DEVELOPING AN ENERGY BENCHMARK FOR RESIDENTIAL APARTMENTS IN AMMAN

JORDAN GBC
المجلس الأردني للأبنية الخضراء
Jordan Green Building Council

FRIEDRICH EBERT STIFTUNG

DEVELOPING AN ENERGY BENCHMARK FOR RESIDENTIAL APARTMENTS IN AMMAN

"How much energy buildings use should matter to you. If you can measure it, you can control it. If you can control it, you can manage it."

The Hashemite Kingdom of Jordan

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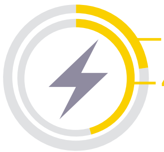
INTRODUCTION

Energy use in residential buildings is becoming an ever-growing sector, accounting for



21.5% of the total share of energy consumption

46% of the electricity use in Jordan

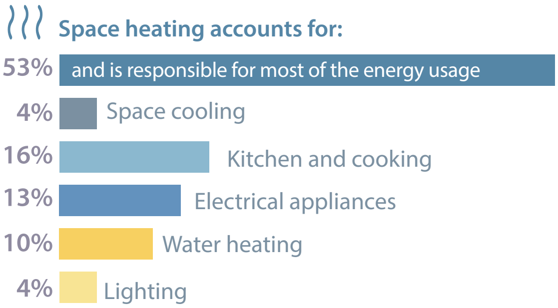
It is necessary to understand the associated energy consumption patterns in this sector to prepare for the ever-growing energy demand in the future.

The booklet targets engineers, designers, decision makers, and occupants and provides them with detailed information and breakdown of residential energy use in terms of heating, cooling, and electricity consumption.

It develops an energy use benchmark for residential apartments and proposes energy efficient measures and strategies in order to enhance buildings' performance and reduce energy consumption.

To achieve this objective, an energy consumption survey was conducted on 400 apartments in Amman. The survey collected relevant data regarding the building general characteristics, building construction situation, heating and cooling methods, lighting, energy use from household appliances and usage patterns.

The results of the survey were used to derive an Energy Use Intensity (EUI) of 91.4 kWh/m^2.a. ,which for the first time represents an energy benchmark of a typical residential apartment in Amman. The value of the benchmark characterizes the current energy consumption profiles and the occupants' behavioral patterns regarding energy use.



These values are important for occupants, designers, and decision makers in order to focus their attention on improving the current situation by implementing efficient strategies for energy upgrades and retrofits.

Multiple design and retrofit strategies are proposed in the booklet, to improve energy performance and enhance the EUI value. These strategies form a guideline for energy saving measures that comply with the local codes in Jordan, regarding site and location, building envelope, passive design strategies, and occupant behavioral patterns.

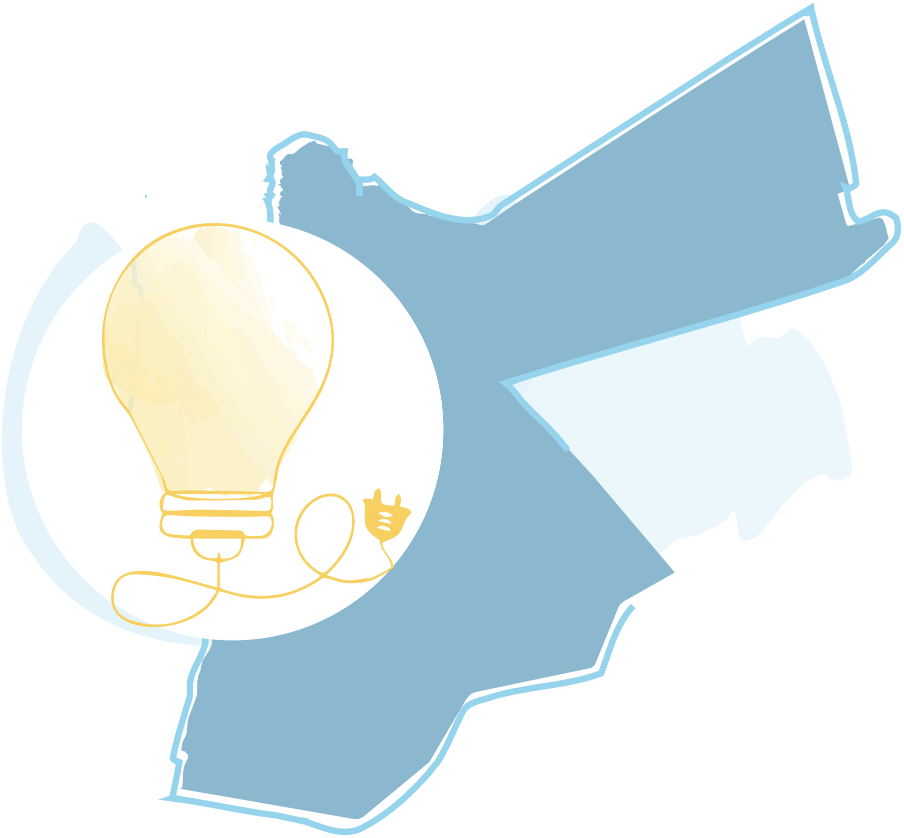
Adopting the 100 guidelines, rules and measures into buildings at the design or retrofitting stage, or during occupancy will lead to major energy savings all while reducing the total energy consumption.

This booklet is in line with the sustainable development goals of increasing energy efficiency through integrating the use of clean renewable energy and technologies in buildings. As a result, it will provide energy saving opportunities for a more sustainable and inclusive community that can resist the upcoming energy challenges.

Keywords: Energy benchmark, Energy consumption, Energy Use Intensity, Household Energy survey, Energy efficient buildings, Building optimization, Sustainable Design.

Chapter 1

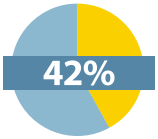
JORDAN ENERGY PROFILE



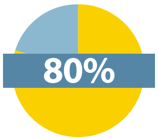
JORDAN ENERGY PROFILE

Dependent on 92% of energy imports

along with the regional instability and major supply disruptions, **Jordan has faced an energy crisis** in the past few years [1]. This crisis is exacerbated by the tremendous increase in the population due to the high influx of refugees adding more pressure on the energy sector, especially in North of Jordan and in the capital Amman where 42% of the population is concentrated [2].



of the population is concentrated in the capital Amman (2).



Urban population in Jordan constitutes for more than 80% of the total population (3).

The population in Jordan increased from

5.3 million inhabitants in 2004 → **10.3 million** inhabitants in 2018 [2]

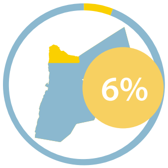
SOURCES OF ENERGY IN JORDAN:

The Jordanian government is developing and prospecting local domestic energy generation sources, however, they are still inadequete and are unable to satisfy the current demand.

The local resources of energy used for domestic production are:

- Crude oil
- Natural gas
- Renewable energy

Local production of energy using these sources did not exceed



of Jordan's total energy needs for the year 2017

thus, Jordan depends highly on imports to cover its energy needs [1].

Jordan has a huge amount of OIL SHALE which exceeds

70 BILLION TONS

Oil shale may be burned directly to generate electricity. The government has signed several investment agreements for the surface retorting for the mined oil shale, but they were delayed due to the decline of oil prices.

Domestic oil production
has increased steadily from

500 tons
in 2015

to 1000 tons
in 2018

but is
projected to decrease
4% by 2025.

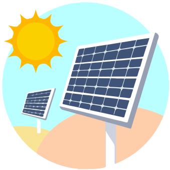
Domestic natural gas
production fell from

4.3 Billion
Cubic Feet (BCF)

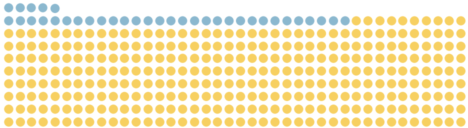
3.3 Billion
Cubic Feet over the same period

It's use is expected
to reach 8%
of the energy share in 2025
(Table 1) [1].

Jordan is consecrated with great amount of **solar energy** that ranges between 5-7kwh/m^2 of annual daily solar irradiance



with



330 sunny days per year.

This ranking is among the highest in the world and makes Jordan an excellent platform for investment in solar energy to meet the residential electricity demands [4].

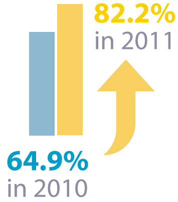
Year	Crude Oil (kt)	Natural Gas (BCF)
2014	1	4.6
2015	0.5	4.3
2016	0.4	4.1
2017	0.3	3.6
2018	1	3.3

Table 1: Domestic Production of Crude Oil and Natural Gas (2014-2018). Source [1]

ENERGY IMPORTS:

Natural gas was the main source of generating electricity in Jordan. However, the huge drop in natural gas supply due to the redundancy and explosion of the gas pipes from Egypt needed to be replaced by crude oil.

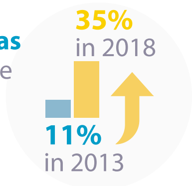
This replacement caused **a significant increase in fuel oil consumption** escalating the weight of oil share in the energy mix from



In 2018, **these values decreased**

The share of **crude oil dropped to 54%**

Natural gas percentage increased from



Although no quantities of natural gas were imported from Egypt in 2017, LNG industries imported quantities by Floating Storage and Regasification Unit (FSRU) (Table 2).

Year	Crude Oil (kt)	Fuel Oil	Liquefied Gas	Diesel	Gasoline	Jet Fuel	Coal	Pet Coke	Total
2014	3221	1255	282	2373	552	51	474	130	**8283**
2015	3513	848	335	1121	670	34	230	203	**6955**
2016	2978	0	327	967	832	64	327	210	**5705**
2017	2795	0	368	1029	923	125	255	170	**5665**
2018	2366	0	357	1145	964	67	292	105	**5296**

Table 2: Imports of Crude Oil and Oil Products (2014-2018) Kt. Source [1]

ENERGY COSTS & PRICES

› The total cost of crude oil and oil products, natural gas and coal imported by Jordan in 2017 increased by **26%** compared to 2016

› The total demand for primary energy in 2017 increased by **4.1%** compared to 2016

› **Consequently,**

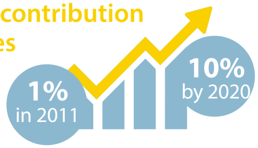
Electricity tariffs increased by **5-15%** in all sectors, including high income households [5].

ENERGY STRATEGY:

Jordan's top priority is achieving energy supply security eliminating its dependence on imports while meeting the growing demand for primary energy.

Accordingly, the government has developed the **National Energy Strategy which sets targets to**

- **Increase the contribution of renewables in the total energy** mix from



- **Reduce the imported crude oil** and products to around **50% by 2025**
- **Maintain the use of coal at 3-5%**
- **Reduce the natural gas share to 8% in 2025**
- **Start using the oil shale reserves up to 10% in 2025** (Table 3) [1].

In addition, the National Energy Efficiency Action Plan (NEEAP) was initiated in 2013 to implement energy saving measures for both, the demand side such as energy labels, lighting and saving energy consumption in all sectors by 20%, and the supply side such as solar water heaters, PVs, capacity building in wind energy, solar power and solar energy code [6].

	2018	2020	2025
Crude Oil and Products	54%	51%	50%
Coal and coke	3%	4%	4%
Renewable Energy	8%	10%	6%
Natural Gas	35%	30%	8%
Electricity Imports	0%	0%	0%
Oil Shale		5%	10%
Nuclear			22%

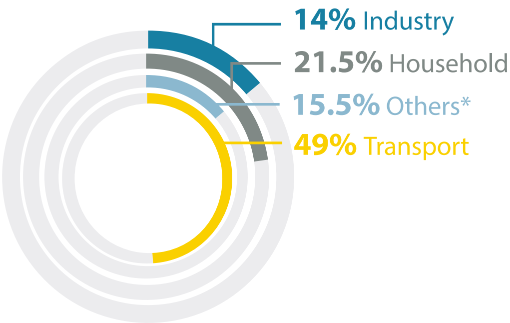
Table 3: Jordan Primary Energy Sources (2018-2025). Source: Ministry of Energy and Mineral Resources (MEMR) Energy 2019 - Facts & Figures.

ENERGY AND ELECTRICITY USE BY SECTOR:

The distribution of final energy consumption varies according to different sectors in Jordan.

The largest consumer is transportation followed by households with a share equal to 21.5% (Figure 1).

Sector Distribution of Final Energy Consumption 2018



** Commercial and agricultural sectors along with street lights*

Figure 1: Sector Distribution of Final Energy Consumption (2018). Source: [1]

Households are the largest consumers of electricity in Jordan accounting for 46% of the electricity consumption

Sector Distribution of Final Electricity Consumption 2018

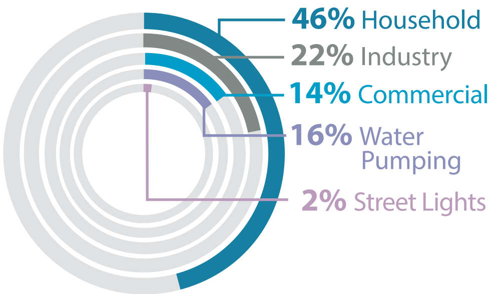


Figure 2: Sector Distribution of Final Electricity Consumption (2018). Source: [1]

JORDAN BUILDING PROFILE

> “The building sector in Jordan is considered one of the most vital contributors of energy consumption, and a main driver for most of the national economic sectors.”

Construction is moving rapidly, and the Jordanian authority is **issuing construction permits adding 4-5% to the building stock** in Jordan yearly.

The largest share of this construction boom **is taking place in Amman** accounting for 46% of the total completed dwellings in 2019 as presented in figure 3.

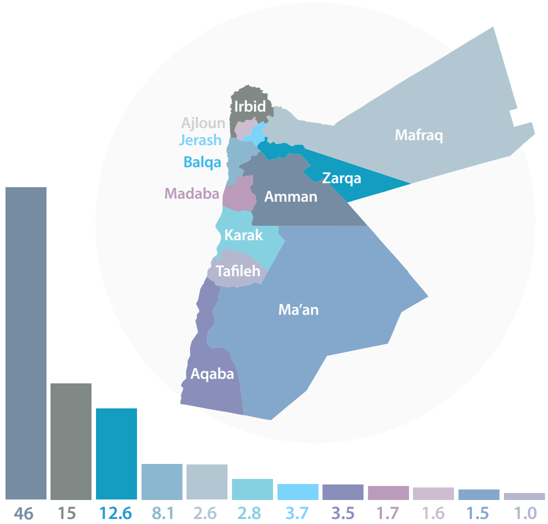
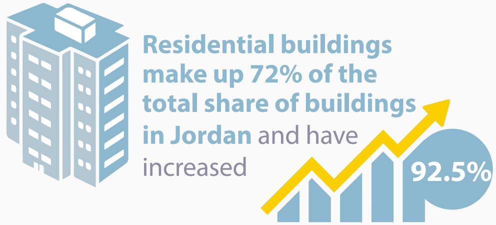


Figure 3: Distribution of Buildings in Cities of Jordan.

Buildings vary in function, areas, and design. They are also divided into standard apartment buildings, one story houses (Dar's), villas and "low standard" apartments. Residential apartments are the most used type consisting of 83.8% in 2015 (Figure 5). There has been an increase in residential buildings containing 3 floors to be 22% compared to 15% in 2004.



Residential buildings make up 72% of the total share of buildings in Jordan and have increased

in the past decade due to the increased demand from the raise of population (Figure 4) [7].

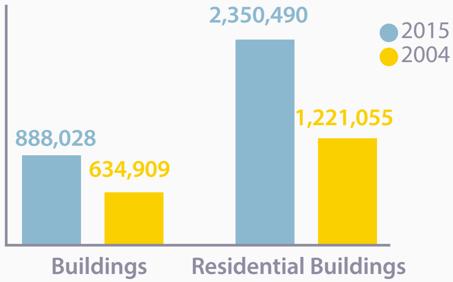


Figure 4: Ratio of Buildings to Residential Buildings

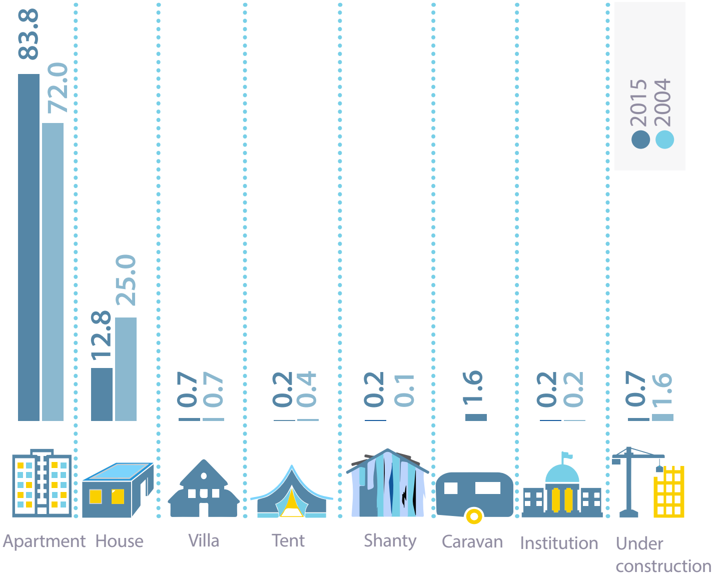
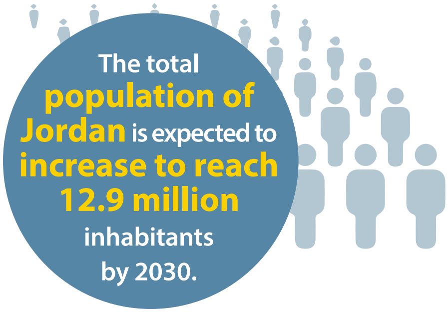


Figure 5: Housing Types Distribution in Jordan

The demand for apartments in Jordan grew from 900,000 households in 2004 to reach 2 million apartments in 2015 [8]. Despite the drop in completed dwellings in 2017 compared to 2016, the annual licenses granted for additions to existing buildings are increasing (Figure 6).



Consequently, to meet the increase in population

49,000 new households
are required annually, to form over
220,000 new households by 2020 [8].

The high demand for housing is finding immense response from the real estate agencies and developers by providing a magnitude of market-oriented buildings to satisfy these prerequisites.

Most buildings are constructed with speed dissenting environmental and contextual attributes and transforming the look and feel of the city. This elevates the need for essential transcribes to **evaluate building energy use and consumption,** ensuring this rapid expansion doesn't contribute to the energy crisis escalating any further.

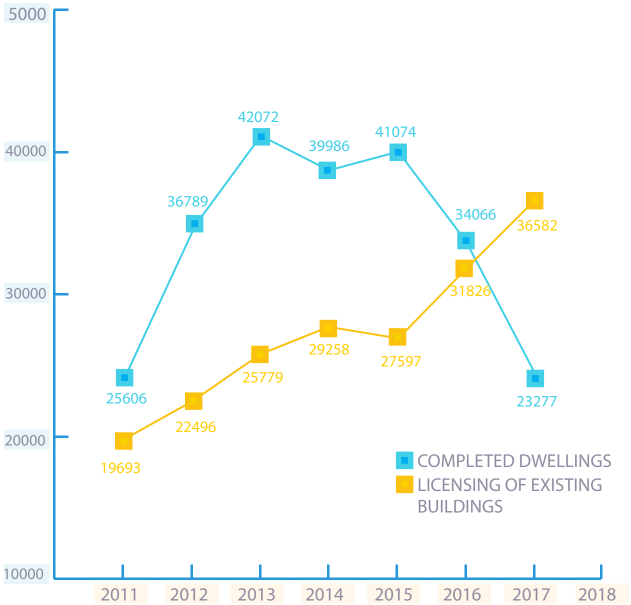


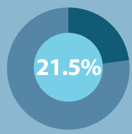
Figure 6: Number of completed dwellings and annual licenses for existing buildings.
Source: Department of Statistics

ENERGY IN RESIDENTIAL BUILDINGS IN JORDAN

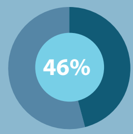
Buildings are part of the problem ….
Buildings can become part of the solution

Residential buildings consume energy through their life cycle; including: planning, design, construction, and mostly in the building operation and maintenance.

Residential buildings are major consumers of energy in Jordan consuming



of the total energy share



of the electricity consumption in 2018 [1].

The amount of electricity generated in 2017 has reached 20760 GWh with a growth of 7% comparing with 2016, while the electricity consumed for the same period reached 17574 GWh recording a growth of 5% approximately comparing with 2016 [1]. The demand for electricity has increased in the household sector due to the increased population, high temperatures in summer, and the expansion in using air conditioning units.

Year	Household	Industry	Commercial	Water Pumping	Street Lights
2014	43	25	15	15	2
2015	43	25	15	15	2
2016	45	23	15	15	2
2017	46	22	15	15	2
2018	46	22	14	16	2

Table 4: Distribution of electricity consumption according to sectors (2014-2018) %

Year	Sector			
	Transport	Industry	Household	Others*
2014	46	20	21	13
2015	48	17	22	13
2016	48	16	20	16
2017	49	14	23	14
2018	49	14	21.5	15.5

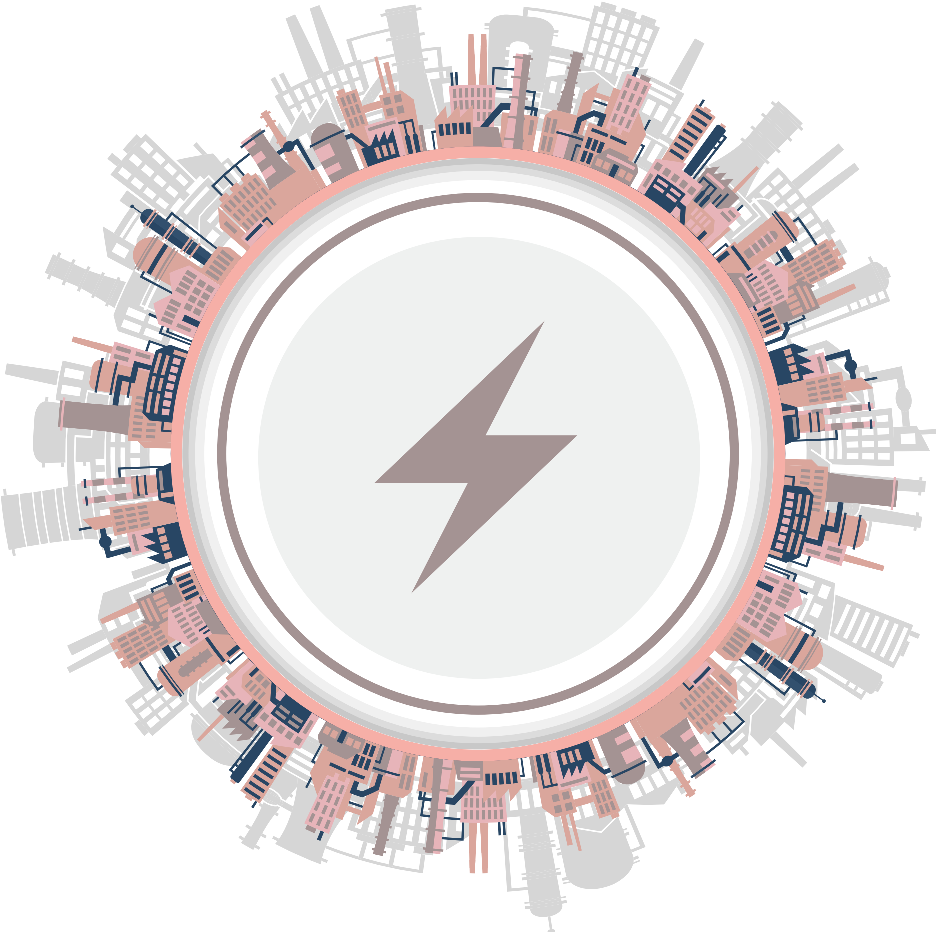
Table 5: Distribution of final energy consumption in sectors (2014-2018) %

** Commercial and agricultural sectors along with street lights*

The residential sector consumes the greatest share of electricity and second greatest share of energy in Jordan, As the demand for electricity increases year after year, it is important to understand energy consumption in residential buildings as a main step towards energy efficiency.

Chapter 2

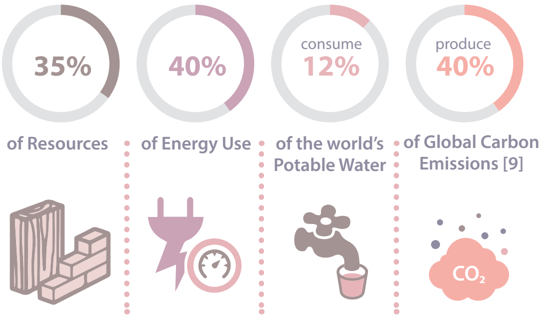
ENERGY IN BUILDINGS



ENERGY IN BUILDINGS:

There is a growing concern about energy consumption in buildings due to their negative impact on natural resources and the environment.

Globally, buildings account for around



Therefore, **improving energy efficiency in buildings is one of the most important approaches** to eliminate major global problems and maintain natural resources.

ENERGY NEEDS IN BUILDINGS:

Buildings need energy through their whole life cycle, starting from construction, to occupancy, and demolition. Since **the largest percentage of that energy is consumed during occupancy;** this section will address the fundamentals of energy and heat flow through buildings to design energy efficient buildings that consume less energy during their occupancy and operation. Energy needs consist of internal gains, natural gains, and delivered energy as illustrated in the diagram below:

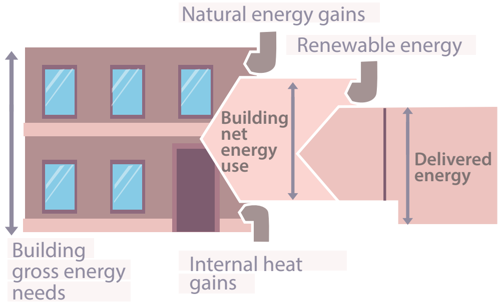
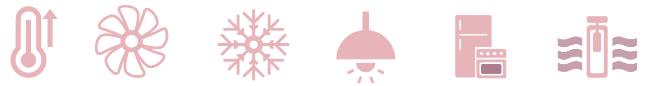


Figure 6: Energy Flow in Buildings. Source: [10]

A. THE GROSS BUILDING ENERGY NEEDS:

The building energy needs represent the required energy to **keep occupants comfortable through:**



The indoor climate requirements, outdoor climatic conditions and the building properties are parameters that affect the energy needs of the building [10].

B. NATURAL ENERGY GAINS:

Natural energy gains include solar gains through the building envelope. It is essential to control the access of natural energy to buildings taking into account climatic conditions, to control the amount of delivered energy required by the building. In hot climates, solar heat gain can increase the indoor temperatures and cause overheating. Therefore, it should be controlled by design strategies such as shading and natural ventilation. On the other hand, in cold climates, natural heat gains can reduce the amount of heating loads through strategies such as passive heating.

C. INTERNAL HEAT GAINS:

Internal heat is the thermal energy from:

that give off heat to the indoor environment. Heat gain from people depends on multiple variables such as metabolic activity, age and gender. Similarly, lighting and appliances produce heat according to their quantity and efficiency. Internal heat gains need to be calculated because they can raise the indoor temperatures and require additional cooling loads in hot climates.

Figure 7: Occupancy heat gains according to their activity. Source: [11]

D. DELIVERED ENERGY:

This is the amount of energy supplied to meet a building's net energy demand (energy for heating, cooling, ventilation, hot water, lighting, pumping and appliances). It usually consists of electricity and/or fuel such as gas, oil and biomass. Delivered energy is expressed in kilowatt hours (kWh) and can be complemented by on-site renewable energy, such as solar PV, solar water heaters or wind.

HEAT TRANSFER THROUGH BUILDINGS:

> Heat transfer is the process of thermal exchange between different systems, where heat transfers from the hotter system to the cooler system.

It is important to understand the mechanism of heat gains and losses through the building envelope, to implement modifications that achieve the required thermal conditions with minimum use of energy resources.

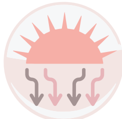
HEAT TRANSFER CAN BE ACHIEVED BY:

Conduction:

Transfer of heat between substances which are in direct contact with each other. This occurs through walls, windows, roof/ceiling, and floor slabs.

Convection:

The heat transfer caused by wind or air movement that causes heated air to move from a warmer to a cooler surface.



Radiation:

Electromagnetic waves, primarily from the sun, that travel through the space. Heat by radiation from the sun is transferred through glazing and windows in the building envelope.

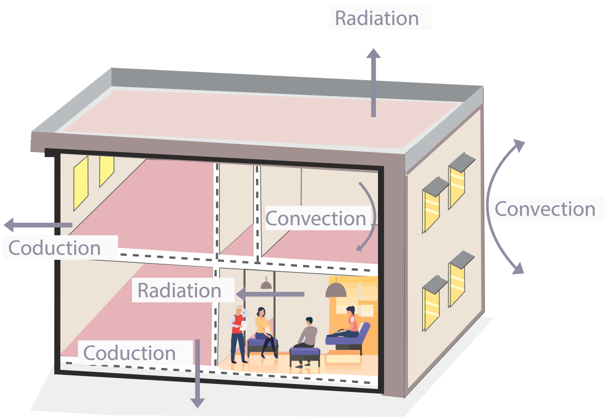
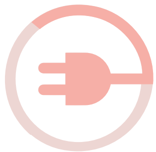


Figure 8: Heat Transfer in Buildings

PATTERNS OF ENERGY CONSUMPTION IN RESIDENTIAL BUILDINGS:

Energy consumption in buildings refers to the total amount of energy used throughout the process from the production of building materials and construction, till the occupancy by inhabitants. Energy consumption in buildings is high and keeps increasing due to industrialization, the improvement of people's living standards, and the rapid development of construction.

Residential Buildings consume about **36% of the total electricity** in Amman [12]



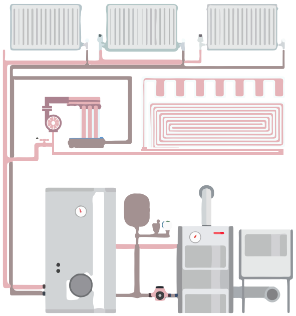
which makes it essential to consider patterns of energy use as part of energy targets and savings. Energy uses in residential buildings are divided into seven main categories as illustrated below:

Figure 9: Patterns of energy consumption in homes

Space Heating:

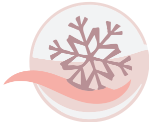
Heating spaces is essential for human comfort. In Jordan, it is mainly powered by electricity or petroleum products such as liquefied petroleum gas (LPG) and Kerosene.

Commonly used heating systems in residential buildings can be divided to central heating and dedicated area/room heating. Central heating systems heat the entire home; they include hot water boilers with radiators, floor or wall heaters. Area-dedicated heating systems are fireplaces or stand-alone heating units by electricity, gas or kerosene, or split unit heat pump AC units.



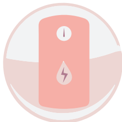
Central Heating

Dedicated Room Heating



Space Cooling:

Space cooling can be accomplished by central cooling systems or room-dedicated systems that mainly run on electricity in residential buildings. Evaporative coolers, ceiling fans, portable fans and split type ACs are all types of space cooling systems. **The demand on air conditioning has increased in Jordan** due to the rise in peak summer temperatures and inefficient natural ventilation in buildings.

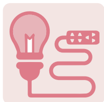


Water Heating:

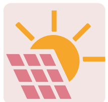
Heated water is used in residential buildings mostly for showers, bathing and washing. Water heating can be produced alone or in combination with space heating systems.

The main energy sources used for water heating systems include:

Gas (LPG)



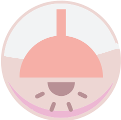
Electricity



Solar thermal systems

Water Pumping:

Water pumps are usually run by electricity to pump water from reservoirs to the dwelling unit or to tanks located on the roofs. Pumps are widely used to increase the water pressure flowing out of faucets and showers, and in the heating systems when using central heating.



Lighting:

Interior and exterior lighting of dwellings are mainly powered by electricity. **Efficient lighting fixtures include compact fluorescent lamps and LEDs** (light-emitting diodes). Off-grid solar applications for external lighting are increasing in popularity and use. Nevertheless, they are currently not yet widely used inside buildings.

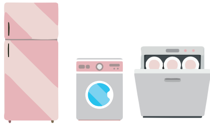
Cooking:

The two energy sources used for cooking are electricity, and LPG. Beside stoves, ovens are also included in the energy consumption for cooking. Cooking appliances such as toasters and microwave ovens are reported under appliances.

Appliances:

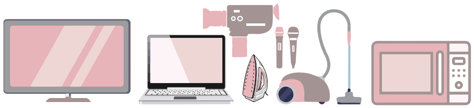
Appliances encompass two main categories:

Large appliances which include:



Refrigerators, freezers, washing machines, clothes dryers and dishwashers

Other appliances such as:



TVs, computers, audio and video equipment, vacuum cleaners, microwave ovens and irons.

Almost all appliances are powered by electricity. In addition to the electricity they consume, appliances also produce heat that is added to the internal heat gains of the building increasing cooling loads in hot climates.

FACTORS THAT AFFECT ENERGY CONSUMPTION IN BUILDINGS:

Multiple factors, both internal and external, affect the amount of energy consumption in buildings. Factors that influence the total building energy consumption can be divided into the following categories:

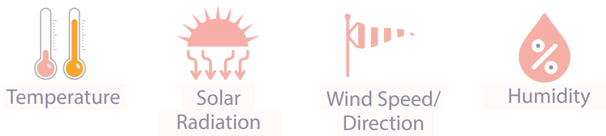
Figure 10: Factors That Affect Energy Consumption in Buildings.

1. ENVIRONMENT AND CLIMATE

Climate is a key-factor for the energy consumption in buildings because it correlates directly to energy demand for heating and cooling [13].

To comply with the required energy needs,

the design of a building should take into consideration the climatic characteristics of the site location such as:



Buildings correspond to the climatic situation by using different materials, shapes, and designs to provide occupants with indoor conditions that are comfortable and protect them against the outdoor environment [14].

2. BUILDING SITE & LOCATION

The location of a household

may contribute

to 46% of the variability in energy consumption [15].

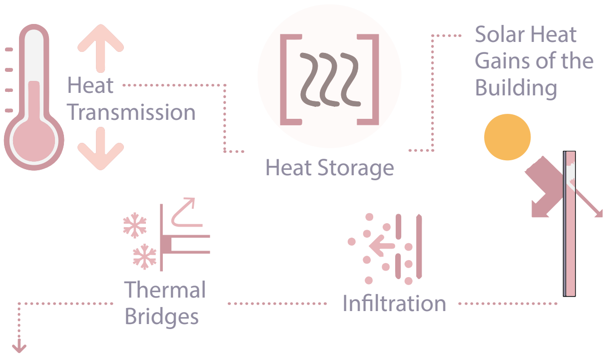
The site characteristics, orientation, topography and setbacks between buildings affect solar access and air velocity around buildings which affect indoor thermal requirements.

3. BUILDING ENVELOPE & CHARACTERISTICS

One of the essential factors that influences the amount of energy consumed in buildings, is the design of the building itself.

The building envelope acts as a thermal barrier between the indoor space and the outside environment where heat losses and gains occur [16].

> "The building envelope may be defined as the totality of (building) elements made up of components which separate the indoor environment of the building from the outdoor environment [17]."



are the fundamental properties of exterior envelopes that affect the indoor temperatures and consequently the energy consumed for heating and cooling [18]. In hot climates, poor design of the building envelope causes the increase in temperatures, which results in additional cooling loads. Similarly, in winter heat losses through thermal bridges and leakages in the envelope increase the heating loads required to achieve comfort temperatures indoor.

Windows are responsible for almost 20% to 40% of energy losses in buildings

The building envelope characteristics include:

Design Parameters such as

- Building Shape
- Orientation
- Window-to-Wall Ratio
- Wall Color and Shading

Construction Parameters such as the type, thermal properties, layers, thickness, and infiltration of materials and glazing [19] [14].

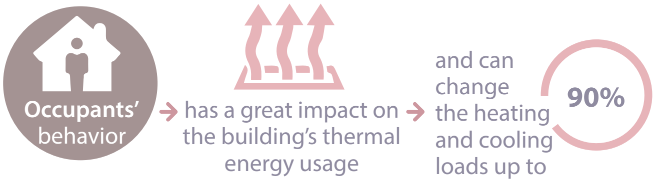
Improving building envelope design can lead to

- Major Savings
- Reduction in Energy Consumption

with the implementation of passive and active strategies either at the design stage or the renovation [20].

4. OCCUPANTS' BEHAVIOR

Buildings don't use energy, occupants do…80% of energy consumption is in the operation and use.



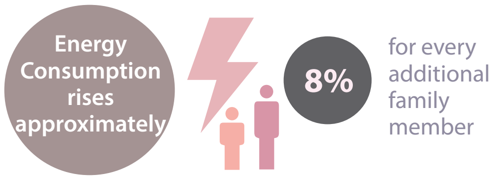
specially in hot climates, which consequently affects the total energy consumption and CO_2 emissions of a building [21] [22].

> **Occupants' behavior can be defined as "the presence of people in the building and the actions occupants take (or not) to influence the indoor environment" [19].**

Occupants' effect on their environment can be divided into two categories: [23] [14].

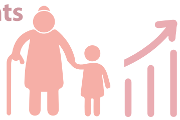
Adaptive actions: Occupants engage in actions to adapt to the indoor environment according to their preferences and comfort, such as opening/closing windows, lowering blinds, adjusting thermostats, turning lighting on/off, and the usage of plug-ins (such as personal heaters, fans, and electrical systems for space heating/cooling) [20] [24]. Energy efficient buildings allow occupants to adapt to the indoor temperature with minimum dependency on mechanical heating and cooling methods.

Non-adaptive actions: Non-adaptive actions include occupants' presence, age, family size and composition [23] [15].



occupying the building as they demand more energy and increase internal heat gains. Similarly, energy use is affected by the age of the occupants;

Residential electricity use rises by around 3% for occupants older than 50 years, and considerably when adults live with children.



The diversity in patterns of energy consumption in buildings offers multiple possibilities and opportunities to improve energy efficiency through different types of behavioral strategies that can further lead to great savings.

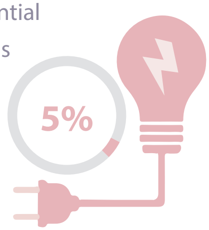
5. BUILDING SYSTEMS AND OPERATION (APPLIANCES, LIGHTING AND TECHNOLOGY):

Building services and systems are strongly correlated to the amount of energy consumed in buildings. They consist of lighting, ventilation and air-conditioning, appliances, and service water heating systems. These services are related to multiple sub factors that affect their energy consumption such as specification, load, age, operation and maintenance schemes, efficiency and condition of the systems.

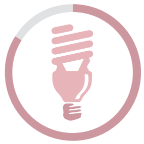
Inefficient traditional large home appliances (freezers, refrigerators, washing machines and dishwashers) are still in use by around 35% of the houses in Jordan [25]

Therefore, the National Energy Efficiency Action Plan (NEEAP) advertised the use of energy labels for electrical equipment and they were enacted by the Jordan Standards and Metrology Organization (JSMO) in 2014 [26] [27] [31].

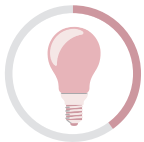
Lighting is also an essential factor to consider in terms of energy efficiency, as it **accounts for about 5% of the households' energy use globally.**



In Jordan,



84% still use at least one compact fluorescent lamp (CFL)



40.1% still use inefficient incandescent lamps that waste 90% of the electricity in the form of heat [25].

Therefore, the Ministry of Energy and Mineral Resources is replacing

150,000 lighting units with

LED light bulbs

in 30,000 houses in Jordan

which aims to reduce electricity consumption up to [31a].

Upgrading traditional lighting systems to more energy efficient bulbs **can reduce** **70-90%** and last up to 25 times longer

In addition, the National Energy Efficiency Action Plan promoted energy efficient lighting by the replacement of 1.5 million incandescent lamps with compact fluorescent lamps [31]. Due to the long lifespan of buildings and high effect of equipment and systems on energy consumption, it is a viable approach to invest in the selection of energy efficient appliances and systems that can further reduce energy consumption and utility costs up to 20%, while guaranteeing comfort for the occupants [20] [14].

6. SOCIO-ECONOMIC AND LEGAL CHARACTERISTICS

Socio-economic and legal characteristics that influence energy consumption are:

Education | Culture | Household Income | Energy Market Prices | Energy Use Regulations [14] [15].

Some studies found that higher income households consume more electricity, since they own more appliances and the standard of comfort will increase accordingly. Occupants' educational level and awareness of energy efficient measures define the acceptance and adoption of innovative and suggested energy behaviors that further reduce energy consumption. In addition, energy policies and building codes can be a great factor in decreasing the energy usage of appliances, machinery and buildings. This can be achieved by voluntary or mandatory regulations in the country, energy efficiency labels, standards and building codes.

Studies have indicated that **if electricity prices increase by 10%, occupants will reduce their demand by 4.5%** [15].

Socio-economic factors are as important as the design of the building itself. Therefore, we need to focus on raising the awareness of occupants and educate citizens to understand how implementing energy saving measures in their buildings reduces energy consumption.

THERMAL COMFORT AND ENERGY EFFICIENCY

Comfort conditions in the indoor environment are comprised of:

Thermal Comfort

Indoor Air Quality

Visual and Acoustic Comfort Parameters

Besides the benefits arising from achieving comfort on the occupants' health, behavior and productivity, it affects the energy consumption in buildings. Buildings that were not designed to satisfy the thermal comfort of users will result with additional heating and cooling loads as a method of adaptation by occupants to obtain comfort, and thus produce more carbon emissions.

> **"Thermal comfort illustrates the relation between the human body and his thermal environment and is defined as 'the condition of mind which expresses satisfaction with the thermal environment (ASHRAE, 1966; ISO7730, 1984)."**

Factors that define thermal comfort conditions are:

Metabolic Rate

Personal physical characteristics impact thermal comfort of the occupants, such as size, weight, age, fitness level and sex.

Clothing Insulation:

Clothes decrease heat losses from the body and resistance to the transfer of energy. The heat insulation value of clothes is expressed by the unit "Clo" and affected by fiber, fabric thickness, thread and weaving patterns.

Air Temperature:

The human body resembles heat balance by maintaining the internal temperature near to 37°C and the skin temperature between 31°C and 34°C. There is an equilibrium between heat generation within the body from food consumption and heat loss from the body to the environment while performing activities [28].

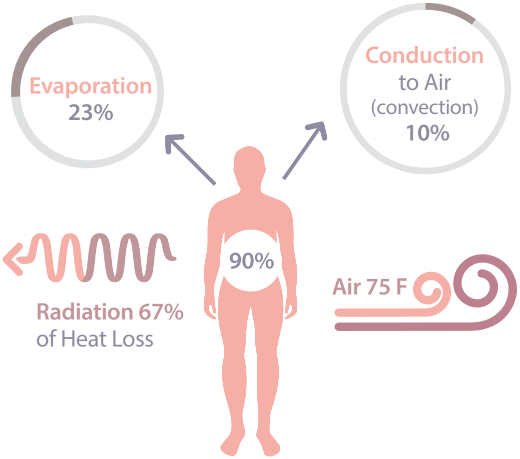
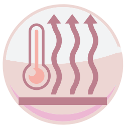


Figure 11: Heat transfer from the human body into the surrounding environment. Source: [29].

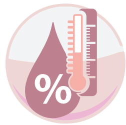


Radiant Temperature:

Radiant temperature is heat that radiates from hot surfaces to the surrounding. The thermal radiation of household appliances and equipment highly influence thermal comfort by increasing room temperatures.

Air Speed:

Air flow rate is the value of air movement in a certain direction measured in unit of time. Careful design strategies should consider the volume of the space, the location of air inlets and outlets, the location and size of the windows and climatic properties to obtain comfortable conditions and maintain air speed around 0.15 m/sec [29].



Humidity:

Humidity levels affect the work efficiency and productivity and contribute to energy consumption savings.

The humidity ratio should be maintained to stay within

40% and 70%

Values not within the range above can cause discomfort and health problem.

> “Visual comfort conditions consist of light, color, view, while, acoustic comfort conditions consist of factors such as sound and noise (Fanger, 1973).”

ADAPTIVE THERMAL COMFORT TO REDUCE ENERGY CONSUMPTION:

"If a change occurs such as to produce discomfort, people react in ways which tend to restore their comfort [20]".

People have a natural tendency to adapt to changing conditions in their environment and is expressed in the adaptive approach to thermal comfort. This response to discomfort of temperature in buildings should be taken in consideration by architects and engineers during the design phase.

It is the designers' challenge to minimize the period of the year when cooling and heating systems need to be used, and allow occupants to adapt passively to reach their comfort temperature with the minimum dependency on mechanical systems. The two key elements in the solution to this challenge are to design better buildings and to use an adaptive approach to achieving comfort.

"In Amman, the comfortable operative temperature ranges at 50% relative humidity are 20–23.5°C for the winter and 23.5–27°C (assuming 30% relative humidity) in summer [30]. It is important to achieve these comfort temperatures when designing the indoor environment in buildings to limit the reliance on mechanical heating and cooling."

ENERGY PYRAMID

The Energy Pyramid is a simple but effective diagram outlining how renewable energy, energy efficiency and energy conservation must work together to achieve our clean energy goals. While renewable energy is important, energy efficiency and energy conservation have the most opportunities and thus we should focus upon them.

ENERGY CONSERVATION is any behavior that results in the use of less energy. It is the base of the energy pyramid and can be achieved through behavioral and operational practices by the occupants: such as unplugging your computer or home appliances when they are not in use, or turning off the lights when you're not in the room.

ENERGY EFFICIENCY is using less energy to provide the same service. It is the foundation of 'sustainable energy' as it can deliver huge benefits by lowering energy consumption. Energy efficiency has two dimensions: efficiency in the use of primary energy such as natural gas and petroleum and efficiency in the use of secondary energy such as electricity. Replacing inefficient incandescent light bulbs with more efficient compact fluorescent bulbs and replacing older model appliances with newer, energy-efficient models are examples of energy efficiency.

RENEWABLE ENERGY is energy that is collected from renewable resources, such as sunlight, wind, rain, tides, waves, and geothermal heat.

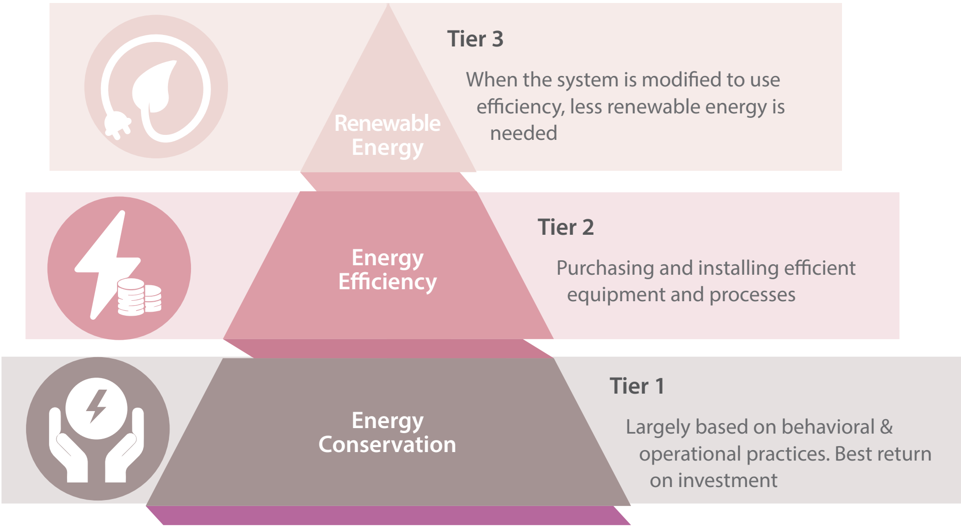


Figure 12: The Energy Pyramid

Chapter 3

ENERGY BENCHMARKING

ENERGY BENCHMARKING

In order to improve energy efficiency, it is essential to understand energy performance by quantifying the consumption in buildings. An energy benchmark is the baseline that indicates how much energy is consumed in buildings and it presents the energy use patterns to determine efficiency measures. This chapter will present the definition of energy benchmarking, methods and benefits to be implemented further in the following chapter in establishing a baseline for residential apartments in Amman.

WHAT IS ENERGY BENCHMARKING

> **“Energy Benchmarking is a method used to determine how much energy the building is using comparing it to buildings that share similar characteristics. Benchmarking establishes a baseline to track each building's energy use and set comparable energy reduction goals.”**

Benchmarking helps building owners and managers understand their building energy use, adopt potential measures for improving efficiency motivating occupants to achieve energy savings through environmental behaviors. In order to compare energy consumption in multiple institutes or buildings, it is essential to have a mutual indicator and unit such as the Energy Use Intensity (EUI).

Energy Use Intensity (EUI), is the most common indicator for energy benchmarking assessing building energy performance and energy saving possibilities

Energy Use Intensity (EUI) varies according to:

$$EUI = \frac{\text{Annual building energy consumption}}{\text{Total gross floor area}}$$

(presented in the units of kWh/m2/year or kBTU/feet2/year [32])

EUI determines whether your actual annual energy consumption exceeds the standard energy consumption required for the size of your building and its occupants. It can be used as a baseline to quantify the amount of energy reduction you should achieve; the lower the value of EUI, the more efficient your building is.

Energy Use Intensity is divided into two types:

Site

- The site type EUI measures the amount of energy used in a building.
- Site EUI is more common because it determines how much the energy use for an individual building has changed over time.

Source

- The source type EUI represents the total amount of energy used to run the building and its systems including energy used in production, transmission, and delivery of energy to the building.
- It is recommended to use source EUI as it provides a complete assessment of energy efficiency in a building.

Levels of Benchmarking:

Energy benchmarking can be done on two levels:

1. Internal Benchmarking:

Internal Benchmarking allows an organization to compare energy use of a building with others within the same organization. The results are used to compare energy performance among the organization and identify buildings with the greatest potential for energy improvement. They can also be used to examine the performance of a building over time to make sure the performance is not slipping.

2. External Benchmarking:

In external benchmarking, buildings are compared to other similar buildings. The results can be used to determine methods of improvements, or to assess the performance relative to peers with similar characteristics against a national performance rating to identify high-performing buildings for recognition opportunities [33].

BENCHMARKING BENEFITS (WHY)

In order to achieve energy efficiency in buildings, we should be able to quantify the energy consumed.

With the increase of energy and electricity consumption in residential buildings in Jordan, it is essential to evaluate the consumption characteristics to promote conservation, efficiency, technology implementation and energy source switching, such as switching to on-site renewable energy [34].

Energy benchmarking in buildings has multiple benefits on the short and long term. **These benefits are summarized as follow:**

1. Energy Saving Benefits:

Measuring the building's energy performance and comparing it to itself and similar buildings, sheds the light on multiple energy efficiency measures and strategies that can be involved in the design phase for future buildings, or system retrofits. Benchmarking brings occupants' attention to energy efficiency, resulting in behavioral and operational changes that conclude with immediate reductions in energy consumption.

Energy benchmarking can result with an annual **energy saving of 2.4%**

Buildings which have been **benchmarked** for three straight years **saved an average of 7%** over the course of that time [35].

2. Market Competition Benefits:

"Research has found that many owners believe their buildings to be more efficient than they actually are [35]". Therefore, the availability of a benchmark for buildings gives tenants an indicator of the energy performance of buildings they aim to buy or rent. Recently, occupants are keener to rent spaces in energy-efficient buildings to demonstrate their commitment to sustainability, improve productivity, and reduce utility costs.

> **"Certified green buildings have proven to achieve higher rents than traditional buildings."**

ENERGY STAR certified buildings experience

9.5% higher occupancy rates

2.5% higher rental rates

than conventional buildings [35].

3. Lower Operational Expenses

The immediate benefit of energy-efficient buildings is lower utility bills. In addition, energy efficient installations and systems are known for longer lasting lives which reduces operational and maintenance costs.

4. Governmental Benefits:

Public benchmarking data shares information about building characteristics and their effect on energy use, which gives an idea for companies to better understand their customers. Benchmarking information allows policy makers to understand where the most inefficient buildings are and design more effective methods of addressing them [35].

5. Environmental and Health Benefits

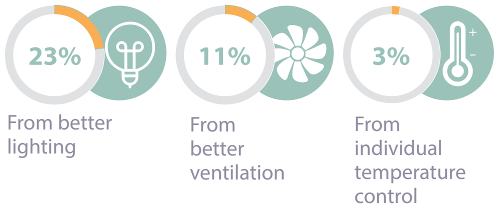
The main goal for developing benchmarks is to create a consistent and transparent yardstick to assess the environmental performance of buildings and reduce the amount of resources and relative environmental impacts in the building sector [13]. Energy benchmarking reduces energy use which consequently reduces greenhouse gas emissions associated with generating energy and improves energy security and independence [35].

Occupants of energy-efficient buildings benefit from:

Indoor comfort

Better health and well-being

translating into an increase in productivity



6. Design and Environmental Awareness

Benchmarking raises environmental awareness for occupants when they understand the effect of their behavior on energy use and consumption. In addition, benchmarking provides designers, local authorities and project managers with guidance to take more informed decisions about siting, facilities, building techniques, materials, design options, affordability, social inclusion and other considerations that leads to energy efficiency [36].

BENCHMARKING TOOLS:

A number of tools and methods are available worldwide to provide building operators and managers with a way to benchmark their buildings' energy use and compare it to similar buildings. Although there are no available metrics applied in Jordan, they can be used as an indication about energy performance in buildings that share similar characteristics.

ENERGY STAR FOR COMMERCIAL BUILDINGS

Energy Star rating system is a voluntary program delivered by EPA (Environmental Protection Agency), to estimate how much energy commercial buildings would use based on multiple parameters such as size, location, climate, number of occupants, and appliances. The rating system determines where the building ranks relative to its peers and assigns a score that ranges between 1-100.

Example:
A score of 80 indicates that the building is better than 80% of its peers

ENERGY STAR PORTFOLIO MANAGER AND TARGET FINDER:

Target Finder is a free interactive online tool provided by the EPA that may be used during the design process to establish energy consumption goals and assess design performance. Target Finder estimates the allowed energy consumption during the preliminary design phase and compares the values to Energy Star limits in the schematic-design phase to apply for the ENERGY STAR certification.

Portfolio Manager is an interactive online energy management tool that helps track and assess energy and water consumption within buildings against similar others in the US and identify strategic opportunities for savings and recognition opportunities through the Energy Star label [37].

Using the data supplied by the building owner, the benchmarking software normalizes a building's energy use for weather, building type, occupancy, and other factors that affect energy consumption [35].

THE ENERGY STAR HOME ADVISOR:

The Energy Star Home Advisor is a tool designed to improve home's energy efficiency while maintaining indoor comfort. It recommends energy saving measures regarding lighting, household appliances, building envelope as well as heating and cooling.

HERS INDEX:

The Home Energy Rating System (HERS) Index aims to assess and calculate homes' energy performance and efficiency. The assessment is done by a certified Home Energy Rater that measures the energy efficiency of homes including building envelope, windows, doors, HVAC systems, water heating system, and thermostat, assigning it a relative performance score (the HERS Index Score). The HERS Index score given is then compared against a reference home that is similar to the size and shape of the assessed home. (Figure 13).

A home with a HERS Index Score of 70 is 30% more energy efficient than the RESNET (Residential Energy Services Network) Reference Home while a home with a HERS Index Score of 130 is 30% less energy efficient than the RESNET Reference Home.

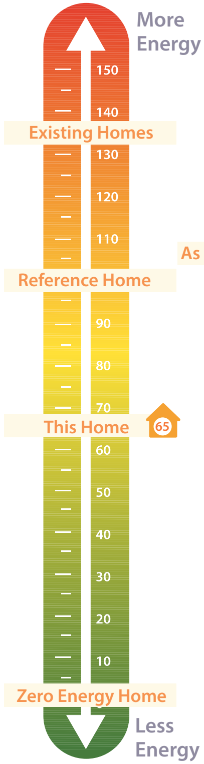


Figure 13: HERS Index.

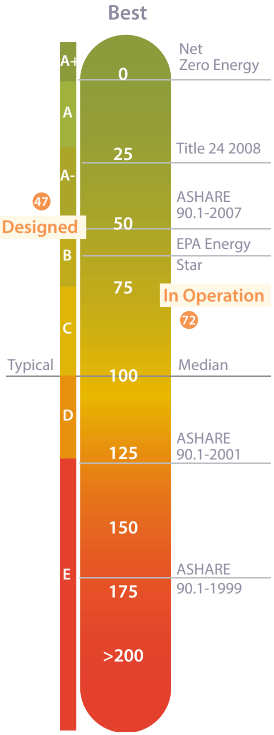


Figure 14: The ASHRAE bEQ Scale. Source: [37]

THE BUILDING ENERGY QUOTIENT (BEQ™) LABELING SYSTEM:

The BEQ rating established by ASHRAE, offers two ratings: one for new designs and one of existing buildings. It represents the ratio of energy use of the rated building to the median energy use of its building type. Energy use in the index is expressed as source energy EUI, or source Btus per square foot per year.

The best energy performance on the BEQ is Net Zero Energy with a rating of zero. The median of building performance for that building type is set at 100, whereas any score of 125 or greater is considered poor (Figure 14).

BENCHMARKING STANDARDS AROUND THE WORLD:

Many countries develop Energy Use Intensity values for buildings to set targets for designers and occupants to achieve in their buildings and understand energy use patterns. EUI values are important to assess energy performance and understand the consumption in different countries. Although these values cannot be compared in different countries and climatic zones, they are mentioned below for referencing.

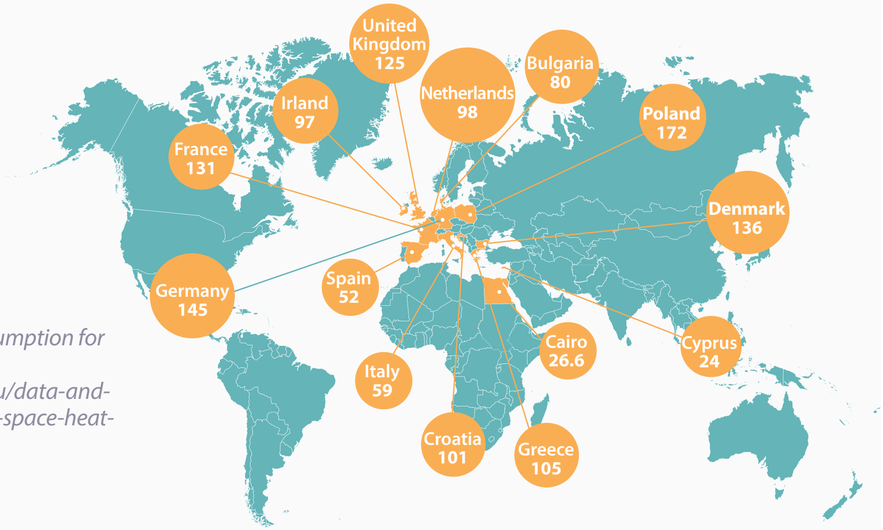


Figure 15: Household energy consumption for space heating per kWh/m2/year Source:https://www.eea.europa.eu/data-and-maps/daviz/unit-consumption-of-space-heating#tab-googlechartid_chart_11

Improving the building envelope and thermal properties is an essential factor to reduce energy consumption. The table below represents values of a typical single-family house with different thermal properties and insulation, which leads to different benchmarks of heating and cooling loads. Passive houses with the tightest envelopes and strict thermal properties require values less than 15 kWh/m2 year.

	Completely Insufficient Thermal Insulation	Insufficient Thermal Insulation	Low Energy Houses	Passive Houses
Heating (kWh/ m^2/year)	270-230	185-140	80-55	Less than 15
Cooling (kWh/m^2 year)	30-20	15-10	10-5	Less than 5

Figure 16: Heating and Cooling Energy Demands of a Typical Single-Family House
Source: ISOVER (2008). Multi Comfort House, Energy Efficient Living

A Net Zero Energy building (NZEB) is a building with zero net energy consumption

The total amount of energy used by the Net Zero Energy building annually is equal to the amount of renewable energy generated by the building. NZEB is the ideal case where the "net" EUI is zero.

Advancing Net Zero is a long-term global project initiated by the World Green Building Council. It aims to promote and support the acceleration of net zero carbon buildings. Several organizations in different countries have signed a commitment to join this project by promoting the practices and regulations that will support the NZ concept.

Jordan GBC has joined this global movement in a hope to create a significant step towards a more sustainable built environment in Jordan. This will improve the life of next generations, strengthen the green economy concept and create several opportunities in the leading sector.

Chapter 4

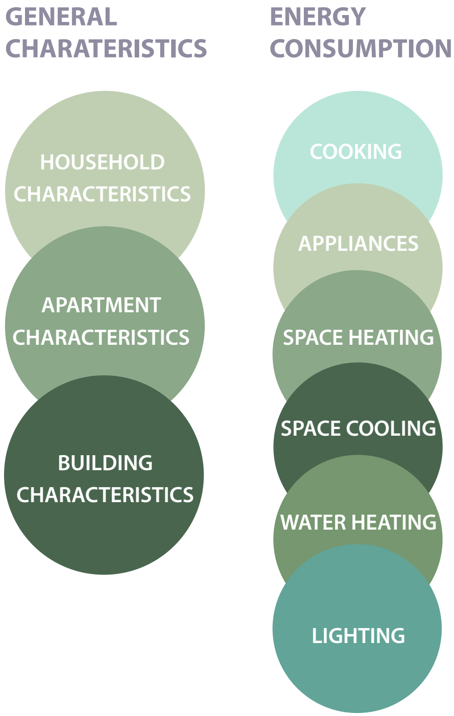
ENERGY CONSUMPTION SURVEY FOR RESIDENTIAL APARTMENTS IN AMMAN

It is essential to develop an energy benchmark to understand energy use in buildings offering opportunities for energy savings through design parameters and behavioral patterns. The most common methods to estimate energy use patterns in buildings and establish a benchmark are linear regression models, neural networks and surveys (52).

This booklet will display the results of a survey that gathered information about physical characteristics and energy use in residential apartments in Amman. The outcomes of which will help derive a benchmark for Energy Use Intensity (EUI)

ENERGY CONSUMPTION SURVEY FOR RESIDENTIAL APARTMENTS

The survey was distributed electronically through email and mobile applications to people living in residential apartments in Amman. The total number of respondents were 400, with a response rate of 90%. The survey contained 50 questions that varied in type from open ended questions to multiple choice, and Likert scale type questions depending on the required data. The questions were listed under 6 categories; household characteristics, building characteristic, heating and cooling characteristics, kitchen appliances, other appliances, and lighting as displayed in the figure.

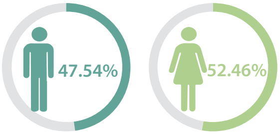


GENERAL CHARACTERISTICS

The survey consisted of information about the respondents in terms of:

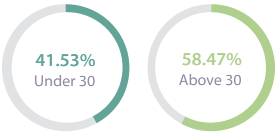
Gender

The survey achieved almost equal distributions between males and females:



Age

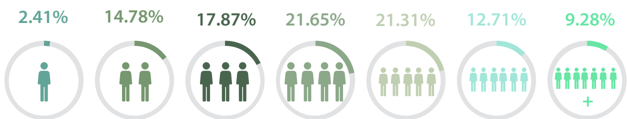
In terms of age, 58.5% of the respondents are above 30 years old, while 41.5% are at the age of 30 or below.



Number of Occupants:

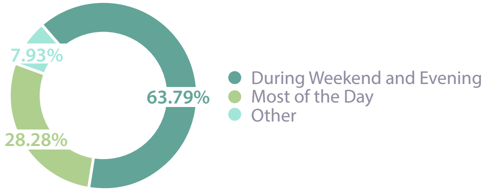
According to the survey conducted by the Department of Statistics, **the average number of family members in Jordan is 4.82.**

This is in line with the results of the survey where 43% of the respondents indicated that the number of occupants is between 4-5.



Occupancy Hours

The occupancy hours are a major parameter that affect energy consumption in homes. From this survey 63.79% of the respondents are employed and occupy their apartments only during weekends and late evenings.

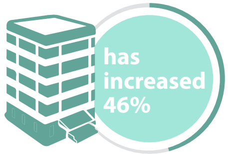


BUILDING CHARACTERISTICS

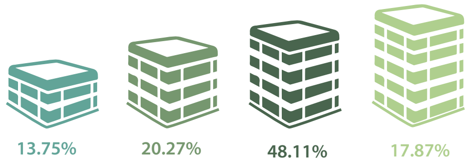
Building characteristics can directly impact the amount of energy consumed in buildings. These characteristics include the building age, number of floors, and the apartment layout.

Number of Floors

The demand on vertical residential building blocks comprised of 3 floors or more

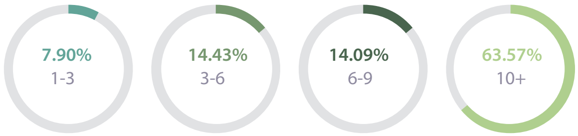


in the last decade (DOS, 2015). This is reflected in the survey results where 48.1% of the buildings contain 4 floors.



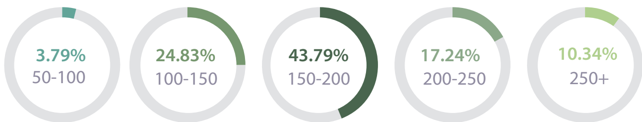
Building Age

Most of the surveyed apartments are located in buildings that are more than 10 years old.



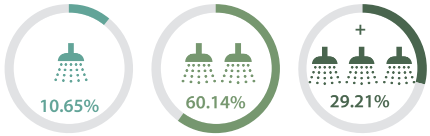
Apartment Area

The results show that apartments with areas between 150 200 m^2 are the most common.

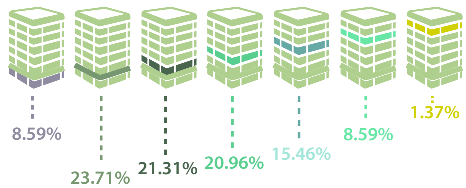


70% of the apartments surveyed contain 3 bedrooms and two full bathrooms and are located equally on the ground, first and second floors.

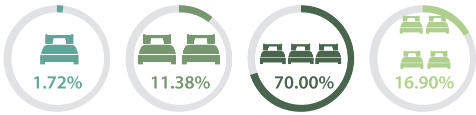
Number of Full Bathrooms



Apartment Floor Location



Number of Bedrooms

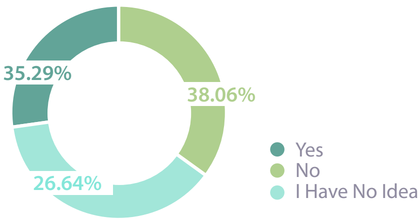


CONSTRUCTION CHARACTERISTICS

Construction material and properties determine the consumption required for heating and cooling loads. The survey explored the condition of the buildings, assessing construction methods and properties in order to propose energy efficient measures accordingly.

Thermal Insulation

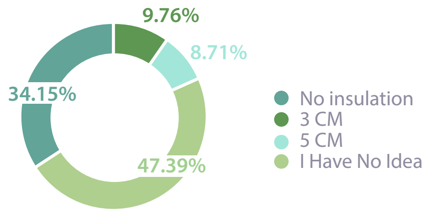
In terms of thermal insulation, 26.64% of the respondents have limited knowledge about the availability of wall insulation in their buildings, due to the fact that most residential apartments are not built by the owner but bought or rented from a developer.



35.29% of the target population believe they have insulation in the walls as oppose to 38%.

Insulation Thickness

Similarly, 47.39% of the people surveyed have no idea about the insulation thickness, while only 9% and 8% declared the insulation thickness is equal to 3cm and 5cm respectively.



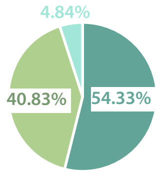
Roof insulation is only noticed in

of the apartments that are located on the last floor of the building, and 50.8% do not have roof insulation

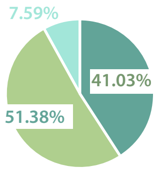
Insulating doors and windows to prevent air leakage is essential in controlling heat losses during the winter season.

Half of the apartments
suffer from windows' air leakage
and the lack of weather stripping on doors.

Window Air Leakage



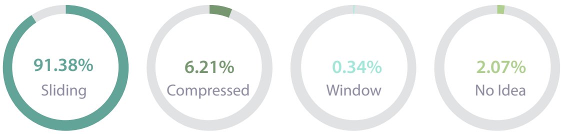
Weather Stripping on Doors



Yes No I Have No Idea

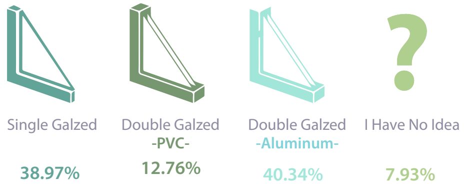
Window Properties

Sliding windows are found in 91.38% of the apartments, while only a few (6.2%) contain compressed windows although they are recommended for compact and energy efficient buildings.



Type of Glazing

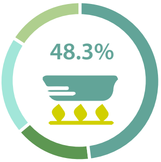
Almost equal amount of apartment buildings have single glazing and double glazing with aluminum frame windows (38.9% and 40% respectively). Although double glazing windows with PVC frames are more energy efficient than the previously mentioned types, they are only found in 12% of the apartments.



KITCHEN & APPLIANCES

Cooking and other kitchen appliances are major contributors to energy consumption in residential buildings. The type of appliances, their energy performance, and the hours of usage were all part of the survey to establish an energy benchmark and propose energy efficient measures in residential apartments.

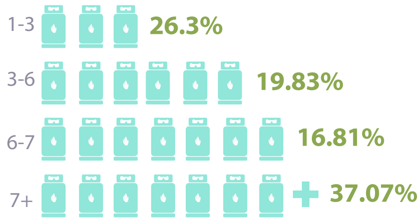
Ovens



of the respondents
use the oven four or more
times a week for cooking

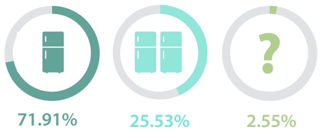
- Three Times a Week 15.68%
- Twice a Week 20.34%
- Less than Once a Week 15.68%

The amount of gas cylinders used
for cooking per year is more than



Number of Refrigerators

Almost all occupants own at least one fridge, and 25.53% have two fridges.



63.4% of the respondents

are aware of energy efficient appliances

and own an energy labeled fridge due to the high energy prices and their direct economic benefits on energy savings.

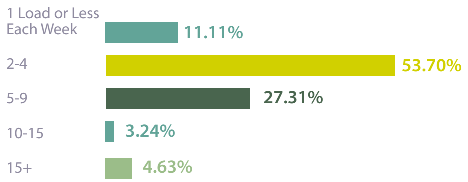
Ownership of Kitchen Appliances

Regarding washing machines and laundry loads,

70.23% of the respondents own an energy labeled clothes washer.

Laundry Loads

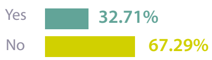
Half of the respondents wash their clothes 2-4 times a week while 27.31% use their clothes washer 5-9 times per week.



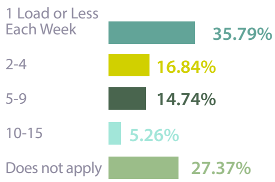
Clothes Dryers

Clothes dryers are not common in residential apartments and are only owned by 32.7% of the respondents whom mostly use it 1-3 hours weekly.

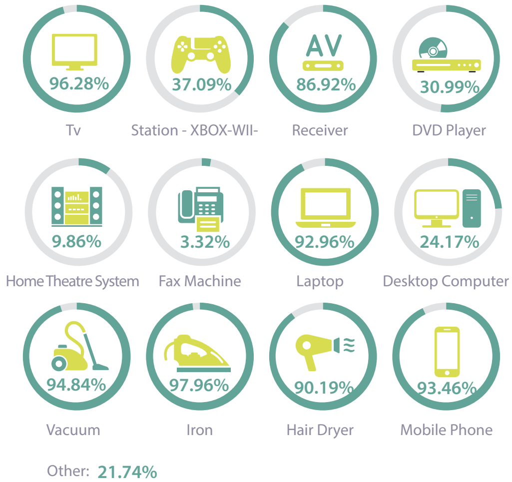
Availability of Clothes Dryer



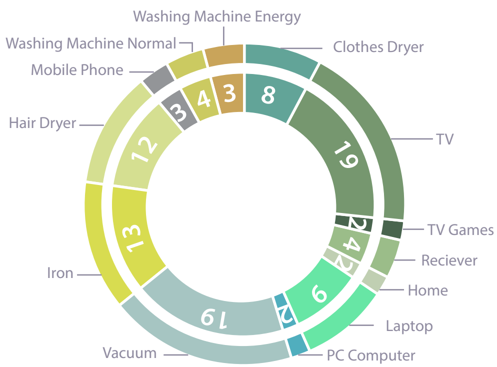
Hours of Usage/ Week



Ownership of Electrical Appliances



Energy Use Distribution from Electrical Appliances in Residential Apartments



SPACE HEATING

All respondents turn on heating in December, January, and February which are the typical heating months in Jordan. However, 69% of the respondents turn on their heating in November, while 48% and 36% use space heating in March and April accordingly.

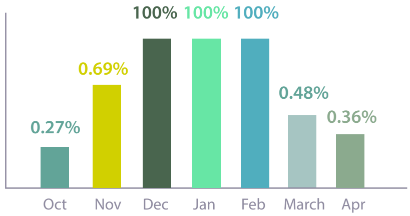


Figure 17: Heating months

Duration of Space Heating

Heating hours depend on the occupants' thermal comfort and the building envelope properties.

- **48%** — **Turn on the main heating system from 1-5 hours**
- **36%** — **Turn on the main heating system 5-10 hours daily**
- **11.6%** — **Turn on the heating system 10-15 hours**
- **4.4%** — **Turn on the heating system 15-24 hours**

Space Heating Systems:

Central heating systems that contain radiators with diesel boilers **are the most common systems** for heating residential apartments in Amman **with a ratio of 34%.**

Gas heating units are widely used in 30% of the apartments

Central heating radiators with gas boilers are used in new apartments as a source of heating but are still **limited to 7% of the apartments**

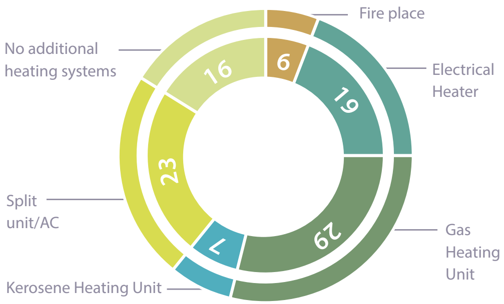
The use of electrical heaters Has decreased by 2.5% compared to the household survey conducted in 2015 to reach 5%.

Split unit ACs are widely spread and are **used in 11% of the apartments**

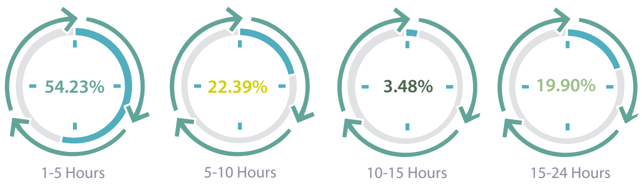
Underfloor heating powered by gas or diesel is more common in single homes and only **in 6% of the apartments**

Additional Space Heating Systems:

Due to the heat losses in the apartments, from insufficient thermal insulation, 85% of the occupants use additional heating sources. Gas heating units and AC split units are used in, 29% and 23% of the apartments respectively. Electrical heating units are used by 19% of the apartments to heat the rooms, whereas fire places and kerosene heating units are only found in 6% and 7% of the apartments respectively.

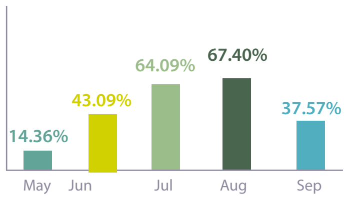


Additional Heating Hours/ Day

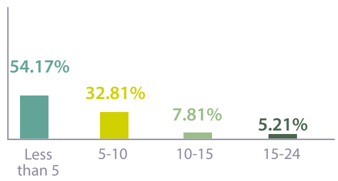


SPACE COOLING

The hottest months in Amman are July and August where the temperatures reash as high as 40^{O} C. Therefore, 64-67% of people use cooling methods. 43% of the respondents use cooling in June, and 37.57% use cooling in September. Half of the respondents use cooling for less than 5 hours a day while 32.81% use the cooling from 5-10 hours a day.



Duration of Space Cooling



Space Cooling Systems:

Cooling systems in residential apartments are based on electricity.

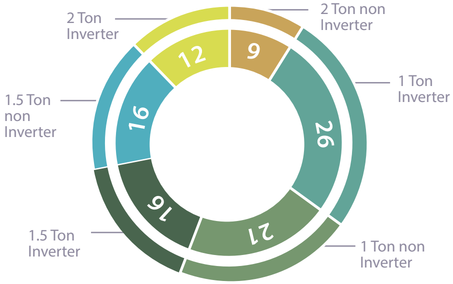
The most common methods used in apartments are AC split units at 40%

Followed by portable fans used in 31% of the apartments

Natural ventilation is essential in reducing the energy demand required for cooling loads, especially in climates like Amman, **it is only used in 19% of the apartments**

Central air conditioning units are not common in the residential sector **and are used only in 4% of the apartments**

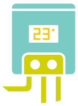
Air conditioning units vary in their size, power and efficiency. The inverter type adjusts the power consumption according to the demand which results in lower electricity consumption and thus energy savings. The most common AC units are 1 Ton capacity units where 26% are of the energy saving inverter units, and 21% are non-inverter.



WATER HEATING

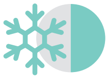
In Jordanian households, water is heated either by:

- Electrical Heaters
- Solar Thermal Heaters
- Gas Fueled Heaters
- Boiler Heating Systems



Electric water heaters

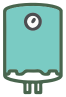
are used by almost:



Half of the apartments in winter

34% of the apartments in summer

due to its low cost and efficiency.



Boiler heating systems

are used by 31% of the apartments

when they already have their heating system on in winter as opposed to 9% in summer

Gas heaters

are used by 11% and 7% of the apartments

in winter and summer respectively

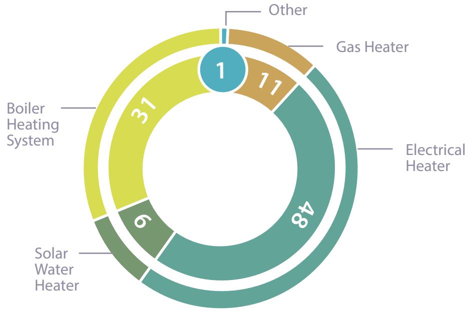
Solar water heaters

are the main source of water heating in 50%

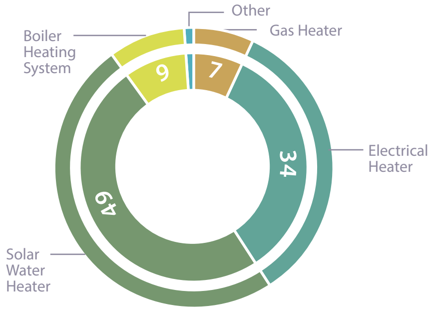
of the apartments in summer

The installation of solar water heaters has increased due to the mandatory requirements imposed on new residential buildings in Jordan, to reduce the primary energy demand by 145000 toe annually [1]. However, the law does not cover existing buildings which if enforced can result with major savings.

Water Heating Sources in Winter



Water Heating Sources in Summer



Energy consumption from water heating equals to 5124.90 MJ (1423.58 KWh), and has been calculated according to the following equation:

$$E_{WH} = \frac{Q_S X\, C_P X\, \Delta T_S}{\eta WH} X\, SD + \frac{Q_S X\, C_P X\, \Delta T_W}{\eta WH} X\, WD$$

Q_S, Q_W: Daily consumption of hot water during summer and winter, respectively (kg/day)
C_p: Specific heat of water (4.19 kJ/kgoC)
ΔT_S and ΔTW: The temperature increase of water for summer and winter
SD and WD: Number of summer and winter days
η_{WH}: the energy efficiency of water heating unit.

(According to the local code of water supply and sewage in the residential sector, the maximum total daily domestic hot water usage for a small family of 4 persons is 250 liters per day at temperature of not less than 55°C).

LIGHTING

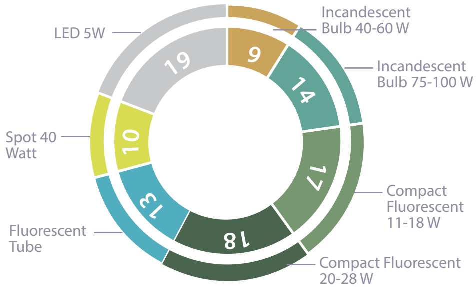
Compact Fluorescent Lights (CFLs) are used in 35% of the apartments

Incandescent light bulbs are used by 22% of the apartments

CFLs use 20-30% less electric power than that used by incandescent bulbs and last 8 to 15 times longer [39]. Although CFLs are more expensive than incandescent bulbs, they save over 5 times their purchase price in electricity costs over their life time. In addition, 90% of the energy used in incandescent light bulbs generates heat which increases energy consumption and cooling loads in summer.

LEDs which are known for their low power, high lumens per watt, longer lifespans, and higher prices, are found only in 19% of the apartments. Finally, fluorescent tubes and spot lights are used by 13% and 10% of the apartments respectively.

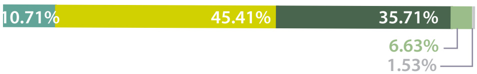
Ownership of different types of light bulbs in apartments



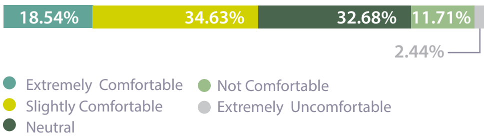
THERMAL COMFORT

The design of the building envelope along with the incorporation of natural ventilation are major drivers for the level of comfort in the buildings. Consequently, energy consumption from heating and cooling loads varies according to the thermal comfort of the occupants indoors. In summer, 45.4% of the occupants stated that they are slightly comfortable with the indoor room temperatures, while in winter 34.6% were satisfied with indoor temperature, and that is due to the poor design of insulation in the building envelope.

Thermal Comfort/ Summer



Thermal Comfort/ Winter



ENERGY USE INTENSITY

The survey results demonstrate the patterns of energy use in residential apartments and the share of energy consumption in each sector. The annual Energy Use Intensity is calculated by dividing the total energy consumed by a typical apartment floor area and resulted with a **value equal to: 91.4 kWh/m2.a.**

Space heating accounts for the highest share of the energy consumption in = 53% followed by cooking and kitchen appliances with a ratio of 16%.

Although the number of split AC units for cooling is increasing, electricity from space cooling is only responsible for 4% of the energy consumption because of the spread of energy saving ACs.

Heating domestic water accounts for 10% of the total energy consumption while electrical appliances consume 13% of the total. Finally, lighting accounts for 3% of the total kWh annually in households which is a small percentage due to the wide spread of energy efficient light bulbs.

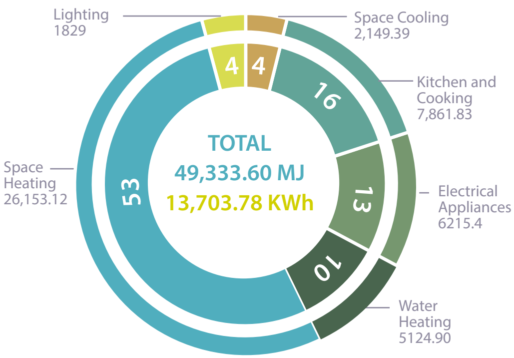


Figure 18: Energy Consumption in Residential Apartments

These values set the scene for energy use patterns and the consumption of each sector in residential apartments. The EUI calculated acts as a base case representing the current situation of energy consumption. Implementing active and passive strategies, improving the building envelope, and adopting energy efficient measures in appliances and systems to qualify as a Net Zero Energy Building can result with an EUI value equal to 50 kWh/m^2.a [52]. The energy benchmark is essential for designers, governmental institutions and decision makers to implement public awareness on behavioral changes and energy efficiency measures to reduce energy consumption in households. This information should be provided for building owners and occupants to better understand their buildings and the effect of their behavior on energy consumption, encouraging them to save energy and enhance EUI values.

Chapter 5

100 DESIGN STRATEGIES

TO IMPROVE ENERGY EFFICIENCY IN HOMES

Developing the energy benchmark for residential buildings and understanding energy patterns from the previous chapter will help us define the challenges and problems that we need to overcome in our buildings. This chapter will present some design strategies and rules of thumb that can be used as a benchmark for designing and refurbishing buildings in order to reduce energy consumption, save electricity and energy bills. Although some decisions should be implemented during the early stages of the design, there are multiple design and behavioral strategies that can be incorporated during the occupancy of the building to obtain energy efficiency.

SITE AND LOCATION

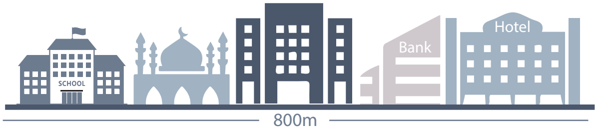
The location and site of the building may contribute to 46% of the variability in consumption. This section will include some points and strategies to consider when selecting your building site to save energy on the long term and help protect the environment.

1. THINK BEFORE YOU BUILD:

Buildings use energy throughout their lives. A decision to refurbish or reorganize an existing building rather than to build something new can reduce energy consumption, minimize resources, increase open spaces, and save the environment.

2. CHOOSE YOUR SITE CAREFULLY

Choose your site to be close to at least 5 amenities with a distance no more than 800 meters from your building. This will reduce travel destinations, costs and carbon emissions. Examples of Amenities are: shopping centers, banks, schools, religious buildings, public parks, pharmacies, restaurants, libraries, post offices, bakeries…

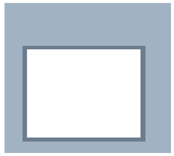


3. STAY CLOSE TO PUBLIC TRANSPORTATION

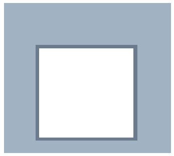
Choose your site to be no more than 800 meters far from at least one public transportation stop. This can ease accessibility to and from your building and give you the opportunity to save costs and carbon emissions.

4. REDUCE THE BUILDING FOOTPRINT

If you are designing your own building, **make sure to increase the area of exterior open spaces on site to be:**



25% of the total site area in urban areas

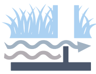


40% of the total site area in the suburbs

This can help

Drop the surrounding temperature

Reduce urban heat island effects



Reduce surface water runoff

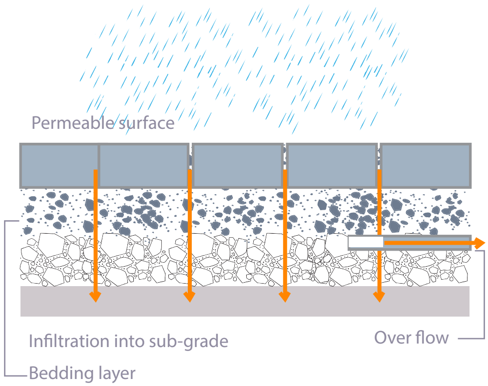
Give you more space to enjoy nature!

5. RAIN WATER HARVESTING

Collect rain water to be reused in irrigation, cleaning the garden, or flushing your toilets. Rain water harvesting systems should be present in all projects were the surface of collecting is $200m^2$ or more.

6. USE PERMEABLE SURFACES OR OPEN GRID PAVEMENTS

Permeable or pervious surfaces allow water to infiltrate through the surface and into the soil. They help to filter out pollutants, reduce surface water run-off, and store rain water. Use permeable tiling and techniques to cover your building site and save water.

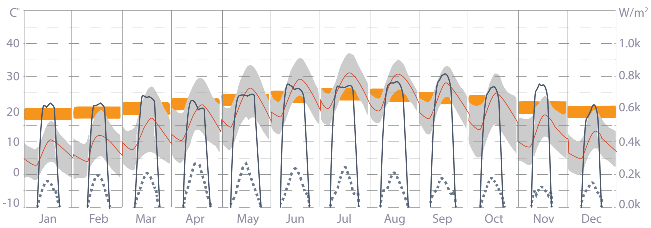


THE CLIMATE

Buildings exist to respond to the climate and provide a comfortable thermal environment for the occupants. The climate is a form generator and the initial step to consider in energy efficient building design. Understanding the sun and wind movements contribute to multiple energy saving opportunities.

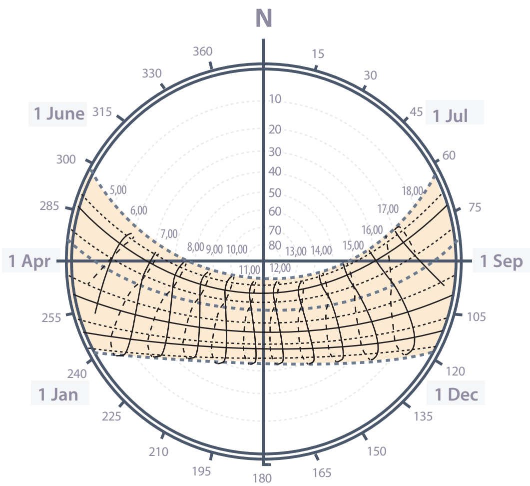
7. UNDERSTAND THE CLIMATE:

There are three climatic zones in Jordan; each requires different design strategies. Amman, the capital is part of the Highlands Region with a moderate to hot and dry climate in summer, whereas the winters are cold and rainy. The average temperature ranges from 8°C to 25.1°C in January and July respectively. The coldest day in the year is in January with temperatures equal to 0ºC, and the hottest day is in July with an extreme temperature reaching 39ºC.



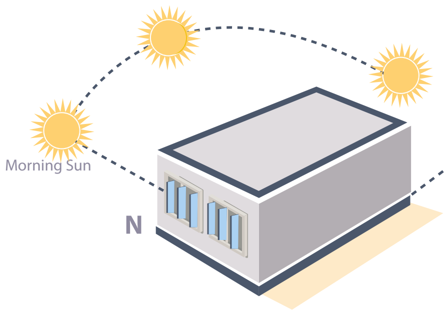
8. HERE COMES THE SUN

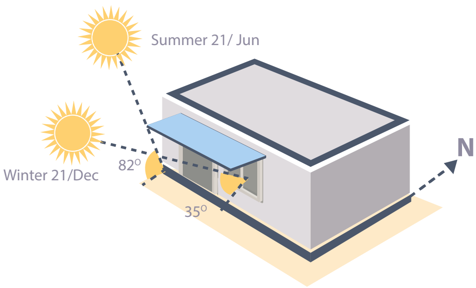
The sun path diagram is a great design tool that helps understand the sun movement in relation to the site on a certain latitude. It contains vertical sun angles (Altitudes) and horizontal sun angles (Azimuth) in different times throughout the year. In summer on the 21st of June, the sun is high in the sky reaching 82º in Amman while in winter on the 21st of December it reaches around 35º in midday. These angles are essential to consider when designing passively for solar access.



9. DESIGN FOR SOLAR ACCESS: IN OR OUT?

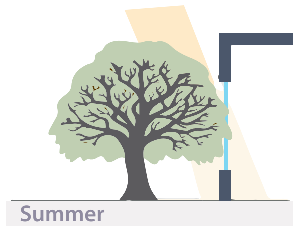
It is important to prevent direct sunlight entering the building in summer because it causes overheating and additional cooling loads. However, in winter it is a free source of heat that can increase the temperature and reduce heating loads in the building. East and west sun is considered low, more intense, and more difficult to control. Southern solar access is perpendicular and higher in sky which makes it easier to block in summer by shading.

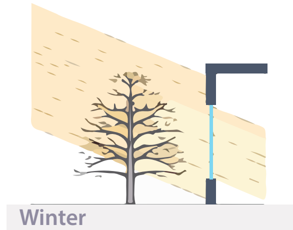


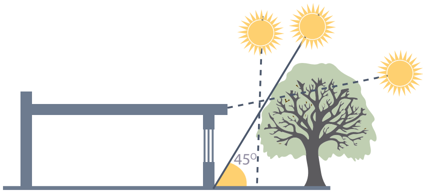


10. TREES CAN CONTROL SOLAR ACCESS

Trees can help in shading our buildings. Deciduous trees can block up to 85% of the sun's radiation in summer. In winter, when the leaves drop, they permit up to 70% of the sun's energy to pass between their branches. A rule of thumb is to place the tree such that the canopy sits outside a line drawn at 45° from the base of the building.





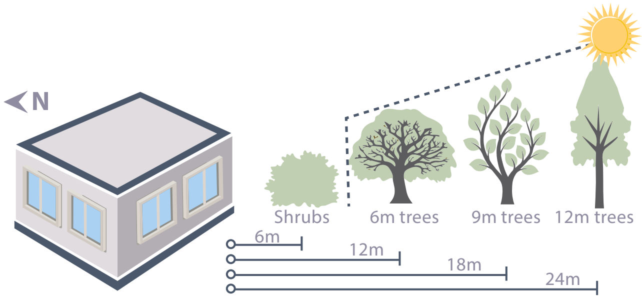


11. PLANT EASTERN AND WESTERN TREE BELTS

Long east and west trees can provide shade and shelter from low sun angles and protect the building from the wind. In Amman, unprotected east and west façades with direct solar exposure can increase the indoor temperature up to 2°C in summer.

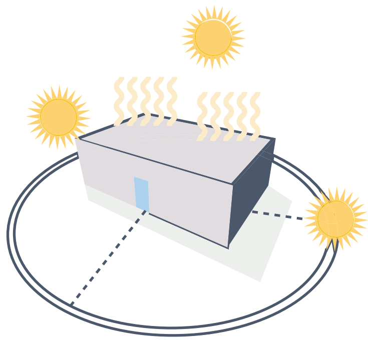
12. PLANT SHORT TREES IN THE FRONT, LONG IN THE BACK

Plant shorter trees and shrubs close to the building and increase the height of the trees as you move further away to provide adequate shading in summer as in the graph below.



13. IT COMES FROM THE TOP

Solar radiation in Jordan is one of the highest values worldwide. Flat roofs experience the highest exposure to solar radiation throughout the day. Solar gain from the roof is transferred into the building and results with an increase in temperature and cooling loads in summer. In addition, **25% of heat losses are from the roof tops in winter,** therefore, thermal insulation of the roof is essential to consider.



14. PROTECT THE ROOFS:

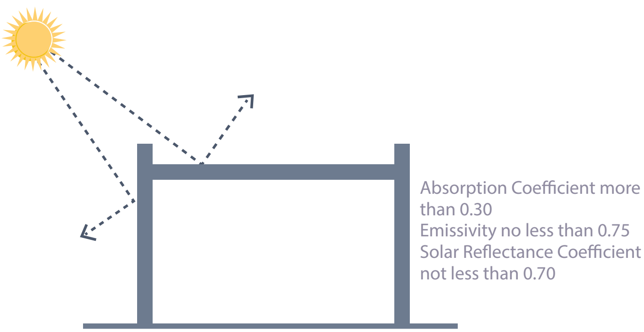
Paint the roof with light colors to reflect solar gains and reduce the heat transferred into the building with the following properties:

- Absorption Coefficient more than 0.30
- Emissivity no less than 0.75
- Solar Reflectance Coefficient not less than 0.70

Solar reflectance:
is the percentage of solar energy reflected by a surface.

Solar reflectance is measured from 0 to 1.0, where 0 indicates that the material absorbs all solar energy and a value of 1.0 indicates total reflectance.

Emissivity is a measure of how well the roof surface emits thermal radiation, energy, and heat.

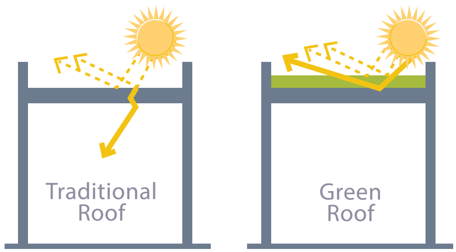


15. GREEN ROOFS PROTECT AGAINST HEAT LOSSES

A green roof is a system that uses vegetation as roof covering. Planting on rooftops has multiple benefits; it protects against heat losses by providing insulation, reduces heat island effect, reduces solar intensity, and consequently decreases cooling loads and energy consumption. **By implementing green roofs, 17% of the heating and cooling energy demand can be reduced** [38]. Placing planting pots on the roof can be rewarding as well.

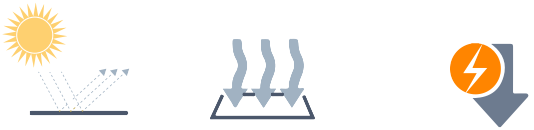
Urban Heat Island Effect (UHI):
is the increase in temperature in urban areas compared to the surrounding rural areas due to human activities.

The annual mean air temperature of a city with 1 million people or more can be 1–3°C warmer than its surroundings and in the evening the difference can be as high as 12°C [43].



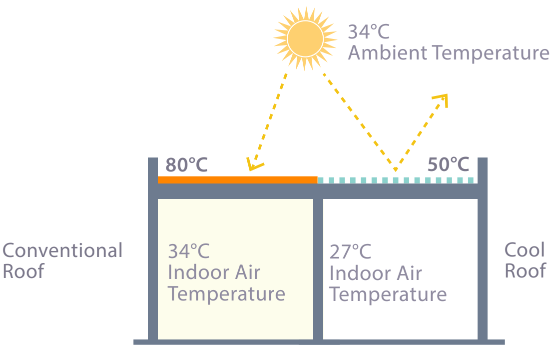
16. MAKE YOUR ROOFS A BIT MORE COOL (COOL ROOFS)

Cool roofs are designed to decrease the temperatures of the roof by:



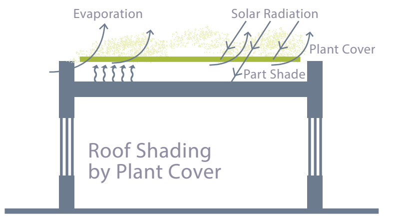
Reflecting more sunlight | Absorbing less heat | Reducing heat gains and energy consumption

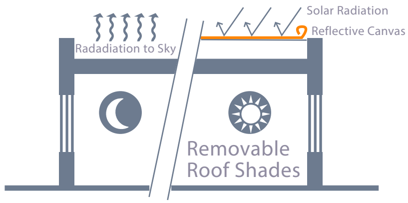
The most common solution for a Cool Roof is to use a High Solar Reflective Cool Roof Coating. The coating is usually light or white colored that creates a high reflective surface, blocking the incoming solar radiation, remaining cooler, and contributing to the energy savings in summer. Try to implement cool roof strategies on 80% to 100% of your building roofs. **Cool Roofs reduce annual air conditioning energy use of a single-story building by up to 15%** [39].



17. SHADING THE ROOF

Shading the roof is an important method to reduce heat gains. Roofs can be shaded by providing roof covers of concrete or plants or canvas. Shading the roof allows the warm air that builds up between the roof and structure to escape by enabling cooler air to pass through. A cover of deciduous plants and creepers is also an alternative to shading the roof. Evaporation from the leaf surfaces brings down the temperature of the roof. Another inexpensive and effective device is a removable canvas cover mounted close to the roof. During daytime it prevents the entry of heat, and its removal at night cools the building through radiation [40].

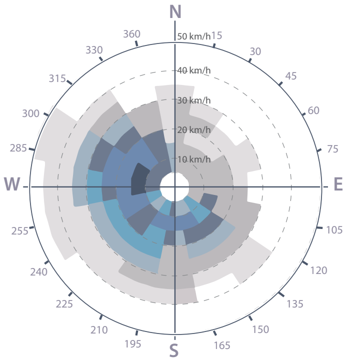




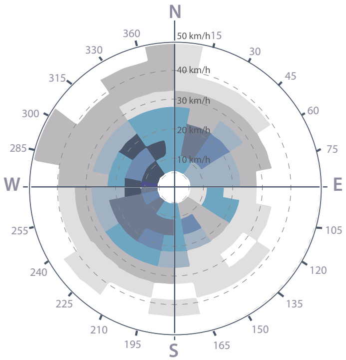
18. CAN WE CATCH THE WIND?

The wind is usually analyzed using Wind Rose diagrams specific for the climatic zone and season. The annual average wind speed in Jordan exceeds 7m/s at 10m height, and 3.16 m/s. Most of the wind is concentrated from west and south west orientations, with some autumn and spring wind from the south and east. It is important to orient the buildings and place the openings to capture cold breezes in summer and avoid direct wind in winter.

Summer Wind

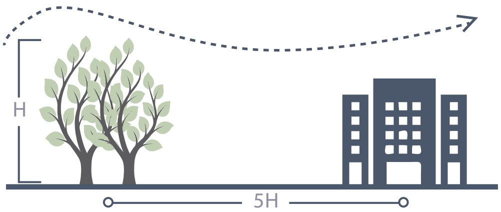


Winter Wind



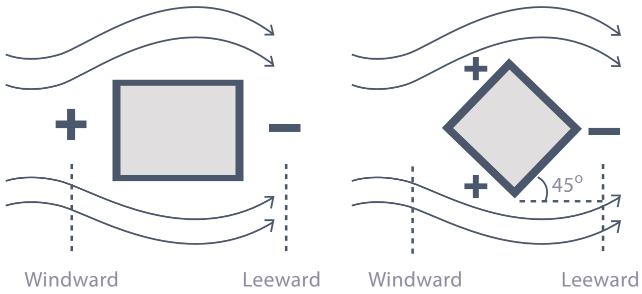
19. CONTROL THE WIND SPEED WITH WIND BREAKS

You can control the speed of the wind by windbreaks such as trees. **Windbreaks reduce wind pressure and velocity by 75-85%.** Height is the most important factor in the windbreak structures because the length of the protected area in front of, and behind the windbreak depends on its height. Controlling wind speed will eliminate pressure differences on the side of the buildings, so in winter warm air stays in the building and cold air stays out. As a result, windbreaks reduce energy use for heating by blocking cold winter winds. Windbreaks also reduce the cooling loads of buildings due to the reduced heat gains from convection and air infiltration created by the developed pressure. **A windbreak placed at a distance five times its height can result with 15% - 20% energy savings** [44].



20. UNDERSTAND THE WIND DIRECTION: WINDWARD OR LEEWARD?

Understanding the direction and movement of the wind is a key element in designing natural ventilation in buildings. The direction from which the wind is coming is called Windward (+), while the opposite is called Leeward (-). The greatest pressure on the wind ward side of the building is gained when it is perpendicular to the wind direction. However, rotating the building 45° from the windward direction will create two windward facades and increase ventilation efficiency.

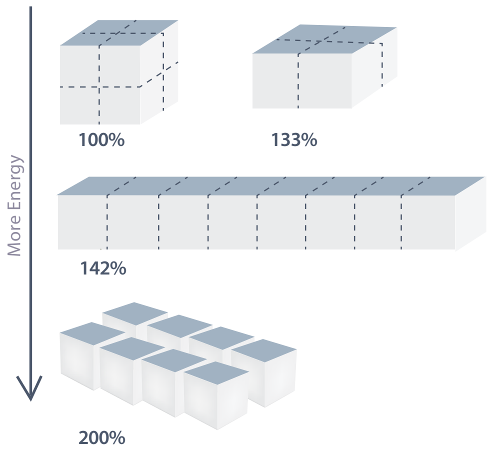


FORM, SHAPE, AND LAYOUT

The way we shape our buildings, orient the spaces, locate the functions and design the facades, contribute to the amount of energy consumption in the buildings and correlate directly to the climatic characteristics of the region.

21. COMPACT BUILDINGS USE LESS ENERGY:

Buildings of similar areas but different external envelope areas vary in energy demand at their operation stage and the demand for building materials at the construction stage. Surface to volume ratio affects heat gains and losses; **the greater the surface area of the building, the more energy needed to overcome heat losses**. More compact forms such as vertical buildings are more energy efficient compared to single housing units.



22. BUILDING LAYOUT AFFECTS ENERGY CONSUMPTION

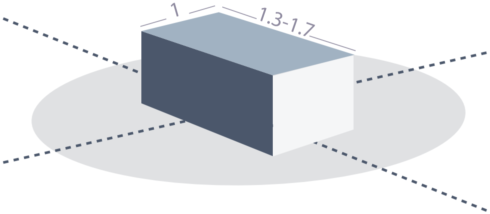
The shape of the building layout affects energy consumption because it relates to the amount of solar radiation falling on the building. Minimise the plan dimensions in east and west facades because they receive the most intense heat from the sun perpendicular to the surface.

The rectangle shape is more suitable for hot climates

The square shape with equal solar exposure from all sides is more suitable for cold climates

23. BUILDING ASPECT RATIO AND PROPORTION DETERMINE ENERGY EFFICIENCY

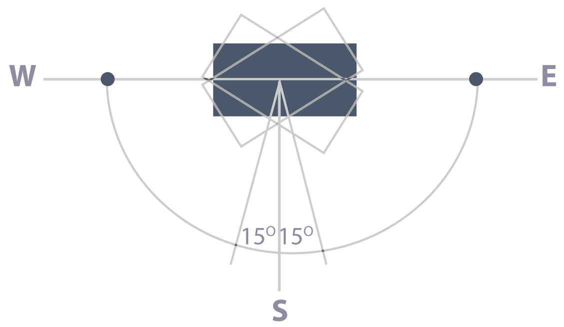
The aspect ratio of a building is one of the most important determinants of energy efficiency. It defines the building surface area by which heat is transferred between the interior and exterior environment. It also defines the amount of building area that is subject to solar gain. **In hot climates, the rectangular form with aspect ratio 1:1.3 or 1:1.7 performs the best.**



24. ORIENTATION ORIENTATION ORIENTATION

Orientation is considered a key sustainable design parameter that can result in 82% reduction in heating and cooling loads [45]. Multiple strategies rely on orienting the building in an optimum direction considering the sun and wind. In addition, good orientation is required to incorporate active systems and renewables such as PV and solar collectors.

Orient your building to insure that the long axis is facing the south with a maximum inclination of 15º. Southern facades have the longest solar exposure during the day but are easy to shade and control, while east and west facades pose a challenge in shading due to their low solar access.

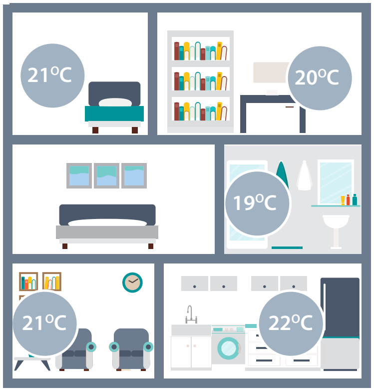


25. OCCUPANCY MATTERS

The zoning layout of your building should relate to the type of function, occupancy hours, and internal heat gains. Locate the most occupied zones towards the shaded southern orientation, the circulation cores and service areas towards the north and west to protect from the cold winter. Based on the occupancy hours and internal heat gains, **it is recommended to place the living rooms towards the south, bedrooms to the east,** and the kitchen to the north east to reduce energy consumption and insure thermal comfort [41].

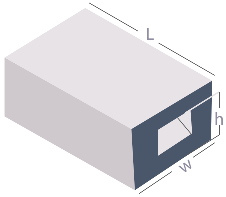
26. DESIGN IN THERMAL ZONES

A thermal zone is a space or collection of spaces that share similar heating and cooling conditions. When designing your building, make sure to separate the functions to be completely enclosed and compact in order to avoid heat losses between the rooms. If you have an indoor staircase, make sure it is closed when turning on the heating and cooling because warm air rises to the top and reduces the efficiency.



27. ROOM DIMENSIONS

Room dimensions are important to consider when designing energy efficient buildings. Shallow plans are recommended because they receive adequate natural daylight and natural ventilation. The following equation can assist you in designing your room depths to ensure the implementation of optimum environmental strategies.



To be successfully daylit from one side, the depth (L) of the room should be limited to meet the following condition:

$$\frac{L}{W} + \frac{L}{h} \leq \frac{2}{(1-R_b)}$$

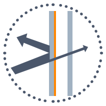
where:
L= depth of room from window to back wall
W= width of room measured aacross the window wall
h= height of window head above floor
R_b = area-weighted average reflectance in the back half of the room (the value for a typical office is likely to be around 0.5)

Source: BS Daylight Code [2], p19

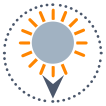
28. WINDOW TO WALL RATIOS (WWR)

Window-to-Wall ratio is the measure of the overall area of all transparent facade openings excluding the frames, divided by the zone's exterior wall area.

WWR is important because:



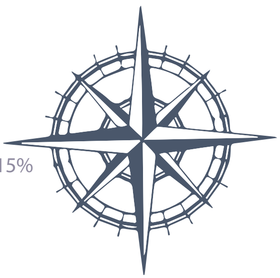
It affects the amount of solar gains



Controls the quantity of daylight

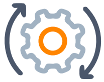
Affects the efficiency of natural ventilation

According to the local codes, WWR should not be less than 15% in living areas, and 10% in the service areas. However, in Amman, WWR should be more specific to each orientation as illustrated in the graph, because each orientation differs in sun and wind exposure.



29. DESIGN FOR NATURAL DAYLIGHT:

Natural daylight has multiple benefits for the occupants; it increases:



Productivity

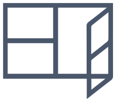
Health

Visual comfort

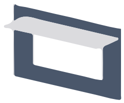
and reduces energy use of a building by reducing the artificial lighting energy demand from 20% to 30%

Daylight should not be confused by direct sunlight and should be designed with a distribution within the space that is visually comfortable and does not create glare. **Many factors affect the daylight distribution such as:**

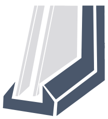
Room depth



Height of the window head



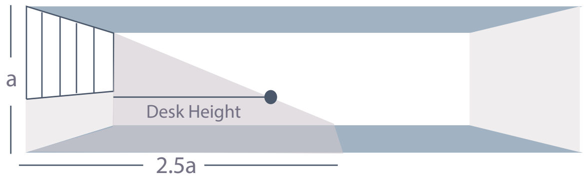
Shading devices



Glazing type

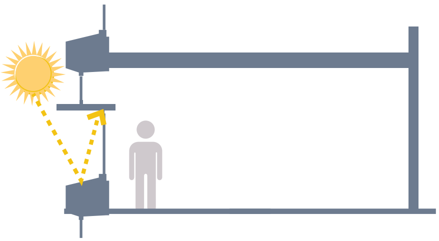
30. DAYLIGHT RULE OF THUMB:

A room will be darker at the back in deep plan rooms that are daylit from a single side. It is important to ensure that the windows provide effective lighting in the space by using the rule of thumb; the depth of daylight penetration in a room is twice and a half the height of the window.



31. TAKE A DEEP FACADE APPROACH

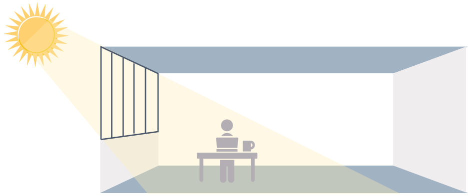
A facade with some depth creates a buffer zone that can create shading, diffuse direct sunlight, avoid glare and ensure uniform daylight distribution in the space.

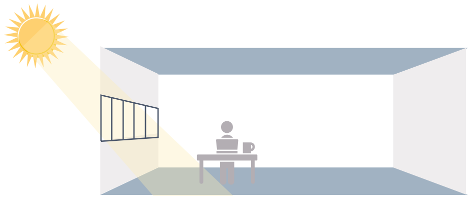


32. WINDOW SHAPE AND POSITION AFFECT DAYLIGHT FACTOR

The higher the window head, the deeper the daylight penetration in the space.

However, it is important not to compromise good visual connection and views to the outside. The easiest way to provide adequate and uniform daylighting is with a nearly continuous strip window. Punched windows are also suitable, but the breaks between windows can create contrasts of light and dark areas.

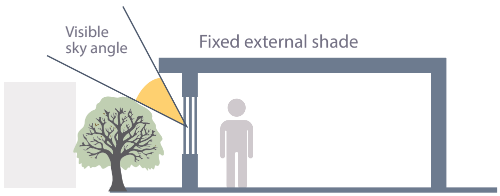


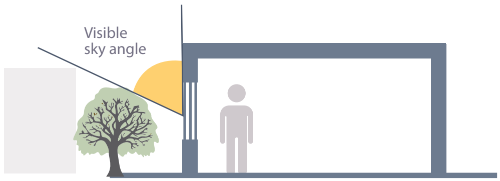


33. LOOK AT THE SKY

Visible sky angle is the vertical angle of the open sky, seen from the center of the window, level with the inside face of the window wall. If the window sees a large angle of open sky, that means that the visible sky angle is large.

Larger sky angles give more visual comfort for occupants. The angle should not be less than 30º.

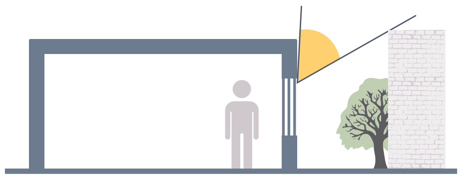




34. WHAT IS THE DAYLIGHT FACTOR?

The "Daylight Factor"
is the relation between illuminance at a surface and the amount of daylight available outside from the overcast sky.

Window openings, the size and proportion affect the amount of daylight entering the building and should be carefully designed to provide the required daylight factor according to the following equation.



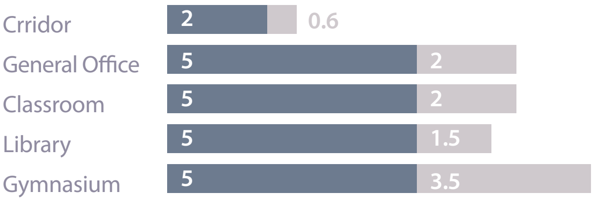
$$\bar{D} = \frac{W}{A} \frac{TO}{(1-R^2)}$$

where:
D= average daylight factor
W= window are in m^2
A= area of all surfaces of the room in m^2 (floor, ceiling, and walls including windows)
T= glass transmittance. (0.75 for clear double glazing)
O= visible sky angle, in degrees
R= average reflectance of area A (0.50 for light surfaces)

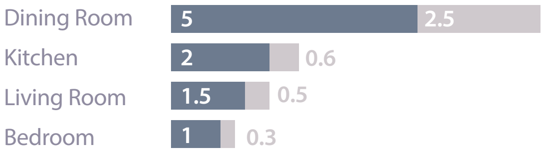
35. HOW MUCH DAYIGHT IS SUFFICIENT?

There are certain daylight factor values that are required in the building to create adequate daylight and visual comfort. These values differ according to the function of the space and should be considered when designing the interior layout.

Commercial/ Institutional



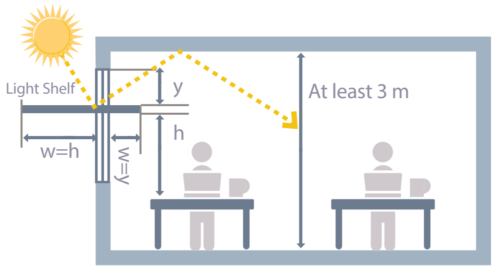
Residential



● Average DF ● Minimum DF

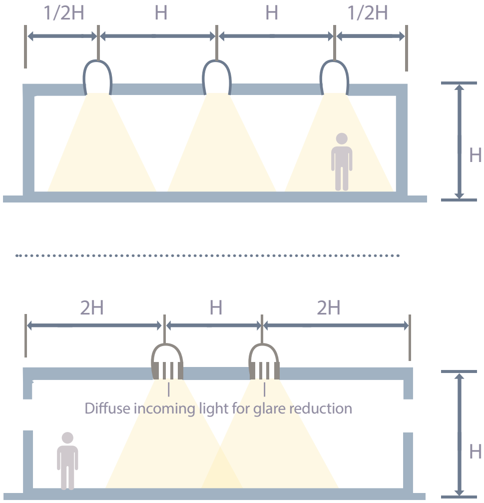
36. LIGHT SHELVES TO PREVENT GLARE

Glare is the visual discomfort of occupants created by the presence of bright light such as direct or reflected sunlight. Light shelves are one criterion to let daylight in the building while preventing glare and can be applied following the rule of thumb below.



37. DAYLIGHT FROM ABOVE

Skylights should be carefully designed in hot climates because of their high exposure to solar heat gain in summer, and heat losses in winter. The glazing should have a high thermal performance and internal shading should be incorporated. A skylight with an area equal to 1% of the space below can provide adequate daylight.

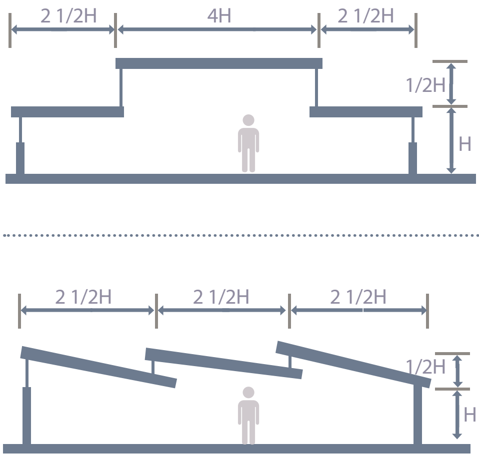


Skylight placement as a function of building height

38. CLERESTORIES:

Clerestory window is a high section of wall that contains windows above eye level.

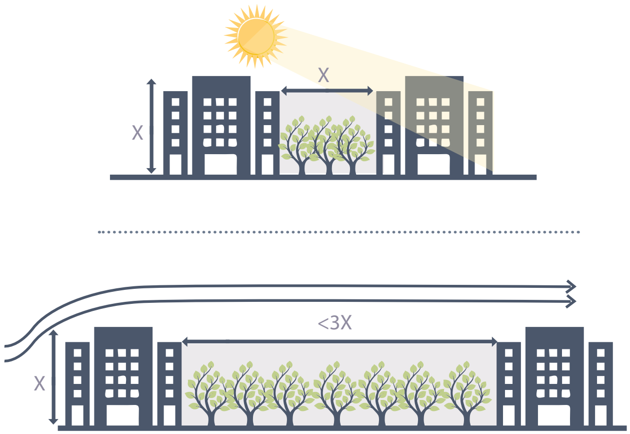
The purpose is to allow light deeper into the room more than windows set at a standard height. They can also be designed to open allowing an exchange of the inside air, while breezes enter through lower openings in the house, they escape from the upper openings due to the difference in air temperature and density.



Clerestory spacing as a function of building height

39. COURTYARDS ARE POWERFUL

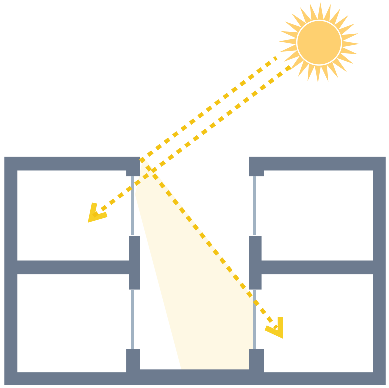
Courtyards are recommended for passive design in hot climates. Shaded courtyards are a good strategy for natural ventilation in summer, because the shaded air is lower in temperatures compared to the interior of the building which forces the air to enter through openings from the courtyard and moderate the indoor temperatures. **The depth of the courtyard should be no more than three times the height of the adjacent building to ensure that it is fully shaded.**



40. TRANSFER SHAFTS INTO LIGHT WELLS

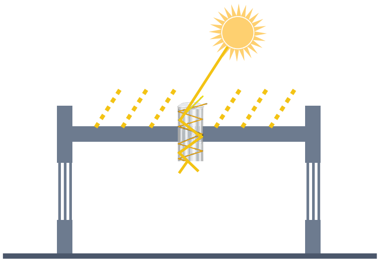
Light well is an internal space provided within the volume of a building to allow light and air to reach what would otherwise be a dark or unventilated area.

A good strategy is to paint the interior walls of the shafts in your building with light colors to enable daylight reflection to enter deeper through the spaces.



41. SUN PIPE

Sun pipe systems are used to bring natural daylight to areas that don't have any windows without producing warmth or heat. The sun pipe systems comprise of a collector, a light tube and a diffuser. A collector is usually located at roof levels and is made of clear dome to collect sunlight from the whole sky hemisphere. The light tube acts as a light transport that will guide the light into the room to be daylit. **Although not yet widely used in Jordan, sun pipes could provide 25% –50% of the work plane** illuminance and reduce lighting energy consumption.

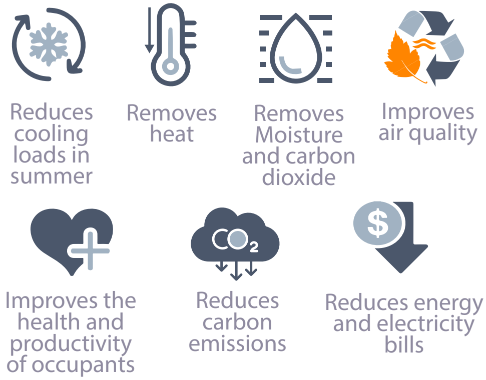


Recommended Sun pipe Sizes for Different Rooms		
Tunnel diameter	**Room size**	**Room type**
15.5cm	0-4m2	Cupboards and short corridors
23-25cm	4-10m2	Hallways, small bathrooms
32-45cm	11-15m2	Large hallways, stairwell and bathrooms
52-55cm	16-22m2	Kitchens, bedrooms and living rooms

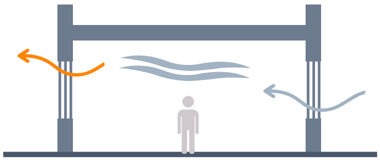
Source: https://www.sterlingbuild.co.uk/info/5-things-you-need-to-know-about-sun-light-pipes

42. NATURAL VENTILATION: ONE STRATEGY, MULTIPLE BENEFITS

Natural forces are utilized to drive natural ventilation such as wind and temperature differences (buoyancy), to circulate air to and from an indoor space. **Natural ventilation:**



If natural ventilation is properly incorporated in building designs, it can **enhance the thermal performance in residential buildings in Amman and reduce energy consumption by up to 30%** [41].



43. HOW MUCH NATURAL VENTILATION DO WE NEED?:

The objective of designing a ventilation system is to determine the ventilation rate, maintain an acceptable temperature as well as acceptable moisture and contaminant levels inside the building.

In living areas and bedrooms, provide a minimum ventilation rate of

4 Liters/ second/person

In kitchens and bathrooms, provide a minumum ventilation rate of

14 Liters/ second/person

44. MAINTAIN HUMIDITY VALUES BETWEEN 40-70%

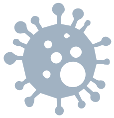
In order to provide thermal comfort indoors, **humidity levels should be kept between 40-70%.**

Low humidity causes:

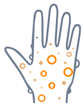
Dry skin

Itching and chapping

High humidity:



Stimulates the growth of molds



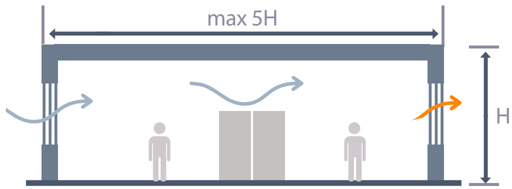
Triggers allergic reactions

Enhances the emission of chemicals from materials which affects interior furniture, walls, and indoor air quality

45. DOUBLE SIDED VENTILATION

Cross ventilation is the most suitable technique for ventilating deep-plan spaces and is highly recommended in the climate of Amman. Double sided ventilation forces air to move from an inlet to the outlet carrying internal heat gains along the way.

As a rule of the thumb,
the depth of the room can be up to 5 times the height,
and the opening area required is approximately
2% of the floor area (1% on each side of the space).



46. SINGLE SIDED VENTILATION

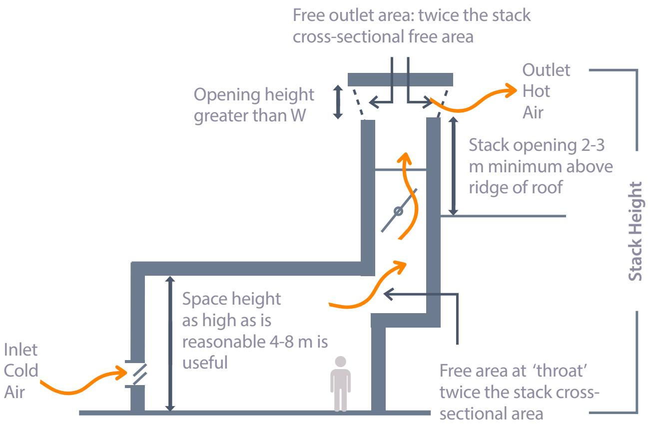
Single sided ventilation is generally effective for room depths not more than 2.5 times the height of the room. The ventilation opening area should be between 5% to 10% of the room's floor area. This technique is more suitable for moderate climates and not effective in hot climates.

Ventilation through a single opening

Ventilation through two openings

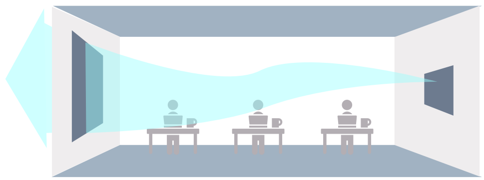
47. STACK VENTILATION

Stack ventilation depends on the temperature differences of air, as well as the stack height. The higher the temperature differences and the stack height, the higher performance of ventilation is achieved. This type of ventilation is effective across a width of 2.5 times the height of the room and a stack height twice as tall as the height of the tallest space it is ventilating.



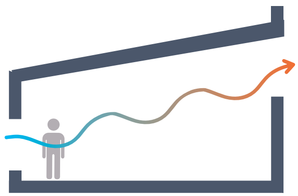
48. PAIRING A LARGE OUTLET WITH A SMALL INLET INCREASES AIR SPEED

Greatest flow per unit area of openings is obtained when the inlet is small, and the outlet is large by at least 25%. The pressure of air acting on the small window, forces air through the opening at a high pressure and faster speed towards the bigger outlet window. This is due to the Venturi Effect that accelerates airflow and reduces pressure within the designed passage of air between the two windows.

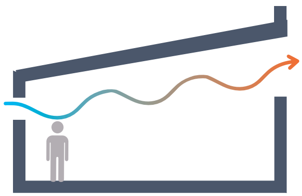


49. THE HEIGHT OF THE OPENING AFFECTS THE INDOOR AIR CIRCULATION

The height of the windows on the wall influence the air movement and direction in the space causing different building elements to be cooled. The higher inlets and outlets provide structural cooling, while lower inlets provide occupants' cooling.



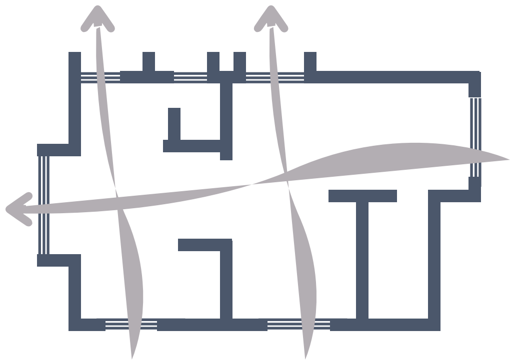
Occupant Cooling



Structural Cooling

50. USE INDOOR PARTITIONS TO INCREASE EFFICIENCY OF NATURAL VENTILATION

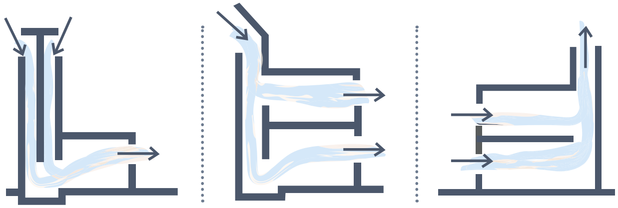
Interior partitions and furniture are important to ensure equal distribution of natural ventilation and should not block the airflow. Large, open spaces should always have large windows on opposite walls to force the air to move through the space. However, with the typical central corridor layout of residential apartments, natural ventilation may be improved by creating an open-air flow throughout the plan by opening doors and windows in summer. Shafts and staircases can be used to combine cross-ventilation with stack ventilation in multistory buildings.



A floor plan that provides effective and natural breeze paths is the basis for effective natural ventilation.

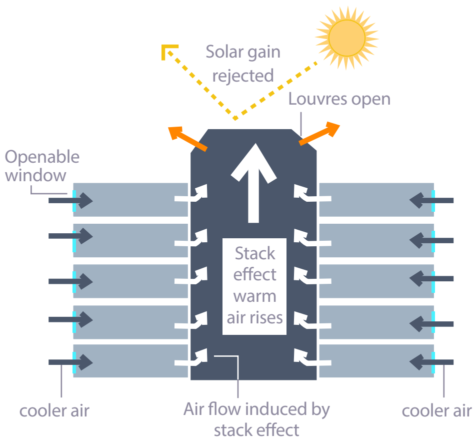
51. USE WIND TOWERS

Wind towers passively cool hot dry outdoor air and circulate it through the building. The outlet openings are placed on the roof or high up on walls on the leeward side of the building structure where the pressure is less than the inside of the building. A cooling method, like placing water porous jars on the top can reduce the air temperature, and increase its density, causing it to move downwards to the building replacing the hot air inside. **Inlet and outlet opening areas for wind towers are to be 3-5% of the floor area they serve.**



52. TURN SHAFTS AND STAIRCASE CORES INTO COOLING ELEMENTS

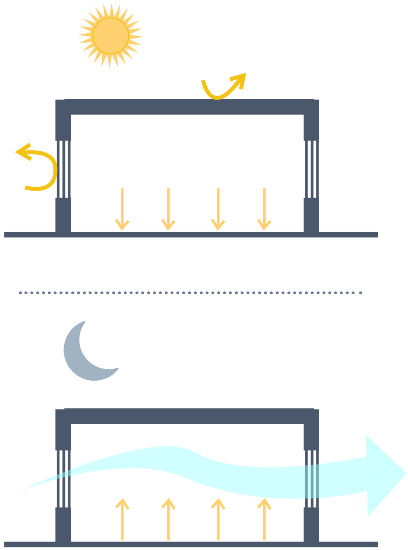
Design the staircase core in the building to serve as a cooling element by placing ventilation outlets at the top. Hot air will rise to the top due to its low density, and cooler air will be replaced to reduce the temperature on the lower levels.



53. NIGHT TIME VENTILATION

With the high temperature differences between day and night in Amman during the summer, it is recommended to close the windows during the day and open them during the night. This will help release the stored heat in the building mass during the day.

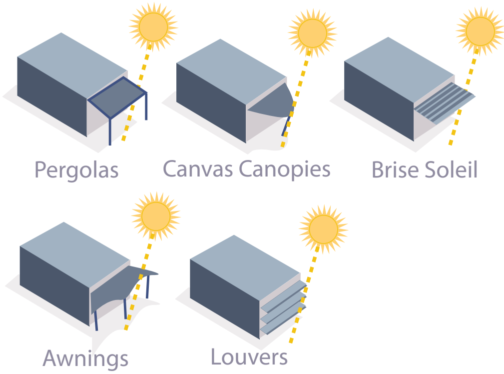
A building with sufficient thermal mass and nighttime ventilation, can reduce peak daytime temperatures by 2° to 3° [46].



SHADING

54. SHADING

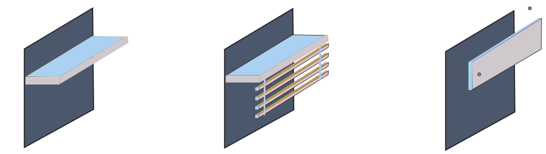
Shading can be implemented indoor or outdoor and can be moveable or fixed. Multiple methods are used for shading and differ according to orientation such as;



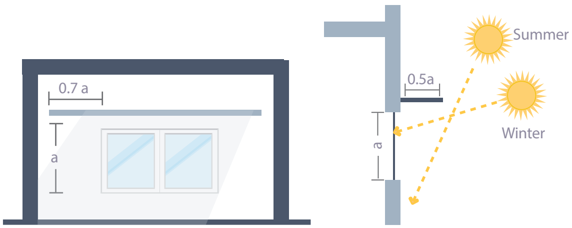
Sun angles should be taken in consideration to block solar access in summer and allow it in winter. Shading can block up to 90% of the heat gain, reduce summer temperatures, improve comfort and save energy. Shading devices should be made of light and reflective materials with a low heat capacity storage and shading coefficient of less than 0.20 to comply with the Jordan Green Building Guide.

55. SOUTH SHADING

For southern facades, when the sun is high, it is recommended to use horizontal shading. **Adding external southern shading is a simple strategy and can reduce 25% of heating and cooling loads in Amman** [47]. The design of southern shading should follow the rule of thumb in the drawing for optimum efficiency.



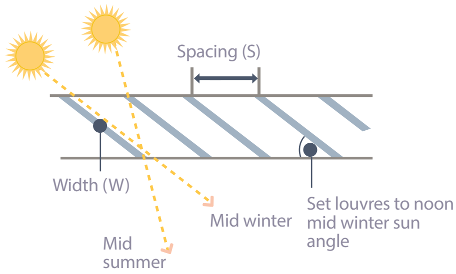
Horizontal Panel — Horizontal Louvres in Vertical Plane — Vertical Plane



56. EAST AND WEST SHADING:

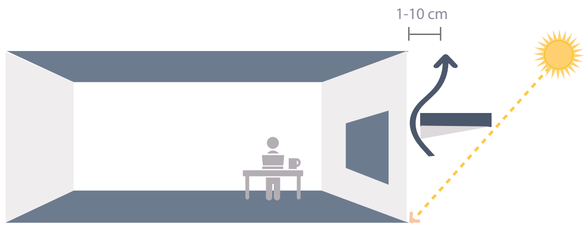
Where sun is low and strong in east and west facades, vertical shading devices or eggcrates can effectively block the sun. Fixed horizontal louvres set to the noon mid-winter sun angle and spaced correctly allow winter heating and summer shading in locations with cooler winters. **As a rule of thumb, the spacing (S) between fixed horizontal louvres should be 75% of their width (W).** The louvres should be as thin as possible to avoid blocking out the winter sun [48].

Vertical Fin — Slanted Vertical Fin — Eggcrate



57. SPACING BETWEEN THE SHADING DEVICE AND THE BUILDING

When designing moveable shading devices, make sure to leave 1-10 cm of air gap between the shading device and the building envelope. This will prevent solar gain below the device, reduce overheating and enable air movement in between.

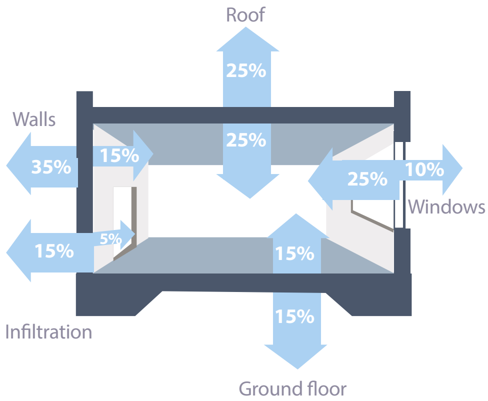


THE BUILDING ENVELOPE

The building envelope is the main link between the outdoor and indoor environment that directly influences heating and cooling loads. The design of the walls, ceilings and floors should correspond to the local climate to maintain comfort temperatures and reduce energy consumption from heating and cooling.

58. FABRIC FIRST

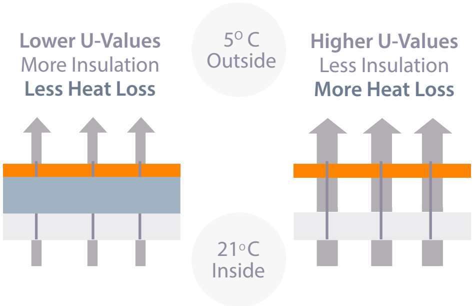
Buildings loose and gain energy through their envelope: the walls, roofs, windows and floors. It is important to understand the materials' thermal properties and design the envelope to limit heat losses and gains depending on the climatic characteristics. Wrap the building envelope continuously with insulation to eliminate heat losses and gains and prevent air infiltration through construction joints that are not airtight.



59. WHAT IS THERMAL TRANSMITTANCE (U-Value)

Thermal transmittance (U-Value) is the rate of heat flow through a unit area of building envelope per unit of temperature difference between the inside and outside air (W/m^{2}K).

The U-value gives an indication about the materials' ability to transfer heat through the building. **The lower the U-value, the better the thermal performance in letting heat in or out the building.** The U-value of the wall is the reciprocal of the sum of the thermal resistances of each material making up the building element.



60. THERMAL RESISTANCE (R)

Thermal resistance (R) is the ability of a material to resist heat flow. Thermal resistance connects with the thermal conductivity (k) and the fabric thickness as follow:

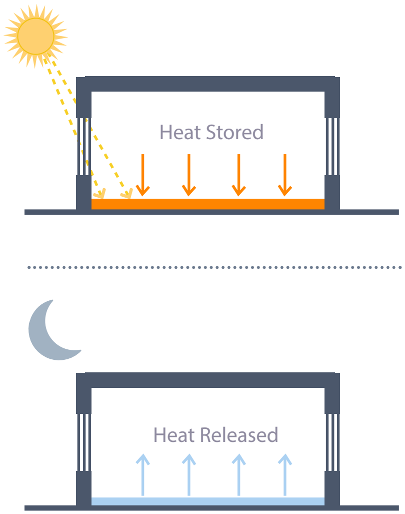
$$\textbf{Thermal Resistance } (\mathrm{m^2K/W}) = \frac{\text{Thickness (m)}}{\text{Conductivity (W/mK)}}$$

Materials that have higher thermal resistance are better insulators and result with lower heat losses. Similarly, increasing the thickness of the material reduces the thermal conductivity (heat flows through the material). Thermal resistance is the converse of thermal transmittance (U-value) as in the following equation:

Thermal Resistance (R)= 1/U-value.

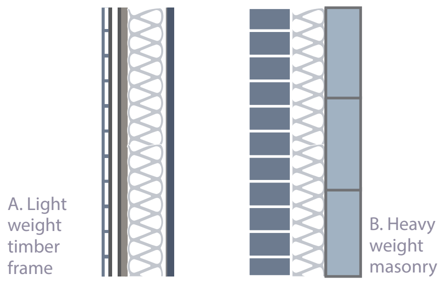
61. THERMAL MASS KEEPS TEMPERATURES STEADY

Thermal mass: is the ability of a material to absorb and store heat. Thermal mass is recommended in climates with a large diurnal temperature difference between day and night. The material stores the heat throughout the day for a duration (time lag) then radiates this heat indoors during the night when temperatures are low.



62. THERMAL MASS AND INSULATION ARE DIFFERENT BUT THEY WORK TOGETHER

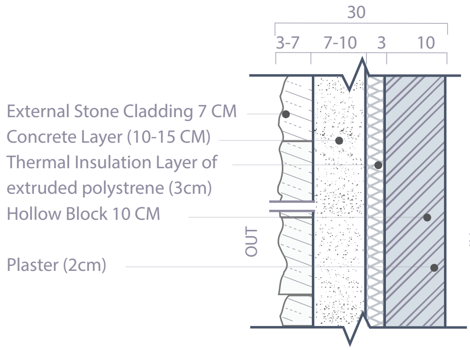
Thermal mass differs from insulation although they work together; **insulation resists heat while thermal mass stores it.** A 10 cm of insulation is 30 times the insulation value of brick with similar thickness, while brick is 300 times the thermal storage capacity of insulation. Buildings with heavy materials such as concrete and brick have high thermal mass; they heat up and cool down slowly. Whereas lightweight materials like timber frame and wood have low thermal mass and allow buildings to heat and cool quickly.



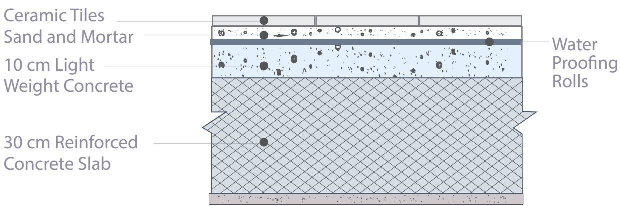
A. and B. may have the same insulation value but B. will have many times the thermal mass [50].

63. LEARN ABOUT THE INGREDIENTS

Typical External Walls in Amman consist of the layers displayed in the figure below. This wall section, which is the most common, has a U-value equal to 0.75 W/m²K which is less efficient than the values set by the local codes.

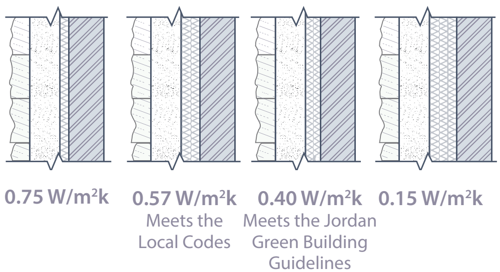


The roofs consist of water proofing rolls, light weight concrete (10cm), and a 30cm reinforced concrete slab, with a U-value equal to 1 W/m²K. Adding a layer of ceramic tiles (1cm), cement morter (2cm), and sand (7cm), will improve the U-value to 0.8 W/m²K. Yet, both values are less efficient than what is require by the local codes.



64. LESS VALUE, MORE EFFICIENCY

In Jordan the U-value set by the local codes for external walls is equal to 0.57 W/m²K. Buildings that comply with the code can save 3% in energy used for heating and cooling compared to the base case. This can also be achieved after occupancy by adding a thermal insulation layer from the interior of the building. In the Jordan Green Building Guide, the recommended U-value is equal to 0.40 W/m²K which is more energy efficient and provides 30% more thermal comfort. However, an enhancement on the codes with a 10cm layer of extruded polystyrene insulation can achieve a U-value equal to 0.15 W/m²K and reduce 25% of the annual heating loads. Make sure to shade and ventilate your house properly in summer to avoid overheating from the additional insulation layer.

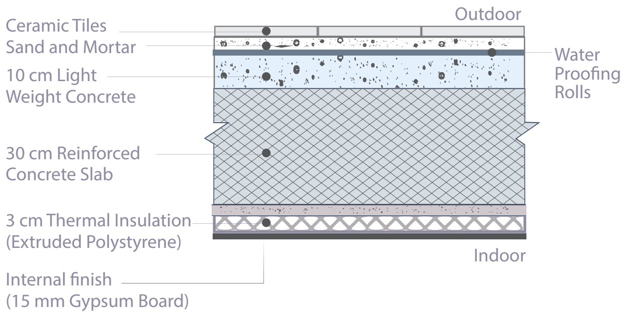


65. THERMAL INSULATION FOR ROOFS

The thermal transmittance of the roofs should be equal to: 0.55 W/m²k to comply with the local codes and 0.40 W/m²k to comply with the Jordan Green Building Guide. Additional improvement can reduce the U-values to 0.13 W/m²k and increase thermal efficiency.

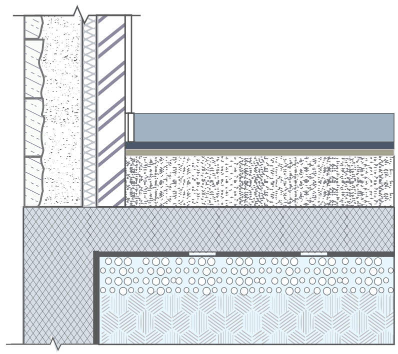
Adding a layer of Extruded Polystyrene thermal insulation to the internal surface of the roof and covering it with a layer of gypsum board or false ceiling panels can improve the U value of the roof to match the required values.

Improving thermal properties of the roof to comply with the code can save up to 8% in heating and cooling loads.



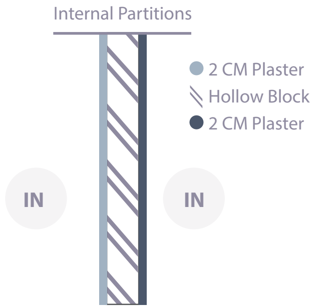
66. THERMAL INSULATION FOR FLOORS

Thermal transmittance of floors should be 0.8 W/m²k to comply with the local codes. However, the Jordan Green Building Guide proposes more efficient U-values equal to 0.75 W/m²k and 0.55 W/m²k.



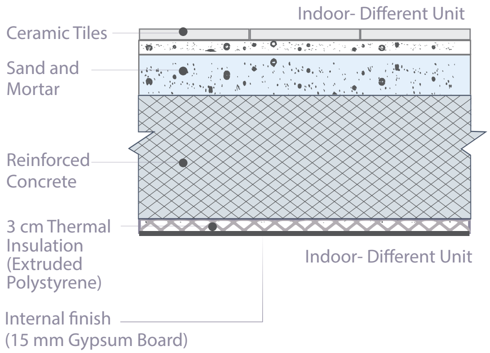
67. THERMAL INSULATION FOR PARTITIONS

Interior partitions between rooms influence heat transfer by convection. Partitions are usually constructed by a 10cm hollow concrete block with cement plastering on both sides. The local code requires a U-value equal to 2 W/m^2k while the Green Building Guide requires improving the efficiency of the materials used to achieve 1.8 W/m^2k of thermal transmittance.



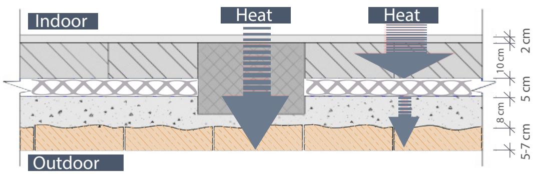
68. THERMAL INSULATION FOR SLABS BETWEEN DIFFERENT FLOORS

Slabs between floors are comprised of a 30 cm reinforced concrete slab with plastering at one side, and ceramic tiles on the other side. The required U-value following the local codes is 1.2 W/m^2k while the U-value required by the Jordan Green Building Guide is equal to 1 W/m^2k.

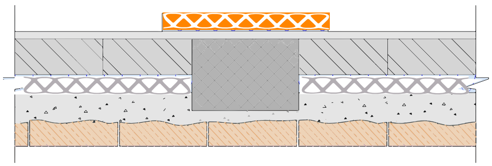


69. THERMAL BRIDGES

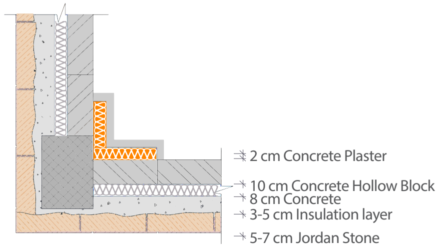
Thermal bridges are junctions in the building envelope where insulation is not continuous causing these areas to be more vulnerable for heat losses. Thermal bridges are found adjacent to structural columns, around the shutter box, and around openings such as doors and windows. Thermal bridges can be avoided by continuous insulation during the construction, or some simple strategies during building retrofits (as mentioned below) which can result with 40% energy savings.



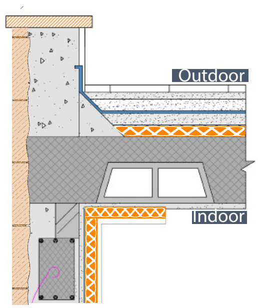
A. Structural Columns Inside the Wall



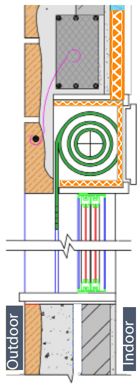
B. Structural Columns at the Corners



C. Roofs and Floor Slabs



D. Windows' Shutter Boxes



Source: [47].

WINDOWS PROPERTIES

70. CASEMENT WINDOWS SAVE A LOT

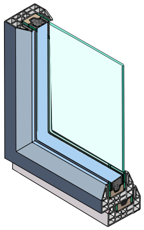
Casement windows are the most energy efficient style of window that can be opened. These windows have a strong seal on all four sides. When a casement window is closed, the sash presses tightly against the frame so air cannot pass through. Sliding windows, which are widely spread in Jordan, are less energy efficient because air can leak in between the sash and the frame. This can result with additional energy consumption and heating loads in winter.

Casement Window

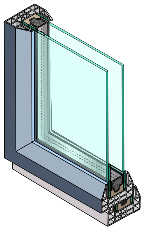
Sliding Window

71. GLASS: HANDLE WITH CARE

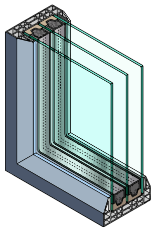
Windows can be comprised of single, double or triple layers of glass. Double glazing is recommended in building designs in Amman and can results with 25% reduction in energy consumption from heating and cooling compared to single glazed windows.



Single Pane



Double Pane



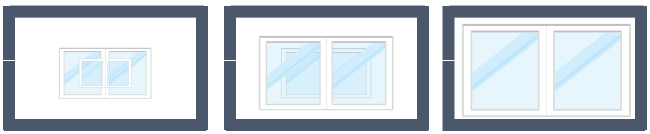
Triple Pane

72. WINDOWS ARE THE WEAK POINT

The U-value of windows differs according to the Window to Wall Ratios. According to the Jordan Green Building Guide, if the WWR was between:

- **10-40%**
  The U value of the glazing in the exterior envelope should not exceed 3.00 W/m^2.K
- **40-70%**
  The U value of the glazing should not exceed 2.00 W/m2.K.
- **More than 70%**
  The U value of the glazing should not exceed 1.60 W/m^2.K.

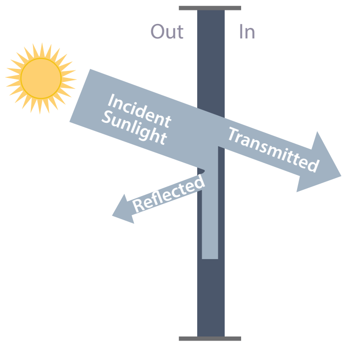
Using lower U value windows will achieve higher thermal efficiency. A window with a U-value equal to 2.00 W/m^2k can result with around 56% of energy savings



WWR= 10-40% U value= <2.00 | **WWR= 40-70%** U value= <3.00 | **WWR= >70%** U value= <1.60

73. VISUAL LIGHTING TRANSMITTANCE (VLT)?

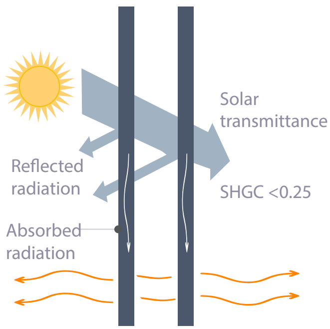
Visual Lighting Transmittance is a glazing property that indicates the portion of visible light transmitted through the window. VLT values range between 0 and 1. The higher the VT, the more light is transmitted to the interior, and the less artificial lighting needed. **The proportion of light transmitted by the glazing (VLT) in Jordan should be more than 0.45**



74. SOLAR HEAT GAIN COEFFICIENT

The Solar Heat Gain Coefficient (SHGC) measurement: is the amount of incident solar radiation admitted through the glazing into the interior space.

SHGC is expressed as a value between 0 and 1. The lower a window's solar heat gain coefficient, the less solar heat it transmits. **The SHGC value in windows in Amman should not exceed 0.25, which means**, only 20% of solar radiation is allowed to pass through the window from the outside to the inside. Solar heat gain should be highly considered in our climate because it can warm a room during the day in winter but it causes overheating in summer.



75. SHADING COEFFICIENT

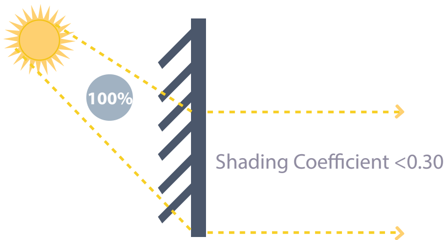
Shading coefficient (SC) is a measure of thermal performance of windows.

It represents the ratio of solar gain from direct sunlight passing through a glass unit to the solar energy which passes through 3mm Clear Float Glass with a total solar heat transmittance of 0.87.

The shading coefficient is calculated from the equation:

$$SC = SHGC / 0.87$$

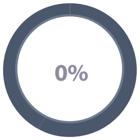
The lower the shading coefficient, the less heat gain and thus more shading is provided by the glass. **Shading coefficient in the glass you choose should be less than 0.30.**



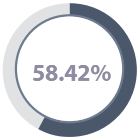
76. WHAT'S IN BETWEEN?

The spacing in between the glazing layers in windows affects the thermal performance. Heat transfer through windows can be reduced by using argon gas between the panes of double glazing instead of air. Argon gas is a low-cost, clear, non-toxic gas with a lower thermal conductance than air. **Use of argon between glazing panes instead of air can improve the R-value of the glazing by 5–20%.**

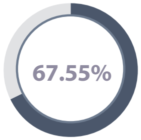
Effect of modified windows on energy saving [51]:



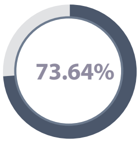
Single Glazing
U-Value = 5.6



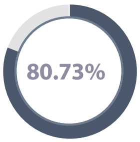
Double Glazing (Air)
U-Value = 2.328



Double Glazing (Argon)
U-Value = 1.817



Triple Glazing (Air)
U-Value = 1.476

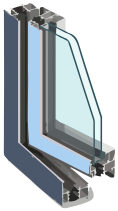


Triple Glazing (Argon)
U-Value = 1.079

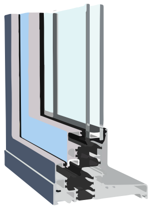
77. THE WINDOW FRAME

The window frame material is an important factor that affects the amount of heat entering through convection. Improving the thermal resistance of the frame can contribute to a window's overall energy efficiency.

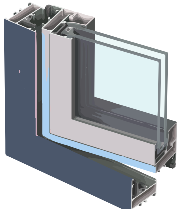
There are multiple options of window frames such as:



Aluminium



Thermally Broken Aluminium

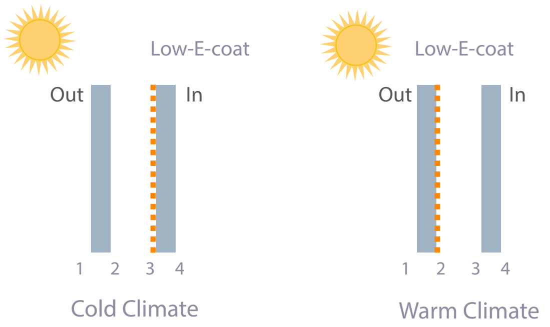


UPVC Window are the most energy efficient windows to be used

Aluminum window frames are the least efficient because they conduct heat and light. However, the low conductivity of uPVC as a material and the tight seals uPVC windows provide, make them the most energy efficient type to be used in buildings.

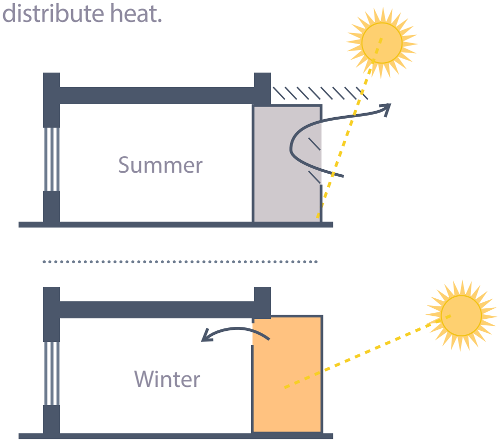
78. GLAZING PROPERTIES (LOW E)

Low emissivity glass or Low-e glass minimizes the amount of infrared and ultraviolet light that comes through your glass, without minimizing the amount of light that enters. Low-E glass windows have a microscopically thin coating that is transparent and reflects heat. 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.



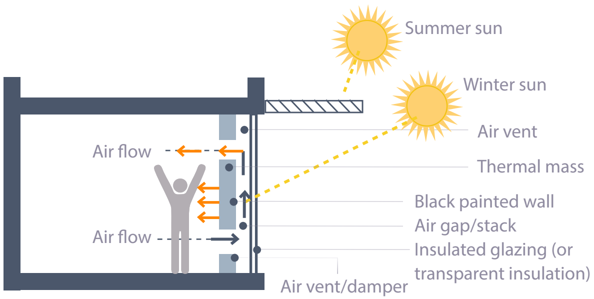
79. CAPTURE FREE HEAT WITH A SUN SPACE

The sunspace is a glazed intermediate space between the inside and outside of the building. It acts as a thermal buffer to protect the interior environment from the external weather conditions and can be used for passive heating during winter. The sunspace should be in the south orientation and shaded properly to avoid solar gain in summer. The sun space has an inlet window towards the interior space that should be closed in summer and opened in winter to control heat that is entering the building. Make the area of the solar oriented glazing 10% of the floor area of the space to be heated, and combine the heat source with natural ventilation to distribute heat.



80. A TROMBE WALL, FREELY TRANSMITS HEAT TO THE INSIDE

The trombe wall is a 20cm sun facing dark wall separated from the outdoor by glass and an air space which absorbs solar energy and releases it towards the interior. Solar radiation will heat the air gap and the vents on the top and bottom will allow heated air to flow via convection into the building interior for passive heating during winter. Usually these vents are closed in summer when heat gain is not desired.



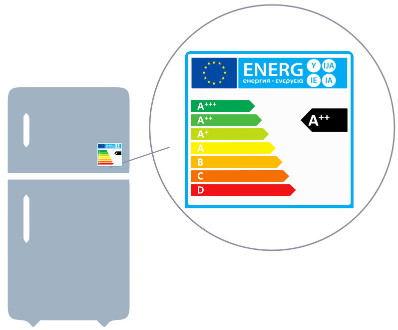
BEHAVIOR

The way we use our homes can affect the amount of energy consumption. This section will present a few strategies that can reduce energy consumption and enhance the energy benchmark. It will include some behavioral patterns and characteristics of appliances and household equipment that can be adopted easily by occupants in their homes and result with major savings.

81. ENERGY LABELED APPLIANCES

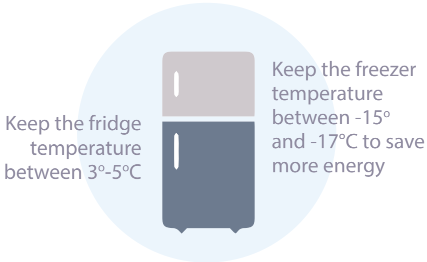
Energy labelling is an indication of the annual power consumption of the appliances relative to a reference consumption.

Labels are specified in terms of an energy efficiency index EEI indicating the efficiency of the appliance with a scale from A+++ (most efficient) to G (least efficient). **Replacing your traditional appliances with energy efficient appliances and systems can reduce energy consumption and utility costs up to 20%.**



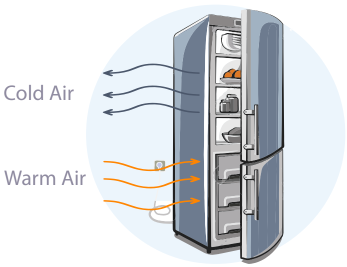
82. CONTROL THE TEMPERATURE

Refrigerators and freezers consume more energy when the temperature is set to a low point; **for every degree below 3°C, the unit consumes 5% more energy.**



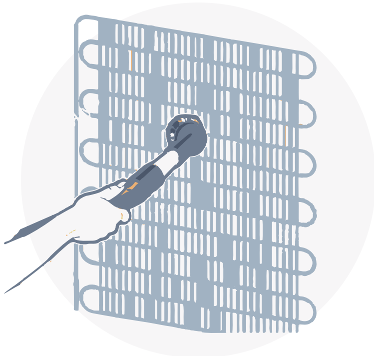
83. ALWAYS CLOSE THE DOOR WITHOUT DELAY!

Every time the refrigerator door is opened, cold air escapes and warm ambient air enters. To compensate for the temperature increase in its interior, the refrigerator consumes additional energy to lower the temperature back to the set point. Always avoid opening the door unnecessarily or for too long.



84. VACUUM THE COILS

The refrigerator coils, located both behind and underneath the fridge, are at the heart of the unit's refrigerant system. The more dust, the less efficient the fan is at removing heat. **Twice a year, use a vacuum cleaner with a long brush attachment to clean thoroughly around the coils.**



85. WASH IN COLD WATER, AND WASH LESS OFTEN

Consider washing with less temperature because:

80-90% of the energy used by a washing machine is used to heat water In addition, only turn on the washing machine when it is fully loaded, this will save water and save energy. *https://www.fix.com/blog/green-laundry-guide/*

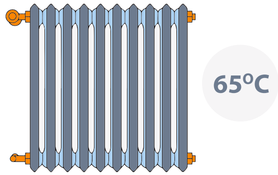
86. TURN OFF THE APPLIANCES INSTEAD OF THE SLEEP MODE

Standby power refers to electricity that is consumed by appliances left on standby mode. **The appliances still use 40% of their energy when they are in sleep mode.**

APPLIANCE	Hourly Standby Usage
Television (LCD)	2.3W
Microwave	2.4W
DVD player	1.5W
Washing machine	1 – 6W
Clothes dryer	2.6W
Dishwasher	3W
Air conditioner	2W

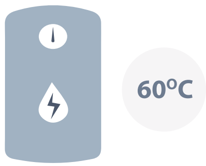
87. SET THE RADIATOR TEMPERATURE TO 65°C

Setting the temperature to 65°C will reduce the amount of fuel used, and reduce energy consumption.



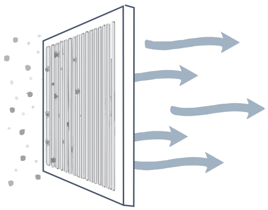
88. SET THE WATER HEATER TEMPERATURE TO 60°C

The amount of electricity consumed by water heater depends on the water temperature coming in the heater and the setting of the thermostat. If the difference between the two temperatures is high, the electricity consumption will increase.



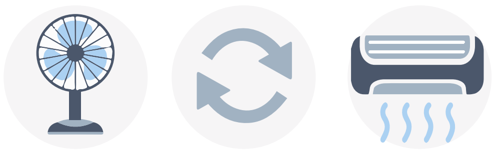
89. SAVE MONEY BY KEEPING YOUR AC FILTERS CLEAN

Cleaning the filter of your airconditioning results with **5% energy saving,** because it increases its efficiency and consumes less energy for cooling. A dirty filter clogs the system and reduces airflow.



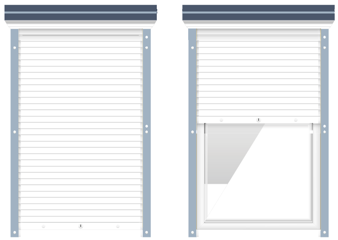
90. ELECTRICAL FANS USE LESS ENERGY THAN ACS

Electrical fans use far less energy than split unit ACs which can result with energy savings and reduced energy bills.



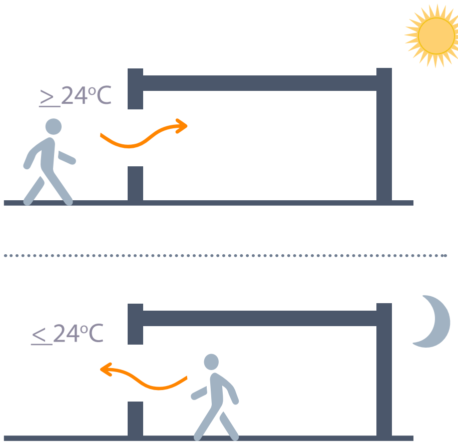
91. CLOSE THE SHUTTERS

Make sure you close the shutters of east rooms from 10am to 2pm, and the west shutters from 4pm in summer in order to prevent solar radiation from heating the rooms.



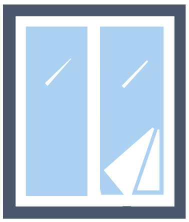
92. WARM AIR WANTS TO BE COOL

Warm air attains equilibrium by moving towards colder air because warm air molecules contain more energy. If the outside air is warmer than the air inside a building it can be a heat source, flowing into the cooler building. Thus, open the right window at the right time; east windows during the evening, and west windows during the early morning when the sun is not at that orientation. South windows are critical if not shaded and can increase heat gains in summer.



93. USE WINDOW FILMS

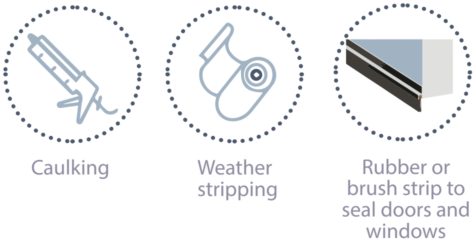
Window films should be used on west and south windows of your house. They can protect you from 40-80% of solar heat and **reflect 80% of the solar radiation.**



94. SEAL AIR LEAKS TO SAVE ENERGY

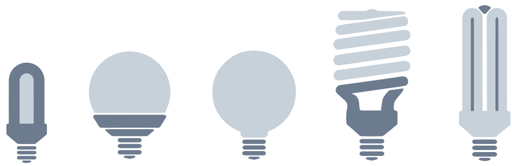
Reducing the amount of air that leaks in and out your home is an easy and cost-effective method to reduce heating and cooling costs, improve durability, increase comfort, and create a healthier indoor environment. Sealing the gaps can be achieved by caulking and applying weather stripping around doors, windows, and shutter boxes. **Sealing air leaks can be easily implemented and result with up to 30% energy savings.**

www.energy.gov



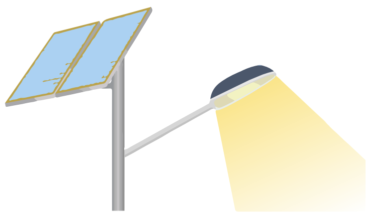
95. REPLACE TRADITIONAL LIGHT BULBS WITH ENERGY SAVING

Replacing conventional lighting fixtures with efficient fixtures can save 10% of energy costs in residential buildings in Jordan. In addition, 90% of the energy used by traditional light bulbs produces heat, which also increases the temperature in summer [42].



96. USE SOLAR LIGHTS TO LIGHT YOUR GARDEN

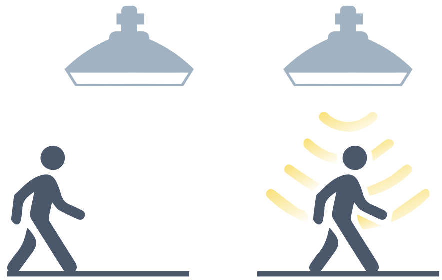
This can cut costs and offer you free source of lighting.



97. TIMER LIGHTING METHODS USING SENSORS

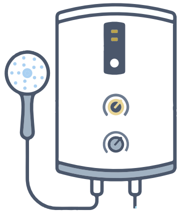
Motion sensor switches are light switches that turn on when they sense someone in the room and are turned off after a certain amount of inactivity.

This type of lighting control can be used outdoors to reduce the possibility of lights being left on and wasting electricity.



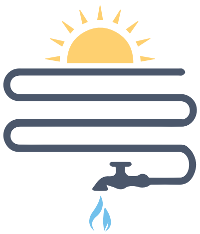
98. USE TANKLESS WATER HEATERS

Tankless water heaters are mountable units that heat the water as soon as you turn the faucet. They work on demand to produce hot water when needed which makes them 12%-34% more efficient than traditional systems. **Replacing your water heater can save 19%** of the total energy consumption used for water heating.



99. REPLACE ELECTRIC HEATERS WITH SOLAR HEATERS

Although electric heaters have low capital cost and better efficiency than fuel based water heaters, **replacing electric water heaters with solar heaters can save 8% in energy consumption** and 13% of the energy costs in Jordan.



100. GO ACTIVE AND SAVE ENERGY!

Active systems such as Photovoltaic systems (PV) can be incorporated when retrofitting existing buildings to reduce electricity bills. PV systems use light from the sun to produce electricity. The system may be costly but the payback period correlates to your monthly electricity bills, the higher the electricity bill, the lower the payback period.

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*

Souce: Marji Group, Jordan, 2017

CONCLUSIONS:

Residential buildings are a major contributor to the total energy consumption in Jordan. The highest share of construction is concentrated in the capital Amman and is comprised mostly of residential apartment buildings. The booklet investigated how much energy these buildings consume and analyzed the patterns of energy use as a vital step towards energy efficiency.

The booklet and accompanying survey set out to assess energy consumption in residential apartments establishing an Energy Use Intensity (EUI) which for the first time represents a benchmark of a typical residential apartment in Amman.

The energy consumption survey targeted 400 apartments covering six categories; household characteristics, building characteristic, heating and cooling characteristics, kitchen appliances, electrical appliances, and lighting. The annual energy use intensity has been calculated from the survey by dividing the total energy consumed by the typical apartment floor area and is equal to: 91.4 kWh/m^2.year.

Space heating accounts for **the highest share of energy consumption** with a **percentage of 53%.**

Central heating radiators using diesel are the most common used space heating methods followed by gas heating units.

Due to heat losses in the apartments, and insufficient thermal insulation,

85% of the occupants use additional heating sources, such as gas and electrical heating units which adds on to the total of heating loads.

The building envelope and its thermal properties correlate directly to the amount of heat losses in the buildings. Half of the apartments suffer from heat leaking out through doors and windows which also requires additional heating loads.

Only 35% of the buildings are thermally insulated

which urges the need to enforce thermal insulation codes and ensure that all buildings apply the sufficient thickness of insulation in order to reduce the energy required for heating, and enhance human comfort.

Space cooling in residential apartments is based on electricity and accounts for 4% of the total consumption in the apartments.

AC split units are becoming more common and **are used by 40% of the occupants**

Natural ventilation is only used by 19%

Designers and architects need to incorporate natural ventilation in their designs to reduce the energy demand required for cooling. In addition, decision makers should inform occupants about the importance of using natural ventilation instead of mechanical methods of cooling to save energy costs and reduce cooling loads.

Water heating accounts for 10% of the energy

Although solar water heater usage has increased due to the mandatory building codes enforcing their installation in new residential buildings, their usage is only limited to 50% of the apartments in Amman as the main source of water heating during the summer.

Electrical home appliances are a major contributor for energy consumption and account for 13% of the total share.

Replacing traditional household appliances with energy labeled appliances is an achievable measure that can save up to 20% of energy consumption and utility costs of the sector.

Finally, lighting accounts for 4% of the energy consumption in the apartments

Efficient light bulbs such as CFLs and LED light bulbs which are the most efficient are limited to 35% and 19% of the apartments respectively. This requires more efforts from policy makers to spread awareness about the benefits of energy efficient lighting and to assist consumers in making informed decisions when purchasing such products.

The energy benchmark and the distribution of energy consumption in apartments are essential to determine which behavioral and building characteristics have the greatest impact on energy consumption, and suggest efficiency measures accordingly. The booklet presents 100 steps and strategies that comply with the local codes in Jordan and result with major savings. The recommendations are distributed in sections as follow: Site selection, building envelope, occupants' behavior, and passive design strategies.

These measures can be implemented in the early stages of the design, during the building retrofit, or during occupancy.Applying these strategies can reduce energy consumption, improve the thermal performance, and enhance the energy benchmark.

Spreading environmental awareness on how to use the buildings, the appliances and systems efficiently is an easy step towards energy saving. Minor changes in habits and the adoption of environmental behavior can reduce energy and electricity consumption in the apartments.

It is recommended to provide building owners with a brief about energy use to motivate them to upgrade their apartments, and encourage future tenants to choose more efficient buildings. Designers and architects can lead major savings in energy and utility costs by applying simple strategies in the early stages of the design. Finally, policy makers are responsible to enforce local energy codes and green building guidelines that can improve the thermal properties of the building sector and further save energy and save the environment.

This booklet developed a benchmark for residential apartments in Amman, however it is important to create benchmarks for all types of buildings in different climatic zones in Jordan to improve energy efficiency in all sectors.

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Phone: +962 79 656 6669
Website: http://www.minervaesc.com/index.php

Ruqn Al Handasa
Silver Membership
Key Services:
Consulting Engineers
Contact Information:
Phone: (06) 4653344
www.ruqn.com

Faris & Faris Architects
Silver Membership
Key Services:
Design and Construction Supervision
Contact Information:
Phone: (06) 464 4600
www.farisandfaris.com

Sabeel Al Handasah Consultant Engineer
Silver Membership
Key Services:
Design and Construction Supervision
Contact Information:
Phone: (06) 590 3030
Website: www.sabeelce.com

Mostaqabel Engineering and Environmental Consultants
Silver Membership
Key Services:
Design and Construction Supervision
Contact Information:
Phone: (06) 592 3602
Website: www.mostaqbal.jo

Abu Assi Contracting Est.
Silver Membership
Key Services:
Design and Supervision
Contact Information:
Phone: 07 9552 2328
Website: https://www.facebook.com/AbuAssiContracting/

Sterling BIM
Silver Membership
Key Services:
Delivering a wide range of services with BIM through working across sectors on all the project stages
Contact Information:
Phone: (06) 5523126
Website: www.sterlingbim.com

Al- Saraya for Housing Projects and Investments
Silver Membership
Key Services:
Design, Construction, Supervision, Realestate
Contact Information:
Tel.: 799080757
Website: http://www.alsaraya.com.jo/index.html

Inside Out Design
Silver Membership
Key Services:
Design and Supervision
Contact information:
Tel.: 795305060
Website: http://insideoutjo.com/

Construction Services and Materials

M.A. Abu – Eisheh & Bros Contracting co.
Silver Membership
Key Services:
Construction and Manufacturers
Contact Information:
Phone: (06) 566 9531
Website: www.abueisheh.com

Moka`ab Constructions
Silver Membership
Key Services:
Building Construction
Contact Information:
Phone: (06) 5538854
Website: www.mokaabconstructions.com

SHUAA ENERGY
Golden Membership
Key Services:
Provide solar energy systems, installations and logistic services
Contact Information:
Phone: 07 8881 0988
Website: www.sdco-jo.com

Arab Technical Construction Co.
Silver Membership
Key Services:
Design and Supervision
Contact Information:
Phone: (06) 567 3424

Arab Italian Waterproofing and Insulation Industries Co.
Silver Membership
Key Services:
Construction and Manufacturers
Contact Information:
Phone: (06) 533 2145
Website: http://www.aiwin-jo.com/

Northern Cement Co.
Silver Membership
Key Services:
Manufacturing
Contact Information:
Phone: (06) 565 0777

Suppliers and Providers

Satchnet
Silver Membership
Key Services:
Manufacturing
Contact Information:
Phone: (06) 4651524
Website: http://www.satchnet.com/

Babel Contracting Company
Silver Membership
Key Services:
Building construction , renovation and rehabilitation works, MEP and infrastructure works, steel structures, communication networks, renewable energy Solutions, decoration works and furnishing.
Contact Information:
Phone: (06) 5150560
Website: www.babel.jo

Consolidated Contractors Company Limited Jordan
Silver Membership
Key Services:
Leads the industry in the adoption of new technology to improve construction efficiency and enhance project controls.
Contact Information:
Phone: (060 4658403
Website: www.ccc.net

Najjar Industrial Trading Company
Silver Membership
Key Services:
Leaders in design, fabrication and erection of steel structures
Contact Information:
Phone: (06) 5601306
Website: www.najjarsteel.com

Prefabricated Buildings Co.
Silver Membership
Key Services:
Prefab, steel, metalform, LGS, solar, learning and office concepts.
Contact Information:
Phone: (06) 566 94 66
Website: http://www.maani.com/

Abolin Co.
Silver Membership
Key Services:
High performance
Innovations and services
Contact Information:
Phone: +30 21 0557 5568
Website: http://www.abolinco.com/

Don Construction Products
Silver Membership
Key Services:
Construction material
Contact Information:
Phone: (06) 5338891
Website: www.dcp-int.com

Jordan Sipes Paints Co. ltd
Silver Membership
Key Services:
Construction paints
Contact Information:
Phone: (06) 4201292
Website: www.sipes.net

Arab Technical Group
Platinum Membership
Key Services:
Arab Technical Group in an engineering trading company that offers high-quality products and innovative solutions for the heating, cooling and renewable energy markets.
Contact Information:
Phone: (06) 5 517 711
Website: www.atgco.com

Petra Engineering Industries Co
Silver Membership
Key Services:
Cooling and heating systems
Contact Information:
Phone: (06) 553 1508
Website : www.petra-eng.com

Ittihad Insulating Glass
Silver Membership
Key Services:
Insulated glass, safety glass and decorative glass
Contact Information:
Phone: (06) 479 0050
Website: www.ittihadglass.com

Ata Rabah for Aluminum - Eylaf
Silver Membership
Key Services:
Windows, doors, interior partitions, and shutters
Contact Information:
Phone: (06) 541 1222
Website: www.atarabah.com

Qatrana Cement Company
Silver Membership
Key Services:
Construction cement providers
Contact Information:
Phone: (06) 580 2000
Website: www.qatranacement.com

Energy and environmental solutions and services

3 Pillars Consulting Engineering and Environment
Silver Membership
Key Services:
Provides comprehensive services related to business development, administration and financial management assistance, study, design and management of environmental solid waste development and infrastructure projects.
Contact Information:
Phone: (06) 5561752
Website: www.3pillars-consulting.com

Awj Water Engineering
Silver Membership
Key Services:
Specialized water and waste treatment company that offers plant and equipment for desalination, ion-exchange demoraliation, clarification, filtration, chlorination, chemical treatment, water pressurization and storage
Contact Information:
Phone: (06) 5332150
Website: www.awj-water.com

Eco Engineering and Energy Solutions - EcoSol
Silver Membership
Key Services:
Energy and Environment consulting
Contact Information:
Phone: (06) 533 0070
Website: www.ecosol-int.com

Energy International Corporation
Silver Membership
Key Services:
HVAC, electromechanical and transportation industries, providing quality products, engineering, design, installation, commissioning and testinglation, commissioning and testing
Contact Information:
Phone: (06) 556 1718
Website: www.energyintl.com

Hanania Solar Systems-Ideal Solar Energy Co.
Silver Membership
Key Services:
Solar energy integrated solutions providers
Contact Information:
Phone: (06) 5333003
Website: www.hanania.jo

Izzat Marji Group
Silver Membership
Key Services:
Heating systems, air conditioning systems, sanitary ware, bathroom and kitchen fixtures, plumbing systems, fixing systems and power tools, solar photovoltaic and acrylic solid services: Energy and sustainability and sustainability consulting, solar thermal systems
Contact Information:
Phone: (06) 5357733
Website: www.marji.jo

ETA-max Energy and Environmental Solutions
Silver Membership
Key Services:
PV systems, energy management and energy training services
Contact Information:
Phone: (06) 5850770
Website: www.eta-max.com

Al Maida Industrial
Silver Membership
Key Services:
Waste water treatment systems
Contact Information:
Phone: (06) 5 858 009
Website: www.al- maida.com

Cambridge Engineering Consulting Co.
Silver Membership
Key Services:
Offering sustainability in MEP and use of renewable energy systems to reduce operational cost
Contact Information:
Phone: (06) 5233822
Website: www.cambridge-cec.com

Eco structures International
Silver Membership
Key Services:
Waste water treatment systems
Contact Information:
Phone: +971 4 289 0922
Website: https://www.eco-structures.net/

E2E
Silver Membership
Key Services:
Energy Policy and Strategy, Energy Efficiency (EE), Clean-tech and Environment
Contact Information:
Phone: (06) 4 6140 05/6
Website: www.e2eco.com

JOECO LLC
Silver Membership
Key Services:
Environmental solutions, consulting, training and workshops
Contact Information:
Phone: 0791219010
Website: www.joeco-jo.com

AJB - high-tech LTD
Silver Membership
Key Services:
Building Automation Systems, Fires and security system, other building services
Contact Information:
Phone: (06) 5 527 778
Website: www.ajbautomation.com

Pivot Jordan for renewable energy
Silver Membership
Key Services:
MEP contracting, photovoltaic systems, thermal solar water heaters, and pumping systems
Contact Information:
Phone: (06) 5377 118
Website: www.pivot-jo.com

Quantum Jordan W.L.L.
Silver Membership
Key Services:
Contractual, commercial and planning services to parties working in the construction industry
Contact Information:
Phone: (06) 5537750
Website: www.qgs.global

CWET
Silver Membership
Key Services:
Consultants in water treatment and environmental technologies
Contact Information:
Tel.: 0795905528
Website: http://cwet.jo/

Legal Advisors

Laswi and Zalloum Law firm
Golden Membership
Key Services:
Legal consultancy
Contact Information:
Phone: (06) 565 4393
Website: www.zllawfirm.com

Educational Institutions

Jubilee School
Silver Membership
Key Services:
National and International Education
Contact Information:
Phone: (06) 5238 216
Website: www.jubilee.edu.jo

Al-Ridwan Schools
Silver Membership
Key Services:
National and International Education
Contact Information:
Phone: (06) 535 5112
Website: rs.edu.jo

Al Sa'adah College Schools
Golden Membership
Key Services:
National and International Education
Contact Information:
Phone: (06) 5662646

Financial and Economic services

The Housing Bank for Trade and Finance
Platinum Membership
Key Services:
Banking financial services
Contact Information:
Phone: (06) 552 1011
Website: www.hbtf.com

Capital Bank of Jordan
Platinum Membership
Key Services:
Banking financial services.
Contact Information:
Tel.: (06)5100200
Website: https://www.capitalbank.jo/

Logistics and Shipping

Aramex International
Silver Membership
Key Services:
Independent voluntary organisation that is devoted to the conservation of Jordan's natural resources
Contact Information:
Phone: (06) 5515111
Website: www.aramex.com

Trading and Retail Companies

Majid Al Futtaim Group
Platinum Membership
Key Services:
Shopping malls, communities, retail and leisure.
Contact Information:
Dubai, United Arab Emirates.
Website: www.majidalfuttaim.com

Marketing and Advertising

Jordan Land Magazine
Silver Membership
Key Services:
Marketing services – 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
Silver Membership
Key Services:
Marketing services – marketing, branding, public relations, and online business solutions studio
Contact Information:
Mobile: +962 79 9088996
Website: www.sadda.jo

Inspection and Standardization

TUV
Silver Membership
Key Services:
Inspects validity of TUV AUSTRIA certificates in Jordan
Contact Information:
Phone: (06) 5686771
Website: www.tuvaustria-jo.com

BDO
Platinum Membership
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

Hospitals and Medical Centers

Specialty Hospital
Silver Membership
Key Services:
Healthcare
Contact Information:
Phone: (06) 500 1111
Website: https://www.specialty-hospital.com/

Associations and Environmental Organisations

The Royal Society for the Conservation of Nature (RSCN)
Silver Membership
Key Services:
An independent voluntary organization that is devoted to the conservation of Jordan's natural resources
Contact Information:
Phone: (06) 533 7931
Website: http://www.rscn.org.jo/

Horizons for Green Development
Silver Membership
Key Services:
Empowering communities through sustainable development
Contact Information:
Phone: 962786543051
http://horizondge.org/

Jordan Cement Producers Association
Silver Membership
Key Services:
Association, supervisors
Contact Information:
Phone: (06) 5850974
Website: https://www.facebook.com/JCPA.Jordn/

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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.

Jordan Green Building Council

المجلس الأردني للأبنية الخضراء

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 adoption 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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