Shutter control Nightime ventilation

Table 5.29. Thermo-physical properties of insulation materials for Group 3 Buildings

Insulation Materials for Group 3 Buildings	Thermal Conductivity W/ m.K	Specific heat J/Kg.K	Density Kg/m³
Rock wool	0.033	710	100
EPS	0.035	1400	25

For air-tightness improvements, the air exchange rate (ACH) is assumed to be improved from 0.7 h^{-1} to 0.4 h^{-1} in heated zones and from 0.9 h^{-1} to 0.7 h^{-1} in unheated zones to repair the cracks and holes on the building envelope. Regarding walls, external walls were insulated from outside for all heated spaces. For unheated spaces, above ground walls of basement floors and gable walls of buildings with gable roof were also externally insulated. However, external wall surfaces accepted as an adiabatic were not insulated since there is not any heat transfer. All external wall types belonging to Group 3 buildings and their old and new heat transfer coefficients are shown in Table 5.30.

As for windows and doors, all window and external door types have been changed for heated zones. Basement windows and basement extrance doors remained unchanged in unheated zones. For windows, existing glazings with single glass were replaced with low-e double pane windows having PVC frames. Regarding doors, entrance doors were replaced with insulated steel doors. Besides, balcony doors were

also considered to be replaced with PVC doors. Table 5.31 indicates the window and door types and their old and new heat transfer coefficients before and after retrofit.

Table 5.30. Specifications of floor and roof types and new overall heat transfer coefficients within Package 1 for Group 3 Buildings

	Package 1 (for walls)	External Wall type	External Insulation of external wall		TS 825 requirements (W/m²K)
			Old U-value (W/m²K)	New U-value (W/m²K)	
Group 3 Buildings	Building 2	B_W2	2,094	0,497	≤ 0.70
	Building 3	B_W6	1,855	0,482	
	Building 5	B_W1	2,109	0,497	
	Building 6	B_W4	1,977	0,488	
		B_W5	2,059	0,494	
		B_W7	0,612	0,315	
		B_W9	1,916	0,486	
	Building 9	B_W3	1,07	0,405	
	Building 10	B_W16	0,928	0,383	
	Building 11	B_W6	1,855	0,482	
	Building 13	B_W20	1,538	0,457	
		B_W21	1,438	0,448	
	Building 16	B_W26	1,811	0,479	

Specifications about Package 2 for Group 3 Buildings: Package 2 was aimed to observe the effect of the combined solutions produced for both vertical and hozirontal components of Group 3 Buildings except for the operational solutions. Therefore, following specifications on the solutions for horizontal building components are presented in addition to above mentioned specifications about the vertical components within Package 1.

Contrary to Package 1, the solutions for the horizontal building components were developed for the floors and roofs. List of the solutions for horizontal building components is the following:

- Insulation of basement floor
- Insulation of ground floor
- Insulation of external floor
- Insulation of attic floor

- Insulation of flat roof
- Insulation of pitched roof

Table 5.31. Specifications of window and door types and new overall heat transfer coefficients within Package 1 for Group 3 Buildings

Window type	Position	Layer name	Thickness (cm)	Frame	Old U-value ($W/m^2.K$)	Position	Layer name	Thickness (cm)	Frame	New U-value ($W/m^2.K$)
	outermost					outermost	low-e clear	0,6		
B_G1		single clear	0,3	iron	5,894		air gap	1,2	PVC	1,771
	innermost					innermost	clear	0,6		
	outermost					outermost	low-e clear	0,6		
B_G2		single clear	0,3	wooden	5,894		air gap	1,2	PVC	1,771
	innermost					innermost	clear	0,6		
	outermost					outermost	low-e clear	0,6		
B_G3		single clear	0,3	aluminium	5,894		air gap	1,2	PVC	1,771
	innermost					innermost	clear	0,6		
	outermost					outermost	steel	0,2		
B_D1		iron	0,3		5,88		insulation	0,33		
	innermost					innermost	steel	0,2		

When insulating all floor types for Group 3 Buildings, it was considered to directly implement insulation materials to the upper level of the existing floor without excavating and then place floor covering material on it. Table 5.32 denotes the specifications about the floor and roof types and their overall heat transfer coefficients before and after the retrofits. Table 5.33 summarizes the specifications about all retrofit solutions and insulation materials used in retrofit implementations and their thicknesses for all building groups.

Table 5.32. Specifications of floor and roof types and new overall heat transfer coefficients within Package 2 for Group 3 Buildings

	The solutions for horizontal building components (floors and roofs)		Floor and roof type	U-value (W/m²K)		TS 825 requirements (W/m²K)
				Old U-value (W/m²K)	New U-value (W/m²K)	
Group 3 Buildings	Building 2	Basement	B_F1	1,442	0,332	≤ 0.45
		Ground	B_F21	2,915	0,364	
		Attic	B_F4	1,356	0,44	
		Pitched roof	B_R1	2,46	0,398	
	Building 3	Ground	B_F20	1,379	0,405	
		Attic	B_F5	2,49	0,365	
		Pitched roof	B_R2	6,667	0,388	
	Building 5	Ground	B_F1	1,442	0,332	
		Attic	B_F7	2,269	0,443	
		Pitched roof	B_R1	2,46	0,398	
	Building 6	Basement	B_F1	1,442	0,332	
		Ground	B_F2	2,821	0,377	
		Attic	B_F3	3,068	0,372	
		External floor	B_F12	3,002	0,388	
		Flat	B_F21	2,915	0,378	
		Pitched roof	B_R1	2,46	0,398	
	Building 9	Ground	B_F20	1,379	0,405	
		Attic	B_F3	3,068	0,372	
		Pitched roof	B_R3	7,141	0,39	
	Building 10	Ground	B_F6	1,255	0,443	
		Attic	B_F3	3,068	0,372	
		Flat	B_F16	2,711	0,385	
		Pitched roof	B_R1	2,46	0,398	
	Building 11	Ground	B_F20	1,379	0,405	
		Attic	B_F3	3,068	0,372	
		Flat	B_F12	3,002	0,388	
		Pitched roof	B_R3	7,141	0,39	
	Building 13	Ground	B_F20	1,379	0,405	
		Attic	B_F3	3,068	0,372	
	Building 16	Ground	B_F1	1,442	0,41	
		Attic/Flat	B_F3	3,068	0,372	

Table 5.33. Specifications about retrofit solutions and insulation materials for all building groups

Case Buildings		Weather stripping	External Wall						Floor																		Window-Door			Operation		
			Exterior insulation of external wall (material-cm)		Interiorinsulation of external wall (material-cm)		Insulation of oriel wall (material-cm)		Insulation of basement floor (material-cm)	Insulation of ground floor (material-cm)				Insulation of attic floor (material-cm)			Insulation of oriel ground floor (material-cm)	Insulation of oriel attic floor (material-cm)		Insulation of external floor (material-cm)				Insulation of the roof at rafter level		Insulation of flat roof		Insulation of oriel roof	Secondary glazing	Double glasses with low emissivity	Changing doors	Shutter control	Nighttime ventilation	Use of oriels as sun space
			RW		WFB		WFB	SW	EPS	SW	EPS			RW			SW	WFB	SW	RW	EPS	SW		WFB	RW	SW	EPS	SW	SW						
			5		3	5	5	3	8	8	5	6	8	5	6	8	6	8	6	8	8	6	8	8	8	8	8	8	8						
G1	Building 4	x			x												x									x				x			x	x	
	Building 7	x			x		x										x	x	x				x			x		x	x	x			x	x	x
	Building 12	x			x		x			x							x	x	x					x		x			x	x				x	x
	Building 14	x			x		x			x							x	x	x			x				x			x	x			x	x	x
	Building 15	x			x					x							x									x				x				x	
	Building 17-18	x			x		x			x							x	x	x			x				x			x	x			x	x	x
	Building 19	x			x		x			x							x	x	x				x			x	x			x				x	x
	Building 20	x			x					x							x						x			x	x	x		x				x	
	Building 21	x			x					x							x									x				x			x	x	
	Building 22	x			x					x							x					x	x			x				x			x	x	
G2	Building 1	x		x	x	x		x	x	x							x	x	x	x				x		x			x		x			x	x
	Building 8	x			x				x	x							x							x		x					x		x	x	
G3	Building 2	x	x									x		x											x						x	x		x	
	Building 3	x	x									x			x										x						x	x		x	
	Building 5	x	x									x			x										x						x	x		x	
	Building 6	x	x						x				x			x					x				x		x				x	x		x	
	Building 9	x	x									x				x									x						x	x		x	
	Building 10	x	x								x					x									x		x				x	x		x	
	Building 11	x	x									x				x									x						x	x		x	
	Building 13	x	x									x				x									x						x	x		x	
	Building 16	x	x									x															x				x	x			

Abbreviations: RW, rock wool; WFB, wood fibre board; SW, sheep wool; EPS, expanded polystyrene

CHAPTER 6

RESULTS AND DISCUSSION

This chapter presents the results of the determined retrofit solutions for the building categories namely Group 1, Group 2 and Group 3, respectively and then the overall evaluation of retrofit scenarios for all case buildings. All case buildings were simulated by using DesignBuilder simulation software version 5.2.003 and 5.5.0.012. The simulation results of the retrofit packages and individual retrofit solutions for each building category were presented in the separate subsections. Comparison of the retrofit packages and with each other and the base case results of the buildings as well as, the comparison of case buildings between each other were also shown.

6.1. The Results of Retrofit Solutions belonging to Group 1 Buildings (HR)

Retrofit scenarios included in Group 1 were determined based on the degree of risk on the heritage value of case buildings in this group. Therefore, two retrofit packages named Package 1 and Package 2, and the individual operational solutions for Group 1 Buildings are generated. This section presents the results of the retrofit packages and their comparisons and individual retrofit solutions belonging to Group 1 Buildings.

6.1.1. The Results of Package 1 for Group 1 Buildings (HR)

Group 1-Package 1 was simulated so as to observe the impact of improvements of annual energy consumption by implementing grouped retrofit solutions, considered to have no risk, i.e. neutral, on the heritage value of registered historic buildings. Table 6.1 and Figure 6.1 present the results comparable with base and retrofitted cases of Package 1 belonging to all buildings in Group 1. They contain the sum of energy (kWh)

consumed for heating and cooling per numbered building through one year simulation period.

For the existing conditions, the highest amount of energy consumption is belonging to Building 17-18, while Building 4 has the lowest. Through the retrofit Package 1, all registered historic buildings have considerable level of energy savings. The highest reduction on energy occurred in Building 22 by the rate of 31% compared to the baseline model. It was followed by Building 19 (17%), Building 20 (15%), Building 7 (14%), Building 17-18 (13%), Building 12 (12%), Building 14 (10%), Building 4 and Building 21 (9%) and Building 15 with the lowest reduction with 8%.

Table 6.1. The results of annual energy consumption of base cases and Package 1 for Group 1 Buildings

Group 1 Buildings	Base Case Total (kWh)	Package 1 Total (kWh)
Building 4	9751	8874
Building 7	27694	23951
Building 12	18834	16628
Building 14	47009	42159
Building 15	26581	24423
Building 17-18	47314	41273
Building 19	35288	28964
Building 20	23615	19912
Building 21	17632	15978
Building 22	41600	28525

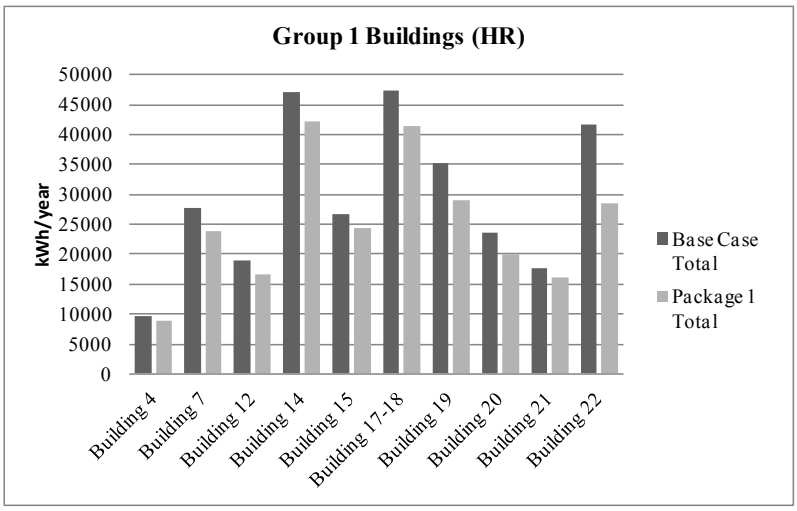


Figure 6.1. Comparison of total energy consumptions before and after retrofits on the annual basis for Package 1 for Group 1 Buildings

6.1.2. The Results of Package 2 for Group 1 Buildings (HR)

Group 1-Package 2 was intended to reveal the effects of both neutral and low risk retrofit solutions by providing as much as energy saving for Group 1 Buildings. All solutions in Package 2 caused changes on building construction by adding a material on the existing components but minimizing their visual effect on building appearance and preserving the heritage value.

Package 2 resulted in substantial decreases for all Group 1 Buildings in terms of total energy consumption when compared the results of the base cases. The highest reduction occurred in Building 22 by 66%, followed by Building 21 (60%), Building 17-18 (59%), Building 7 (53%), Building 14 (52%), Building 19 (44%), Building 15 (41%), Building 4 (39%), Building 20 (38%) and Building 12 (35%). The values of the total energy consumption with and without retrofit for Package 2 are shown in Table 6.2. Moreover, Figure 6.2 indicates the comparison of total energy consumptions between the base case results and Package 2 for Group 1 Buildings.

Table 6.2. The values of the total energy consumption with and without retrofit for Package 2 in Group 1 Buildings

Group 1 Buildings	Base Case Total (kWh)	Package 2 Total (kWh)
Building 4	9751	5977
Building 7	27694	13149
Building 12	18834	12305
Building 14	47009	22437
Building 15	26581	15638
Building 17-18	47314	19614
Building 19	35288	19868
Building 20	23615	14706
Building 21	17632	7089
Building 22	41600	14229

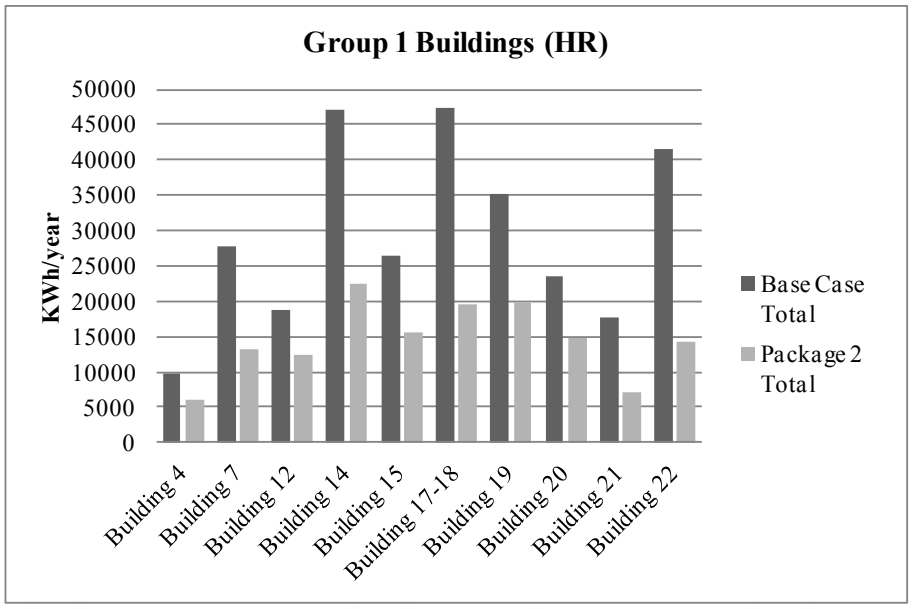


Figure 6.2. Comparison of total energy consumptions before and after retrofits on the annual basis for Package 2 for Group 1 Buildings

6.1.3. Assessment of Operational Retrofit Solutions for Group 1 Buildings (HR)

Operational retrofit solutions are separately simulated so as to see the individual effects on each building and to make the comparisons between each other. However, each solution is not completely implemented for each case building, because some of buildings do not have the required structural properties to make realize all proposals.

The strategy of the use of oriels as sunspace was conducted for Building 7, 12, 14, 17-18 and 19. This solution provided slight reductions in total energy consumption for all Group 1 Buildings except for Building 17-18 in comparison with the base case results. Nevertheless, the best result was reached on this strategy with Building 7 with the highest rate of 3,8%. This was followed by Building 19 (1,7%), Building 12 (1,5%), and Building 14 (1,4%). Moreover, there is no difference in total energy consumption after the retrofit work for Building 17-18. Table 6.3 presents the values of total energy consumption on annual basis with and without retrofit regarding the use of oriels as a sunspace. Figure 6.3 shows the comparison of energy consumptions before and after retrofit.

Table 6.3. The values of the total energy consumption with and without retrofit for the use of oriels sunspace for Group 1 Buildings

Group 1 Buildings	Base Case Total (kWh)	Use of oriels as sunspace Total (kWh)
Building 7	27694	26634
Building 12	18834	18546
Building 14	47009	46366
Building 17-18	47314	47360
Building 19	35288	34684

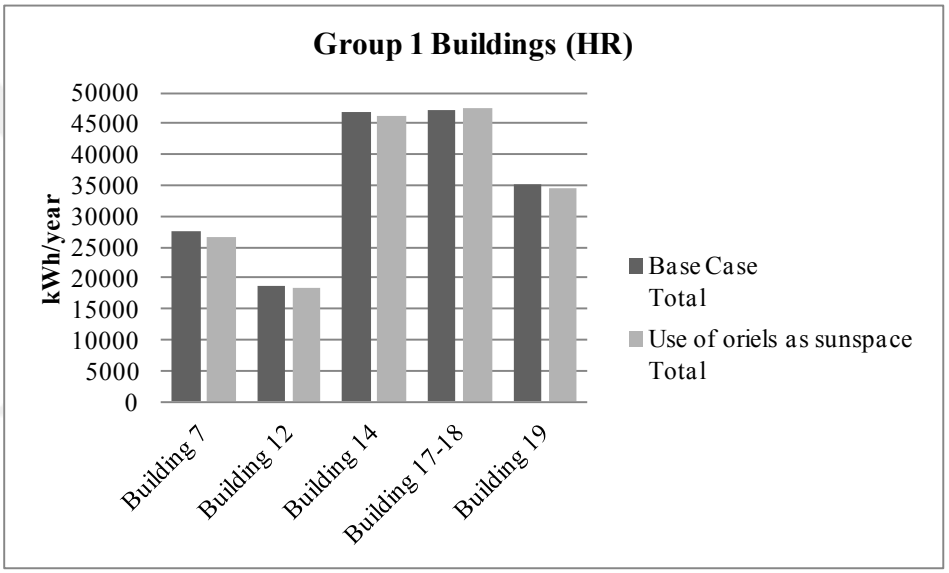


Figure 6.3. Comparison of total energy consumptions before and after retrofit for the strategy of use of oriels as sunspace for Group 1 Buildings

The strategy of nighttime ventilation was conducted for all Group 1 Buildings. According to the results of the simulations after the retrofit work, the highest amount of decrease in total energy consumption was occurred in Building 22, relatively by a major reduction (23%) compared to the other buildings. This was followed by Building 7 (5%), Building 15 (4%), Building 4 and 19 (3%), Building 12 and 14 (2%), Building 17-18 and 21 (1%). There is no difference in total energy consumption between before and after the retrofit in percent for Building 20. Table 6.4 presents the values of total energy consumption on annual basis with and without retrofit for nighttime ventilation. Figure 6.4 illustrates the comparison of the total energy consumptions before and after the retrofit for the nighttime ventilation.

Table 6.4. The values of the total energy consumption with and without retrofit for nighttime ventilation for Group 1 Buildings

Group 1 Buildings	Base Case Total (kWh)	Nighttime ventilation Total (kWh)
Building 4	9751	9451
Building 7	27694	26387
Building 12	18834	18411
Building 14	47009	45880
Building 15	26581	25599
Building 17-18	47314	46941
Building 19	35288	34373
Building 20	23615	23613
Building 21	17632	17783
Building 22	41600	32235

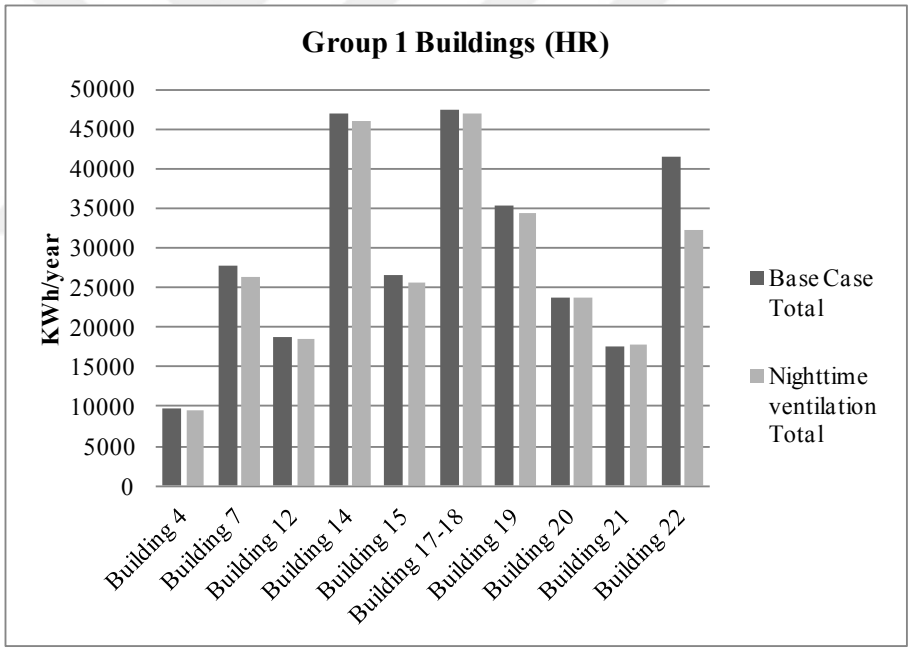


Figure 6.4. Comparison of total energy consumptions before and after retrofits for the strategy of nighttime ventilation for Group 1 Buildings

Adding a shutter control system was planned to diminish overheating in occupied zones for the case buildings. This solution was only developed for the existing shutters of windows of Group 1 Buildings. Therefore, a new shutter system was not implemented on the windows. Additionally, Building 4, 15 and 21 are excluded from this implementation since they have no shutters.

The best results was obtained from Building 22 by 22% as a major reduction in comparison to the other case buildings in Group 1. This was followed by Building 7 (4%), Building 20 (3%), Building 19 (2%) and lastly Building 4 (1%) with the lowest reduction. A significant difference in percentages was not observed on Building 17-18 because of a very slight reduction on total energy consumption. Table 6.5 shows the values of total energy consumption on annual basis with and without retrofit for shutter control. It was also indicated the comparisons of the total energy consumptions of Group 1 Buildings before and after retrofit for shutter control in Figure 6.5.

Table 6.5. Total energy consumption values with and without retrofit for shutter control for Group 1 Buildings

Group 1 Buildings	Base Case Total (kWh)	Shutter control Total (kWh)
Building 7	27694	26477
Building 12	18834	18533
Building 14	47009	46363
Building 17-18	47314	47180
Building 19	35288	34653
Building 20	23615	22991
Building 22	41600	32500

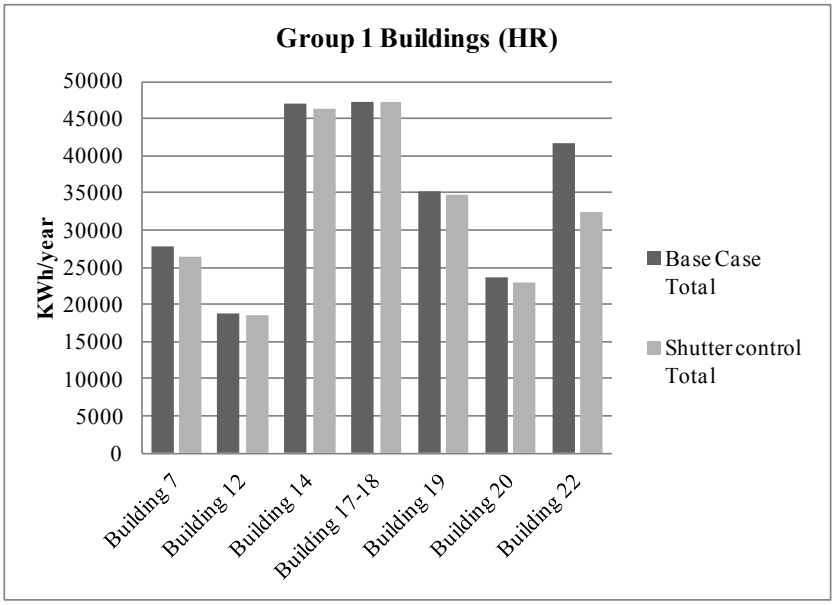


Figure 6.5. Comparison of total energy consumptions before and after retrofits for the strategy of shutter control for Group 1 Buildings

6.1.4. Evaluation of Retrofit Packages for Group 1 Buildings (HR)

According to the retrofit impact assessment for Group 1 Buildings, two packages including Package 1 and Package 2 were identified. The effect of Package 1 Package 2 and also the effect of individual retrofits within operational solutions were presented in the previous sections. In this section, the retrofit packages and individual retrofit solutions were compared with each other and base cases and then they were evaluated.

Regarding annual energy consumption for heating, there is a significant difference between Package 1 and Package 2 even if both of the packages provide major energy savings. Amount of energy saving for Group 1 Buildings ranged from 9% (Building 15) to 17,89% (Building 19) by implementing Package 1. This rate reached by Package 2 from 34,64% (Building 12) to 60,6% (Building 22) (Table 6.6).

Considering cooling energy consumption on annual basis, package 1 significantly reduced energy consumption of almost all buildings. However, there existed an increase in cooling consumption by 25,92% and 41,7% in Building 15 and 21, respectively. Minimum energy saving achieved by Package 1 was 2,45% in Building 12, while maximum energy saving is 85,87% for Building 22. Moreover, Package 2 provided major energy reductions for all case buildings. This combination resulted in an increase with minimum 28,11% (Building 15) and maximum 91,15% (Building 22) energy saving in comparison to the base cases (Table 6.6).

The results of total energy consumption also indicated that minimum annual energy saving obtained from Package 1 is minimum 8,12% (Building 15) and maximum 31,43% (Building 22). Moreover, the energy saving rate increased by minimum 34,67% (Building 12) and maximum 65,8% (Building 22) through Package 2 in proportion to the base cases (Table 6.6).

Single results of operational solutions indicated that they presented slight improvements for energy saving. But, they had not any detrimental effect on buildings' envelope and the heritage value. It could be remarked that the nighttime ventilation slightly differed from the other operational solutions, in terms of providing more energy savings specifically for cooling consumption and applicability to all existing windows of Group 1 Buildings. Use of oriels as a sunspace and shutter control strategy did not completely performed for all case buildings because of the use of only existing shutters and the fact that

all buildings do not have an oriel. These solutions which can be implemented to the existing building components gave close results with the nighttime ventilation strategy (Table 6.7).

Table 6.6. The rate of change in energy consumption compared to the base cases of Group 1 Buildings through Package 1 and Package 2

Group 1 Buildings	Package 1		Package 1 Total	Package 2		Package 2 Total
	Heating	Cooling		Heating	Cooling	
Building 4	-9,09	-6,74	-8,99	-38,84	-35,24	-38,70
Building 7	-13,31	-18,93	-13,52	-52,00	-66,50	-52,52
Building 12	-11,92	-2,45	-11,71	-34,64	-36,08	-34,67
Building 14	-10,25	-12,38	-10,32	-52,47	-46,65	-52,27
Building 15	-9,00	25,92	-8,12	-41,51	-28,11	-41,17
Building 17-18	-13,12	-3,99	-12,77	-59,68	-30,25	-58,55
Building 19	-17,89	-19,02	-17,92	-43,71	-43,38	-43,70
Building 20	-15,97	-5,31	-15,68	-37,84	-33,61	-37,72
Building 21	-11,19	41,70	-9,38	-60,60	-36,96	-59,79
Building 22	-11,30	-85,87	-31,43	-56,42	-91,15	-65,80

Figure 6.6 displays the comparisons of Package 1 and Package 2 with the actual conditions of case buildings in terms of heating, cooling energy consumption on annual basis.

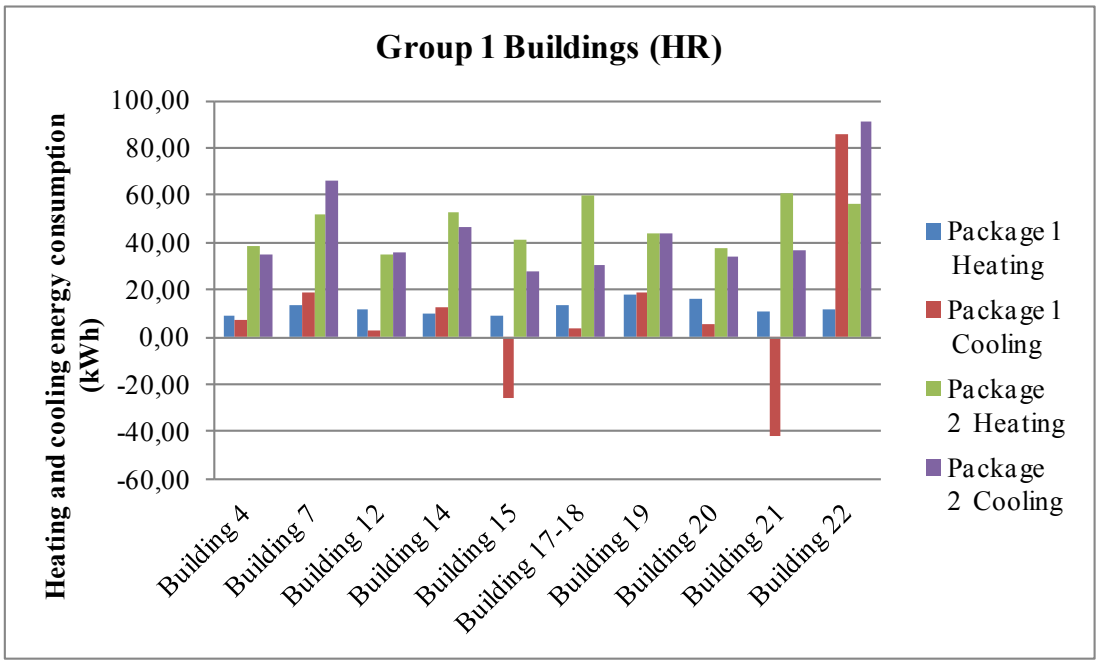


Figure 6.6. Comparison of Package 1 and Package 2 with the base cases of Group 1 Buildings regarding heating and cooling of annual energy consumption

The overall results on the package basis clearly showed that there occurred a significant difference in energy saving rates between Package 1 and Package 2. In this scope, the retrofit solutions with low risk solutions greatly contributed to the decrement in energy consumption of all Group 1 Buildings. One reason for this situation may be explained by the exterior wall insulation and adding a secondary glazing to existing windows have a major contribution to Package 2, because walls and windows take a wide surface area on buildings'envelope. However, the retrofit solutions with low risk cause more changes on buildings' construction and components compared to Package 1 in terms of affecting building appearance, façade constituents, interior details and decoration elements. Therefore, these solutions carry a certain risk for the heritage value of buildings. Package 1 provided as much energy saving as possible considering the heritage value protection.

Table 6.7. The rate of change in energy consumptions compared to the base cases of Group 1 Buildings through single solutions within the operation solutions

Group 1 buildings	Use of oriels as a sunspace			Nighttime ventilation			Shading Control		
	Heating	Cooling	Total	Heating	Cooling	Total	Heating	Cooling	Total
Building 4				-3,2	-0,9	-3,1			
Building 7	-4,0	1,1	-3,8	-4,0	-23,7	-4,7	-3,9	-16,3	-4,4
Building 12	-1,5	-4,2	-1,5	-1,5	-37,6	-2,2	-1,6	-3,1	-1,6
Building 14	-1,6	6,0	-1,4	-1,7	-23,1	-2,4	-1,6	5,5	-1,4
Building 15				-2,8	-37,7	-3,7			
Building 17-18	-0,3	8,9	0,1	-0,3	-13,5	-0,8	-0,3	-1,0	-0,3
Building 19	-1,9	4,5	-1,7	-1,9	-28,2	-2,6	-1,9	1,2	-1,8
Building 20				0,0	-0,3	0,0	-2,5	-8,9	-2,6
Building 21				0,7	4,1	0,9			
Building 22				0,0	-23,3	-22,5	0,0	-4,8	-21,9

6.2. The Results of Retrofit Solutions belonging to Group 2 Buildings (HNR)

Group 2 Buildings are officially non-registered buildings but they are compatible with the other historic buildings located in the street and historic urban fabric in terms of physical, visual and material characteristics of the buildings' envelopes and façades. Therefore, Building 1 and 8 in the case area are included in this group and the retrofit scenarios were determined considering these criteria. Two types

of retrofit packages named as Package 1 and Package 2 as well as three individual operational solutions are described and evaluated for Group 2 Buildings.

6.2.1. The Results of Package 1 for Group 2 Buildings (HNR)

Package 1 was separately simulated to improve energy efficiency of the buildings by applying the retrofit solutions with low risk on the effect on the façade characteristics. Then, this package is also combined and simulated with the other two packages. Package 1 has a significant decrease in total energy consumption for Building 1 in proportion to Building 8. Table 6.8 shows the values of total energy consumption on annual basis with and without retrofit for Package 1. It is also evident in Figure 6.7 that the total energy consumption reduction was occurred in Building 1 by 15% and Building 8 by 9% compared to actual conditions of Group 2 Buildings.

Table 6.8. Total energy consumption values with and without retrofit for Package 1 for Group 2 Buildings

Group 2 Buildings	Base Case Total (kWh)	Package 1 Total (kWh)
Building 1	18546	15694
Building 8	25415	23024

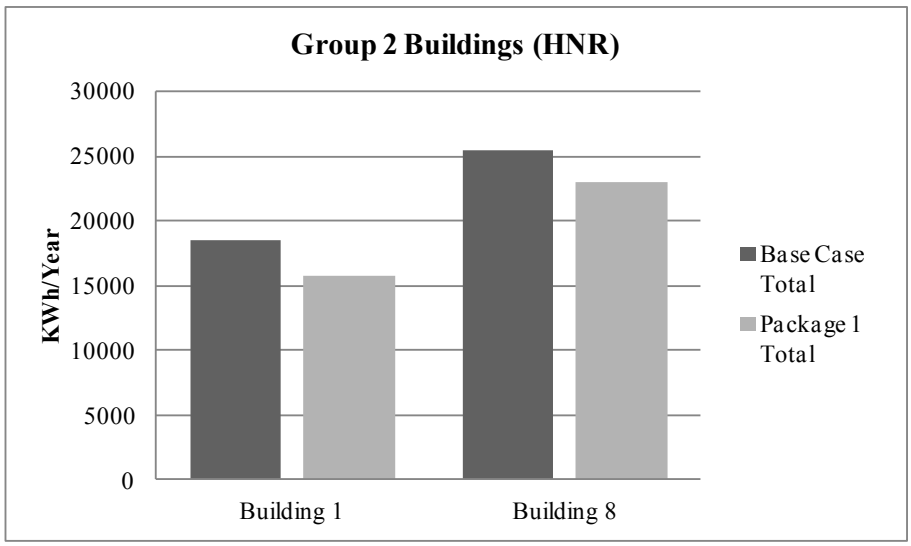


Figure 6.7. Comparison of total energy consumptions before and after retrofits on the annual basis for Package 1 for Group 2 Buildings

6.2.2. The Results of Package 2 for Group 2 Buildings (HNR)

Through Package 2, it was aimed to display how much energy saving provided by the energy-efficient solutions causing changes on buildings' envelope but also respecting buildings' façade characters and appearances. The simulation results of Package 2 showed that considerable amount of annual energy savings were achieved for both two case buildings. The highest decrease was seen in Building 1 by 45% while Building 8 had an energy consumption reduction of 42%. It was clear that there are no big differences between two buildings. Total energy consumption values on annual basis with and without retrofit for Package 2 are illustrated in Table 6.9. Figure 6.8 introduces changes on total energy consumptions before and after retrofit of Package 2 within Group 2 Buildings.

Table 6.9. Total energy consumption values with and without retrofit for Package 2 for Group 2 Buildings

Group 2 Buildings	Base Case Total (kWh)	Package 2 Total (kWh)
Building 1	18546	10265
Building 8	25415	14649

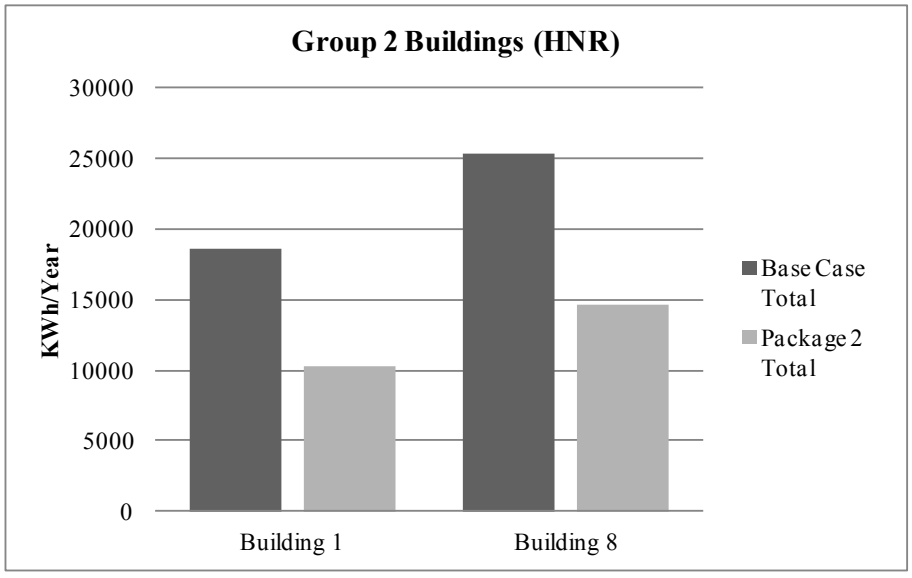


Figure 6.8. Comparison of total energy consumptions before and after the retrofits on the annual basis for Package 2 for Group 2 Buildings

6.2.3. The Results of Operational Solutions for Group 2 Buildings (HNR)

Operational solutions cover the use of oriels as a sunspace, nighttime ventilation and shutter control. All retrofit solutions are performed and then simulated to observe their individual effects on each case building and to make the comparisons between each other. However, all solutions within the package could not be experienced on each case building due to their structural properties.

The strategy of the use of oriels as a sunspace was only conducted for Building 1. Total energy consumption showed a minor reduction when compared to the base case result of Building 1. Therefore, total energy saving is provided by this scenario about %1,6. Table 6.10 shows the values of total energy consumption on annual basis with and without retrofit. Figure 6.9 presents the comparison of the total energy consumptions before and after the retrofit for the use of oriel as a sunspace.

Table 6.10. Total energy consumption values with and without retrofit for the use of oriel as a sunspace for Building 1

Group 2 Buildings	Base Case Total (kWh)	The use of oriel as sunspace Total (kWh)
Building 1	18546	18247

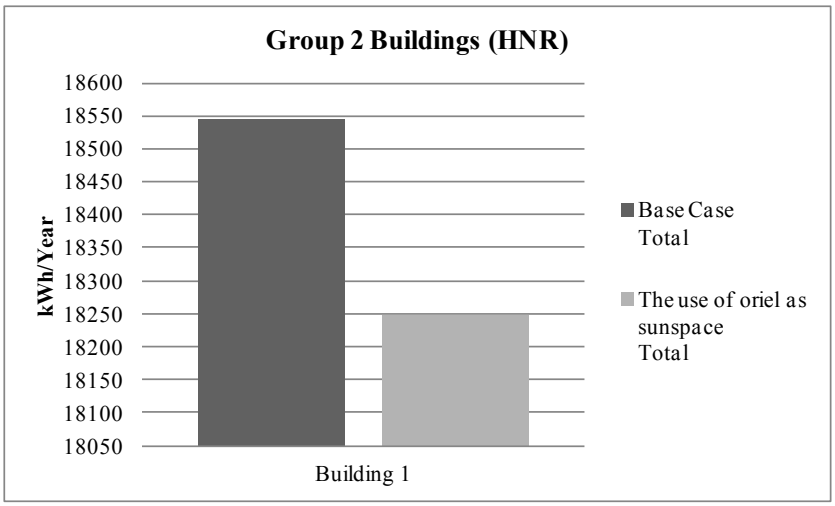


Figure 6.9. Total energy consumption with and without retrofits on the annual basis for the strategy of use of oriels as sunspace for Building 1

The nighttime ventilation strategy was developed for both two buildings. After the simulation of this strategy, it was shown that the maximum decrease in total annual energy consumption was achieved in Building 8 by 3,4% with a minor difference even if there were no big differences among levels of energy savings for both two buildings. Following, Building 1 has an energy saving rate of 2,2%. Table 6.11 presents the values of total energy consumption on annual basis with and without retrofit. The comparisons of the total energy consumptions before and after the nighttime ventilation strategy can be seen in Figure 6.10 on the annual basis.

Table 6.11. Total energy consumption values with and without retrofit for the nighttime ventilation for Group 2 Buildings

Group 2 Buildings	Base Case Total (kWh)	Nighttime ventilation Total (kWh)
Building 1	18546	18133
Building 8	25415	24552

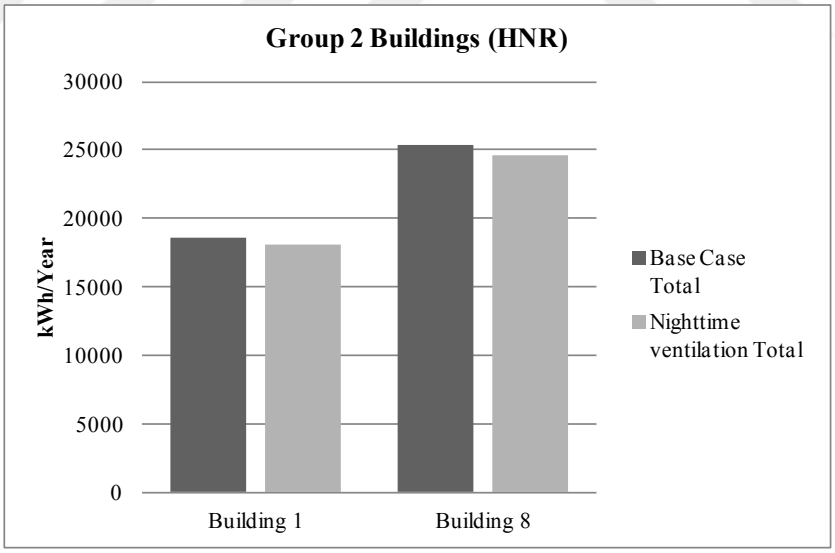


Figure 6.10. Comparison of total energy consumptions with and without retrofits on the annual basis for the nighttime ventilation strategy for Group 3 Buildings

Finally, shutter control system has been conducted for both two buildings however, the strategy was only proposed for existing shutters on the windows. Furthermore, the best results were not obtained on the strategy of shutter control for

both case buildings. Table 6.12 initiates the values of total energy consumption on annual basis with and without retrofit. It was shown that it is possible to save annually 2,2% energy for Building 1 and 2,8% energy for Building 8 by using shutter control system compared to base cases of buildings (Figure 6.11).

Table 6.12. Total energy consumption values with and without retrofit for the shutter control for Group 2 Buildings

Group 2 Buildings	Base Case Total (kWh)	Shutter Control (kWh)
Building 1	18546	18135
Building 8	25415	24704

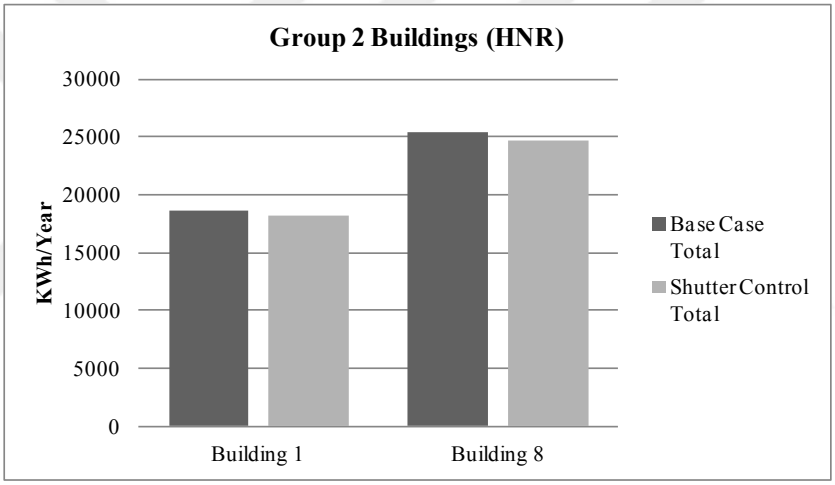


Figure 6.11. Total energy consumptions with and without the retrofits on the annual basis for the shutter control strategy in operational solutions

6.2.4. Assesment of Retrofit Packages for Group 2 Buildings (HNR)

In previous sections, two retrofit packages named as Package 1 and Package 2 and individual operational solutions were introduced. The results of Package 1 and Package 2 and operational solutions were seperately presented and discussed. This section addresses an overview about the retrofit solutions/packages and also their comparisons with each other and the base cases of Group 2 Buildings.

Results of heating energy consumption on annual basis indicated that there was a marked difference between Package 1 and Package 2. Through Package 2, the highest

reduction was occurred in Building 8 by 47,34% and Building 1 by 42,63%. On the other hand, the use of Package 2 decreased energy comsumptions by 17,56% in Building 1 and 10,06% in Building 8 compared to the base cases (Table 6.13).

Results of annual energy consumption for cooling showed that Package 1 and Package 2 unexpectedly increased energy consumptions of two buildings while only Package 2 provided a reduction of 23,98% for building 8. The increase rate was 34,99% for Building 1 and this rate reached to 13% for Building 8 through Package 1 (Table 6.13).

Considering total annual energy saving rates, there was a significant difference of 30-35% between Package 1 and Package 2. Maximum benefit obtained from Package 2 is 44,65% for building 1 and 42,36% for Building 8. Minimum energy saving rate is 9,41% for Building 8 and 17,56% for Building 1 by applying Package 1 (Table 6.13).

Table 6.13. The rate of change in energy consumptions compared to the base cases of Group 2 Buildings through Package 2

Group 2 Buildings	Package 1		Package 1 Total	Package 2		Package 2 Total
	Heating	Cooling		Heating	Cooling	
Building 1	-17,56	60,13	-15,38	-47,34	48,69	-44,65
Building 8	-10,06	34,99	-9,41	-42,63	-23,98	-42,36

Figure 6.12 shows that the comparisons of Package 1 and Package 2 with the base cases of buildings in terms of heating and cooling energy consumption on annual basis.

Individual operational solutions provided minor energy savings for Group 2 Buildings. Nevertheless, the solutions can be considered as favourable in terms of not damaging the building envelope and appearance, although Group 2 Buildings do not officially registered. Among individual solutions, the strategy of the use of oriels as a sunspace could not conduct for only Building 8. Apart from this, all solutions showed the same result for heating energy consumption while cooling energy consumption rates became different from each other. But, it can be said that the nighttime ventilation strategy is more effective for reducing cooling energy consumption (Table 6.14).

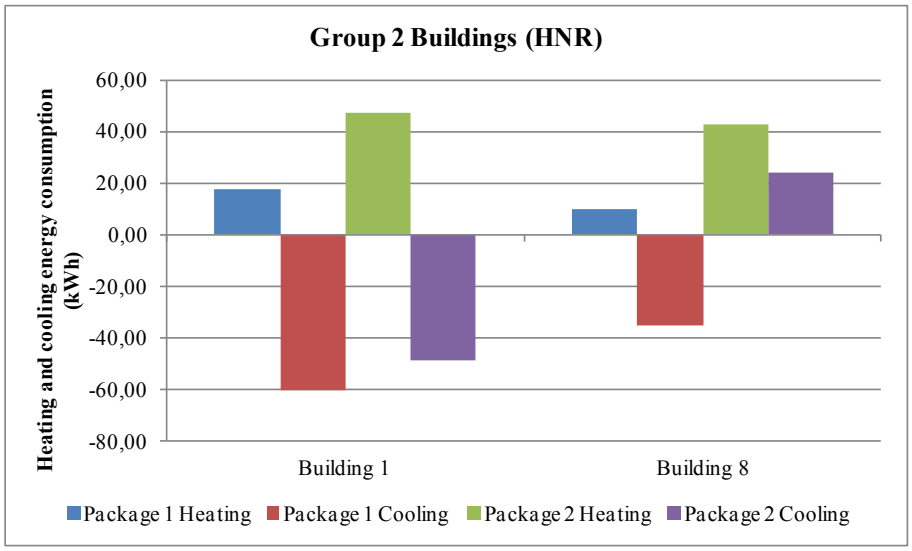


Figure 6.12. Comparison of Package 1 and Package 2 with the base cases of Group 2 Buildings regarding heating and cooling of annual energy consumption

Table 6.14. The rate of change in energy consumptions compared to the base cases of Group 2 Buildings through individual operational solutions

Group 2 Buildings	Use of oriels as a sunspace			Nighttime ventilation			Shading control		
	Heating	Cooling	Total	Heating	Cooling	Total	Heating	Cooling	Total
Building 1	-1,7	2,6	-1,6	-1,7	-19,4	-2,2	-1,7	-20,1	-2,2
Building 8				-2,9	-34,9	-3,4	-2,9	2,0	-2,8

The overall results of Group 2 Buildings culminated in major energy savings on the package basis. Nevertheless, Package 2 has the highest energy reduction for the case buildings compared to Package 1. The reasons are that Package 2 predominated over Package 1 in terms of the number of solutions and effectiveness of some solutions on energy savings. Therefore, internal insulation of external walls and changing windows may be considered to be more effective among all solutions of Package 2 due to the majority of surface area where the solutions are applied on the building envelope.

6.3. The Results of Retrofit Solutions belonging to Group 3 Buildings (C)

Group 3 Buildings are composed of contemporary buildings having no historic and heritage value. Two retrofit packages including Package 1 and Package 2 and also

operational retrofit solutions are determined for this group. While Package 1 includes the solutions applied to the only vertical building components, i.e. walls, windows and doors, Package 2 is composed of both vertical and horizontal building components. This section presents the results of Package 1 and Package 2 and the individual results of operational solutions for Group 3 Buildings.

6.3.1. The Results of Package 1 for Group 3 Buildings (C)

Via application of Package 1, it is possible to provide a considerable amount of energy saving for most Group 3 Buildings. As is evident from Figure 6.13, the highest decrease in total energy consumption occurred in Building 2 by 50,91%. It is followed by Building 11 (44,06%), Building 6 (36,41%), Building 13 (27,9%), Building 10 (19,9%), Building 9 (16,22%), Building 3 (9,83%) and Building 16 (9,26%) compared to base case results of Group 3 Buildings.

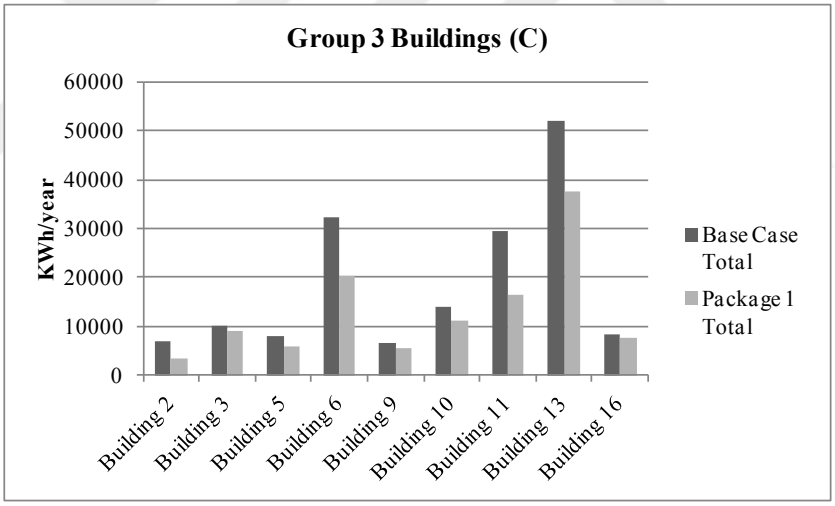


Figure 6.13. Comparison of total energy consumptions with and without retrofits on the annual basis for Package 1

6.3.2. Assesment of Package 2 for Group 3 Buildings (C)

It was aimed to observe the total effect of all retrofit solutions that cause changes on the building components by vertically and horizontally. The results showed that the Package 2 provides substantially decline in total energy consumption for most Group 3

Buildings. Building 11 hold the highest energy saving rate by 67,05%. It is followed by Building 3 (51,82%), Building 6 (51,41%), Building 16 (48,42%), Building 10 (43,37%), Building 3 (39,48%), Building 13 (36,39%) and Building 5 (27,9%) (Figure 6.14).

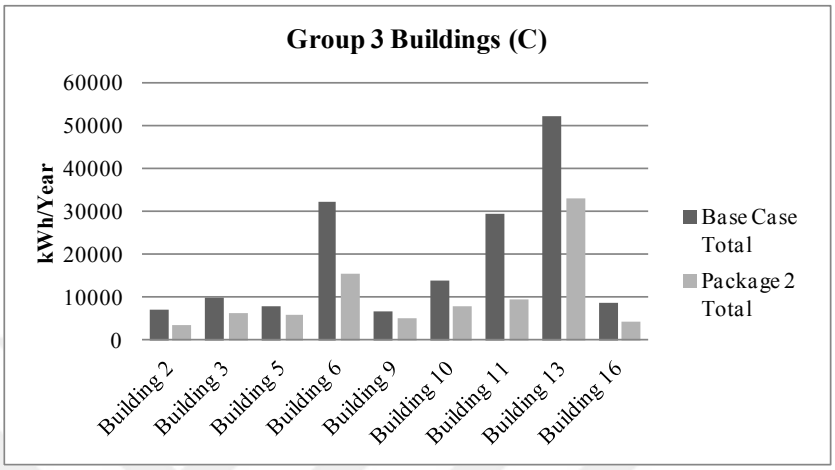


Figure 6.14. Comparison of total energy consumptions with and without the retrofits on the annual basis for the Package 2 for Group 3 Buildings

6.3.3. Assessment of Operational Solutions for Group 3 Buildings (C)

Operational solutions for Group 3 Buildings include two retrofit solutions including shutter control and nighttime ventilation. The use of oriels as sunspace is out of this type of solutions since no building has an oriel in this group. Moreover, shutter control has been conducted for all Group 3 Buildings by adding new shutters to all existing windows. However, both shutter control and nighttime ventilation strategy could not be conducted for building 16, because it has no glazing.

Implementation of new shutters on existing windows results in slight energy saving for most Group 3 Buildings. On the other hand, there is an increase of 0,1% and 12,1% in energy consumption for Building 5 and 9, respectively. Moreover, the highest reduction occurred in Building 3 by 36%, followed by Building 11 (13,6%), Building 6 (9,1%), Building 2 (3,9%), Building 10 (1%) and Building 13 (0,4%) (Figure 6.15).

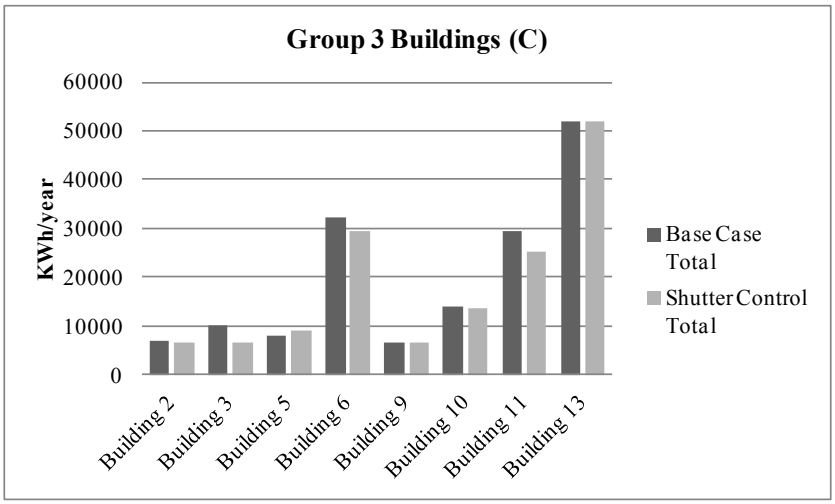


Figure 6.15. Comparison of total energy consumptions with and without retrofits on the annual basis for shutter control for Group 3 Buildings

The nighttime ventilation gave close results with shutter control. There is 0,3% and 12,2% increase in energy consumption for Building 5 and 9, respectively. In terms of decreasing total energy consumption, the best result was obtained from Building 3 by 34,5% while Building 10 has the lowest energy saving by 1%. The rates of energy consumption reduction of the other buildings were presented as follows; Building 11 is 15,3%, Building 6 is 9,1%, Building 2 is 3,2% and Building 13 is 1,1% (Figure 6.16).

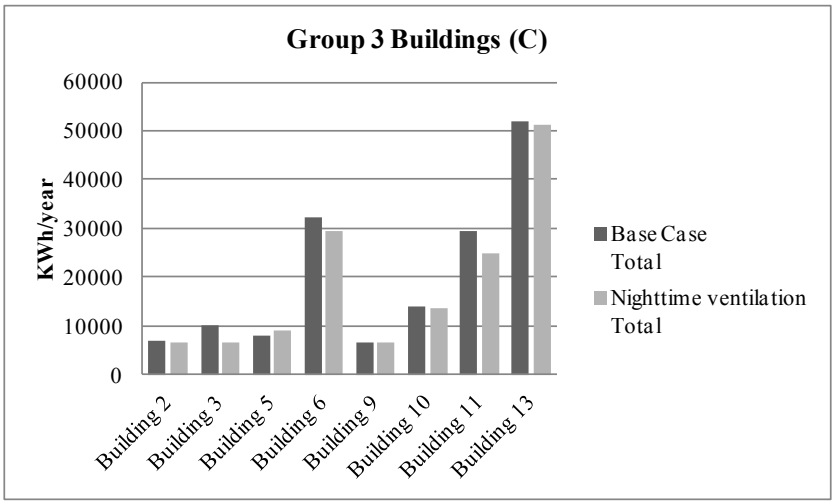


Figure 6.16. Comparison of total energy consumptions with and without retrofits on the annual basis for nighttime ventilation strategy for Group 3 Buildings

6.3.4. Assessment of Retrofit Packages for Group 3 Buildings (C)

In previous sections, retrofit packages including Package 1 and Package 2, and individual operational solutions covering shutter control and nighttime ventilation strategy have been conducted for Group 3 Buildings. Moreover, the results of each packages and individual operational solutions were presented. This section focuses on an overview about all retrofit packages, individual solutions and discusses their comparisons with each other and the base case results of buildings in terms of heating, cooling and total energy consumptions on annual basis.

The results of annual heating energy consumption showed that there occurred significant differences between Package 1 and Package 2 for most of Group 3 Buildings. However, there occurred slight increases for energy saving in Building 2 (0,75%) and Building 5 (0,89%) through the implementation of Package 2 after Package 1. The highest energy reduction for heating occurred in Building 11 (67,43%) through Package 2, while the lowest one resulted in Building 16 (9,3%) by Package 1 (Table 6.15).

The results of cooling energy consumption on annual basis indicated that there was a significant increase for most Group 3 Buildings through the implementation of Package 2 in comparison to Package 1. However, less energy was saved by Package 2 (16,4%) compared to Package 1 (43,7%) for Building 6. The highest reduction for cooling energy consumption occurred in Building 16 (83,59%) through the implementation of Package 2 while Package 1 caused to the lowest reduction of 8,77% in Building 16 (Table 6.15).

Regarding total annual energy consumption, although Package 2 saved more energy than Package 1, both two retrofit packages provided significant energy savings for all Group 3 Buildings. Besides, there occurred a slight difference in energy saving between Package 1 and Package 2 for Building 2 and Building 5. Maximum energy saving rate was 67,5% for Building 11 through Package 2, while minimum one occurred in Building 16 (9,26%) (Table 6.15).

Table 6.15. The rate of change in energy consumptions compared to the base cases of Group 2 Buildings through Package 1 and Package 2

Group 3 Buildings	Package 1		Package 1 Total	Package 2		Package 2 Total
	Heating	Cooling		Heating	Cooling	
Building 2	-51,74	-35,14	-50,91	-52,49	-39,01	-51,82
Building 3	-9,31	-13,82	-9,83	-35,13	-72,95	-39,48
Building 5	-26,12	-49,91	-26,88	-27,01	-54,75	-27,90
Building 6	-36,25	-43,70	-36,41	-52,15	-16,40	-51,41
Building 9	-15,50	-41,25	-16,22	-25,29	-46,88	-25,89
Building 10	-18,95	-54,58	-19,90	-43,83	-26,65	-43,37
Building 11	-44,93	-26,32	-44,06	-67,43	-59,27	-67,05
Building 13	-27,56	-40,40	-27,90	-36,14	-45,66	-36,39
Building 16	-9,30	-8,77	-9,26	-45,51	-83,59	-48,42

Figure 6.17 shows the comparisons of Package 1 and Package 2 with the base cases of Group 3 Buildings in terms of heating and cooling energy consumption on annual basis.

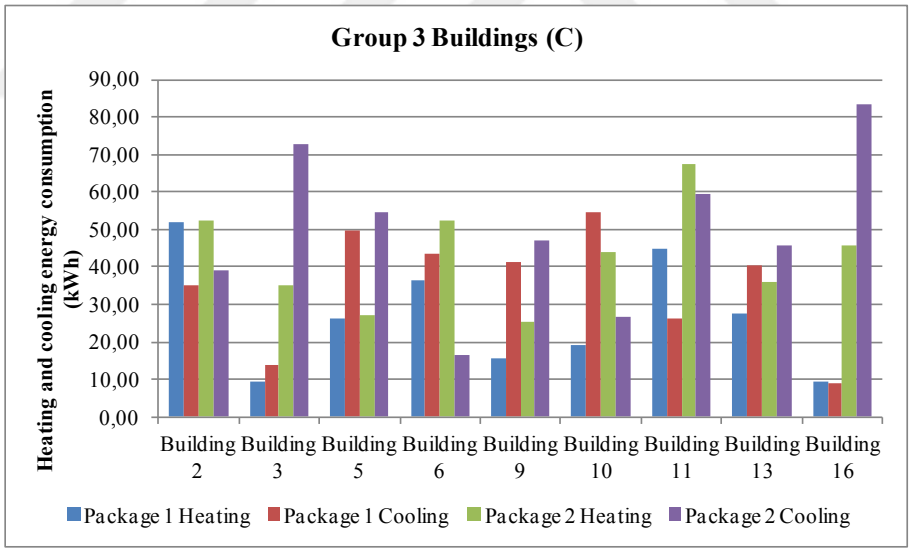


Figure 6.17. Comparison of Package 1 and Package 2 with the base cases of Group 3 Buildings regarding heating and cooling of annual energy consumption

Individual operational solutions provided more energy savings compared to the other building groups. Both of the strategies including nighttime ventilation and shutter control gave close results for heating and cooling energy consumptions. Shutter control resulted in more energy saving for Building 2 and 3 with a marked difference. On the

other hand, the nighttime ventilation strategy is more effective on Building 11 and 13 compared to shutter control for cooling energy consumption.

Table 6.16. The rate of change in energy consumptions compared to the base cases of Group 3 Buildings through individual operational solutions

Group 3 Buildings	Nighttime ventilation			Shutter Control		
	Heating	Cooling	Total	Heating	Cooling	Total
Building 2	-0,9	-46,4	-3,2	-0,9	-60,9	-3,9
Building 3	-30,2	-67,8	-34,5	-30,2	-80,5	-36,0
Building 5	12,3	10,0	12,2	12,3	6,8	12,1
Building 6	-8,9	-14,9	-9,1	-8,9	-14,9	-9,1
Building 9	0,0	12,3	0,3	0,3	-4,8	0,1
Building 10	-0,5	-22,3	-1,0	-0,5	-21,1	-1,0
Building 11	-13,9	-43,7	-15,3	-13,9	-7,9	-13,6
Building 13	-0,3	-33,4	-1,1	-0,3	-4,3	-0,4
Building 16	4,6	3,0	4,5			

The overall results of Group 3 Buildings resulted in major energy savings on the package basis. Differently from the other building groups, Package 1 and Package 2 gave results for Group 3 Buildings except for Building 3, 10 and 16. However, it was observed that Package 2 solutions are more effective on Group 3 Guildings than package 1.

6.4. General Evaluation of Retrofit Solutions for Case Buildings

Group 1 Buildings represents 50% of the case buildings. Group 2 Buildings constitutes 9% of the case buildings and the rest 41% is Group 3 Buildings. General evaluation of the results of total energy consumption is presented as follows:

Evaluation among Building Categorizations: For Group 1 Buildings, Package 1 (the neutral solutions) provided average 15,11% energy saving while the highest energy savings is 50,90% obtained from Package 2 (the combination of the low risk and neutral solutions). Considering Group 2 Buildings, 11,93% of energy saving achieved by implementing Package 1 (the neutral solutions) while Package 2 (the combination of the low risk and neutral solutions) provided 43,33% of energy saving. Regarding Group 3 Buildings, Package 1 (the retrofit solutions for vertical building components) provided

30,11% energy saving for Group 3 Buildings. Package 2 (the combination of solutions for both vertical and horizontal building components) resulted in 50,90% of energy saving rate (Table 6.17).

Among all building categories, Package 2 achieved the maximum energy saving of 50, 90% while the minimum energy saving rate of 11,93% was obtained from Package 1. It is deduced that for all building groups, Package 2 saved considerably more energy than Package 1. Only for Group 3 Buildings, there occurred a close energy saving result between Package 1 and Package 2 compared to the other building groups (Table 6.17). On the other hand, Package 2 carries a risk for Group 1 and Group 2 Buildings due to the low-risky solutions and causing more intervention on buildings' envelope as against Package 1.

Regarding the individual operational solutions, the strategy of shutter control provided the highest energy saving of 5,25% for Group 1 Buildings while the strategy of use of oriels as sunspace resulted in the lowest energy saving rate 1,45%. For Group 2 Buildings, three individual operational solutions presented a slightly same result with 4%. As to Group 3 Buildings, two individual solutions have been conducted and they showed very close results.

Among all building groups, the nighttime ventilation strategy saved the highest energy of 6,81% for Group 3 Buildings. The minimum energy saving rate of 1,45% was obtained from the strategy of use of oriels as sunspace for Group 1 Buildings. Morever, the nighttime ventilation is the most effective solution in terms of energy saving among individual operational solutions.

Individual operational solutions provided minor energy savings in comparison to the solution included in packages for case building groups. Although these individual solutions do not provide as effective energy savings as the packages, they do not cause any changes on buildings' envelope; therefore these solutions have an importance in terms of protecting the the heritage values and the characteristics of Group 1 and Group 2 Buildings.

Evaluation of All Case Buildings: For all case buildings, the maximum energy saving was provided by Package 2 with 48,57% while minimum energy saving obtained from Package 1 with 19,8% (Table 6.18).

Table 6.17. Evaluation of the enegy consumption results among building categories

%	Retrofit Packages		Individual Operational Solutions		
	Package 1	Package 2	Use of oriels as sunspace	Nighttime ventilation	Shutter control
Group 1 Buildings	-15,11	-50,90	-1,45	-4,96	-5,25
Group 2 Buildings	-11,93	-43,33	-4,49	-4,40	-4,35
Group 3 Buildings	-30,11	-45,83	_	-6,81	-6,38

Table 6.18. Evaluation of the enegy consumption results for retrofit packages in all case buildings

All Case Buildings	**Annual Energy Consumption**		
	Base Case	Package 1	Package 2
Total (kWh)	506924	406568	260735

Among individual operational solutions, the nighttime ventilation and shutter control provided slightly same energy savings. The energy saving rate is 5,2% and 5,4%, for the nighttime ventilation and shutter control respectively. Use of oriels as sunspace resulted in a minor energy saving rate of 1,5% for all case buildings (Table 6.19).

Table 6.19. Evaluation of the enegy consumption results for individual operational solutions in all case buildings

All Case Buildings	**Annual Energy Consumption**			
	Base Case	Use of oriels as sunspace	Nighttime ventilation	Shutter control
Total (kWh)	506924	191837	480556	420493

Evaluation of Case Buildings based on Energy Classes: In this section, all building groups were evaluated according to the energy classes for energy consumption. For new and existing buildings, Building Energy Performance Regulation of Turkey stipulates for preparing a 'Building Energy Certificate' that includes a classification of energy performance varying between A (the best) and G (the worst). According to the Regulation, the new buildings are required to have class-C more in the sense of energy consumption. Although there is no restriction about energy class of historic buildings, Group 1 Buildings are included in this evaluation. Building energy classes are composed of seven categories and calculated according to the purpose of use and heating region (Bayındırlık ve İskân Bakanlığı, 2008) (Table 6.20).

Table 6.20. Energy Classes based on Primary Energy Consumption
(Adapted from Bayındırlık ve İskân Bakanlığı, 2008)

Building Energy Classes	Energy Classes based on Primary Energy Consumption (kWh/m².year)	Residential (Single/Double Houses)	Residential (Apartments)	Commercial
A	EP < 0,4*RG	EP < 66	EP < 72	EP < 96
B	0,4*RG ≤ EP <0,8*RG	66 ≤ EP <132	72 ≤ EP <144	96 ≤ EP <192
C	0,8*RG ≤ EP < RG	132 ≤ EP < 165	144 ≤ EP < 180	192 ≤ EP < 240
D	RG ≤ EP < 1,20*RG	165 ≤ EP < 192	180 ≤ EP < 216	240≤ EP < 288
E	1,20*RG ≤ EP < 1,40*RG	192 ≤ EP < 231	216 ≤ EP < 252	288≤ EP < 336
F	1,40*RG ≤ EP < 1,75*RG	231 ≤ EP < 289	252 ≤ EP < 315	336≤ EP < 420
G	1,75*RG ≤ EP	289 ≤ EP	315 ≤ EP	420≤ EP

Energy class of the buildings is determined calculating annual primary energy consumption per unit occupied floor area. Therefore, the primary energy consumption of each building was calculated for the base cases and retrofitted cases of buildings. Table 6.21, Table 6.22 and Table 6.23 present the primary energy consumptions and energy classes of the base and retrofitted cases of Group 1, Group 2 and Group 3 Buildings, respectively.

Among Group 1 Buildings (HR), two base case buildings (Building 14 and 20), three buildings with Package 1 (Building 14, 20 and 21) and seven buildings with Package 2 (Building 4, 7, 14, 17-18, 20, 21 and 22) meet the minimum energy class C according to Building Regulation. On the other hand, Building 12, 15 and 19 do not meet minimum energy class C in any cases before and after retrofit.

Package 1 provided the highest change rate on energy class for Building 22 (F-C) compared to base bases. There was no change in energy class for Building 4, 12 and 15 by implementing Package 1. Moreover, by applying Package 2, the highest change rate on energy class occurred in Building 17-18 and 22 (F-B). It was followed by Building 7 and 21 (E-B), Building 19 (G-D), Building 12 and 15 (F-D), Building 4 (E-C), Building 14 and 20 (C-B) compared to the base cases (Table 6.21).

Table 6.21. Primary energy consumptions and energy classes of the base and retrofitted cases for Group 1 Buildings

Group 1 Buildings	Base Case Total (kWh/m²)	Base Case Energy Class	Package 1 (kWh/m²)	Package 1 Energy Class	Package 2 (kWh/m²)	Package 2 Energy Class
Building 4	215,05	E	195,95	E	132,20	C
Building 7	202,25	E	174,40	D	94,71	B
Building 12	278,61	F	246,71	F	181,91	D
Building 14	143,52	C	128,58	B	68,85	B
Building 15	281,06	F	261,41	F	166,57	D
Building 17-18	247,14	F	216,66	E	105,92	B
Building 19	294,44	G	241,56	F	165,81	D
Building 20	149,90	C	126,95	B	93,57	B
Building 21	197,56	E	183,52	D	81,44	B
Building 22	256,66	F	138,46	C	70,31	B

Table 6.22. Primary energy consumptions and energy classes of the base and retrofitted cases for Group 2 Buildings

Group 2 Buildings	Base Case Total (kWh/m²)	Base case Energy Class	Package 1 (kWh/m²)	Package 1 Energy Class	Package 2 (kWh/m²)	Package 2 Energy Class
Building 1	130,58	B	114,12	B	76,75	B
Building 8	257,70	F	235,66	F	149,44	C

Table 6.23. Primary energy consumptions and energy classes of the base and retrofitted cases for Group 3 Buildings

Group 3 Buildings	Base Case Total (kWh/m²)	Base case Energy Class	Package 1 (kWh/m²)	Package 1 Energy Class	Package 2 (kWh/m²)	Package 2 Energy Class
Building 2	426,99	G	209,61	C	205,74	C
Building 3	293,56	E	264,69	D	177,65	B
Building 5	389,43	F	237,58	C	234,28	C
Building 6	117,72	B	74,63	B	58,33	A
Building 9	325,13	E	272,39	D	240,94	D
Building 10	159,92	C	126,16	B	91,49	B
Building 11	203,05	D	115,73	B	67,85	A
Building 13	156,28	C	111,99	B	98,89	B
Building 16	506,16	G	459,27	G	261,06	D

Considering Group 2 Buildings (HNR), the base case and all package results of energy classes were found as energy class B for Building 1. For Building 8, energy classes of both base case and Package 1 were found as energy class F, which is not acceptable in Building Regulation of Turkey. Through Package 2, Building 8 reached minimum energy class (C), which is minimum acceptable level in Building Regulation of Turkey (Table 6.22).

Among Group 3 Buildings, two base case buildings (Building 10 and 13), six buildings with Package 1 (Building 2, 5, 6, 10,11 and 13) and seven buildings with Package 2 (Building 2, 3, 5, 6, 10, 11 and 13) meet the requirements for energy class. Moreover, Building 6 showed a favourable energy class (B) for its base case. After the implemention of Package 1, the majority of case buildings resulted in energy class B and C. Through Package 1, the highest change rate in energy class (G-C) was provided in Building 2. Energy class of Building 16 did not change compared to the base cases. Through Package 2, energy classes of most buildings found in energy class B. The highest change rate of energy class occured in Building 2 (G-C). It was followed by Building 3 (E-B), Building 5 (F-C), Building 11 (D-A), Building 16 (G-D), Building 6 (B-A), Building 13 (C-B) and Building 9 (E-D) compared to the base cases (Table 6.23).

For all building groups, Package 2 provided the highest improvements on energy classes compared to Package 1. Moreover, Group 3 Buildings showed the better performance in energy classes in comparison to the other building groups.

Evaluation of the Relationship between Design Parameters and Building Energy Consumption: Pearson correlation analysis is conducted to find the most influential bulding design parameters on existing annual energy consumption of the buildings. Therefore, seven design parameters about buildings' form have been evaluated:

- Total surface area (m^2) to conditioned volume (m^3) ratio (S/V)
- Window area (m^2) to wall area (m^2) ratio (WWR)
- Window to wall ratio (WWR) for main façades face to the street
- Shape factor (building length (m) to depth (m))
- Usable ground floor area (m^2) to conditioned volume (m^3)
- Total usable floor area (m^2) to conditioned volume (m^3)
- Building height (m) to plan depth (m)

The calculated values of these parameters belonging to each case building are presented as follows (Table 6.24):

Table 6.24. The calculated values for design parameters of all case buildings

All Building Groups	Total energy consumption (kWh)	Total window to wall ratio (WWR)	WWR Main façade faces to street	Total surface area (m²) to conditioned volume (m³) (S/V)	Length (m) / Depth (m)	Usable ground floor area/volume m²/m³	Total usable floor area/ volume m²/m³	Height (m) / Depth (m)
Building 1	18546,45	14,83	16,86	0,89	2,26	0,179	0,366	1,27
Building 2	6980,19	10,82	3,48	1,36	0,51	0,215	0,21	0,52
Building 3	10072,96	12,6	31,55	1,28	1,40	0,338	0,34	0,45
Building 4	9750,90	1,54	7,79	1,51	0,57	0,179	0,36	0,78
Building 5	8030,71	9,17	46,4	1,40	0,67	0,290	0,29	0,37
Building 6	32205,86	5,58	20,14	0,80	0,58	0,138	0,36	0,74
Building 7	27693,98	7,08	11,19	1,16	1,84	0,246	0,41	1,10
Building 8	25414,80	4,25	19,04	1,08	0,74	0,157	0,31	0,78
Building 9	6670,72	4,83	18,86	1,56	0,84	0,178	0,36	0,85
Building 10	13831,17	7,96	12,88	1,02	0,73	0,240	0,38	0,70
Building 11	29327,03	12,13	51,91	1,16	0,96	0,148	0,45	1,63
Building 12	18834,18	6,37	21,11	1,58	0,98	0,181	0,38	1,06
Building 13	51986,99	5,51	14,63	0,64	0,79	0,104	0,31	0,74
Building 14	47009,47	3,87	16,66	0,88	0,58	0,151	0,49	0,64
Building 15	26581,31	3,76	19,84	1,14	0,66	0,147	0,29	0,64
Building 16	8538,26	-	-	1,96	2,58	0,395	0,40	1,50
Building 17-18	47314,48	8,33	19,02	1,23	2,61	0,182	0,34	1,25
Building 19	35287,91	6,28	28,3	1,33	0,41	0,185	0,36	0,77
Building 20	23614,83	5,56	16,85	1,29	0,55	0,221	0,51	0,95
Building 21	17631,81	3,41	17,33	1,17	0,67	0,170	0,34	0,74
Building 22	41600,29	11,74	19,9	0,81	1,41	0,182	0,37	0,75

According to Pearson correalation analysis, all variables are evaluated for all case buildings and Pearson correlation coefficients were presented. Among the variables, surface to volume ratio (S/V) and usable ground floor area (m^2) to conditioned volume (m^3) are negatively and significantly related to total energy consumption of buildings. Hence, it means that buildings that have higher levels of S/V and usable ground floor area (m^2) to conditioned volume (m^3) are likely to experience lower energy consumption (Table 6.25).

Width/length, total usable floor area and building height to depth, on the other hand, are the variables are positively related to energy consumption although the correlation is statistically insignificant (Table 6.26).

Table 6.25. Pearson correlation coefficients

Design Parameters	r value
WWR	-0.100082
WWR façade to facade	-0.012648
S/V	-0.660320***
Width/Length	0.219320
Ground floor area	-0.565679***
Total Usable Floor Area	0.289929
Height/Depth	0.260149

*** represents statistical significance at 1 %

Table 6.26. The relationship between design parameters and Pearson correlation coefficients

Pearson coefficient analysis	WWR	WWR façade to facade	S/V	Width/Length	Ground floor area/ volume	Total Usable Floor Area	Height/Dept
r value	-0.100082	-0.012648	-0.660320***	0.219320	-0.565679***	0.289929	0.260149
Relation	Very low	Very low	Medium	Very low	Medium	Very low	Low

CHAPTER 7

CONCLUSION

Energy-efficient retrofit of historic urban fabric has been a prominent subject of research in the last decade beyond the studies associated with conservation principles. Specifically in urban areas, historic buildings differ from existing building stock by their inherent characteristics such as sustainable material use, construction type, spatial decisions and better relation to the environment as well as the heritage value.

Considering historic buildings, it is crucial to ensure proper re-use to meet modern-day requirements, enhance comfort conditions, i.e. thermal and visual and reduce user expences, and to maintain distinctive characteristics as well as prevent rises in energy demand. However, they could not be treated similar to other existing buildings when considering energy-efficient retrofit works. Historic buildings require a methodical approach, conprehensive analysis and case-specific solutions.

This thesis presents a study at a neighbourhood scale, consisting of totally 22 historic and contemporary buildings with residential and commercial use in a historic urban fabric of İzmir, Turkey. The Metropolitan Municipality of İzmir has been prepared a façade rehabilitation project for 1273 Street. In the scope of the project, surveying, restitution and restoration projects of the façades of buildings facing 1273 Street and architectural elements defining street fabric, i.e. courtyard walls, annexes, wells and urban furnitures have been prepared. Within this project, energy-efficient approach is not considered on the physical improvement process.

This study showed an energy-efficient approach to the buildings located in 1273 Street. It principally aimed at improving energy performance of the buildings' envelope by proposing energy-efficient retrofit solutions in different impact categories, while protecting and maintaining the heritage value of historic buildings and character.

A quick survey has been developed to provide data to envelope-based retrofit study. Documentation, on-site measurements and short interviews with the building occupants were carried out to collect the information about the buildings' components, geometry, materials, structural and façade properties within site investigations. Data sheets for each case building were prepared and the collected information has been

recorded in these data sheets. In the direction of the collected information, 3D BPS models of case buildings were created by using DesignBuilder dynamic simulation tool to calculate annual energy consumptions and observe the effects of the retrofit solutions after determining energy-efficient retrofit packages for the case buildings. The study also discussed the relationship between the most-related design parameters for all building groups and the values of total annual energy consumption of the case buildings' envelope.

Three building groups including Group 1, Group 2 and Group 3 were generated based on the heritage value assessment. Group 1 consists of 11 officially registered historic buildings of high importance considering the heritage value. Group 2 has two buildings which are not officially registered but having façade characteristics compatible with the historic fabric. Lastly, Group 3 is composed of nine contemporary buildings. Therefore, two separate retrofit packages (Package 1 and Package 2) and three individual operational solutions (the nighttime ventilation strategy, shutter control and use of oriels as sunspace) are implemented for each group of case buildings.

The simulation results of Group 1 Buildings (HR) indicated that, Group 1-Package 2 presented major reductions in total energy consumption of case buildings. For total energy and cooling energy consumptions, Building 22 presented the highest energy saving potential among Group 1 Buildings. For heating consumption, the highest reduction occurred in Building 19. On the other hand, individual operational solutions have no considerable effect on energy consumption of Group 1 Buildings except for Building 22. Building 22 has the most energy saving potential through the nighttime ventilation strategy. The two façade facing the street and glazing surface area on the façades may be the reasons of the energy saving potential of Building 22.

Regarding energy classes for Group 1 Buildings (HR), the highest energy class change rate (from F to C) occurred in Building 22 with Package 1 and Package 2. However, Building 12, 15 and 19 did not meet minimum energy class (C) and their energy class remained at energy class D after the implementation of Package 2. Furthermore, although Building 22 presented the highest energy saving potential, it did not rank foremost among the most-related design parameters (S/V and usable ground floor area (m^2) to conditioned volume (m^3)) with energy consumption.

The simulation results of Group 2 Buildings (HNR) showed that, Group 2-Package 2 provided the highest energy saving rates in total energy consumption. Building 1 presented the most energy saving potential compared to Building 8.

Although, two packages reduced the total energy consumptions, they caused an increase in heating and cooling consumptions of Group 2 Buildings (HNR), except for cooling consumption for Building 8 by Package 2. Among the individual operational solutions, the nighttime ventilation strategy has the most energy saving potential for Building 8.

Considering energy classes of Group 2 Buildings, the energy class did not change through the packages and all situations presented a favuorable energy class (B) for Building 1. On the other hand, only Package 2 provided minimum energy class (C) for Building 8. For design parameters, there is no strong relationship between the design parameters and energy consumptions for Group 2 Buildings (HNR).

The simulation results of Group 3 Buildings (C) showed that, there was no marked difference in total energy consumption between Package 1 and Package 2, except for Building 3 and 16. The highest energy saving rate occurred in Building 11 with Package 2. For heating energy consumption, the highest energy saving potential existed in Building 11 while Building 16 had the highest energy reduction rate for cooling energy consumption. Morever, no increase was observed in cooling energy consumptions in Group 3 Buildings (C). Among the individual operational solutions, Buildings 3 presented the highest energy saving potential through shutter control strategy with a significant difference compared to the other Group 3 Buildings (C). Moreover, this is the highest energy saving potential among all building groups for individual operational solutions.

As for energy classes, the most energy class change occurred in Group 3 Buildings compares to other building groups. The highest change rate of energy class occured in Building 2 (from G to C). Building 6 and 11 reached the highest energy class (A) after the implementation of Package 2. However, Building 9 and 16 did not meet minimum energy class and they remained at energy class D after Package 2.

Integrated Approach to Identify Case-specific Energy-efficient Solutions for Retrofit Strategy of Larger Scale Historic District: For larger scale studies, the need of developing a retrofit strategy has been confronted while deciding solutions to which buildings providing the most energy saving in a short time. Moreover, in cases with limited building data, it is required to focus on accessable data derived from building envelope with a quick field survey. In this scope, this thesis introduces an integrated approach to identify case-specific energy efficient solutions for retrofit strategy of larger scale historic district.

This approach is composed of eight main steps. The approach starts with the determination of a number of design parameters related to energy consumption of buildings. The most-related parameters were identified among design parameters. Then, identified parameters within themselves are sorted and 50% of buildings consuming more energy are determined. The same building(s) in each identified design parameter are determined. Moreover, BPS model of the determined buildings are created and their annual energy consumption are calculated. Energy classes of the buildings considering primary energy consumption are defined. Following, the buildings meet the minimum energy class (C) and above (B and A) are eliminated and the retrofit solutions / packages have been decided to apply in the rest of building(s)' BPS model. Finally, the building(s) are decided that meet minimum energy class (C) (Table 7.1).

Table 7.1. An integrated approach to identify case-specific energy efficient solutions for retrofit strategy of larger scale historic district

1	• Determination of the design parameters related to annual energy consumption of buildings
2	• Identification of the most-related ones among the design parameters
3	• Sorting identified parameters within themselves and determination of 50% of buildings consuming more energy
4	• Determination of same building(s) in each identified design parameter
5	• Creation of determined building(s)' BPS model and calculation of their annual energy consumption
6	• Identification of energy classes based on primary energy consumption of the building(s)
7	• Elimination of the building(s) that meet minimum energy class (C) and application of retrofit solutions/ packages in the rest of building(s)' BPS model
8	• Determination of the building(s) that meet minimum energy class (C)

Through the findings from the relationship between the design parameters and energy consumption results of the case buildings, the retrofit strategy of this study is presented. In this study, two most influential parameters including S/V ratio and usable ground floor area (m^2) to conditioned volume (m^3) are determined and sorted from minimum value to maximum value. 50% of case buildings consuming more energy are

identified based on design parameters. 50% of case buildings corresponded to 11 case buildings and after the sorting process, the number of case buildings decreased to eight. Identified case buildings as signed 50% were shown in Figure 7.1 (a) for S/V ratio and Figure 7.1 (b) for usable ground floor area (m^2) to conditioned volume (m^3) ratio. Then, same buildings in both parameters were determined as shown in blue coloured in Figure 7.1.

50%

All case buildings	Total surface area (m^2) to conditioned volume (m^3) (S/V)
Building 13 (C)	**0,64**
Building 6 (C)	**0,80**
Building 22 (HR)	0,81
Building 14 (HR)	**0,88**
Building 1 (HNR)	**0,89**
Building 10 (C)	1,02
Building 8 (HNR)	**1,08**
Building 15 (HR)	**1,14**
Building 7 (C)	1,16
Building 11 (C)	**1,16**
Building 21 (HR)	**1,17**
Building 17-18 (HNR)	1,23
Building 3 (C)	1,28
Building 20 (HR)	1,29
Building 19 (HR)	1,33
Building 2 (C)	1,36
Building 5 (C)	1,40
Building 4 (HR)	1,51
Building 9 (C)	1,56
Building 12 (HR)	1,58
Building 16 (C)	1,96

(a)

50%

All case buildings	Usable ground floor area/volume m^2/m^3
Building 13 (C)	**0,104**
Building 6 (C)	**0,138**
Building 15 (HR)	**0,147**
Building 11 (C)	**0,148**
Building 14 (HR)	**0,151**
Building 8 (HNR)	**0,157**
Building 21 (HR)	**0,170**
Building 9 (C)	0,178
Building 4 (HR)	0,179
Building 1 (HNR)	**0,179**
Building 12	0,181
Building 22 (HR)	0,182
Building 17-18 (HNR)	0,182
Building 19 (HR)	0,185
Building 2 (C)	0,215
Building 20 (HR)	0,221
Building 10 (C)	0,240
Building 7 (C)	0,246
Building 5 (C)	0,290
Building 3 (C)	0,338
Building 16 (C)	0,395

(b)

Figure 7.1. The determined and sorted case buildings based on S/V ratio (a) and usable ground floor area (m^2) to conditioned volume (m^3) ratio

Energy classes of the same buildings based on primary energy consumption were presented. Then, the buildings that meet minimum energy class (C) in base cases were eliminated. These buildings are Building 1 (HNR), 6 (C), 13 (C) and 14 (HR). Finally, the rest four buildings including Building 8 (HNR), 11 (C), 15 (HR) and 21 (HR) were evaluated according to the enegy class change of the retrofit packages. Building 15 (HR) was disregarded in the evaluation, because Package 1 and Package 2 did not cause any change on energy class of this building. Finally, three buildings

(Building 8 (HNR), 11 (C) and 21 (HR)) that do not meet minimum energy class (C) were determined as the buildings can be initially retrofitted (Table 7.2).
Package 1 solutions provided an improvement for only Building 11 (C) from D to B. Package 2 solutions provided an improvement for Building 8 (HNR) from F to C, for Building 21 (HR) from E to B and for Building 11 (C) from D to A.

Table 7.2. Energy classes of the same buildings based on primary energy consumption

Case buildings	Base Case Energy Class	Package 1 Energy Class	Package 2 Energy Class
Building 13	C	B	B
Building 6	B	B	A
Building 14	C	B	B
Building 1	B	B	B
Building 8	F	F	C
Building 15	F	F	D
Building 11	D	B	A
Building 21	E	D	B

As a conclusion, three buildings which can initially be retrofitted represent each building group in this study. Building 21 (HR) belongs to Group 1 Buildings, Building 8 (HNR) belongs to Group 2 Buildings and Building 11 (C) belongs to Group 3 Buildings. Moreover, through Package 2, Building 8 (HNR) and 21 (HR) are the second most energy saving buildings in their own groups. Package 1 did not gave effective energy saving results for Building 8 (HNR) and 21 (HR). Building 11 (C) has the second most energy saving potential by Package 1 and the most energy saving potantial by Package 2 among Group 3 Buildings (Table 7.3).

General Concluding Remarks: This thesis shows the evidence of the possibility of descreasing energy consumption for a neighbourhood scale study through quick survey analysis. Overall considerations in determining possible energy-efficient retrofit solutions for the building stock hosting both historic and contemporary buildings is a significant contribution in terms of bringing different approaches come together. In this thesis, different approaches, e.g. energy-efficient retrofit of different building groups, were enlightened. This study also revealed the following remarks:

- Necessity of implementing an integrated approach to identify case-specific energy efficient solutions for retrofit strategy of larger scale historic fabric

- Possibility of improving energy efficiency of buildings having different characteristics and heritage significance level
- Requirement of a methodical approach, comprehensive analysis and case-specific solutions for historic urban fabric
- Applicability of the proposed retrofit strategy on how to decide solutions to which buildings providing the most energy saving in a short time

Table 7.3. Prioritized buildings where the retrofit solutions can be applied

9% energy saving by Package 1	9% energy saving by Package 1	44% energy saving by Package 1
60% energy saving by Package 2	42% energy saving by Package 2	67% energy saving by Package 2
Building 21 (HR)	**Building 8 (HNR)**	**Building 11 (C)**

Concluding Remarks for Historic Buildings: The study reveals a number of concerns specifically for historic buildings. There is an argument between conservation principles and energy-efficient approach for historic buildings in the practice and literature. Therefore, proposing energy-efficient retrofit solutions especially for officially registered buildings is a major subject that needs to act with deliberation. It is expected to minimum intervention on historic buildings in terms of conservation principles. In this scope, it is significant to propose the retrofit solutions which do not require intervention and/or require minimum intervention for protecting the heritage value of buildings. If an intervention will be proposed for historic buildings, any retrofit solutions should be thoroughly considered. Particular attention should also be paid to the situations in which retrofit solutions caused. These are the changes on building

construction, increase of the thickness of building components, decrease the volume of conditioned space and the effect of insulation on interior spaces, decoration elements, and details. Another concern is condensation problems for historic buildings after the retrofit implementations. Actually, they have the building envelope which provides moisture balance due to the use of breathable construction materials. Therefore, the selection of breathable retrofit materials is crucial, otherwise it is inevitable that historic buildings' envelope do not breathe and the moisture risk is exposed.

Another concern is that each historic building necessitates a case-specific approach when the energy-efficient retrofit is subject. Each solution may not be appropriate for each building. Moreover, a low-risky solution, i.e. internal insulation of external wall, for a historic building may not take any risk for another historic building.

This study also draws attention to the applicability of TS 825 requirements for historic buildings. In the case of energy-efficient improvements, it is controversial whether historic buildings can be treated as other existing buildings or given them a specific U-value, because there is no restriction about historic buildings in the Building Energy Regulation of Turkey. In this sense, the EU leaves the decision to its Member States on whether or not to enforce the requirements for historic buildings (European Union, 2002; European Union, 2010; European Union, 2012). The recent EPBD remarks that the testing of new solutions for improving the energy performance of historical buildings and sites should be encouraged while safeguarding and preserving heritage values (European Enion, 2012). Furthermore, CEN EN 16883 presents a systematic approach, or procedure, to facilitate the best decisions for historic buildings. It does not presuppose a need for energy improvements in all historic buildings (BSI Committee B/560, 2015). However, there is not an explicit calculation procedure for energy requirements for historic buildings. This situation needs to be discussed in a concensus between energy policy and conservation discipline. In this study, TS 825 requirements has been considered, because there is no calculation procedure.

Further Studies: In the light of the results presented and discussed, the further research would be conducted:

- Geographical Information System (GIS) could be used for querying, analyzing and visualizing of the results obtained from the case buildings because GIS a useful tool for a larger scale studies.
- The scale of the case area and accordingly the number of the investigated buildings could be increased

- The number of examined design parameters can be increased in order to establish more relationships with energy consumption results of buildings
- The number of proposed retrofit solutions and retrofit packages can be increased to observe more comprehensive outcomes.

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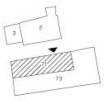
APPENDIX A

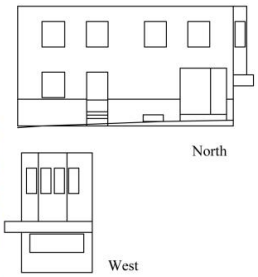
DATA SHEETS PREPARED FOR THE CASE BUILDINGS

Door Number	Street	Building Plot
2	1273. Street	
Number of Floor	Height	
2+1 basement	7.20 m (6.20m+1m subbasement)	

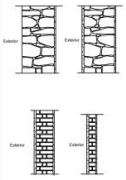
Location:

Building Components

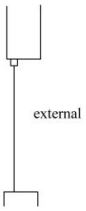
Plan / Façade Scheme



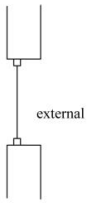
Exterior Walls

Feature	Section
Basement(cm/material): 50 cm/stone Ground(cm/material): 30cm solid brick First(cm/material): 30 cm/solid brick	

External Doors

Feature	Section
Glass: single/double single Basement(cm/material) - Ground(cm/material) Iron First(cm/material) -	 external

Windows

Feature	Section
Glass: single/double single Basement(cm/material) iron frame Ground(cm/material) wooden frame First(cm/material) wooden frame	 external

Construction Period	Construction Type	Courtyard Garden
~1930-1940	Masonry-solid brick	available
Plant on Garden	Waterpond	Well
Lemon and bay tree	-	-
Outer Color	Number of Flat	Occupancy
tile red	2	1

Attic	Oriel
Reinforced concrete floor	available

HVAC Loads

Heating	Cooling
?	?
Fuel Source	Solar Panel
?	?

Notes:

There is an oriel on west façade in the second floor

Building Components

Ground Floor

Feature	Section
Concrete floor	

Ceiling

Feature	Section
Reinforced concrete floor	

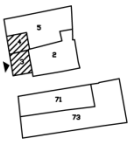
Roof

Feature	Section
Roof Type: Hipped roof Roof Material: wooden and tile Occupied/Unoccupied: Unoccupied	85 cm-overhang

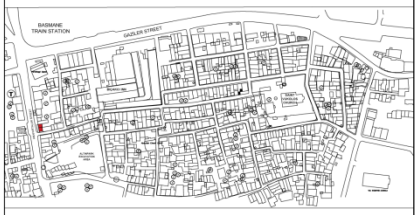
Shadings

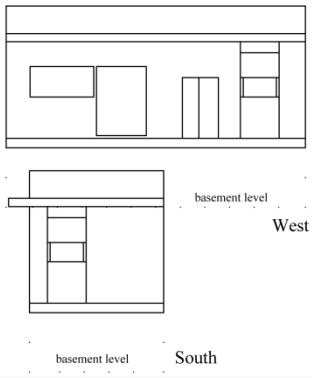
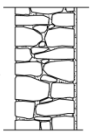
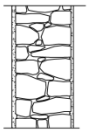
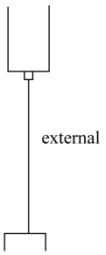
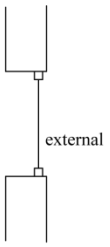
Feature	Section
Iron shutters on windows located on north direction in ground and first floor	

Figure A.1. Data sheet of Building 1

Door Number	Street	Building Plot
866	1273. Street	
Number of Floor	Height	
1	3.50m	

Location:



Building Components			
Plan / Façade Scheme		Exterior Walls	
		Feature: Basement(cm/material): ~50 cm Ground(cm/material): 50 cm-stone First(cm/material): -	Section: external  external 
External Doors		Windows	
Feature	Section	Feature	Section
Glass: single/double single Basement(cm/material) - Ground(cm/material) aliminum First(cm/material) -		Glass: single/double single Basement(cm/material) - Ground(cm/material) aliminum frame First(cm/material) -	

Construction Period	Construction Type	Courtyard Garden
Before 1923	Masonry	-
Plant on Garden	Waterpond	Well
-	-	-
Outer Color	Number of Flat	Occupancy
pink	1	Bookmaker
Roof Floor	Oriel	
-	-	

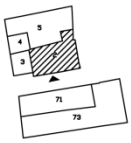
HVAC Loads

Heating	Cooling
air conditioner	air conditioner
Fuel Source	Solar Panel
electricity	-

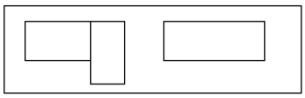
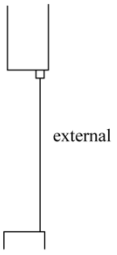
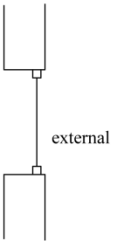
Notes:

Building Components			
Ground Floor		Ceiling	
Feature	Section	Feature	Section
Ceramic tile covering			
Roof		Shadings	
Feature	Section	Feature	Section
Roof Type: Hipped roof Roof Material: Wooden and tile Occupied/Unoccupied: Unoccupied	75 cm-overhang	No shutters on windows	

Figure A.2. Data sheet of Building 2

Door Number	Street	Building Plot
1	1273. Street	
Number of Floor	Height	
1- no basement	2.85 m	

Location:

Building Components			
Plan / Façade Scheme		Exterior Walls	
		Feature	Section
 South		Basement(cm/material): - Ground(cm/material): 20cm brick First(cm/material): -	external
External Doors		Windows	
Feature	Section	Feature	Section
Glass: single/double single Basement(cm/material) - Ground(cm/material) Aluminium First(cm/material) -	 external	Glass: single/double single Basement(cm/material) - Ground(cm/material) Aluminium First(cm/material) -	 external

Construction Period	Construction Type	Courtyard Garden
?	Masonry	-
Plant on Garden	Waterpond	Well
-	-	-
Outer Color	Number of Flat	Occupancy
Champagne	1	Coffeehouse
Roof Floor		Oriel
-		-

HVAC Loads	
Heating	Cooling
?	?
Fuel Source	Solar Panel
?	-

Notes:

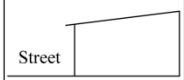
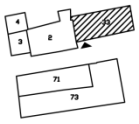
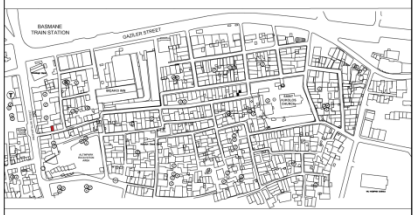
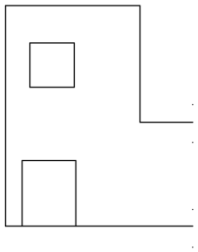
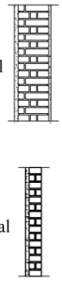
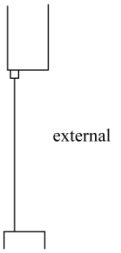
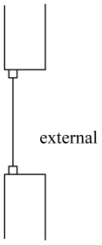
Building Components			
Ground Floor		Ceiling	
Feature	Section	Feature	Section
		PVC ceiling cover	
Roof		Shadings	
Feature	Section	Feature	Section
Roof Type: Pent roof Roof Material: Eternit and metal Occupied/Unoccupied: Unoccupied	Overhang ~ 50 cm  Street	No shutters on windows	

Figure A.3. Data sheet of Building 3

Door Number	Street	Building Plot
3A	1273. Street	
Number of Floor	Height	
2	5.90 m	

Location:



Building Components			
Plan Scheme		Exterior Walls	
		Feature	Section
 South		Basement(cm/material): - Ground(cm/material): ~30 cm solid brick First(cm/material): ~30 cm solid brick	 external external
External Doors		Windows	
Feature	Section	Feature	Section
Glass: single/double single Basement(cm/material) - Ground(cm/material) iron First(cm/material) -	 external	Glass: single/double single Basement(cm/material) - Ground(cm/material) - First(cm/material) wood frame	 external

Construction Period	Construction Type	Courtyard Garden
1930-1940	Masonry	-
Plant on Garden	Waterpond	Well
-	?	?
Outer Color	Number of Flat	Occupancy
Tattletale gray	1	?

Roof Floor	Oriel
-	-

HVAC Loads	
Heating	Cooling
?	?
Fuel Source	Solar Panel
?	-

Notes:

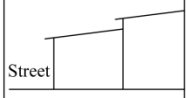
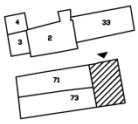
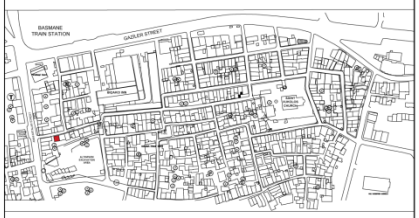
Building Components			
Ground Floor		Ceiling	
Feature	Section	Feature	Section
		Wooden	
Roof		Shadings	
Feature	Section	Feature	Section
Roof Type: Pent roof Roof Material: Wooden and tile Occupied/Unoccupied: Unoccupied	Overhang ~ 50 cm  Street	No shutters on windows	

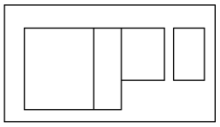
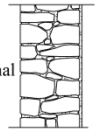
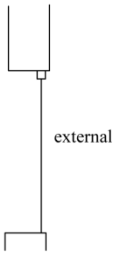
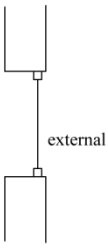
Figure A.4. Data sheet of Building 4

Door Number	Street	Building Plot
	1273. Street	
Number of Floor	Height	
1+30 cm subbasement	3.80m (380-30cm subbasement)	

Photograph:

Location:



Building Components			
Plan Scheme		Exterior Walls	
		Feature	Section
 North		Basement(cm/material): - Ground(cm/material): 50cm-stone First(cm/material): -	external 
External Doors		Windows	
Feature	Section	Feature	Section
Glass: single/double single Basement(cm/material) - Ground(cm/material) iron frame full glass First(cm/material) -	external 	Glass: single/double single Basement(cm/material) - Ground(cm/material) iron frame First(cm/material) -	external 

Construction Period	Construction Type	Courtyard Garden
1930-1940	Masonry	-
Plant on Garden	Waterpond	Well
-	-	-
Outer Color	Number of Flat	Occupancy
Gray	-	Shop (no occupant)

Roof Floor	Oriel
-	-

HVAC Loads

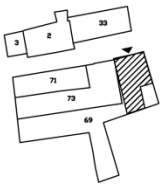
Heating	Cooling
?	?
Fuel Source	Solar Panel
?	?

Notes:

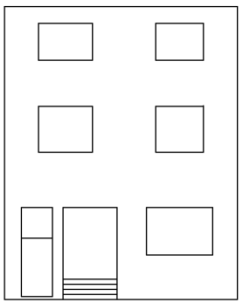
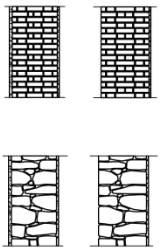
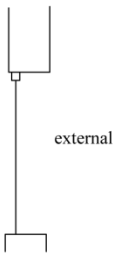
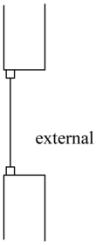
There is no ceiling cover. It can be seen wooden beams and a roofboard from the inside

Building Components			
Ground Floor		Ceiling	
Feature	Section	Feature	Section
Concrete floor			
Roof		Shadings	
Feature	Section	Feature	Section
Roof Type: Pent roof Roof Material: Wooden and tile Occupied/Unoccupied: Unoccupied	50cm- Overhang	No shutters on windows	

Figure A.5. Data sheet of Building 5

Door Number	Street	Building Plot
6 and 6A	1273. Street	
Number of Floor	Height	
3+50cm subbasement	9.60m (960-50cm subbasement)	

Location:

Building Components			
Plan Scheme		Exterior Walls	
		Feature	Section
 North		Basement(cm/material): - Ground(cm/material): 55cm-solid brick First(cm/material): 55cm-solid brick	
External Doors		Windows	
Feature	Section	Feature	Section
Glass: single/double single Basement(cm/material) - Ground(cm/material) Two iron doors First(cm/material) -	 external	Glass: single/double single Basement(cm/material) - Ground(cm/material) wooden frame+ wrought iron First(cm/material) wooden frame	 external

Construction Period	Construction Type	Courtyard Garden
1950-1960	Masonry	-
Plant on Garden	Waterpond	Well
-	-	-
Outer Color	Number of Flat	Occupancy
Gray	3	Mehmet Helvacı House

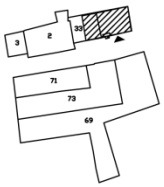
Roof Floor	Oriel
-	-

HVAC Loads	
Heating	Cooling
?	?
Fuel Source	Solar Panel
?	?

Notes:

Building Components			
Ground Floor		Ceiling	
Feature	Section	Feature	Section
		Reinforced concrete	
Roof		Shadings	
Feature	Section	Feature	Section
Roof Type: gable roof Roof Material: Wooden and tile Occupied/Unoccupied: Unoccupied	50cm- Overhang	No shutters on windows	

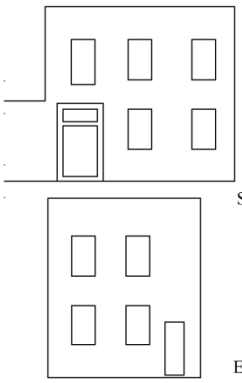
Figure A.6. Data sheet of Building 6

Number	Street	Building Parcel
3	1273. Street	
Number of Floor	Height	
2-no basement	7.20m	

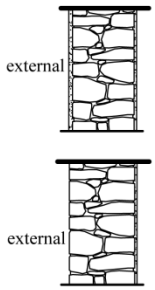
Location:

Building Components

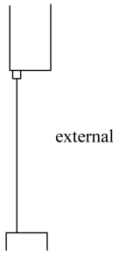
Plan Scheme



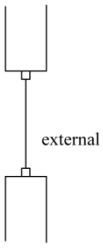
Exterior Walls

Feature	Section
Basement(cm/material): - Ground(cm/material): 55cm-stone First(cm/material): 55cm-stone	

External Doors

Feature	Section
Glass: single/double single Basement(cm/material) - Ground(cm/material) iron First(cm/material) -	

Windows

Feature	Section
Glass: single/double single Basement(cm/material) - Ground(cm/material) wooden frame First(cm/material) wooden frame	

Construction Period	Construction Type	Courtyard Garden
before 1923	Masonry	available
Plant on Garden	Waterpond	Well
?	?	?
Outer Color	Number of Flat	Occupancy
Champagne	1	2 (Gülay and Orhan)

Roof Floor	Oriel
-	There is an oriel south façade

HVAC Loads

Heating	Cooling
stove (coal and wood)	?
Fuel Source	Solar Panel
?	?

Notes:
There is an oriel on the first floor. It made of wooden and it has four windows with single glass. The height of the oriel from the ground is 4.10m.

Building Components

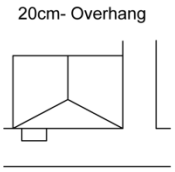
Ground Floor

Feature	Section
Marble covering	

Ceiling

Feature	Section
Wooden	

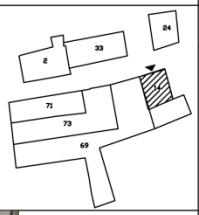
Roof

Feature	Section
Roof Type: Hipped roof Roof Material: Wooden and tile Occupied/Unoccupied: Unoccupied	

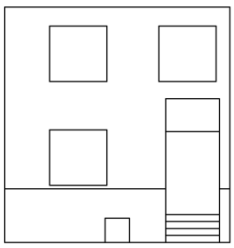
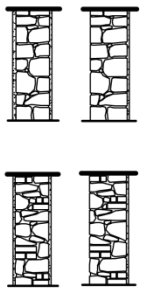
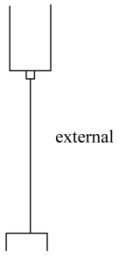
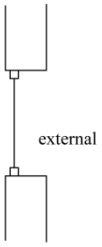
Shadings

Feature	Section
All windows have shutters	

Figure A.7. Data sheet of Building 7

Number	Street	Building Plot
8	1273. Street	
Number of Floor	Height	
2+80cm subbasement	7.50m (750-80)	

Location:

Building Components			
Plan Scheme		Exterior Walls	
		Feature	Section
 North		Basement(cm/material): min. 22 cm Ground(cm/material): 35cm-brick and stone First(cm/material):	
External Doors		Windows	
Feature	Section	Feature	Section
Glass: single/double single Basement(cm/material) - Ground(cm/material) iron / no glass First(cm/material) -	 external	Glass: single/double single Basement(cm/material) one closed window Ground(cm/material) wooden frame First(cm/material) wooden frame single glass	 external

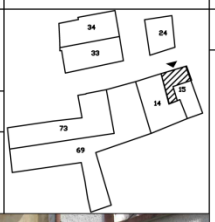
Construction Period	Construction Type	Courtyard Garden
1940's	Masonry	?
Plant on Garden	Waterpond	Well
?	?	?
Outer Color	Number of Flat	Occupancy
white	1	Dericiler house
Roof Floor	Oriel	
-	-	

HVAC Loads	
Heating	Cooling
?	?
Fuel Source	Solar Panel
?	?

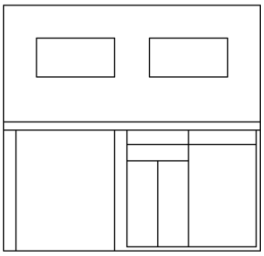
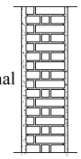
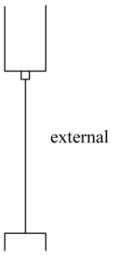
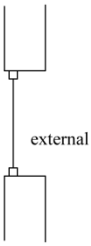
Notes:
Basement Height: 2.00m

Building Components			
Ground Floor		Ceiling	
Feature	Section	Feature	Section
Marble covering			
Roof		Shadings	
Feature	Section	Feature	Section
Roof Type: Hipped roof Roof Material: Wooden and tile Occupied/Unoccupied: Unoccupied	30 cm- overhang	There is one shutter on window on the ground floor	

Figure A.8. Data sheet of Building 8

Number	Street	Building Plot
10 and 10a	1273. Street	
Number of Floor	Height	
2-no basement	6.00m	

Location:

Building Components			
Plan Scheme		Exterior Walls	
		Feature	Section
 North		Basement(cm/material): - Ground(cm/material): ~30 cm solid brick First(cm/material): ~30 cm solid brick	external 
External Doors		Windows	
Feature	Section	Feature	Section
Glass: single/double single Basement(cm/material) - Ground(cm/material) iron First(cm/material) -	external 	Glass: single/double single Basement(cm/material) - Ground(cm/material) iron frame First(cm/material) aluminum frame	external 

Construction Period	Construction Type	Courtyard Garden
?	Masonry	?
Plant on Garden	Waterpond	Well
?	?	?
Outer Color	Number of Flat	Occupancy
white	?	available

Roof Floor	Oriel
-	-

HVAC Loads	
Heating	Cooling
?	?
Fuel Source	Solar Panel
?	?

Notes:
The building is used as a workplace

Building Components			
Ground Floor		Ceiling	
Feature	Section	Feature	Section
Roof		Shadings	
Feature	Section	Feature	Section
Roof Type: Pent roof Roof Material: Sheet metal Occupied/Unoccupied: Unoccupied	No overhang	No shutters on windows	

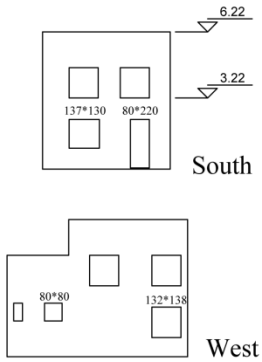
Figure A.9. Data sheet of Building 9

Number	Street	Building Plot
5	1273. Street	
Number of Floor	Height	
2	6.22m	

Location:

Building Components

Plan Scheme



Exterior Walls

Feature	Section
Basement(cm/material): - Ground(cm/material): at least 35 cm solid brick First(cm/material): 35 cm solid brick	external

External Doors

Feature	Section
Glass: single/double single Basement(cm/material) - Ground(cm/material) iron First(cm/material) -	external

Windows

Feature	Section
Glass: single/double single Basement(cm/material) - Ground(cm/material) iron frame First(cm/material) iron frame	external

Construction Period	Construction Type	Courtyard Garden
1950-1960	Masonry	?
Plant on Garden	Waterpond	Well
?	?	?
Outer Color	Number of Flat	Occupancy
white	?	-

Roof Floor	Oriel
-	-

HVAC Loads

Heating	Cooling
?	?
Fuel Source	Solar Panel
?	?

Notes:
There is a terrace on north façade in the first floor.

Building Components

Ground Floor

Feature	Section

Ceiling

Feature	Section

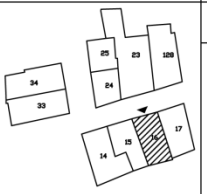
Roof

Feature	Section
Roof Type: Pitched roof Roof Material: wooden and tile Occupied/Unoccupied: Unoccupied	45 cm-overhang

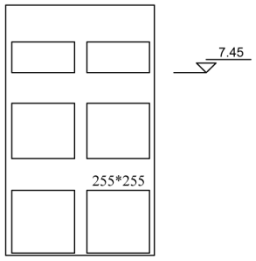
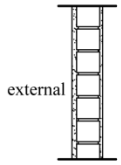
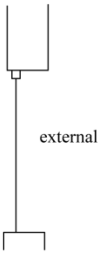
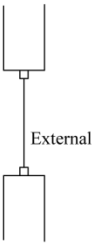
Shadings

Feature	Section

Figure A.10. Data sheet of Building 10

Number	Street	Building Plot
12A	1273. Street	
Number of Floor	Height	
3		

Location:

Building Components			
Plan / Façade Scheme		Exterior Walls	
		Feature: Basement(cm/material): - Ground(cm/material): 20 cm hollow brick First(cm/material): 20 cm hollow brick	Section: 
External Doors		Windows	
Feature	Section	Feature	Section
Glass: single/double single Basement(cm/material) - Ground(cm/material) aliminum First(cm/material) -		Glass: single/double single Basement(cm/material) - Ground(cm/material) aliminium frame First(cm/material) wooden frame	

Construction Period	Construction Type	Courtyard Garden
1980-1990	Reinforced concrete	?
Plant on Garden	Waterpond	Well
?	?	-
Outer Color	Number of Flat	Occupancy
yellow	4	first floor-workplace

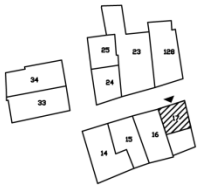
Roof Floor	Oriel
-	-

HVAC Loads	
Heating	Cooling
?	Air conditioned system
Fuel Source	Solar Panel
?	?

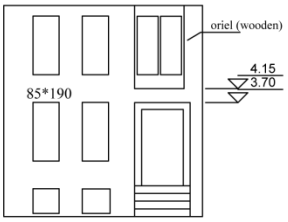
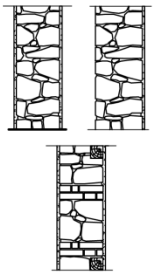
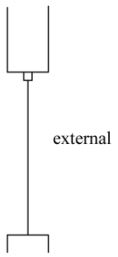
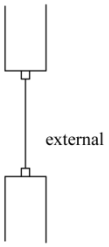
Notes:
Roof of the building is composed of two types. One part is a tiled roof and the other half is flat roof

Building Components			
Ground Floor		Ceiling	
Feature	Section	Feature	Section
Roof		Shadings	
Feature	Section	Feature	Section
Roof Type: Pent roof Roof Material: Tile Occupied/Unoccupied: Unoccupied	No overhang	No shadings	

Figure A.11. Data sheet of Building 11

Number	Street	Building Plot
14	1273. Street	
Number of Floor	Height	
2+1 basement		

Location:

Building Components			
Plan / Façade Scheme		Exterior Walls	
		Feature	Section
 North		Basement(cm/material): ? Ground(cm/material): 40 cm Stone and solid brick First(cm/material): 40 cm Stone and solid brick	
External Doors		Windows	
Feature	Section	Feature	Section
Glass: single/double Basement(cm/material) iron / no glass Ground(cm/material) iron / single glass First(cm/material) -		Glass: single/double Basement(cm/material) closed/no glass Ground(cm/material) wooden frame /single glass First(cm/material) wooden frame /single glass	

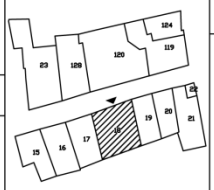
Construction Period	Construction Type	Courtyard Garden
before 1923	masonry	?
Plant on Garden	Waterpond	Well
?	?	-
Outer Color	Number of Flat	Occupancy
grey	2	available
Roof Floor	Oriel	
-	available	

HVAC Loads	
Heating	Cooling
?	
Fuel Source	Solar Panel
?	?

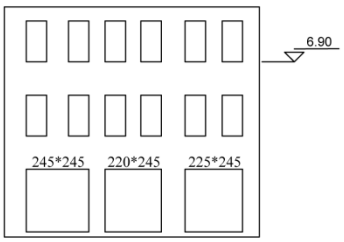
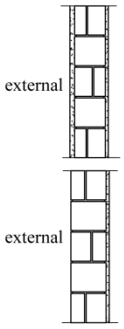
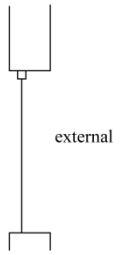
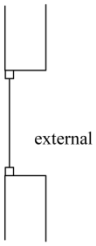
Notes:
There is an oriel on the first floor. It made of wooden and it has four windows with single glass.

Building Components			
Ground Floor		Ceiling	
Feature	Section	Feature	Section
Roof		Shadings	
Feature	Section	Feature	Section
Roof Type: pent roof Roof Material: wooden and tile Occupied/Unoccupied: Unoccupied	no overhang	shutters on ground floor	

Figure A.12. Data sheet of Building 12

Number	Street	Building Plot
16	1273. Street	
Number of Floor	Height	
3	9.00m	

Location:

Building Components			
Plan / Façade Scheme		Exterior Walls	
		Feature	Section
 North		Basement(cm/material): - Ground(cm/material): 25 cm hollow brick First(cm/material): 25 cm hollow brick	
External Doors		Windows	
Feature	Section	Feature	Section
Glass: single/double Basement(cm/material) - Ground(cm/material) iron / single glass First(cm/material) -		Glass: single/double Basement(cm/material) Ground(cm/material) wooden frame /single glass First(cm/material) wooden frame /single glass	

Construction Period	Construction Type	Courtyard Garden
new	reinforced concrete	-
Plant on Garden	Waterpond	Well
-	-	-
Outer Color	Number of Flat	Occupancy
grey	2	?

Roof Floor	Oriel
-	-

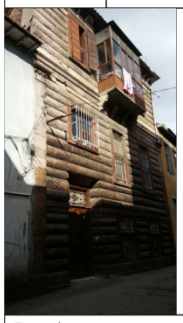
HVAC Loads	
Heating	Cooling
?	air conditioned system
Fuel Source	Solar Panel
?	?

Notes:

Building Components			
Ground Floor		Ceiling	
Feature	Section	Feature	Section
Roof		Shadings	
Feature	Section	Feature	Section
Roof Type: Hipped roof Roof Material: wooden and tile Occupied/Unoccupied: Unoccupied	50 cm-overhang	No shutter	

Figure A.13. Data sheet of Building 13

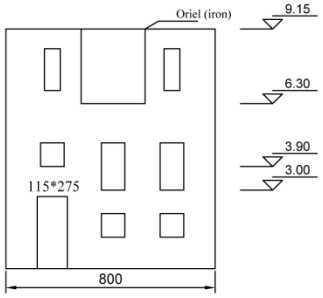
Number	Street	Building Plot
16	1273. Street	
Number of Floor	Height	
3	9.00m	



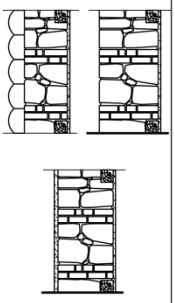
Location:

Building Components

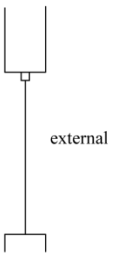
Plan / Façade Scheme



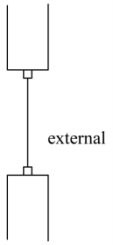
Exterior Walls

Feature	Section
Basement(cm/material): - Ground(cm/material): 50cm-stone piled revetment First(cm/material): 50 cm stone and solid brick	

External Doors

Feature	Section
Glass: single/double Basement(cm/material) Ground(cm/material) iron / no glass First(cm/material) -	 external

Windows

Feature	Section
Glass: single/double Basement(cm/material) wooden frame/no glass Ground(cm/material) wooden frame/ single glass First(cm/material) wooden frame/ single glass	 external

Construction Period	Construction Type	Courtyard Garden
before 1923	masonry	available
Plant on Garden	Waterpond	Well
-	?	-
Outer Color	Number of Flat	Occupancy
light brown	3	shop and house

Roof Floor	Oriel
-	available

HVAC Loads

Heating	Cooling
?	?
Fuel Source	Solar Panel
?	?

Notes:
There is a face stone cladding on south façade.
There is an iron oriel on the second floor.

Building Components

Ground Floor

Feature	Section

Ceiling

Feature	Section

Roof

Feature	Section
Roof Type: Pent roof Roof Material: Eternit Occupied/Unoccupied: Unoccupied	45 cm-overhang

Shadings

Feature	Section
Two shutters on second floor	

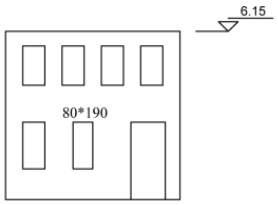
Figure A.14. Data sheet of Building 14

Number	Street	Building Plot
9	1273. Street	
Number of Floor	Height	
2	6.85m	

Location:

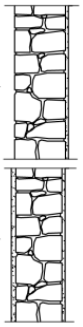
Building Components

Plan / Façade Scheme

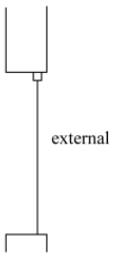


South

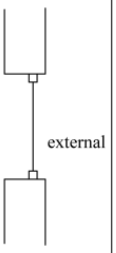
Exterior Walls

Feature	Section
Basement(cm/material): - Ground(cm/material): 35cm-stone First(cm/material): 35cm-stone	 external external

External Doors

Feature	Section
Glass: single/double single Basement(cm/material) - Ground(cm/material) iron / no glass First(cm/material) -	 external

Windows

Feature	Section
Glass: single/double Basement(cm/material) wooden frame/no glass Ground(cm/material) wooden frame/ single glass First(cm/material) wooden frame/ single glass	 external

Construction Period	Construction Type	Courtyard Garden
before 1923	masonry	available
Plant on Garden	Waterpond	Well
-	?	-
Outer Color	Number of Flat	Occupancy
yellow	2	available

Roof Floor	Oriel
-	-

HVAC Loads

Heating	Cooling
?	?
Fuel Source	Solar Panel
?	?

Notes:There is an occupant on the first floor.

Building Components

Ground Floor

Feature	Section

Ceiling

Feature	Section

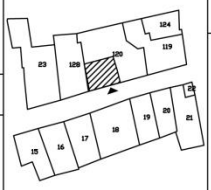
Roof

Feature	Section
Roof Type: gable roof Roof Material: wooden and tile Occupied/Unoccupied: Unoccupied	30 cm-overhang

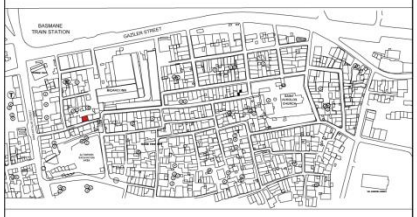
Shadings

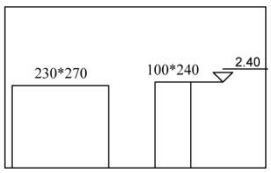
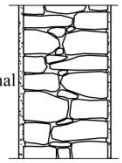
Feature	Section
No shutters	

Figure A.15. Data sheet of Building 15

Number	Street	Building Plot
11B	1273. Street	
Number of Floor	Height	
1	6.85m	

Location:



Building Components			
Plan / Façade Scheme		Exterior Walls	
		Feature	Section
 South		Basement(cm/material): - Ground(cm/material): 60cm -stone First(cm/material): -	 external
External Doors		Windows	
Feature	Section	Feature	Section
Glass: single/double single Basement(cm/material) - Ground(cm/material) iron/no glass First(cm/material) -	external	Glass: single/double no window Basement(cm/material) Ground(cm/material) First(cm/material)	

Construction Period	Construction Type	Courtyard Garden
?		?
Plant on Garden	Waterpond	Well
?	?	?
Outer Color	Number of Flat	Occupancy
pink	1	

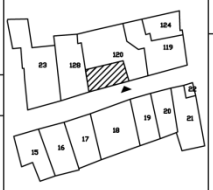
Roof Floor	Oriel
-	-

HVAC Loads	
Heating	Cooling
?	?
Fuel Source	Solar Panel
?	?

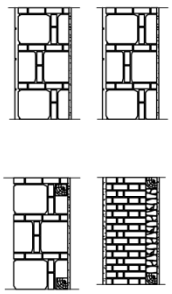
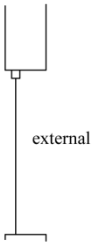
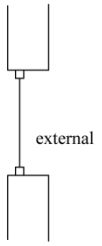
Notes: Total height of the building is not measured because the top elevation of the roof is not specified during site investigations.

Building Components			
Ground Floor		Ceiling	
Feature	Section	Feature	Section
Roof		Shadings	
Feature	Section	Feature	Section
Roof Type: concrete flat roof Roof Material: Occupied/Unoccupied:	No overhang	No shutters	

Figure A.16. Data sheet of Building 16

Number	Street	Building Plot
11	1273. Street	
Number of Floor	Height	
2		

Location:

Building Components			
Plan / Façade Scheme		Exterior Walls	
South		Feature	Section
		Basement(cm/material): Ground(cm/material): 50-55cm stone and brick First(cm/material):	
External Doors		Windows	
Feature	Section	Feature	Section
Glass: single/double Basement(cm/material) iron/single glass Ground(cm/material) iron/single glass First(cm/material) -		Glass: single/double Basement(cm/material) Ground(cm/material) wooden frame/ single glass First(cm/material)	

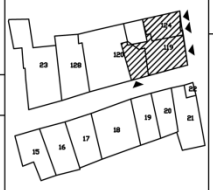
Construction Period	Construction Type	Courtyard Garden
before 1923	masonry	?
Plant on Garden	Waterpond	Well
?	?	?
Outer Color	Number of Flat	Occupancy
green-green stone	2	basement and ground floor
Roof Floor		Oriel
-		-

HVAC Loads	
Heating	Cooling
?	?
Fuel Source	Solar Panel
?	?

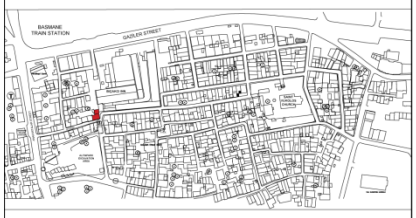
Notes:

Building Components			
Ground Floor		Ceiling	
Feature	Section	Feature	Section
Roof		Shadings	
Feature	Section	Feature	Section
Roof Type: Flat roof Roof Material: Occupied/Unoccupied:	No overhang	Shutter on windows on ground floor	

Figure A.17. Data sheet of Building 17

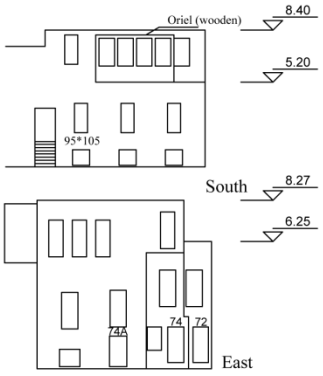
Number	Street	Building Plot
11A-74-74A-72	1273. and 1270. Street	
Number of Floor	Height	
2+1 basement		

Location:

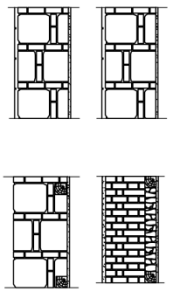


Building Components

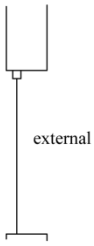
Plan / Façade Scheme



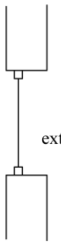
Exterior Walls

Feature	Section
Basement(cm/material): Ground(cm/material): stone and brick First(cm/material): stone and brick	

Exterior Doors

Feature	Section
Glass: single/double Basement(cm/material) metal/no glass Ground(cm/material) metal/single glass First(cm/material) -	 external

Exterior Windows

Feature	Section
for left side façade; Glass: single/double single Basement(cm/material) wooden frame Ground(cm/material) wooden frame and shutter First(cm/material) wooden frame and shutter	 external

Construction Period	Construction Type	Courtyard Garden
before 1923	masonry	?
Plant on Garden	Waterpond	Well
?	?	?
Outer Color	Number of Flat	Occupancy
green-green stone	2	Burhanzade Abdurrahman Bey
Roof Floor		Oriel
-		available

HVAC Loads

Heating	Cooling
?	?
Fuel Source	Solar Panel
?	?

Notes:
Green stone and brick are used for all façades.
There is an oriel on the second floor. It is made of wooden.

Building Components

Ground Floor

Feature	Section

Ceiling

Feature	Section

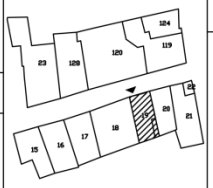
Roof

Feature	Section
Roof Type: hipped roof Roof Material: wooden and tile Occupied/Unoccupied: unoccupied	

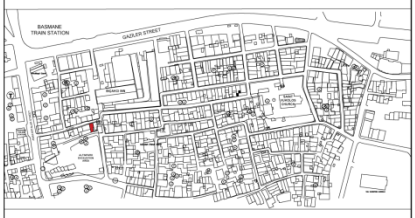
Shadings

Feature	Section

Figure A.18. Data sheet of Building 18

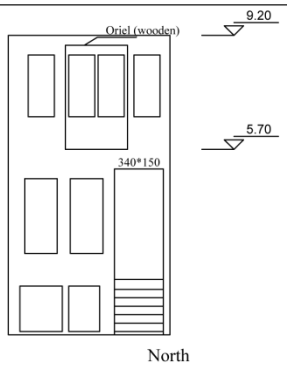
Number	Street	Building Plot
18A	1273. Street	
Number of Floor	Height	
2+1 basement		

Location:

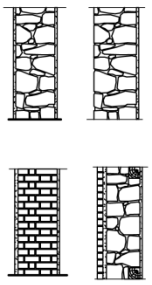


Building Components

Plan / Façade Scheme



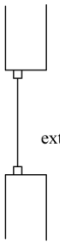
Exterior Walls

Feature	Section
Basement(cm/material): Ground(cm/material): 40cm - stone First(cm/material): 40cm - stone	

External Doors

Feature	Section
Glass: single/double Basement(cm/material) iron/single glass Ground(cm/material) iron/no glass First(cm/material) -	external

Windows

Feature	Section
Glass: single/double single Basement(cm/material) wooden frame Ground(cm/material) wooden frame First(cm/material) wooden frame	 external

Construction Period	Construction Type	Courtyard Garden
before 1923	masonry	?
Plant on Garden	Waterpond	Well
?	?	?
Outer Color	Number of Flat	Occupancy
grey	2+1 basement	basement and ground floor

Roof Floor	Oriel
-	available

HVAC Loads

Heating	Cooling
?	?
Fuel Source	Solar Panel
?	?

Notes:

There is an oriel on the second floor. It is made of wooden
Roof of the building is composed of two types. One part is a pent roof and the other half is flat roof

Building Components

Ground Floor

Feature	Section

Ceiling

Feature	Section

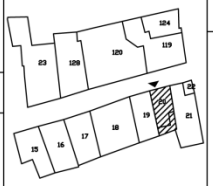
Roof

Feature	Section
Roof Type: pent and flat roof Roof Material: wooden and tile Occupied/Unoccupied: unoccupied	30cm-overhang

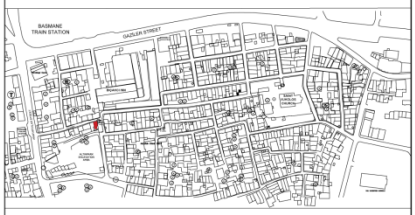
Shadings

Feature	Section
Ground floor iron shutters First floor wooden shutters	

Figure A.19. Data sheet of Building 19

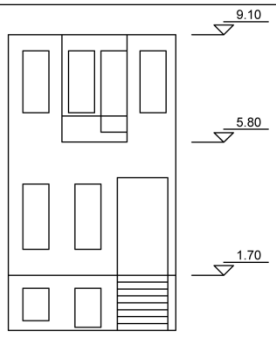
Number	Street	Building Plot
20A	1273. Street	
Number of Floor	Height	
2+1 basement		

Location:



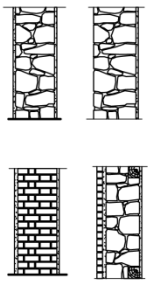
Building Components

Plan / Façade Scheme



North

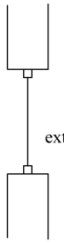
Exterior Walls

Feature	Section
Basement(cm/material): stone Ground(cm/material): 50cm - stone First(cm/material):	

Exterior Doors

Feature	Section
Glass: single/double Basement(cm/material) metal/no glass Ground(cm/material) metal/no glass First(cm/material) -	external

Exterior Windows

Feature	Section
Glass: single/double single Basement(cm/material) Ground(cm/material) wooden frame/ single glass First(cm/material) wooden frame/ single glass	 external

Construction Period	Construction Type	Courtyard Garden
	masonry	?
Plant on Garden	Waterpond	Well
?	?	?
Outer Color	Number of Flat	Occupancy
grey	2+1 basement	
Roof Floor	oriel	
-	-	

HVAC Loads

Heating	Cooling
?	?
Fuel Source	Solar Panel
?	?

Notes:

The oriel on the second floor has been converted to a balcony.
Roof of the building is composed of two types. One part is a pent roof and the other half is flat roof

Building Components

Ground Floor

Feature	Section

Ceiling

Feature	Section

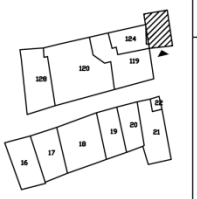
Roof

Feature	Section
Roof Type: pitched roof Roof Material: wooden and tile Occupied/Unoccupied: unoccupied	35cm- overhang

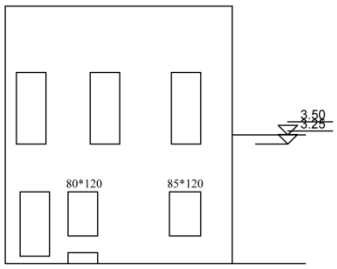
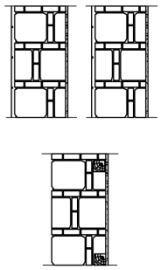
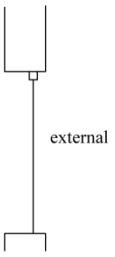
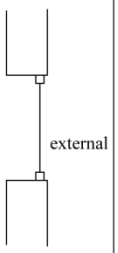
Shadings

Feature	Section
ground floor iron shutters	

Figure A.20. Data sheet of Building 20

Number	Street	Building Plot
70	1270. Street	
Number of Floor	Height	
2+1 basement		

Location:

Building Components			
Plan Scheme		Exterior Walls	
		Feature	Section
		Basement(cm/material): ? Ground(cm/material): stone and brick at least 50 cm First(cm/material): stone and brick 50 cm	
Exterior Doors		Exterior Windows	
Feature	Section	Feature	Section
Glass: single/double Basement(cm/material) Ground(cm/material) iron / no glass First(cm/material)		Glass: single/double Basement(cm/material) Ground(cm/material) aluminum frame /single glass First(cm/material) aluminum frame /single glass	

Construction Period	Construction Type	Courtyard Garden
before 1923	masonry	
Plant on Garden	Waterpond	Well
-	?	?
Outer Color	Number of Flat	Occupancy
Green-pink	1	-

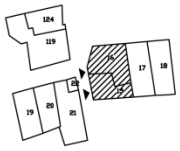
Roof Floor	Oriel
-	-

HVAC Loads	
Heating	Cooling
?	?
Fuel Source	Solar Panel
?	?

Notes:

Building Components			
Ground Floor		Ceiling	
Feature	Section	Feature	Section
		wooden	
Roof		Shadings	
Feature	Section	Feature	Section
Roof Type: gable roof Roof Material: Tile Occupied/Unoccupied:	20 cm- overhang	No shutters on windows	

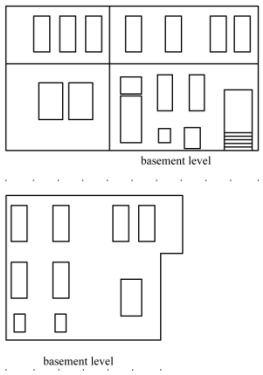
Figure A.21. Data sheet of Building 21

Number	Street	Building Plot
1-3	1270. Street	
Number of Floor	Height	
2+1 basement		

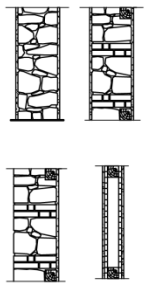
Location:

Building Components

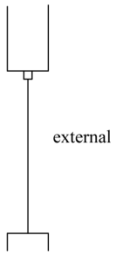
Plan Scheme



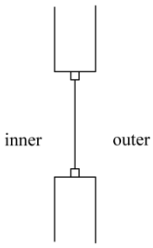
Exterior Walls

Feature	Section
Basement(cm/material): stone Ground(cm/material): 40 cm- stone First(cm/material): stone and brick oriel: timberwork (bağdadi)	

External Doors

Feature	Section
Glass: single/double Basement(cm/material) Ground(cm/material) iron / single glass First(cm/material)	 external

Windows

Feature	Section
Glass: single/double Basement(cm/material) metal Ground(cm/material) aluminum / Single glass First(cm/material) aluminum	 inner outer

Construction Period	Construction Type	Courtyard Garden
before 1923	masonry	-
Plant on Garden	Waterpond	Well
-	?	?
Outer Color	Number of Flat	Occupancy
grey	2	available

Roof Floor	Oriel
-	protrusion

HVAC Loads

Heating	Cooling
Fuel Source	Solar Panel

Notes:
Basement height: 1.50 m
There is a protrusion on west façade in the first floor.

Building Components

Ground Floor

Feature	Section

Ceiling

Feature	Section

Roof

Feature	Section
Roof Type: Pitched roof Roof Material: wooden and tile Occupied/Unoccupied:	

Shadings

Feature	Section
shutters on windows on west façade in the ground floor	

Figure A.22. Data sheet of Building 22