Your Guide to Building Envelope Retrofits for Optimising Energy Efficiency & Thermal Comfort in Jordan

JORDAN GBC
المجلس الأردني للأبنية الخضراء
Jordan Green Building Council

FRIEDRICH EBERT STIFTUNG

Your Guide to

Building Envelope Retrofits for Optimising Energy Efficiency & Thermal Comfort in Jordan

The Hashemite Kingdom of Jordan

The Deposit Number at the National Library: 2018/9/4454
ISBN: 978-9957-8789-1-7

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Acknowledgment

Jordan Green Building Council and all of its members would like to acknowledge the following individuals for their valuable contributions to the preparation of this booklet:

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The council would like to acknowledge Friedrich Ebert Foundationn (FES) for their cooperation and great support in the development of this Guide.

The council would also like to thank Eng. Khaleel Awwad, Dr Paola Boarin, Eng. Mohammed Elshabasy, and Eng. Ghalib Mheirat for their valuable support.

This Guide has been further developed and built on a previous Master thesis tilted "Energy retrofit of the existing building envelope in Jordan: A study on mixed-use buildings (Retail and office) in Amman" at the University of Auckland supported by the New Zealand Government under the New Zealand Development Scholarship programs (NZDS).

ABSTRACT

Energy security is a significant challenge facing Jordan and a burden on the Government due to the limited local energy resources. Ensuring the country's sustainable development requires an effective energy reduction plan mainly on the existing building stock due to its high energy consumption rate, as residential and public buildings in Jordan consume around 20% of the total Energy consumption. Existing buildings provide great opportunities to reduce energy demand when being retrofitted following energy efficient approach, especially in Jordan as the annual construction work on existing buildings, that have been given licenses, has increased by approximately 46% from 2007 to 2017 while the annual newly-built areas have decreased by around 33%. Since people are already renovating existing buildings, building on them, or reusing them for a different function, this guide aims to promote and discuss the Energy Retrofit concept as well as the related issues with a special focus on the building envelope to optimize energy efficiency and thermal comfort. It also provides an understanding of the current situation of the main existing building envelope components, issues and practices, an assessment of the thermal performance of roofs, external walls, Fenestration, Partition walls between different units and slabs between different floors, and suggests retrofit solutions, which are internal or external insulation, with a calculation of the minimum thermal insulation thicknesses required to achieve the requirements of the Jordanian Energy Efficient Building Code for each building envelope component. The four main building envelope retrofit strategies, which are improving the thermal performance of the building's ROOF and EXTERNAL WALLS by adding thermal insulation and improving the thermal performance of the building's transparent surfaces by installing double-glazed WINDOWS with enhanced thermal performance for glass and frames, as well as installing SHADING devices on the south facing windows are examined for two building typologies, commercial and residential, in two climate zones in Jordan (Amman and Aqaba) in order to show the potential of energy savings. The results have proved that when combining the four main proposed energy retrofit strategies, it reduces the total cooling and heating energy use for commercial buildings by 53 % in Amman and 45% in Aqaba, For the residential typology, the total reduction percentage is around 50% in Amman and 47% in Aqaba.

Keywords: building envelope, energy retrofit, energy-efficient buildings, energy optimization, thermal insulation, thermal insulation, thermal comfort

1

Chapter

BACKGROUND ON ENERGY AND BUILDINGS IN JORDAN

1. ENERGY IN JORDAN & THE BUILT ENVIRONMENT

1.1. Background

Jordan has been facing significant challenges including ensuring its energy supply; the country relies on foreign energy resources [1]. It imports more than 95% of its energy needs, which are mainly natural gas and oil, from neighboring countries, taking into account being a country with limited indigenous energy resources [2]. The contribution capacity of natural gas has amounted to 88% of the total electricity generated in the country [2]. This reliance added another burden onto the Jordanian government between 2011 and 2013 when the natural gas supply dropped due to several explosions in gas pipelines in Egypt which resulted in more pressure on oil products [1]. Oil products represent more than half of the energy mix with 61% in 2008 which decreased to 56% in 2016, and it is projected to slightly decline to reach 50% in 2025 (table 1). Even so, it is still an enormous and dominant percentage, and there is a need for energy conservation plans to decrease energy demands.

Figure 1: The energy mix in Jordan 2016, 2020, and 2025.

Source: Ministry of Energy and Mineral Resources, 2017.

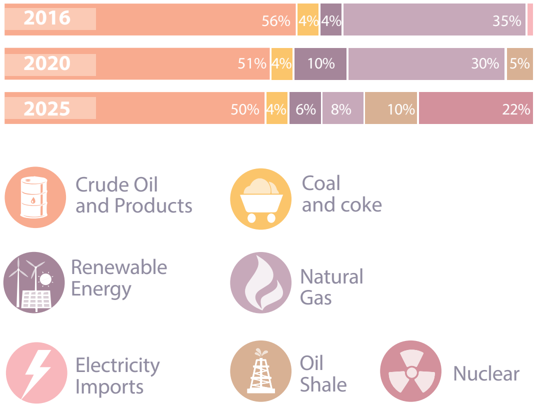
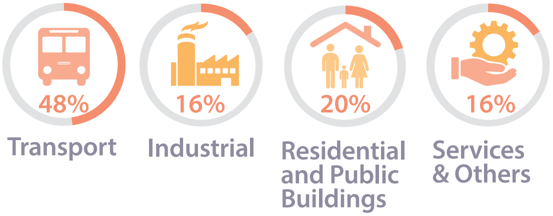


Table 1: Final Energy Consumption by sector 2012-2016.

Source: Ministry of Energy and Mineral Resources, 2017.

	2012	2013	2014	2015	2016
Transport	2520	2734	2558	2811	3184
Industrial	921	924	1079	991	1064
Residential and Public Buildings	1198	1109	1152	1272	1342
Services & Others	744	617.1	718	754	826
Total	5383	5384.1	5507	5828	6416

Figure 2: Final Energy Consumption by sector 2016.
Source: Ministry of Energy and Mineral Resources, 2017.



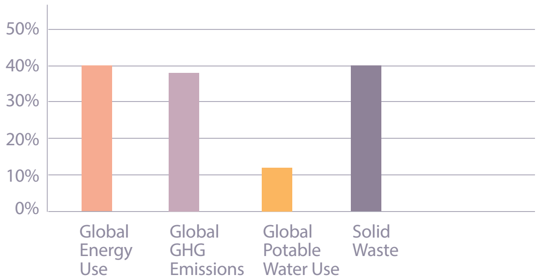
1.2. Energy in Buildings

The building sector consumes 40% of global energy consumption and contributes to around one third of global Green House Gas (GHG) emissions. When Buildings become energy efficient, they will have a high potential to reduce energy usage on large scale. The GHG emissions of buildings are more likely to be significantly reduced in comparison to other main emitting sectors [3].

Energy consumption of new and existing buildings can be reduced by estimated 30% up to 80%, "with potential net profit during the building life-span", using "proven and commercially available technologies".[3]

All the above facts emphasize the imperative need for promoting Energy Efficiency in Buildings throughout their lifespan; during design, construction and operation.

Figure 3: Contribution of buildings in Global energy and water use, GHG emissions, and solid waste.
Source: UNEP, 2012.

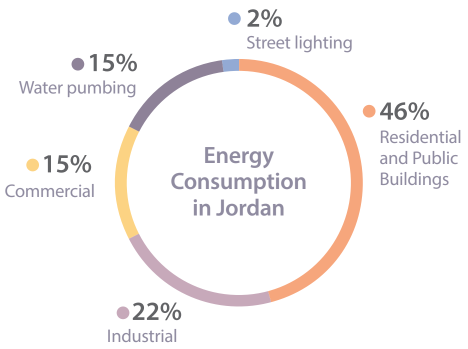


The last few decades in Jordan have seen an enormous increase in the energy usage in the building sector. The noticeable increase in the residential sector's electricity consumption is due to improving the Residential and Public Buildings's power purchase which has increased the acquirement of additional appliances [2]. Modern conveniences have spread among Jordanians and resulted in higher energy consumption for electricity [4]. Residential and public buildings in Jordan accounts for around 46% of the total electricity consumption and is considered the largest portion of energy usage in 2017 [5].

To sum up, Buildings have a high potential to reduce energy demand when being retrofitted towards an energy efficient approach, and therefore reduce GHG emissions.

Figure 4: By sector, The total electrical energy consumption in Jordan in 2017

Source: Ministry of Energy and Mineral Resources, 2017.



1.3. Jordan's Current Response to the Energy Problem

Jordan has been developing national targets, such as a 20% national target for energy efficiency by the year 2020 [1], and action plans for energy efficiency, such as the Second National Energy Efficiency Action Plan (NEEAP) in 2017[2].

The Energy Efficiency Midterm Action Plan (NEEAP), first practiced in the EU, has been developed for the implementation of good practice standards in the matter of policy making for energy efficiency. The NEEAP for the Kingdom of Jordan has established coherent measures tackling issues pertaining to energy supply by managing demand efficiently. It has set targets for energy saving until the year 2020 and proposed a variety of measures for the following sectors; residential sector, commercial and services sector, industrial sector, water pumping sector, street lighting, municipal level, transport sector [2]. These concrete measures were proposed for many key sectors to achieve the aims by 2020. The measures deal with both demand and supply. As an example of;

Demand:

By 2020 Reducing Energy Usage 15%
in Jordanian public buildings

including hospitals, schools and administrative buildings.

Supply:

Set goals for **Photovoltaics and Solar Water Heaters**, **Solar Energy Code** was published in 2012.

It is clear that Jordan is trying to meet all the previously mentioned responsibilities and tackle the energy problem, but further work is needed, especially in the energy conservation sector.

2

Chapter

WHY EXISTING BUILDINGS & WHY THE BUILDING ENVELOPE?

2. WHY EXISTING BUILDINGS & WHY THE BUILDING ENVELOPE?

2.1. The Existing Building Stock

Buildings do not have to be new to be efficient and sustainable. Today, many building owners around the globe are retrofitting their buildings, converting them into models of sustainability. It is expected that most opportunities to improve efficiency in the next decades will be in existing buildings, as they represent the largest stock in the building sector and most of them are constrained by aging infrastructure, inadequate operations resources, ineffficient performance, and old equipment [6].

Current retrofitting rates

of the existing building stock every year

according to the Global Alliance for Building and Construction.

retrofitting rates must increase by

each year starting in 2017

and should accelerate for every year of delay to achieve the Paris agreement objective regarding climate change [7].

From an economic point of view, retrofitting existing buildings is more feasible than constructing new green ones [8]. Improved efficiency of the existing building stock through sustainable retrofitting measures represents a high-volume and low-cost approach to reduce energy demand as well as greenhouse gas emissions. Retrofitting an existing building expands the building's life cycle, thus the building will be responsible for fewer GHG emissions throughout its lifecycle [9].

Why retrofitting existing buildings in Jordan?

The energy performance levels of the Jordanian existing building stock are much lower than the requirements of the local Energy Efficient Building Code [9]. Although the Local Thermal Insulation Code has been mandatory since 2009, people in Jordan used to ignore it to avoid additional costs accompanying it resulting in having a large number of inefficient buildings. Transforming the built environment in Jordan through a sustainable approach is a must towards conserving water, energy, and other resources.

The Energy Retrofit approach will assist the country to reduce energy usage in buildings, thus decrease energy costs on a large scale and enhance Jordan's sustainable development.

The number of the annual licences
for construction projects in Jordan has increased by [10]

46% for Existing Building's projects

comparing the issued licences in 2007 and 2017,

while for the same period,

The number of the annual licences
for construction projects has been decreased

33% for Completely New Buildings

This increase provides an opportunity to promote Energy Retrofitting as people are already going towards renovating existing buildings, adding to them or reusing them for a different function.

Table 2: Number of Annual Construction Licenses in Jordan
Source: Department of Statistics (DOS), 2018. http://www.dos.gov.jo/dos_home_a/main/linked-html/Bulding_indi.htm

YEAR	The number of Licences given to Construction Projects		
	Type of license		
	New Buildings	Addition to Existing buildings	Existing buildings
2007	2283	147	7654
2012	2333	299	6352
2017	1527	202	14368

2.2. Energy Audit

Definition: It is a systematic approach to solve problems and make decisions. The main goals of an energy audit are qualifying and quantifying the current performance of the building energy systems, the potential for improving the performance, and the outcomes of the improvements from the different point of views financially and non-financially.

Energy Audit is the first step to figure out the amount of energy consumed in an existing building. The energy audit report of the current situation of the building's energy usage can identify the need for retrofitting as well as show the opportunities the retrofitting strategies can provide.

Why? **Goals of conducting Energy Audit:**

- To understand how energy is used in a building and if it is wasted.
- To identify and analyse cost-effective ways of using energy within a building.
- To perform economic analysis of the available alternatives (identified in the previous step) and decide which ones are more cost-effective.

When? Energy Audit can be performed anytime during the life-cycle of a building, preferably when there is a potential for retrofitting or renovation.

Energy Audit for existing buildings can be conducted for two main cases:

- A building that has the potential to a considerable reduction of its energy consumption.
- A building that is already going through a renovation process, so conducting an energy audit would add value to the renovation through transforming the building into an energy efficient building.

Levels of Energy Audits [11]

As the complexity of energy audit increases, the accuracy of site assessment increases as well as the collection of more data and the outcome details in the final energy audit results. This effort would be reflected into a higher energy saving.

Type of Audit

Level 1: Walk-through Analysis/ Preliminary Audit

Level 2: Energy Survey and Engineering Analysis Audit

Level 3: Detailed Analysis of Capital-Intensive Modification Audits

Type of Audit Brief Description

Level 1:

- Brief on-site survey of the building
- Savings and cost analysis of low-cost/no-cost
- Energy Conservation Measures (ECMs)
- Identification of potential capital improvements meriting further consideration

Level 2:

- More detailed building survey
- Breakdown of energy use
- Savings and cost analysis of all Energy Conservation Measures (ECMs)
- Identification of ECMs requiring more thorough data collection and analysis (Level 3)

Level 3:

- Attention to capital-intensive projects identified during the Level 2 audit
- More detailed field analysis
- More rigorous engineering analysis
- Cost and savings calculations with a high level of accuracy

What could be tested in an Energy Audit?

Testing the lighting system and the main appliances for energy efficiency.

Testing the Heating, Cooling and Ventilation Systems to identify efficiency and combustion safety issues.

Water heating systems for energy efficiency.

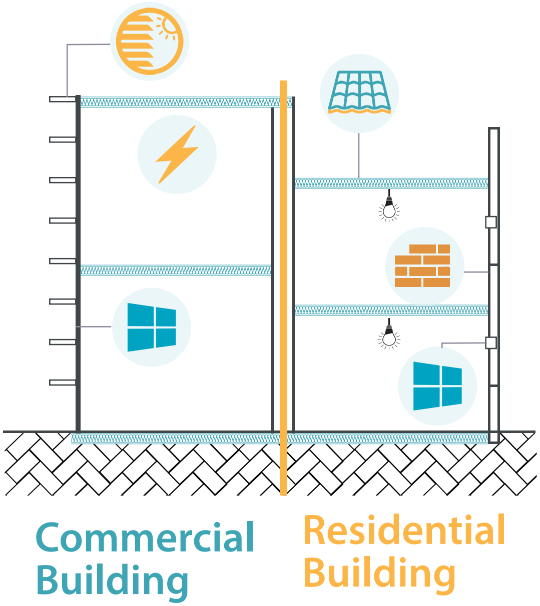
Testing the Building Envelope components which include:

- The Roof for thermal insulation and general status.
- External Walls for thermal insulation and air leaks.
- Doors and Windows for glazing type, thermal characteristics, weatherstripping, infiltration...Etc.

The diagram next shows the potential savings that could be achieved when retrofitting the roof, external walls and windows as well as installing external shading devices on the building's Southern facade. These retrofitting strategies were examined on two cases, a residential and commercial building, in two climate zones, Amman and Aqaba, and will be discussed in details in the last chapter.

The Dutch Embassy in Jordan, the first building in Jordan to achieve the international green building certification (LEED) in 2010.

Figure 5: Building Envelope Energy Retrofit Reduction Potentials, Case Study Results.



Commercial Building

- **Building Envelope Energy Retrofit**
  achieves an average saving of the total cooling and heating energy use
  Amman: 53% per year
  Aqaba: 45% per year

- **Roof Retrofit**
  Reduction of the total cooling and heating energy use
  Amman: 3% per year
  Aqaba: 2% per year

- **External walls retrofit**
  Reduction of the total cooling and heating energy use
  Amman: 8% per year
  Aqaba: 5% per year

- **Window retrofit**
  Reduction of the total cooling and heating energy use
  Amman: 29% per year
  Aqaba: 27% per year

- **External Solar Shading Devices**
  Reduction of the total cooling and heating energy use
  Amman: 25% per year
  Aqaba: 21% per year

Residential Building

- **Building Envelope Energy Retrofit**
  achieves an average saving of the total cooling and heating energy use
  Amman: 17% per year
  Aqaba: 12% per year

- **Roof Retrofit**
  Reduction of the total cooling and heating energy use
  Amman: 6% per year
  Aqaba: 4% per year

- **External walls retrofit**
  Reduction of the total cooling and heating energy use
  Amman: 17% per year
  Aqaba: 12% per year

- **Window retrofit**
  Reduction of the total cooling and heating energy use
  Amman: 25% per year
  Aqaba: 28% per year

- **External Solar Shading Devices**
  Reduction of the total cooling and heating energy use
  Amman: 8% per year
  Aqaba: 9% per year

2.3. What is the Building Envelope?

The Building envelope is considered the first line of defense against environmental impacts on the building. The main functions of the building envelope are to provide shelter, security, thermal, solar control, indoor air quality and moisture control, access to daylight, fire resistance, views to outside, acoustical control, aesthetical value to a building [12].

The following figure shows the main components of a typical building enclosure. These principal components as well as building type, climate, geographic location, building materials, and construction practice significantly affect a building energy performance during its lifetime and occupancy.

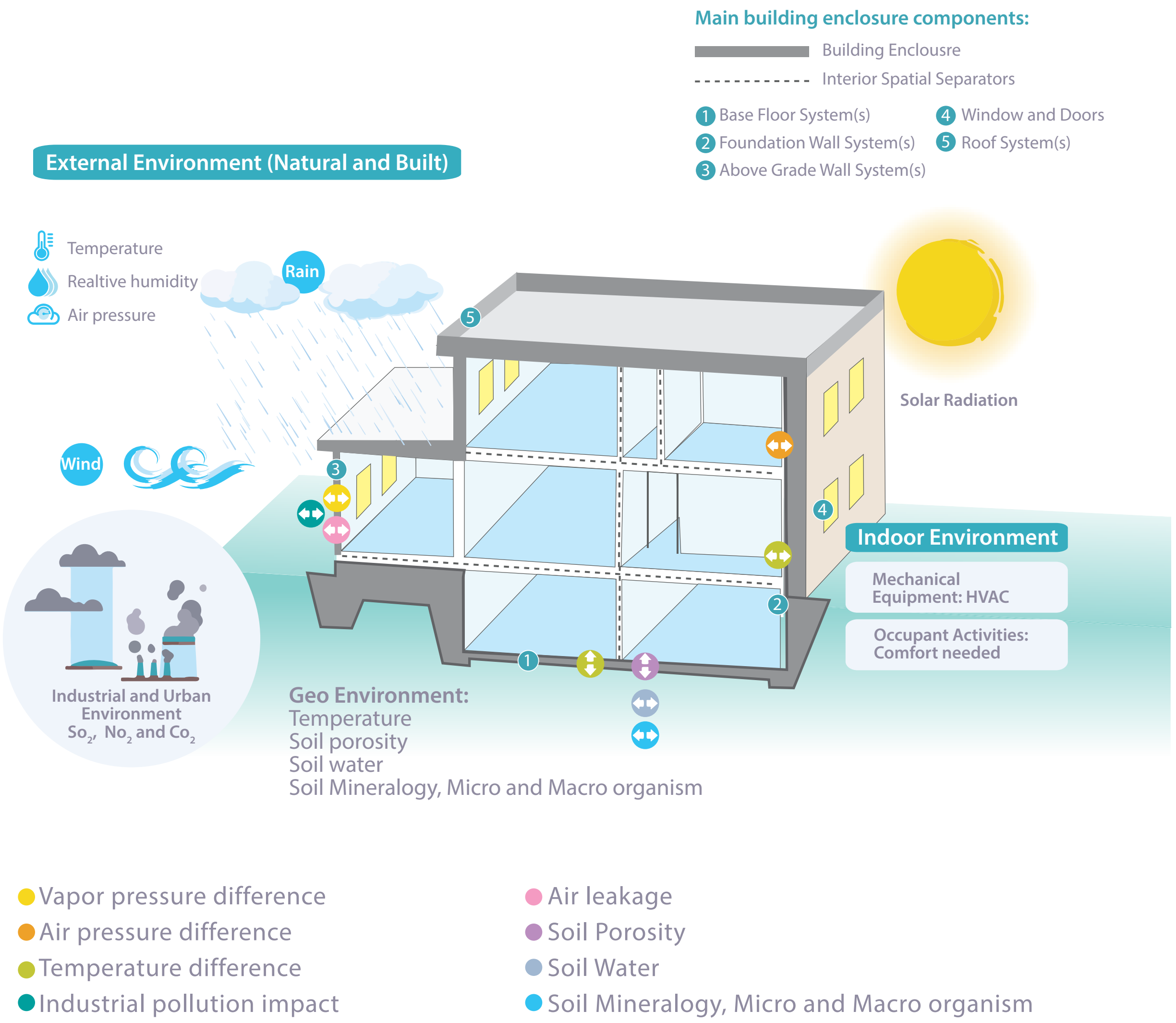
The building envelope has regulatory functions to decrease the environmental impacts on the indoor environment of buildings such as thermal control, moisture, and indoor air quality control. It interacts with three main parts of the building, which are:

- Exterior environment including external environment and geo-environmental.
- Interior environment.
- The envelope system itself.

The envelope is crucial in determining the energy required for heating and cooling in buildings [13]. Therefore, it should be optimized when retrofitting an existing building to develop a long-term energy reduction strategy by minimizing heating and cooling loads. Retrofitting an existing building envelope to be energy efficient plays a major role in enhancing building sustainability. It should comply with the requirements of the local building codes including Thermal Insulation Code and Energy Efficient Building Code.

Figure 6: The main building enclosure components and Environmental loads on the building envelope in Amman.

Source: Iwaro & Mwasha, 2013.



Enhancing Indoor Environment Quality (IEQ):

Since keeping the outside out and the inside in is the main function for the building's envelope, it means that building envelope controls the Indoor Environment of a space. Therefore Indoor Environmental Quality factors must be taken into consideration when retrofitting a building envelope. These factors are closely related and cannot be addressed apart. They depend on many variables including temperature, relative humidity, airflow, air velocity, occupancy concentration of pollutants, lighting, noise… Four major areas can define the indoor environment quality, namely [14]:

- Thermal Comfort
- Visual Comfort
- Indoor Air Quality
- Acoustic Comfort

Figure 7: What affects Indoor Environment Quality of a building?

Source: Almeida, Freitas, & Delgado, 2015.

Building
- Enclouser
- Construction materials
- Furniture

Building Services
- HVAC systems
- Lightning

People and Activities
- HVAC use
- Use of paints, vamishes, glues
- Cleaning

External Conditions
- External temperature
- Air pollution
- Environmental noise
- Sun and natural lightning
- Green environment

2.4. Why Retrofitting?

Retrofitting the building envelope optimizes:

Energy Use in buildings.

The building envelope has a significant influence on the heating and cooling demand of buildings [15]. Therefore, enhancing the energy efficiency of the building envelope reduces the energy costs on the building scale by reducing the need for heating, cooling and ventilation.

Indoor air quality.

The building envelope influences the comfort of the building occupants. Improving the situation of an existing building envelope to improve ventilation could lead to enhancing their productivity, and reducing the impact of the indoor environment of their health and reduce the need for artificial ventilation.

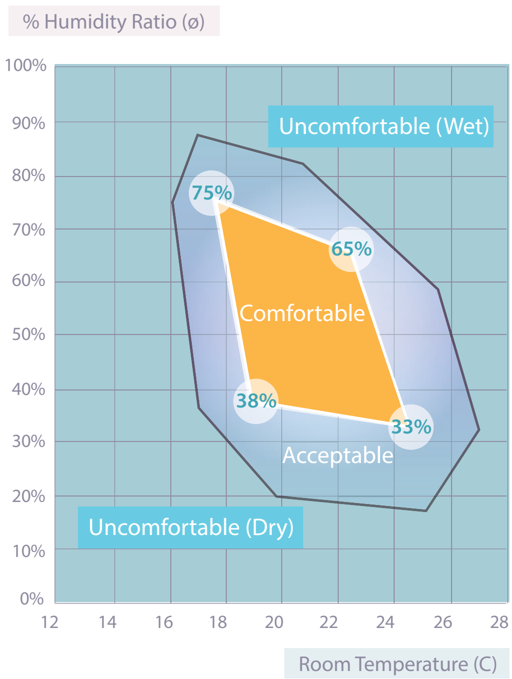
Thermal comfort.

Optimising thermal insulation of an existing building envelope will reduce heat loss in winter and heat gain in summer, thus enhance the occupants thermal comfort.

An Energy Efficient Building Envelope highly enhances Indoor Air Quality as well as thermal comfort using less amount of energy. Regarding thermal comfort, the following figures illustrate simplified graphical methods to evaluate thermal comfort inside buildings according to the local Thermal Insulation Guide, the effect appears on thermally insulated and non-insulated walls [16] [17].

Figure 8: The relation between humidity and room temperature showing the uncomfortable, acceptable and comfortable areas.

Source: Thermal Insulation Guide, 2018.



The thermal comfort of the occupants is affected by the temperature of the room surfaces even when the indoor temperature meets the requirements of the comfort zone. The reason is that, for example, the occupant's body will be radiating towards the cold room surfaces, which are not thermally insulated, in winter even when the room is heated and has a temperature level that is comfortable. This would make the occupants feel uncomfortable, and therefore require more heat to be released in the room which will increase the energy demand for heating. The following figure illustrates the relation between the temperature of the room surfaces and the indoor temperature to achieve thermal comfort [16].

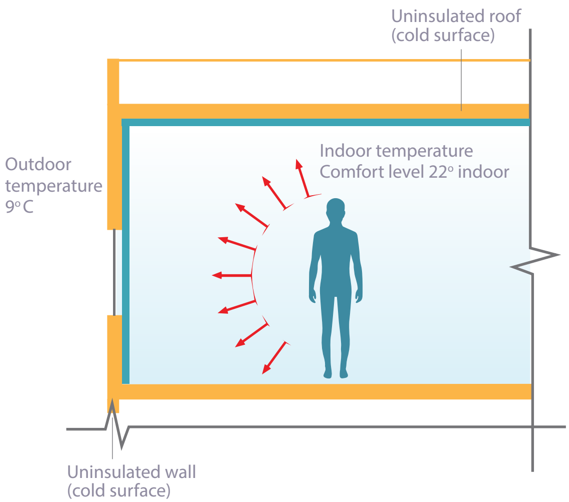
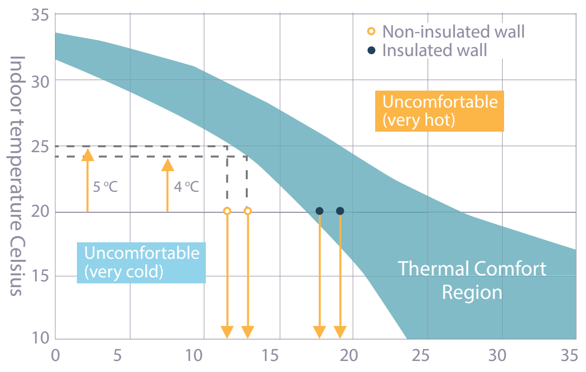


Figure 9: The relation between the temperature of the room surfaces and the indoor temperature to achieve thermal comfort.

Source: Thermal Insulation Guide, 2018.

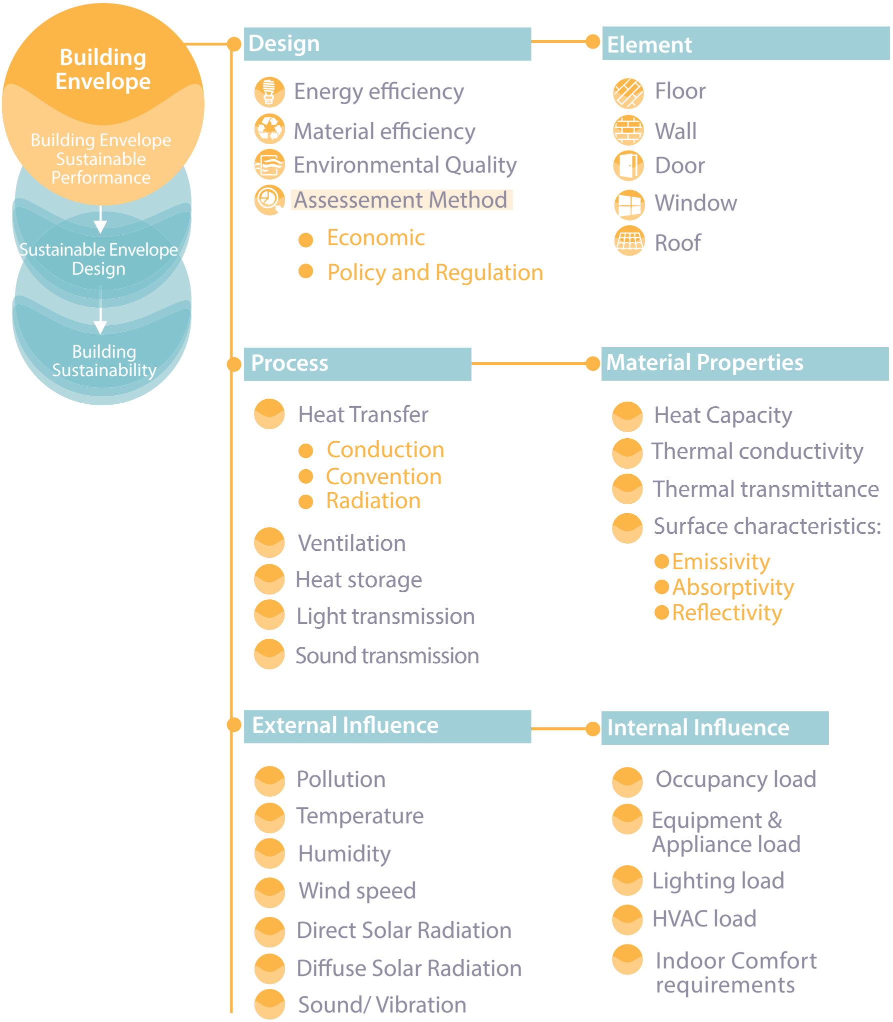


The temperature of the room surfaces (insulated & Non-insulated building). Celsius.

In general, achieving buildings' sustainability, especially when dealing with existing buildings is considered challenging because you need to deal with many factors. External and internal environmental factors have significant impacts on building sustainability, followed by other factors such as the building envelope, building elements, material properties and thermal processes as illustrated in the following figure [18].

Figure 10: The connection between building envelope and building sustainability.

Source: Iwaro & Mwasha, 2013.



3

Chapter

The Thermal Performance of Existing Buildings' Envelope in Jordan

3. The Thermal Performance of Existing Buildings' Envelope in Jordan

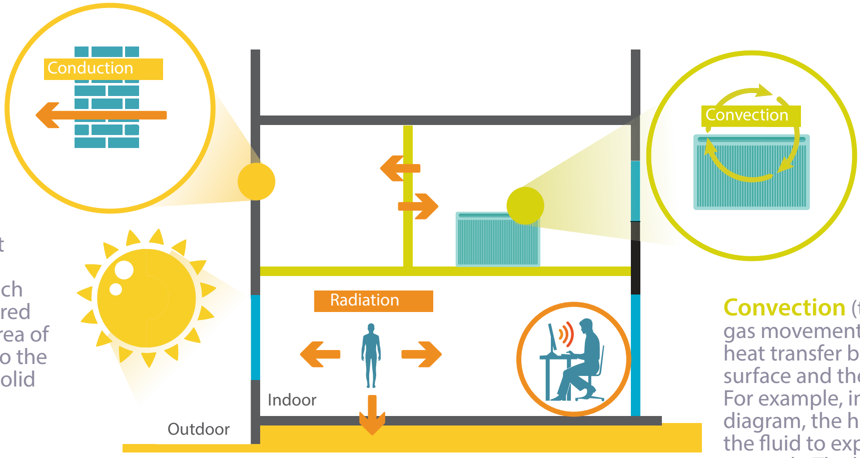
3.1. Principles of Heat Gain and Heat Los in Buildings

This section covers the basic principles to simplefy the concept of heat gain and heat loss in buildings. It is very important for an energy efficient envelope to avoide heat loss in winter and heat gain in summer in order to reduce the amount of energy needed for heating and cooling the building and to mainatin the desired comfort levels for occupants.

What is Heat Transfer?

Heat transfer is the movement of thermal energy from one thing to another thing of different temperature [34]. It is the process of transferring heat from the high-temperature reservoir to a low-temperature reservoir.

There are three different methods for the heat to be transferred from one place to another [34]:



Conduction (through direct contact); is a process by which heat is transferred from the hot area of a solid object to the cool area of a solid object.

Convection (through fluid or gas movement); is the process of heat transfer between the solid surface and the liquid or gas. For example, in the following diagram, the heat source causes the fluid to expand and rise upwards. The hot fluid gives up its heat energy to cooler parts of the fluid. A convection current of warm fluid is set up. A roomful of air can be heated by convection.

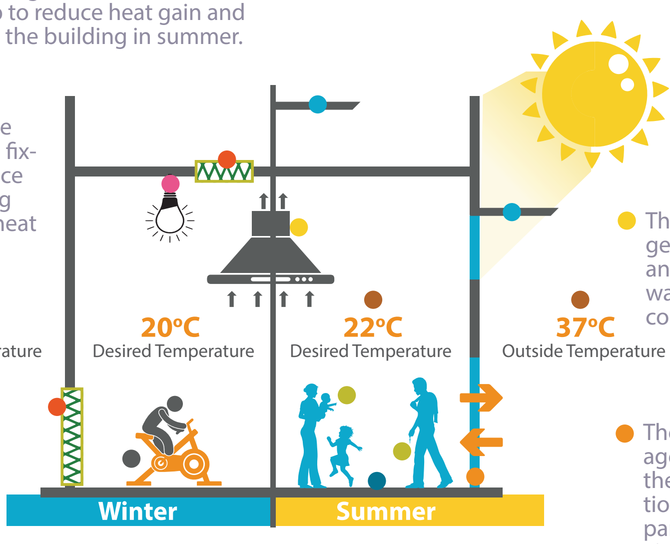
Radiation (through electromagnetic waves); is the process where infrared radiation is emitted by a hot object towards a cool object such as the sunlight entering the building causing the heat of the structure.

Heat Loss in a building: *the amount of heat a building loses through the different elements of the building envelope such as the exposed walls and roofs, windows and floors.*

Heat Gain in a building: *the amount of heat a building gains from different sources such as actual outdoor temperature, the building's occupants, lights, appliances, furniture, computers, ovens, etc.*

HEAT GAIN AND HEAT LOSS THROUGH A BUILDING DEPENDS ON:

- The shading of windows, walls, and roofs. For example, two identical buildings with different orientation will be exposed to a different amount of heat gain from the sun, shading the elevations and if possible, the roof will help to reduce heat gain and reduce the need for cooling the building in summer.
- The temperature difference between outside temperature and people's desired temperature that achieve thermal comfort levels.
- The amount of lighting in the room. Incandescent lighting fixture produce heat into a space while high-efficiency lighting fixtures generate very little heat that could be neglected.
- The heat the appliances generate. For example, an oven, computers, washing machines, TV contribute to heat.



- The type of construction and the amount of insulation in roof and external walls.
- The amount of air leakage from the outside into the indoor space. Infiltration plays an important part in determining the air conditioner sizing. Cracked windows, door gaps, shafts, shutter boxes are the doorways for air to entering the building from the outside, into a living space.
- The buildings surface area, more surface area means more heat gain in the summertime and more heat loss in wintertime.
- Activities and other equipment within a building. Cooking? Hot bath? Gymnasium?
- The number of occupants in a building. For example, the more occupants you have in a space, the more time and energy you will need to cool that space, while it is the opposite for heating the same space.

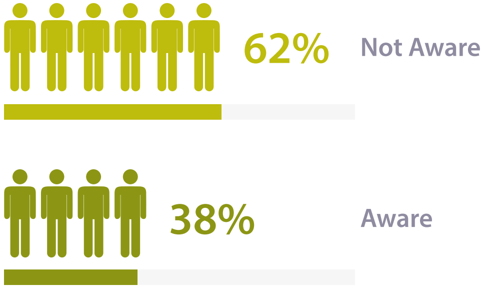
3.2. Related Local Building Codes & Green Building Rating Systems

The Jordanian National Building Codes have been formulated since 1993 under Law No.7 and the amended law of 2004 [20]. The codes are prepared and modified by local researchers and experts from both the public and private sectors. The Jordanian National Building Council approves the prepared codes before publication. The Council of Ministers approves these codes before they became mandatory.

There is a consensus about the fact that Jordanian building codes are not entirely implemented in the construction sector for many reasons. Many engineers and local experts claim that this is a critical problem, and the main reasons are lack of awareness and the high initial costs associated with implementing the required codes. Concerning people's awareness about this issue, a study by Jordan GBC in 2012 found that the lack of knowledge of the various Jordanian building codes reached 62% amongst normal residents [21].

Figure 11: Awareness of the various Jordanian building codes

Source: Jordan GBC, 2012.



The inefficient Energy performance of today's existing buildings is as a result of:

1. The non-compliance with the local thermal Insulation Code, which was first, issued in 1985.
2. The non-existence of many important codes, which are available today such as the local Energy Efficient Building Code, Solar Energy Code and Jordan Green Building Guide.

As the focus is on existing building retrofits in the building sector has been increasing worldwide and is necessary for Jordan's building stock, it is highly recommended to develop a local code for existing building retrofits towards a sustainable approach. This Guideline has been developed for this purpose but it focuses on the building envelope.

3.2.1. Jordan Thermal Building Insulation Code (JTIBC)

This code defines thermal design principles for buildings in Jordan. Although the first version was issued in 1985, many people used to ignore it due to the additional costs that accompany it [9]; [22] ; [23].

The main chapters covers the following [20]:

- Materials used in thermal insulation
- Principles of thermal design in buildings
- Thermal design calculations
- Design requirements

Figure 12: The covers of the Thermal Insulation Code and Thermal Insulation Guide.

Source: National Jordanian Building Council, 2009.

Source: National Jordanian Building Council, 2018.

> The calculations for heating and cooling loads of the case studies in this guide have been developed based on the standards of the Thermal Insulation Code.

The Guide for Thermal Building Insulation code

It is an explanatory guide for the original Thermal Installation Code for practitioners involved in the construction sector during the stages of design and implementation.

It aims to illustrate many issues related to thermal insulation in buildings to improve energy efficiency in buildings by reducing energy demand for cooling, heating, and provide a healthy indoor environment and thermal comfort for the occupants [16].

The Guide gives information about thermal insulation materials available in the Jordanian market, strategies for implementation, and practical solutions and methods for insulating buildings that meet the requirements of the Jordanian Thermal Insulation Code. It also discusses problems and damage that is caused by humidity inside buildings such as surface and interstitial condensation and suggests solutions, as well as solutions to improving thermal insulation in existing buildings.

3.2.2. Jordan Energy Efficient Building Code (JEEBC)

This Code aims to lower energy consumption in buildings and improve thermal performance; it provides guidelines, minimum requirements for all buildings types including commercial ones, and standards for the building envelope [24].

The building envelope standards that are used in this guide are taken from the JEEBC code although the code does not cover existing buildings. International, regional and local building codes were also utilized, and the needs of the Jordanian market was considered [25].

The main chapters cover the following:

- Architectural design principles and requirements
- Mechanical ventilation
- Heating and air conditioning
- Hot water supply
- Lighting system
- Electrical power

3.2.3. Green Building Rating Systems

There are many sustainability assessment methods for buildings worldwide. Building Research Establishment Environmental Assessment Method (BREEAM) was the first method launched in 1990 for Britain's building industry [26]. Since then, many other assessment methods have been developed all across the world such as the American system, Leadership in Energy and Environmental Design (LEED) in 1998; CASBEE (Japan) in 2001; Green Globe (Canada), and Green Star (Australia, New Zealand and South Africa) [27]. In general, there is not much focus on the sustainable performance of the building envelope in existing assessment methods, and due to regional variations, many of them are not applicable to other regions with different geography and climate. This highlights the need for developing comprehensive and integrated approaches that set a sustainable building envelope performance, and this is an important step to achieving building sustainability.

Figure 13: Green building rating systems and tools.
Source: Related associations

Jordan is a country that needs effective green building rating systems due to poor resources and the inefficiency of its buildings in the field of resource conservation. In the last decade, researchers have shown interest in contributing to a better understanding of the idea of developing local green building assessment tools that suit the context of Jordan environmentally, socially and economically. The result was the developing and releasing of the voluntary 'Jordanian Green Building Guide', it was developed by the National Construction Council and managed by the Royal Scientific Society (RSS) in 2013. Other non-governmental organisations such as Jordan Green Building Council developed a local assessment-building tool for Green residences. Today, the two recently developed local green building rating systems in Jordan; are for new construction, but both are working on developing an amended version to cover existing buildings.

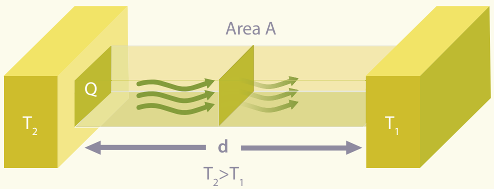
3.3. Thermal Insulation of Existing Buildings in Jordan

Thermal insulation is the reduction of heat transfer (the transfer of thermal energy between objects of differing temperature) between objects in thermal contact.

The most important aspect of an insulation material is its performance for resistance to the passage of heat throughout the lifetime of the building which is known as (Thermal Conductivity).

Thermal Conductivity (k)

It measures *"the ease with which heat can travel through a material by conduction. Conduction is the main form of heat transfer through insulation. The lower the figure, the better the performance. It is measured in (W/mK)"* [29].



source:Greenspec, 2018.

Thermal Resistance (R):

source: [29]

It is a figure connecting a material's Thermal Conductivity to its Width using the following equation;

Thermal Resistance (m^2K/W) = Thickness (m) / Conductivity (W/mK).

The greater thickness, the fewer heat flows (a lower conductivity). A building component with a high Thermal Resistance is a good insulator.

3.3.1. Insulation materials and their thermal Characteristics:

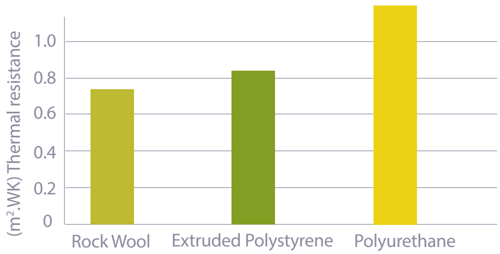
Thermal insulation materials are classified according to their shape into three main types [16]:

1. Rigid panels such as extruded polystyrene.
2. Semi-rigid panels such as rock wool.
3. Loose-fill insulation such as loose rock wool and light rubble.

Figure 14: Some common insulation materials used in the Jordanian building sector.
Source: Jordan GBC, 2012.

Rockwool, Polystyrene and Polyurethane are the common thermal insulation materials used in the Jordanian building sector [23]. The lower figure illustrates their Thermal Resistance [16]. Some local experts claim that extruded polystyrene is the most common insulation material; it is considered the best choice in the Jordanian market due to its thermal performance, emissions and its reasonable price compared to other insulation materials. [23].

Figure 15: Comparisons between the most common thermal insulation materials in Jordan in terms of thermal resistance with a 30 mm thickness.
Source: National Jordanian Building Council, 2015.



3.3.2. Common Practices for Thermal Insulation Application

The requirements of the local Thermal Insulation Code have been obligatory. However, people used to ignore thermal insulation in buildings, and the codes are not enforced nor checked for installation by authorities. Although there are penalties for non-compliance with the code, they are not implemented in reality [9]; [22]; [23].

Thermal insulation challenges in Jordan has two aspects:

The Technical aspect, such as

- Construction techniques
- Labor skills

The Non-technical aspect, such as

- People's awareness and knowledge of thermal insulation code
- Requirements and some myths

The technical aspects or challenges mainly happened because of the following [9]; [23]:

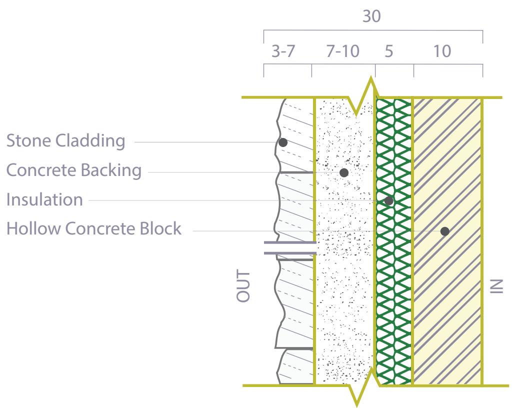
1. The construction method used traditionally
2. The continuity of thermal insulation (When used)
3. Achieving the required thermal resistance value required by the code

All of these problems, resulted in inefficient thermal performance of many buildings in Jordan, even the thermally insulated ones, which resulted in wasteful energy usage in Jordan [16]; [23].

Typical External Walls in Jordan consists of the following layers (from the inside out):

1. Plaster of 2cm.
2. Hollow Concrete Block 10cm
3. Thermal Insulation Layer, 5cm
4. Pour in site Concrete layer, 7-10cm
5. Stone cladding, 3-7cm

Figure 16: Typical Jordanian insulated external wall.



3.3.2.a. Some Non-Technical Common Problems Related to Thermal Insulation: [9]; [30].

1) The confusion between water insulation (waterproofing) and thermal insulation, thinking that water insulation for roofs and walls is enough, which is not correct since as stated in their names, each insulation layer deals with different issue.

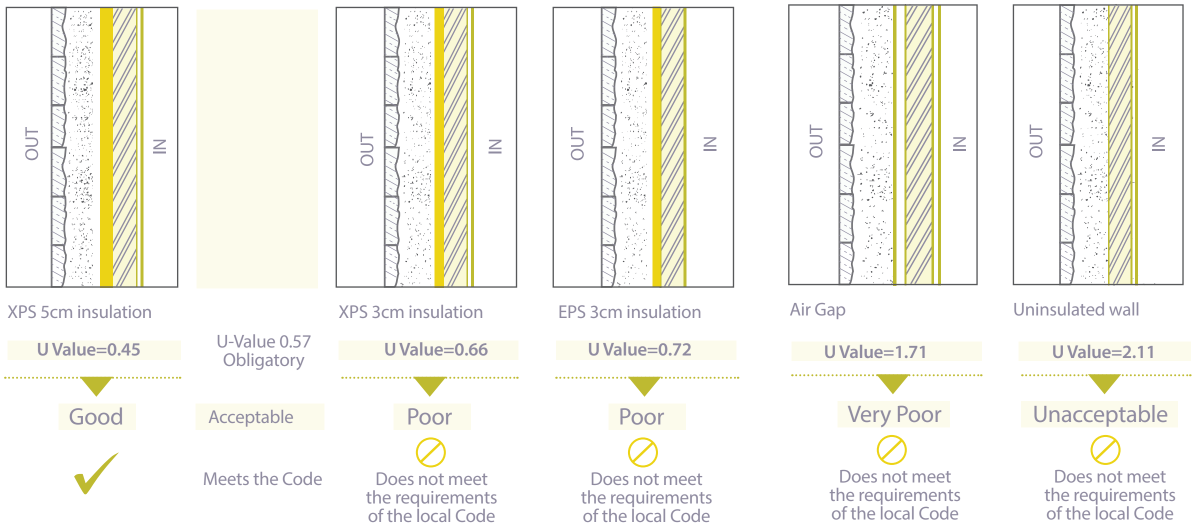
2) Thinking that adding thermal insulation layer to external walls is enough for completely insulate a building, neglecting the importance of thermal insulation in roof, although it could be more important in low-rise buildings.

3) Thinking that Air Gap in a wall composition is enough to provide the required Thermal Insulation, although an air gap provides thermal insulation, it is not enough to achieve the values obligatory by the code.

4) Adding an insufficient thickness of thermal insulation material. When deciding the thickness of the thermal insulation layer, the goal is to achieve the required standard in the Energy Efficient Building Code [30]. For example, the use of a 3cm thick Extruded Polystyrene in an external wall does not achieve the required value for thermal insulation but the 5cm thickness of the same material will.

Figure 17: An evaluation of some common local cases showing their U-Value.

Source: Jordan GBC, 2012.

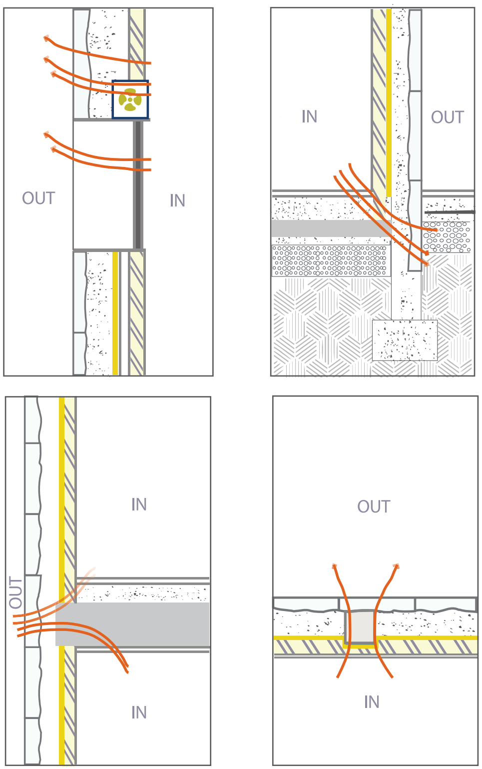


**Note: U-value is the thermal transmittance (W/m² k)*
XPS: Extruded Polystyrene
EPS: Expanded Polystyrene

Some Technical Common Problems Related to Thermal Insulation: [9]; [16]; [23]; [30].

1. Avoiding thermal bridges is rarely achieved when constructing buildings in Jordan, due to poor implementation and awareness of how to overcome this problem.

Figure 18: An illustration of some common local cases with thermal Bridges.
Source: Jordan GBC, 2012.



2. Installing thermal insulation material without consistency, when using boards or even sprayed type of installation. When thermal installation is not regularly and evenly installed, thermal bridges will be created and will affect the thermal comfort of occupants and the thermal insulation performance of the whole building.

3. The common process of constructing a conventional wall in Jordan affects its insulation capacity negatively. The internal block wall is built first; then, the insulation material board is installed. After that, rows of stone are built, followed by pouring concrete to fill the gap between the stone and the insulation material boards. By applying this conventional process, the insulation is compressed by the concrete, therefore affecting its thermal capacity. While the correct way of constructing the same wall is by installing the insulation boards after pumping the concrete into the external walls and waiting until it dries as shown in the following figure [18].

Figure 19: External Wall Construction showing the conventional process (on the right) and the alternative recommended method (on the left).
Source: National Jordanian Building Council, 2015.

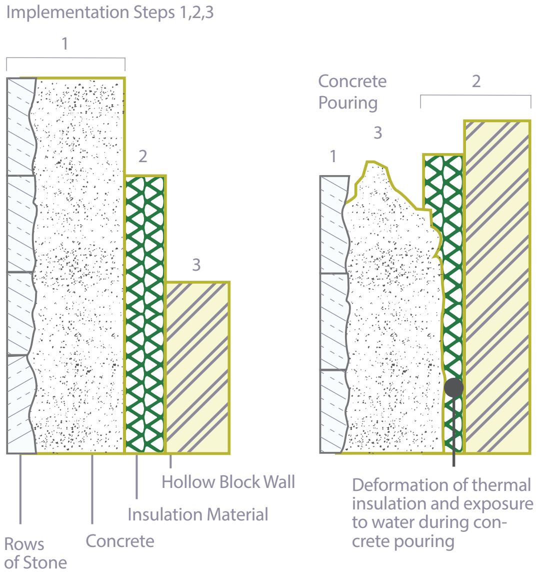
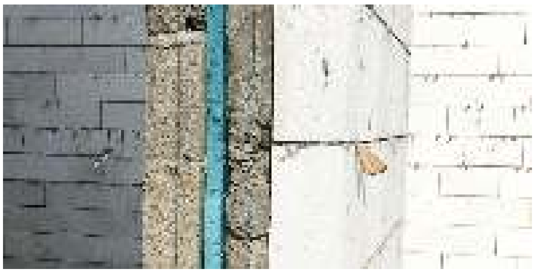


Figure 20: A real case in Madaba following the recommended method.
Source: Eng. Khaleel Awwad, 2018.



3.4. The Construction and Thermal Performance of Existing Buildings' Envelope in Jordan

The building envelope has a significant influence on the heating and cooling demand of buildings. As this Guide aims to improving the performance of the building's envelope in relation to energy efficiency and thermal comfort, it is important to identify the current situation of the building envelope components in regards to thermal performance in Jordan. The focus will be on building's Envelope main components that separate the exterior environment from interior, they include:

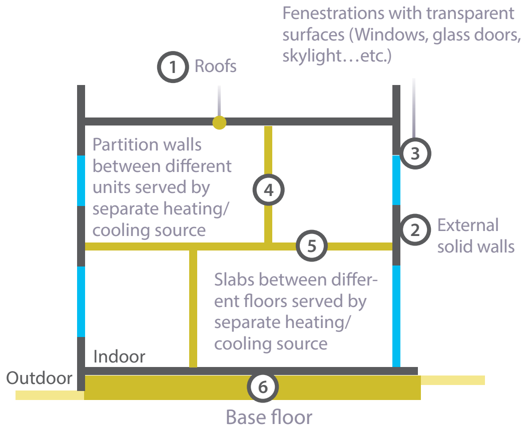


Figure 21: The main building envelope components examined in this study.
Source: Shamout, S. 2016.

How to calculate the current thermal performance of the building's envelope components?

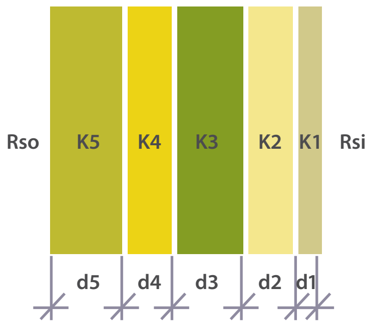
It is important to calculate the U-value of each component and compare it with the maximum Limit according to the Local Energy Efficient Building Code.

> **Thermal Transmittance or Heat Transfer Coefficient (U-factor):**
>
> is the rate of heat flow through a unit area of building envelope material or assembly, including its boundary films, per unit of temperature difference between the inside and outside air. The U-factor is expressed in (W/m².K) [20].

The following equations illustrate the calculation method of the U-value. The U-value varies according to the thickness of the layer (m) (or component) and the thermal conductivity (k-value) as shown in the following equations.

The calculations will be represented in tables; each building component has a separate calculation showing its structural components and thermal quality (total U-value) [9]. All the values and the following equations used in the calculations are taken from Jordan Thermal Insulation Code (2009) [20].

Figure 22: Example of an envelope component.
Source: National Jordanian Building Council, 2018.



$$R = \frac{d}{k} \quad (m2.K/W)$$

$$U\omega = \frac{1}{(Rsi + R1 + R2 + R3 + R4 + R5 + Rso)}$$

Where:

- R is the thermal resistance ($m^2.k/W$)
- d is the thickness (m)
- K-value is the thermal conductivity (W/m.K)
- U-value is the thermal transmittance ($W/m^2.k$)
- Rsi is the thermal resistance at the inside surface (air).
- Rso is the thermal resistance at the outside surface (air).

3.4.1. The Roof (R)

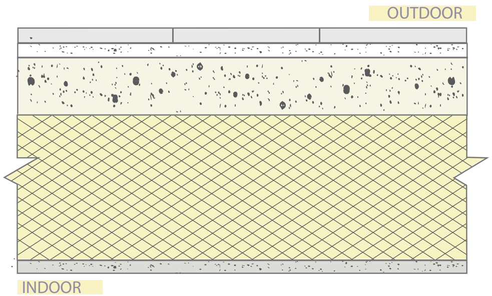
The most common type of roof construction in Jordanian buildings is reinforced concrete roof [9]; [23]. Next are two common roof compositions and their thermal charecteristics.

R.01. Uninsulated flat Reinforced Concrete Roof with Tiles.

Table 3: Calculation of the current thermal performance of R.01.

Layer	Name	Thickness [mm]	k-Value [W/mk]	R-Value [m²K/W]
Rso	External Surface Resistance	-	-	0.040
1	Ceramic Tile	8	1.05	0.008
2	Cement mortar	20	0.54	0.037
3	Sand & Gravel	70	0.3	0.233
4	Water Proofing- bitumen Roll	4	0.17	0.024
5	Light weight Concrete	100	0.16	0.625
6	Reinforced Concrete Slab	300	1.85	0.162
7	Cement Plastering	20	0.72	0.028
Rsi	Internal Surface Resistance	-	-	0.100
Total		522		1.26
	Current U-value			0.80
U-value [W/m²K]	Maximum Limit According to the Energy Efficient Building Code			0.55

Figure 23: Illustration of the components of R.01.

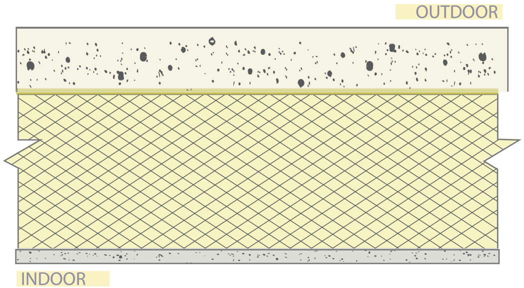


R.02. Uninsulated flat Reinforced concrete Roof.

Table 4: Calculation of the current thermal performance of R.02.

Layer	Name	Thickness [mm]	k-Value [W/mk]	R-Value [m2K/W]
Rso	External Surface Resistance	-	-	0.040
1	Water Proofing-bitumen Roll	4	0.17	0.024
2	Light Weight Concrete	100	0.16	0.625
3	Reinforced Concrete Slab	300	1.85	0.162
4	Cement Plastering	20	0.72	0.028
Rsi	Internal Surface Resistance	-	-	0.100
Total		424		0.979
U-value [W/m²K]	Current U-value			1.02
	Maximum Limit According to the Energy Efficient Building Code			0.55

Figure 24: Illustration of the components of R.02.



3.4.2. The External Walls

The prime function of external walls is “*to provide shelter from the outdoor environment including high or low temperatures, rain and wind, and to provide reasonable indoor thermal comfort for occupants*“ [9]; [31]. Exterior walls of buildings in Jordan differ in wall thickness, number of layers, construction materials, and external cladding. In most cases, thermal insulation is not present in existing buildings’ except for recently built structures. As in the case of roof construction, building with concrete is the most common construction material for vertical walls, external walls can be grouped into three main types:

- Uninsulated Solid Walls (W.01);
- Uninsulated Cavity Walls (W.02);
- Insulated walls (W.03).

Uninsulated External Solid Walls (W.01)
W.01. Uninsulated ‘stone-clad’ wall - hollow concrete blocks.

Table 5: Calculation of the current thermal performance of W.01.

Layer	Name	Thickness [mm]	k-Value [W/mk]	R-Value [m2K/W]
Rso	External Surface Resistance	-	-	0.040
1	Stone	60	2.27	0.026
2	Cast in site Concrete	80	1.17	0.068
3	Hollow Concrete Block	100	1.00	0.100
4	Cement Plastering	20	0.72	0.028
Rsi	Internal Surface Resistance	-	-	0.130
	Total	260		0.392
U-value [W/m^2K]	Current U-value	2.55		
	Maximum Limit According to the Energy Efficient Building Code	0.57		

Figure 25: Illustration of the components of W01.1.
Source: Shamout, S. 2016.

Cavity Walls (W.02)

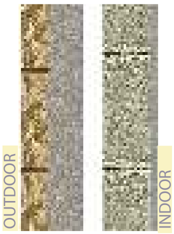
W.02.1. 'Stone clad' wall _ Concrete hollow blocks.

Table 6: Calculation of the current thermal performance of W.02.1.

Layer	Name	Thick-ness [mm]	k-Value [W/mk]	R-Value [m2K/W]
Rso	External Surface Resistance	-	-	0.040
1	Stone	60	2.27	0.026
2	Cast in site Concrete	80	1.17	0.068
3	Air gap	50	-	0.110
4	Hollow Concrete Block	100	1.00	0.100
5	Cement Plastering	20	0.720	0.028
Rsi	Internal Surface Resistance	-	-	0.130
Total		310		0.502
U-value [W/m²K]	Current U-value			1.99
	Maximum Limit According to the Energy Efficient Building Code			0.57

Figure 26: Illustration of the components of W.02.1.

Source: Shamout, S. 2016.



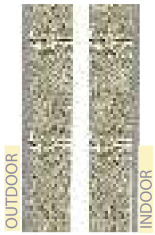
W.02.2. Cavity wall - Concrete hollow blocks.

Table 7: Calculation of the current thermal performance of W.02.2.

Layer	Name	Thick-ness [mm]	k-Value [W/mk]	R-Value [m2K/W]
Rso	External Surface Resistance	-	-	0.040
1	Plaster	20	0.72	0.028
2	Hollow Concrete Block	100	1.00	0.100
3	Air gap	50	-	0.110
4	Hollow Concrete Block	100	1.00	0.100
5	Cement Plastering	20	0.720	0.028
Rsi	Internal Surface Resistance	-	-	0.130
Total		290		0.785
U-value [W/m²K]	Current U-value			1.27
	Maximum Limit According to the Energy Efficient Building Code			0.57

Figure 27: Illustration of the components of W.03.

Source: Shamout, S. 2016.



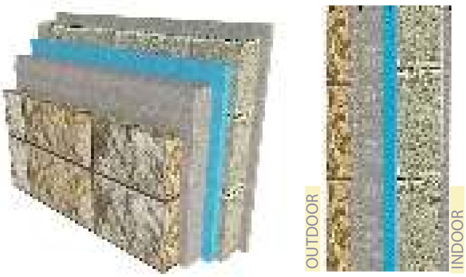
Insulated walls
W.03. Insulated 'Stone clad' wall

Table 8: Calculation of the current thermal performance of W.03.

Layer	Name	Thickness [mm]	k-Value [W/mk]	R-Value [m2K/W]
Rso	External Surface Resistance	-	-	0.040
1	Jordan Stone	60	2.27	0.026
2	Cast in site Concrete	80	1.17	0.068
3	Extruded Polystyrene	30	0.032	0.938
4	Hollow Concrete Block	100	1.00	0.100
5	Cement Plastering	20	0.720	0.028
Rsi	Internal Surface Resistance	-	-	0.130
	Total	290		1.33
U-value [W/m²K]	Current U-value			0.75
	Maximum Limit According to the Energy Efficient Building Code			0.57

Figure 28: Illustration of the components of W.03.

Source: Shamout, S. 2016.



3.4.3. Fenestration with Transparent Surfaces (Windows, Glass Doors, Skylights…etc.)

Fenestration especially windows, plays a significant role in providing natural light and natural ventilation to buildings. But, they are considered a source of heat loss in winter and heat gain in summer since they are rarely designed with proper shading and the majority of existing buildings in Jordan have single pane windows with hollow aluminum frames which is resulting in high heat transmission and weak airtightness [9]; [16]; [23] .

Figure 29: Illustration of the components of single glazed windows with Aluminium frames

Table 9: Thermal properties of single pane windows [16].

Glazing	Thermal Characteristics
Single glazing with Metal Frame	U-value= 5.7 W/m²K
Clear	SHGC = 0.82

SHGC: Solar Heat Gain Coefficient

3.4.4. Partition Walls between Different Units Served by Separate Heating/ Cooling Source [9]

PW.01 Internal Walls - Vertical partition

Table 10: Calculation of the current thermal performance of Internal walls between different Units.

Layer	Name	Thick-ness [mm]	k-Value [W/mk]	R-Value [m2K/W]
Rsi	Internal Surface Resistance	-	-	0.130
1	Cement Plastering	20	0.72	0.028
2	Hollow Concrete Block (01)	100	1.00	0.179
3	Cement Plastering	20	0.72	0.028
Rsi	Internal Surface Resistance	-	-	0.130
Total		140	-	0.416
U-value [W/m²K]	Current U-value for PW.01			**2.41**
	Maximum Limit According to (EEBC)			**2.0**
PW.02	(15 CM) Hollow Concrete Block	Does not comply		**2.15**
PW.03	(20 CM) Hollow Concrete Block	comply		**1.94**

Figure 30: Illustration of the components of vertical partition

Source: Shamout, S. 2016.

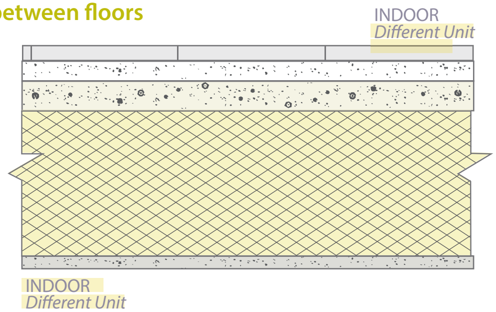
3.4.5. Slabs between Different Floors Served by Separate Heating/ Cooling Sources

SF.01 Slab between Floors

Table 11: Calculation of the current thermal performance of Slabs between different Floors.

Layer	Name	Thick-ness [mm]	k-Value [W/mk]	R-Value [m2K/W]
Rso	External Surface Resistance	-	-	0.130
1	Ceramic Tiling	8	1.05	0.0076
2	Concrete mortar	20	0.54	0.037
3	Gravel and sand	70	0.30	0.233
4	Reinforced Concrete	300	1.85	0.162
5	Cement Plastering	20	0.720	0.028
Rsi	Internal Surface Resistance	-	-	0.130
Total		418		0.59
U-value [W/m²K]	Current U-value			**1.7**
	Maximum Limit According to the Energy Efficient Building Code			**1.2**

Figure 31: Illustration of the components of slab between floors



4 Chapter

Energy Retrofit Strategies for the Building Envelope

4. Energy Retrofit Strategies For The Building Envelope

This chapter discusses the Energy-Related building envelope's retrofit strategies. It simply explains how to improve the Energy Performance of the building envelope's components including the External Walls and the Roof as well as the Transparent Surfaces such as windows and skylights.

Retrofitting the building envelope will achieve many benefits, but with the focus on energy, **the main benefits would include:**

- **Optimizing energy efficiency in the building as a whole and reducing energy bills related to the Cooling and Heating of the building.**
- **Improving the thermal comfort for occupants.**
- **Enhancing the health and increasing the productivity of occupants.**
- **Reducing maintenance costs related to the decaying of the building structure.**

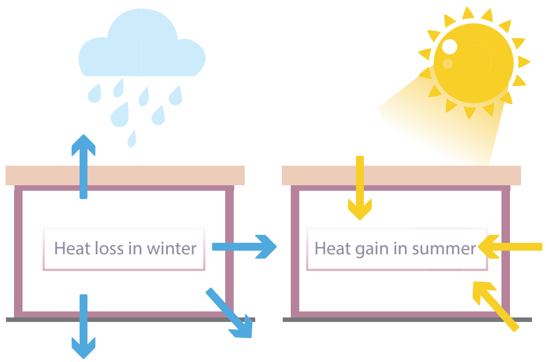
Examples of Energy related retrofit strategies for the building envelope include:

- **Improving the thermal performance of the building's External walls and Roof by adding thermal insulation.**
- **Improving the thermal performance of the building's transparent surfaces by installing double glazing windows and skylights.**
- **Eliminating thermal bridges in the building's envelope by adding thermal insulation in critical joint areas.**
- **Reducing heat gain in the building's envelope by introducing shading devices.**
- **Improving airtightness of the envelope by weatherstripping openings, joints and penetrations of surfaces.**

4.1. Improving the thermal performance of the building's External Walls and Roof

How is it affecting the Energy Performance of the Building Envelope?

The building envelope's components, including external walls and roof, affect the amount of energy required to cool and heat the buildings. They are the largest surfaces and directly affecting the buildings' heat loss in winter and heat gain in summer, which relate to the energy needed to achieve the required thermal comfort levels for occupants.



How to retrofit external walls and roof to improve energy efficiency?

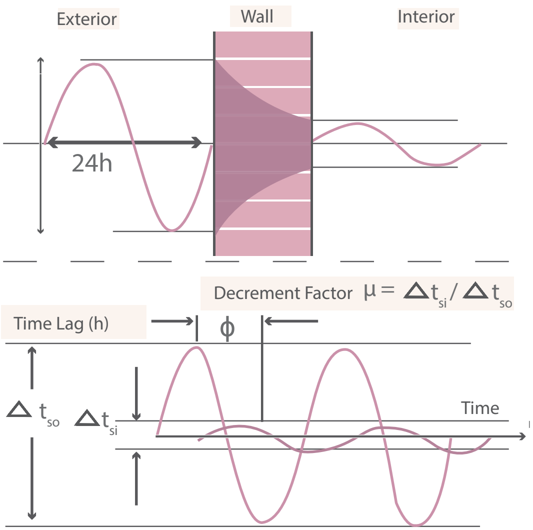
Retrofitting a building's envelope with a goal of achieving a reduction in energy consumption means increasing the envelope's Thermal Resistance.

Increasing the Thermal resistance of external walls, roofs and internal partitions is usually achieved by adding a thermal insulation material to the construction layers. This will result in achieving a lower total U-Value (the rate of heat flow through a unit area of building envelope assembly per unit of temperature difference between the inside and outside air (W/m^2.K)).

The total U-value does not change by changing the position of the insulation layer, whether it is installed in between layers or toward the internal or external face of the assembly, but, it affects the time lag associated with heat flux (ϕ) and the 'Decrement Factor (μ) (as shown in the figure) [16].

Figure 32: Thermal mass, heat wave movement from external surfaces to internal surfaces for an external wall, introducing Time Lag & Decrement Factor. (During Summer time)

Source: National Jordanian Building Council, 2018.

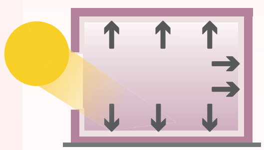


Tsi= Temperature of internal surface
Tse= Temperature of external surface

- **The Time Lag** (ϕ) is the time delay due to the thermal mass of material. The thicker and more resistive the material, the longer it will take for heat waves to penetrate.
- **The Decrement Factor** (μ) is the reduction in cyclical temperature on the inside surface compared to the outside surface.

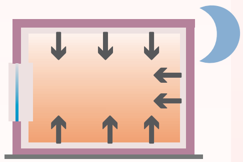
The required time for the temperature to move from the external surface of the wall to the interior surface as well as the temperature difference depends on the characteristics of the external wall material, the Thermal Conductivity (k), the Density (p), Specific Heat(Cp) and the Thickness (d).

Thermal mass' describes the capacity of materials for absorbing, storing and releasing heat. For example, concrete and water have a high capacity for heat storage and are considered as 'high thermal mass' materials [35]. In contrast, Insulation foam has a little heat storage capacity and considered as having 'low thermal mass'. The following drawing shows how thermal mass works in winter heating.



Daytime absorption

Daytime: solar radiation enters the building through windows and heats up the interior space and walls.



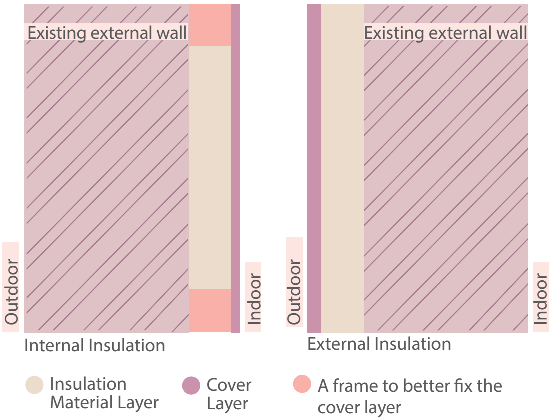
Evening heating

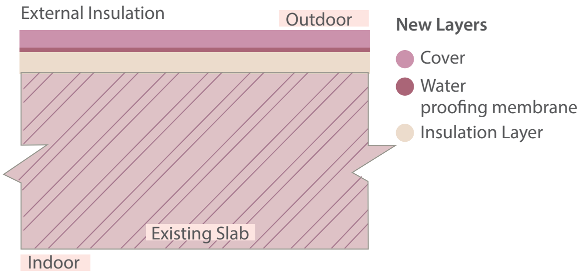
Night: the heated walls radiate the heat into space.

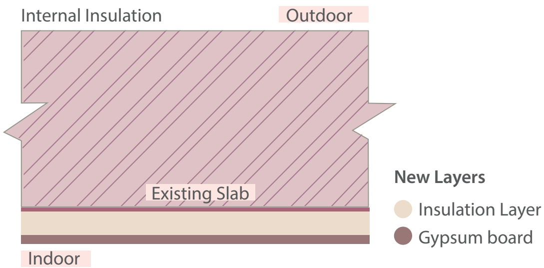
This Guide proposes two main retrofitting solutions for walls and roofs to increase the thermal resistance of the building's envelope component [9]. The solutions will be further explained in the next chapter with more details.

The two main solutions are:

1. Adding thermal insulation layer to the INTERNAL face of wall/roof
2. Adding thermal insulation layer to the EXTERNAL face of wall/roof





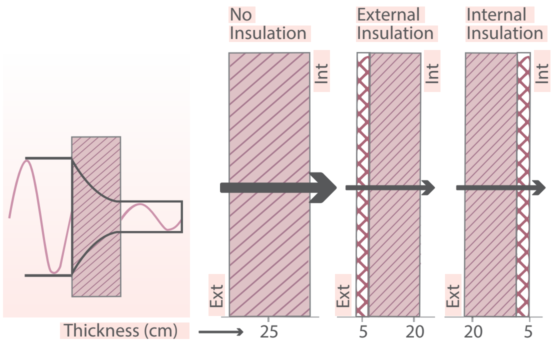


Deciding on the location of the added insulation layer, whether its internal or external depends on many factors including the most severe season (summer or winter-cooling or heating dominant building), climate as well as the heating and cooling source. Furthermore, when retrofitting buildings in Jordan, adding an external insulation layer as a coat would not be appropriate in some cases, for example, stone-clad facades are very common, due to the traditional use of stone in the Jordanian buildings [23]. Therefore, in this Guide, there will only be one appropriate solution for stone-cladded facades, which is adding the thermal insulation layer from the inside [9].

Figure 33: The impact of the position of the insulation layer in construction elements.

Source: National Jordanian Building Council, 2018.

The impact of the position of the insulation layer in construction elements



	No Insulation	External Insulation	Internal Insulation
U-value (w/m².k):	3.39	0.66	0.66
Decr. Factor (μ):	0.40	0.02	0.56
Time lag (ϕ) (h):	6.30	8.20	5.30

Enhancing building envelope integrity [36]

The absence of thermal insulation in parts of a building's envelope causes thermal /cold bridges- areas where heat is rapidly lost from inside a heated space. Cold bridges causes humidity condensation inside the building, especially on the internal corners and surfaces of external its walls. This issue is directly related to health problems caused by mold and energy inefficiency caused by escaped heat.

The building envelope is a complete system, while this guide covers the energy performance for the building envelope, other important issues should be considered when retrofitting the envelope of existing buildings such as waterproofing and preventing rainwater leakage.

Figure 41: Bituminous Membrane Waterproofing Method.

Source: theconstructor.org, (n.d). https://theconstructor.org/practical-guide/bituminous-waterproofing-membrane-roof/13285/

The need for installing waterproofing layer is critical when the retrofit includes adding the thermal insulation layer on the external part of the roof. Therefore, adding an external thermal insulation layer considered more expensive and time consuming than adding the thermal insulation from inside. It requires more effort and technical expertise, and more protection is needed for waterproofing, airtightness and Ultraviolet radiation (UV) protection.

The following are the main waterproofing methods commonly used in buildings in Jordan:

Bituminous Waterproofing Membrane
is used in insulating all types of roofs, foundations, floors, bathrooms, swimming pools.

Waterproofing & Protective Coatings
is used as a primer in walls, roofs and floors, and as an insulation material for foundations, and retaining walls underground.

Mastics & Sealants
is used when filling gaps and cracks and protecting metal roofs.

Bonding Asphalt
is used as an adhesive before using Bituminous Waterproofing Membranes.

Waterproofing & Damp-proofing Felts
is used as preventive layers against humidity to insulating roofs, floors...etc.

Acrylic-based water-proofing coatings
is normally used in the case of retrofitting existing walls, roofs or any surfaces. Its light colour has an effect in reducing heat gain in roofs and walls.

Cool Roof [37]

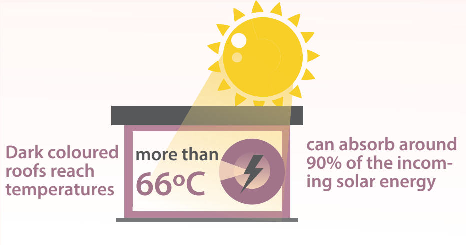
"Cool roofs can help cool down buildings and cities".

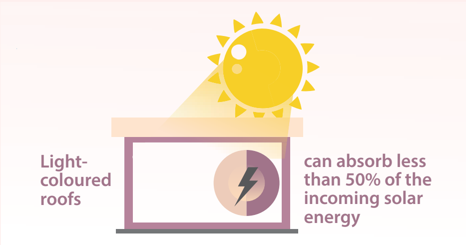
What Is a Cool Roof?

It is a roof designed to lower roof temperatures when the sun is shining by reflecting the heat consequently reducing heat gain. This strategy is highly recommended when retrofitting an existing roof to optimise energy efficiency in climate with hot summer.

How does it work?

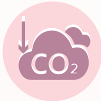
A Cool roof's surface reflects the sunlight and emits heat more efficiently than a dark roof so it will be cooler in the sun.





Benefits:

Reduced energy use: cool roofs transfer less heat into the building, and therefore reducing the use of air conditioning.



Reduced GHG emissions and air pollution when reducing energy demand.

Improved human health and thermal comfort when maintaining a high-quality indoor environment inside buildings in terms of air temperature.

The most common solution for Cool Roof is the use of High Solar Reflective Cool Roof Coating, usually light or white coloured. It forms an extremely high reflective mat surface that blocks the incoming solar radiation and remains cooler, contributing to the saving of energy for cooling needs.

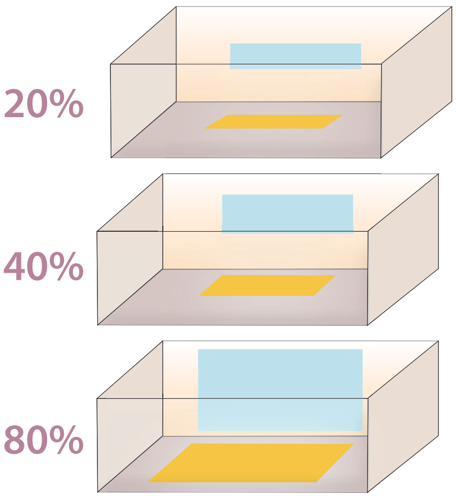
Figure 42: A cool coating is applied to a dark roof.

4.2. Improving the Thermal Performance of the Building's Transparent Surfaces

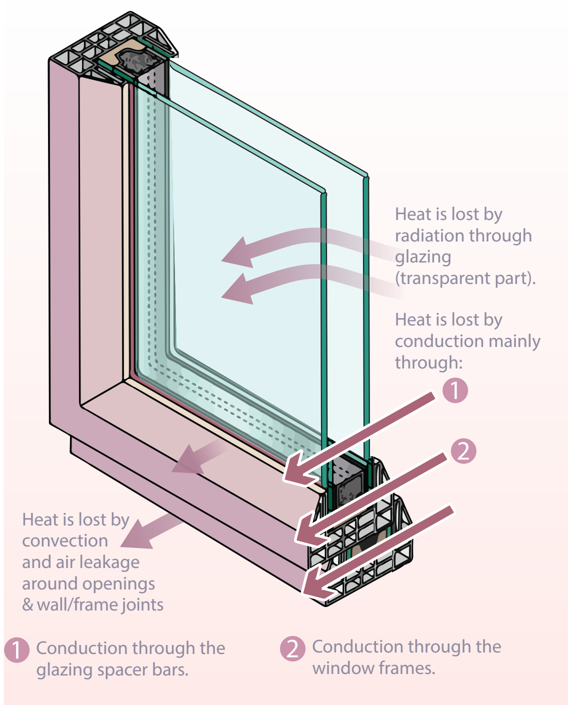
How is it affecting the energy performance of the building's envelope?

Improperly installed or poorly made windows, doors and skylights, significantly increase the energy needed for heating and cooling in a building since they are considered the main source for heat loss in winter and heat gain in summer. The higher the window to wall ratio (WWR) is, the more impact it would have on the thermal performance of the building's envelope.

Figure 34: Examples of window to wall ratios.



Transparent surfaces of a building (windows, glass facades, skylights...) lose heat through the following means:



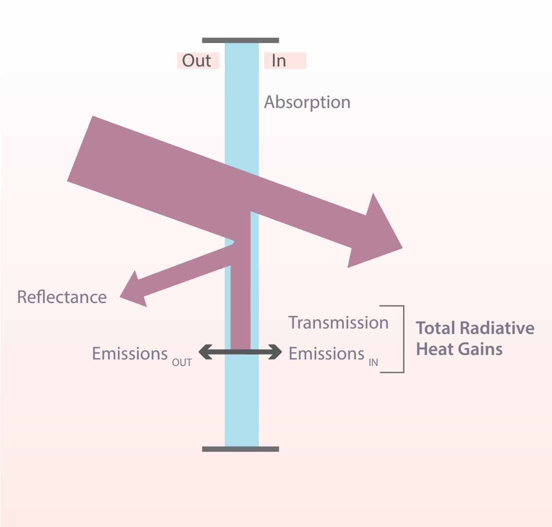
On the other hand, windows gain heat through:

- **Heat is gained by primary transmittance:** the direct transmission of solar gain through the glazing.
- **Heat is gained by secondary transmittance:** the absorbed energy by glazing and the subsequent transfer inwards by both radiation and convection.

The thermal and optical performance of a glazing unit weather it is a window, a glass door/facade or a sky-light, is determined by the following characteristics:

Thermal Transmittance (U–value) is the rate of heat flow through a unit area of building envelope assembly per unit of temperature difference between the inside and outside air (W/m2.K). The lower the U-value, the better the glass thermal performance is. Glass units with 'low-E' layer (low-emissivity) will have lower U-value and offer better thermal insulation.

Figure 35: Radiant Energy transfer.
Source: (Jariry, 2016)



Solar Heat Gain Coefficient (SHGC) is the total fraction of the available solar radiation which is transmitted through windows as heat gain. The value is expressed to be between 0 and 1, which gives the energy proportion from the sun passing through windows, including frames, into interior spaces. For instance, when the SHGC value is 0.6, it means that 60% of solar radiation will be passing through the window from the outside to the inside. In the cooling season, blocking solar heat gain is essential especially in hot climates, while solar heat gain is beneficial in heating season as it passively heats indoor spaces.

Shading coefficient is the ratio between the solar heat gains, which passes through a specific kind of glass to the solar energy which passes through 3mm clear float glass with a total solar heat transmittance of 0.87. The shading coefficient value can be derived from SHGC using this equation:

SC = S.H.G.C/0.87.

Visual Light transmittance is the percentage of light in the visible spectrum transmitted through the glass. A higher VT indicates a higher amount of daylight that is transmitted to space, and therefore, reduces the need for artificial light and the associated energy consumption.

How to retrofit glazed surfaces to enhance thermal performance and energy efficiency in a building?

Many factors have to be considered when retrofitting a building's glazed surfaces including:

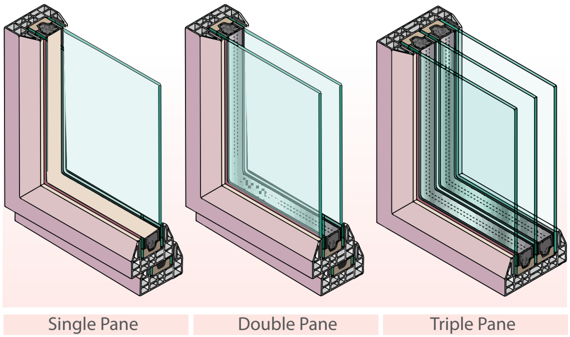
- Replacing Single Pane glazed Surfaces with Double-glazing Units
- Selecting Glass Type with Solar Control Characteristics
- Selecting a Glazed Frame Material that has High Thermal Resistance

There are other factors that affect the thermal performance of glazed surfaces, such as the orientation of the openings and the size of the windows, but they cannot be considered for retrofitting options since they should be considered in the original design.

Replacing Single Pane glazed Surfaces with Double-glazing Units (Insulated Glass)

It is highly recommended to replace single pane windows and other glazed surfaces such as skylights with double- glazed units, this could save up to 30% of the heating load, it is also worth mentioning that although triple glazing units are more efficient but not cost effective in the context of Jordan in terms of climate and cos

Figure 36: A Typical Single, Double & Triple Pane window sections



Replacing single pane windows with double- glazing save up to
30%
of the **heating load [38]**

Selecting Glass Type with Solar Control Characteristics

The proper selection of the type of glass can achieve up to
30%
reduction of the annual energy cost [38]

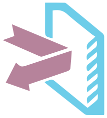
The main types of glass are:

- **Clear glass:** It allows the highest transfer of energy and has poor thermal insulation while permitting the highest daylight transmission.

- **Tinted Glass:** It is used to reduce heat gain, but it also reduces visible light as compared to clear glass. The tint is useful in controlling glare but has no effect on the U-factor. In a retrofit situation, special films can be applied to clear glass to change existing clear glass in windows to tint.

- **Coated Glass:** A metallic coating is applied to clear glass to enhance its thermal performance.

In order to have a greater solar control when improving the performance of existing windows or replacing them, many properties could be combined including

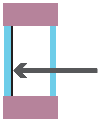


Reflective Surface (Mirror like effect)

A reflective coating is used to lower the solar heat gain coefficient by increasing the surface reflectivity of the glass. The coating consist of thin metallic or metal oxide layers, it comes in various metallic colors—silver, gold, bronze—and they can be applied to clear or tinted glazing. Films with reflective properties can be applied to existing windows to achieve the desired results.

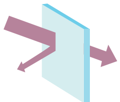
Note

A reflective window that acts like a mirror to the outside during the day will look like a mirror on the inside during the night. These coatings will not provide visual privacy at night if interior lights are on.



Low-E Coated Surface

A microscopically thin metallic coating is added to the glazing surface, which lets light through but reflects short-wave infrared radiation. This suppresses the radiant heat flow. In a climate with heating dominant, low-e layer should be installed on the inside face of the inner pane to reflect heat inside the space, while if cooling is dominant low-e layer should be applied to the inner face of the external pane.



Spectrally Selective Characteristics

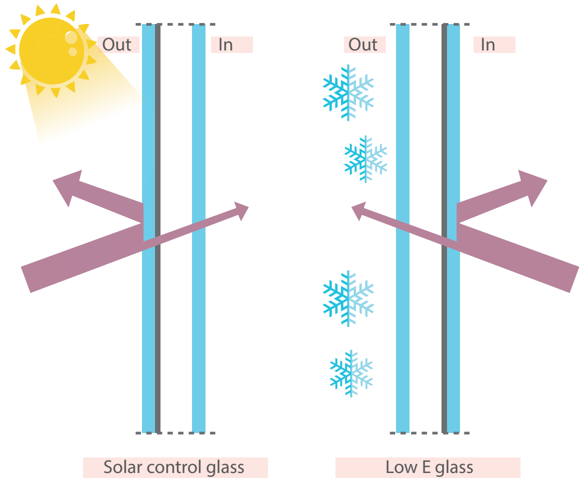
Spectrally selective glazing maximizes the amount of visible light that gets into a building but minimizes the amount of solar heat that passes through.

Note

Solar control window film reduces solar heat gain by reflection and absorption. As they also block solar heat gain in winter months, these films are ideal for cooling-dominated climates. Window films can be tinted for solar heat and glare control, but some recent window film options reflect solar heat while maintaining a relatively clear appearance. The lower a film's solar heat gain coefficient (SHGC), the less solar heat it transmits. The higher the visible transmittance (VT) number, the more light is transmitted. Window film does not provide substantial insulating benefits.

Window film often is applied to the room-side glass surface of windows. Since window film absorbs the portion of solar heat that it does not reflect or transmit, it increases the glass temperature and may cause thermal stress on the glass or insulated glazing seals, particularly on sunny but cold days.

Figure 37: Illustration of Solar Control Glass and Low E glass. *Source: (Jariry, 2016)*



Selecting a Glazing's Frame Material that has High Thermal Resistance

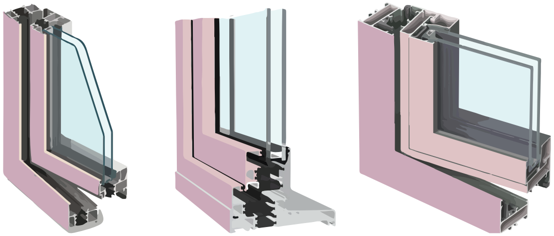
Improving the thermal resistance of the frame can contribute to a window's overall energy efficiency, particularly its U-factor. There are advantages and disadvantages to all types of frame materials, but vinyl, wood, fiberglass, and some composite frame materials provide greater thermal resistance than metal. The following table compares three different types of frames and glazing composition [39].

Table 12: Different types of frames and glazing R-Values

(R-window total: the higher the R value, the better the thermal performance of the window) IGU= Insulated Glazing Unit
Source: Level.org.nz, 2018.

Window frame material	Single Glazing	IGU with 4 mm glass and 8 mm air space	IGU with 4 mm glass and 12 mm air space	IGU with 4 mm glass, 12 mm air space and low-e pane	IGU with 4 mm glass, 12 mm air space, low-e pane and argon gas fill
Aluminium Frame	R0.15	R0.25	R0.26	R0.31	R0.32
Thermally broken Aluminium Frame	R0.17	R0.30	R0.31	R0.39	R0.41
UPVC Frame	R0.19	R0.34	R0.36	R0.47	R0.51

Figure 38: Types of frames according to material and thermal resistance



Aluminium | Thermally Broken Aluminium | UPVC Window

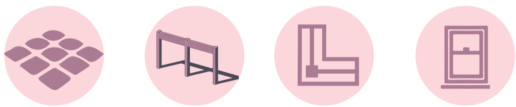
4.3. Eliminating Thermal Bridges in Building's Envelope by Adding Thermal Insulation in Critical Joint Areas.

A thermal bridge is a penetration in the insulation layer with a highly conductive material, allowing increased amounts of heat flow through that material and this is a big problem in the building envelope. The thermal bridge causes heat gain or loss in a wall, roof and/or a ground floor, it results in;

- Increasing Energy bills for heating and cooling
- Reducing interior thermal comfort
- Compromising the building's integrity

Thermal Bridges in in Existing Buildings in Jordan

Most of the current local construction techniques in Jordan result in creating thermal bridges when constructing the building envelope, even in insulated buildings that claim to comply with the local standards such as the Energy Efficient Building Code [9]; [23]; [30]. A continuous insulation layer can be rarely found as many areas are not usually insulated including:

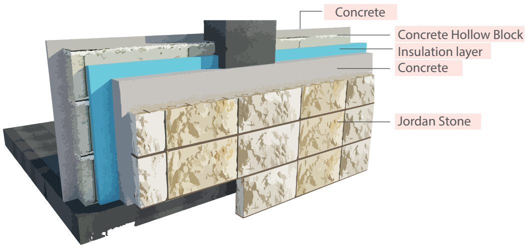


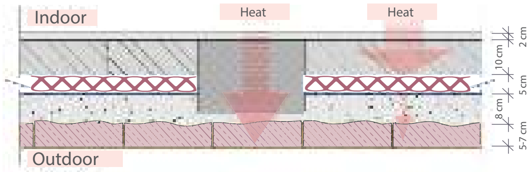
Ground floor | Structural Columns | External face of Slabs | Windows' shutter boxes

How to Retrofit External Walls and Roof to Improve Energy Efficiency and Eliminate Thermal Bridges?

The following table illustrates major thermal bridges locations in a typical Jordanian building. Problems are the result of untrained construction workers and common wrong practices. The table suggests energy retrofit strategies for each case to eliminate the thermal bridges and their negative performance on the building's envelope [9].

Table 13: Thermal bridges elimination options. *Source: Elaboration of the Author based on (Shamout, S. 2016).*

<table>
<tr><th>Thermal Bridge Location</th><th>Current Situation</th><th>Proposed Energy Retrofit Solution</th></tr>
<tr><td>Structural Column Inside Wall</td><td>




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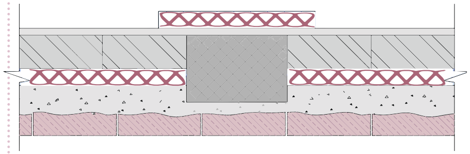
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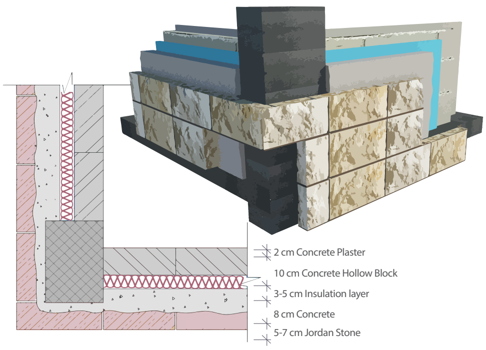
<tr><td>Structural Column at Corner</td><td>


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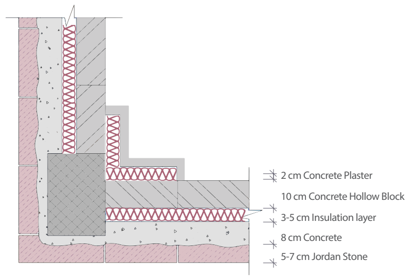
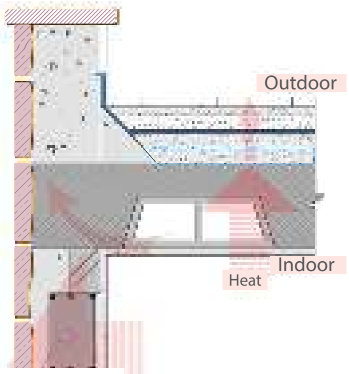
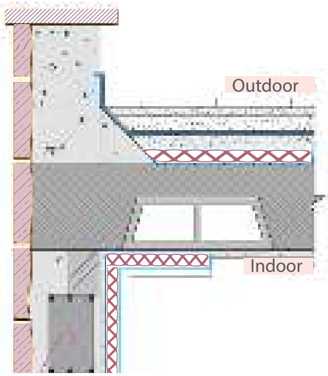
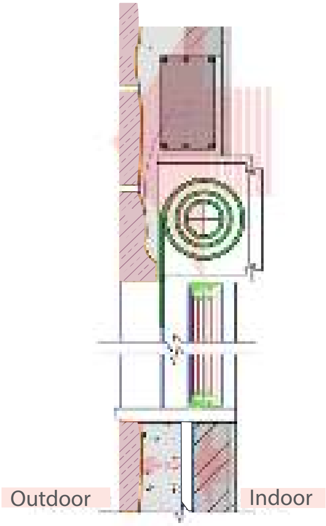
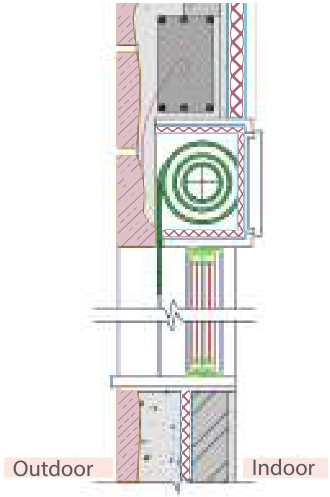


</td></tr>
</table>

Thermal Bridge Location	Current Situation	Proposed Energy Retrofit Solution
Between Floors Slab/ Roof		
Windows' Shutter Box		

How to discover thermal bridges in an existing building envelope?

Thermal Imaging Camera (TIC): An infrared camera can help quickly see and find the sources of energy efficiencies and used for building diagnostic, it helps locating thermal bridging, insulation irregularities, and air leakage and moisture intrusion issues.

Thermal imaging does not directly measure temperature; it measures radiated thermal energy.

4.4. Reducing Heat Gain in the Building's Envelope by Introducing Shading Devices.

How Shading Devices Affect The Energy Performance Of The Building Envelope?

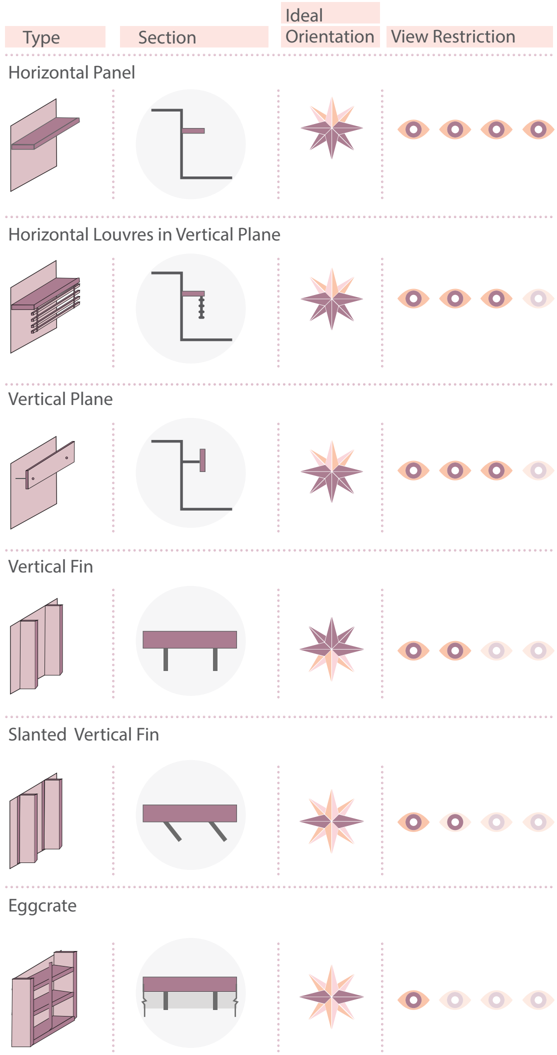
Shading Devices aim to control sunlight by allowing it to enter the building when it is needed for heating in winter as well as preventing sunlight from entering the building in summer. It also controls glare and reduces heat gain through the solar radiation when entering the building, and therefore reducing the energy demand of the building. The higher the window to wall ratio is, the more impact it would have on the thermal performance of the building envelope.

What shading Device should be Installed to Improve Energy Efficiency of the Building's Envelope?

To achieve energy efficiency in a building's envelope, exterior solar shading devices such as vertical fins, overhangs and light shelves with energy-efficiency measures should be employed careful understanding of the orientation of the façade as well as the visual impact of the selected device as shown in the following figure and notes [40].

Figure 39: General types of exterior shading devices.

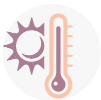
Source: American Institute of Architects (AIA) &Society of Building Science Educators (SBSE), 2012.



- The Horizontal overhangs on southern elevations are the best external shading strategy as it results in an efficient performance regarding energy and cost [38].

- In case of having a low window to wall ratio of 10% or below, and high-performance glass, it is recommended not to install external shading devices as they would have minimal savings that can barely recover the initial cost of investment [38].

- Cooling loads represent the highest energy consumer in commercial buildings, thus reducing cooling loads should be given priority when retrofitting through reducing solar radiation by the installation of external shading devices. Solar radiation contributes to about 40% of the total cooling loads when using the typical types of glazing (Jariry, 2016). However, the negative effects of fixed external shading devices in winter should be also considered, which are;



Increase heating loads since it eliminates the penetration of deep winter sun if the devices are not well design.

Increase the energy used for lighting.

Therefore, it is recommended to employ a consultant in order to design the appropriate shading devices. The Effects of external shading devices vary according to many design configurations such as the orientation of the building and the type and area of glazing.

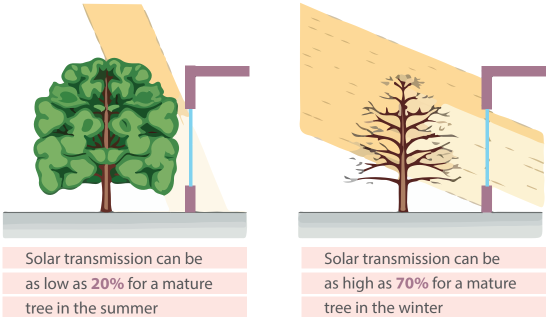
The following figures show some proposed solutions for external shading according to a local study.

Below are some examples of external shading devices.

Besides manufactured external shading devices, there are other ways to prevent sunlight from entering the interior space of a building such as interior shading devices, building self-shading by the design of the building's mass and vegetative shading. Vegetative shading achieved by planting trees or creepers to filter the sunlight entering the building [9]; [40].

Figure 40: Vegetation shading.

Source: American Institute of Architects (AIA) & Society of Building Science Educators (SBSE), 2012.



A Local Case Study

Source: Jordan GBC, 2018.

External shading devices in Jordan are usually designed using Aluminium or reinforced concrete when it's built-in. For the retrofitting case, the initial costs maybe high as it varies based on the materials costs and desired design. However, other local materials has been experimented, such as the case of Jordan's GBC where they designed and implemented shading devices from reused materials in Deir Alla in cooperation with the local community within a program for the Green Affordable Homes project. The aim of the project is to encourage the use of green local products creatively.

4.5. Improving Air Tightness of the Envelope by Weather Stripping Openings, Joints and Penetrations of Surfaces.

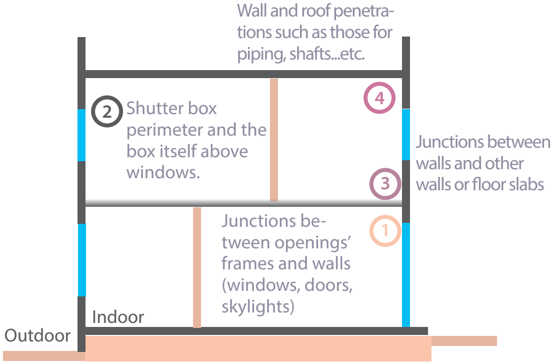
Building's Envelope Airtightness can be defined as the resistance to inward or outward air leakage through unintentional leakage points or areas in the building envelope. Differential pressures drive this air across the building envelope due to the combined effects of stack, external wind and mechanical ventilation systems.

How is it Affecting the Energy Performance of the Building's Envelope?

Airtightness is the fundamental building property that affects infiltration and exfiltration in a building, and therefore contribute the reduction of heat loss. On the other hand many buildings including the existing ones suffer from air leakage. **Air leakage is a major problem in buildings; since it is:**

- **Contributing to the increased costs of heating and cooling**
- **Affecting the occupant's thermal comfort and health**
- **Causing moisture problems and decaying of structural elements**

Air leakage is mainly caused by:



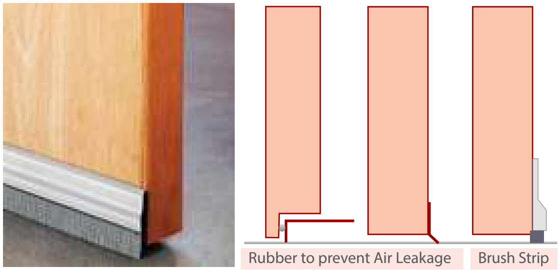
How to Improve Air Tightness in Existing Buildings?

A number of studies have shown substantial energy savings by tightening building envelopes and reducing heat loss. There are many ways to decrease air leakage in existing buildings, several methods and techniques are available including:

A. Caulking: Apply caulking (several types available such as urethane, latex, and polyvinyl) to seal various leaks such as those around the window and doorframes, and any wall penetrations such as holes for water pipes.

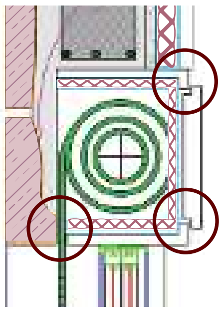
B. Weatherstripping: Sealing of windows and doors can be provided by various materials and techniques, such as:

- **Sealing the gaps under and around doors using rubber or brush strips [16].**



- **Sealing the gaps around windows' frames using rubber, brush strips or silicone weatherstripping.**

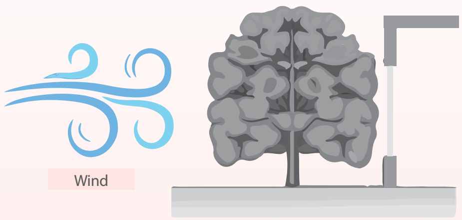
- **Sealing gaps around windows' shutter box by using weatherstripping.**



Air Retarders: These systems consist of one or more air-impermeable components that are applied around the building exterior shell to form a continuous wrap around the building's walls. There are several air retarders (AR) types such as liquid-applied bituminous, sheet bituminous and sheet plastic. The AR membranes usually applied to obstruct the vapor movement through the building's envelope and thus act as vapor retarders. Unless the building is planned to have an overall building envelope retrofit, these systems are typically expensive and inapplicable to install for existing buildings.

IDEA

Plant shrubs or trees around the building to reduce wind effects and air infiltration.



IDEA

Generating Electricity by installing Building Integrated Photo Voltaic Panels (BIPV) in/on the building's external surfaces.

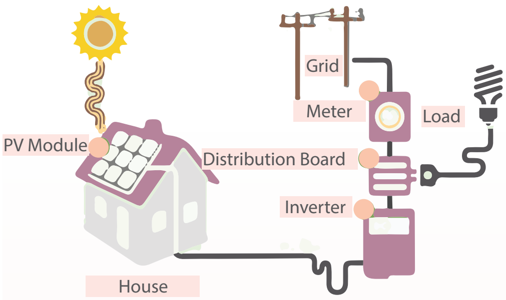
Although generating electricity from PV panels is an active design strategy, it can be integrated into the building's envelope to create an 'Energy Generating Envelope'.

A photovoltaic (PV) system uses light from the sun to generate electricity. It can be grid connected thanks to Jordan's renewable energy law 13 for the year 2012.

Integrating PV cells when retrofitting an existing building aims at eliminating or minimizing electricity bills. The cost of the PV system depends on the current electric bill.

Figure 41: Photovoltaic (PV) grid connected system.

Source: ETA max for energy and environmental solutions.



The following figure gives information about the cost and payback period of PV systems installed on the roof of a residential building based on the market price for photovoltaic systems.

Figure 42: Estimated Cost and Average pay back period

Marji Group, Jordan, 2017

Monthly Electric Bill (JD)	PV System Cost	Payback of PV System
15	1,800-2,500	10-14 yr
25	2,500-3,500	8.5-12 yr
50	4,000-5,400	6.6-9.0 yr
75	4,800-6,700	5.4-7.0 yr
100	5,700-7,800	4.7-6.5 yr
125	6,400-8,800	4.3-5.9 yr
150	7,000-9600	3.9-5.3 yr
200	8100-11200	3.4-4.7 yr
300	10,500-14,400	2.9-4.0 yr
500	15,100-20,800	2.5-3.5 yr

** Note: Numbers above are estimated numbers based on Nov 2016 Electric Tariffs of Residential Sector*

The benefits of using BIPVs in an Energy Retrofit project includes:

Reducing electricity bills significantly since electricity will be produced locally and traded with an electricity provider.

Reducing heat gain of the building when it is installed on the top roof and/or the façade and providing shading areas which will be reflected on a reduction of the cooling load.

Figure 43: A- Local examples for integrating PVs on a local building's façade.

Al-Huson University College

Figure 44: B- Local examples for integrating PVs on a local building's rooftops.

ALhasad Al-tarbawi Schools

5

Chapter

Case Study-Building Envelope Retrofit For Optimizing Energy Efficiency

5. Case Study-Building Envelope Retrofit For Optimizing Energy Efficiency

5.1. Building Envelope Retrofit for Optimizing Energy Efficiency

After discussing the current thermal performance for buildings in Jordan, and identifying the main building envelope components in Chapter 3, this section will propose basic retrofit options. The selected materials for retrofitting are chosen based on availability in the local market and the familiarity of application by local contractors.

When adding a layer of thermal insulation in a retrofit option, the minimum thicknesses required to comply with the current Jordan Thermal Insulation Code and Jordan Energy Efficient Building Code is used. This target is used for roofs, external walls, and partition walls separating different units, and slabs between different floors.

The requirements for Jordan Thermal Insulation Code and Jordan Energy Efficient Building Code is shown in the following figure and tables.

At the end of this chapter, two building typologies; commercial and residential; in two climate zones; Amman (Zone 2) and Aqaba (Zone 1) will be tested to find the improvement in the thermal performance by applying the selected energy-retrofit strategies to their building's envelope.

Figure 45: The maximum allowed U-Values of the building envelope component by local codes.
Source: National Jordanian Building Council, 2018.

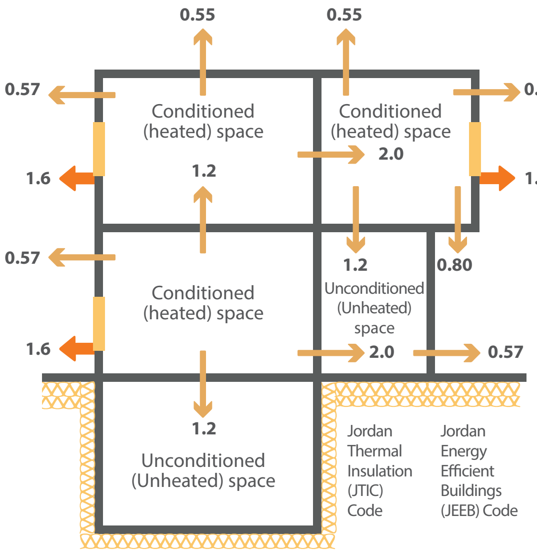


Table 14: Maximum U-values for external and internal walls required by the JEEBC.
Source: National Jordanian Building Council, 2010.

Walls	Max. U-value [W/m²K]
Opaque External Wall or any part of it	0.57
The total area of External Walls including windows, doors & openings	1.60
Partition walls, separating areas with independent energy source each	2.00
Partition walls, separating areas where one is air-conditioned and the other is not	2.00

Table 15: Maximum U-values for exposed floors, roofs, and internal slabs required by the JEEBC.
Source: National Jordanian Building Council, 2010.

Exposed Floors and Roofs		Max. U-value [W/m²K]
Floors/ Roofs Exposed to outdoor air	Heat transfer towards the top	0.55
	Heat transfer towards the bottom	0.80
Floors/ Roofs separating floors with independent energy source each		1.20
Floors located above unheated/ air-conditioned basements or spaces		1.20

Table 16: Windows maximum U-values and window-to-wall ratios required by the JEEBC.
Source: National Jordanian Building Council, 2010.

Window type	Max U-Value [W/m²K]	Maximum allowed window-to-wall ratio
Windows with aluminum/ steel frame, single glazing	5.70	20.1 %
Windows with aluminum/ steel frame, Double glazing*	3.40	36.4 %
Windows with a wooden/ plastic frame, single glazing	4.80	24.3 %
Windows with a wooden/ plastic frame, double glazing*	3.10	40.7 %
*with 6 mm spacing between glass panes		

All the proposed retrofitting solutions are presented in sectional drawings, showing the layers of construction materials and calculations are presented in tables.

(Note: In the following section, each building component has a special code to be identified with such as (W.01) that is used for the first case of external walls, and (R.01) that is used for the first case of roofs. Furthermore, the improved thermal performance will be calculated.)

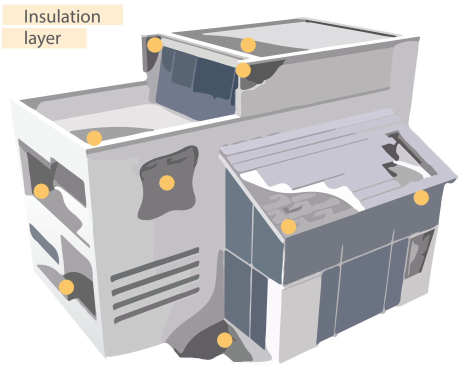
As mentioned earlier, the thermal insulation layer can be added to either side (exterior or interior) of the opaque envelope element. However, some factors limit the applicability of adding thermal insulation layer to the external surface of wall or roof composition, such as:

- When the external façade of the building has a durable expensive material such as stone, glass, metal or wood cladding panels. In this case, it is more practical to apply thermal insulation layer to the interior surface of the wall [23].

- When the roof of the building is occupied by water tanks and other service equipment. In this case, it is not practical to apply thermal insulation to the top of the roof, and applying the thermal insulation to the internal face of roof composition more is practical and feasible in terms of time and cost [9].

- When the roof of the building has good waterproofing and well maintained finish material such as good quality tiling, in this case it is better to keep the top of roof as is and work on adding the insulation layer to its internal surface.

Figure 46: Casing the building envelope by applying thermal insulation to all external walls and exposed roofs, increase air-tightness and install thermal efficient windows would increase energy efficiency of building and create a comfortable, healthy environment.



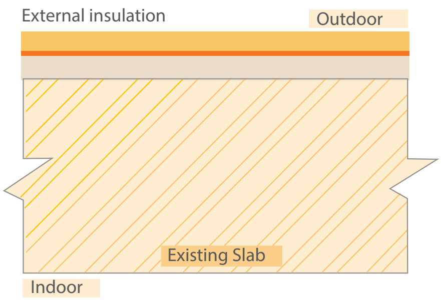
5.1.1. Retrofitting the Roof

The aim of retrofitting existing roof structures is to comply with the minimum requirement for thermal transmittance (U-Value) of external roofs as per Jordan Energy Efficient Building Code (2010), the code requires a maximum value of (0.55 W/m2K) which is not met in many existing buildings.

Enhancing the thermal performance of an existing roof is the most efficient and easiest way is achieved by adding a layer of thermal insulation material to the roof/slab composition. This Insulation could be added to the internal or external surface.

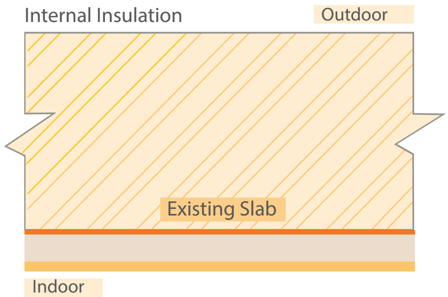
Thermal Insulation Added to Internal Surface of Roof/Slab (Cold Roof): This option is implemented by adding a layer of thermal insulation material to the existing inner surface of the roof, then covering it with a suitable finish material such as gypsum boards, or wood panels or false ceiling panels.

Figure 47: Proposed solutions for improving thermal performance of the exposed roof, external and internal options.
Source: Elaboration of the Author.



(Results of improved U-Values are calculated assuming three different insulation materials: Extruded Polystyrene boards (XPS), Polyurethane foam (PUR) and Rock Wool boards (Rockwool) with minimum thickness complying with Code. (The suggested cover layer is ceramic tiling with mortar.) See table 18

Thermal Insulation Added to External Surface of Roof/Slab (Warm Roof): This option is implemented by adding a layer of thermal insulation material to the existing external surface of the roof and then covering it with a waterproofing membrane. A protective cover is preferably installed on top; this could be a layer of poured concrete or tiles. Metal mesh could be used to protect thermal insulation panels from breakage if needed when the roof is used heavily.



HINT

Using light color material as the finish layer of the roof is highly recommended and is called Cool Roof. A cool roof is one that has been designed to reflect more sunlight and absorb less heat than a standard roof. Cool roofs can be made of a highly reflective type of paint, a sheet covering, or highly reflective tiles. This strategy is most useful in hot climate since it will reduce cooling load in summer.

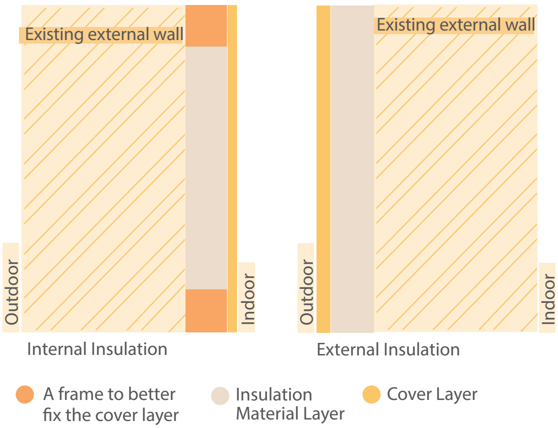
5.1.2. Retrofitting External Opaque Walls

The aim of retrofitting existing wall structures is to comply with the minimum requirement for thermal transmittance (U-Value) of external opaque walls as per Jordan Energy Efficient Building Code (2010), the code requires a maximum value of (0.57 W/m2K) which is not met in many existing buildings.

Enhancing the thermal performance of existing external walls in the most efficient and easiest way is achieved by adding a layer of thermal insulation material to the wall composition. This Insulation could be added to the internal or external surface of the wall.

Thermal Insulation Added to Internal Surface of External Wall: This option is implemented by adding a layer of thermal insulation material to the existing inner surface of the external wall, then covering it with a suitable finish material such as gypsum boards, or wood panels or plaster.

Figure 48: Proposed solutions for improving thermal performance of the external opaque walls



Thermal Insulation Added to External Surface of External Wall: This option is implemented by adding a layer of thermal insulation material to the existing external surface of the wall and protecting it with the desired cladding or finish material, such as mechanically fixed stone, cladding panels or cement base mortar as render topcoat with backing mesh.

(Results of improved U-Values are calculated assuming three different insulation materials: Extruded Polystyrene boards (XPS), Polyurethane foam (PUR) and Rock Wool boards (Rockwool). with minimum thickness complying with Code. (The suggested interior finish material is 15mm thick Gypsum Board) See table 19

Example for a retrofitted residence. External thermal insulation boards were added to external walls and covered with topcoat cement based mortar and weather resistant decorative finish (External Wall Insulation System). (source- Weber)

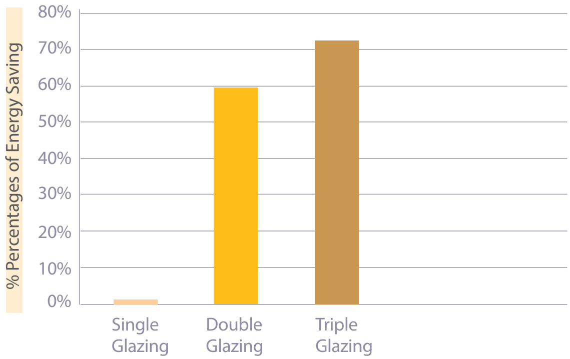
Figure 49: External Wall Insulation System.
www.uk.weber

NOTE: External Wall Insulation System (EWI) some companies provide the full system including the insulation, cement base mortar as render topcoat with backing mesh.

5.1.3. Improving the Thermal Performance of Windows

Between single, double and triple-glazed windows, double glazed (or double-pane) windows are the most feasible in Jordan. According to a study conducted on a residential building in Amman/Jordan, double glazed windows can save energy up to 59% compared to single glazed windows considering thermal transmittance. While triple glazed windows are much more expensive, they achieve an additional 12% in energy savings compared to double glazed windows (figure 62).

Figure 50: Energy savings percentage when using double and triple-pane glazed windows, compared to single-pane glazed windows in residential buildings.
Source: RSS, 2008.



This Guide recommends replacing all single glazed windows with double glazed windows (with 12mm spacer), low-e layer, and using UPVC frames.

Replacing the windows will result in around 60% improvement in their thermal conductivity (U-value) based on the U-values given by the Thermal Insulation code.

Figure 51: Replacing single glazing with double-glazing [20].

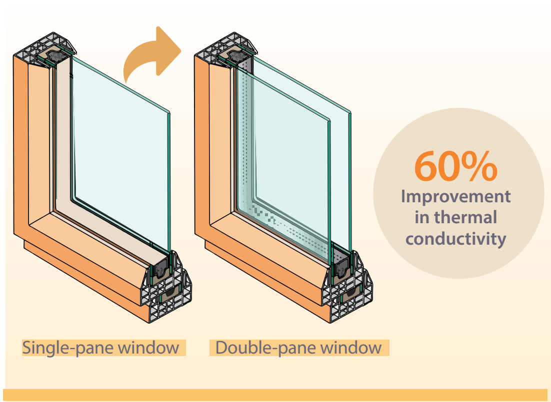


Table 17: Thermal properties of the proposed double-pane window. *Source: Thermal Insulation code, National Building Council, 2009.*

Double-Glazed with 12 mm spacing and PVC frames	U-Value [W/m²k]
Double glazing	2.8
Double with low E (E=0.2)	2.3

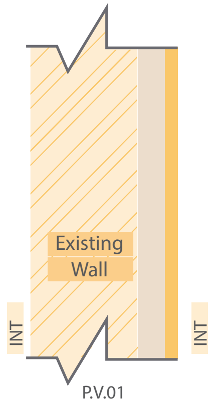
5.1.4. Retrofitting Partition Walls Between Different Units Served by Separate Heating/Cooling Sources

The Maximum U-value limit of internal partition walls located between different areas served by separate heating/cooling sources or separating two areas only one of them is air-conditioned is 2.00 W/m^{2}K according to the code.

The guide proposes enhancing the thermal conductivity of the partition walls by adding a thin thermal insulation layer to either side of the wall, then covering it with the desired internal finish material or cladding. The cover layer could be cement plaster, gypsum board or decorative panels.

Figure 52: the proposed solution for improving thermal performance of internal partition walls. *Source: Shamout, S. 2016.*

(Results of improved U-Values are calculated assuming three different insulation materials: Extruded Polystyrene boards (XPS), Polyurethane foam (PUR) and Rock Wool boards (Rock-wool) with minimum thickness complying with Code.
(The suggested interior finish material is 15mm thick Gypsum Boardsee table 20

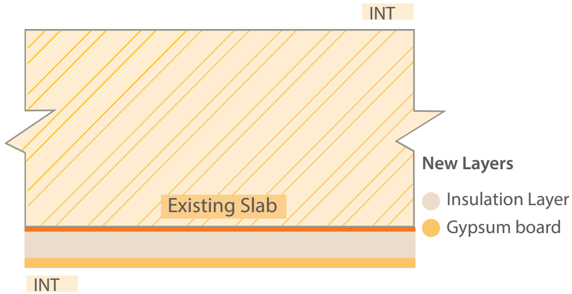


5.1.5. Slabs Between Different Floors Served by Separate Heating/Cooling Sources

The Maximum U-value limit of slabs between different floors, separating areas served by separate heating/cooling sources or separating two areas only one of them is air-conditioned is 1.20 W/m2K according to the code.

The guide proposes enhancing the thermal conductivity of the existing slab by adding a thin thermal insulation layer to the bottom side, then covering it with the desired internal finish material or cladding. The cover layer could be cement plaster, gypsum board or decorative ceiling panels.

Figure 53: The proposed solution for improving thermal performance of between floors' slabs
Source: Shamout, S. 2016.



(Results of improved U-Values are calculated assuming three different insulation materials: Extruded Polystyrene boards (XPS), Polyurethane foam (PUR) and Rock Wool boards (Rockwool) with minimum thickness complying with Code.)
(The suggested interior finish material is 15mm thick Gypsum Board) see table 21

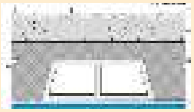
5.2. Building Envelope Optimization Summary

The following tables summarise the proposed treatments for retrofitting existing building's envelope components including roof, external walls, internal partition walls and between floors slabs as discussed earlier in this chapter, in order to comply with the Jordan Thermal Insulation Building Code (2009) requirements. The calculations of improved U-Values were prepared to assume three different insulation materials: Extruded Polystyrene boards (XPS), Polyurethane foam (PUR) and Rock Wool boards (Rockwool) with minimum thickness needed to comply with Code. Although, it is understood that limited thicknesses of insulation boards are available in the local market, but knowing the minimum required thickness will give building owners and contractors flexibility working with the material. For example, the extruded polystyrene (XPS) comes in cubical forms and can be cut to the desired thickness. In addition, the Polyurethane foam insulation is applied by a spray gun that makes it easy to decide the needed thickness.

ROOF

Table 18: Results for enhancing the thermal conductivity of existing roofs

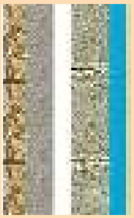
Source: Elaboration of the Author based on (Shamout, S. 2016).

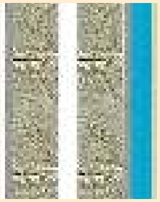
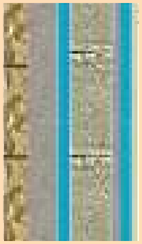
Current Situation		Scenario		Most common Insulation materials in Jordan					
Code	Section and Original U-value [W/m²K]	Code Target [W/m²K]		XPS K-value=0.035 [m²K/W]		PUR K-value=0.026 [m²K/W]		Rockwool K-value=0.04 [m²K/W]	
				External *	Internal	External	Internal	External	Internal
R.01	Existing U-value= 0.80 	Target : 0.55	Suggested Insulation Thickness (mm)		15		15		20
			Improved U-value		0.55		0.53		0.55
			Improvement %		31%		34%		31%
R.02	Existing U-value= 1.02 	Target : 0.55	Suggested Insulation Thickness (mm)	25	30	20	20	30	35
			Improved U-value	0.51	0.49	0.53	0.55	0.54	0.52
			Improvement %	50%	52%	51%	46%	47%	50%

EXTERNAL WALLS

Table 19: Results for enhancing the thermal conductivity of existing external walls

Source: Elaboration of the Author based on (Shamout, S. 2016).

Current Situation		Scenario		Most common Insulation materials in Jordan					
Code	Section and Original U-value [W/m²K]	Code Target [W/m²K]		XPS K-value=0.035 [m²K/W]		PUR K-value=0.026 [m$^{2K/W]}$		Rockwool K-value=0.04 [m²K/W]	
				External *	Internal	External	Internal	External	Internal
W.01.1	Existing U-value=2.55 	Target : 0.57	Suggested Insulation Thickness (mm)	–	45	-	35	-	55
			Improved U-value	–	0.52	-	0.57		0.56
			Improvement %	–	79%	-	78%	-	76%
W.02.1	Existing U-value = 1.99 	Target : 0.57	Suggested Insulation Thickness (mm)		40	-	35	-	50
			Improved U-value	-	0.55	-	0.52	-	0.55
			Improvement %	-	72%	-	74%	-	72%

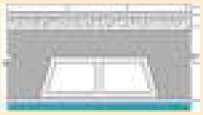
Current Situation		Scenario		Most common Insulation materials in Jordan					
Code	Section and Original U-value [W/m^{2}K]	Code Target [W/m^{2}K]		XPS K-value=0.035 [m^{2}K/W]		PUR K-value=0.026 [m^{2}K/W]		Rockwool K-value=0.04 [m^{2}K/W]	
				External *	Internal	External	Internal	External	Internal
W.02.2	Existing U-value = 1.87 	Target: 0.57	Suggested Insulation Thickness (mm)	40	40	35	35	50	50
			Improved U-value	0.53	0.57	0.53	0.57	0.55	0.54
			Improvement %	70%	68%	70%	68%	70%	70%
W.03	Existing U-value = 0.75 	Target: 0.57	Suggested Insulation Thickness (mm)	-	15	-	10	-	15
			Improved U-value	-	0.53	-	0.56	-	0.56
			Improvement %	-	22%	-	25%	-	25%

**Note: External thermal insulation was not considered as an option in external walls with stone cladding.*

SLABS BETWEEN DIFFERENT FLOORS SERVED BY SEPARATE HEATING/COOLING SOURCE

Table 20: Results for enhancing the thermal conductivity of existing between floors' slabs

Source: Elaboration of the Author based on (Shamout, S. 2016).

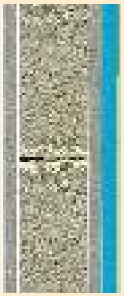
SF 01	Existing U-value = 1.70 	Target: 1.2	Suggested Insulation Thickness (mm)	–	10	-	10	-	10
			Improved U-value	–	1.00	-	1.70	-	1.10
			Improvement %	-	31%	-	41%	-	35%

**Note: Thermal insulation on upper part of the slab was not considered as an option due to unreasonable complications.*

INTERNAL PARTITION WALLS BETWEEN DIFFERENT UNITS SERVED BY SEPARATE HEATING/COOLING SORCE

Table 21: Results for enhancing the thermal conductivity of existing internal partition walls

Source: Elaboration of the Author based on (Shamout, S. 2016).

Current Situation		Scenario		Most common Insulation materials in Jordan		
Code	Section and Original U-value [W/m^2K]	Code Target [W/m^2K]		XPS K-value=0.035 [m2K/W]	PUR K-value=0.026 [m2K/W]	Rockwool K-value=0.04 [m2K/W]
				Internal	Internal	Internal
PW 01	Existing U-value = 2.41 	Target: 2.0	Suggested Insulation Thickness (mm)	5	5	5
			Improved U-value	1.53	1.47	1.63
			Improvement %	36%	39%	32%
PW 02	Same as PW 01 but using 15 cm Hollow Concrete Block Existing U-value = 2.15		**By adding Gypsum Board layer it will comply with code Improved U-Value= 1.64**			
PW 03	Same as PW 01 but using 20 cm Hollow Concrete Block Existing U-value = 1.94		**Will comply with Code by adding a 15 mm Gypsum Board Layer only**			

5.3. Case Study: Optimizing the Thermal Performance of the Existing Building's Envelope

This section contains analysis for retrofitting the building's envelope and improving the thermal performance of its different components. It makes comparisons between before and after retrofit cases, and investigates the enhanced performance of the four main retrofit strategies discussed earlier and listed below:

- **Improving the thermal performance of the building's ROOF by adding thermal insulation.**
- **Improving the thermal performance of the building's EXTERNAL WALLS by adding thermal insulation.**
- **Improving the thermal performance of the building's transparent surfaces by installing double-glazed WINDOWS with enhanced thermal performance for glass and frames.**
- **Installing SHADING DEVICES on southern elevation (horizontal overhangs, 0.60 m depth).**

The previous strategies are examined for two building typologies:

40% — **A two-story commercial building with large south facing glazed façade and 43% Window to Wall Ratio (WWR).**

32% — **A two-story residential building (single unit) with 32% Window to Wall Ratio (WWR).**

The two typologies are tested in two climate zones in Jordan:

- First Location Amman (Jordan- Zone 2)
- Second Location Aqaba (Jordan- Zone 1)

Table 22: Average Temperature values used for Amman & Aqaba

Source: 2017 ASHRAE Handbook- Foundamentals (SI)

Month	Average Temperature (°C): Aqaba	Average Temperature (°C): Amman	Horizontal Solar Irradiance (kWh/m2.day): Aqaba	Horizontal Solar Irradiance (kWh/m2.day): Amman
January	16.2	8.5	16.2	8.5
February	17.7	9.5	17.7	9.5
March	20.9	12.6	20.9	12.6
April	24.9	16.8	24.9	16.8
May	29.2	21.6	29.2	21.6
June	32.3	24.7	32.3	24.7
July	34.1	26.6	34.1	26.6
August	34	26.6	34	26.6
September	31.5	24.4	31.5	24.4
October	27.7	21.1	27.7	21.1
November	22.3	15.1	22.3	15.1
December	17.7	10.3	17.7	10.3

Base case building profile is created using Energy-Plus- based, Real-Time Analysis Simulation Tool for each typology in the two selected climates. Cooling and heating annual energy use is determined for the base case. Selected retrofit strategies are tested individually and collectively to find the potential reduction on heating and cooling energy use.

Required information for heating and cooling calculations

- Climate and outdoor design conditions
- The desired indoor design conditions and thermal comfort of the space
- Indoor Air Quality and Outdoor Air Requirements
- Building Characteristics
- Operation Schedule

The three Climatic zones in Jordan:

Jordan is divided geographically and topographically into three main climatic regions:

Figure 54: the three main climatic regions in Jordan

Source: INC as cited in Hashemite Kingdom of Jordan and UNFCCC, 2010.

1 **Zone 1:** The Jordan Valley, known as 'the Ghore Region', i.e. the lowland

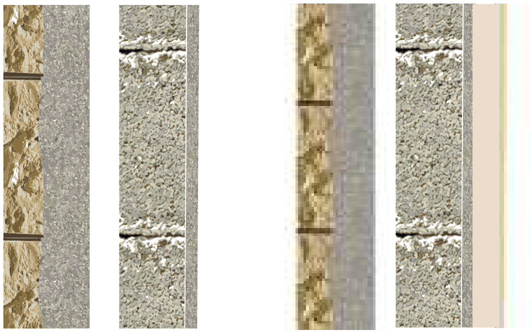
2 **Zone 2:** The Highlands Region. It has the typical Mediterranean climate with cold winters and hot summers and includes. Around 88% of human settlements in Jordan lie in this region, including Amman, Zarqa, Irbid, Karak, and Ma'an

3 **Zone 3:** The Desert Region (Badia), a semi-desert plateau that covers 80% of the country's land.

To improve the thermal performance for the roof and the external walls, extruded polystyrene boards were selected; with thicknesses chosen according to the most common available in the local market, 3.0 cm and 5.0 cm.

The two typologies will have the same envelope components regarding type of wall, roof and windows. In addition, the same retrofit treatment will be used to enhance their thermal performance. Below are the existing building envelope components and the selected treatments:

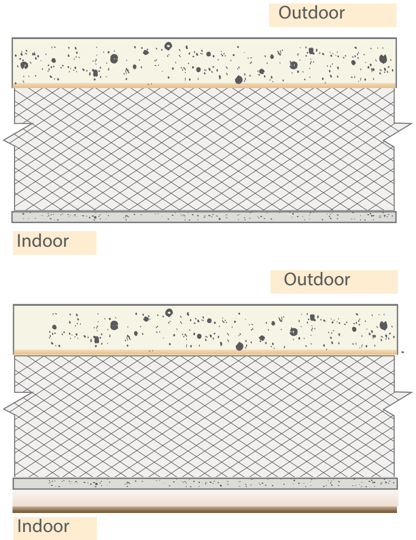
Figure 55: External wall before and after retrofit
Source: RSS, 2008.



EXTERNAL WALL

Wall Code: W.02.1
Pre-retrofit U-value = 1.99 W/m²K
Post-retrofit U-value = 0.46 W/m²K
Treatment: 5 cm thick XPS with 15 mm Gypsum board as a cover

Figure 56: Roof slab before and after retrofit



ROOF

Roof Type: Code: R.02
Pre-retrofit U-value = 1.02 W/m²K
Post-retrofit U-value = 0.49 W/m²K
Treatment: 3 cm thick XPS with 15 mm Gypsum board as a cover

WINDOWS

Pre-retrofit: Clear, single-glazed, with a metal sliding type frame
U-value= 5.7 W/m2K, SHGC= 0.82

Post-retrofit: Clear, double-glazed, low-e, with UPVC hinged type frame
U-value= 2.3 W/m2K, SHGC=0.57, weather-stripped

Expected Retrofit Cost:

The following cost assumption for estimated retrofit cost are calculated based on current local market prices, they will help to understand the cost related with such retrofit strategies:

External Walls Retrofit

Material & Labour Cost:

Item 1: Wooden studs, to support and fix the gypsum board layer= 1.50 JDs/m2.

Item 2: 5.0 cm thick Extruded Polystyrene Panels =5.5 JDs/m2

Item 3: Gypsum boards as the cover = 2.5 JDs per m2

Item 4: Paint= 0.50 JDs per m2

Total Cost of Materials = 10 JDs

Additional costs of implementation= 25 % of the total material costs = 2.5 JDs

Total Cost = 12.50 JDs per meter square*

**Including labour and tax*

Roof Retrofit

Material & Labour Cost:

Item 1: 3.0 cm thick Extruded Polystyrene Panels = 5.5 JDs/m2

Item 2: Gypsum board as the cover= 2.5 JDs per m2

Item 3: Paint = 0.50 JDs per m2

Total Cost of Materials per meter square = 8.5 JDs

Additional costs of implementation = 25 % of the total material costs = 2 JDs

Total Cost = 10.5 JDs per meter square*

**Including labour and tax*

Windows Retrofit

Material & Labour Cost:

Double-glazed with UPVC frame window= 70 JD/m2

Low-e (to improve thermal conductivity) = +10 JD/m2

Hinged window frame (to increase airtightness and reduce infiltration) = +10 JD/m2.

Total = 90 JDs + 15 JDs (Sales tax) = 105 JDs/m2

Assuming old windows are sold= -15 JDs/m2 (this amount will be deducted)

Total Cost = 90 JDs per meter square*

**Including labour and tax*
Note: if tented glass is use add 4 JOD to the price of m^2.

Solar Shading Devices

Material & Labour Cost:

Aluminium overhangs = 50 JDs per meter long.

The expected calculated for a two-floor building with a total built-up area of 400 m^2.
(Equals to 2 large size apartments. 200 m^2 each)

Table : Expected cost for retrofit options.

Commercial

	Walls	Roof	Windows	Solar Shading Devices	All
Area (m^2)	288	200	192	80	
Cost (JD/ m^2)	12.50	10.50	90.00	50.00	
Total Cost (JD)	3600	2100	17280	4000	26980

Residential

	Walls	Roof	Windows	Solar Shading Devices	All
Area (m^2)	244	200	116	40	
Cost (JD/ m^2)	12.50	10.50	90.00	50.00	
Total Cost (JD)	3050	2100	10440	2000	17590

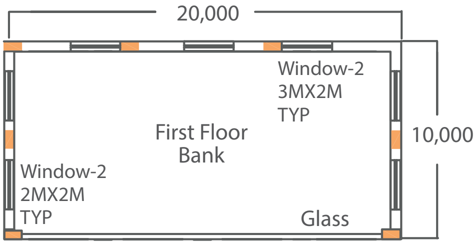
5.3.1. Case Study 1:

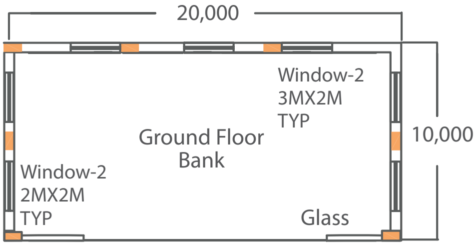
Commercial Building Energy Retrofit

The purpose of this study is to investigate the impact of the main energy retrofit strategies that have been discussed in this guide on an existing two-storey commercial building with a southern glazing façade under the typical climate of Amman and Aqaba. The plans and drawings below give information about the assumed layout. Other assumptions:

Figure 57: Commercial Building Case Study, (a) First Floor Plan. (b) Ground Floor Plan, Building before retrofit (d) Building after retrofit d.

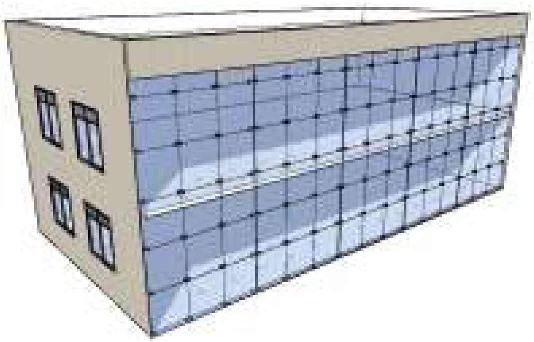
(a)



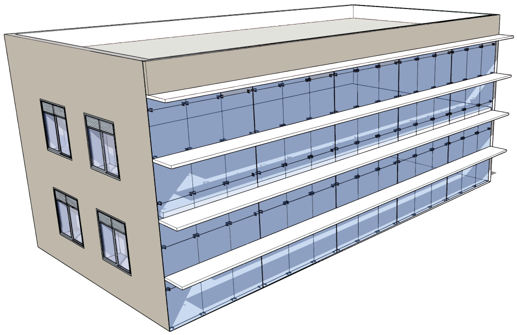


(b)

(c)



(d)



Location 1: Amman, Jordan

- Latitude: 32.0 Deg.N
- Longitude: 36.0 Deg.E
- Elevation: 773 m

Location 2: Aqaba, Jordan

- Latitude: 29.6 Deg.N
- Longitude: 35.0 Deg.E
- Elevation: 12 m

Commercial Building

- Total Floor Area = 400 m2
- Ceiling Average Height = 4 m.
- Open plan assuming that it is a gallery, a company or a bank, for example.
- The building is Air conditioned, cooled in summer and heated in winter.
- Coefficient of performance (COP) = 3.5
- Set Point for Heating = 21 Deg. C
- Set Point for Cooling= 23 Deg. C
- Setback Temp.= 15 heating, 30 cooling
- Cooling/ Heating Hours= 8 hr/day
- Working Days= 5 day/week
- WWR= 40%
- Equipment Power Density= 10 W/m2
- Lighting Power Density= 12 W/m2
- Occupancy density= 10 m2/person

Study Results: Existing Commercial Building

It is clear that there is a considerable reduction in the total cooling and heating energy consumption when implementing the four proposed energy retrofit strategies reaching a total reduction of above 50 % of the annual cooling and heating energy use of the building. The individual effect for each strategy as a reduction from annual Cooling and Heating energy use is listed below:

Location 1: Amman

Energy Retrofit Strategy	Reduction From Annual Cooling and Heating Energy Use %
Improving thermal insulation of external walls	≈ 8 %
Improving thermal insulation of roof	≈ 3 %
Replacing single-glazed windows with double-glazed *	≈ 29 %
Adding external shading devices on the southern façade	≈ 25 %
Combined Energy Retrofit Strategies	≈ 53%

Location 2: Aqaba

Energy Retrofit Strategy	Reduction From Annual Cooling and Heating Energy Use %
Improving thermal insulation of external walls	≈ 5 %
Improving thermal insulation of roof	≈ 2 %
Replacing single-glazed windows with double-glazed *	≈ 27 %
Adding external shading devices on the southern façade	≈ 21 %
Combined Energy Retrofit Strategies	≈ 45 %

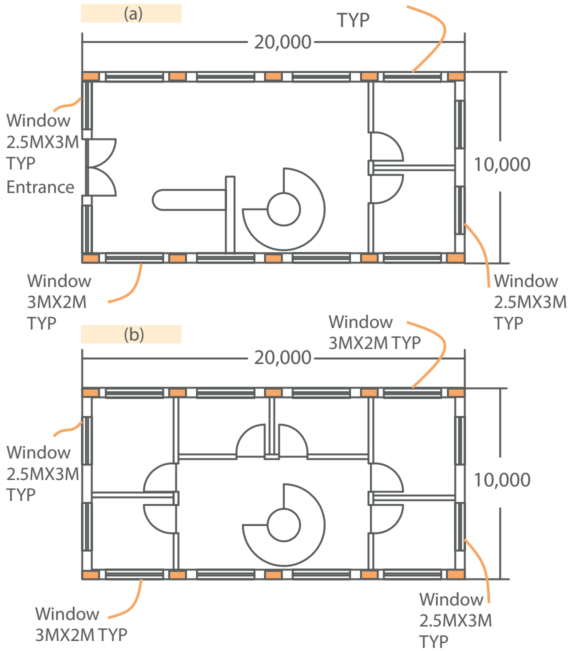
**Note: if selecting a tented glass for the windows with Solar Heat Gain Coefficient (SHGC) <0.4, the load reduction will be much more by window alone and may almost eliminate the need for shading devices.*

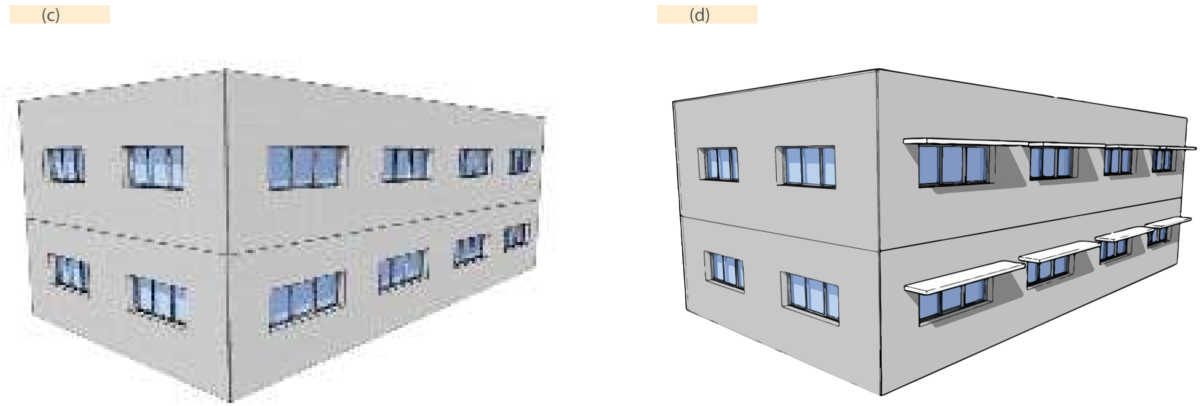
5.3.2. Case Study 2:

Residential Building Energy Retrofit

The purpose of this study is to investigate the impact of the main energy retrofit strategies that have been discussed in this guide on an existing two-storey single residence under the typical climate of Amman and Aqaba. The plans drawings below give information about the assumed layout, other assumptions are:

Figure 58: Residential Building Case Study, (a) First Floor Plan. (b) Ground Floor Plan, (c) Building before retrofit (d) Building after retrofit





Location 1: Amman, Jordan

- Latitude: 32.0 Deg.N
- Longitude: 36.0 Deg.E
- Elevation: 773 m

Location 2: Aqaba, Jordan

- Latitude: 29.6 Deg.N
- Longitude: 35.0 Deg.E
- Elevation: 12 m

Residential Building

- Floor Area = 400 m2
- Ceiling Average Height = 3 m
- The building is Air conditioned, cooled in summer and heated in winter
- Coefficient of performance (COP) = 3.5

- Cooling/ Heating Hours= 10 hr/day
- Working Days=7 day/week
- Set Point for Heating = 21 Deg. C
- Set Point for Cooling= 23 Deg. C
- Setback Temp.= 15 heating, 30 cooling
- WWR= 32 %
- Equipment Power Density= 5 W/m2
- Lighting Power Density= 10 W/m2
- Occupancy density= 50 m2/person

Study Results: Existing Residential Building

It is clear that there is a considerable reduction in the total cooling and heating energy consumption when implementing the four proposed energy retrofit strategies reaching a total reduction of about 50 % of the annual cooling and heating energy use of the building. The individual effect for each strategy as a reduction from annual Cooling and Heating energy use is listed below:

Location 1: Amman

Energy Retrofit Strategy	Reduction From Annual Cooling and Heating Energy Use %
Improving thermal insulation of external walls	≈ 17 %
Improving thermal insulation of roof	≈ 6 %
Replacing single-glazed windows with double-glazed *	≈ 25 %
Adding external shading devices on the southern façade	≈ 8 %
Combined Energy Retrofit Strategies	≈ 50%

Location 2: Aqaba

Energy Retrofit Strategy	Reduction From Annual Cooling and Heating Energy Use %
Improving thermal insulation of external walls	≈ 12 %
Improving thermal insulation of roof	≈ 4 %
Replacing single-glazed windows with double-glazed *	≈ 28 %
Adding external shading devices on the southern façade	≈ 9 %
Combined Energy Retrofit Strategies	≈ 47 %

**Note: if selecting a tented glass for the windows with Solar Heat Gain Coefficient (SHGC) <0.4, the load reduction will be much more by window alone and may almost eliminate the need for shading devices.*

5.3.3. Case Study Summary of Results:

Four main energy retrofitting strategies have been tested to find their individual and collective effect on reducing the total cooling and heating energy use of a residential and a commercial building in two different climate zones in Jordan (Amman and Aqaba). The tested strategies were improving the thermal conductivity of the Roof, the External Walls, and the Windows of the selected building as well as adding External shading devices above windows on the southern elevation. A summary of results is below:

- Residential buildings both in Amman and Aqaba benefit from improving the wall thermal conductivity, mostly Amman residence since it is heating dominated building and since WWR is around 30% that means 70% of the facades are solid walls, so improving the external wall means a large area of the envelope has been improved.

- Commercial buildings both in Amman and Aqaba benefit from shading the south facing windows due to the large area of glass facing south in the tested design and since both are cooling dominated buildings.

- The roof has the least influence on all buildings, but it has better reduction percentages in residential buildings.

- The improvements of the thermal performance for windows in regard to thermal conductivity and Solar Heat Gain Coefficient (SHGC) resulted in achieves largest reduction in the cooling and heating energy use, it ranges between 25%- 29% of total HVAC energy use.

Figure 59: Comparison between maximum and minimum achieved reduction percentages of original total heating and cooling load before and after Energy Retrofit.

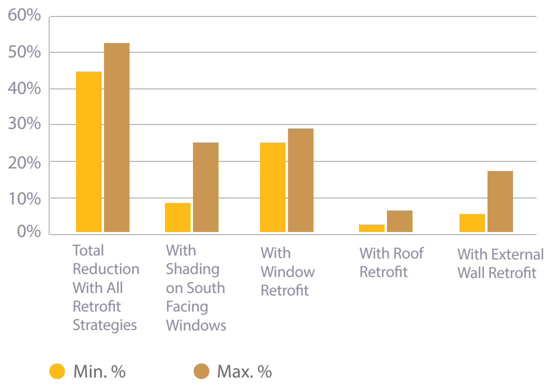
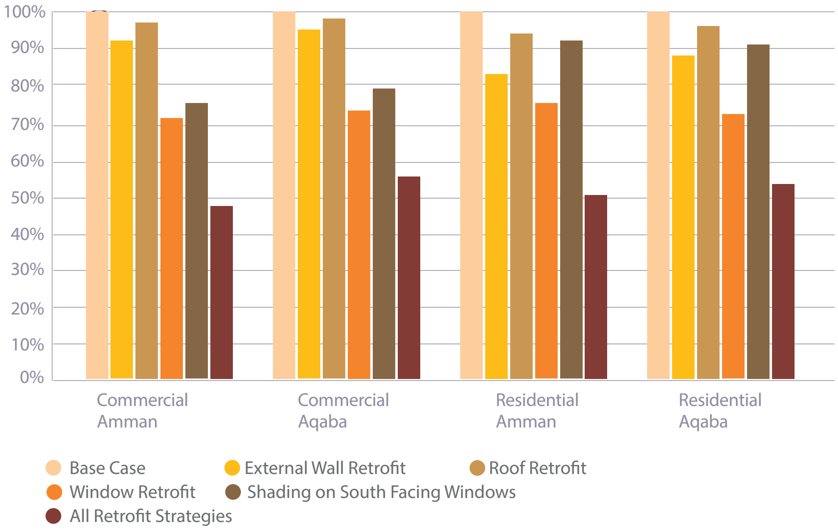


Table 3: Total Heating and Cooling Energy Use Reductions Energy Related Retrofit Strategies

	Commercial		Residential	
	Amman	Aqaba	Amman	Aqaba
With Wall Retrofit	8 %	5 %	17 %	12 %
With Roof Retrofit	3 %	2 %	6 %	4 %
With Window Retrofit	29 %	27 %	25 %	28 %
With Shading Devices on South Facing Windows Retrofit	25 %	21 %	8 %	9 %
With All Retrofits Strategies	53 %	45 %	50 %	47 %

Figure 56: Total Heating and Cooling Load Reduction Percentages- Comparison before and after Energy Retrofit



Conclusion

This Guide has discussed issues related to energy and buildings in the context of Jordan, local building codes, and the concept of retrofitting the existing building envelope with a special focus on energy conservation. It aims to provide a better understanding of the current situation of the energy performance of the existing building stock in Jordan and the issues related to the building envelope retrofits. The Guide has assessed the current thermal performance of the existing building envelope's main components and developed a retrofit guideline to achieve compliance with the Jordanian Energy Efficient Building Code as the main target, with respect to thermal transmittance limits.

Improving the thermal performance of windows as well as external walls and roof is very important to avoid heat loss in winter and heat gain in summer, which results in large demand for heating and cooling to maintain thermal comfort in the indoor environment. To improve the condition of the building envelope, it is important to develop heat transfer calculations before starting a retrofitting project, taking into consideration the heat capacity of the building's envelope as the function of its thermal mass.

The main passive design solution proposed for retrofitting external walls and roofs is adding a thermal insulation layer on the inner or outer surface of the structure. Compared to the external insulation option, in most cases, the internal insulation would be a better selection as it requires less effort and cost for implementation. The external insulation solution also requires more protection regarding waterproofing, Ultraviolet radiation (UV) and a durable top finish such as tiles. In addition, in many local cases, physical obstacles exist on the roof such as water tanks and mechanical equipment.

However, the internal ceiling might have lighting fixtures or mechanical installation that will make it hard to work around; the internal insulation solution might also cause a slight reduction in the height of the internal spaces. Therefore, the decision of where to add the insulation layer (on the external or the internal face of the roof) depends on the individual building's situation and should be examined on a case by case base.

For external wall retrofit, the two concerns would be external cladding material and taking of the internal area of the space. In Jordan, the natural stone cladding is very popular and durable, therefore when stone cladding exists; it is preferable to select adding thermal insulation to the internal face of the wall.

For internal partitions and slabs, retrofitting is only required when it separates two different units heated/cooled with different energy resources.

While windows' retrofitting could be a costly choice, it is a successful investment since windows considered the largest contributor to heat loss and heat gain in buildings. Changing from single-pane (the most common type in existing buildings in Jordan) to double-pane window unit, improves the thermal performance by more than 40%, while changing the frame from aluminium to UPVC will not only increase the thermal performance of the window, but will reduce the infiltration and enhance the thermal comfort for occupants. When considering additional treatments such as low-e glass, the thermal conductivity improvement can exceed 50%.

When comparing the thermal performance for common local building envelope compositions, the code-compliance post-retrofit thermal performance improved dramatically. Depending on the thermal conductivity of the tested current elements, improvements to comply with the thermal insulation code can reach above 70% in external solid walls, between 50% - 70% in external cavity walls, and 25% in already insulated walls. While in the roof structure, improvement of thermal conductivity can reach 50%. This thermal performance improvement results in significant energy savings in buildings as well as better indoor environment quality and thermal comfort for occupants.

This Guide has proved that the requirements of the Jordan Thermal Insulation Code and the Jordan Energy Efficient Building Code can be achieved by using current, common building materials.

In the last section of this guide, four main energy retrofitting strategies have been tested to find their individual and collective effect on reducing the total cooling and heating energy use of a residential and a commercial building in two different climate zones in Jordan (Amman and Aqaba). The tested strategies were improving the thermal conductivity of the Roof, the External Walls, and the Windows of the selected building as well as adding External shading devices on the windows of the southern elevation.

The outcome results show that retrofitting the building walls to meet the requirements of the local code resulted in reducing the energy use between 5% and 17%. Residential buildings both in Amman and Aqaba benefited from improving the wall's thermal conductivity, mostly the Amman residence since it is a heated dominated building and since WWR is around 30% that would leave most of the facades as solid walls, so improving the external walls means that a large area of the envelope has been improved. While the roof has the least influence on all buildings, it has better reduction percentages in residential buildings.

The improvements of the thermal performance for windows in regards to thermal conductivity and Solar Heat Gain Coefficient (SHGC) resulted in achieving the largest reduction in the cooling and heating energy use, it ranges between 25% and 29% of total HVAC energy use.

It is noticeable that commercial buildings, both in Amman and Aqaba, benefitted from the strategy of adding solar shading devices on the southern facade. The total Energy savings range between 21% and 25%. This significant reduction is due to the large glazing facade facing the south, in the selected case, and because commercial buildings in this climate are cooling-dominated buildings.

When combining all tested strategies together, they would have a total reduction in cooling and heating energy use between 45% and 53%. This highlights the great potential to reduce energy bills in Jordanian buildings, and increase the thermal comfort of occupants that will enhance their health conditions.

Therefore, the process of energy retrofitting gives tangible results at an individual level, but there is a lack of knowledge about its benefits. Besides the potential energy reduction, it improves the quality of life for occupants inside buildings, where they spend more than 85% of their time. It also provides an opportunity to extend building lifespans, preserve embodied energy in buildings, and control urban expansion such as the unplanned growth of Amman.

Developing strategies to encourage people to invest in improving the condition of their buildings through energy retrofitting would reduce energy demand on a large scale. Reducing energy usage in buildings requires an effective cooperation between the government and the local community; it is highly recommended to develop awareness plans as well as incentive programs to encourage building's owner to retrofit their buildings envelopes with focus on energy conservation.

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Phone: (06) 5662646
Website:
www.saadahschools.com

Financial and Economic services

The Housing Bank for Trade and Finance
Business Membership -Platinum

Key Services:
Banking financial services

Contact Information:
Phone: (06) 552 1011
Website: www.hbtf.com

Capital Bank of Jordan
Business Membership -Platinum

Key Services:
Banking financial services

Contact Information:
Phone: (06) 510 0200
Website: www.capitalbank.jo

Sky Bound Group
Business Membership - Gold

Key Services:
Internationally-positioned investment and asset management company headquartered in Amman, Jordan with diversified interests in multiple sectors including property and real estate development, financial services, food and beverage, and education

Contact Information:
Phone: (06) 5376677
Website: www.skyboundgroup.com

Trading and Retail Companies

Majid Al Futtaim Group
Business Membership - Platinum

Key Services:
Shopping malls, communities, retail and leisure.

Contact Information:
Website:
www.majidalfuttaim.com

Logistics and Shipping

Aramex International
Business Membership - Silver

Key Services:
An independent voluntary organization that is devoted to the conservation of Jordan's natural resources

Contact Information:
Phone: (06) 5515111
Website: www.aramex.com

Marketing and Advertising

Jordan Land Magazine
Business Membership - Silver

Key Services:
Marketing services - Jordan Land Magazine is a comprehensive economic magazine - dealing with real estate and construction. It is the first magazine focused on the real estate sector through its coverage and distribution in the Arab world and MENA region

Contact Information:
Phone: +962 6 5511680
Website: www.jordanland.net

SADDA marketing & business solutions
Business Membership - Silver

Key Services:
Marketing services - SADDA is a marketing, branding, public relations, and online business solutions studio

Contact Information:
Mobile: +962 79 9088996
Website: www.sadda.jo

Inspection and standardization

BDO
Business Membership - Platinum

Key Services:
Audit and assurance, tax services, business services and outsourcing, risk management and risk advisory services as well as wide range of advisory and consulting services

Contact Information:
Phone: (06) 5816033
Website: www.bdo.com.jo

TUV
Business Membership - Silver

Key Services:

Inspects validity of TÜV AUSTRIA certificates in Jordan

Contact Information:
Phone: (06) 5686771
Website: www.tuvaustria-jo.com

Environmental Organizations

The Royal Society for The Conservation of Nature
Business Membership - Silver

Key Services: An independent voluntary organization that is devoted to the conservation of Jordan's natural resources.

Contact Information:
Phone: (06) 5337931/2
Website: www.rscn.org.jo

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Getting Involved

Established in 2009, the Jordan Green Building Council is a member-based Civil Society and cross-sector Non-profit, Non-Governmental organization registered at the Ministry of Social Development. It received its “Established Member” status after the formal acceptance of the World Green Building Council in April 2012.

Its Mission is to: Promote and advocate for the adoption of the Green Built Environment Practices, leading towards making Green Buildings a widespread reality in Jordan. Our Council is part of a global network of more than 74 GBCs worldwide and holds the authority to represent the World Green Building Council (WGBC) in the Hashemite Kingdom of Jordan. The Jordan Green Building Council is currently the Vice Chair of MENA (Middle East and Northern Africa) Regional Network.

Jordan GBC has evolved to be a global leader in this field and will continue to serve and make the Kingdom proud. This representation has turned out to be a great opportunity to enhance the Kingdom’s position as a leader in this field and now the Jordan GBC can contribute effectively in the development, implementation and dissemination of the Green Built Environment policies globally.

To become a member or a volunteer in Jordan Green Building Council, all you have to do is to visit our location in Amman and register.

We offer training programs and awareness sessions all year long among many other services. So if you’re an individual, a professional, an organization, a start-up or a well-established company, please come and join our journey.

Established in 2009, Jordan Green Building Council is a member based, civil society and cross-sector non-profit, non-Governmental organization registered at the Ministry of Social Development. Its Mission is to: Promote and advocate for adoptation of the Green Build environment, leading towards making the Green Build environment a widespread reality in Jordan.

Our Council is part of a global network of more than 74 GBCs worldwide and holds the authority to represent the World Green Building Council (WGBC) in the Hashemite Kingdom of Jordan. The Jordan Green Building Council is serving as the Vice Chair of MENA (Middle East and North Africa) Regional Network. Jordan GBC has evloved to be global leader in this field and will continue to serve and make the Kingdom proud.

The awareness process happens through four major processes: Firstly, and most importantly the membership and networking; where we seek potential members in the green sector of Jordan in order to shed the light on the most important services, products or internal processes that are Eco friendly though sharing their own experiences using our green promotion and networking platforms.

Secondly, the Green Academy which is meant to enhance the public's awareness and education by being committed to proving high quality education in green practices and processes in order to train professionals to develop, manage and successfully execute green projects. Jordan GBC builds these capacities through professional workshops and trainings realted to Green Buildings.

Thirdly; Outreach activities and events where customized to serve different target groups to suit their awareness needs in order to send the message of Eco friendly buildings and build environment. The outreach events can target School student, universities, engineers of different fields.

Lastly, Reserach and Innovation; we constantly work on developing the council through researching potential for projects and engaging different stakeholders from mutiple sectors.

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ISBN: 978-9957-8789-1-7

The Deposit Number at The National Library: 2018/9/4454

Amman, Jordan