Status of the Public Building Sustainability in Lebanon: A Case Study on Fares Library

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Submitted to the
Institute of Graduate Studies and Research
in partial fulfilment of the requirements for the degree of

Master of Science
in
Civil Engineering

Eastern Mediterranean University
February 2015
Gazimağusa, North Cyprus

Approval of the Institute of Graduate Studies and Research

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ABSTRACT

In recent years, green buildings have become particularly vital for development of commercial buildings around the world. Some of the benefits of sustainable buildings can be listed as; lowering the usage of water, energy and the overall negative effects to the occupant's health and the environment. Green building concept is currently may not be the priority for Lebanon, who faced many crises over the last forty years, which resulted in serious damages to its environment, infrastructure and structures. However, the need for re-building Lebanon urges this to be in a sustainable manner.

The objective of this research is to find out how ready Lebanon is to implement green building concept, particularly for public buildings. This aim was achieved through; seeking information from authorities, local associations and citizens; a survey distributed to general public, engineers and architects to identify their knowledge and motivation; a case study was conducted on a Library building where some of the green features are present. Furthermore, this building was evaluated using Leadership in Energy and Environmental Design (LEED) certification system to show the benefits of the application of green building concept. It was found that currently Lebanon does not have green building policies in place. But, younger age group seems to have awareness, will to learn, use and apply such concepts. Furthermore, non-government organizations (NGO) appear to have joined forces and giving strong support towards this matter being seriously handled by the authorities.

Keywords: green buildings, LEED, library building, build capacity

ÖZ

Son yıllarda, yeşil bina konsepti, özellikle dünyadaki ticari binaların gelişiminde hayati önem arz etmektedir. Sürdürülebilir binaların faydalarından bazıları şöyle sıralanabilir; su ve enerji kullanımının ve bınada yaşayanların sağlığına ve çevreye olan olumsuz etkilerin genelde azaltılması. Son kırk yıl içerisinde çevre, altyapıya ve binalara ciddi zarar veren birçok krizle karşı karşıya kalmış Lübnan'da, şu anda yeşil bina konsepti öncelik olmayabilir. Fakat Lübnan'ın tekrar yapılaşma gereksinimi bunu sürdürülebilir yapmasına zorlamaktadır.

Bu araştırmanın amacı, Lübnan'ın yeşil bina konseptini özellikle kamu binalarında uygulamaya ne kadar hazır olduğunu anlamaktır. Bu amaca şu şekilde ulaşılmıştır; yerek makamlardan, yerel dernekler ve vatandaşlardan bilgi edinerek; sıradan halk, mühendisler ve mimarların konu alakalı bilgi ve motivasyonlarını ölçmek için anket vererek; bazı yeşil özelliklerin bulunduğu bir kütüphane binasına vaka çalışması yaparak. İlaveten, yeşil bina konseptinin faydalarını göstermek için, bu bina Enerji ve Çevre Tasarımında Önderlik (LEED) sertifika programı kullanılarak değerlendirilmiştir. Şu anda Lübnan'da yeşil bina politikası olmadığı ama genç neslin bu konsepti öğrenme, kullanma ve uygulama iradesi ve farkındalığı olduğu görülmüştür. Ayrıca bu konunun devlet tarafından daha ciddi ele alınması için sivil toplum kuruluşlarının güç birleşimi yaptığı ve konuya ciddi destek verdiği gözlemlenmiştir.

Keywords: yeşil binalar, LEED, kütüphane binası, çevre

ACKNOWLEDGMENT

This report could not have been written if it were not for the contribution and support of few people.

The author wishes to thank his thesis supervisor Asst. Prof. Dr. Mürüde Çelikağ for her extensive advices and continuous support. She thoroughly checked every chapter of this thesis and helped the author to develop an understanding of the subject and beyond by guiding and by providing her knowledge about "GREEN BUILDING".

This report would not have been written without the perseverance of the author, and the restless nights spent to complete the thesis. Moreover, the devotion and encouragement of author's family and fiancée must be mentioned. They patiently supported the author throughout this work.

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kW-h	Kilowatt-hour
Wh	Watt-hour
m^3	cubic meter
m^2	square meter
$	United States Dollar

Chapter 1

INTRODUCTION

1.1 General Introduction

Today our planet faces many grave dangers that target its environment and natural resources. The pollution has reached a critical level which is threatening all creatures living on this planet. The natural resources are depleting with time and they will soon be gone while Mother Nature is unable to recycle all the used materials. Pollution has a great impact on different aspects including public health and the world economy.

Sustainable building also known as green building represents one of the major solutions for the above mentioned problems. Sustainable building has an ancient history, dating back to the era of cavemen. It was 1980's of the last century when an organised approach for green building have been adopted. A green building cannot be built arbitrarily and should respect international codes and standards in order to get an eligible certificate such as LEED (Leadership in Energy & Environmental Design) and BREEAM (Building Research Establishment Environmental Assessment Methodology).

This type of construction is considered to be of high importance. Green buildings are known to have a huge amount of benefits like improved aesthetics, less water consumption, thermal insulation, energy conservation, material recycling, noise reduction, improved air quality and positive effects on the wildlife. Although many

consider that green buildings save us a lot of trouble through all these benefits, one should take into consideration the cost of achieving such type of building due to the methods and materials used in the construction process. Therefore, there should always be a balance between the cost and efficiency of any green project.

These types of projects are gaining a lot of support especially in developed countries like United States and Europe. While governments are trying to do everything possible to support sustainable construction, companies in developing countries, such as Lebanon, rely on international loans to achieve such projects which are very rare to get in Lebanon.

Lebanon has suffered from a big crisis which is the civil war. Infrastructure, buildings, airport and ports faced severe damages. The rehabilitation of these structures was done by following traditional construction approaches rather than sustainable one. A study in "Zouk Mosbeh" area by El Asmar and Taki [1] showed that this city is suffering from pollution due to existence of power plant and the industrial solid waste disposal in the nearby sea. The survey distributed for Zouk Mosbeh inhabitants showed that 65 percent of the respondents endure of anxiety from smoke and noise coming from the structures mentioned earlier.

The green building industry is still fairly new in Lebanon. While some large projects are starting to take sustainable design into consideration, most projects including many small and moderate ones are still following traditional design. Yet, the sustainable design concepts are slowly making their in the Lebanese market. This is due to the formation of few Lebanese professional organizations, such as the Lebanese Green Building Council, which are raising awareness for adopting the

green buildings concepts in Lebanon. The LGBC offers a certificate (ARZ certificate) based on a green building rating system.

1.2 Objective of Research

In recent years, green buildings, which are also known as sustainable building, have become particularly vital for development of commercial buildings around the world. Some of the benefits of sustainable buildings can be listed as follows; lowering the usage of water, energy and the overall negative effects to the occupant's health and the environment. Healthier buildings can be created by using the resources more efficiently which improve human health and help to build a better environment and lead to cost savings too. Most of the advanced projects somehow lead to serious environmental problems due to the excess in consumption of natural resources. Green buildings are most vital in Europe and in the United States where the Leadership in Energy and Environmental Design (LEED) System was developed by a non-profit national organization called the United States Green Building Council (USGBC). It provides a guideline and rating system for green buildings.

On the other hand, green building concept is currently may not be the priority for developing countries, like those in the Middle East. For example, Lebanon faced many crises over the last fourty years which resulted in serious damages to its environment, infrastructure and structures. So, there is a need for comprehensive development in Lebanon and this is better to be in a sustainable manner. Hence, there is need to build capacity to implement green building concept. However, there is need to know the level of knowledge, awareness of people and professionals and availability of facilities to assess where to start this process.

The objective of this research is to find out where Lebanon stands with respect to matters relating to green building concept. This was achieved through; seeking information from authorities, local associations and citizens; prepared and administered a survey among people from different disciplines and educational background to identify their knowledge and motivation; a case study was conducted on a Library building to find out if traditionally some green features are already applied to such buildings and also to evaluate this building using LEED to show the benefits of the application of green building concept.

It should be noted that despite of all the efforts made towards collecting more data about Lebanese green building status, author faced many obstacles in gathering information for this thesis. This was mainly due to the lack of corporation from the official organizations, as they refused to accept the author's visit due to security reasons, as they claimed.

1.3 Outline of Thesis

- Chapter 1 of the thesis introduces the green building concept and objective of the study.
- Literature review for the thesis subject is covered in Chapter 2 together with sustainability features.
- The methodology of the research is given in Chapter 3.
- Chapter 4 provides the details of the case study on Fares Library.
- The survey conducted for people from different disciplines and the results of the survey are reported in Chapter 5.

  Chapter 6 is the overall conclusion drawn from the research carried out.

Chapter 2

GREEN BUILDING CONCEPTS

2.1 Introduction

The green building concepts are oriented towards reducing the water and energy consumptions through using certain types of sustainable materials. There are many concepts that exist almost in every single aspect of the green building to be constructed. Green concepts include the use of nontoxic and sustainable materials, green roofs, sustainable drainage, sustainable transportation, grey water and rainwater recycling and reuse, reducing the energy consumption including the energy required for heating, cooling and lighting, etc.

Yet in order to achieve these goals, a good design should be conducted. The design should account for architectural and structural aspects, the quality and availability of the materials being used, the introduction of new technologies to maximize the efficiency of any element in the design. Also the designer should have a balance between the cost of design and total project cost. It is very important to have a sustainable and affordable design in order to achieve a certain success.

2.2 Green Roofs

Green roofs are considered to be a very promising application in green buildings especially in big cities. They are basically consisted of, from top to bottom, a plantation layer, a growing medium or substrate layer, a drainage layer and a

waterproofing membrane. Each layer has its own properties which would provide a lot of benefits for the entire building [2].

2.2.1 Types of Green Roofs

The types of green roofs depend on the materials, plants and thickness of the layers. While extensive layers are usually made out of thin layers with a plant topping consisting of usually sedum, intensive layers include large plants which require a certain depth of growing medium from 1 to 3 feet [2].

The main beneficial functions of a green roof shall depend on the plant and the properties of substrate layers. These two layers hold certain coefficients regarding their density, evapotranspiration properties, water absorption capacity, thermal transmission, soil reflectivity index [1]. All these properties and coefficients plus the layers thickness shall provide the building with many benefits discussed later on.

Figure 1: Extensive Green Roof [3]

Figure 2: Intensive Green Roof [4]

It is important to realise that those coefficients and the durability of the materials are highly dependable on the surrounding atmosphere. Therefore, it is strongly advisable to use local plants which can grow in the local conditions where they can reach their best quality [2].

2.2.2 Benefit of Green Roofs

2.2.2.1 Aesthetics and Well Being

The first feature of green roof is that they can provide an improved view for the building from the top view and sometimes from other views depending on the shape of the building.

On the other hand, intensive green roofs provide a roof garden which is considered to be a gathering and entertaining space for the inhabitants of the building.

Figure 3: Architectural Aspects of Green Roofs [3]

2.2.2.2 Heat Insulation

Green roofs provide higher heat insulation than normal insulated roofs. The degree of insulation depends on the properties and thickness of the materials used. This will allow the reduction of the cost of energy used for heating and cooling inside the building [2].

In this particle property, the drainage medium plays an important role in heat insulation. Gravel remains as the best material when it comes to heat insulation, despite the fact that some of the new products made out of industrial polymers are trying to replace gravel.

2.2.2.3 Storm Water Runoff

Green roofs have the ability to store a significant amount of water runoff which helps reducing the bad effects of rainfall on roofs. After complete saturation, the rest of the water shall be disposed through the drainage layer [2].

2.2.2.4 Improvements in the atmosphere

The heat island effect represents the rise of temperature in large cities due to the absorption of solar heat by the traditional roofs which have a low solar reflectivity index.

Green roofs have a better reflectivity than traditional roofs. Moreover, the plants cool down the surrounding air using evapotranspiration.

On the other hand, green roofs improves the surrounding air quality in the cities by purifying it from many gases including CO_2 and producing more oxygen [2].

2.2.3 Green Roof Design

When designing a green roof, certain parameters should be taken into consideration. First the designer should account for additional dead loads and live loads resulting from the materials own self-weight plus water and also should account for a greater live load due to more people accessing the roof.

The designer should choose the appropriate materials which are preferred to be local as mentioned earlier. The types of materials should be of high quality in order to last longer and require less maintenance later on.

Also the designer should account for safety regulations and appropriate drainage and watering systems. Figure 4 shows an existing green roof in Ropemaker, Islington.

Figure 4: Accessible green roof on a new office development, Islington [5]

2.3 Sustainable Drainage

Nowadays, sustainable drainage is becoming a necessity in order to reduce the pollution of water and the damages of surface water runoff especially in large cities due to floods [6].

The sustainable drainage consisting of a chain of components including the storage and detention of water, land modeling, water collection, natural water treatment, up to the final disposal or recycling of water [6].

Sustainable drainage consist of 3 major steps

- Water collection
- Water treatment

- Water disposal or reuse

2.3.1 Sustainable Drainage in Rural Areas

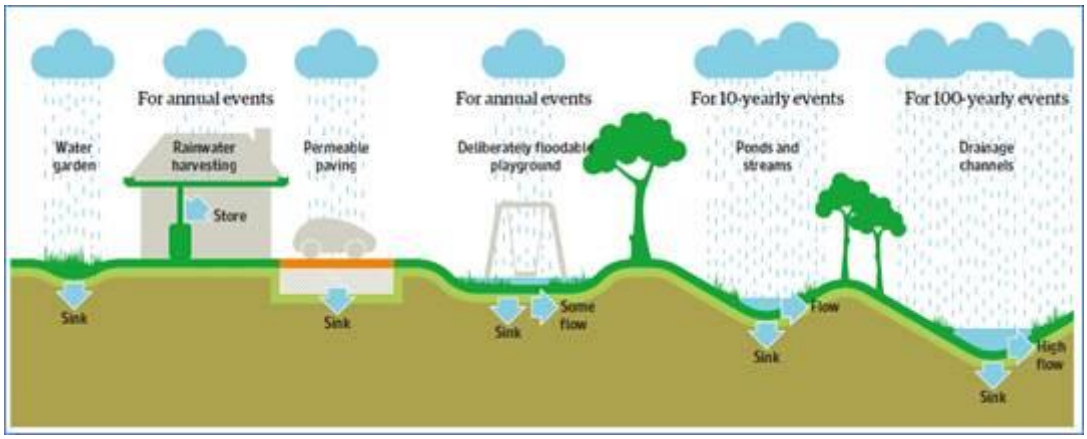

Figure 5: Sustainable Drainage System [7]

Usually, sustainable drainage in rural areas is much easier than large urban areas. The main reason is that there are a lot of available spaces where the water is drained naturally.

Yet several measures shall always be present to ensure a proper drainage to the water especially on roadways where a careful design is needed to avoid any flooding. This design includes proper sloping and landscaping and the use of appropriate ditches and inlets.

On the other hand, sustainable drainage is not limited to a good drainage system. It also focuses on the treatment and recycling of water. Therefore, the available spaces in rural areas should be invested to create artificial ponds and wetlands where water can be naturally treated and then disposed into the ground or even used in certain applications like irrigation [6].

Figure 6: Wet Pond [8]

Ponds and wetlands use natural and cheap processes to treat water like the sedimentation process where suspended solids are pushed downwards by the effect of gravity. Biodegradation by aqua plants is also available in certain cases. Also the sun radiations contribute in the disinfection of water [6]. The sketch in Figure 7 illustrates how artificial ponds work.

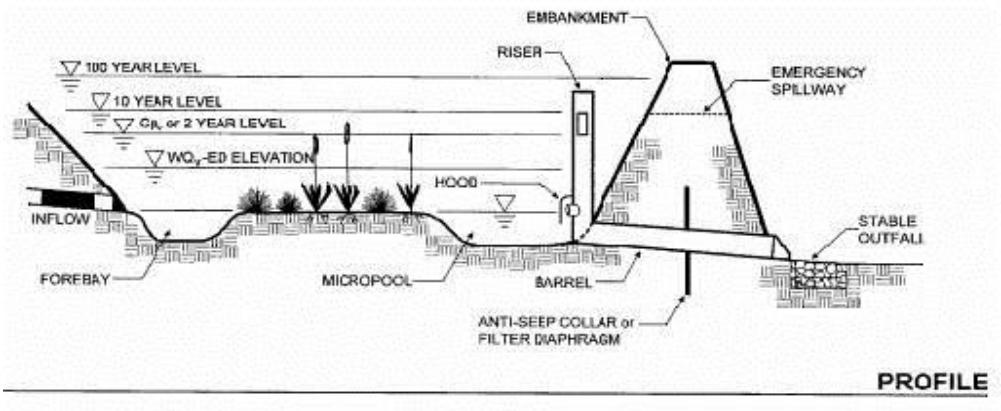

Figure 7: Wet Pond System [9]

2.3.2 Sustainable Drainage in Urban Areas

Storm water runoff has become a major problem in large urban areas. The storm water can potentially cause floods and damage the properties inside the city. The

main reason for this problem is the dense and wide spreading of buildings and pavements on the expense of green spaces. This has caused a huge pressure on the traditional drainage system [10].

There are many solutions to fight this problem. As mentioned before, green roofs help reducing or delaying the storm water runoff. Also parks and green spaces can do the same. Yet these types of solution are not enough.

The most effective solution for the storm water runoff so far has been the use of permeable concrete. Permeable concrete is an excellent material that allows the water to go right through where the water can be directly dissipated in the underground soil or perforated pipes [10]. It can be applied on sidewalks, parking spaces and even roads.

Figure 8: Permeable Concrete [11]

One of the major advantages of this type of concrete is providing a sort of filtration which helps to treat the runoff water [10]. This feature is very important and allows the recycling of the runoff water.

Figure 9: Porous paving at a supermarket in Wokingham, Berkshire [12]

2.4 Greywater and Rainwater

The water demand in urban locations is increasing while sources for fresh and usable water are decreasing. With time, the water demand shall exceed the capacity of the states in most parts of the world if innovative methods are not used to find new solutions for this problem.

2.4.1 Rainwater

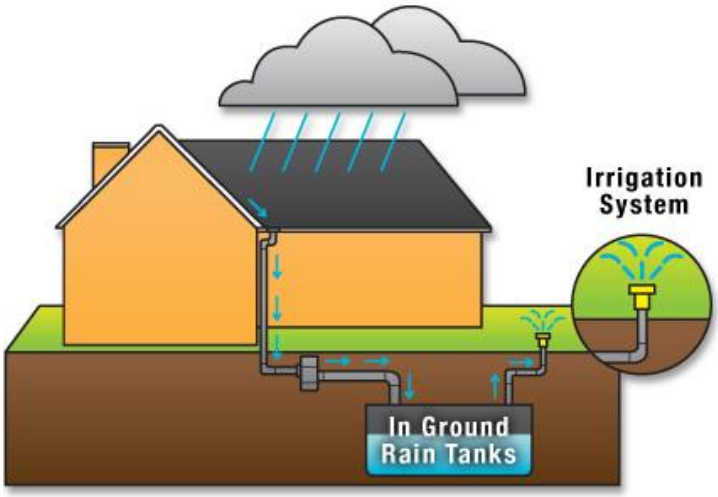

Figure 10: Rainwater Harvesting [11]

In the past, most governments and municipalities have been treating the rain water as something that just needs to be drained. Yet today, this perspective is certainly changing.

Nowadays, the rainwater harvest and recycling is gaining a lot of attention in the green building industry today. The rainwater harvesting is very simple. Usually the rainwater is collected from the roofs, whether they are normal or green roofs, and guided through pipes into a rainwater storage tank which can be above or below ground [13].

Rainwater harvesting can be very beneficial especially in high water stressed areas. It can be used for irrigation, car washing, toilet flushing and other non-potable water applications.

Other benefits are the reduction of storm water runoff and the reduction of municipal water demand which has a great influence in reducing the capacity need of the sewerage systems [13].

Usually the rainwater is fairly clean and needs no more treatment than coarse filtration. Yet in some case disinfection is needed.

One has to be careful though when it comes to designing the harvesting system as the rain quantities are unpredictable and unstable. Therefore, there should always be a way to drain the excess of rain during heavy rainy days. On the other hand, storage tanks can be shared between many apartments or houses to reduce cost. Also a

pumping system needs to be installed in order to pump the rainwater for reuse. This can be a complicated manner for high-rise buildings [13].

Figure 11 is illustrating the rainwater harvesting system in the Kokugikan sumo wrestling arena in Tokyo, Japan.

Figure 11: Kokugikan sumo wrestling arena, Tokyo, Japan [14]

2.4.2 Greywater

Greywater is the product that we get right after taking a bath, doing laundry, washing our hands. It should be distinguished from black water which comes from toilet flushing. As rainwater, the recycling of grey water is also gaining a lot of attention in many developed countries [15].

It has the same benefits of rainwater harvesting yet there are some differences and the methods used are certainly different.

Unlike rainwater, greywater treatment is a must. There are many different ways for treating greywater. One of the treatment methods includes physical filtration and

biological treatment and disinfection [15]. The biological treatment is used to reduce nutrients in the grey water using anaerobic bacteria. Some systems merge between both the filtration and biological treatment processes like the membrane bioreactors (MBR). This treatment can become very complicated especially for the application in small buildings. Yet it is applicable in large buildings. The treatment consist of disposing the water initially in a treatment tank then it goes into another tank which may or may not contain water from the rainwater harvesting process [15].

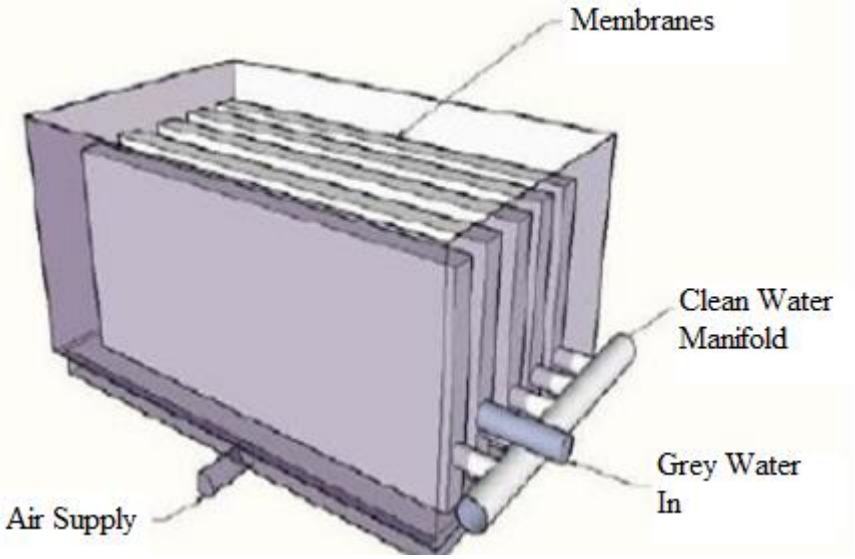

Figure 12: Greywater Treatment

Treated greywater and rainwater can both be used for the same applications. Yet greywater is more predictable that rainwater. It is best to merge the two processes together by installing one storage tank for both types of water to get the best results. The bigger the building, the more efficient shall be the system.

2.5 Cementitious Materials

Cementitious materials are used to form cement. The cement industry dates back to several thousand years. The traditional Portland cement was introduced in the United States in the year 1860 [16]. Fabrication is known to consume a lot of heat energy

and is a major cause of CO_2 emissions especially in the clinkering reactions [16]. The clinkering reaction consists of the formation for C_3S through the reaction of C_2S and lime (CaO). This reaction is the main cause of CO_2 emissions.

Nowadays, sustainability requires reducing the consumption of materials, energy, and the CO_2 emissions. This can be done by the use of other cementitious materials and admixtures which can enhance the green qualities of concrete [16].

Figure 13: Cement Plant [11]

2.4.1 Composite Cement

Figure 14: Cementitious Materials [11]

Composite cement is a combination of Portland cement and other cementitious materials like fly ash, silica fume and concrete slag. The use of composite cements

are so far considered to be the best way to reduce energy consumption and CO_2 emissions [15].

Concrete mixed with composite cement usually have better properties that normal the one mixed with pure Portland cement including the compressive strength of concrete [16].

2.4.2 Admixtures and Sustainability

Admixtures are chemical component added to the concrete mix and used to reach desired properties for the mix. The use of chemical admixtures has been very effective in enhancing the properties of concrete and has made a revolution in the concrete industry.

This is considered to be great in terms of sustainability because the quality of concrete have resulted in reducing the quantity needed for building design, therefore have resulted in saving energy and materials.

There are many types of admixtures including accelerators, retarders, plasticizers, shrinkage reducers, colouring admixtures, etc.

This wide collection of admixtures has resulted in a wide and new variety of concrete applications. These applications include concrete cladding, and architectural concrete floors. Using these types of concrete replaces the traditional use of stone cladding and floor tiling saving energy and materials [16].

Figure 15: Concrete Panels [11]

2.6 Heating, Ventilation and Air Conditioning (HVAC)

When it comes to sustainable design for heating, ventilation and cooling in a green building, a careful design needs to take place in order to set a clear scheme for the entire building. The total areas and volumes, the orientation of the building, the windows and doors, the walls and everything else all need to be taken into account [17].

A green HVAC design starts by proper insulation. A good insulation shall best work if the entire building is well insulated. This means the use of double exterior wall with an insulating medium, double glazed windows and doors, and other important features. This practice may cost a bit more money yet it can reduce the required size of the cooling and heating systems and the amount of electricity needed for their operation.

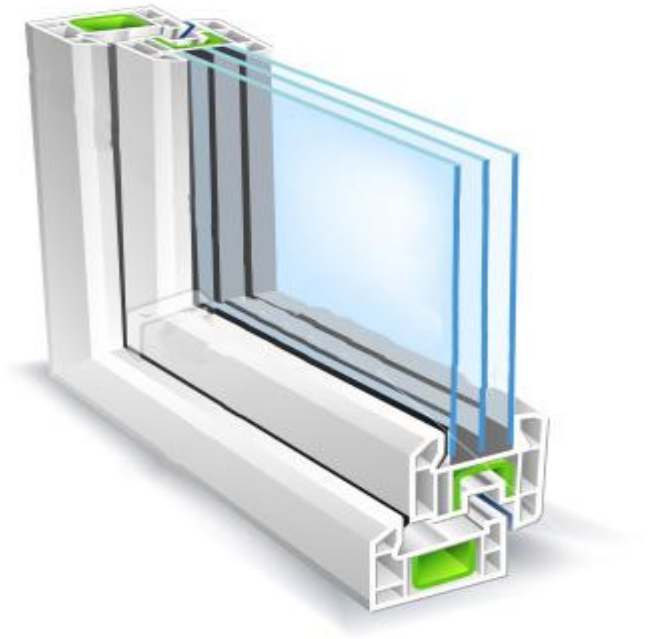

Figure 16: Triple Glazing [11]

As for the heating and cooling systems, new technologies allow the best efficiencies/energy ratios for cooling and heating. The installation of automated motors and sensors for temperatures and CO_2 content is necessary for the efficiency for the heating, cooling and ventilation systems for fans [17]. The proper insulation of the duct ensures a better efficiency, a good circulating air quality and the best comfort.

The designer should make use of the available advanced products in the market today, in order to choose the most efficient and energy saving systems for cooling, heating and ventilation. Designer should take into consideration the best type of systems which can be used. Usually central systems like chillers and boilers are best fitting for large buildings while independent systems like cooling split-units are better for smaller buildings [17].

In order to consider the HVAC system as a green system, it is not enough for it to save energy, it system should be clear of any greenhouse gases emissions. It has to also meet certain requirements set in green building rating systems like LEED and BREEAM.

2.7 Solar Energy

Solar energy is one of the cleanest renewable energy sources. Solar energy is well known as an alternative energy for fossil fuels such as coal and oil. Solar energy has many applications like heating, cooling, ventilation and electricity production. Yet it should be used wisely for the best results.

Figure 17: Solar Panels [18]

2.7.1 Advantages

Not only solar energy has direct environmental benefits including the reduction of greenhouse gases emissions like Carbon Dioxide CO_2 [19], but it is also considered simpler than other methods for producing energy. It does not need heavy installations or factories to produce energy. A small solar cell system can do the trick. This characteristic can be very useful especially in rural or far areas.

The main advantages of using solar energy can be classified as follows:

- Reduction of greenhouse gases (CO_2, NO_2, SO_2, etc.)
- Diversification of energy sources.
- Independence of the solar energy systems.
- Application in rural areas with no need for major electrical installations.

2.7.2 Applications

The solar energy can be applied in the following fields:

- Electricity production using photovoltaic solar cells:

There is a large amount of research concerning this type of electricity production. Until today, this application remains inefficient in case of installation on buildings inside the city due to its high cost and low efficiency [20]. Yet it can be efficient in some areas that are far from built up cities or regions where a high concentration of sun radiation exists.

Figure 18: Photovoltaic solar panels [21]

The photovoltaic solar panels are still not widely used in Lebanon due to high installation cost. However, some Lebanese villages are operating their street lighting by using this system with the aid of NGO's to cover its implementation costs [22].

- Water heating which can be used in different applications:

Thermal solar panels are widely used and have many applications like water heating, refrigeration or as a part of a cooling system using a hot-water driven absorption chiller [20].

Even though Lebanon is rich in solar radiation, the use of solar energy systems is still nominal. The main application of these systems are for producing hot water as Lebanon consumes an estimated sum of 108,000 m^3/day for residential buildings and 220 to 1140 m^3/day for public buildings. A study shows that 61% of implemented solar energy systems are in residential buildings, which demonstrates that commercial buildings are not using these systems efficiently. However, according to research carried out by Kinab and Elkhoury [23] huge installation of solar energy units in some public buildings lead to a production of 133,000 kW-h/year, which reduced 19,000 liters of diesel fuel. Thus, this example clearly indicates that Lebanon can decrease the energy consumption for hot water production through the use of solar energy [23].

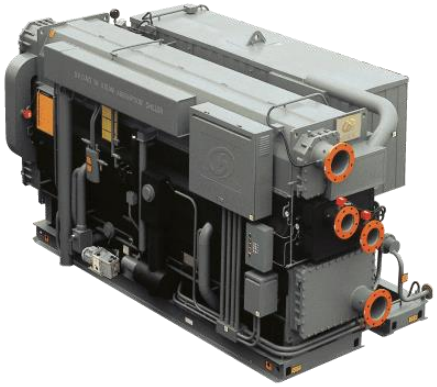

Figure 19: Hot Water Driven Absorption Chiller [24]

- Natural ventilation using stack pressure:

This method relies on the temperature difference in an air channel which helps in the ventilation process. The difference in temperature is due to temperature convection from hot-water pipes heated by solar panels [20].

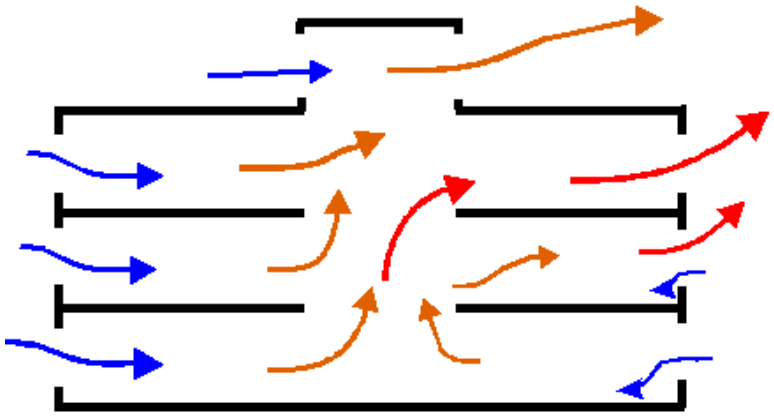

Figure 20: Stack Pressure [25]

2.7.3 Efficient Usage of Solar Energy

Solar energy may be beneficial, yet it can also be too expensive if not used wisely. The designer should take care of all the details like the type of solar panels, materials used and orientation. For example, a study shows that a well-designed 150 m^2 area covered with thermal solar panels can satisfy heating and air conditioning for an area of 460 m^2 in Shanghai [19].

Another aspect of solar energy is the indirect benefits on the environment. That is why many governments are putting a good effort to assure development for this industry. The following table shows the solar energy development in different countries.

Table 1: Electricity produced from solar photovoltaic cells in various countries [19]

Year	USA(MW)	Europe(MW)	Japan(MW)	Worldwide (MW)
2000	140	150	250	1000
2010	3000	3000	5000	14,000
2020	15,000	15,00	30,000	70,000
2030	25,000	30,000	72,000	140,000

Therefore, a careful design may lead to good results when it comes to solar energy, yet it should be used wisely. Also, many studies are taking place today to find new and more efficient techniques.

2.8 LEED

In 1998, the US Green Building Council (USGBC) has originated The Leadership in Energy and Environmental Design known as LEED [26]. This program mainly concentrates on green buildings; e.g. its design and its construction.

LEED is one of the most important green buildings certification programs in the world. Green buildings in Lebanon mostly rely on LEED and other local certification programs such as the "ARZ rating program" to get their certification.

Engineers and architects utilize LEED to plan and construct sustainable buildings. Furthermore, LEED is also used as an assessment for variety types of buildings: existing, fresh, and commercial centres and renewed [26].

2.8.1 Aspects of LEED

LEED provisions the entire sustainable building performance, starting from the planning phase toward the construction and processing phases.

A 5 essentials component is comprised in LEED as stated by USGBC. They are as follows:

2.8.1.1 Sustainable Sites [26]

Prerequisite 1: Eco-friendly Construction Activity.

Credit 1: Site Selection (1 point)

Credit 2: Development Density & Community Connectivity (5 points)

Credit 3: Brownfield Redevelopment (1 point)

Credit 4: it consists of the following credits

Credit 4.1: Alternative Transportation—Public Transportation Access (6 points)

Credit 4.2: Alternative Transportation—Bicycle Storage and Changing Rooms: (1 point)

Credit 4.3: Alternative Transportation—Low-Emitting and Fuel-Efficient Vehicles (3points)

Credit 4.4: Alternative Transportation—Parking Capacity (2 points)

Credit 5: it consists of the following credits

Credit 4.1: Site Development—protect or Restore Habitat (1 point)

Credit 4.2: Site Development—Maximize Open Space (1 point)

Credit 6: it consists of the following credits

Credit 6.1: Storm water Design—Quantity Control (1 Point)

Credit 6.2: Storm water Design—Quality Control (1 Point)

Credit 7: it consists of the following credits

Credit 7.1: Heat Island Effect—Nonroof (1 Point)

Credit 7.2: Heat Island Effect—Roof (1 Point)

Credit 8: Light Pollution Reduction (1 Point)

2.8.1.2 Water Efficiency [26]

Credit 1: Water Efficient Landscaping (2-4 points)

Credit 2: Innovative Wastewater Technologies (2 points)

Credit 3: Water Use Reduction (2-4 points)

2.8.1.3 Energy and Atmosphere [26]

Credit 1: Optimize Energy Performance (1–19 Points)

Credit 2: On-site Renewable Energy (1–7 Points)

Credit 3: Enhanced Commissioning (2 Points)

Credit 4: Enhanced Refrigerant Management (2 Points)

Credit 5: Measurement and Verification (3 Points)

Credit 6: Green Power (2 Points)

2.8.1.4 Material and Resources [26]

Credit 1: it consists of the following credits

Credit 1.1: Building Reuse-Maintaining Existing Walls, Floors and Roofs (1-3 Points)

Credit 1.2: Building Reuse-Maintain Interior Non Structural Elements (1 Point)

Credit 2: Construction Waste Management (1-2 Points)

Credit 3: Materials Reuse (1-2 points)

Credit 4: Recycled Content (1-2 points)

Credit 5: Regional Materials (1-2 Points)

Credit 6: Rapidly Renewable Materials (1 Point)

Credit 7: Certified Wood (1 Point)

2.8.1.5 Indoor Environmental Quality [26]

Credit 1: Outdoor Air Delivery Monitoring: (1 point**)**

Credit 2: Increased Ventilation: (1 point)

Credit 3: it consists of the following credits

Credit 3.1: Construction Indoor Air Quality Management Plan (1 point)

Credit 3.2: Construction Indoor Air Quality Management Plan—before occupancy: (1 point)

Credit 4: it consists of the following credits

Credit 4.1: Low-Emitting Materials—Adhesives and Sealants: (1 point)

Credit 4.2: Low-Emitting Materials—Paints and Coatings: (1 point)

Credit 4.3: Low-Emitting Materials—Flooring Systems: (1 point)

Credit 4.4: Low-Emitting Materials—Composite Wood and Agrifiber Products: (1 point)

Credit 5: Indoor Chemical and Pollutant Source Control: (1 point)

Credit 6: it consists of the following credits

Credit 6.1: Controllability of Systems—Lighting: (1 point)

Credit 6.2: Controllability of Systems—Thermal Comfort: (1 point)

Credit 7: it consists of the following credits

Credit 7.1: Thermal Comfort—Design: (1 point)

Credit 7.2: Thermal Comfort—Verification: (1 point)

Credit 8: it consists of the following credits

Credit 8.1: Daylight and Views—Daylight: (1 point)

Credit 8.2: Daylight and Views—Views: (1 point)

2.8.2 LEED Credit Weighting

Corresponding to the human and environmental benefits, the points linked to the LEED credits differs. These benefits are related to several factors: greenhouse gas

emissions, air and water pollutants, fossil fuel use, toxins and indoor environmental conditions.

LEED credits have a value of at least 1 point and positive with no fraction used.

2.8.3 LEED Certification

In order to get the project certified, it has to encounter all the prerequisites detailed in the LEED rating system and attain a specific number of points.

The scale of certification based on LEED 2009 is:

Table 2: LEED Rating Points

Certified	**40-49 points**
Silver	50-59 points
Gold	60-79 points
Platinum	80 points and above

2.8.4 Why LEED Is Chosen for Rating Buildings?

Attention to sustainable structure performance and design is encouraged by LEED. These sustainable structures are shown to produce environmental benefits, health benefits and economic benefits.

Initially, LEED certified structures affect the environment positively. They diminish the impact of a home's construction; materials are used more efficiently; energy is less used in order to reduce pollution from fossil fuel sources; and the natural water hydrology is improved. Likewise, LEED structures are healthy structures that use non-toxic materials which lower the exposure to mildew and mould. They are also thoughtfully designed in a way that uncomfortable rooms are eliminated. Moreover, LEED certified structures are durable that are constructed to withstand with less maintenance. They aim to reduce electricity, water, and natural gas bills and provide up to 51% reduced heating bills, or more. An appraised property value is increased by LEED strategy. On the other hand, LEED strategy provides higher air quality and a comfortable place to be in for occupiers. It targets for open spaces, large windows, and are built with occupier comfort in mind. Thus productivity will be improved. Summarizing all the above, LEED certification is the symbol of a business that strongly cares about moral environmental practices and is willing to occupy significant resources pursuing them. Though the upfront costs are weighty, money is saved in long term and can noticeably improve the public image.

Thus, LEED is more desirable than the other rating systems in the world such as Green globes, energy star, BREEAM, green star and BOMA Go green

2.9 ARZ Certification

The ARZ building rating system is a product of Lebanon Green Building Council (LGBC) in cooperation with the International Finance Corporation (IFC). A group of engineers and architects used international green building standards to form ARZ's standards in order to be applicable in Lebanon. Even though the ARZ's standards have similarities with LEED, it rates only the existing buildings especially commercial building. This system consists of 5 levels of certification distributed as follows: uncertified (<80 points), certified (80 points), bronze (100 points), silver (120 points) and gold (135 points). These points are given according to the green features available in the building.

Using the ARZ rating system, the client can benefit from the initiative of the Bank of Lebanon. The banks in Lebanon are giving loan for customers according to their building certification level for 1% interest rate for 14 years.

The ARZ system is becoming more used to rate buildings in Lebanon. It has some projects in Lebanon such as the BLC headquarters which have been certified with a "Bronze" level.

Chapter 3

METHODOLOGY

3.1 Data Collection

A survey is generated to explore the peoples' motivation and knowledge about "Green Building". The survey is distributed among 100 Lebanese citizens according to their gender, age and education level including civil engineers (CE), mechanical engineers (ME) and architects (AR). This survey was aimed to illustrate the degree of awareness of professionals and general public towards green building concept in Lebanon. The results are discussed in chapter 4.

3.2 Green Building Questionnaire

Table 3: Survey Questions

1. Have you heard about "Green Building"?	YES	NO
2. Do you prefer to construct a sustainable building rather than traditional one?	YES	NO
3. Do you afford to build a green commercial building which may cost more than traditional building?	YES	NO
4. Do you know any sustainable commercial building in Lebanon?	YES	NO
5. Do you desire to construct a traditional or a sustainable commercial building on your land?	YES	NO
6. Do you know what kinds of construction materials are used in "Green Building"? a) Reinforced concrete b) Steel		

c) Stone d) Wood e) Other specify.....		
7. What differentiates traditional commercial building from sustainable commercial building: a. Quality of materials used b. Construction Cost c. Eco-friendly building		
8. Which one of these buildings in Lebanon is a "GREEN BUILDING": a. Habtoor Hotel b. Beirut City Centre Mall c. City Mall		
9. What is the percentage of cost difference of a sustainable commercial building compared to a traditional one: a. 15% b. 20% c. 25%		
10. Do you know if there are standards and nongovernmental organizations that rate buildings in Lebanon?	YES	NO
11. Have you heard about "ARZ certification" in Lebanon?	YES	NO
12. Do think that traditional building construction is more desirable than "GREEN building" construction?	YES	NO
13. Do you think that the government should put some rules in order to support and encourage investors to construct sustainable buildings rather than traditional ones?	YES	NO

14. Which item is the most important for a "Green Building"? a. Green roofs b. Energy saving c. Sewage recycling		
15. Are you aware of the benefits gained by constructing a sustainable commercial building?	YES	NO
16. Which one of these benefits is the most important: a. Reduction of annual fees b. Saving the environment		
17. Sustainable building is most important for: a. Environment b. Humanity c. Economic	YES	NO
18. Do you think your employees are knowledgeable and trained to handle sustainable projects?	YES	NO
19. Do you know what construction industry workers at different levels need to know and be able to apply for sustainable construction?	YES	NO
20. Do you think Lebanese construction material suppliers keep stock of materials for sustainable construction	YES	NO

3.3 Case Study

Most contractors in Lebanon use the traditional way to construct residential, commercial, educational and governmental buildings without being aware of sustainable buildings construction. One way to check how sustainable are the

building in Lebanon is by generating a case study on an existing traditional building. An existing library in Kalhat located in north Lebanon will be investigated in order to verify if sustainable or not by following LEED.

Chapter 4

CASE STUDY: ISSAM FARES LIBRARY

4.1 General Information on the Construction Industry in Lebanon

In spite of the political and economic problems that Lebanon has been facing for many years, construction industry, even in a slow manner, is still growing. This industry needs variety of raw materials for its continuity. In Lebanon, cement is mainly supplied by two companies called HOLCIM and AL-SABAA which are located in the north province of Lebanon. In addition, sand and gravel are excavated from AMIOUN" and "DANNIYEH which are mountainous areas located also in the northern part of Lebanon. Moreover, the steel bars used for building construction are supplied from a well-known company in Lebanon called YARED, which is located in Beirut and they import material from abroad. Unfortunately, the construction industry is still following the traditional building construction concepts rather than sustainable one. What is traditional building in Lebanon is the reinforced concrete framed structure. Hence, the construction industry in Lebanon uses ready mix concrete, however in some situations where the construction site is located far from cities, in-situ concrete mixing is used. In addition, wood is the material used for formwork and concrete wall blocks are made by a local company in Tripoli. Moreover, mortar consisting of water, sand and cement are used for external plastering with painting materials resistant to water and heat. On the other hand, the building roofs are flat and covered with screed and water and heat insulation materials. The governmental laws obligate new constructed public buildings to have

spaces at least 3 meters between buildings and 1.5 meters from the road. Moreover, underground parking areas should be available with security guards on the gate.

Therefore, since Lebanon needs comprehensive re-building then it is better to be built in sustainable manner. Since it is primarily the duty government to introduce and enforce law related to sustainable construction, then it is only natural for such construction methods to be first applied in public buildings which are directly under the control of government. In order to find out how much green building concept may be known or can currently be applied in Lebanon, one of the recently constructed public buildings which appears to have sustainable features was decided to be investigated using the evaluation approach of LEED. This investigation and evaluation would help to understand the knowledge and awareness of constructors and investors towards green buildings and availability of green construction materials, finishing products and utilities. It can also help to understand whether green building approach would provide some economy to users and more importantly reduction in the usage of natural resources.

4.2 Introducing Case Study

The Issam Fares library construction was completed and it started to serve the community in 2009. It is located in the Koura district at the north province of Lebanon. The surrounding of the Issam Fares library is constructed in traditional manner without any green building features. The building is reinforced concrete frame with double skin masonry for external walls. In addition, ceramic board were used for external wall cladding.

The library building is constructed on a plot of 5900 m^2. The buildings' base area is approximately 2600 m^2. The library consists of 2 basement floors and 3 floors above ground. It contains auditoriums, study rooms, computer laboratories, lounge areas, ticketing offices, projection rooms, a saloon and various departments for books and journals. It has a wide variety of books and journals in different languages (mainly Arabic, English and French).

Figure 21: Issam Fares Library

For this research, the Issam Fares Library is considered as a case study which would be rated based on the LEED certification program. The library was not intended to be built as a green building, yet it contains many sustainable features which is discussed later on in this section

On the other hand, some feasible and sustainable aspects were not taken into consideration during LEED rating. These aspects are also discussed later in this section. The purpose of these discussions is to find some suggestions and solutions inspired by methods and products found in the Lebanese market.

4.3 Sustainability of Library's Location

Figure 22: Library Location [27]

4.3.1 Location

The library’s location does not have any environmental impact regarding water resources, wildlife or green spaces. Therefore, the location is considered to be adequate.

4.3.2 Sustainable Transportation

LEED gives credit for a green building in case it is located near a sustainable transportation station (i.e., train station, bus station, and metro) [26]. The library is located near a bus stop which is within a short walking distance.

On the other hand, LEED gives credit for green buildings which provide bicycle parking, changing rooms, and priority parking spaces for environmental vehicles [26]. Unfortunately, this option is not available at the library.

4.3.3 Pollution Reduction

The LEED program offers extra points for measures towards reducing pollution. In particularly, LEED mentions the heat island effect. This effect can be reduced by

either the existence of green spaces around the building or the existence of high SRI (solar reflectivity index) roofs. These high SRI levels are mainly obtained in case of green roofs.

This library meets only part of these criteria suggested by LEED. While green spaces are available around the library, the library roof is a conventional one with no special features. Therefore, the library only partially meets the requirements to get partial credit by LEED.

4.4 Water Efficiency at the Library

There are certain aspects which were taken into consideration when building the library in order to make the water consumption more efficient. Yet other water consumption reducing methods were unfortunately not taken into consideration.

4.4.1 Water Consumption Reduction

The library contains various efficient water reducing installations. These products include micro-irrigation systems, dual-flush toilets and tap water equipped with automatic sensors. The dual-flush toilets and faucets are certified by Water Sense [28].

The micro-irrigation systems are very important as they may reduce the water consumption by up to 50% compared with the normal water sprayers [28].

Figure 23: Micro Irrigation System [29]

In addition, a type of dense soil was used in the library garden. This type of soil does not absorb a lot of heat coming from the solar radiations. Therefore, it would greatly reduce the water needed for irrigation. Also the trees and plants used are local plants, which require less water than other foreign plants.

Small bounded areas for the plants (Figure 24) are used for the library grounds to reduce water consumption for irrigation.

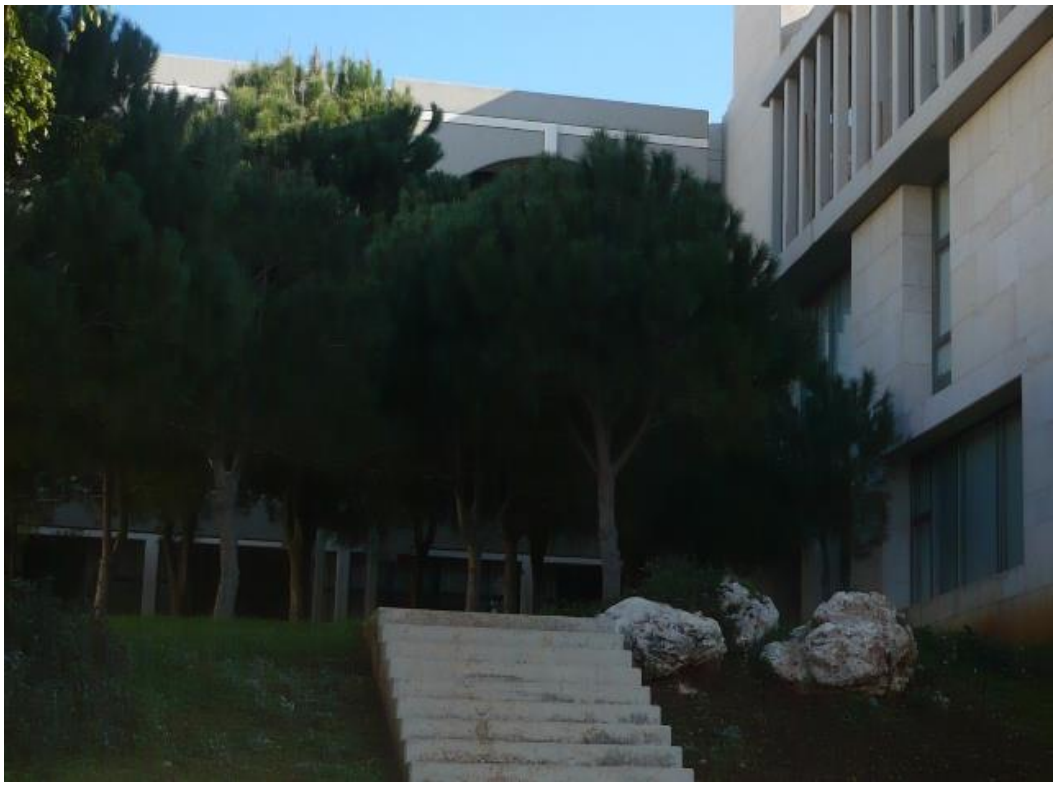

Figure 24: Library Garden

On the other hand, smart water installations such as tap water equipped with automatic sensors and dual-flush toilets are also available. These features can also have a good effect regarding the reduction of potable water consumption [26].

Figure 25: Tap Water Sensor [30]

This reduction of water in the library may give the building some partial credits for water efficiency according to the credits WE Credit 1 and WE Credit 3 offered by the LEED certification program [26].

Even though appliances in the water closets in the building can reduce water consumption, yet there are many other methods which were not taken into consideration. The main reason is that these products are either not available or rarely found in the Lebanese market. An example for such materials is the composting toilets which are toilets that use little or no flushing water [26]. These products require some extra space compared to traditional products and therefore they are not popular in the Lebanese market.

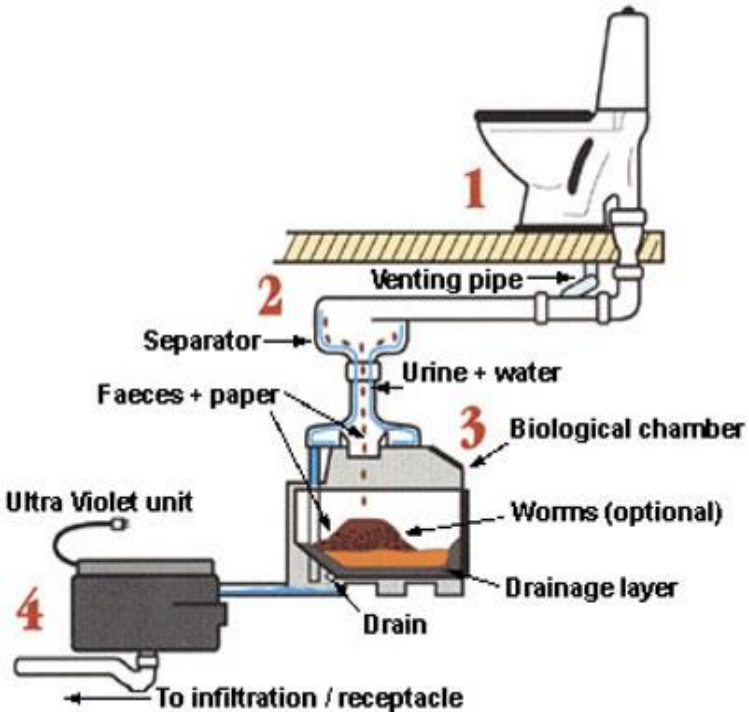

Figure 26: Composting Toilet System [31]

4.4.2 Waste Water Recycling

Another aspect for water efficiency is water recycling. As discussed earlier in Chapter 2, this can be done by the harvesting of rainwater, the treatment and reuse of greywater, and other available methods. The water may be treated on site and reused

directly or treated and supplied by municipal or governmental water treatment facilities.

Unfortunately water recycling is not used at the Issam Fares Library. The building does not include any type of rainwater harvesting system nor a greywater treatment and reuse system. The library relies totally on potable water sources. Therefore all credits offered by LEED regarding this issue are lost.

4.5 Energy and Atmosphere

This section of LEED is about the reductions in energy consumption. It focuses mainly on ways to reduce energy consumption for lighting, heating, cooling and ventilation [26].

Even though it was not intended to design the library as a green building, yet the Issam Fares library has many features that are used to save energy. Those features include stack driven ventilation, proper insulation, natural lighting and others. Those features shall be credited by LEED following the requirements for the EA credit 1 [26]. This is due to significant reduction in the used amount of energy. Also the library can be credited for the use of new HVAC systems which does not contain any refrigerants that may harm the ozone layer.

On the other hand, some other features including the use of energy efficient lamps and the use of renewable energy sources are totally missing. This would cause the loss of many LEED credits.

4.5.1 Stack Driven Ventilation

The Issam Fares library uses a mechanical system for ventilation relying mostly on stack pressure. This system uses the differences in air temperatures to move the air. This system requires no or little energy consumption.

Figure 27: Pictures of the hall taken from inside the library

Figure 28: Library inside the hall

The system works by providing openings at the top of a hall located at the centre and covered with skylights. The hall is shared between the library and other buildings in the university. Here is a sketch that demonstrates how exactly this system works.

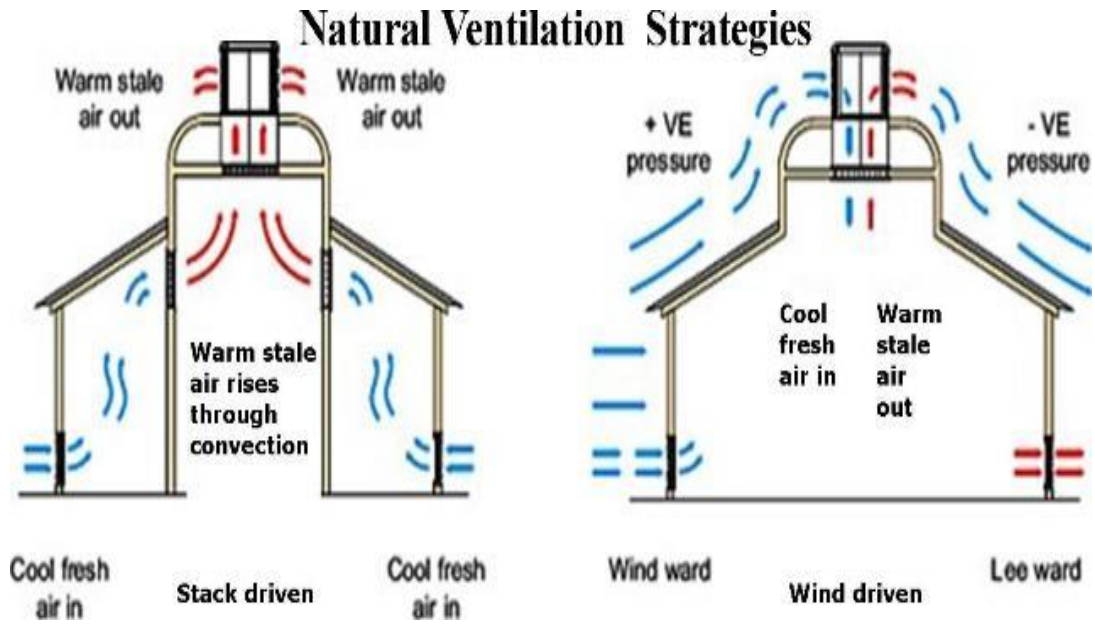

Figure 29: Ventilation by Stack Pressure [32]

4.5.2 Insulation

The building envelope is covered with double masonry walls with an empty space in the middle. Also all the windows are double-glazed and are provided with proper interior shading (curtains).

On the other hand, the main entrance consists of 2 successive set of glass-aluminium doors (Figure 30). This type of entrances assures a good insulation and minimizes the effects of wind and noise infiltration. Therefore the building is properly insulated which results in a significant reduction of the heating and cooling loads.

Figure 30: Library Entrance

4.5.3 Lighting

The Issam Fares library is covered with wide windows from 2 sides (East and North Sides), not to mention the presence of skylights at the central hall. Therefore, the library relies essentially on natural sunlight during the day which reduces a large amount of energy needed for lighting.

On the other hand, during the night, the library relies on conventional lighting system which consumes a lot of electricity. The Issam Fares library uses various types of lamps with different voltage and lifetime as shown in the table below.

Table 4: Conventional Lamps

Type	Voltage in Watts	Number of lamps	Lifetime in years
Fluorescent	36	245	3
	26	510	3
	18	550	3
	20	27	3
Incandescent	75	10	0.40
Metal-Hilde	250	12	4
Sodium	70	18	8

A small study is conducted in order to compare the cost of conventional lightings with the cost of the more efficient LED lighting.

The following table represents the amount of LED lamps needed to replace the conventional ones.

Table 5: LED Lamps

Lamp Type	Voltage in Watts	Number of lamps	Replacement
LED	15	490	1
	20	842	1
	30	40	1

4.5.3.1 Conventional Lighting Cost

Table 6: Conventional Lamps Cost

Lamp Type	Voltage Watts	Number of lamps	Replacement	Cost of a single lamp in USD	Total costs of lamps in USD
Fluorescent	36	245	2.67	2.2	1,439.13
	26	510	2.67	2	2,723.4
	18	550	2.67	1.6	2,349.6
	20	27	2.67	1.6	114.34
Incandescent	75	10	20	0.3	60
Metal-Hilde	250	12	2	12	288
Sodium	70	18	1	2.8	50.4
Total					**7,024.87**

The total cost of these lamps for 8 years is equal to **7,024.87 USD**

The following table shows the cost of electricity consumption for the lamps in the library. The results are based on calculations made for each type of lamp and are based on an 8-year period.

The Lebanese government charges 200 Lebanese pounds (LBP) for each kW-h of consumed energy. The energy amount and cost are calculated using the following formulas.

$$\text{Amount of energy used} = \text{Lamp Voltage (kW)} * \text{Number of Lamps} * 8\frac{\text{hrs}}{\text{day}} * 315\frac{days}{year} * 8years$$

$$Cost\ of\ energy\ used = Amount\ of\ enegy\ used * \frac{200 lebanesePounds}{1500 Lebanesepounds/\$}$$

Table 7: Electricity consumption and cost of using conventional lamps

Lamp Type	kW-h for 8 years of use	Cost of 8 years of use in USD
Fluorescent	177,811.2	23,708.16
	267321.6	35,648.88
	199584	26,611.2
	10886.4	1,451.52
Incandescent	15,120	2,016
Metal-Hilde	60,480	8,064
Sodium	25,401.6	3,386.88
Total	**756,604.8**	**100,880.64**

The total cost of lighting in the library = 100,880.64+ 7,024.87 = **107,905.51 USD**

The total energy consumption = **756,604.8 kW-h**

4.5.3.2 LED Lighting Cost and Consumption

Table 8: Cost of LED lamps

Lamp Type	Voltage in Watts	Number of lamps	Replacement	Cost of a single lamp in USD	Total costs of lamps in USD
LED	15	490	1	23	11,270
	20	842	1	26	21,892
	30	40	1	30	1,200
Total					**34,362**

Table 9: Electricity consumption and cost of LED lamps

Lamp Type	kWh for 8 years of use	Cost of 8 years use in USD
LED	148,176	19,756.8
	339,494.4	45,264.92
	24,192	3,224.6
Total	**511,862.4**	**68,248.32**

The total cost of lighting using LED in the library = 34,362+68,248.32= **102,610.32 USD**

The total energy consumption using LED lamps in the library = **511,862.4 kW-h**

4.5.3.3 Use of Photovoltaic Panels for Electricity Production

Photovoltaic panels are efficient systems to produce solar energy based electricity in the library in addition to the use of LED lights. Every 20 photovoltaic panels produces 5 kW-h and 40 panels produces 10 kW-h energy and the cost of implementation of these systems in North Cyprus are around 9,120 USD and 17,100 USD, respectively, with a life cycle of 20 years. The daily energy consumption of library using LED bulbs is calculated as follows:

Table 10: Cost of LED lamps and their daily energy consumption

Lamp Type	**Voltage in Watts**	**Number of lamps**	**Daily Energy Consumption in Wh**
LED	15	490	7,350
	20	842	16,840
	30	40	1,200
Total			**25,390**

The number of photovoltaic panels needed = $\frac{Total\ Daily\ Energy\ Consumption\ (Wh)}{Energy\ produced\ by\ 1\ panel\ (Wh)}$ = $\frac{25390}{245}$= 103 panels

There is a need for 3 number of 10 kW-h energy systems which can produce 29,400 (Wh) approximately 4,010 Wh more than required. The cost of photovoltaic panels for 20 years = $\frac{Number\ of\ photovoltaic\ panels\ needed}{20\ panels}$* cost of whole system = 3 * 17,100 = 51,300 USD

The cost of photovoltaic panels in 1 year = 51,300 / 20 = 2,565 USD

The energy cost of using LED lamps in 1 year = 68,248/8 = 8,531 USD

The photovoltaic solar energy systems are estimated to have 80% energy production efficiency. Thus, the 20% will be used from the traditional electricity supply and hence an extra cost should be allowed for this. This cost corresponds to the usage of the government electricity during cloudy and windy days. This cost is 20% of the total cost of electricity consumed by the LED lamps by using government electricity in 1 year.

The cost of photovoltaic panels in 1 year + 20% of the cost of the use of LED lamps in 1 year = 2,565 + 0.2*8,531 = 4,271 USD

When photovoltaic panels are used instead of government electricity the saving on the cost of electricity each year is expected to be around

[1- (4,271 / 8,531)]*100 ≅ 50%.

This would also mean that the reduction in the use of government electricity is 80%, thereforem saving both on cost and use of fuel based energy.

It can be summarized that an 8-year period is enough to break even between the conventional and LED lighting systems. In addition, the combination of LED lighting and photovoltaic solar energy is very efficient because it leads also to a reduction in energy consumption and cost for lighting system in the library.

4.5.4 Renewable Energy Sources

Even though the conditions surrounding the library are considered to be suitable for the use of renewable energy due to the existence of wind and solar radiations

throughout the year, the Issam Fares library does not use any sort of renewable energy sources like solar, wind or geothermal energy.

One of the most efficient methods to be used in the future may be the installation of solar panels on the roof for water heating. These types of solar panels are available in the Lebanese market and are considered by many as feasible product.

The following study illustrates the advantages of installing solar panels for water heating.

4.5.4.1 Electrical Water Heating versus Solar Water heating

The library building contains 29 basins and 3 steel sinks. As an estimate, each basin has a hot water demand of 15 gallons per hour and each sink has a hot water demand of 20 gallons per hour. Thus, the hot water demand for the library is

= 29x15 + 3x20 = 435 + 60 = 495 gallons per hour.

The total hot water demand = 495xdemand factor = 495x0.4 = 195 gallons per hour.

The library contains 4 electric water heater of Power Miser 6 type characterized by a capacity of 50 gallons per hour and by a voltage of 5,500 Watts. The cost of each Power Miser 6 is 200 USD. Thus, the total cost of the whole system is 800 USD.

The study is made on the basis of 8 years use. The following table shows the cost of electrical water heating using the Power Miser 6 water heaters during an 8-years period.

The energy consumption and cost are calculated using the following formulas.

$$\text{Amount of energy used} = \text{Heater Voltage (kW)} * \text{Number of Heaters} * 8\frac{\text{hrs}}{\text{day}} * 315\frac{days}{year} * 8years$$

$$Cost\ of\ energy\ used = Amount\ of\ enegy\ used * \frac{200lebanesePounds}{1500Lebanesepounds/\$}$$

Table 11: Electric Water Heater Consumption and Cost

Electric water heater	**Number**	**Replacement**	**kW-h for 8 years**	**Cost of use for 8 years in USD**
Power Miser 6 (5,500 Watts)	4	1	443,520	59,136

The total cost of water heating in the library = 800 + 59,136 = **59,936 USD**

The total energy consumption for 8 years use = **443,520 kW-h**

Now the same calculations shall be repeated yet this time solar panels shall be installed. Since the library is located on an open and vast land, the consideration of solar panels might be a feasible alternative for water heating. Solar panels offer free and renewable energy. The only implemented cost for a solar panel system is the initial cost of the materials and installation. The following table shows the required solar panels for the library's demand of hot water. The solar panels mentioned in this table are available at a local company in Lebanon called "G.M.G. Tabbouch" located in the nearby city of Tripoli.

Table 12: Solar Panels Cost

Solar panels type	Number of Panels	Cost of unit in USD	Lifetime in years	Replacement	Cost in USD
300 L	2	1,250	20	1	2,500
240 L	1	1,125	20	1	1,125
Total					**3,625**

The total cost of the solar panels during the 8years = **3,625 USD**

An extra cost should be taken into account. This cost corresponds to the usage of the electric water heater during windy days (especially during the winter season). This cost is approximated at 30% of the total cost consumed by the electrical water heater in case of absence of the solar panels.

Table 13: Extra Cost for Mixed Solar Panel-Electric Water Heater System

Electric water heater	kW-h use in 8 years	Cost of 8-years use in USD
Power Miser 6 (5,500 Watts)	13,3056	17,740.8

Total Cost of solar panel + extra cost of electric water heater = 3,625 + 17,740.8 = **21,364.8 USD**

It can be noticed that the total cost for a mixed solar panel-electrical water heater system is far cheaper than a simple system relying only on conventional electrical water heaters. These results show that the installation of solar panels for water heating is very efficient in the long term for the case of the library building.

4.6 Materials and Resources

4.6.1 Waste Management and Recycling

The LEED certification program offers a lot of credit points for the use of recycled and sustainable materials. It also gives credit for minimizing the volumes or quantities of construction waste products. In addition, LEED gives credit for the use of materials from nearby regions surrounding the site as this process reduces the bad effects of transportation.

While there isn't enough data concerning the construction period of the library, there is no indication of the use of any recycled materials or the adoption of any policies that may reduce the quantities of construction waste.

However, it is known that all the concrete used in the construction has been provided from a very nearby town called "Chekka". This can be credited by LEED.

4.6.2 Library Framing and Waterproofing

LEED requires a good design which shall protect the building materials and allow their durability. In order to do so, a proper building framing and waterproofing techniques shall be provided.

Innovative waterproofing and thermal insulating materials such as autoclaved aerated concrete (ACC) can be used as a building framing material. Such innovative materials could have been used in the library. Yet the library framing consists of a normal Portland cement concrete along with double masonry walls for exterior framing and single masonry walls for interior framing. In addition, double glazed doors and windows have been used as mentioned earlier.

On the other hand, the library uses waterproofing materials such as “Tinosealant Base coat & sealant” for exterior waterproofing, and “Tiromembrane S.F. Floor Coating” for WC floors waterproofing.

4.7 Indoor Environmental Quality

The indoor environmental quality as mentioned in LEED focuses on proper ventilation, good quality of air inside the building, thermal comfort and the provision of natural lighting and view.

4.7.1 Air Quality in the Library

According to LEED, the air quality depends on proper ventilation, proper flooring and painting materials which consist of low-emitting materials, and a good design for managing any toxic materials inside the building.

Most of these characteristics are available at the Issam Fares library. The library is well ventilated, the only chemicals (cleaning products) are well stored in distant isolated rooms, and most of the materials used inside the library (Tables, Chairs, Desks, Tiling, etc…) are considered to be safe materials. Yet there isn’t enough data regarding the type of paints and coatings used inside the building.

4.7.2 Controllability of the Temperature and Lighting

Even though the library provides a good thermal and lighting comfort, yet the HVAC and lighting installations still cannot meet the ASHRAE standards required by LEED. The main reason is the lack of a control system which allows the occupants to control the HVAC and lighting options inside the building.

4.7.3 Natural Lighting and Views

As mentioned earlier, the library is covered with wide windows and is also surrounded by open green areas. This shall allow the occupants to constantly enjoy

natural lighting from the sun's radiations and natural views provided by the surrounding areas which are accessible by looking from the library windows. In addition, the skylight covering the hall provides an excellent source of natural lighting.

Figure 31: Library Skylight

4.8 Results

There is no doubt that the Issam Fares Library has many green features integrated in its design such as the use of solar lighting, natural ventilation, green vegetation and some energy efficient techniques. Yet unfortunately, it was not designed as a green building.

The library is missing many features that could have been easily implemented in the design. Some of these features are LED lighting, rainwater harvesting and solar heating are considered to be feasible as discussed earlier in the case study. These features could have given the library a much higher potential to gain extra credits and get a LEED certification with a silver or gold rating. However, the current conditions

of the library make it hard to reach the minimum requirements to get a LEED certification with just a “certified” rating.

Tables 14 to 16 summarize the results of the green building adequacy of the library as a result of evaluation by using LEED certification requirements.

Table 14: Sustainability of Location

Sustainability of Location	**Results**		
Location of the library	Adequate		
Transportation	Partially Adequate	Bus Station	✓
		Bicycle parking and others	X
Pollution Reduction	Partially Adequate	Green spaces around library	✓
		Green roof	X

Table 15: Water Efficiency

Water Efficiency	**Results**
1. Water Consumption Reduction	
i. Tap Water	✓
ii. Dual Flush	✓
iii. Micro-Irrigation	✓
iv. Dense Soil	✓
v. Composting Toilets	X
2. Waste Water Recycling	

i. Rain Water Harvesting	X
ii. Greywater Treatment	X

Table 16: Indoor Air Quality

1. Air Quality in the Library	**Results**
i. Proper ventilation	✓
ii. Proper flooring	✓
iii. Low-emitting Material	✓
2. Controllability of the temperature and lighting	X
3. Natural Lighting and view	
i. Wide Windows	✓
ii. Skylight	✓
iii. Green area surrounded	✓

Chapter 5

SURVEY DATA ANALYSIS

5.1 Survey Results

The following table shows the survey results.

Table 17: Survey Results

Age				
Gender: Male	59			
Female	40			
Status	N\A			N\A
Education: Educated CE: civil Engineers, AR: Architects, ME: Mechanical Engineers	73			
	CE	AR	ME	
	35	22	16	
Non-Educated	26			
Nationality: Lebanese	89			
Other	10			
	YES			NO
1. Have you heard about “Green Building”?	72			17
Male	45			14
Female	28			12
Age:				
20-30	30			12
31-41	24			9
42-52	18			6
Educated	59			14
Non-Educated	14			12
2. Do you prefer to construct a sustainable building rather than traditional one?	61			38
Male	42			17
Female	26			14
Age				
20-30	32			10
31-41	27			6
42-52	9			15
	YES			NO
Educated	50			23

Non-Educated	11	15
3. Do you afford to build a green commercial building which may cost more than traditional building?	32	67
4. Do you know any sustainable commercial building in Lebanon?	28	71
Male	22	37
Female	16	24
Age		
20-30	25	17
31-41	19	14
42-52	11	13
Educated	31	42
Non-Educated	10	16
5. Do you desire to construct a traditional or a sustainable commercial building on your land?	64	35
6. Do you know what kinds of construction materials are used in "Green Building"?		
a. Reinforced concrete	99	0
b. Steel	26	73
c. Stone	32	67
d. Wood	41	58
e. Other specify ……	7	92
7. What differentiates traditional commercial building from sustainable commercial building		
a. Quality of materials used	43	56
b. Construction cost	68	31
c. Eco-friendly building	99	0
8. Which one of these buildings in Lebanon is a "Green Building"		
a. Habtoor Hotel	14	88
b. Beirut City Centre Mall	65	20
c. City Mall	20	79
	YES	NO
9. In your opinion what is the percentage difference in cost of sustainable commercial building compared to a traditional one?		
a. 15%	26	73
b. 20%	53	46
c. 25%	21	72
10. Do you know if there are standards and non-governmental organizations that rate buildings in Lebanon?	45	54
Male	22	37
Female	23	17
Age		
20-30	19	23
31-41	14	19

42-52	10	14
Educated	28	45
Non Educated	10	16
11. Have you heard about “ARZ certification” in Lebanon?	37	62
Male	21	38
Female	16	24
Age		
20-30	15	27
31-41	11	23
42-52	9	14
Educated	33	40
Non-Educated	8	18
12. Do you think that traditional building construction is more desirable than a “Green building” construction?	58	41
13. Do you think that the government should put some rules in order to support and encourage investors to construct sustainable buildings rather than traditional ones?	80	19
14. Which item is the most important for a “green building”?		
a. Green Roofs	51	48
b. Energy Saving	55	44
c. Sewage Recycling	29	70
	YES	NO
15. Are you aware of the benefits gained by constructing a sustainable commercial building?	54	45
16. Which one of these benefits is the most important:		
a. Reduction of annual fees	73	26
b. Saving the environment	42	57
17. Sustainable building is most important for		
a. Environment	57	42
b. Humanity	40	59
c. Economy	35	64
18. Do you think your employees are knowledgeable and trained to handle sustainable projects?	25	74
19. Do you know what construction industry workers at different levels need to know and be able to apply for sustainable construction?	92	7
20. Do you think Lebanese construction material suppliers keep stock of materials for sustainable construction?	33	66

The answers provided for question 1 show that 70% of women and 76% of men heard about Green Building and 20-30 age group is the one most aware about this concept. It is not surprising to find out that those people who are educated at university level and they are engineers or architects are more conscious about Green Building.

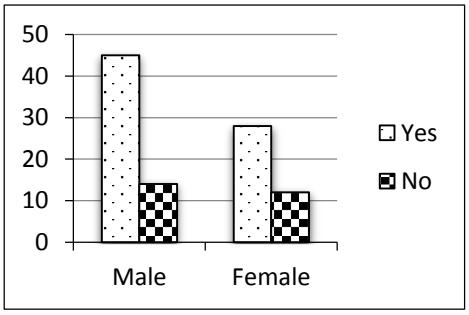

Figure 32: Question 1-Gender Bar Chart

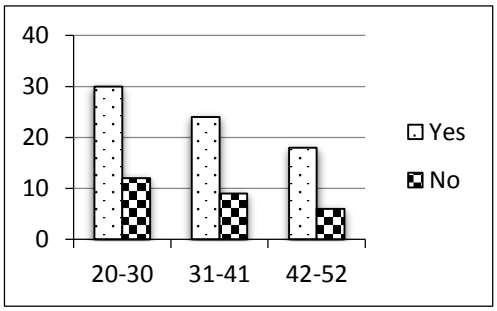

Figure 33: Question 1-Age Group Bar Chart

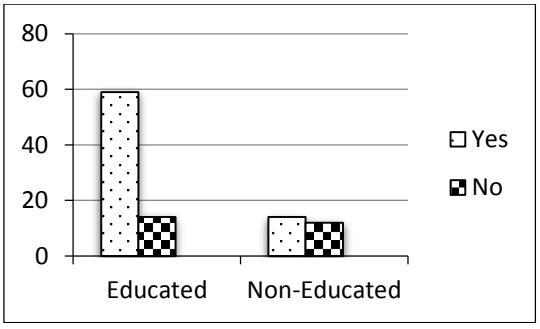

Figure 32: Question 1-Education Bar Chart

Question 2 was asked to reinforce the results given for the question 1. Answers to this question are in line with the first question and 65% of women and 70% of male prefer to choose sustainable building. In addition, the 20-30 age group and the people educated at university level, who are the most aware of Green Building concept prefer to construct a sustainable building. Despite these positive results when it comes to cost 67 people stated in question 3 that they cannot afford to construct such

a building. However, 64 people said in question 5 that, if they can afford, they would construct a sustainable commercial building. On the other hand, in question 12, 80 of the respondents stated that they desire to have a traditional building.

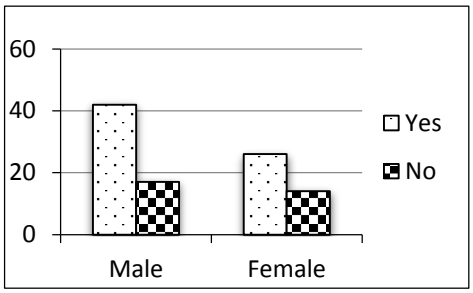

Figure 33: Question 2 - Gender Bar Chart

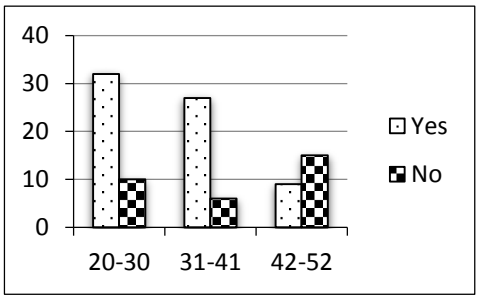

Figure 34: Question 2 - Age Group Bar Chart

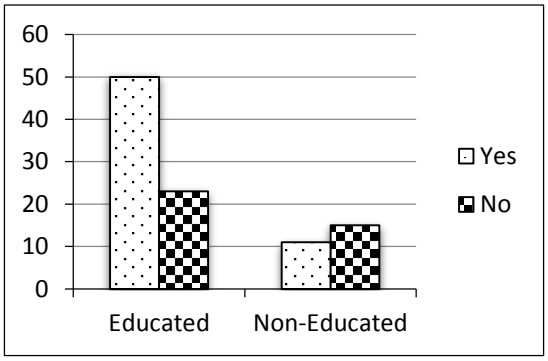

Figure 35: Question 2-Education Bar Chart

According to question 3, only 32% of men and 67% of women appear to know about presence of sustainable commercial building in Lebanon and most of the people who are educated at a university level are not aware of such buildings existing in Lebanon. But, surprisingly 65 people knew about the "GREEN BUILDING" in Beirut City Centre in question 8.

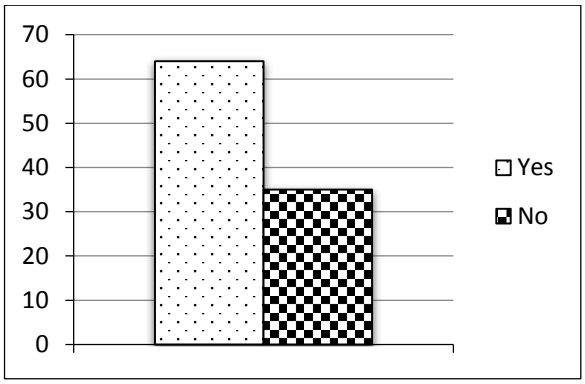

Figure 36: Question 5- Bar Chart

In question 6, it was revealed that out of the four suggested sustainable construction materials all respondents chose reinforced concrete and among the rest of materials wood was chose as second with 41. On the other hand in question 7, all of the people participated accepted Green Buildings as eco-friendly. Furthermore, 68% knew that Green buildings cost more, while 43% were aware that there are differences in construction materials for green buildings.

Majority of the people had a good guess by saying 20-25% about the difference in construction cost of a sustainable building when compared to a traditional one.

Questions 10, 11 and 13 were related to standards, regulations and certification relating to sustainable buildings. 58% of women and 36% of men know at least one organization that rate buildings. As in other questions, 20-30 age group is the most aware about this matter and surprisingly, 53% of those people who are educated at university level have not heard of such organization.

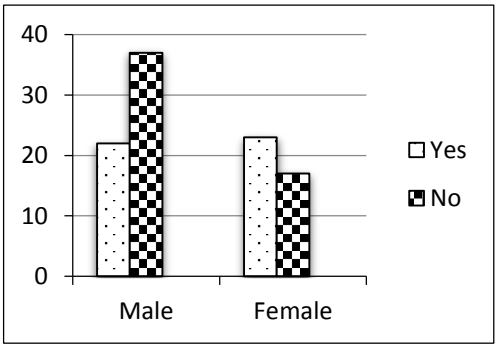

Figure 37: Question 10-Gender Bar Chart

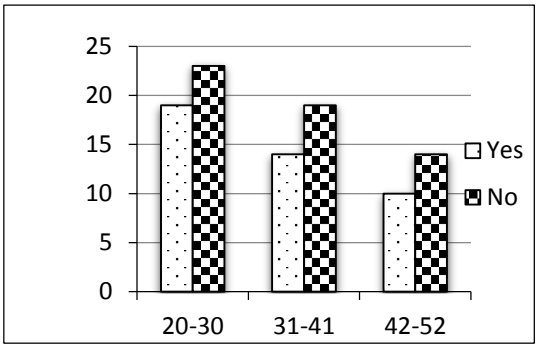

Figure 40: Question 10-Age Group Bar Chart

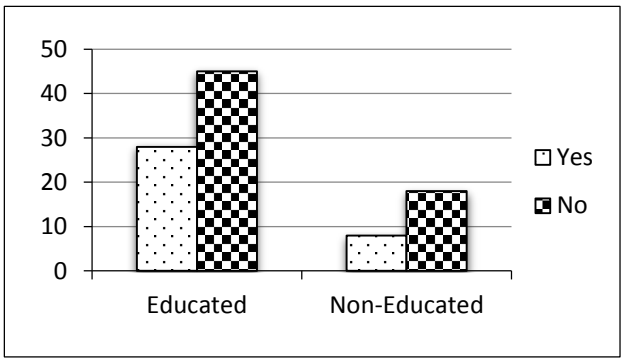

Figure 41: Question 10-Education Bar Chart

Results were similar when they were asked in question 11 if they know about "ARZ certification" in Lebanon. 65% of male and 60% of female responded negatively to this question. Only 45% of people, who are educated at a university level, answered positively.

Despite people generally being positive towards having sustainable buildings and generally being aware of this matter unfortunately only 51 responses were positive towards establishing new rules to encourage investors to construct sustainable buildings rather than traditional ones in question 13. This shows the general unwilling attitude of people towards change in developing countries

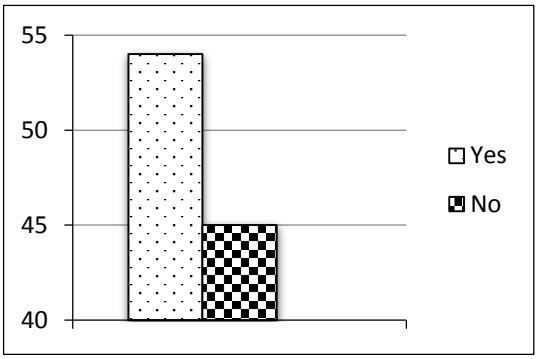

Figure 42: Question 13-Bar Chart

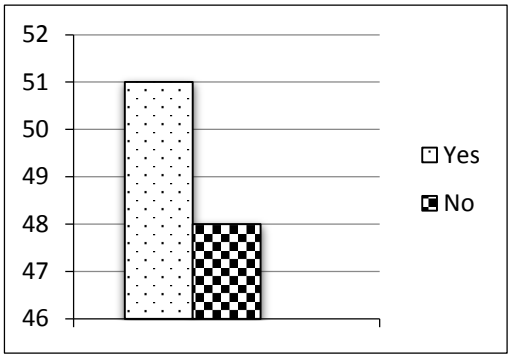

Figure 43: Question 15-Bar Chart

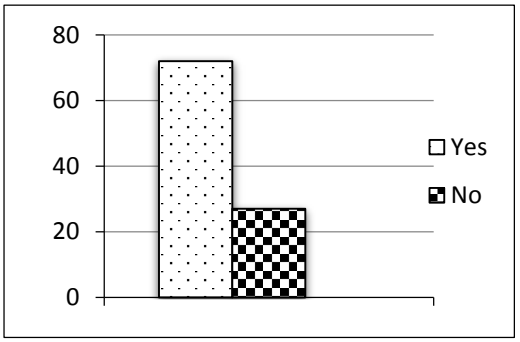

Figure 44: Question 16-Bar Chart

Answers to questions 14 to 17 showed that 55 people think that green roof is the most important item in Green building and 45 people do not know about the benefits of Green Building.

Questions 16 and 17 answers have conflict with each other. In question 16 majority said that annual fee reduction is important whilst in question 17, 57 people choose the environment benefits

Considering the answers for questions 18 and 19, 92 people do not think that the employees have enough knowledge and proper training for sustainable projects.

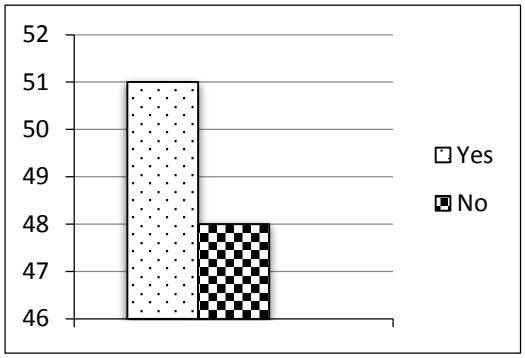

Figure 45: Question 19-Bar Chart

and majority of them also do not know what construction industry workers at different levels need to know and be able to apply for sustainable construction.

The responses of 66 people were negative to question 20. Lebanese construction material suppliers do not keep stock of materials for sustainable construction.

5.2 Discussion of Survey Results

According to the survey analysis, Green Building is getting more known by Lebanese people, especially by the younger age group, 20-30. In addition, results show that they desire to construct a sustainable building rather than a traditional one. This gives hope for the Green Buildings to spread more among people in Lebanon. Despite of these results, less than half of the people, including the educated group, have not heard about ARZ Organization in Lebanon. This may be due to lack of publicity. Additionally, more than half of the respondents consider themselves to have adequate knowledge of the benefits of the Green Buildings. However, the majority of their answers indicated that they prefer traditional building construction and they are not yet prepared to change. Cost is certainly not the only problem, other

factors, such as, lack of industry practices and technical knowledge would be a great issue and can lead to such responses. Furthermore, the political and economic problems in Lebanon have big influence on the application and widespread use of Green Building Concepts. The government is not providing laws and regulations to facilitate, encourage and support investors for using green concepts. Government should provide incentives to promote this approach. On the other hand, the majority of engineers are seeking huge profits from their investments without having enough awareness of the benefits of applying such green features. It is obvious that the initial cost of buildings may increase as a result of these features but the long term benefits are undeniable. So both government, investors, public and construction industry should become more aware of this issue so that green building concept would be applied to public buildings.

Chapter 6

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The green industry is very critical for our planet. Global awareness towards this industry should be raised in order for this concept to spread and succeed around the world. While some countries like the United States and EU countries are putting a lot of effort to apply green features in their urban and rural areas, other countries like Lebanon are still lacking a lot of knowledge and resources regarding this topic.

Nowadays, the construction sector in Lebanon mostly relies on traditional rather than sustainable building. Some green features may be found in the Lebanese market, yet they are still very rare. The Issam Fares library is a good example illustrating the general condition of the green industry in the country. The library design did not take into consideration many of the feasible green features that could have improved the economy and quality of the building. The owner should have hired accredited professionals specialized in sustainable building design. These professionals are able to provide the contractor with proper recommendations and techniques and generate an assessment for the library building's design. This assessment could have improved the building's chance to gain a high rating LEED certificate which can be used to acquire a lot of funding for the project.

Furthermore, the survey results show lack of awareness in the Lebanese public opinion towards the green building concepts. Also, it shows the people's concerns regarding the high cost of the applications used in these concepts. This is considered to be a great issue regarding the sustainable construction development in the country.

6.2 Recommendations

Major steps need to be taken in order to raise awareness and support the green industry in Lebanon. Thus, non-governmental organizations (NGOs) such as the "Lebanon green building council" (LGBC) can play a major role to promote green features and products throughout conferences and advertising campaigns. In addition, these NGOs can cooperate with the governmental and private banking sector to provide funding for green buildings. In this manner, the government should take responsibility by investing in green projects and providing full support for the private sector in order to encourage green building construction.

To sum up, major efforts should be taken to support the green industry in Lebanon. Each Lebanese citizen particularly engineers, university professors, state officials should be involved. Brave initiatives are the key for motivation and change in the Lebanese society to better understand the importance of sustainable construction.

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