Techno-Economic Analysis of LEED Certification of Homes in Pakistan

By

Waqas Ahmad Khalil

Reg #: 00000170673

Session 2016-18

Supervised by

Dr. Muhammad Bilal Sajid

A Thesis Submitted to the Centre for Energy Systems in Energy in partial fulfillment of the requirements for the degree of

Masters of Science in

ENERGY SYSTEMS ENGINEERING

U.S. Pakistan Center for Advanced Studies in Energy Systems (USPCAS-E)

National University of Sciences and Technology (NUST)

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THESIS ACCEPTANCE CERTIFICATE

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Abstract

This study systematically investigates all the categories of LEED for Homes rating system, points system, credits, prerequisites, then compare the practices of conventional building and LEED certified home in Pakistan and finally doing the economic analysis of both the homes. For this purpose every measure of LEED Homes rating system which are categorized into integrative process, site sustainability, location and transportation, water efficiency, energy and atmosphere, material and resources, indoor air quality, innovation and regional priority have been analyzed if they are implementable in the country or not and finding the costs related to these measures.

All the credits and prerequisites of LEED for homes rating system are examined and then compared to conventional homes in Pakistan. Environmental Impact and resilience level are also compared. Awareness level and skills of the stakeholders in the construction industry in the country are accessed by surveys which were conducted in different parts of the country. Simulation is carried out for implementing Green Building features in a typical house of Pakistan to study its feasibility, environmental impact, financial implications, and risk analysis. Pakistan building codes and building energy codes are analyzed. Policies of the development authorities are analyzed in this research work and recommendations to promote Green Building practices in the country are proposed.

According to a conservative estimate, buildings consume more than 40% of the electricity in the country. And the demand is increasing at a rate of 14% per annum because of the high rate of urbanization, rapid development projects and increases in the standard of living throughout the country. The significance of this research lies in the fact that by energy conservation measures Pakistan can save up to 1100MW of energy in domestic sector.

This research includes a simulation of a retrofitted project a case study in Islamabad region considering its climatic conditions. Different features of Green Buildings like its feasibility, environmental impact, cost implications, risk study, and economic analysis are analyzed. A bank loan for retrofitting the project is taken into consideration to find its payback period and different economic parameters like discount rate, inflation, interest rate, and annual payments. Risk analysis has been done using NPV analysis throughout the lifetime of this project. Environmental impact of the base case and the proposed case has been analyzed and annual GHG emissions are calculated.

The objective of this research project is to assess different parameters of green buildings to find out where Pakistan stands if we start implementing these parameters. The technical and economic analysis shows that there is significant gap between local practices and sustainable residential construction. The upfront costs are higher for building green homes but the energy and water savings result in a shorter payback period.

Keywords: LEED, Green buildings, sustainable energy, sustainable homes, energy efficient homes, net-zero energy homes, high-performance home, high-performance buildings, green materials, sustainable buildings, LEED, environment-friendly homes, green homes

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- **Waqas Ahmad Khalil**, Sadia Gul, Rafia Akbar, Sophia Owais, Dilshad Ahmed Khan, and Muhammad Bilal Sajid, **Sustainable Residential Buildings in Pakistan: Challenges and Opportunities** published in the Proceedings of First International Conference on High-Performance Energy Efficient Buildings and Homes 2018, Lahore, Pakistan.

- Sadia Gul, **Waqas Ahmad Khalil**, Sophia Owais, Rafia Akbar, and Muhammad Bilal Sajid, **Energy Consumption Profile of a K-12 School Building and Identification of Energy Conservation and Energy Efficiency Measures** published in the Proceedings of First International Conference on High-Performance Energy Efficient Buildings and Homes 2018, Lahore, Pakistan.

- Rafia Akbar, Sophia Owais, Waqas Ahmad Khalil, Sadia Gul and Muhammad Bilal Sajid, **Design of an 87 kW Photovoltaic System for a University Building to Support LEED Certification,** published in the Proceedings of First International Conference on High-Performance Energy Efficient Buildings and Homes 2018, Lahore, Pakistan.

- Sophia Owais, Rafia Akbar, **Waqas Ahmad Khalil**, Muhammad Bilal Sajid, and Sadia Gul, **Energy Consumption in Residential Sector of Pakistan**, published in the Proceedings of First International Conference on High-Performance Energy Efficient Buildings and Homes 2018, Lahore, Pakistan.

Chapter 1

Introduction to Green buildings

According to the EPA definition: “Green building is the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building’s life-cycle from siting to design, construction, operation, maintenance, renovation, and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort. Green building is also known as a sustainable or high-performance building.”[1] In short, Green Buildings are environment-friendly, energy efficient, water efficient, produce less waste, provide better indoor environmental quality and do not harm the surrounding habitat and natural resources.
The requirement of energy resources is increasing day by due to an increase in human population and activities. Our unsustainable practices will make us run out of earth’s limited resources soon. In the US, buildings account for 39% of the total energy, 68% of electricity, 30% of landfill waste and 38% of CO2 emissions. [2]. Buildings have negative environmental impact; they disturb the natural animal habitat, emit potentially harmful atmospheric emissions, contribute to global warming, soil erosion, and landfill waste generation. Green building certifications, standards, and rating systems have been created to mitigate the environmental impact of buildings through sustainable and environment-friendly design.

Green Buildings can reduce Energy Use by 24-50%, CO2 emissions by 33-39%, Water Use by 40% and Solid Waste by up to 70%. [3]

Green buildings are the structures that use energy and resources in efficient and ecological manner during its design, built, renovation, operation, maintenance, and demolition stage. Any structure consumes energy and resources during different stages of its lifetime and has impact on environment as well. Green building term used for that structure/building which has reduced energy as well as resource consumption and energy efficient. The more efficient and more environment friendly, the more green it is. Green buildings are also known as “sustainable” and “high performance” buildings as well. Comfort, utility, durability, and economy are also taken into account in this practice. When we talk about Green Buildings, we take different important parameters into account like site sustainability, location and transportation, water efficiency, energy efficiency, material and resources, indoor environmental quality, innovation, and regional priority.

Integrative process intends to train, set objectives, motivate and spread awareness among workers involved in the construction process. The process unifies workers and engineers of different fields to work as a single team to achieve the desired objectives.

Site sustainability ensures that no pollution is created during the construction stage. It also ensures protection of the structural material of the house from external elements and deal with pests without damaging the environment. This category also tries to manage the rainwater and reduce the rise of temperature of the environment due to the building structure.

Location and transportation category protects the home from flood or any other natural disasters and protects the natural habitat, farmlands, and natural ecosystem. This category encourages to build a home near transit and community resources to reduce the environmental impact of transportation.

Water efficiency category targets indoor and outdoor water consumption reduction. Metering of water is an important part of this category. This category encourages techniques that can be used to reduce indoor and outdoor water use.

Energy and atmosphere are considered the most important category. Energy metering and educating the homeowner/tenant is mandatory. Small size is encouraged to reduce the development footprint. Hot water distribution system, solar energy, HVAC, building orientation, air infiltration, windows type/size/location, insulation, space cooling and heating equipment, lighting, appliances, and renewable energy are analyzed to ensure proper use of energy through the building and reduce wastage.

Material and resources category ensures that durable, certified, environmentally preferable construction materials are used and construction waste should be reduced and diverted from landfills.

The indoor environmental quality category is used to provide a better indoor environment and thermal comfort to the occupants by having natural air ventilation, venting of combustion gases, filtering the outside air, preventing the infiltration of tobacco smoke, control of contaminants, protection from garage pollutants and using low emitting products.

Innovation category introduces new technologies and techniques to deal with issues that are not addressed by LEED for Homes rating system.

Regional priority category encourages people to build homes in defined areas to reduce the development footprint.

1.1 Impacts of buildings on the environment

Undoubtedly, buildings and infrastructure provide us with countless benefits but on the other hand, it has significant health and environmental impacts as well. Environmental Protection Agency is working on numerous projects to mitigate the effects of buildings but this is not possible until everyone takes individual responsibility to work for a common cause. We all have observed that environment is sacrificed every time when development takes place in society. If the same practice continues, the planet would become inhabitable for the human race. During the last 100 years, a temperature rise of 0.5°C was recorded and it is further increasing at a much faster rate. There is strong evidence that the reason behind this is an increase in Green House Gas emissions which come from fossil fuels that are burned to produce energy. Out of global total energy, 45-50% is consumed in buildings [4]. Developed countries enjoy a high standard of living and are responsible for a significant portion of Green House Gas emissions. The developed countries need to enhance their energy efficiency and look for alternative renewable energy sources. Energy used in the manufacturing of building materials, during construction activities and consumed by occupants of the building throughout its lifetime contributes to a large portion of carbon dioxide. The human race cannot survive without water and 50% of water is

consumed in buildings [4]. Although 75% of the earth is covered with water but potable water is less than 3%[5]. This amount is decreasing at a fast pace due to excessive extraction of underground water sources. Water can be conserved in buildings by adopting water efficiency measures and water recycling. Development activities require materials and 60% of the total materials is consumed by buildings and roads [4]. Agricultural land is lost to build new homes and buildings to accommodate the rising population and 80% of the agricultural lands are converted to commercial and residential lands every year [4]. Wood is an essential material used in construction activities and 60% of wood including soft and hardwood is consumed in buildings [4]. Due to the high demand of wood for construction activities, forests are cut to fulfill the demand and 25% of the rain forest destruction is associated with buildings [4]. This leads to flash floods in mountainous regions and also in rivers. Construction and sewerage waste is dumped in rivers and oceans which is destroying marine life and several species have become endangered. The waste is consumed by marine life and cycles back in our food chain affecting our health. And coral reef which acts as a food source for fishes, 50% of its destruction is due to buildings [4].

Resource Consumption	(%)
Energy	45-50%
Water	50%
Materials for buildings and road (by bulk)	60%
Agricultural land loss to buildings	80
Timber products for construction	60 (90% of hardwood)
Coral reef destruction	50 (Indirect)
Rainforest destruction	50 (Indirect)

Table 1: Global resources used in buildings

Main types of pollution are air, water, and land. Other are noise and light pollution. Toxic pollution effect 200 million people worldwide. The pollution is responsible for the birth of babies with defects, loss of 30-40 IQ points and life expectancy of as low as 45 years because of different diseases like cancer, skin diseases and aging[6]. Most of the city population is affected by air pollution due to poor air quality. Development activities, buildings, and transport pollute the air. Underground drinking water and water in rivers and oceans are polluted due to industrial and sewerage waste of the cities. Out of which 40% is attributed to buildings. Construction activities produce waste 50% of the landfill waste which is attributed to buildings [4]. Soil erosion and sedimentation happen due to construction activities. Whenever there is construction activity, the health of the workers working on the site as well as people living in the surrounding is affected by the dust produced by construction activities and are a cause

of respiratory and skin diseases. Ozone is protecting the earth from harmful UV radiation of the sun but from the last few decades, due to the high rate of development and industrial activities, this layer is depleting and causing fatal diseases like skin cancer. This layer act as a protective layer for the planet and without this layer, the planet would become inhabitable for the living population. 50% of the depletion of this layer is linked with buildings because energy derived from fossil fuel for construction activities on site, contribute to Green House Gas emissions [4]. The materials that are transported from different places to the construction site also includes transportation footprint. Materials required for construction especially bricks are produced in a kiln which contributes to emissions. Materials produced in industries like tiles, cement, paints, steel requires fuel and energy to manufacture and produce harmful gases and waste which contributes to climate change and effects the health of people. Indoor pollution level can be 10 times higher than outdoor pollution levels [7]. The reason is air does not change effectively as much as outside and the paints and coatings have Volatile Organic Compounds and formaldehyde content which affects the health of the occupant and produce respiratory problems.

Pollution	%
Air quality (cities)	23
Climate change gases	50
Drinking water pollution	40
Landfill waste	50
Ozone depletion	50

Table 2: Global pollution attributed to buildings

1.2 Why Going Green is important?

Pakistan is the 7th most vulnerable country to climate change [8]. Recently the highest temperature of 50.2°C was recorded on earth in Sindh, Pakistan in the month of April 2018 [9]. The country has the highest deforestation rate in whole Asia to fulfill the demand of high rate of population. And furthermore, 29.5% of its population is below the poverty line and cannot afford to protect themselves from heatwaves [10]. This 29.5 % of the population is likely to be affected the most. Especially the labor class that works whole day under the sun. Karachi city which is the economic hub of Pakistan has 15 million population, and has only 7% of green space. The Heat Island effect is making the life of people unbearable. The country is also facing energy crisis and people are facing 8-12 hours of blackout. Serious measures need to be taken to deal with climate change and Going Green can solve many problems. Green Buildings can reduce energy use from 24-50%, CO2 emissions from 33-38%, water usage up to 40% and land waste up to 70% [3]. In the COP21 it was concluded that if the global temperature rise was not controlled under 2°C, the results could be devastating and the effects of climate change would be irreversible. It was decided that the sectors like construction, transportation and industrial sectors must reduce GHG emissions by 84 $GtCO_2$ by 2050 [11]. This could be only possible if we follow the Green Building guidelines to play our part in fighting climate change.

1.3 Current climate change mitigation actions of Pakistan

Pakistan has passed Climate Change Act in 2017 and NCCP was introduced which provided a framework for its implementation. The purpose of this act was to pursue a sustained economic growth and mitigate the effects of Climate Change. Integration of climate change policy with inter-related national policies was also part of this act. Water, food and energy insecurity which arise from the effects of Climate Change should be addressed. Risks should be minimized because of tropical storms, floods, and droughts. And conservation of natural resources and long term sustainability is also the part of this policy. Institutions are established like Directorate of Climate Change and Multilateral Environmental Agreement were established to deal with the issues. In the transport sector, the standard of fuel used is improved and the urban public transport system was built to discourage usage of individual vehicles. Projects of renewable energy like Quaid-e-Azam Solar Power Project, Wind power projects in wind corridor of Sindh were started. Hydel power plants are being built to produce clean energy and storage of water. To reduce the share of oil in the energy mix of Pakistan, LNG is imported which will reduce emissions. Afforestation projects like Billion Tress Tsunami, Green Pakistan Project have been implemented. Green Charter for cities has been introduced in Pakistan which is working of improvement in building performance during its life cycle. In the supply side, grid efficiency has been enhanced to reduce losses. Coal efficiency has been improved and Integrated Gasification Combined Cycle has been introduced in coal power plants to control the emissions. On demand side, incandescent bulbs are being replaced with LED lights. Efficient stoves and water heaters have been introduced in the market. Energy efficient air conditioners, fans, and other electric appliances have started manufacturing in Pakistan. Import ban has been imposed on CFC based refrigerants and green refrigerants are used in new manufactured air conditioners and fridges. [12]

1.4 Local Awareness and Skill Assessment

The most important part of building a structure is its design and the architect is considered as the key member of the construction team. The cost of energy efficiency and conservation can be greatly reduced just by keeping the sun path in mind and the design should be oriented in such a way that it uses passive diffuse natural lighting during the day, should block the sunlight during summer and allow the sunlight to enter in the building during winter. This is possible only when architects are aware of these practices. According to a survey carried out in Pakistan, 90% of the architects are aware of green/sustainable buildings and 47% aware of Green Building certifications because of their part of the curriculum. 56% of the homeowners are aware of the green home concept and 39% are satisfied with the energy performance of the building because they are not aware that it can be improved. In Pakistan, there is no process and organizations to train the labor and keep them updated with the new machinery and products in the construction industry which leads to inefficiency and delayed construction processes.

1.5 Sustainable Development Goals and Green Buildings

Sustainable Development Goals (SDGs) are also known as Global Goals and is a global call of action to ensure an end to poverty, protect the planet and all people

should live with peace and prosperity. These goals were first introduced in 2012 at Rio de Janeiro in United Nations Conference on Sustainable Development with the objective to have international goals that could help in protecting the planet, and deal with the economic and political challenges of the world. These goals were set to improve the human wellbeing and standard of living. These goals were based on Millennium Development Goals also known as MDGs which was an international effort of 2000 to end the poverty of people. MDGs were developed to provide primary education to all the children, end extreme poverty and measures to be taken for preventing deadly diseases.[13]

Figure 1: Sustainable Development Goals

Green buildings are closely related to some of the SDGs and play an important role in achieving them. Green buildings provide the indoor environment and improve the health and wellbeing of the people and help in achieving Good Health and Wellbeing goal. Green buildings promote renewable energy and provide cheaper energy to the occupants which are related to affordable and clean energy goal. Green building industry creates jobs in construction as well as other industries and creates jobs and helps in boosting the economy which helps in achieving Decent Work and Economic Growth goal. Green buildings are climate resilient and innovative in nature so helps in achieving Industry, Innovation, and infrastructure goal. Green buildings are a building block of sustainable communities and cities helps in achieving Sustainable Cities and Communities goal. Green buildings consume resources in an efficient manner and help in Responsible Consumption and Production goal. Green buildings are environmentally friendly and help in achieving Climate Action goal. Green buildings protect other species of the earth and promote diversity which helps in achieving Life on Land goal.

Figure 2: Green Buildings and SDGs

1.6 Benefits of Green Buildings

- Occupants of green buildings are healthier and productive
- Green building industry create jobs and helps in boosting the economy
- Using green building guidelines, we can make cities and communities sustainable
- Green buildings have fewer emissions and help in tackling climate change
- Green buildings create a strong global partnership with members of other organizations and specialties
- Green buildings use renewable energy and provide cheaper energy sources
- Green buildings bring innovation in the communities and make them resilient to climate change
- Green buildings do not waste resources and reduce the waste
- Green buildings save water resources
- Green buildings help in reducing in the deforestation rate
- Green buildings promote biodiversity and protect plant and animal species

Chapter 2

Literature Review

2.1 Green Building Rating Systems and Credentials

Green building rating systems are developed to quantify the sustainability of green buildings. This rating system was developed based on the different sustainability parameters and location. Some rating system operates in specific areas and some are international. Some are very stringent and some are easy to implement. Some rating system target few types of building types while other targets every type of building. Every rating system tries its best to make homes and building sustainable in one way or other. Well-known green building rating systems are LEED (Leadership in Energy and Environmental Design), BREEAM (Building Research Establishment's Environmental Assessment Method), NAHB (National Association of Home Builders), Green Globes, CASBEE (Comprehensive Assessment System for Built Environment Efficiency), ENERGY STAR, and Green Star. The energy rating system is explained below in detail. Every rating system has evolved with time and updated timely to increase the level of sustainability in buildings.

2.1.1 BREEAM

BREEAM was introduced in 1990. It was the first green building rating assessment introduced in the world. It is operated by BRE (Building Research Establishment) in the UK. It is also considered that another rating system which was introduced later was influenced by BREEAM. It has 8 different categories. Which are Energy having weightage of 43%, water 11%, waste 3%, pollution 6%, innovation 10%, management 12%, materials 8%, health and wellbeing 17%. The process has some design targets, wider design opportunities, procurement process, contractor requirements, and some additional measures. It is a flexible rating system and involves local codes and conditions and also permits application in international buildings. It covers new, existing, retrofitting projects. It has its own infrastructure manuals for planners, local authorities, builders, developers, and investors. BREEAM has certified 560,000 buildings until now. And the number is increasing at a faster pace. BREEAM holds 80% of the total market share of certified sustainable buildings. It was five levels of certification depending on no of points achieved which are a pass for greater or equal to 30, good for greater or equal to 45, very good for greater and equal to 55, excellent for greater or equal to 70 and outstanding for greater or equal to 85. Trained assessors assess every building and then award points according to the measures which were taken. There are also third-party assessors which assess

Figure 3: BREEAM Logo

different parameters of the building. These third-party assessors are managed by BRE. It has a different rating system for every different project type like BREEAM Courts, BREEAM Education, BREEAM Industrial, BREEAM Healthcare, BREEAM Offices, BREEAM Retail, BREEAM Prisons, and BREEAM Multi-residential. [14]

2.1.2 NAHB rating system

NAHB was introduced in 2008. It has an online scoring tool. Over 100,000 green homes were built and certified by NAHB members. More than 30 state and local programs have been established based on green guidelines of NAHB. NAHB focuses on 7 categories which are also known as guiding principles. These are Lot design, preparation and development, resource efficiency, water efficiency, energy efficiency, indoor environmental quality, and owner education. This rating system is only for new homes. No project registration is required in this rating system. First online scoring tool is used to see the performance of house then assessors verify the measures taken on site and then certification is awarded. It has 3 tiers of certification bronze, silver, and gold. [15]

Figure 4: NAHB Logo

2.1.3 Green Globes rating system

Green Globes was first developed in Canada using BREEAM as a starting point. The development process for new construction started in 1996 and completed in 2002. For an existing building, it was developed in 2004 which is known as Go Green Plus. The building can earn up to 1000 points in 7 categories. In which energy has 300 points, indoor environment 160 points, resources/materials 145 points, water 130 points, site 120 points, project management 100 points and emissions 45 points. There are 4 tiers of certification which are one globe for achieving 35 to 54 points, two globes for 55 to 69 points, three globes for 70 to 84 points and four globes for 85 to 100 points. Although 1000 points are available in Green Globes rating system but levels are determined by percentages of each category. [16]

Figure 5: Green Globes

2.1.4 CASBEE rating system

Comprehensive Assessment System for Built Environment is a rating system that evaluates the building performance, environmental performance, and built environment. It was established in 2001 through the collaboration of industry, academia, and government. It was established for Japan by Sustainable Building Consortium by Ministry of Land, Infrastructure, Transport, and Tourism. It is a rating system which can be

Figure 6: CASBEE Logo

applied from a single home to the whole city. It was designed to improve the health of people and reduce the environmental burden due to the built environment. It has different tiers of certification. For evaluation two variables built environment quality and built environment load are taken into consideration and the graph is plotted. The slope of the graph is considered as Built Environment Efficiency (BEE). Depending on the BEE value, level of certification is awarded like C for poor with BEE value less than 0.5, B for fairly poor with BEE value ranges from 0.5-1 B+ for good with BEE value range from 1.0-1.5, A for very good with BEE value 1.5-3.0 and S for excellent with BEE value 3.0 or more. In the same way, stars are awarded from 1 to 5 according to these levels. Every site is assessed by design and management team. Third part agencies like JSBC (Japan Sustainable Building Consortium) are also part of this rating system. Different CASBEE rating system is developed for different project types like Pre-design, new construction, existing building, and renovation. [17]

2.1.5 ENERGY STAR rating system

ENERGY STAR was introduced by the Environmental Protection Agency in 1990. It was first introduced for energy-efficient computers but later this rating system was extended to 65 product categories. In 1995 ENERGY STAR for homes was developed and agreements were signed with the U.S Department of Energy to implement it on the national level. 88% of the US homebuilders use this rating system. These homes are 15-30% energy efficient. In 2016, 79,000 houses were retrofitted and the website visits were recorded as 8 million. In 2015 the saving of $360M was recorded by implementing the ENERGY STAR rating system.[18]

Figure 7: ENERGY STAR Logo

2.1.6 Green Star rating system

Green Star was launched by Australia in 2003 by Green Building Council. It is the only national level rating system. It is available for every building type. The categories of Green Star are management indoor, environment, quality, energy transport; water materials land use and ecology, emissions and innovation. It assesses the building at all stages of the building's lifecycle. Projects of type design, built, interiors and community can

Figure 8: Green Star logo

achieve certification of 4-6 stars. While buildings using Green Star performance rating tool can achieve a rating from 1-6 stars.

Figure 9: Green Star Rating System

2.1.7 Green Buildings Standards and Products Certifications

Standards related to green buildings are developed such as ANSI, ASHRAE, and ASTM. ANSI/ASHRAE/USGBC/IES Standard 189.1, *Standard for the Design of High-Performance Green Buildings except Low-Rise Residential Building* provides mandatory requirements and building codes during site selection, design, construction and operation, and maintenance stage. These standards have different categories of water efficiency, energy efficiency, indoor environment quality, materials and resources during construction and operations of the buildings.

Certified Green Products which have a minimal environmental impact are an important part of Green Buildings. Green Products certification systems include Energy Star developed by U.S.EPA and DOE is for energy-consuming products, WaterSense labeling for water-efficient products like showerheads, toilets, faucets, urinals, and valves was developed by U.S.EPA, Forest Stewardship Council for the certification of forests and forestry products. Scientific Certification Systems (SCS) Global Services is a third-party certification system which certifies products based on formaldehyde content, biodegradable and recycled products. It includes a wide range of products like carpets, textiles, wood products, insulation and more. Green Seals certify products like windows, window films, adhesives, paints, lamps, and electric chillers. Other certifications include Cradle to Cradle which certifies building materials, interior design products, and homecare products, Green Guard certify indoor air quality products and Green Squared verify tiles and tile installations.[19]

2.1.8 LEED

LEED stands for Leadership in Energy and Environmental Design is designed by U.S Green Building Council in 1998. It is an international standard for green buildings and countries like Canada, Australia, and Hong Kong have developed their own version of LEED. It provides guidelines which make buildings healthier for human beings, highly efficient and cost saving. Until now 94000 projects are using LEED and 2.4 million square feet area has been certified. It is operating in 165 countries. Different rating systems are developed for different

project type. LEED BD+C (Building Design and Construction) for new construction. ID+C for interior fit-outs. O+M for building operations and maintenance, ND for new land development projects. LEED homes apply to a single story and low rise up to 3 stories multifamily homes. [20]

2.1.8.1 LEED for Homes

LEED for Homes rating system is developed specially for home design and construction. Single-family homes and multifamily buildings up to 3 stories are eligible for this certification. Midrise multifamily buildings of four or more stories can also be certified using LEED for Homes rating system. LEED homes are healthy, consume less energy and water, conserve natural resources and provide clean indoor air quality to the occupants. LEED certified homes have better market value and sell quicker compared to other houses.[20]

2.1.8.1.1 LEED for Homes Certification Process

1. The first step to certify a home is to **register.** Visit LEED online and check the minimum program requirements to confirm the eligibility of the project. The project is registered online; relevant information is entered and payment is made.
2. The second step in **verification.** Every milestone and measure taken on the site is verified on site to check the performance of each measure. Green rater performs the verification at the pre-drywall and final construction phase.
3. The third step is the **review** step, all the necessary information, calculations, forms, and documentation is completed and submitted to the Green Rater. GBCI reviews the application.
4. The last step in **certification.** After the Green rater performs onsite inspections, they review the documentation of the project and submit it to the GBCI. After reviewing the application, the project is awarded certification or denied. The project team is notified.

2.1.8.1.2 Costs of Certification

The registration fee for homes 1-25 is $150 for silver, gold and platinum level members while for organizational or non-members are $225. And for homes more than 25, the registration fee for members is $50 while non-members are charged $125. Certification fee of one home for members is $225 while $300 for non-members. Appeals are charged for $175 per project. Project CIRs which are also known as formal inquiries are charged as $220 per credit. The registration fee of the multifamily building is $900. Certification fee of 0-49 units of multifamily buildings is 0.035 per square feet for members and $0.045 per square feet for non-members. For more than 50 units of the multifamily building, $0.030 per square feet is charged from members and $0.040 per square feet from non-members. Appeals of the multifamily building for complex credits are $800 per credit and for simple credit, it is $500. CIRs are charged for $220 per credit. [20]

2.1.9 Home Construction Process in Pakistan

Home construction process in Pakistan is different from other countries. A client first buys in a certain plot in any area. Then finds an architect and discuss his requirements. He first makes the first proposal and discusses with the client. The client tells him the changes and the architect make amendments until all the requirements of the clients are met. During the design stage, the architect is responsible for following all the local and national building codes relevant to that specific area. After the design stage is complete, the client finds a home builder and set the terms and conditions of the construction. The contract is signed between the client and the home builder. The contract is of different types and depends on the convenience of the builder and client. The client applies for electricity connection which takes about two weeks to process. The client also applies for the natural gas connection and it takes up to 6 months for the department to process. The construction is started and the client makes payments to the home builder every Thursday. In Pakistan, Friday is an off day for the labors and they are paid on weekly basis on every Thursday. When the construction is completed, the home builder and client take measurements of the work done and the rest of the payment is made to the home builder by the client.

Chapter 3

Methodology

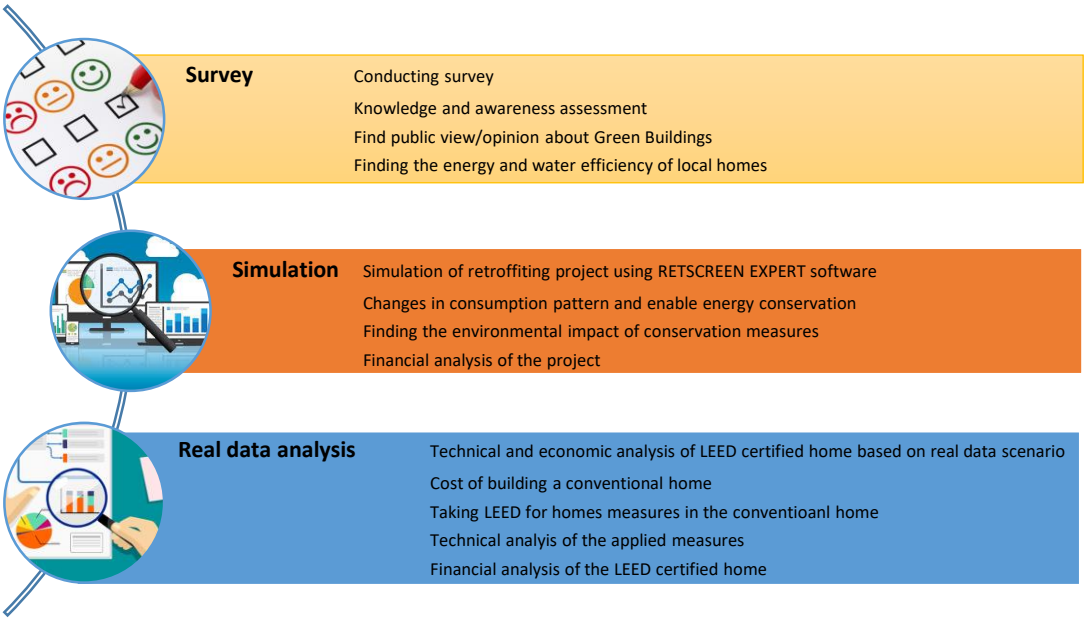


Figure 10: Research Methodology

3.1 Research Approach

This research work has three parts, after a detailed review of the LEED for Homes rating system, it was important to find out the current situation of the construction industry of Pakistan. There was also no data available about the construction industry of the country so data collection was very important to find out where do we stand currently in terms of sustainability

3.1.1 Survey

For this purpose, the stakeholders of the construction industry were divided into 7 categories. Categories are homeowner/client who built home for his own requirement of family, home builder is a person who deals in building homes, general public are common people who are occupants of the houses, home investors are people who invest in homes construction for profit purposes, government officials are people who work for the government in organizations like utility companies and energy-related organizations, architect are specialist people who design homes, material supplier are those people who supply materials to the construction sites.

For the development of the survey forms, it was important to do detailed research on the difference between conventional home in Pakistan and LEED certified home. For this purpose, detailed research was conducted on LEED for Homes rating system and then compared with the homes built conventionally. The differences between conventional home and LEED certified home were compiled. The differences were distributed into the group of the stakeholders

involved in the construction industry. The seven types of surveys were conducted from people living in major cities of Pakistan.

3.1.1.1 Sampling method

For the determination of sample size of the survey, the population data of the major cities of Pakistan which are Karachi, Lahore, Rawalpindi, Peshawar, and Islamabad were taken into consideration. Online available calculators were used to find the sample size which came out to be 165. The survey results give an idea of the level of awareness of the stakeholders involved in the construction industry of Pakistan. It also identified the perception, public opinion, view and thinking of people regarding sustainability and conservation measures. The results of the survey are discussed in a later section of this thesis.

3.2 Simulation of the retrofitting project

After the survey, simulation of the high-performance home was done using RETSCREEN Expert software. The simulation included retrofitting actions of converting the conventional home into the high-performance home. Change of appliances like lights, air conditioning equipment, space heating, water heating equipment, installation of sustainable features and installation of renewable energy generation plant on the rooftop was considered in the simulation. Simulation results showed the reduced CO_2 emissions, NPV, IRR, payback period and economic feasibility of the project. Many of the LEED for homes measures were not included in the simulation because of the limitation of the software.

3.3 Comparison of conventional and LEED certified home

To do the technical and economic analysis of all LEED for homes features, due to the unavailability of the software, the manual method was used for the analysis. For this purpose, real data of a newly built multifamily home in Peshawar, Pakistan was considered. The cost of construction from design to finishing stage was considered. Then the cost of measures of LEED for homes was included in the calculation and found the incremental cost of LEED-certified home in Pakistan. The challenges and limitation associated with their construction. The technical and economic barriers were analyzed in the analysis.

Chapter 4

Simulation of High-Performance Home by RETScreen Expert

4.1 Simulation data

A simulation of the retrofitting project is carried out by RETScreen Expert to evaluate the performance, environmental impact and feasibility of the project including all the parameters and techno-economic analysis is done. The site for the project was selected in Islamabad region of Pakistan which has covered an area of 1900sq feet and situated in 2A- Hot-Humid Climate Zone and 502m elevation. The humidity of the region ranges between 42% - 75%. Daily solar radiation ranges from 2kWh/m^2/d and the wind speed ranges from 1.5 to 3.9m/s. This concludes that wind power is not feasible but the solar project is feasible in the region. The target of 15% was set to reduce 15,200kWh to 12,920kWh and saving 2,280kWh annually. 5 air conditioners are replaced with inverter/energy efficient air conditioners, R13 insulation is installed on all walls, energy efficient windows are installed, facades are installed on south and west sides, plywood door is replaced with solid wooden doors. Lights are replaced with LED lights, fans, laptops; clothes washer, TV and dryer are replaced with ENERGY STAR rated. The photovoltaic system of 5KW and solar water heater of 75 liters storage capacity is installed on the site.

Information of site	
Location	Islamabad, Pakistan
Area	1900 Sq.feet
Type	Detached dwelling/Single family home
Climate Zone	2A- Hot-Humid
Humidity	42-75%
Daily solar radiation	2KWh/m^2/d
Wind speed	1.5-3.9 m/s
Bedrooms + bathrooms	4
Kitchen	1
Living area	2
Car porch	1

Table 3: RETSCREEN Expert Project Information

Target

Summary

	Fuel consumption kWh	Fuel cost $	GHG emission tCO_2
Base case	57,407	5,500	22.7
Proposed case	4,469	1,125	3.4
Savings	52,938	4,375	19.3
%	92.2%	79.5%	84.9%

Figure 11: Proposed target of retrofitting project

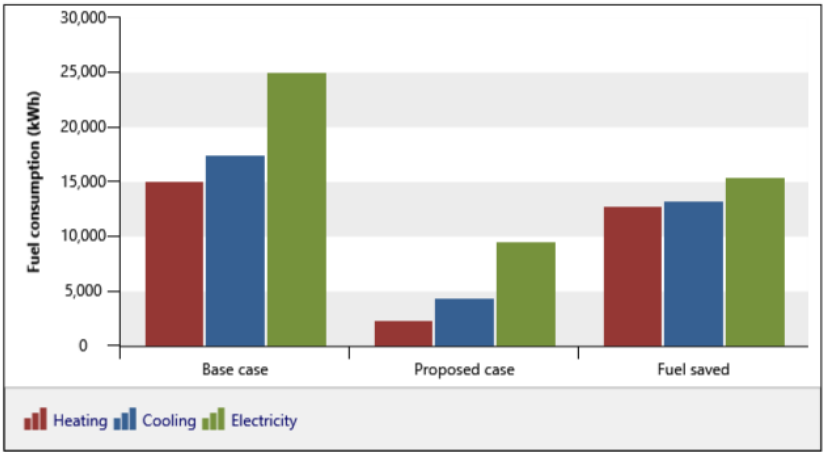


Figure 12: Proposed target of retrofitting project

Fuel consumption	Heating kWh	Cooling kWh	Electricity kWh	Total kWh
Base case	15,036	17,461	24,910	57,407
Proposed case	2,287	4,291	9,495	16,073
Fuel saved	12,749	13,170	15,414	41,334
Fuel saved - percent	84.8%	75.4%	61.9%	72%

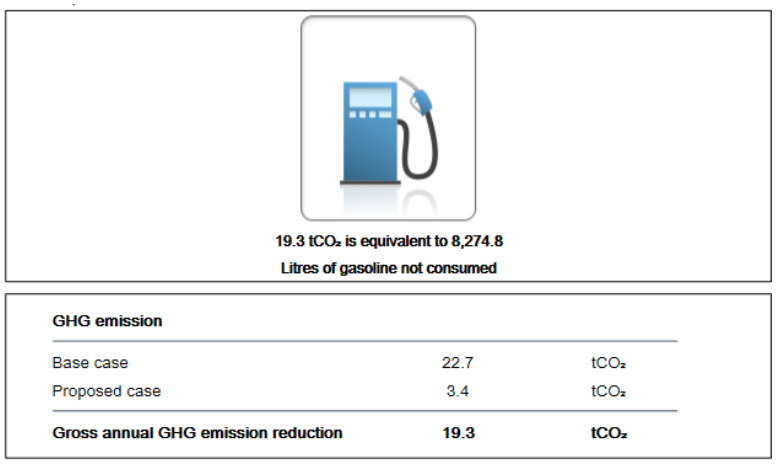
Figure 13: Proposed target of retrofitting project

4.1.1 Results

The results show that 18.6% savings in space cooling loads, 16.9% savings in space heating loads. These retrofitting with cost $30,305.

4.1.2 Environmental Impact

Base case energy mix analysis shows that 73.8% of total energy consumption is electricity and 26.2% is gas. Electricity and gas are responsible for 20 tons and 2.7 tons of CO_2 annual emissions respectively. In the proposed case energy mix 47.5% is electricity and -23.8% is gas. This was also noted that in the proposed case electricity CO_2 emissions can be reduced to 4.2 tons and gas emissions to -0.8 tons annually. Electricity is a dominant factor responsible for CO_2 emissions in both cases. After the retrofitting project, the GHG emissions can be reduced by 85%. Before the retrofitting project implementation, the site was responsible for producing 22.7 tons of CO_2 and the proposed case was to reduce this figure to 3.4 tons to save 19.3 tons of CO_2 annually. This is equivalent to saving 8274.8 liters of gasoline every year.



GHG emission		
Base case	22.7	tCO₂
Proposed case	3.4	tCO₂
Gross annual GHG emission reduction	**19.3**	**tCO₂**

Figure 14: GHG emissions in base case and proposed case

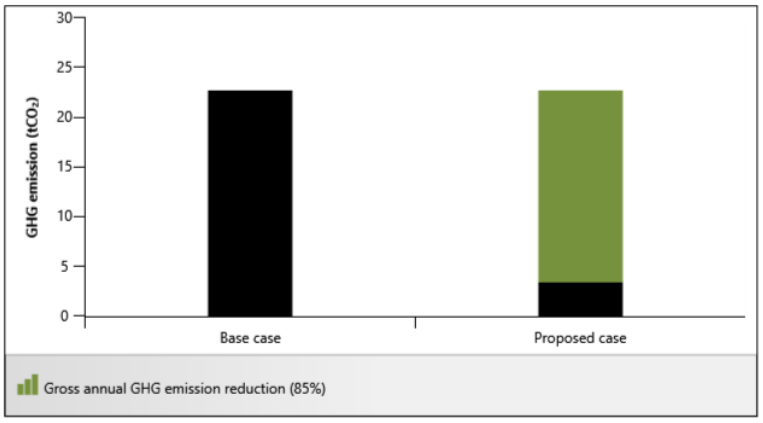


Figure 15: GHG emissions in base case and proposed case

4.1.3 Financial and Risk Analysis

This retrofitting project will cost $34,305 initial costs. But $815 can be saved in a form of operation and maintenance costs annually because of the reduction in energy use and fuel saving. In the proposed case, annual fuel costs will be $1125. And the loan of total $24,014 is taken at fuel cost escalation rate of 2%, 9% discount rate, 5% inflation rate, a debt ratio of 70%, a debt interest rate of 7%, our debt payments will be $2637/year. Total annual costs combining fuel and debt payments are $2947/year. The debt term is 15 years and the debt interest rate is 7%. Although the project life is more than 15 years but even if it is considered 15 years, the benefits are quite convincing. This project will have a simple payback period of 6.6 years, equity payback is 3.6 years and cost-benefit ratio of 2.7. Total annual savings will be $5500.

General		
Fuel cost escalation rate	%	2%
Inflation rate	%	5%
Discount rate	%	9%
Reinvestment rate	%	9%
Project life	yr	15
Finance		
Debt ratio	%	70%
Debt	$	24,014
Equity	$	10,292
Debt interest rate	%	7%
Debt term	yr	15
Debt payments	$/yr	2,637

Figure 16: Financial parameters of the project

Initial costs			
Incremental initial costs	100%	$	34,305
Total initial costs	**100%**	**$**	**34,305**
Annual costs and debt payments			
O&M costs (savings)		$	-815
Fuel cost - proposed case		$	1,125
Debt payments - 15 yrs		$	2,637
Total annual costs		**$**	**2,947**
Annual savings and revenue			
Fuel cost - base case		$	5,500
Total annual savings and revenue		**$**	**5,500**

Figure 17: Costs, Savings, and Revenue

Financial viability		
Pre-tax IRR - equity	%	29.7%
Pre-tax MIRR - equity	%	16.6%
Pre-tax IRR - assets	%	6.1%
Pre-tax MIRR - assets	%	7.6%
Simple payback	yr	6.6
Equity payback	yr	3.6
Net Present Value (NPV)	$	17,831
Annual life cycle savings	$/yr	2,212
Benefit-Cost (B-C) ratio		2.7
Debt service coverage		2
GHG reduction cost	$/tCO$_2$	-115

Figure 18: Financial viability of retrofitting project

Taking all the financial parameters into account, risk analysis has been done by Net Present Value. If the specified values range between 25%, the level of risk is 10% and the median NPV of this project is $17,555.

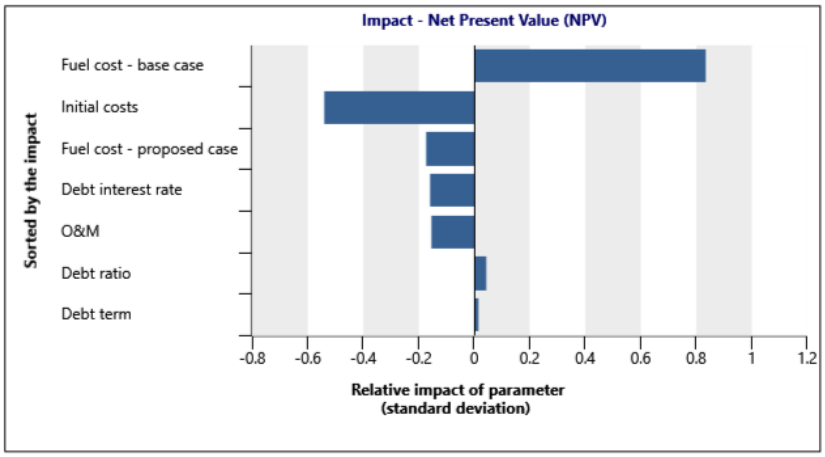


Figure 19: Impact – Net Present Value (NPV)

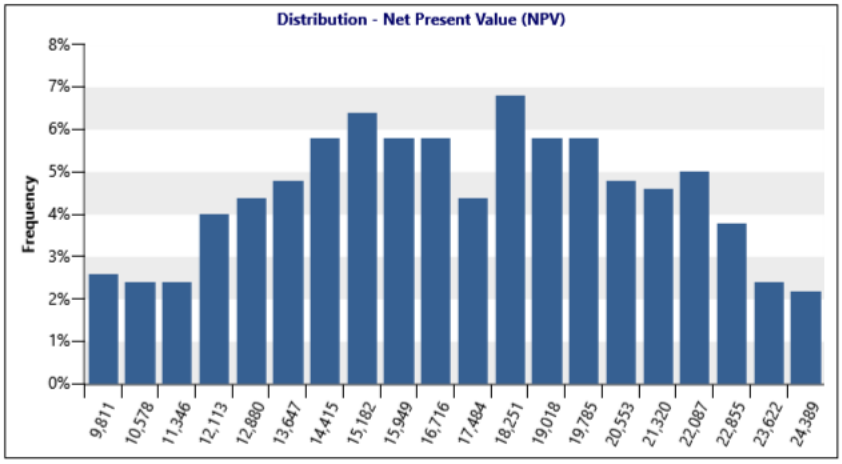


Figure 20: Distribution – Net Present Value (NPV)

Chapter 5

Results and Conclusion

5.1 Survey results and analysis

5.1.1 Awareness of LEED Certification in Pakistan

This study reveals that only 46.5% of the architects know about LEED certification. They interact with the client directly and can be a source of motivation and encouragement for the client to build Green Home. Only 33.3% of Material suppliers know about LEED certification. Suppliers of products like insulation, heat reflectors, heating and cooling equipment, renewable energy service providers, structural material providers, glass providers should have known about Green Building certifications.

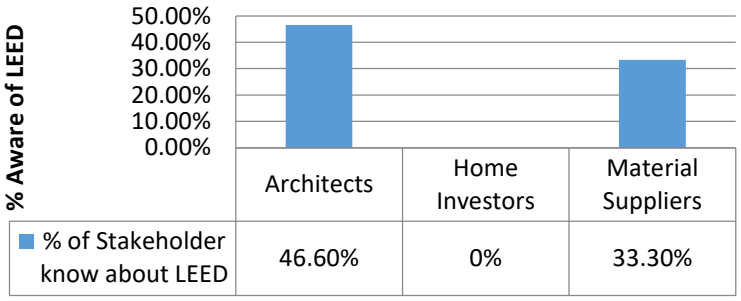


Figure 21: Knowledge of Stakeholders about LEED

5.1.2 Integrative Process

Integrative Process has 2 points. It ensures the distribution of knowledge and education about Green Buildings and LEED rating system which lacks in our construction industry in Pakistan. It is evident from figure 2 in Pakistan that 90% of architects know about Green/Sustainable Buildings due to part of their curriculum during university. There is little or no awareness about Green Buildings in Homebuilders, Home Investors, Home Owners, and Material Suppliers. There is no process of knowledge sharing and integrated team concept in Pakistan and the people mostly get information from social media, print media and the internet.

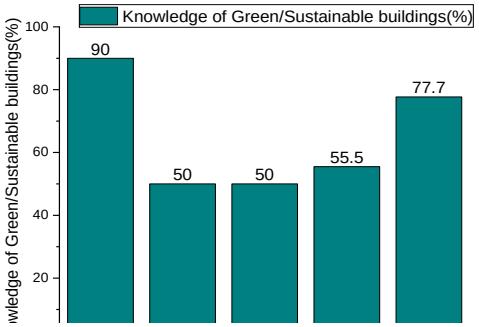


Figure 22: Knowledge of Stakeholders about Green Buildings

5.1.3 *Location, Transportation and Site Sustainability*

LEEDv4 has 15 points in location and transportation section including 1 prerequisite and 7 points in Site Sustainability including 2 prerequisites. 84.4% of the homeowners look for parks, community resources, and public transport. 83.7% of ..homeowners prefer local products rather than imported products.

Type of vegetation in a home affect the water consumption and thus native plants should be preferred over invasive and exotic plants. Results showed that 52.2% of the Home Owners have native plants at home as shown in figure 3.

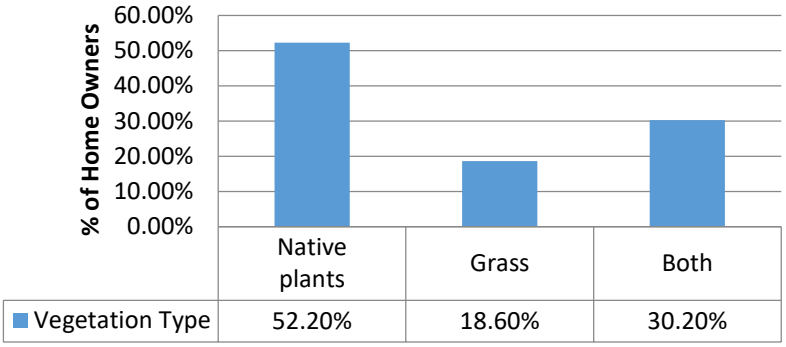


Figure 23: Vegetation preference of Home Owners

5.1.4 Water Efficiency

Water is a very precious resource and LEED certified homes are designed to be water efficient. In LEED Homes, outdoor and indoor water metering is done to utilize every opportunity to conserve water. Water Efficiency category in LEED Homes carries 12 points. Surveys results show that 78% of the general public is aware of water conservation measures. Unfortunately, the prices of the water efficient products are extremely high and most of the people cannot afford it. They look at the capital cost and ignore saving associated with the products.

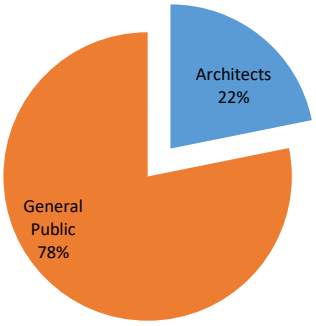


Figure 24: Awareness of Water Efficiency

Despite the fact that Pakistan has the best irrigation system in the world, it is still a water scarce country. And the country is expected to be severely affected by climate change in the next few years which will make the problem worse.

Green Buildings can reduce water usage by up to 40%. In Pakistan 32% of the people are unaware of the water efficiency in our homes and buildings, people like to prefer quality, design, and cost while buying sanitary products and are not concerned about water efficiency. On the other hand, 81% of architects are also unaware of the WaterSense labeled products. The architects and interior designers should consider WaterSense and water-efficient products in their design to spread awareness of water efficiency in the country.

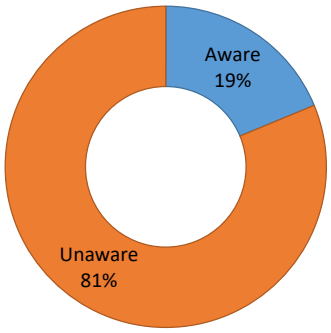


Figure 25: WaterSense Labeling Awareness of Architects

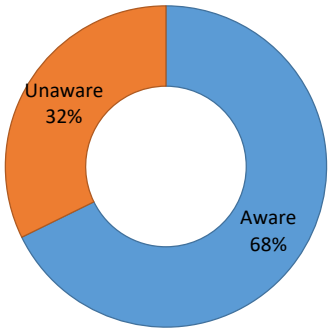


Figure 26: Water Efficiency Awareness in General Public

5.1.5 Energy and Atmosphere

Energy and Atmosphere are the important section of LEEDv4 Homes has 38 points and 4 prerequisites. For a home to be energy efficient, its design should be supportive and the architect should know about the energy efficient design. Unfortunately, only 40% of the architects have designed Green Home in Pakistan and 40% of the architects are aware of ENERGY STAR rated products.

The retrofitting process of incandescent lighting to LED lighting is on its way and 42% of the homeowners use LED lights 58% incandescent lights. Due to the fall of prices of LED lighting in the Chinese market, the trend of lighting has been shifted to LED by the home builders.

5.1.6 Material, Resources and Indoor Environment Quality

Material and resources section has 10 and indoor environment quality has 16 points in LEEDv4. Pakistan has the highest deforestation rate in South Asia and forests cover only 2% by area because 35% of the people prefer pure wood rather than composite material in construction.

More than half of the population of Pakistan lives in rural areas and they use wood and biowaste for cooking and heating purposes due to non-availability of natural gas. The results showed that 28.8% of the people use fire stove inside their rooms which is harmful to health and could cause deaths.

5.1.7 Innovation

There are six points in the Innovation category which are awarded for the use of innovative solutions to solve the problems not discussed in LEED. The use of smart sensors and appliances ensure the efficient use of energy and water. 41% of the Home Builders know about smart sensors and appliances because of prior experience in projects. However, there is no awareness of smart sensors and appliances in the General Public.

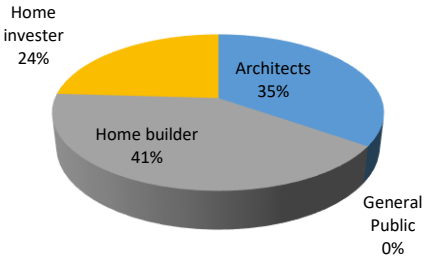


Figure 27: Knowledge of Stakeholders about Smart Sensors and Appliances

5.2 Comparison of costs related to LEED and conventional home

For the comparison of the costs involved in building a LEED-certified home in Pakistan, we took a newly built multifamily low-rise home building located in Peshawar. The covered area of the project is 10,000sq feet. Land costs are not included in the calculation because it varies with respect to the location of the site. The land transfer fee was also not considered because it varies with respect to local rules and government. The architect took Rs 45,000/- to design the house which included, layouts, electrical, plumbing, public health, steel structure, and 3D design. Development charges of Rs 30,000/- were paid to the Peshawar Development Authority. Electricity connection cost Rs 15,000/- and took 2 weeks to get a meter installed from PESCO. Gas connection charges of Rs 15,000/- were paid to Sui Northern Gas Pipeline Limited (SNGPL). Water connection charges of Rs 15,000/- were paid to Peshawar Development Authority.

5.2.1 LEED rating system

LEED for Homes rating system has a total 110 points. A project that achieves 40-49, 50-59, 60-79, 80+ points are Certified, Silver, Gold, and Platinum certified. These points are distributed in 9 categories which are the Integrative Process, Location and Transportation, Sustainable Sites, Water Efficiency, Energy and Atmosphere, Material and Resources, Indoor Environmental Quality, Innovation, and Regional Priority. Every category has its own prerequisites which are mandatory to fulfill and credits which are optional measures. Each category is explained below in detail.

5.2.1.1 Integrative Process

Integrative Process category has 2 points. The intent of this category is to have an integrative approach in building a LEED home and should be cost-effective. There are 3 options to achieve these 3 credits.

First is to have an integrative project team during construction which could include architect, energy engineer, green building specialist, civil engineer, landscape engineer and planning engineer. 3 of these members should be part of a project team to get 1 point. These specialists should be present at least 3 stages of the construction. Civil engineer, architect are already part of the construction team and the cost of hiring energy engineer is included which is about Rs 40,000/-.

The second option is Design Charrette which is conducting one full day workshop or two half-day workshops with the project team so that project teams are aware of the green strategies which need to be incorporated to get the credit. Rs 10,000/- are considered to arrange this workshop. 1 point can be achieved by arranging this workshop.

The third option is Trades Training which has 1 point. Trades include plumbing, mechanical systems, insulation, and electrical work. When people are hired for these works, 8 hours of training should be arranged for them to inform them about the green aspects of the building and how are they related to LEED prerequisites and credits. The cost of this training was part of Design Charrette.

5.2.1.2 Location and transportation

5.2.1.2.1 Prerequisite: Floodplain Avoidance

Location and Transportation section has one prerequisite Floodplain Avoidance. A house should not be built in flood hazard zones defined by EPA or regional organization. If it is built legally designated to be designed and built in flood zone must have flood provisions. Flood hazard is available for Pakistan and can be used to identify the areas and this prerequisite could be met.

5.2.1.2.2 Credit: LEED for Neighborhood Development

LEED for Neighborhood Development has 15 points for homes and midrise buildings with the intention that homes are built in LEED for Neighborhood Development certified communities. Unfortunately, there isn't any community which has received LEED-ND certification and this credit is unable to achieve in Pakistan.

5.2.1.2.3 Credit: Site Selection

This credit has 8 points and available for homes and midrise buildings. This credit intends to build homes in areas which are previously developed and usage of sensitive land should be reduced. Option 1 is sensitive land protection having 3-4 points. If the area is more than 75% developed, 4 points are achieved. If the house is not built on prime farmland, parkland, wetlands, and other sensitive areas, 3 points are achieved. Option 2 is infill

development having 2 points is meant to build a home in the previously developed area. Option 3 is an open space which has 1 point. This credit can be claimed if there is an open space of 3/4acre within 800 meters of the site. Option 4 is a street network, if there are 90 intersections within 400meters radius of the site, 1 point can be achieved. Option 5 is bicycle network and storage which requires to have a bicycle network within 180 meters if the site. These measures do not have any costs and can be achieved during the selection of the site.

5.2.1.2.4 Credit: Compact Development

This credit has 3 points and can be achieved if there are more than 7 dwelling units per acre 1 point is awarded if more than 12 dwelling units/acre 2 points are awarded and if there are more than 20 dwellings/acre 3 points are awarded. This credit can be met by selecting a site in the existing developed area.

Single-family and low-rise multifamily projects		Midrise multifamily projects		Points
DU/acre of buildable land	DU/hectare of buildable land	DU/acre of buildable land	DU/hectare of buildable land	
≥ 7	≥ 17	≥ 30	≥ 74	1
≥ 12	≥ 30	≥ 55	≥ 136	2
≥ 20	≥ 50	≥ 80	≥ 198	3

DU = dwelling units

Table 4: Points for housing density

5.2.1.2.5 Credit: Community Resources

This credit has 2 points and intents to have more community resources in the neighborhood of site. Community resources include supermarket, banks, gym, laundry, café, restaurant, childcare, offices, post office, food store, clothing store, farmers market, hardware store, pharmacy etc. If the site has 4-7 uses, 1 point is awarded. If there are 8-11 uses, 1.5 points are awarded and 2 points are awarded if more than 12 resources are in the neighborhood. This measure does not cost anything and can be achieved during site selection. The site should be in the city where these resources are available.

Uses	Points
4–7	1
8–11	1.5
≥ 12	2

Table 5: Points for proximity to uses

5.2.1.2.6 Credit: Access to Transit

This credit has 2 points with the intention to reduce pollution and land development effects from use of personal cars. The project should be within 400 meters of a bus stop or streetcar stop. If the bus trips are 72 per day, 1 point is awarded, if 144, 1.5 points are awarded and for 360 trips per day, 2 points are awarded. If the project is near to rail or ferry service. For 24, 40, 60 daily trips, 1, 1.5 and 2 points are awarded. This credit does not cost anything and can be achieved during the site selection stage.

Weekday trips	Weekend trips	Points
72	40	1
144	108	1.5
360	216	2

Table 6: Minimum daily transit service for projects with multiple transit types (bus, streetcar, rail, or ferry)

Weekday trips	Points
24	1
40	1.5
60	2

Table 7: Minimum daily transit service for projects with commuter rail or ferry service only

5.2.1.3 Sustainable Sites

5.2.1.3.1 Prerequisite: Construction Activity Pollution Prevention

The intention of this prerequisite is to reduce the pollution which is caused by the materials present on site. An amount of Rs 20,000/- is specified to prevent air pollution because of the materials on site by covering the materials with plastic sheets and stockpile every material.

5.2.1.3.2 Prerequisite: No Invasive Plants

Invasive species are species that could harm the home or other plants. This measure does not cost anything and can be implemented easily.

5.2.1.3.3 Credit: Heat Island Reduction:

This credit has 2 points which intended to reduce the heating effects of the buildings on the environment because of their heat absorbing properties. This effect can be reduced by using non-absorptive materials on site. If 50-75% of the area is shaded or used non-absorptive material, 1 point is awarded and for more than 75%, 2 points are awarded. There are ENERGY STAR rated products having high Solar Reflectance. A cost of Rs 450,000/-

is included in this study for solar reflective paints done on roof and walls on all side walls of the site.

Percentage	Points
50–64%	1
65–79%	2
≥ 80%	3

Table 8: Points for percentage area with shading or non absorptive material

5.2.1.3.4 Credit: Rainwater Management

This credit has 3 points with the intention to reduce the rainwater runoff volume from the site. If 50-64%, 65-79% and >80% of the area is a permeable area, 1, 2 and 3 points are awarded respectively. Rs 30,000/- are assigned for this measure to divert the rainwater from the roof, design and build an underground rainwater tank for storage.

Percentage of hardscape area	Points
50–75%	1
> 75%	2

Table 9: Points for permeable area, as percentage of total lot area

5.2.1.3.5 Credit: Nontoxic Pest Control

This credit has 2 points with the intention to deal with the pests with the safest way possible. Each measure has 0.5 points. Measures include installing mesh barrier for termite control, post tension slabs, treat all wood, discharge pipes, having 18inch space between plantation and exterior wall. Rs 50,000/- are assigned for these tasks in this case study.

5.2.1.4 Water Efficiency

5.2.1.4.1 Prerequisite: Water Metering

Water metering is a mandatory requirement of LEED home. The objective is to monitor the water consumption pattern and usage of the site. For a single home, one meter can be installed. For multifamily building, one meter can be installed for the whole building or different submeters can be installed for each unit. Rs 15,000/- are assigned to install a water meter on the site.

5.2.1.4.2 Credit: Total Water Use

This credit has 12 points with the intention to reduce the water consumption of the site by high-efficiency fixtures and intelligent outdoor water use techniques. The baseline is set to measure consumption. For shower it is 2.5gpm, for lavatory and kitchen it is 2.2gpm, for toilet it is 1.6gpm, for dishwasher it is 6.5gpm. Water usage can be calculated by a water usage calculator. For 105, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 points are awarded. Rs 20,000/-

are assigned to get 5 points and Rs 40,000/- for getting 9 points for this credit.

Fixture	Baseline flush or flow rate		Estimated fixture usage	Estimated water usage	
Shower (per compartment)	2.5 gpm	9.5 lpm	6.15 minutes	15.4 gallons	58.4 liters
Lavatory, kitchen faucet	2.2 gpm	8.3 lpm	5.0 minutes	11 gallons	41.5 liters
Toilet	1.6 gpf	6 lpf	5.05 flushes	8 gallons	30.3 liters
Clothes washer	9.5 WF	9.5 WF	0.37 cycles @ 3.5 ft^3 (@0.1 m^3)	15.1 gallons	57.1 liters
Dishwasher	6.5 gpc	24 lpc	0.1 cycles	0.7 gallons	2.4 liters

gpm = gallons per minute
gpf = gallons per flush
WF = water factor
gpc = gallons per cycle
lpf = liters per flush
lpm = liters per minute
lpc = liters per cycle

Table 10: Indoor water baseline consumption (per person per day)

5.2.1.4.3 Credit Indoor Water Use

This credit has 6 points. Faucets, showerheads, toilet fixture should have WaterSense aerator to get 2, 2, 2 points respectively. Clothes washer should be ENERGY STAR and 1 point can be achieved for it. Rs 30,000/-, Rs 50,000/-, Rs 60,000/- are assigned for installation of aerators, water efficient toilet fixture, ENERGY STAR clothes washer respectively.

5.2.1.4.4 Credit Outdoor Water Use

This credit has 4 points. The more native plants area, the more points can be earned and usage of turf grass is discouraged.

Turf grass area		Native or adapted plant area	Points
< 60%	and	> 25%	1
< 40%	and	> 50%	2
< 20%	and	> 75%	3
< 5%	and	> 75%	4

Table 11: Points for reducing turf grass and increasing native plantings, as percentage of total landscape area

Percentage reduction	Points
10%	1
15%	2
20%	3
25%	4
30%	5
35%	6
40%	7
45%	8
50%	9
55%	10
60%	11
65%	12

Table 12: Points for reducing indoor and outdoor water use

5.2.1.5 Energy and Atmosphere

5.2.1.5.1 Prerequisite: Minimum Energy Performance

The intention of this prerequisite is to reduce the energy consumption and greenhouse gas emissions of the site. The house or building must meet all the requirements of ENERGY STAR for homes version 3. HERS rating should equal or more than limits of ENERGY STAR. The site should also have at least one appliance ENERGY STAR certified which includes refrigerator, dishwasher or clothes washer. Slab insulation is strongly recommended but not required.

For midrise building whole building energy simulation should be done and demonstration of 5% improvement over the baseline building performance rating. For multifamily buildings, the commissioning should be done by ENERGY STAR protocols. The checklist of ENERGY STAR is available online and can be downloaded and measures can be taken accordingly.

5.2.1.5.2 Prerequisite: Energy Metering

The purpose of this prerequisite is to have energy data so that proper energy saving and conservation measures could be taken. This prerequisite requires the home to have one whole house electric and gas meter installed. If this multifamily building, there can be one whole building energy meter or sub-meters for every unit. In this case study, the costs of these meters are considered.

5.2.1.5.3 Prerequisite: Education to Homeowner, Tenant or Building Manager

Behaviors of occupants are related to the sustainability of the site. This prerequisite intends to train the occupants regarding operation and maintenance of LEED features and sustainability. This measure requires

signing accountability form from the occupants. A manual should be printed or CD should be given to the occupants which include the checklists of ENERGY STAR, manuals of equipment, O&M guidance manuals, information of local green power options and sharing the site data with USGBC. The occupant should be given a walkthrough in the house/building, equipment should be identified and information should be provided regarding how to operate the equipment and O&M.

5.2.1.5.4 Prerequisite: Home Size

This requisite reduces energy consumption and GHG emissions by encouraging compact houses and buildings. This prerequisite is met by following the no of bedrooms with respect to conditioned area. In this prerequisite bonus points can be achieved for every 4% decrease in conditioned space with respect to no of bedrooms specified by ENERGY STAR for homes version 3. But points are also lost for every 4% increase in conditioned area compared to ENERGY STAR reference. This credit has no cost and can be achieved by designing the house/building according to the ENERGY STAR requirement.

Bedrooms	1	2	3	4	5	6	7	8 or more
Floor area (square feet)	1,000	1,600	2,200	2,800	3,400	4,000	4,600	+ 600 ft^2 per additional bedroom
Floor area (square meters)	93	148	204	260	315	371	427	+ 55 square meters per additional bedroom

Table 13: Exterior wall area of LEED reference home, by number of bedrooms

5.2.1.5.5 Credit: Annual Energy Use

This credit has maximum 30 points with the intention to improve the energy performance of the house or building by using the ENERGY STAR checklist, HERS rating system and conditioned area of a house/building. For homes, this credit has two options. A house or building should be designed and constructed in such a way that its annual energy usage is less than LEED budget. Glazing should be 15% of the floor area. The ceiling should be insulated. Percentage reduction in annual energy consumption will decide how much points can be earned in this category. The minimum point is 1 for 1% reduction and maximum points are 29 for 90% reduction. The second option is to have HERS rating of 70 or less. The least points are 70 which lead to earning 5 points and maximum 0 HERS rating for earning 29 points. HERS rating system is not available in Pakistan but the measures can be implemented.

Percentage reduction	Points
1%	1
2%	2
3%	3
4%	4
5%	5
6%	6
7%	7
8%	8
9%	9
10%	10
12%	11
14%	12
16%	13
18%	14
20%	15
22%	16
24%	17
26%	18
28%	19
30%	20
32%	21
34%	22
37%	23
40%	24
50%	25
60%	26
70%	27
80%	28
90%	29

Table 15: Points for reducing energy usage below LEED energy budget

HERS index	Points
70	5
69	6
68	7
67	8
66	9
65	10
64	11
63	12
62	13
60	14
58	15
56	16
54	17
52	18
50	19
45	20
40	21
35	22
30	23
25	24
20	25
15	26
10	27
5	28
0	29

Table 14: Points for achieving HERS index ratings

5.2.1.5.6 Credit: Efficient Hot Water Distribution System

This credit has 2-5 points with the intention to improve the efficiency of the hot water distribution system. This can be done by designing a hot water distribution system based on maximum pipe length, and volume. LEED has a table which specified the required size of hot water pipe, length of pipe of circulation or non-circulation loop. This measure has maximum of 2 points. If the system is circulating one, it should not run continuously and there should be a timer or sensor which could control its operation. The second option is to test the flow of hot water fixtures and it should be in the range of WaterSense. This measure has 3 points. And the third option is to have at least R-4 insulation on hot water distribution pipes. This measure has 2 points. Here in Pakistan PPR and PPRC pipes are used for hot water distribution and have good insulation properties.

Nominal pipe size (inch)	Maximum pipe or tube length	
	Hot water source is a water heater or boiler with no circulation loop or heat traced pipe or in multifamily buildings a central circulation loop or heat traced pipe (feet)	Hot water source is a circulation loop or heat traced pipe serving a single unit or house (feet)
1/4	50	16
5/16	50	16
3/8	50	16
½	43	16
5/8	32	12
¾	21	8
7/8	16	6
1	13	5
1 ¼	8	3
1 ½	6	2
2 or larger	4	1

Table 16: Maximum length of pipe

Nominal pipe size (mm)	Maximum pipe or tube length	
	Hot water source is a water heater or boiler with no circulation loop or heat traced pipe or in multifamily buildings a central circulation loop or heat traced pipe (meters)	Hot water source is a circulation loop or heat traced pipe serving a single unit or house (meters)
6	15	5
8	15	5
9	15	5
13	13	5
16	10	4
19	6	2
22	5	2
25	4	2
32	2	1
38	2	1
50 or larger	1	0.3

Table 17: Maximum length of pipe (SI)

5.2.1.5.7 Credit: Advanced Utility Tracking

This credit has 2 points with the purpose to have a real-time monitoring system of energy and water use so that energy and water efficiency measures can be taken effectively. This measure has two options. The first option is to have permanently installed energy meter that can record data in intervals of one hour or less and should be able to send data at a remote location. If the irrigation area is more than 1000 sq feet than submeter should be installed to meter irrigation water usage. Second option having 1 point is that the builder-owner should share the applicable utility date with USGBC. If it is a multifamily building, submeters can be installed for each unit. In Pakistan, new meters installed have the option of sending data to a remote location and are able to record data at an interval of 10 seconds.

5.2.1.5.8 Credit: Active Solar Ready Design

This credit has 1 point with the objective that the site should be designed and constructed in such a way that the photovoltaic system can be installed. This credit has 1 point but two options to achieve this credit. The first option to have photovoltaic ready design and the second option is to have solar direct hot water ready design so that future occupants can install the photovoltaic system or solar geyser. Local companies are available to install these systems.

5.2.1.5.9 Credit: HVAC Start-Up Credentialing

This credit has 1 point and ensures that heating, cooling, and ventilation system operate at its maximum efficiency by commissioning the HVAC system by a technician with North American Technician Excellence certification. The technician should meet all the requirements of ENERGY STAR for homes version 3. In Pakistan, houses do not use HVAC system for houses because it is not a cost-effective solution. There isn't any organization that trains HVAC technicians and provides certification.

5.2.1.5.10 Credit: Building Orientation for Passive Solar

This credit having 3 points tries to have a design that can utilize the natural daylight to reduce the energy consumption of the site and reduce the solar heat gain in summer from windows. This is done by having more glazing on the south side which could be shaded in summer. This measure does not cost anything and can be implemented at the design stage.

5.2.1.5.11 Credit: Air Infiltration

This credit has 1-2 points intends to reduce the wastage of energy due to unwanted air leakage from outside into conditioned space. This measure can be achieved by proper weather stripping all the doors and windows.

IECC climate zone				
1–2	*3–4*	*5–7*	*8*	*Points*
4.25	3.5	2.75	2.0	1
3.0	2.5	2.0	1.5	2

Table 18: Points for reducing air leakage, in ACH50

Performance requirements IECC climate zone				
1–2	*3–4*	*5–7*	*8*	*Points*
.195	.16	.125	.0925	1
.1375	.115	.0925	.0675	2

Table 19: Points for reducing air leakage, in cfm50 per sf envelope area

Performance requirements IECC climate zone				
1–2	*3–4*	*5–7*	*8*	*Points*
5.94	4.87	3.81	2.82	1
4.19	3.50	2.82	2.06	2

Table 20: Points for reducing air leakage, in cmm50 per 100 square meter envelope area

5.2.1.5.12 Credit: Envelope Insulation

This credit has 1-2 points to have properly insulated homes. The R value should be more than described by International Energy Conservation Code (IECC), Chapter 4 or local code. 1 and 2 points are awarded for a percentage improvement of 10% and 20% respectively. Very few houses have insulation in Pakistan because of less awareness and no government restriction on people. Different insulation types like Polystyrene and extended polystyrene is available in Pakistan for insulation.

5.2.1.5.13 Credit: Windows

This credit has 1.5-3 points improves the energy performance of windows. This is done by using the choosing the glass with described U and Solar Heat Gain Coefficient value. These can be calculated by equations. In Pakistan double glazed glass meets the requirement of this measure but most people still use single glazed glass because of the incremental cost of efficient windows. For this case study, double glazed glass is taken into consideration.

Percentage improvement	Points
10%	1
20%	2

Table 21: Points for exceeding code requirements for R-value

	Climate zone					Points
	1, 2	3	4	5–8		
U-factor	≤ 0.45	≤ 0.30	≤ 0.26	≤ 0.26		1.5
SHGC	≤ 0.25	≤ 0.25	≤ 0.40	Any		
U-factor	≤ 0.30	≤ 0.26	≤ 0.22	≤ 0.22		3
SHGC	≤ 0.25	≤ 0.25	≤ 0.40	Any		

SHGC = solar heat gain coefficient

Table 22: Points for exceeding baseline window ratings

5.2.1.5.14 Credit: Space Heating and Cooling Equipment

This credit has 1-4 points related to heating and cooling system by having properly insulated ducts. But in Pakistan gas heaters are used for the heating purpose in homes and split ACs are used cooling in summer so this measure can be achieved.

Climate zones 4–8							
	Central AC, air source heat pump	*Gas furnace*	*Boiler, oil furnace (gas, oil, diesel, propane)*	*Ground-source heat pump*			*Points*
				Open loop	*Closed loop*	*Direct expansion*	
Cooling	≥ 14 SEER			≥ 17.8 EER	≥ 15.5 EER	≥ 16.5 EER	1
Heating	≥ 10 HSPF	≥ 92 AFUE	≥ 87 AFUE	≥ 4.0 COP	≥ 3.6 COP	≥ 3.9 COP	1
Cooling	≥ 15 SEER			≥ 19.4 EER	≥ 17 EER	≥ 18 EER	2
Heating	≥ 10.5 HSPF	≥ 94 AFUE	≥ 90 AFUE	≥ 4.3 COP	≥ 4.0 COP	≥ 4.2 COP	2
Climate zones 1–3							
	Central AC, air source heat pump	*Gas furnace*	*Boiler, oil furnace (gas, oil, diesel, propane)*	*Ground-source heat pump*			*Points*
				Open loop	*Closed loop*	*Direct expansion*	
Cooling	≥ 15.5 SEER			≥ 17.8 EER	≥ 15.5 EER	≥ 16.5 EER	1
Heating	≥ 8.6 HSPF	≥ 90 AFUE	≥ 85 AFUE	≥ 4.0 COP	≥ 3.6 COP	≥ 3.9 COP	1
Cooling	≥ 16.5 SEER			≥ 19.4 EER	≥ 17 EER	≥ 18 EER	2
Heating	≥ 9.0 HSPF	≥ 92 AFUE	≥ 87 AFUE	≥ 4.3 COP	≥ 4.0 COP	≥ 4.2 COP	2

AC = air-conditioning
AFUE = annual fuel utilization efficiency
COP = coefficient of performance
EER = energy efficiency ratio
HSPF = heating seasonal performance factor
SEER = seasonal energy efficiency ratio

Table 23: Points for HVAC equipment that exceeds Energy Star requirements

5.2.1.5.15 Credit: Heating and Cooling Distribution System

This credit has 2-3 points to reduce energy loss by using efficient heating and cooling distribution system. This credit has 3 options. Option 1 is to have all ductwork in conditioned space, this option has 3 points. Option 2 has 2 points and can be achieved by keeping the leakage rate of less than 3.0 cfm of the unconditioned ductwork.

5.2.1.5.16 Credit: Efficient Domestic Hot Water Equipment

This credit has 1-3 points ensures efficient hot water distribution equipment. This measure is achieved by installing ENERGY STAR qualified water heater. ENERGY STAR rated water heater are not available in Pakistan and locally manufactured geysers are not efficient.

	Points
ENERGY STAR water heater	1
EF or thermal efficiency greater than 0.9	1.5
EF or thermal efficiency greater than 1.8	2
Solar water heaters	
Solar water heater: ≥ 40% of annual DHW load	2
Solar water heater: ≥ 60% of annual DHW load	3

Table 24: Points for high-efficiency water heater

5.2.1.5.17 Credit: Lighting

This credit has 0.5-2 points with the purpose to reduce energy usage of interior and exterior lighting. 0.5,1 and 1.5 points can be achieved by having a maximum lighting power density of 0.72, 0.60 and 0.48 w/sq ft. Currently, most of the homes have CFL lights in homes but new homes use LED lights. But there is no awareness of lighting power density in people and lighting is designed by not following any design. Option 2 has 0.5 point which requires exterior lighting to be sensor based. Unfortunately, this is not followed by homeowners.

Maximum lighting power density (W/sf)		Points
W/sq. ft.	W/sq. m.	
0.72	7.7	0.5
0.60	6.5	1
0.48	5.2	1.5

Table 25: Points for reducing lighting power density

Percentage reduction	Points
35%	0.5
45%	1
55%	1.5

Table 26: Points for reducing interior lighting from baseline

5.2.1.5.18 Credit: High-Efficiency Appliances

This credit has 0.5-2 points reduces energy consumption by the installation of efficient appliances. 1 point can be achieved by installing ENERGY STAR rated refrigerators, ceiling fans and 0.5 for the dishwasher. In Pakistan, NEECA has introduced a rating system for ceiling fans which rate fans with 1, 2, 3 stars with respect to efficiency. This rating system can be used instead of ENERGY STAR. For this case study, 3-star NEECA approved fans are considered.

5.2.1.5.19 Credit: Renewable Energy

This credit has 1-4 points encourages production of energy from renewable sources. 1, 2, 3, 4 points are achieved by producing 500, 1000, 1500, 2000 annual kWh. For this case study, a renewable energy system of 2kW is considered for this case study which will produce more than 2000 annual kWh.

Annual kWh	Required points in rest of EA	Points
500	1	1
1,000	2	2
1,500	3	3
2,000	4	4

Table 27: Points for electricity generation from renewable sources

5.2.1.6 Material and Resources

5.2.1.6.1 Prerequisite: Certified Tropical Wood

This prerequisite requires that the wood that is used in the building must be non-tropical, reused or certified by Forest Sustainability Council or USGBC equivalent. The tree species that are grown between Tropic of Cancer and Tropic of Capricon region. In Pakistan, forest department manages the forest and wood that are logged under government rules can be considered for this prerequisite.

5.2.1.6.2 Prerequisite: Durability Management

This prerequisite aims to ensure durable construction by designing the building in such a way that it is material efficient and durable, using durable material and following best construction practices. These measures include indoor moisture control measures in areas like the area of the bathtub, shower, kitchen, laundry room, exterior door, water tank, clothes washer. This prerequisite also requires meeting all the requirements of ENERGY STAR for Homes v3, water management checklist. This prerequisite is not practiced in conventional homes which is the reason that the seepage occurs in these areas soon after the construction is complete.

5.2.1.6.3 Credit: Durability Management Verification

This credit has 1 point to ensure that moisture control measures are installed correctly. This credit requires to have a verification team that inspects and measures that is on ENERGY STAR for Homes v3 water management system builder checklist. This role can be played by a home builder in Pakistan because of their vast experience in construction activities.

5.2.1.6.4 Credit: Environmentally Preferable Products

This credit has 0.5-5 points with the objective to use products that have a less environmental impact. This credit requires 50% of the material by weight/volume which includes framing, concrete, and drywall should be locally produced. A material that is extracted, processed and manufactured within 160km of the site is considered local. Option 2 of this credit requires that 90% of the material should have the following features:

The material should contain at least 25% reclaimed material.

Wood should be Forest Stewardship Council Certified (FSC).

The product should contain 25% postconsumer content or 50% pre-consumer content.

Bio-based material should be legally harvested and tested under ASTM Test Method D6866.

Concrete should have at least 30% fly ash or slag.

Buying from the manufacturer that is part of extended producer responsibility program.

Maximum distance from extraction, processing and manufacturing to project site:	% of building component required to meet criteria (0.5 points per component)
Locally: 100 miles (160 km)	50%

Table 28: Percentage of component to meet local credit

5.2.1.6.5 Credit: Construction Waste Management

This credit has 0.5-3 points for reduction of construction waste and reuses the waste debris. A baseline waste for LEED reference home is set depending on the no of bedrooms, conditioned area and waste produced. Points are awarded when waste generated is reduced than the baseline. 0.5, 1, 1.5, 2, 2.5, 3 points can be earned for percentage reduction of 10%, 20%, 30%, 40%, 50%, 60% respectively. In Pakistan, the waste generated is either used on site for filling or they are sent to landfills.

Bedrooms	*Conditioned floor area (sf)*	*Waste (lbs)*
1	1,000	4,200
2	1,600	6,720
3	2,200	9,240
4	2,800	11,760
5	3,400	14,280
6	4,000	16,800
7	4,600	19,320
8 or more	—	Area (sf) * 4.2

Table 29: Baseline waste for LEED reference home

Bedrooms	*Conditioned floor area (sq. m)*	*Waste (kg)*
1	93	1 905
2	148	3 048
3	204	4 191
4	260	5 334
5	315	6 477
6	371	7 620
7	427	8 763
8 or more	—	Area (sq. m) * 20.5

Table 30: Baseline waste for LEED reference home

5.2.1.6.6 Credit: Material-efficient Framing

This credit has 0.5-2 points with the objective to conserve resources by efficient framing materials. The measures that are described in this credit are not applicable in Pakistan because the structure is constructed using bricks and no framing is done in projects.

Percentage reduction	*Points*
10%	0.5
20%	1.0
30%	1.5
40%	2.0
50%	2.5
60%	3.0

Table 31: Points for reducing construction waste below baseline

5.2.1.7 Indoor Environmental Quality

5.2.1.7.1 Prerequisite: Ventilation

This prerequisite reduces the moisture problems in homes/buildings and reduces to exposure of occupants to the pollutants of kitchen, bathrooms and laundry rooms. If it is single family home then ASHRAE 62.2-2010 sec 4,5 and 7 and Section 1504.4 of the International Residential Code (IRC) 2009. This prerequisite requires that all bathrooms and kitchen should have exhaust system installed. And the exhaust systems should be routed to outdoors. If the project is in the US, all exhaust systems should be ENERGY STAR rated, if not then exhaust systems of equivalent performance should be used. For intermittent exhaust system, the table having minimum flow rate should be followed. The second requirement is that the whole house should have a mechanical ventilation system installed with flow rate described by the table.

	Minimum air flow
Kitchen	100 cfm (47 liters per second); vented range hood required if continuous exhaust fan flow rate is less than 5 kitchen air changes per hour
Bathroom, half-bath	50 cfm (23 liters per second)

Table 32: Minimum air-flow requirements for intermittent local exhaust

Conditioned floor area (ft^2)	Bedrooms				
	0, 1	2, 3	4, 5	6, 7	> 7
≤ 1,500	30	45	60	75	90
1,501–3,000	45	60	75	90	105
3,001–4,500	60	75	90	105	120
4,501–6,000	75	90	105	120	135
6,001–7,500	90	105	120	135	150
> 7,500	105	120	135	150	165

Table 33: Simplified minimum air-flow requirements (cfm) for continuous ventilation systems

5.2.1.7.2 Prerequisite: Combustion Venting

This prerequisite limits the leakage of combustion gases into conditioned space. This prerequisite is met by not installing any unvented appliance, CO sensors should be installed on each floor and combustion equipment should be properly sealed if located inside conditioned space.

5.2.1.7.3 Prerequisite: Garage Pollutant Protection

This prerequisite intends to reduce the exposure of occupants to the pollutants of the garage. This prerequisite requires that all air handling equipment and ductwork should not be installed in garage. All the windows, doors and opening in the garage should be weather-strip and sealed to stop penetration of pollutants from the garage to conditioned spaces. In Pakistan, garages are open and have a proper ventilation system in most of the case

except in few places where closed garage adjacent to the entrance of the house is used because of less space available.

5.2.1.7.4 Prerequisite: Radon-resistant Construction

This prerequisite intends to reduce the exposure of radon and other soil gases from the soil. If the site is in radon zone then proper measures need to be taken to reduce its penetration into the conditioned space. The data for Radon zones is available only for the US. For this reason, radon measurement should be taken on site to see the radon levels in the conditioned spaces. If the measurements exceed safe levels, then proper radon resistance measurements should be taken.

5.2.1.7.5 Prerequisite: Air Filtering

This prerequisite intends to reduce the particulate material in the air supply system. To meet this prerequisite, filters of Minimum Efficiency Reporting Value 8 or more should be used as described by ASHRAE 62.2-2010. Non-ducted systems are exempted from this requirement. Those projects that have earned EPA indoor airPLUS label automatically meet this prerequisite. In Pakistan, ducting systems are not used in homes so this is not applicable to this case study.

5.2.1.7.6 Prerequisite: Environmental Tobacco Smoke

This prerequisite discourages smoking and intends to limit the exposure of environmental tobacco smoke. This prerequisite requires that smoking should not be allowed in the building, and there should be designated space 25 feet far from the home entrance. No smoking signs should be used inside the house and building to prohibit smoking inside the house/building.

5.2.1.7.7 Prerequisite: Compartmentalization

The purpose of this prerequisite is to limit the air leakage from one cell to the other so that exposure to air pollutants can be controlled. This prerequisite can be met by properly sealing the common walls and ceiling of the units and weather-stripping doors and windows to other cells. Blower door testing can be used to verify the measures.

5.2.1.7.8 Credit: Enhanced Ventilation

This credit has 1-3 points and related to enhanced ventilation prerequisite. 1 point can be earned by having occupancy sensor, continuous operating exhaust or exhaust with 20 minutes timer installed in a bathroom with shower, bathtub or spa. 2 points can be earned by having a whole house ventilation system meeting the requirement of ASHRAE 62.2-2010 standards.

5.2.1.7.9 Credit: Contaminant Control

This credit has 0.5-2 points to reduce contaminant exposure. Option 1 state that 0.5 points can be earned in this category by installing walk-off mats 4 feet long. Option 2 states that shoe removal and storage space should be present near entryway can earn 0.5 points. Preoccupancy flush for 48 hours will earn 0.5 points. And air testing in the house for formaldehyde, VOCs (Volatile Organic Compounds) and Carbon Monoxide levels will earn 0.5 points. In Pakistan, mats are used in the entryways to get rid of mud on the shoes while entering the house. Shoe removal and storage space are also used and preoccupancy measure is also taken. The air testing measure is not taken in the country because these services are not available in the market.

Contaminant	*Maximum concentration*	*Maximum concentration (Healthcare only)*	*ASTM and U.S. EPA methods*	*ISO method*
Formaldehyde	27 ppb	16.3 ppb	ASTM D5197; EPA TO-11 or EPA Compendium Method IP-6	ISO 16000-3
Particulates (PM10 for all buildings; PM2.5 for buildings in EPA nonattainment areas)	PM10: 50 micrograms per cubic meter PM2.5: 15 micrograms per cubic meter	20 micrograms per cubic meter	EPA Compendium Method IP-10	ISO 7708
Ozone (for buildings in EPA nonattainment areas)	0.075 ppm	0.075 ppm	ASTM D5149 - 02	ISO 13964
Total volatile organic compounds (TVOCs)	500 micrograms per cubic meter	200 micrograms per cubic meter	EPA TO-1, TO-15, TO-17, or EPA Compendium Method IP-1	ISO 16000-6
Target chemicals listed in CDPH Standard Method v1.1, Table 4-1, except formaldehyde	CDPH Standard Method v1.1–2010, Allowable Concentrations, Table 4-1	CDPH Standard Method v1.1–2010, Allowable Concentrations, Table 4-1	ASTM D5197; EPA TO-1, TO-15, TO-17, or EPA Compendium Method	ISO 16000-3, 16000-6
Carbon monoxide (CO)	9 ppm; no more than 2 ppm above outdoor levels	9 ppm; no more than 2 ppm above outdoor levels	EPA Compendium Method IP-3	ISO 4224

ppb = parts per billion; ppm = parts per million; µg/cm = micrograms per cubic meter

Table 34: Maximum concentration levels, by contaminant and testing method

5.2.1.7.10 Credit: Balancing of Heating and Cooling Distribution Systems

This credit has 1-3 points and improves thermal comfort and energy performance. There are two cases in this credit: 1. Forced Air systems 2. Radiative systems

In forced air system case 1-point can be earned by having at least two independent space conditioning zones with thermostats. Or 1 point air flow

rates in each room should be tested by energy rater using a flow hood with closed doors and windows. Or 1 point can be earned by having a pressure difference of more than 3Pa with respect to the other parts of the house having windows closed and the air handler is operating at full speed.

For radiative systems, 1 point can be earned by having at least 2 independent zones with thermostats and 1 point can be earned by having a room by room controls that can control the flow of every radiator.

Forced air systems and radiative systems are not used in homes in Pakistan, for cooling split ACs are used in specific areas and for heating gas heaters are used.

5.2.1.7.11 Credit: Enhanced Compartmentalization

This credit has 1-3 points with the purpose to minimize the transfer of pollutants from one unit to other. This credit can be earned by carrying blower door testing of the site and the maximum allowable leakage should be 0.15cfm50 per sq feet of enclosure. The service of blower door testing is not available in Pakistan.

5.2.1.7.12 Credit: Combustion Venting

This credit has 1-2 points and the purpose to reduce the exposure of combustion gases. 2 points can be earned by having no fireplace and wood stove in the home. 1 point can be earned by having an enhanced combustion venting measure. The stove should have fixed glass front, gasketed door, and electronic pilot system. In Pakistan, most of the houses don't have fire stove or fireplace at home. Some homes use fire stove in the open air outside because of the non-availability of natural gas option for cooking. Most of the houses don't have an electronic hood but the trend is increasing with time.

5.2.1.7.13 Credit: Enhanced Garage Pollutant Protection

This credit has 1-2 points to limit the pollutants from the adjacent garage. For a single-family home, 1-point can be earned by installing an exhaust fan in the garage and should be ENERGY STAR rated performance equivalent. 2 points can be earned by not having a garage in the house or detached garage is constructed or open-air space garage(carport) having one complete wall shared with the home. In Pakistan, most of the homes have carport garage system so these 2 points can be earned easily.

5.2.1.7.14 Credit: Low-Emitting Products

This credit has 0.5-3 points intend to use low emitting products in the interior of the house. For the projects inside the US, the interior paints and coatings, flooring, insulation, adhesives and sealants should be California Department of Public Health Standard Method V1.1-2010. The materials used should be checked for formaldehyde content. This practice is not followed in Pakistan and neither is it part of any local or national building code in the country.

5.2.1.7.15 Credit: No Environmental Tobacco Smoke

The credit has 1 point intends to discourage smoking inside the conditioned space. This credit can be earned by prohibiting smoke inside the building; it should be communicated to the tenants and future occupants. Signs and other strategies should be used to enforce this measure.

5.2.1.8 Innovation

5.2.1.8.1 Prerequisite: Preliminary Rating

This prerequisite aims to ensure cost-effectiveness and integrative approach to sustainable design and construction strategies. This credit is earned by conducting a preliminary rating of the project in which verification and project teams are summoned for a meeting. An action plan is created to target LEED certification level, the credits to be achieved to reach certification and deciding the parties responsible for meeting the requirement of each credit.

5.2.1.8.2 Credit: Innovation

This credit has 1-5 points and tries to achieve the exemplary performance of the current credits. There are 3 options in this credit. 1 point can be achieved by innovation which means addressing any environmental issue by methods that are not described in LEED for Homes rating system. 1 point can be achieved by taking one measure listed in the LEED Pilot Credit Library available online. The measures in this list are in the pilot phase and might be included in the later versions of LEED. 1-3 points can be achieved by achieved by taking any measure described above plus achieving better performance beyond the LEED maximum threshold.

5.2.1.8.3 Credit: LEED Accredited Professional

This credit has 1 point and can achieve by having 1 LEED Homes Accredited Professional should be one of the principal participants. An architect, home builder or green building consultant can be considered as a principal participant. Unfortunately, LEED AP for homes are not available in Pakistan and this credit is not considered in this case study. But they can be invited to Pakistan from other countries to carry out on site visits, however this will incorporate a large cost in the calculation.

5.2.1.9 Regional Priority

5.2.1.9.1 Credit: Regional Priority

This credit has 1-4 points to encourage housing in US specified areas to address environmental, social and health priorities. These points cannot be earned in Pakistan because these points are available for a house that is built in the US only.

5.3 Conclusions

- Houses in Pakistan can be certified LEED for Homes rating system but due to unavailability of technical support and professionals the cost will be higher compared to other countries but the sustainability measures can be implemented which will improve the energy, water efficiency and will improve the indoor environmental quality
- 34 points of the LEED for Homes rating system will have zero cost while implementing them in Pakistan because either they are design rated or best practices
- 22 points of the LEED rating system are low-cost measures (under Rs 40,000/-)
- 33 points of the LEED rating system are high-cost measures (more than Rs 50,000/-)
- The total cost of a conventional multi-family home in Pakistan is around Rs 1,15,00,000/- for building 8500 sq feet home.
- The rate of constructing a home in Pakistan is Rs 1352/sq feet
- If a home of 8500 sq feet is built on LEED parameters with target level LEED Certified having points 49.5, the incremental cost will be 8.8%
- If a home of 8500 sq feet is built on LEED parameters with target level LEED Silver having points 56.5, the incremental cost will be 10.2%
- If a home of 8500 sq feet is built on LEED parameters with target level LEED Gold having points 69.5, the incremental cost will be 12.51%
- If a home of 8500 sq feet is built on LEED parameters with target level LEED Platinum having points 88.5, the incremental cost will be 21.16%
- The costs of meeting only the prerequisites of LEED for Homes are 5.16% of the total house construction cost
- The labor costs are a major part of construction cost and it increases the time of construction project due to manual methods
- The labor costs can be decreased by training the labor and providing with tools and equipment that will make their work easy and efficient
- Most of the home builders are not properly trained and illiterate which makes it difficult to convince them in going towards green features
- There are no construction codes related to the energy performance of the houses and this is the reason homes are unsustainable

5.4 Limitations

- Non-availability of LEED AP for Homes and LEED Green Rater in Pakistan
- Non-availability of LEED-certified neighborhood
- The labor is not trained according to the modern construction practices
- No organization to rate the heat reflective performance
- There is no check on the chemicals used in pest control chemicals
- Water meters are not installed on most of the homes and there is no restriction on the amount of water pumped out of the ground due to which the groundwater table is going deep day by day
- There is no proper training organization that could train and certify HVAC technician
- Blower door testing service is not available in Pakistan
- No performance rating system for windows and glass
- No culture of recycling and awareness programs
- Radon map is not available for Pakistan
- No rating system to measure formaldehyde content in building materials

Chapter 6

Summary and future work

LEED certified homes conserve energy, water, and resources and provide better indoor air quality. Homes cannot be LEED certified in Pakistan due to non-availability of technical staff and resources. LEED professionals are also not available. The prerequisites cannot be met currently in the country but the measures of LEED for Homes can be implemented in homes and their performance can be improved. The capital costs are high but the savings can be enjoyed throughout the lifetime of the house.

The future work of this research work includes:

- The above technical parameter can be further studied in detail
- The study can be further extended to other economic parameters like NPV, payback period and IRR
- Financing options can be researched and included in this research
- The same case study can be analyzed for other cities of Pakistan
- Costs of implementing pilot projects can be included in this case study
- The same case study can be analyzed for other parameters other than these
- Same building can be energy simulated and the performance can be analyzed
- Renewable energy on the rooftop can be designed by software and be part of this case study

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Sustainable Residential Buildings in Pakistan: Challenges and Opportunities

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Abstract

This study systematically investigates potential opportunities and challenges pertaining to sustainable residential buildings in Pakistan. Throughout the world the concept of sustainable buildings is rapidly gaining popularity and to assess the potential of such buildings in Pakistan, various stakeholders were surveyed. It targets architects, builders, contractors, home owners, service providers, material providers, investors and general public. This study tells us about the awareness of the stakeholders in the areas of construction environmental impacts, energy efficiency and conservation, environmentally preferable products, materials recycling, reduction of waste and water efficiency. We also considered government policies and incentives in reducing emissions and renewable energy integration and overall people's perception about features and design of buildings.

Keywords

Green buildings, Energy Efficient Homes, High Performance Building, LEED, Green Homes

1. Introduction

According to the EPA definition: "Green building is the practice of creating structures and using processes that are environmentally responsible and resource efficient throughout a building's lifecycle from siting to design, construction, operation, maintenance, renovation and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability and comfort. Green building is also known as a sustainable or high performance building."("Basic Information | Green Building |US EPA," n.d.). In short, Green Buildings are environmentally friendly, energy efficient, water efficient, produce less waste, provide better indoor environment quality and do not harm the surrounding habitat and natural resources.

Requirement of energy resources is increasing day by due to an increase in human population and activities. Our unsustainable practices will make us run out of earth's limited resources soon. In US, buildings account for 39% of the total energy, 68% of electricity, 30% of landfill waste and 38% of CO2 emissions ("Importance of Green Buildings," n.d.). Buildings have negative environmental impact, they disturb the natural animal habitat, emit potentially harmful atmospheric emissions, contribute to global warming, soil erosion and landfill waste generation. Green building certifications, standards and rating systems have been created to mitigate the environmental impact of buildings through sustainable and environment

friendly design. Green Buildings can reduce the Energy use by 24-50%, CO2 emissions by 33-39%, Water use by 40% and Solid Waste by up to 70%. (Muenprasertdee(USGBC), 2013)

2. Green Building Rating Systems and Standards

Green Building certification systems rate the buildings according to resource efficiency, environmental impact and location. The first green building rating system was introduced in 1990s in UK known as BREEAM. ENERGY STAR was introduced in 1992 which was not only specific to homes but also included other categories of electronics and products. In 2000, US introduced LEED rating system. Green Globes was introduced in 2005 in US. Other rating systems include National Association of Home Builders (NAHB) and Green Building Certification Inc (GBCI).

ANSI/ASHRAE/USGBC/IES Standard 189.1, *Standard for the Design of High-Performance Green Buildings except Low-Rise Residential Building* provides mandatory requirements and building codes during site selection, design, construction and operation and maintenance stage. These standards have different categories of water efficiency, energy efficiency, indoor environment quality, materials and resources during construction and operations of the buildings.

Certified Green Products which have minimum environmental impact are an important part of Green Buildings. Green Products certification systems include Energy Star, WaterSense labeling for water efficient products, Forest Stewardship Council for the certification of wood products in different categories like pure, mixed and recycled wood. Scientific Certification Systems (SCS) Global Services is a third-party certification system which certify products based on formaldehyde content, biodegradable and recycled products. Green Seals certify products like windows, window films, adhesives, paints, lamps and electric chillers. Other certifications include Cradle to Cradle, Green Guard and Green Squared.(Vierra, Stephanie(Vierra Design & Education Services, 2016)

3. Green Buildings in Pakistan

The concept of sustainable buildings construction is rapidly gaining popularity worldwide but in Pakistan due to lack of awareness such practices are not followed particularly in residential sector. Pakistan has the 5th largest population, high rate of urbanization and rapid economic rate coupled with increase in residential buildings construction in near future. Demand for new houses will remain high in the near future and there exists huge opportunity for promoting sustainable building concept in residential sector of Pakistan.

Pakistan Green Building Council is the only representative of the World Green Building in Pakistan which advocates, promotes, develops region specific green guidelines and certify sustainable/green building practices and products. (PGBC, n.d.) It is a non-profit organization which provides buildings codes and standards to the construction industry to promote natural resource efficient, water efficient, energy efficient and buildings that provide better indoor environment quality to the occupants based on local codes because sometimes the international codes of green building certification system are not applicable in some areas. PGBC is working in coordination with World Green Building Council which is a union of 98 Green Building Councils throughout the world and the largest international organization which influences green building marketplace.

4. LEED Green Building Certification

Leadership in Energy and Environmental Design (LEED) is a globally acknowledged certification system for Green Buildings. For different project types there are different LEED certifications like for new buildings, existing buildings, homes and community we have Building Design+Construction (BD+C), Existing Buildings Operation and Maintenance (EBOM), LEED Homes and LEED Neighborhood Development (ND) respectively. LEED certification system has different categories having different prerequisites and credit points. Prerequisites are the mandatory tasks for project LEED certification and credits are the points on the basis of which different level certifications are achieved. There are 9 categories of LEED rating system, total 110 points and four levels of certification Platinum, Gold, Silver and Certified.

5. Awareness of LEED Certification in Pakistan

This study reveals that only 46.5% of the architects know about LEED certification. They interact with the client directly and can be a source of motivation and encouragement for the client to build Green Home. Only 33.3% of Material suppliers know about LEED certification. Suppliers of products like insulation, heat reflectors, heating and cooling equipment, renewable energy service providers, structural material providers, glass providers should have knowledge about Green Building certifications.

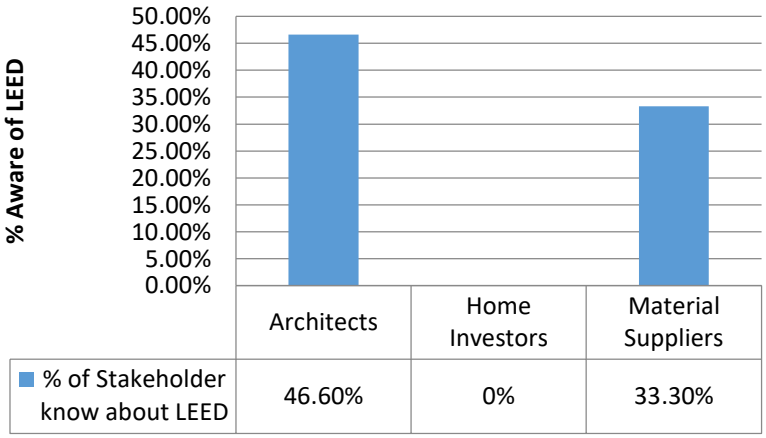

Figure 28: Knowledge of Stakeholders about LEED

6. Research Methodology

In this study the differences between conventional and LEEDv4 certified home have been analyzed and on the basis of the analysis questionnaire was developed. Surveys were conducted from 7 stakeholders which included home owners, home investors, home builders, architects, government officials, material suppliers and general public. The survey forms consisted of multiple choice questions and open-ended questions. The purpose of this research was to gauge the level of knowledge of general public and stakeholders about high performance buildings. This work analyzes the perception of the people and identifies opportunities and challenges faced by construction industry to shift from conventional homes to Green Homes.

7. Results and Discussions

In this study the set of procedures and practices of a conventional home in Pakistan and LEED certified green home in Pakistan were compared and comparison of Integrative Process, Water Efficiency and Innovation had been done.

7.1 Integrative Process

Integrative Process having 2 points which ensure the distribution of knowledge and education about Green Buildings and LEED rating system which lacks in our construction industry in Pakistan. It is evident from figure 2 in Pakistan that 90% of architects know about Green/Sustainable Buildings due to part of their curriculum during university. There is little or no awareness about Green Buildings in Home builders, Home Investors, Home Owners and Material Suppliers. There is no process of knowledge sharing and integrated team concept in Pakistan and the people mostly get information from social media, print media and internet.

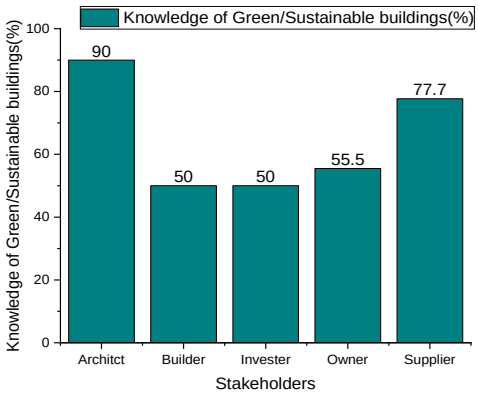

Figure 2: Knowledge of Stakeholders about Green Buildings

7.2 Location, Transportation and Site Sustainability

LEEDv4 has 15 points in location and transportation section including 1 prerequisite and 7 points in Site Sustainability including 2 prerequisites. 84.4% of the home owners look for parks, community resources and public transport. 83.7% of the home owners prefer local products rather than imported products.

Type of vegetation in a home effect the water consumption and thus native plants should be preferred over invasive and exotic plants. Results showed that 52.2% of the Home Owners have native plants at home as shown in the figure 3.

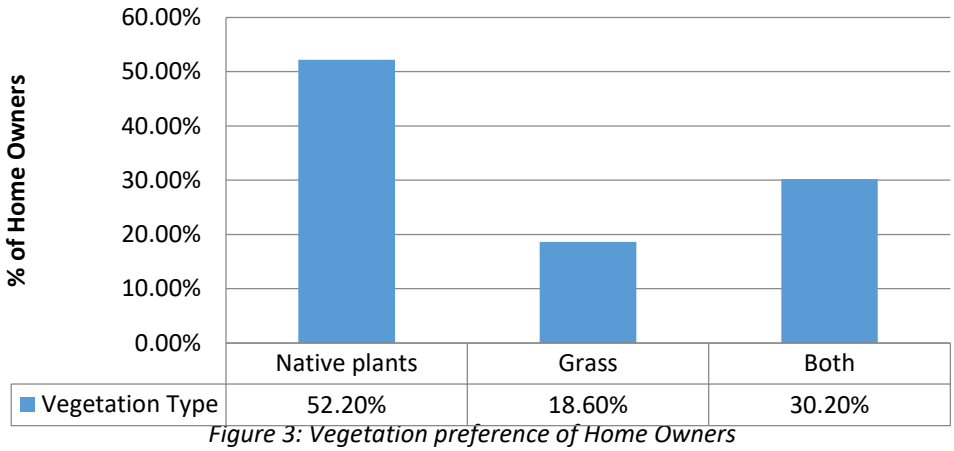

Figure 3: Vegetation preference of Home Owners

7.3 Water Efficiency

Water is a very precious resource and LEED certified homes are designed to be water efficient. In LEED Homes, outdoor and indoor water metering is done to utilize every opportunity to conserve water. Water Efficiency category in LEED Homes carries 12 points. Surveys results show that 78% of the general public are aware of water conservation measures. Unfortunately, the prices of the water efficient products are extremely high and most of the people cannot afford it. They look at the capital cost and ignore saving associated with the products.

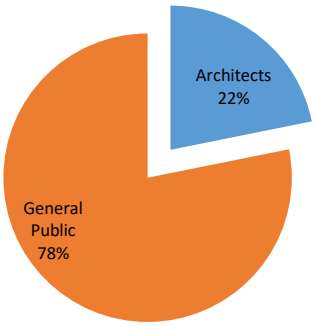

Figure 4: Awareness of Water Efficiency

Despite the fact that Pakistan has the best irrigation system in the world, it is still a water scarce country. And the country is expected to be severely affected by the climate change in a next few years which will make the problem worse. Green Buildings can reduce the water usage by up to 40%. In Pakistan 32% of the people are unaware of the water efficiency in our homes and buildings, people like to prefer quality, design and cost while buying sanitary products and are not concerned about water efficiency. On the other hand, 81% of architects are also unaware of the watersense labeled products. The architects and interior designers should consider WaterSense and water efficient products in their design to spread awareness of water efficiency in the country.

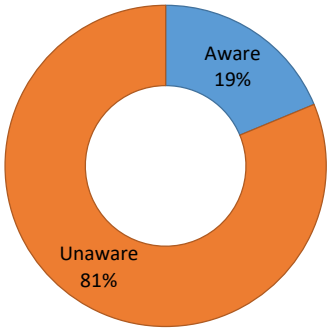

Figure 5: WaterSense Labeling Awareness of Architects

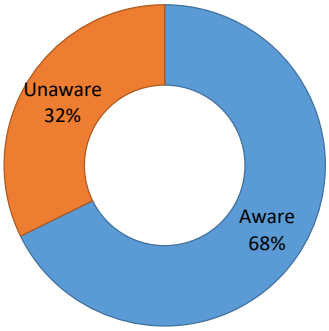

Figure 6: Water Efficiency Awareness in General Public

7.4 Energy and Atmosphere

Energy and Atmosphere being the important section of LEEDv4 Homes has 38 points and 4 prerequisites. For a home to be energy efficient, its design should be supportive and the architect should know about the energy efficient design. Unfortunately, only 40% of the architects have designed Green Home in Pakistan and 40% of the architects are aware of ENERGY STAR rated products.

The retrofitting process of incandescent lighting to LED lighting is on its way and 42% of the home owners use LED lights 58% incandescent lights. Due to the fall of prices of LED lighting in Chinese market the trend of lighting has been shifted to LED by the home builders.

7.5 Material, Resources and Indoor Environment Quality

Material and resources have 10 and indoor environment quality has 16 points in LEEDv4. Pakistan has the highest deforestation rate in South Asia and forests cover only 2% by area because 35% of the people prefer pure wood rather than composite material in construction. More than half of the population of Pakistan lives in rural areas and they use wood and biowaste for cooking and heating purposes due to non-availability of natural gas. The results showed that 28.8% of the people use fire stove inside their rooms which is harmful for health and could cause deaths.

7.6 Innovation

There are six points in the Innovation category which are awarded for the use of innovative solutions to solve the problems not discussed in LEED. The use of smart sensors and appliances ensure the efficient use of energy and water. 41% of the Home Builders know about smart sensors and appliances because of prior experience in projects. However, there is no awareness of smart sensors and appliances in General Public.

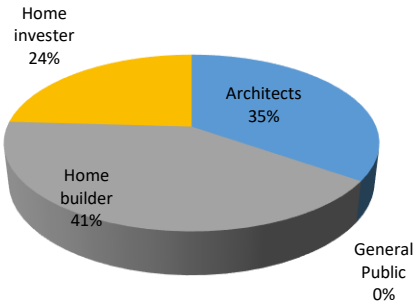

Figure 7: Knowledge of Stakeholders about Smart Sensors and Appliances

8. Recommendations

- According to the Integrative Process of LEED certified home, the client, home builder, architect, civil engineer and the labor should be on a same page from design to construction stage. That can be done by monthly one full-day meeting where they can discuss their progress, future work and problems and hurdles they face.
- One should select a site for construction where it doesn't affect natural habitat of any specie. It should have access to public transport, parks, community centers, hospitals, schools and universities.
- Home owner and builder should ensure that
    - the construction activities do not pollute the neighborhood
    - space is reserved for plants and trees that can provide shade to the home and this will keep the house cool during summers.
    - rain water is properly managed during construction phase

- Insulation should be in MUST-TO-DO list while constructing a home in Pakistan. Energy efficient appliances and lighting should be used to conserve energy. Windows should be airtight. Generation of onsite renewable energy should be considered while designing a home.
- Certified tropical wood and durable products should be used and the waste should be diverted from landfills.
- A LEED certified home uses environment friendly products. It has better exhaust system in kitchens and garages.

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