Net Zero Onsite Energy Homes: Opportunities and Challenges

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THESIS ACCEPTANCE CERTIFICATE

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Dedicated to

my Parents

for their love, support and

encouragement

Abstract

Energy demand in residential sector of Pakistan is escalating every year. Increased energy demand makes fossil fuels the most realistic option for obtaining energy. Around 64% of energy is obtained from burning of fossil fuels and producing CO_2 Emissions of 65000 K tonne. The research is carried out to determine the feasibility of NZEH concept in Pakistan. The study analyses the energy consumption pattern of domestic sector and assess their potential of renewable energy for clean energy production. For this purpose, survey is being conducted based on the set of questions regarding building, occupants and area climate in selected cities of Pakistan. Based on results, energy efficient measures promoting the energy conservation and available in market are discussed. Ranging from no cost to high cost depending upon their viability in certain climate. The results also showed that being a temperate region residential sector of Pakistan has enormous potential of going net zero energy plus home. Implementing net zero energy home concept will provide benefits that extend far beyond energy cost savings like improved health, sustainable future and amplification effect on other buildings along with reduced carbon footprint.

Keywords: Net Zero Energy Homes in Pakistan; Energy Conservation Measures in Pakistan; Renewable Energy; HelioScope modelling, Energy Efficient Building

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Chapter 1 Introduction

1.1 Climate Change Around the Globe

Climate change is one of the biggest crises being faced currently by our planet as its temperature rises day by day. Rise in world population has led to rise in carbon emissions along with other GHG emissions. Over the last 50 years 2°C rise in earth surface temperatures has been observed due to global warming[1]. Global warming includes long term warming of earth temperature, increase in average rainfall humidity level, heavy rain storms in some places whereas drought in others, crop production pattern changes, melting glaciers, shrinking ice sheets, sea levels rising and getting more acidic over time. These consequences of climate change are affecting the earth life adversely. Human activities such as burning of fossil fuels and deforestation play key role in increasing the heat trapping gases in the air[2].

NASA defines climate change as: ‘‘A broad range of global phenomenon created predominantly by burning fossil fuels, which add heat-trapping gases to Earth’s atmosphere’’.[3]

1.2 Global Warming and Energy

Currently, serious threat is being faced by human life on earth due to the rapid increase in anthropogenic gases (GHGs). Fossil fuels are the major source of CO_2 emissions. Around 80% of world energy is obtained by burning fossil fuels. With the rise in human population, energy demands are also increasing globally[4]. Industry and building sectors are the major consumer of world total energy as shown (Figure 1.1).

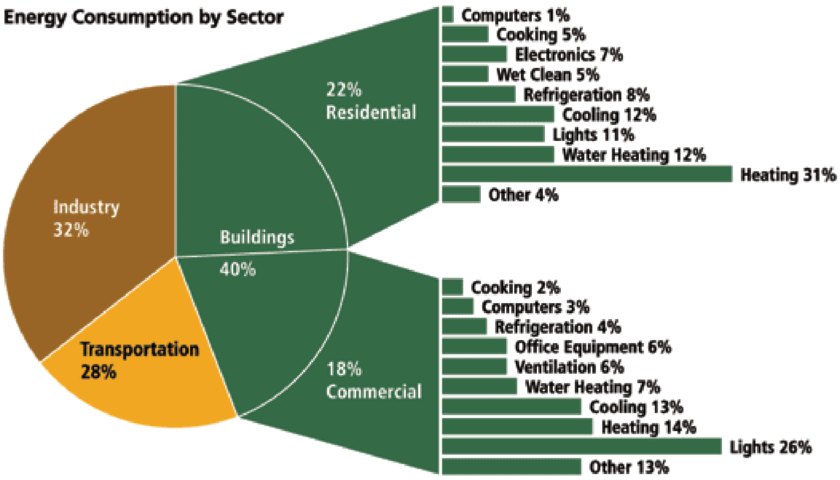

Figure 1-1 Sector-wise Consumption of World Energy

Buildings play important role in the development of any country and contribute a major share i.e. 40% of total world energy. According to an analysis by NASA, Earth's surface temperature in 2017 has been ranked as the second time highest since 1880. Increase in urbanization affected the environment to great extent in terms of energy consumption, it increased the CO2 atmospheric level up to 400 ppm from 280 ppm during the last 150 years[3].

Energy used in buildings include energy of building materials during the construction process and after its completion the energy consumed by the residents throughout its lifetime contribute to substantial percentage of building carbon footprint[5][6].

Among the buildings, residential sector plays critical role in energy consumption worldwide and produces one third of total world GHG emissions. This growing risk of global warming and climate change has directed attention on the correlation between energy consumption and environmental pollutants[7][8]

Facing current challenges, countries are taking actions to curb fossil fuel energy consumption to mitigate GHGs and to seek a low carbon economy. Measures include exploring renewable energy sources and decreasing reliance on fossil fuel through emission reduction technologies, in addition to inefficient utilization techniques, which all are imperative steps toward a low-carbon economy. Understanding the elements of energy utilization and related ozone depleting substance emanations worldwide and at local level will be basic for accomplishing mitigation targets and low carbon economy. Humans have caused major climate changes already and have set a base to cause more in future. Earth takes a while to respond, if emission of harmful gasses is stopped today, the effects of global warming will be seen for decades because these predominant heat trapping gases are locked up in the air for thousands of years[9].

According to the latest report if no action for reducing emissions is taken now, the global temperature will rise to 6°C in future and it might cause irreversible global disaster[10]. There are 2 steps in responding toward the climate change such as,

1. Reducing the emission to maximum level by adapting cleaner energy generation and technology.
2. Mitigating the future flow of GHG emissions to step toward sustainable and green future.

Climate change is justly a social, political and economic concern at global level. The solution requires effort from local and international level both through sustainable planning, policy making and implementation, EE measures, financial support etc.

1.3 Net Zero Energy Building in Pakistan

To deal with the currently increasing energy demand and to limit the climate change concept of Net Zero Energy building concept was introduced According to which energy used by the building on an annual basis is roughly equal to the amount of energy created by it through onsite clean sources while increasing its energy efficiency. Net Zero Energy Building include the integration of passive measures with active systems to increase the energy efficiency of building and reduces its annual energy demand.

As Pakistan is facing severe energy crisis nowadays. And the gap between supply and demand is widening with every passing year. The current electricity production including all energy sources is of 19000 MW with installed capacity of around 25000

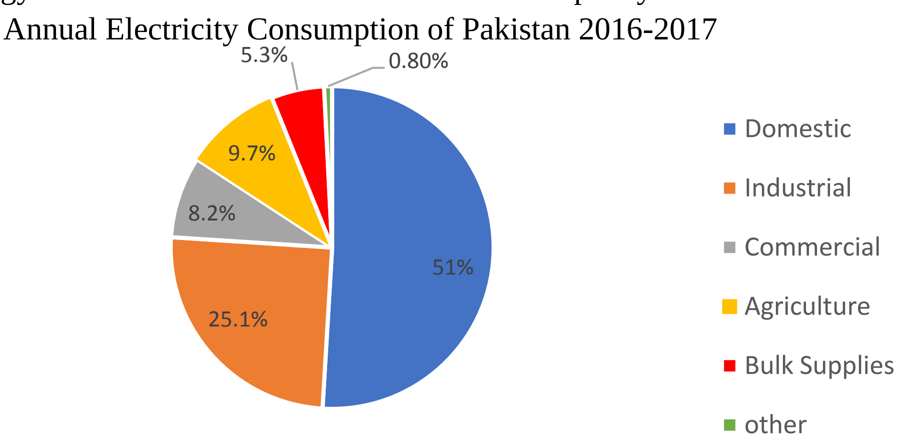

Figure 1-2 Annual Consumption of Electricity

MW and shortfall of almost 4000 MW. Residential sector of Pakistan plays crucial role in its energy consumption i.e. 51% of the total electricity demand and around 64% energy is produced through burning of fossil fuels.[11][12](Figure 1.2)

Pakistan may not be among the major contributors to the Green House Gases (GHGs) emissions, yet they have adequate potential to mitigate GHGs in various sectors. The power sector is one of the major contributors to GHGs in Pakistan i.e. 65000 K tons of CO2 emissions in 2016. The Federal Minister for Climate Change in Pakistan stated that it is the 7th most vulnerable country to climate change and due to its geographic and climatic regions it also suffers high number of casualties each year. According to 2016 report of climate risk index, Pakistan has been ranked 40th in the list for suffering approx. 566 casualties. Besides, death toll in Pakistan has reached to 523.1 lives per year since 1997. However, contribution of Pakistan in world CO2 emissions is less than 1%, yet it is considered as highly effected nation by global climate change.

Pakistan has faced number of casualties under natural disasters and climate change effects such as,[13]

- Highest temperature was recorded in Nawab shah, Sindh, Pakistan of 50.2°C in the month of April 2018. Similarly, heatwave in Karachi caused death of 1200 lives in 2015
- According to economic survey 2013 our country faced loss of 16 billion dollars due to flooding in 2010,2011 and 2012. More than 3000 lives were lost, large area of land was destroyed and country's economy was damaged severely.
- 2015 heatwave in Karachi led to the death of more than 1,200 people.[14]
- Melting of glaciers on north coastal areas increasing water scarcity by converting freshwater into seawater.
- According to report by ADB, Pakistan will be facing serious water per capita issues in coming years.
- Increased droughts in Baluchistan and Sindh provinces, leading to rigorous agricultural deprivation.

1.4 Limitations

Monetary support from government is one of the substantial factor in promoting energy conservation as retrofitting of house increases its initial upfront cost hence restrain the owner. Similarly, awareness among the occupants is another hurdle toward the progress as average person has no or minimal concept of Net Zero Energy Homes and energy conservation techniques. Furthermore, another influencing factor and the most important factor is building infrastructure as all case studied houses have numerous air infiltrations, single glass windows, poor ventilation system and no insulation on building envelope . All these factors are hindering the penetration of Ne Zero Energy Building concept in Pakistan.

Summary

This chapter includes the brief introduction of climate change and human influence on climate change in terms of energy. Widespread effects of global warming on human life are also discussed. 2°C change in global temperature might sound small but it corresponds to the enormous change in environment over long period of time in future. Pakistan has minor contribution in global GHG emissions but has significant potential in mitigating the carbon footprint for the future. Importance of Net Zero Energy Building concept was also discussed briefly.

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Chapter 2 Literature Review

Earth climate is changing from decades but the trend picked up pace within last few years. Life on earth depends on the energy radiations coming from sun. Ninety percent of high frequency radiations known as infrared are reflected from earth surface but certain gases in the atmosphere block heat from escaping which results in the increase of air temperature. These harmful gases are known as greenhouse gases and include

- Water Vapours
- Nitrous Oxide
- Methane Gas
- Carbon Dioxide
- Chlorofluorocarbons(CFCs)

Chlorofluorocarbons play major role in depletion of ozone layer which are being regulated to some extent currently. Water vapours (H_2O) play key role in climate change[1]. These are available abundantly in atmosphere and increase the precipitation level, hence raising the earth temperature. N_2O, CH_4, CO_2 are produced because of human activities majorly (e.g.: biomass burning and deforestation)[2]. Although effects of Methane gas are vigorous but atmospheric CO2 has proved to be lethal gas because of its abundance in atmosphere as compared to methane.

According to fifth assessment report the main factor behind growing these anthropogenic gases in air is growing industrial activity. Around 80% of world energy is obtained through fossil fuel burning. Rise in energy demand has led to increase in coal and oil demand. World population is predicted to be doubled by 2030.[3]

Global warming is a long-term effect. Major changes in world climate pattern is predicted to happen in near future. Predominant heat trapping gas CO_2 has been releasing for more than hundreds of years but the planet Earth has taken time to exhibit the result in terms of global warming. Limiting the GHG emissions is the only possible solution for creating a habitable environment for future generation.

For this purpose, concept of Net Zero building has been introduced. Building sector is one of the major consumer of world total energy and it causes one third of world's total greenhouse gas emissions on yearly basis.[4]

2.1 Net Zero Energy Building

Net zero energy building (NZEB) is a measure of energy performance of building over the period of one year. NZEB can be defined in variety of terms. According to Torcellini & Pless [11] utility grid is used to define net use concept. The definitions discussed are,[5][6] [7]

1. Net-Zero Site Energy.
2. Net-Zero Source Energy.
3. Net-Zero Energy Costs.
4. Net-Zero Energy Emissions.

2.1.1 Net Zero Site Energy:

A NZEB that produces at least as much energy on site as it consumes in a year, accounted for at the site. In this case boundary for the site is drawn, energy consumed within the boundary is accounted for its performance and doesn't need any other factors.

2.1.2 Net Zero Source Energy:

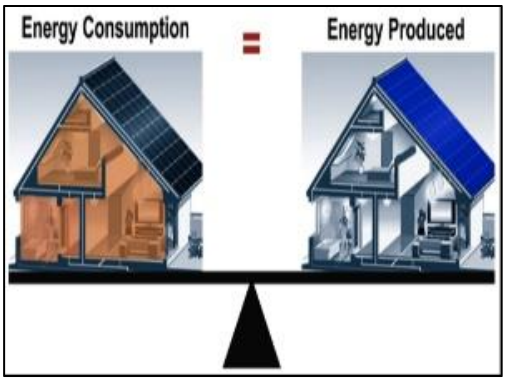
A NZEB that produces at least as much energy as it uses in a year, accounted for at the source. Source energy considers the primary energy obtained from grid through conventional sources which also incorporates the energy used for generation and transportation of the energy to the building site. This is important when accounting for energy consumed from the grid, where a significant portion of energy is lost during transmission from generator to site, and in thermal generation efficiency losses are high. Site to source energy factor must be determined for each source and it is applied in during energy neutralization process.

2.1.3 Net Zero Energy Cost:

A Net Zero Energy Cost building balances the costs rather than the units of energy. A building should receive as much financial credits for exporting clean and green energy as much as it costs for using grid connection on site. Renewable energy generation is highly variable, depending highly on the resource it may not balance the required cost parameter consistently in real time. Due to this reason achieving this definition building requires intensive demand reduction strategies and demand management systems.

2.1.4 Net Zero Energy Emissions:

A different metric is used to define the balance this time i.e. emissions. The building produces at least as much emission-free energy to offset the emission intensive energy imported from the grid. Here, non-energy differences between fuels such as carbon emissions, and other types of pollution are accounted for. This makes it a comprehensive definition than others but as a result, it is more difficult to implement.



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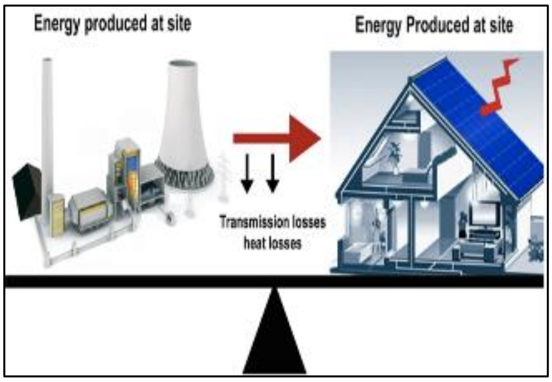

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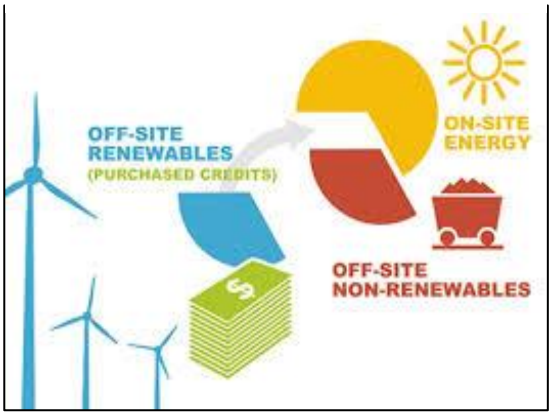

d

Figure 2-1(a): Net Zero Site Energy(NZE-Site), 2.1(b): Net Zero Source Energy(NZE-Source), 2.1(c): Net Zero Energy Cost(NZE-C), 2.1(d): Net Zero Energy Emission (NZE-C)

A net zero-energy building (NZEB) is a residential or commercial building with significantly reduced energy needs through efficiency gains such that the balance of energy needs can be supplied with renewable technologies[6][8]. The net-zero energy concept is that building which could generate enough on-site energy to balance-out or exceed their annual energy consumption. The term net indicates that the building may use energy from the utility grid (electricity/natural gas) during some time of the day but supplies renewable energy back to the grid during other times, in a balance that equals out over the course of a year[8].

NZEB can also be defined as grid-tied net-zero home using conventional energy sources from utility companies in case on-site clean energy production is not enough to meet building load demand. When the on-site generation is greater than the building's loads, excess electricity is exported to the utility grid. By using the grid to account for the energy balance, excess production can offset later energy use [4].

NZEB Onsite classified further into 4 systems;

- **NZEB-A** (renewable production on footprint of building to achieve any definition of NZEB).
- **NZEB-B** (renewable production on project site of building to achieve any definition of NZEB).
- **NZEB-C** (renewable production on footprint of building also import renewable energy from offsite to generate onsite energy and achieve any definition of NZEB).
- **NZEB-D** (renewable production on footprint of building, onsite, optionally import offsite renewable source, purchase offsite renewable energy to achieve any definition of NZEB).[3][9]

2.2 Net Zero Energy Home

Net Zero Energy Home term is relatively new but shifting toward the low energy homes combined with solar energy have been started since mid-20th century. By 1969 solar heating systems had been installed in approximately 13 houses in US.[10]

One of the earliest implementation NZEH concept was in Hannover, Germany by Erhard Wiers-Keiser and the organization named Ecological Future in 1989. The project miscalculated the consumption due to less air tightness and less development in solar storage technology.[11]

In the past decade while many experimental and practical energy-neutral homes have been built across the US and around the world, obstacles blocking the integration of the concept into mainstream building construction remains.

2.3 2030 Challenge and Paris Agreement 2050

Approximately two-third of the building area that exists today will still exist in 2050. Cities are responsible for over 70 percent of global energy consumption and CO2 emissions, mostly from buildings, marking a significant opportunity to focus climate change mitigation and adaptation efforts on dense urban environments. As urban built environment is responsible for 75% of annual global GHG emissions: buildings account for 40%. Eliminating these emissions is the key to addressing climate change and meeting Paris Climate Agreement targets.[12]

Paris Agreement global average temperature rise must be limited to under 2C threshold and develop financial system to promote clean environment developments[13]. A significant increase in the rate of existing building energy efficiency renovations, generation and procurement of renewable energy is required to meet emissions reduction targets set by the Paris Agreement. While number of cities have taken the responsibility of carbon emission reduction through different strategies.[14]

Around 196 countries have signed Paris Agreement including Pakistan according to which Net zero carbon target should be achieved by 2050[15] i.e.

- All new buildings must be carbon zero from 2030
- All buildings must have zero carbon emission by 2050

NZEB is introduced as measure of guarantee to ensure the achievement of global GHG emissions reduction targets by EU, according to which they have to maintain the global temperature rise below 2 °C, and to reduce overall GHG emission by at least 20 % below 1990 industrial levels by 2020[2]

Challenge 2030 is an initiative of Edward Mazria. An organization named Architecture 2030 with the collaboration of world architectures and construction community was introduced. The purpose was to plan reduced GHG emission building designs for coming future and to retrofit existing building system. It can be defined as carbon neutral challenge and doesn’t limit the amount of renewable energy produced on site. It might be claimed for only up to 20% of the required reduction.

Targets to be achieved by different countries are shown in the table,

Table 2-1Targets to Achieve Zero Carbon 2050 Set by Different Countries

COUNTRIES	ZERO ENERGY TARGET	REFERENCE
England	Zero carbon homes by 2016	UK Energy Efficiency Action Plan
Wales	Zero carbon buildings (in relation to space heating, hot water and lighting) by 2011	UK Energy Efficiency Action Plan
France	By 2020 all new buildings are energy-positive	European National Strategies to move towards very low energy buildings
Ireland	NZEBs by 2013	Low energy buildings in Europe: Current State of Play, definitions and best practice
The Netherlands	Energy-neutral buildings in 2020	Low energy buildings in Europe: Current State of Play, definitions and best practice
Hungary	Zero emissions for all new buildings by 2020	The Hungarian Climate Change Strategy 2008–2025 (HCCS)
USA (California)	Net zero energy performance in residential buildings by 2020 and in commercial buildings by 2030	AB212
USA (Massachusetts)	Net Zero Energy for all new buildings by 2030	Getting to Zero: Final Report of the Massachusetts Zero Net Energy Buildings Task Force
South Korea	All residential buildings are required to achieve zero energy emissions by 2025	Measures to Develop Green Cities and Buildings

2.4 Achieving NZEH Concept

Whilst the overall goal of a NZEB is to produce at least as much energy as the building consumes, it is critical to note that the energy consumption of the building plays a major part in this balance. By reducing energy use as much as possible, it becomes an easier goal to achieve NZEB status by minimizing the renewable energy requirement, saving both required installation space and, of course, upfront cost of system Energy consumption can be reduced through a range of measures. Implementation of efficient appliances, such as lighting, mechanical systems, the passive design of a building to work with the climatic conditions of the site, integrating active systems, as well as the behavior of the building occupants, can all contribute to the overall reduction in energy consumed by the building.

2.4.1 Building Envelope

The building envelope is defined as the barrier that separates the indoor space from the outdoors and is considered critical to the comfort of occupants, energy and thermal efficiency[16]. The envelope varies significantly based on the climatic conditions of the site. A non-engaging envelope maintains a solid, separate barrier between internal and external environments. This is used where the outdoor climate is typically not hospitable such as very low or high temperatures. An engaging envelope is one which allows interaction between occupants and the outdoors, such as operable windows and doors when the climate is comfortable. An engaging envelope typically results in a more efficient building, with reduction in HVAC loads. [3][17][18].A study of a hotel building in the Mediterranean by Sozer [19] found that heating/cooling energy savings of 40% could be achieved by applying passive design principles such as appropriate thermal insulation, glazing and shading elements. The effectiveness of shading was examined in Pacheco et al. [20]A disadvantage highlighted was that they limit the availability of daylight, increasing the need for artificial lighting. An increase in artificial light leads to an increase in heat generation within the building. It is important that these implications are considered when designing shading elements for the building envelope to ensure that excessive shading doesn't have detrimental effects on the building energy efficiency, or occupant comfort.

For a Sydney specific climate, Bambrook et al.[21] recommended high levels of insulation in the building envelope, as well as low U-values in window assemblies to minimize heat transfer. Windows should also be sized suitable to their orientation and have appropriate shading. Pacheco et al. [20]concluded that the factors which had the most influence on the final energy demand of a building are the orientation, the shape, and the compactness of the building (the ratio between external surface area and building volume). It was also found that the design measures which contribute to benefits in one season may be detrimental in another season. More research was recommended into the estimation of solar radiation in urban areas due to influence of surrounding buildings. Building wall material also effect the cooling and heating load. Another study concluded that a Window-to-Wall ratio of no more than 30%-40% would also improve energy use. However, above this level, the building risks overheating and glare[22].

2.4.2 Electrical Load

It is claimed that around 30% of a building energy use can be attributed to artificial lighting. One important consideration about lighting is their influence on the thermal load of the buildings. Artificial lighting generates heat which then creates follow-on effects for the HVAC system in the building. Whilst this thermal load effect may be of benefit in winter, it will come as a disadvantage during summers[23][24]. One way to reduce the thermal effects of artificial lighting is to introduce more daylight. It has been suggested through simulation in Bodart & De Herde[25] that by optimizing the amount of daylighting in the building, the artificial lighting required can be reduced by 50 to 80%. Introducing daylighting eliminates the electrical energy required to power the light, as well as the additional energy required to remove waste heat generated by the light. The effect of daylighting on building energy savings was investigated in Krarti et al. [26]. It was found that the daylighting aperture (the product of window visible transmittance and window-perimeter floor area ratio) had a significant impact on energy savings. Increasing the daylighting aperture leads to increased energy savings. A point of diminishing returns was identified as being a daylight aperture of 0.3, and that results seem to be consistent across varying geographical locations. A review of energy saving potential of electric lighting found that reduction in lighting intensity of 50% is feasible and that for a low energy office building, a lighting intensity of 10kWh/m2 is a realistic target to adopt. Strategies discussed by Dubois & Blomsterberg[22] regarding the reduction in lighting energy use was concerned mostly with new technology, for instance; installing low energy fluorescent and LED lamps, new efficient ballasts, and improved luminaires.

2.5 Renewable Integration

Commonly used and commercially feasible source of on-site renewable energy is Solar Photovoltaic (PV). Other sources of energy such as wind are considered as possibilities.

2.5.1 Solar PV

Given the ubiquity and abundance of sunlight in most locations on earth and historically, the rapid simultaneous increase in performance and decrease in cost of solar PV modules, achieving the NZEB goal has become more and more viable in recent years[27][28]. When considering the total amount of energy reaching the earth from the sun, as well as the efficiency of solar arrays and inverters, a rule-of-thumb is that 11.25 W/ft2 of power supplied to the building can be achieved. This is 46% larger than the average energy use intensity(EUI) of a commercial building[29]. Given this fact, on-site solar PV is a very attractive way of offsetting energy use in NZEB buildings. The major factors to be considered when designing a solar PV system for a building roof are the system size and position[30]. The energy output of a solar PV system is mainly dependent on the climatic and weather conditions which have a bearing on the amount of irradiance striking the surface of the solar panel. Irradiance is defined as the amount of power striking a surface. During given time, the solar insolation may be described as the amount of energy that falls on the specified surface during that given time. This can be described in term of kWh/m2/time. Often it is useful to express the time of the insolation as a day [10].

Griffith et al.[31]found that energy efficiency improvements in commercial buildings in the US can reduce consumption by 43% on average. This agrees with the previous trend in the literature that buildings with the greatest potential for energy conservation and efficiency improvements are most probable to achieve NZEB status. One of the major factors in a building not achieving NZEB status is that the required roof area for an adequately sized PV system was too small. Through energy consumption reduction, the required PV capacity becomes smaller, reducing the required roof area.

2.5.2 Wind

While large centralized wind farms have reached the point of technological maturity in the past few decades, the notion of small-scale wind energy is very much an emerging technology. Small turbines of less than 10kW installed in the built environment are classified as microgeneration[32]. The challenge presented by wind generation in the built environment is that the wind resource is unpredictable and highly variable. Obstructions from surrounding structures are known to greatly diminish the potential output for a wind turbine due to the turbulence generated and reductions in local wind speed[33] Since every building and its surrounding structures are different, it is a difficult task to assess the feasibility of a small-scale wind turbine installation following a consistent methodology[34]. The feasibility of micro wind generation in New Zealand was addressed in Mithraratne [35].The average capacity factor in New Zealand of a commercial, large scale wind farm is quoted as being around 45%. Through studies of urban houses in the US, UK, and Europe, rooftop wind generation capacity factors lie in the range of 4% to 6.4%. Recommendations to improve performance include sites selection with a minimum average wind speed of 5.5 m/s, and a building roof 50% higher than surrounding objects.

Overall conclusions from Mithraratne[35] were that small-scale wind generation in New Zealand is suitable only in selected sites and will make minor contribution to meeting overall electricity demands. It is recommended that conventional energy reduction and efficiency measures be implemented first to reduce demand, and that wind turbines be installed in conjunction with roof top solar to meet overall electricity demand. It was estimated that large scale wind farms have 11 times the generating capacity than that of small scale wind energy. However, a life cycle analysis has shown that the energy and carbon intensity of small scale wind turbines are less than grid electricity if supply chain and recycling measures are carefully considered. When considered in these terms, small scale wind technology could be of benefit to New Zealand as part of a holistic strategy of energy conservation and other small scale renewable technologies.

2.6 Other Effecting Factors in the Adaption of NZEH

2.6.1 Occupant Behavior

NZEB concept can't be achieved without considering the occupants behavioral effect. Households play major and most important role in NZEB. Energy conservation in project can only be achieved through the good understanding of energy use in residents of house. Carolina hiller highlighted the fact that household sustain huge impact in achieving zero energy concept as energy consumption of similar houses with different number of households differ as their demand and thermal comfort level changes as per necessity. The relation between water use, indoor temperature and number of persons living were also analyzed.[36]

2.6.2 Indoor Environment

On average a person spent 90%of his time in indoor environment. Indoor environment has great effect of human health. Thermal Comfort is of great importance while achieving NZEH objectives. Indoor air Quality of house can achieve the NZEH target if they are based on ASHRAE Standards version 90.1. which is specifically designed to improve the efficiency of building without compromising human well-being[18]. Moncef Krarti[37] stated an holistic and integrative energy analysis approach in residential sector to improve energy efficiency in residential buildings along with their effect on human comfort level . It shows that 52% annual savings for new homes can be achieved through installing energy efficient appliance and insulating the outer walls and roof to reduce their U-value.

2.7 Examples Around Globe

2.7.1 NIST Zero Energy Residential test facility

In 2012 NIST completed the construction of a Net-Zero Energy Residential Test Facility (NZERTF) on its campus in Gaithersburg,MD to demonstrate the possibility to achieve net-zero house with conventional architecture, desired features and size comparable to those being constructed in the surrounding area. NIST US designed a pilot project of NZEH using efficient appliances and passive house design in Maryland and observed its performance during first year operation.[38]

2.7.2 zHome

zHome is first 10 house unit implementing the concept of NZEH and became real life experiment of sustainable living Home in Issaquah, WA. It uses cutting edge technologies along smart design to reduce its carbon footprint and fulfil two third of energy demand. Expanded polystyrene having R-value of 60 in ceiling and R-10 under Slab is used to provide thermal bridge. Homes in zhome project use 60% less water and have clean indoor air as compared to a conventional home. Double-paned low e, argon-filled Pella fiberglass windows were use It also integrates solar PV system of 72.25 kW having module capacity of 240 W for the remaining one third consumption.[39].

2.7.3 Yannell Residence

The Yannell Net Zero Energy Residence is the first single-family residence having an area of 3,000 sq. Ft. in Chicago which was designed with a goal of building a "net zero energy" house. The home produces more energy than it uses during a year. The project involves the use of passive solar systems, a geothermal system, natural ventilation, solar thermal for domestic hot water and heating systems, and photovoltaics for generating on-site power. All systems for the building were incorporated into a complex energy model with several iterations to determine the most efficient building configuration. The project has achieved Platinum level certification of Leadership in Energy and Environmental Design (LEED) for Homes in 2009.The home also features the first residential greywater system in Chicago which reuses water from the washing machine for toilet flushing.

2.7.4 Cottle Zero Energy Home

The Cottle Zero Energy Home was the 1st Net Zero Energy new home in California and is recognized as one of the highest-performance, greenest and most energy efficient homes in the State. It was awarded a special commendation by the California Energy Commission along with other certifications like LEED Platinum, Passive House Certified and HERS. It boasts all the features you would expect in a custom luxury home in Silicon Valley, and much more. This ground-breaking contemporary home redefined performance standards for indoor air quality, comfort, energy and water efficiency, and of course, modern style and luxury. It also produces surplus solar energy for Electrical Vehicle charging.

2.7.5 Reid's Heritage Homes

Reid's Heritage is new construction in Ontario, Canada. It achieved the NZEH goal in 2016. The Discovery Home in Guelph has applied passive design in building architecture to the maximum level. It has fresh air ventilation system that significantly lowers energy demand and eventually dropped building annual utility cost. Building is efficiently designed as it only consumes power equivalent to that of a compact fluorescent light bulb i.e. approx. 13.5 Watts.

2.7.6 The Fraser House

This custom net-zero energy residence was designed in extremely harsh environment, with the integration of passive and active building technologies. The project is grid tied home with area of 5232 sq. ft. used for generating 17 KW PV system and placing evacuated solar thermal array to fulfil the electricity and heating load of house. The project also includes 2 electric plug-in vehicles. HERS score of house is -22 as extensive modelling is done to design highly efficient building. However conventional house has HERS score of 100.

The design for the home was put through extensive energy modelling to guide the design of the building. As a result, the home is extremely energy efficient with a HERS (Home Energy Rating System) score of -22. For reference, a typical home built to building code is a HERS 100; a home built to Energy-Star requirements is a HERS 85.it also incorporated the idea of green roof to ensure high energy performance. A site forested with pine and aspen trees, the landscape design intent was to keep the re-vegetation native and natural. The green roof allowed us to introduce drought tolerant grasses, sedums, and colorful wildflowers, while protecting the plants from local wildlife and extreme wind.

Figure 2-2 Net Zero Energy Home Residential Test Facility (NIST)

Figure 2-3 Yannell Residence

Figure 2-5 zHome

Figure 2-4 Reid Heritage

Summary

This chapter gives an overview of net zero energy building concept and describe the parameter through it can be achieved. From the above literature review it is clear that conventional residential building has huge potential for improvement. Retrofitting measures involve in NZEH may ranges from low to high cost and adapted based on their efficiency. The world is already progressing toward NZEB through signing the Paris Agreement 2050. There are various factors which effect the adaption of concept and block its integration in mainstream buildings.

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Chapter 3 Methodology

The purpose of this study is to estimate the annual energy consumption in domestic sector of Pakistan and evaluate the potential of net zero energy home concept. For this purpose, the set of questionnaires has been designed by conducting a site survey. Responses collected from survey are analyzed based on different techniques and measures. Then renewable integration potential is determined using HelioScope software to achieve the zero-energy concept. Financial analysis is also done to estimate the feasibility of idea. Detailed steps followed for achieving the objectives of this study are discussed below. However, basic layout plan for carry research is shown (Figure 3.1).

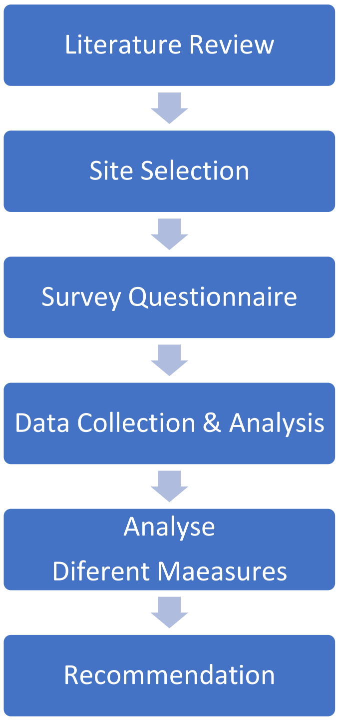

Figure.3-1Methodology for Conducting Research

3.1 Site Selection

Pakistan is one of few countries in the world to have every kind of geological structure and climate Pakistan lies in tropical to temperate zone. The climate of Pakistan is generally considered arid, characterized by extreme weather variations such as hot summers and cold winters. It also has a monsoon season with adequate rainfall, and a dry season with less rainfall.

Three sites were selected for conducting survey brief description of which is given below.

- Islamabad
- Lahore
- Mirpur

A *B* *C*

Figure 3-2(A): Lahore, (B): Mirpur, (C): Islamabad

Climatic conditions of each selected city are slightly different from each other. Islamabad capital of Pakistan has Mediterranean climate very cold winters with dry hot summers. Whereas Lahore is provisional capital and largest city of Punjab and has steppe climate and require more cooling days on annual basis. Similarly, Mirpur Azad Kashmir lies in relatively humid and semi-arid temperature zone and has high cooling demand in summers and moderately cold winters.

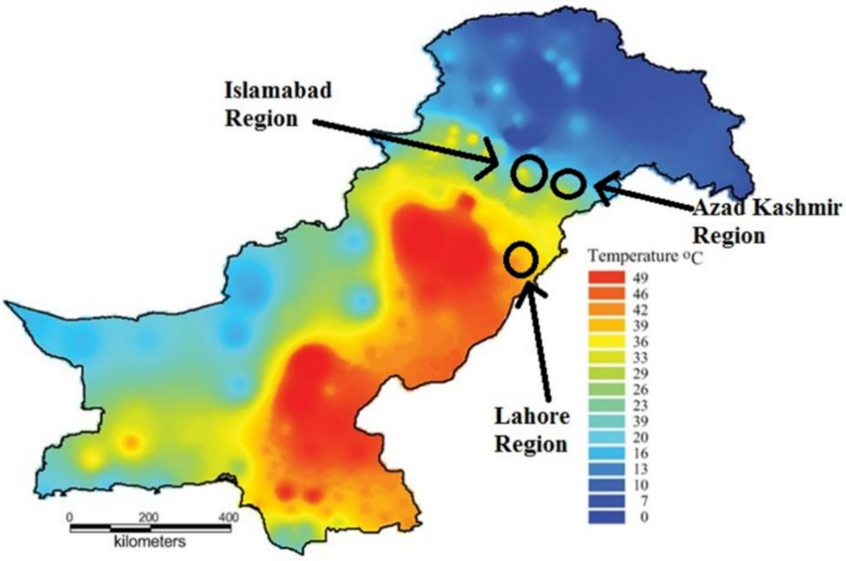

Figure 3-3.: Climatic Representation of Pakistan

The detailed analysis of the weather of Islamabad and Lahore city is made from RETScreen software's climate data section. The software has unique assistance of obtaining data from ground monitoring stations, as well as NASA's satellite database. The temperature data showed that monthly average values of air temperature varied from minimum 12°C to a maximum value of 35°C; the high annual average values indicated the severity of cooling requirement in each city during summers.

3.2Survey

Residential sector is one of the major consumer of energy after industrial. Huge amount of power is wasted in domestic sector worldwide due to lack of awareness about efficiency measures. Energy consumption in residential sector influenced by many factors apart from area and weather such as

- Sample Number
- Distribution pattern
- Area of Living
- Occupancy behaviour

In this study survey is being conducted which focus on all these areas and help me analyses the occupational behavior and load pattern of residential sector of country.

The survey was conducted through Statistics survey. Questionnaire was sent to a sample of homeowners in different cities of Pakistan. For my research total number of 100 samples are collected from 3 focusing areas of Pakistan i.e. Islamabad Lahore and

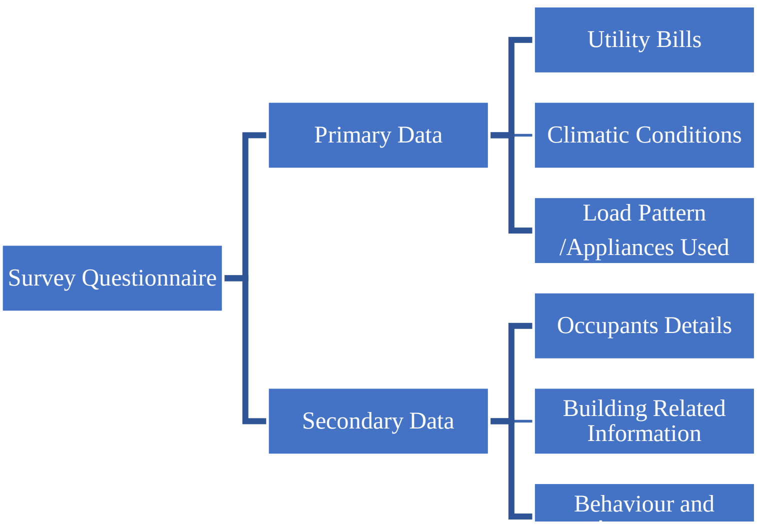

Figure 3-4Survey Focussed Areas

Azad Kashmir (Mirpur. And number of households selected for survey from each city are 46,32 and 22 respectively.

The questionnaire consisted of five parts. Section A included questions about the existing conditions of the building envelope components. Section B included questions regarding the installed appliances in building and their utility bills. Section C includes the occupant's awareness of energy conservation measures and their perception section D includes their knowledge about NZEH and renewable integration. In section E they were asked grade their willingness toward adaption of NZEH concept.

3.2.1 Building Envelope

Building infrastructure plays important/critical role in reducing the energy demand as the orientation of building along with its design have huge impact on the thermal performance in cold and hot climate. This section collects the information about building area, type of residence such as bungalow, flats or single detach house, number of stories, roof availability, total number of rooms, approximate room area, number of windows installed, type of insulation on walls roofs and windows.[1]

3.2.2 Occupants Behavior and Details

This section include the personal detail of homeowner as total family members living in the house, Apart from basic information regarding occupant's education; financial condition also play important role.[2][3] It include monthly income of the owner, total family member ,their level of education which will provide the idea of their knowledge of energy efficient measures.

3.2.3 Appliances Usage Pattern and Type

In this section we collected the information regarding all the electrical appliances installed and consume power in house along with their rated wattage and time of use, that help us to estimate the load pattern. Similarly, data regarding Natural gas based appliances are also considered. Utility bills of respondent house are also collected in order to analyses their annual demand and consumption of energy.[4][5]

3.2.4 Awareness about Energy Conservation and Renewable Integration

This section includes the questions indicating the behavior of occupant towards the energy conservation. This section also provides information about any other source installed either conventional or non-conventional for energy generation. Solar being abundant source of clean generation in Pakistan can help in reducing the burden on grid so the perceptive of homeowners regarding the installation of renewable sources were also analyzed.

3.2.5 Perceptive Toward the Adaption of Net Zero Energy Concept

In this section questions asked related to NZEB determine their understanding about it along with their willingness toward its adaption and adapt the required energy efficient low or high cost measures. The level of measures they can perform to achieve the zero-energy home were also inquired. [6]

3.3Data Collection

Collection of data is a long and time taking process. Hundred of samples were collected 100 from 3 areas of Pakistan. Each city has different number of surveys such as number of homeowners responded to questionnaire from Islamabad are 46 similarly 32and 22 from Lahore and Mirpur AK respectively. Other general parameters of selected sites are shown below [7].

Table 3-1 Defined Parameters for Survey

Parameters	Islamabad	Lahore	Mirpur
Sample Size	46	32	22
Area (Km^2)	906	1772	1010
Population	2.01 million	9.2 million	0.16 million
Number of houses (millions)	0.12	10.5	-
Average Min & Max temperature (in °C)	14-33	15-35	12-32

3.4 PV Modelling

Incorporating solar PV with residential building is important part of onsite zero energy home as it provides the carbon offset by neutralizing the efficiently reduced energy demand provided by national grid[8]. There are many softwares available for designing PV system for building. In this research HelioScope software is used to predict the potential of rooftop solar.

3.4.1 HelioScope Software

It is a web-based software recently introduced by Folsom Lab which can be used on any connected computer after buying the license on monthly or annual basis. Through this software we can easily design solar system and also accounts for losses due to climate, shading, wiring, along with efficiencies of components and losses due to mismatching of panel. It also provides recommendations for array layout in system design. HelioScope software is similar to PVSyst but with the additional feature of AutoCad.[9]

Main features

- Simple engineering and fast design of solar arrays
- User friendly
- Collaborate in real-time
- Large data set/library

When using HelioScope, the user enters the location's address, roof area being selected for the PV array being, specifies a PV module parameter, and then chooses an inverter size and model. HelioScope also performs shading analysis of designed system. With this method, one can do a complete site assessment and design without setting foot on the actual project area. Through this software solar installer can design system 5-10 times faster which saves considerable time and expense.

To do a comprehensive design of our grid tied PV system for residential sector. The following steps are done:

New Project

Create new blank project as shown in figure. Location of building can be added using google earth and SketchUp, drawing software. Locating home in google earth and then imports its 3D layout SketchUp model in HelioScope.

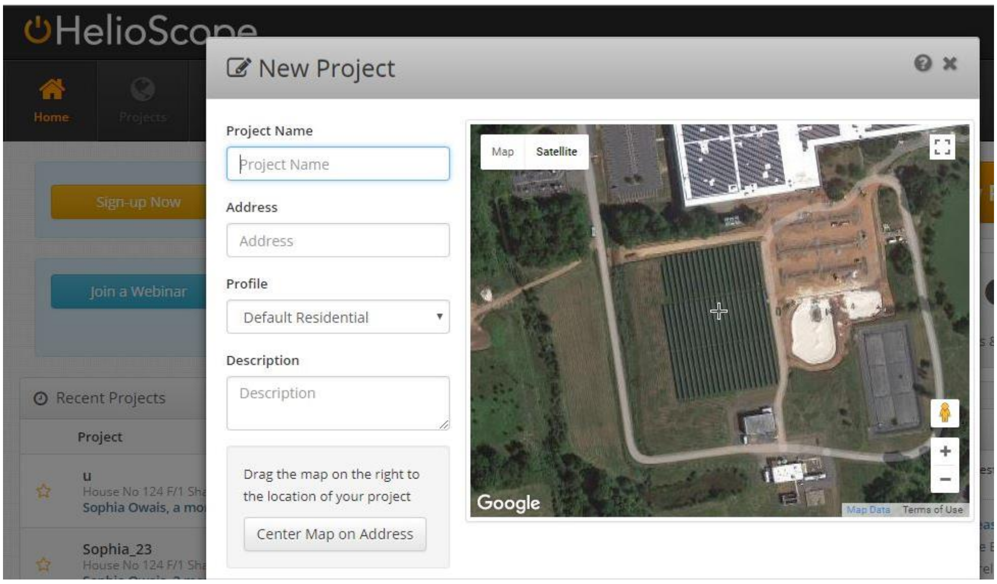

Figure 3-5 Creation of New HelioScope Project

Mechanical layout

A mechanical layout based on field segment is designed which include the site area available on rooftop for PV system installation and then required parameters for

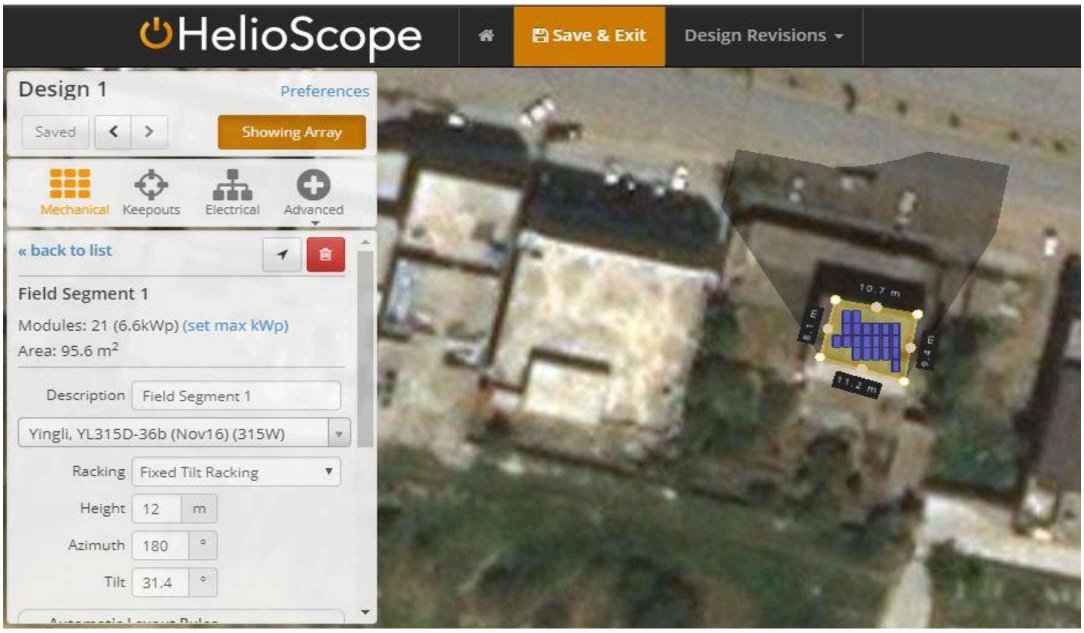

Figure 3-6 Generation of Field Segment

module designing such as type of panels, their orientation, tilt angle, spacing etc. are defined. Row spacing will be set along with module setback for maintenance purpose.

Generate keep out zones

Keep out Zones which defined as the areas which are to be excluded from project site. It also includes the heighted trees giving shade during the peak solar irradiance hours.

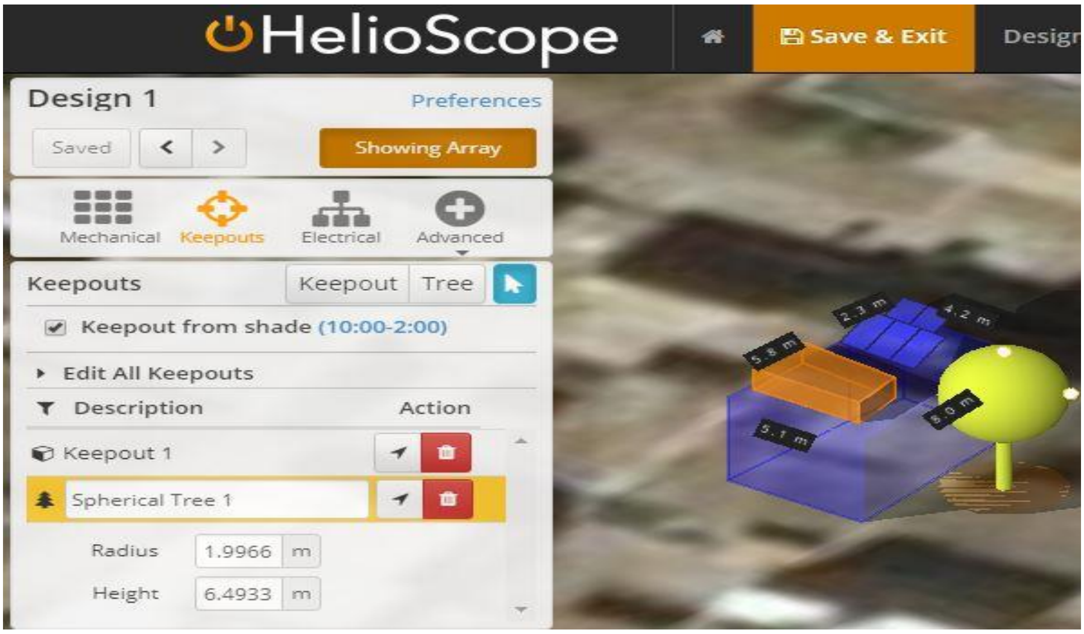

Figure 3-8 Identifying Keep out Areas

Climatic Conditions and Shading Analysis

Based on the area climatic conditions will be selected which will help in performing shading analysis as inclination angle, solar irradiance and other parameters varies with respect to each site

Figure 3-9 Setting Climatic Conditions

Summary

This chapter gives an overview of process through which the research has been conducted. This also highlighted the areas focused on survey such as Islamabad, Lahore and Mirpur AK. Chapter also includes the introduction of software used for integrating renewable energy into building footprint and the steps required for it.

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Chapter 4 Results

Pakistan's residential sector share in total energy demand is 25% and it cover 51% in country electricity demand whereas 22% in total natural gas consumption. Energy utilization in domestic sector is increasing every year due increase in population growth rate. (Pakistan year book 2017). This chapter discusses the study conducted in Pakistan to identify the potential of NZEB concept in residential sector. For this purpose, designed survey of 100 households conducted in 3 cities of Pakistan, from which 10 houses comprise less than or 4 Marla and 70 were between 5 to 10 Marla.

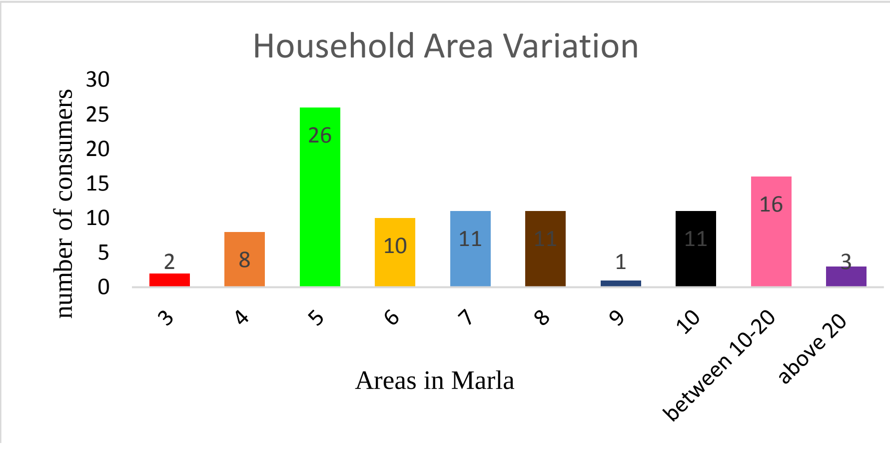

Figure 4-1 Frequency Distribution Household Areas

4.1 Annual Energy Consumption

Main source energy consumption in typical house of Pakistan is electricity for cooling, lighting and other plug loads whereas for cooking, heating space and water natural gas is used so their primary data include utility bills and are collected over the period of 12 month to cater the seasonal variation in demand. Cumulative Annual utility consumption of houses are shown (Figure 4-2).

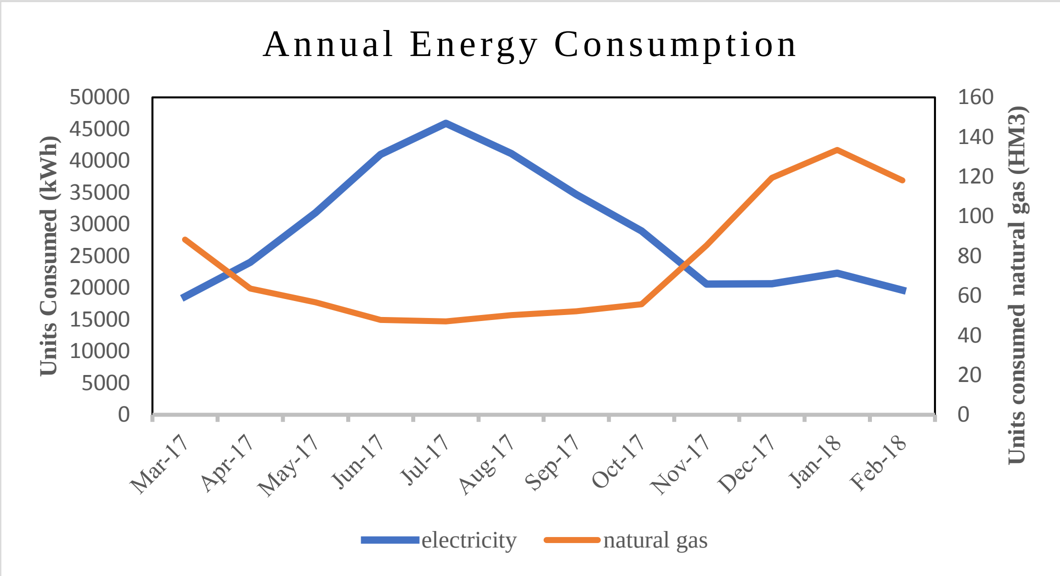

Figure 4-2 Monthly Cumulative Energy Consumption of Households over 12 Months

Pakistan lies in an arid environment has more cooling months than heating[1]. During summer season i.e. between May to August electricity demand is at its peak due to high cooling needs. Whereas heating shows peak demand during winter season i.e. between November and February. Approximately 66 households have units greater than 300 while, 38 have consumed greater than 500 units during summers.

Similarly, there are 29 number of households having natural gas consumption higher than 2 HM3 in winters. However, out of 100 respondents 17 doesn't have the natural

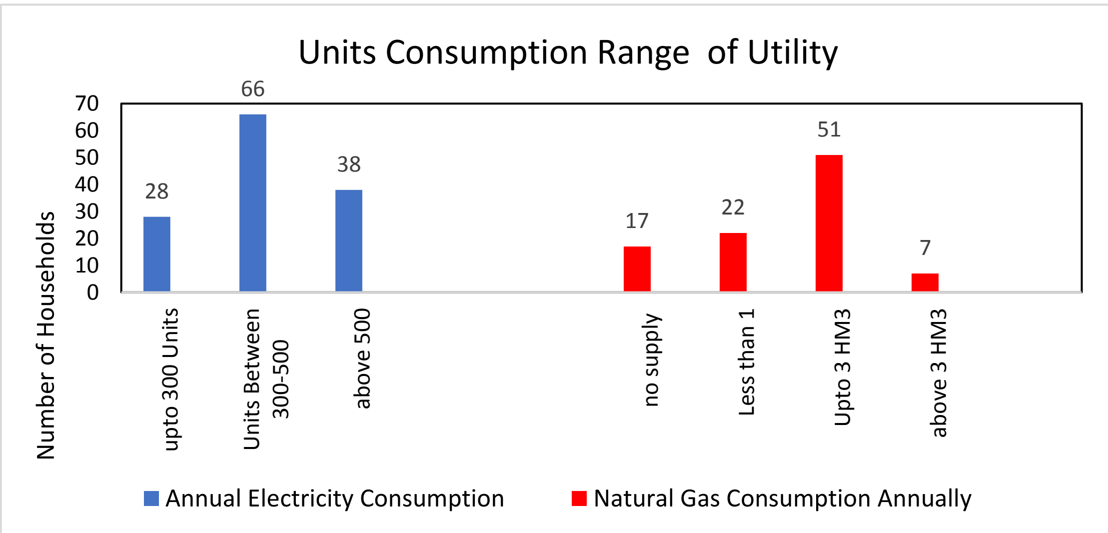

Figure 4-3 Energy Usage Ranges for Electricity and Natural Gas

gas supply and 22 of them used for cooking purpose only due to limited supply in winters.

There are different tariff slabs for both electricity and natural gas depend on sectors determined by NEPRA and OGRA[2][3]. Each slab has different threshold and crossing that threshold increase the cost per unit above that limit. Natural gas has 3 tiers for residential sector whereas electricity has 6 tiers including subsidy provided by Govt for domestic users. (Figure 4.3, 4.4)

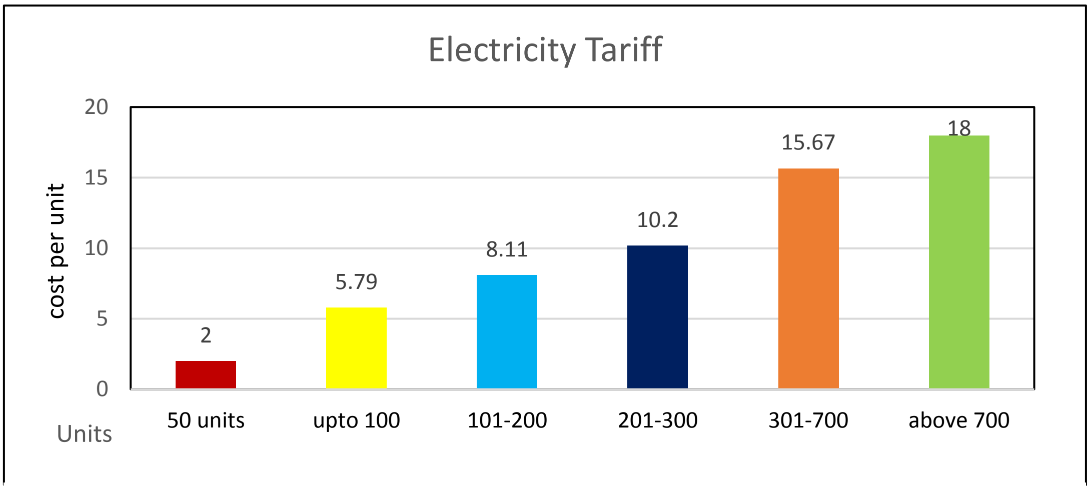

Figure 4-4 Defined Tariff for Residential Electricity Use

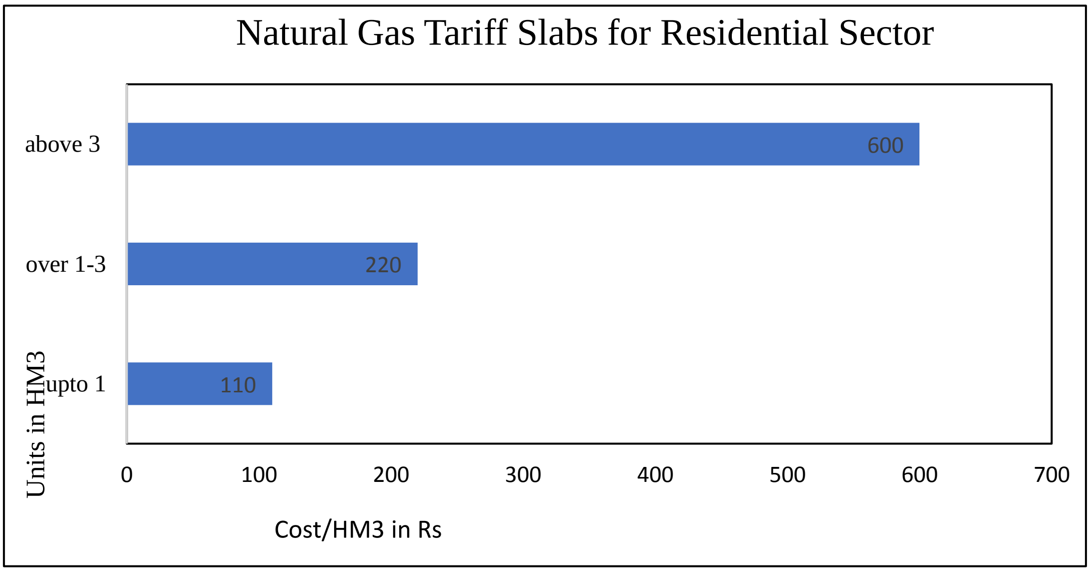

Figure 4-5 Tariff Slabs for Natural Gas

Graph shows the cumulative energy consumption of total sample size in MJ unit of energy. From the graph it is clear that natural gas plays major role whereas in terms of cost electricity is driving factor.

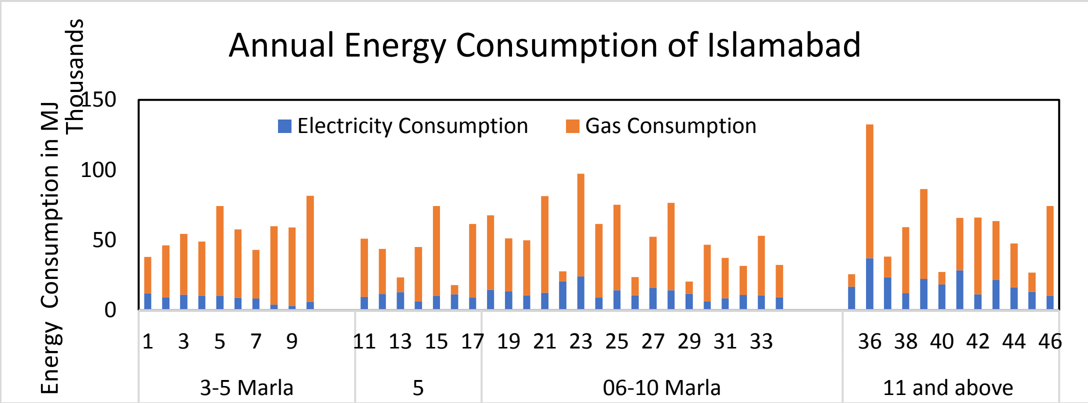

Figure 4-7 Annual Cumulative Energy Consumption of Islamabad Households

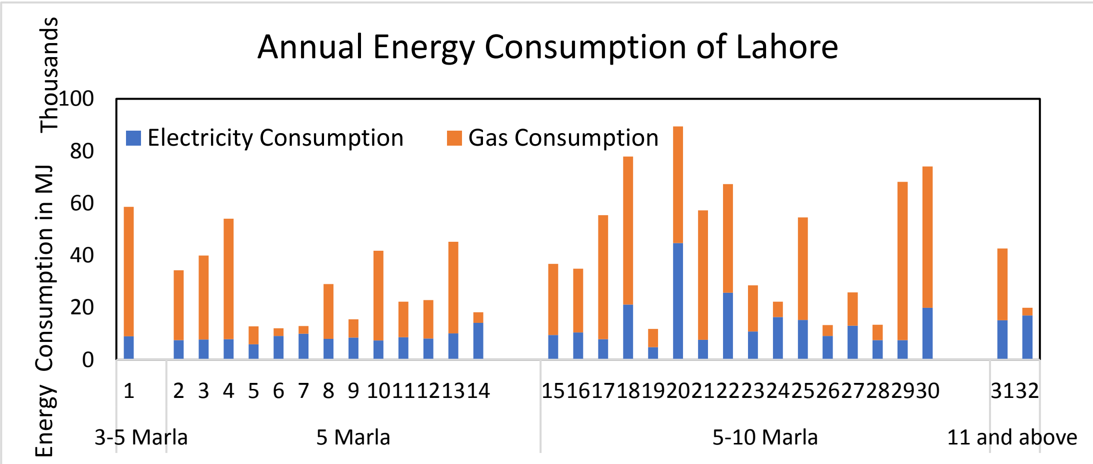

Figure 4-8 Annual Cumulative Energy Consumption of Lahore Households

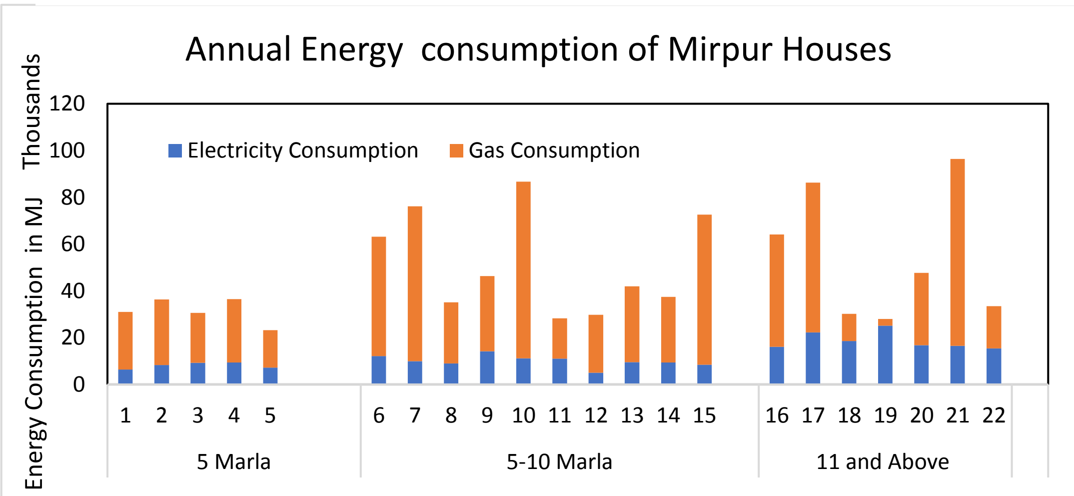

Figure 4-6 Annual Cumulative Energy Consumption of Mirpur A.K Households

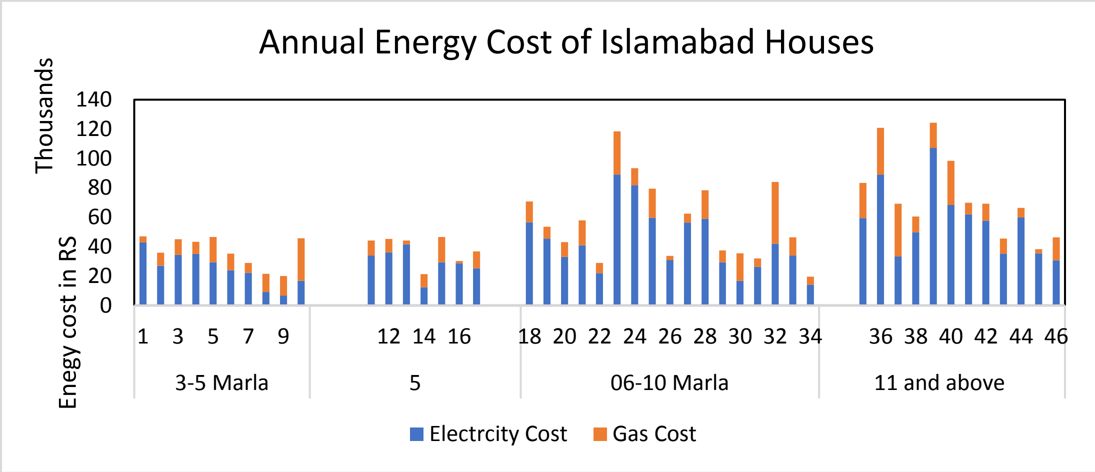

Figure 4-10Annual Cumulative Energy Consumption Cost of Islamabad Households

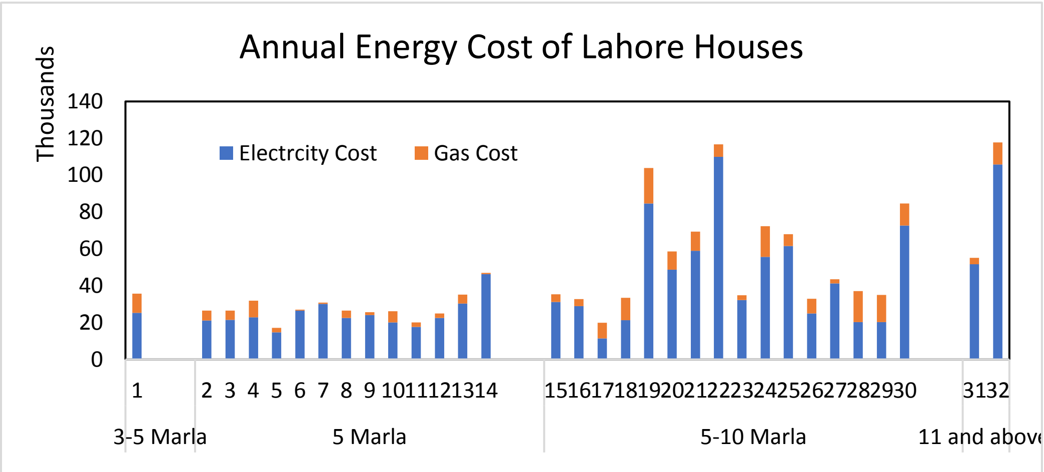

Figure 4-11 Annual Cumulative Energy Consumption Cost of Lahore Households

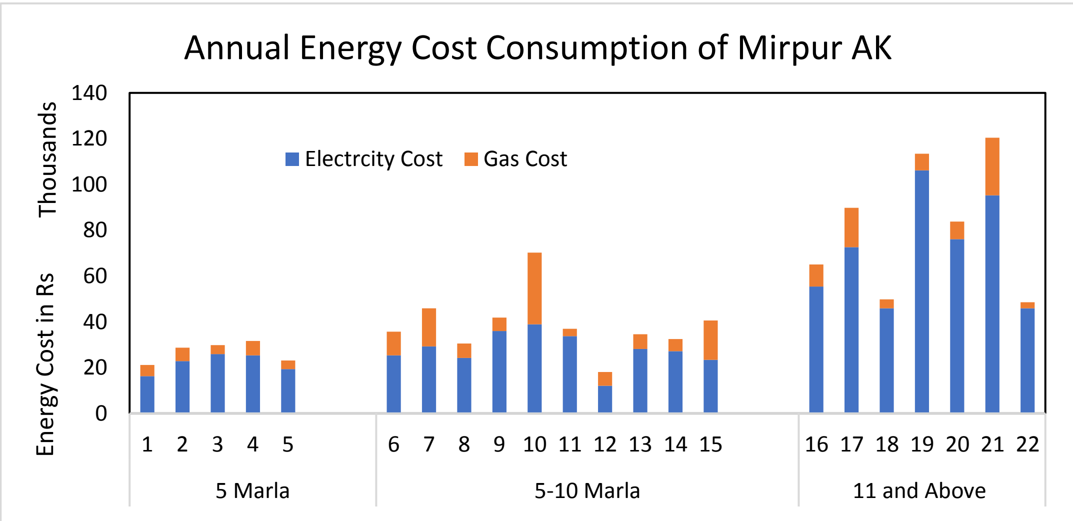

Figure 4-9 Annual Cumulative Energy Consumption Cost of Mirpur A.K Households

4.2 Electrical Load

There are various appliances used in the house which waste much more electricity on daily basis. They are two main types of electrical load in building: permanent load and plug load. Permanent load includes lighting heating, cooling and ventilation while plug load include all the other appliances that consume power on standby mode, TV, washing machine refrigerators, iron, mobile laptops etc.

Other than Air Conditioners, fans and lighting system, primary plug load include refrigerators irons consume high power. From the survey we obtained that 34 households have 1 air conditioners, 11 home owners have installed two ACs and only 13 have 3 or more air conditioners, similarly 16 owners have more than one refrigerators and 20 number of households have more than one iron which can also affect the load demand.

4.3 Natural Gas Load

In Pakistan Natural gas may have low cost but its energy value is higher than the electricity. Households consume natural gas mainly for cooking, space heating and water heating. The results showed that 68% households have geysers installed for water heating and 60 % households have heaters for space heating purpose.

4.4 No Cost Measures

There are few measures which require no expense or financial assistance yet the cooperation and understanding of user through which demand of energy can bring down to some degree. Such as

- Switch off the unnecessary lights.
- Keep the door close tightly during HVAC to prevent air infiltrations or heat loss.
- Utilize daylights during as much as possible.
- Use warm clothes to keep you warm in winters.
- Wear light tone clothes during summer and dark tones in winters
- Use blinders and curtains during summers
- Set the Temperature of ACs and Heating system to optimised level while maintaining the human comfort.

- Install controlled devices to systems.
- Switch off all the load while not in use. Don't keep them on standby or sleep mode.

4.5 Low to High Energy Conservation Measures(ECM)

4.5.1 Lights

Switching the lighting system to efficient lighting is the fastest and easiest way to cut the utility bills, as plays significant role cooling and heating demand of house depending on climate[4][5]. Lights consumed total 8% of total cumulative energy consumption of total sample. The graph showed 50% is consumed by CFL, 37% by fluorescent lights and 12 % by incandescent bulbs (Figure 4.8). It's been seen that lighting system of houses weren't designed based on lumen/m2. Incandescent bulbs are highly inefficient and convert only 10% of energy into light and waste the 90% energy into heat which exert additional load on the electricity grid. replacing the conventional lights into highly efficient lights LED which consume 90% less energy and provide the same lux level. Efficient lights (LED) are easily available in market by different manufactures like Philips, Osaka etc.

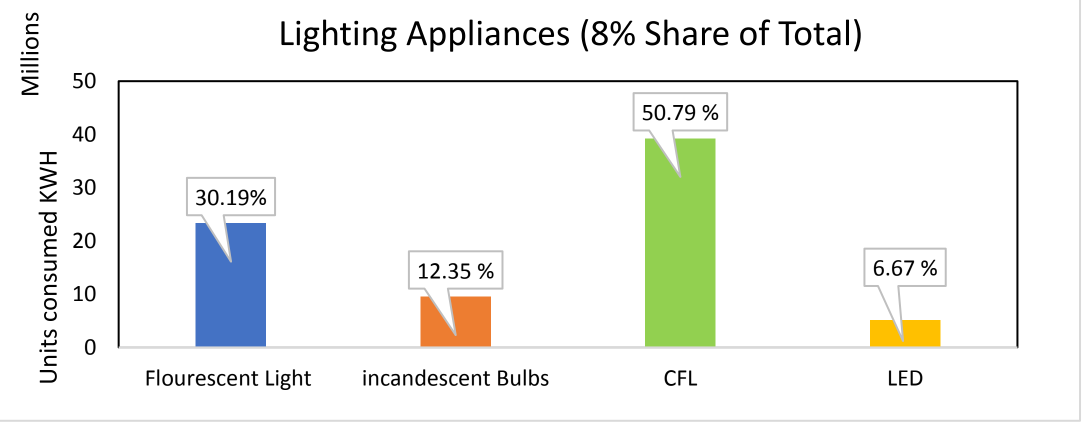

Figure 4-12Lighting System Contribution to Cumulative Electricity Demand of Total Household Sample

4.5.2 Fans

Areas under consideration for research have approximately 8 months of cooling requirement. And ceiling fans are used as main source of fulfilling the cooling demand in Pakistan. Old and conventional fans are highly inefficient and consume 37% of total cumulative energy. It was found that 82.49 % installed fans were inefficient and only 17%fans were energy star labelled which consume half the energy.

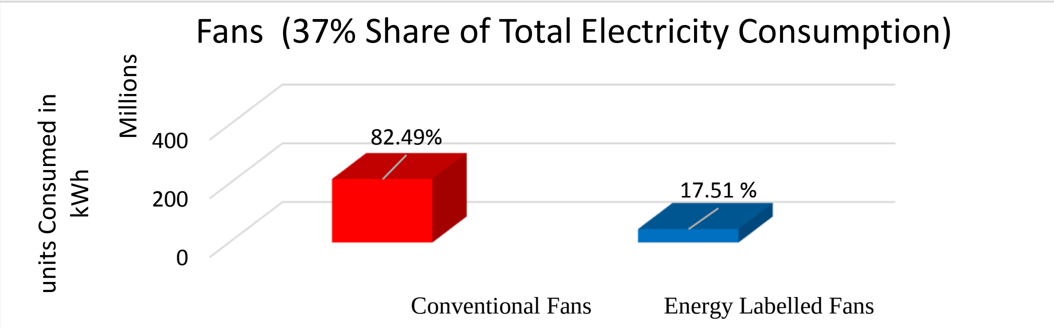

Figure 4-13 Dependence on Conventional Fans

NEECA collaborated with few manufacturers to promote energy conservation and introduced energy labelled fans, which consumes half of energy and great potential in energy conservation[3]. (Table 4.1)

Table 4-1 List of manufacturers providing Energy Labelled Fans

Manufactures	**Models**
GFC	56’’ ,48’’
PAK FANS	All models
ROYAL FANS/YOUNIS	56’’
SUPER ASIA	48’’

It was the general concept the bigger the fan more cooling it will provide but on average 48´´fan is enough for 12*12 Ft. room without compromising on its thermal comfort level.

4.5.3 Air Conditioners

Average house in Pakistan is keen to have at least one air conditioner. Whereas middle class may have more than 1 AC and used during peak of summers only. Whereas just 13% homeowners have more than 3 air-conditioning units installed. 92% installed units were conventional and uses R22A refrigerant which has negative impact on the environment. However, these are banned in developed countries but still used in less developing ones due to high upfront cost of efficient[3].

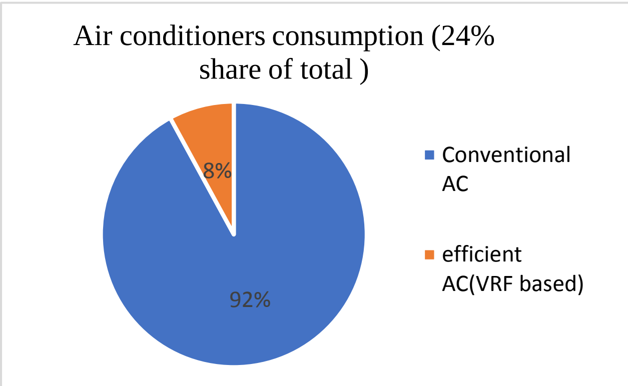

Figure 4-14 Cumulative share of Inefficient Air Conditioners

They operate for approx. 10 hrs. with constant speed whereas newly introduced ACs have VRF installed which vary the speed of compressor according to the user temperature demand and operate on less power. EPA has classified 3 types of refrigerant as environmental friendly. i.e. R-410A, R-407A and R-134A. Newly designed ACs have installed variable speed drives which reduce speed of compressor according to set temperature and high COP value, ultimately reducing the power consumption. Recently introduced air conditioners in Pakistan are also energy labelled high COP value and consume up to 50% less energy as compared to conventional. Also known as dc invertors in Pakistan. Manufacturers listed below are providing energy efficient appliances. (Table 4.2). Replacing the conventional with VRF conditioners having high COP,3D thrust, high air flow rate and many other features to save electricity up to 50% and provide healthy indoor environment.

Table.4-2: List of Efficient AC Manufacturers in Pakistan

Company	Models	Price (Rs)
Acson	A5WMY15LR A5WMY18LR A5WMY10S2 A5WMY15S2 A5WMY25JR	65,000 to 140,000
Dawlance	Inspire PlusPlus 15 Inspire PlusPlus-30 Inverter Series 15 Inverter Series 30	50,000-85,000
Gree	Gree G10 Eco Inverter series Gree Premium GS-12UITH3 Gree Premium GS-18UITH3 Gree Premium GS-18UCITH1	60,000-120,000
Haier	Haier HSU-12HQA/R2-DB Haier HSU-12HZE/R2-DB Haier HSU-18HZE/R2-DB Haier HSU-18HNH/DC Haier HSU-24HNH/DC Haier HSU-12HNF/DC Haier HSU-18HNF/DC Haier HSU-24HNF/DC	60,000-100,000

Kenwood	Kenwood Inverter TechKET series	50,000-75,000
Toshiba	Toshiba RAS series	65,000-135,000
Samsung	Samsung AR18HVSSBWKNSS Samsung AR24HVSSBWKNSS	95,000-120,000
Orient	Ultron Classic Atlantic DC Invertor series	49,000-65,000

4.5.4 Miscellaneous/Plug Load

When it comes to plug load it includes refrigerators, washing machine, iron, air water cooler, television sets (LCD, LED TV) and all other electronic devices. They may have consumed nominal power but their time of duration and constant use impact the daily energy consumption of house. Among these refrigerators have the significant role as they operate 24hr. Conventional 16cuft refrigerator consumes 1680kWh approx. annually whereas, energy rated consumes only 256kwh. Replacing energy rated refrigeration and washing machine system can save more than 2 times of their conventional energy. They also have positive impact on environment as they use environment friendly gases some of the manufacturer easily available are shown (Table 4-3) (Table4-4)).

Table4-3: Energy Rated Models of Washing Machines Available in Pakistan

Company	Model	Price in Rs
Panasonic	NR-BW Invertor Series	60,000-1,95,000
Dawlance	Energy saver Series(9188WB)	40,000-44,000 39,000-41,000.

	LVS Series (Dawlance LVS 9170WB)	
Samsung	Samsung RF858QALAXW model (French door) Samsung (RT47K6358SL)	370,000-380,500.
Haier	HRF Series (380,300,322,272,155)	24,000-64,000
Orient	OR – 114 Series F	25,000.40,000
Whirlpool		

Table 4-4: Energy Rated Refrigerators Available in Pakistan

Company	Model	Price
Dawlance	• dawlance DWT-275TB G ES Fully Automatic • DWT-235TB W ES • Dawlance DWD 85400S INV	34,500-45,000 76,500
Haier	• HWM SERIES (HMS1000TVE HWM60-10866) • W100-HB1297NZP	14,000-175,000
Samsung	• WF8558NMW/XSG • WF8590NHW/XSG • WD0704REW/XSG	44,500 48,000

		105,000
LG	• F1 Series(F1480FDS5 F10C3QDP2)	
Panasonic	• NA-148VG3 • NA-F115A1	82,990 65,500

Moreover, all electronic devices having standby option must be off when not used as they will continue to consume power during sleep mode and reduce their lifespan.

4.6 Geysers

There are various of EE options available in Pakistan market include

- Efficient Gas heaters
- Instant heaters
- Solar water heaters

4.6.1 Storage Geyser

When it comes to a gas geyser, Storage geyser are one of the most demanded water heaters nowadays. They operated on natural gas for supply. Installing energy rated geysers help in saving gas consumption to tremendous level. As they contain automatic thermostat switch along with rust free galvanized tank for storage of hot water. Various models contain different capacities that range from 10 litres to 50 gallons are available in market. 5 star rated geyser consumes less gas for heating water as well as has much less heat loss. Singer water heaters are highly energy efficient and reduces your monthly gas bills as it consumes gas at a rate of 28.5cft/hr. Also insulated with thick glass wool insulation that helps in retaining temperature and pocket friendly.

4.6.2 Instant Geyser

For household instant geysers are the best choice. It requires less space and ready to use whenever need the hot water. As kitchen demands immediate hot water for washing for limited time using instant water heater reduce the load on utility since no storage tank is involved and saves plenty of time. Different brands are available in instant water geysers like Canon, Corona, Lecston and Rays. Its capacity ranges from 6 litres to 12 litres. Instant geysers are available in both electric and gas type. (Table 4-5).

Table 4-5 Instant Water Heating System Available in Pakistan

Geyser	Model	Price in Rs	Power(KW)	Capacity
Canon instant heaters	8 Liter Instant 16 HD	7000-9000	2KW	8L/min
Corona Instant Gas Water Heater	6L-SS EXC-S	7000-8500	Gas	6L/min
Centon Instant Electric Heater	CWH-707E	11000-13000	6 KW	2L/Min
Nasgas Electric Geyser	DE series	10,000-28000	1.2 KW	1.5L/min approx.
Aurora Electric Water Heater	AWR-9040R	19000-21000	500-1500	2L/min
Lecston Instant Heater	Elite EL-212	12000-14000	3-8KW	2L/less than min

In countries like Pakistan where demand of natural gas is maximum and supply is limited in winters, Electric geysers are viable option. They are manufactured using advance technology and can work efficiently in severe weather conditions. Not only in kitchens but the installing electric instant heater in bathrooms will also help you in taking the hot water shower immediately, as they warm the water within minutes. These geysers are an ideal home appliance that aids in reducing the burden on grid and save time required to take a bath.

4.6.3 Solar water heater

Conventional gas heaters play major role in natural gas consumption and increases carbon emissions by installing solar water heater along with gas geyser can give 50% reduction in energy consumption also reduce the greenhouse gas emissions. The efficiency and reliability of solar water heating systems have significantly increased over the last few decades while the cost has also come down[6].

4.7 Heaters

For a moderate climate zones like Islamabad, a well-insulated room will require electric heater with power input of 2 kW whereas gas heater of 6-8 MJ in case of poor or no insulation more heating will be required i.e. 2.4 kW of electric heater and 10-12 MJ of conventional gas heater. Heating demand in Lahore is minimal as it has hot and dry climate. Whereas demand in Mirpur vary due to occupancy and climate. There are various technologies have been introduced to reduce the environmental impact of burning natural gas. Using more warm cloth is the cheapest one it can reduce the overall heating demand but it is highly occupant driven. Other than that, replace the old conventional heaters with efficient ones. Some are easily available in Pakistan are

- Fuel efficient Gas Heater (dual plate system)
- Halogen heaters
- Fan heaters

In Islamabad winters are dry and cold and last longer than in Lahore use of heaters is more prevalent in capital city than others. Being a cheap solution to keep indoor temperature warmer than outer people prefer gas heaters than costly electric heaters.

4.7.1 Fan Heater

Fan heaters are highly energy efficient and human friendly especially for asthmatic patient or any kind of nasal problem it is portable, light in weight, adjustable speed design and compact system. Above of all require less energy to operate.

4.7.2 Halogen Heater

Halogen heaters use tubes which contain halogen to get the radiant heat. These tubes are a combination of non-metallic elements that heat up quickly while creating a warm and comfortable environment. They have zero environmental impact on house allowing clean and efficient way for space heating (Table 4-6).

Table 4-6: Efficient Space Heating Systems Available

Electric heaters	Price (in Rs)	Power (Watts)
Blower heaters	4000-5000/-	400,800
Halogen heaters	2000-5000/-	400, 800, 1200
Hybrid Heaters	4000-7000/-(2nd hand imported) 40,000(Japanese new)	15-25 ,34-46kW(gas)

4.8 Cost Analysis

Shifting toward environmentally friendly appliance without compromising on human comfort level is need of upcoming era. Due to high end technology and aim to reduce the global warming and developing sustainable future, energy efficient appliances are designed. They may have high upfront cost but their payback period is small and their saving in term of energy and annual cost is also striking. By adopting only low or no cost measure tremendous amount of energy can be conserved. As through lighting on selective site households we can save 4% whereas through energy labelled fans 50% energy can be reserved and through AC we can save up to 10% from conventional measures.

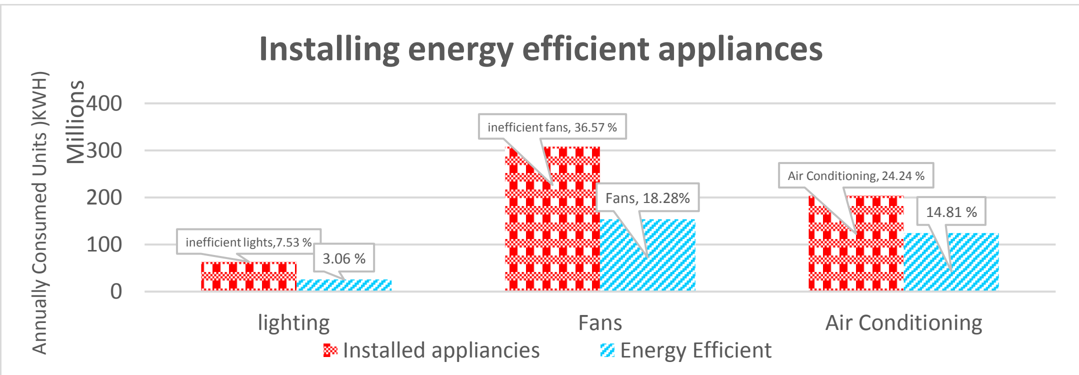

Figure 4-15Energy Saving Through Available Energy Conservation Measures

Table 4-7 Payback of Energy Efficient Appliances

Appliances	Wattage	Time Of Use (Hr)	Annual Power Consumption	Annual Cost(Rs)	Savings	Payback(New Buy)(Yr)
Conventional Fans	120	4320	518.4	6220.8		
Energy Labelled Fans	60	4320	259.2	3110.4	3110.4	0.321502058
Fluorescent light	40	1825	73	876		
Led Tube	18	1825	32.85	394.2	481.8	1.452885015
Incandescent Bulb	100	1825	182.5	2190		
Led Bulb	18	1825	32.85	394.2	1795.8	0.178193563
CFL	25	1825	45.625	547.5		
Led	9	1825	16.425	197.1	350.4	0.285388128
Ac (1ton)	1800	720	1296	15552		
Invertor (1 Ton)	700	720	504	6048	9504	4.103535354

Orient	1500	720	1080	12960	2592	0.771219136
GREE	1100	720	792	9504	6048	0.826719577
Ac 1.5 Ton	2700	720	1944	23328		
Invertor 1.5 Ton	1650	720	1188	14256	9072	5.401234568
Samsung	1400	720	1008	12096	11232	0.712250712
GREE	1600	720	1152	13824	9504	1.999158249
Refrigerator (16 Cuft)	250	6120	1530	18360		
Energy Rated Refrigerator	180	1440	259.2	3110.4	15250	0.459028434
Washing Machine(11kg)	650	180	117	1404		
Energy Rated Washing Machine	450	180	81	972		

4.9 Building Envelope

Building envelope plays a major role in building energy consumption. Poor insulation of exterior walls and roof of house increases its cooling and heating needs. Heat resistance of constructing materials define the heat capturing capability of house.

Constructed houses can add supplementary layer of insulated material to reduce its thermal conductance (U-value). Survey results showed, no single sample house have insulation on walls and roof. Only 3% have used reflective material on roof to reduce the thermal heat conductance.

There are various types of insulations available in Pakistan as shown(Table4-8).

Table 4-8: Available Thermal Insulations in Pakistan

Insulations	**Prices (Rs)**
Spray/foam	40-60/ ft^2
XPS	50-90 Rs/ft^2
EPS	8-15Rs/ft^2
Thermophore sheets	120 Rs /sheet (meter×2 meter)
False Ceiling (plaster of Paris)	80-100 Rs/ft^2

Other techniques which are relatively of low prices can also be incorporated such as white enamel paint, Lime wash, Green sheets on roof. Through which thermal blanket can be created and increasing the resistance value of building. These are some of the vendors for providing the insulating materials in Pakistan

- Diamond Jamblon
- Industrial Enterprises (Pvt.)
- Samz

Diamond Jambolon, has been producing quality insulation in Pakistan[3]. 4´´ EPS layer insulation is used to provide required thermal comfort, while 2 inch layer of XPS insulation can provide the same required thermal bridge. XPS has long lifespan due to waterproof property. Half of thickness is required for XPS than EPS but cost is almost double than EPS.

Diamond Jambolon is the only manufacturer of XPS in Pakistan and largest seller of insulations panels countrywide approximately 24,000 per month, assuming a size of 3ft×6ft(0.91m×1.83m) panels with the thickness of 50mm. These insulations panels can directly be installed on walls, or extra layer of bricks can also be used with it which increases the initial cost.

4.9.1 Window

Heat gain from windows is far greater than walls so reducing the WWR will ultimately reduce the cooling load in summers. They can also reduce the heating demand of house by passively heating the room. Highly efficient window glass along with glazing should be installed as they reflect solar heat and let the visible light in, reduce the lighting load. There are 2 types of measures being adopted in Pakistan i.e.

- Double Glazing on Window Glass
- Reflective Coating /Tinted Windows

According to Ghani Glass, projects using double-glazing are installed mainly on industrial projects with huge budget i.e. 5 to 10 million USD or more. Result showed that none of the houses has any type of glazing installed nor have reflective coating on their window. Double-glazing is used for less than 2% of new construction in Pakistan however the cost of the double-glazed window constitutes up to 2% of the total amount of the building construction. As well as the glass cost is concerned, the window frame cost is also considered as barrier. To accommodate double glass three types of frames can be installed such as

- Aluminium
- Steel
- UPVC

UPVC is preferred as it has low embodied heat energy and high durability but has high cost factor. Given the very low market share of double-glazing, the window frame cost for double-glazing is also high. (Table 4.8)

Table 4-9 Window Insulation Cost in Pakistan

Glazing	Replace	Retrofit
Double glazed • Aluminum • Wooden • UPVC(preferred)	620-700 Rs/Ft2	Around 900Rs/ft^2
Tinted /Reflective	450-600Rs/ft2	70-150 Rs/ft^2

4.10 Renewable Solar PV Integration

As defined NZEH (onsite)can be achieved through reducing the demand on grid to a minimum by applying highly EE techniques and measures and generate the clean energy, balances the grid use[7]. Therefore, renewable integration is essential part of NZEB. Pakistan has solar potential of 4.7 kWh/m^2/day on average which is huge solar potential for clean energy generation. HelioScope by Folsom is sophisticated tool used to model PV systems on homes. It is smart and highly efficient software which can be used in industry for demonstrating true potential of PV system.

It includes 5 main steps as:

1. Create Project
2. Create Design (Mechanical & Electrical)
3. Create Condition Set
4. Run Simulation
5. View Report

Figure shows the creation of project design based on house location from google maps (Figure 4.16)

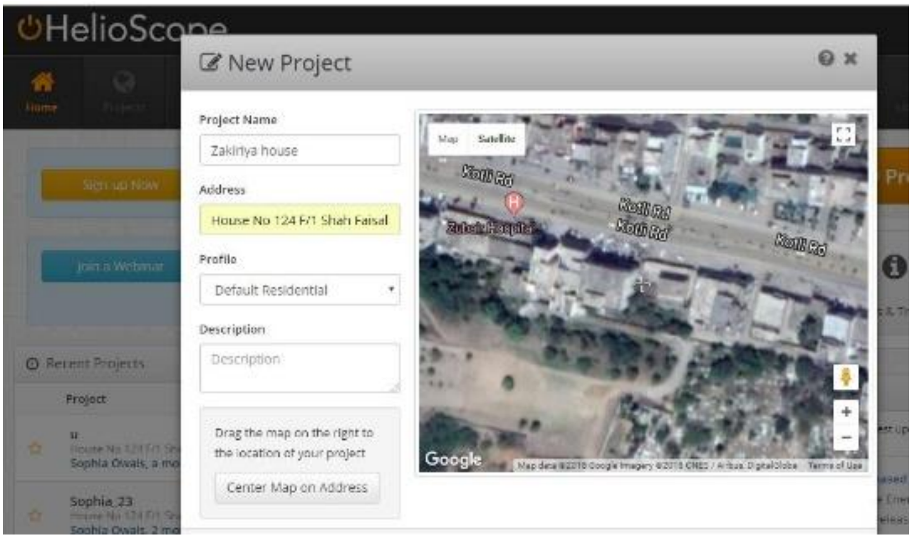

Figure 4-16 New Project Created for House

Then its electrical and mechanical segmentation is done by selecting the area available for PV system as shown. Building footprint area was 10 Marla(252m^2) but available area for PV system was only 95m^2.estimated energy production by system was 6.6 kWh installing 21 modules.

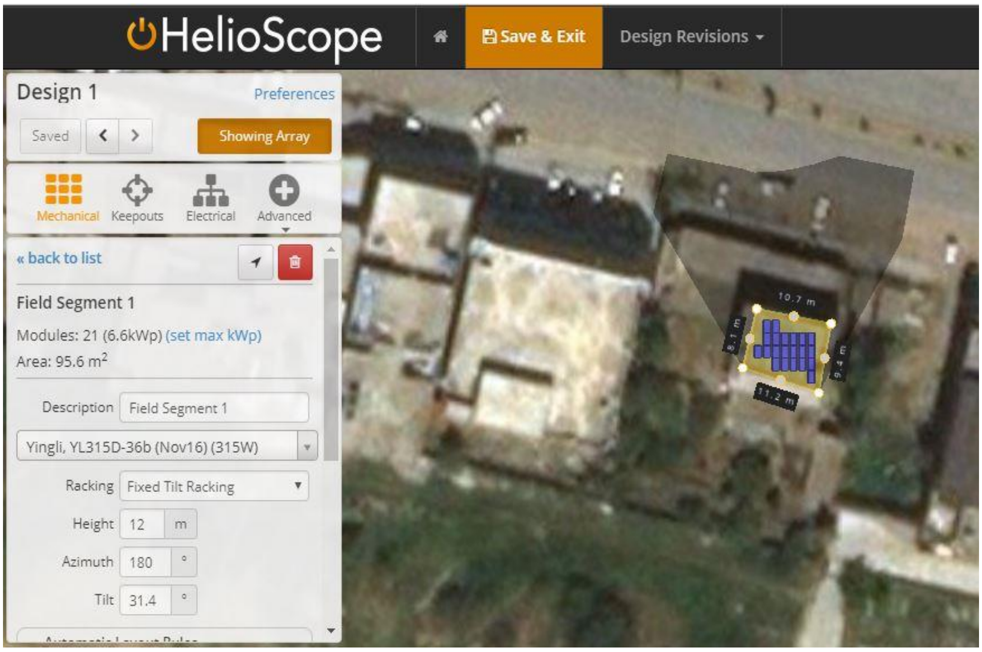

Figure 4-17 Design Field Segmentation

We have selected YL315D-36b(315W) panel having 72 Si-Mono cells each for module manufactured by Yingli solar Company which have the specifications as shown (Figure 4-18).


Spec Sheet

Name	YL315D-36b (Nov16)
Manufacturer	Yingli
Power	315.0 W
Vmp	36.2V
Voc	45.5V
Isc	9.21A
Imp	8.69A
Technology	Si-Mono (72 cells)
Dimensions	0.99m x 1.96m
Temp Coefficient Pmax	-0.42%/°C
Temp Coefficient Voc	-0.32%/°C
Temp Coefficient Isc	0.05%/°C
Source	Photon DB
Last Update	11/3/16 11:37 PM

Other Characterizations

Figure 4-18 PV Panel Parameters

Manual changes in placing panels can be done. Setback and row spacing is set to value of .7m and 0.2m respectively to allow the manual cleaning process of PV modules.

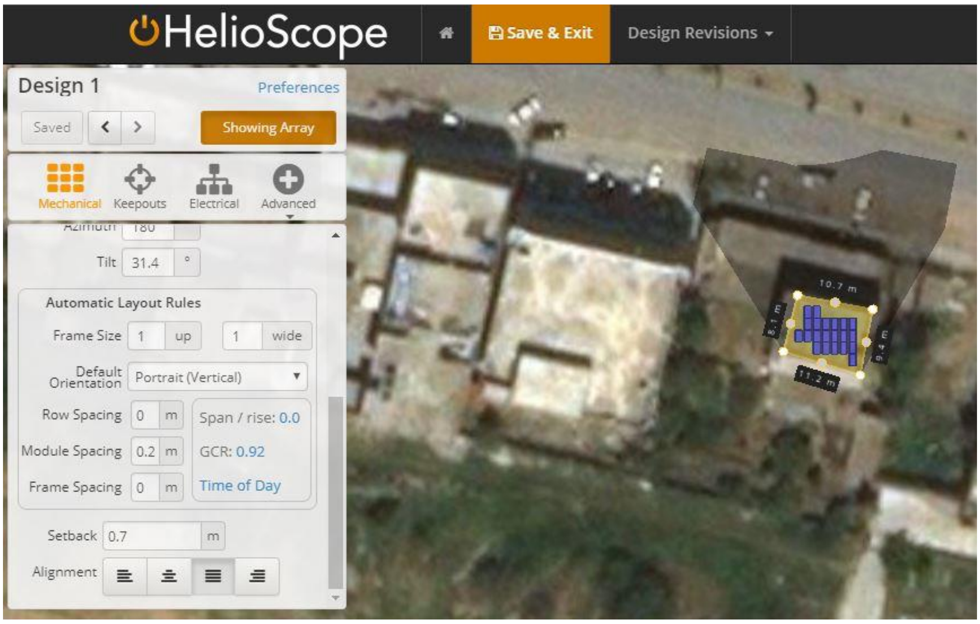

Figure 4-19: Mechanical Design

Afterwards, keep outs will be added and other components of PV system include invertors, wirings were also selected from the system library (Figure 4.21). We have chosen single invertor PVI 5000 OUTD-US-Z (240 V) produced by ABB Invertors, One of main invertor suppliers in Pakistan. Electrical specifications of invertor are shown (Figure 4.20).

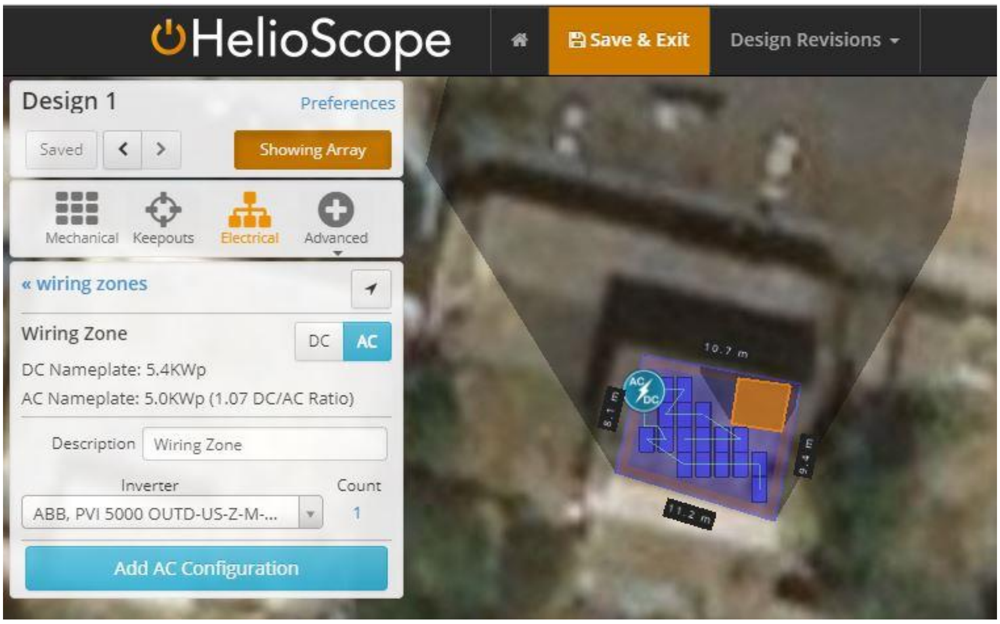

Figure 4-20 Electrical Parameters Selection

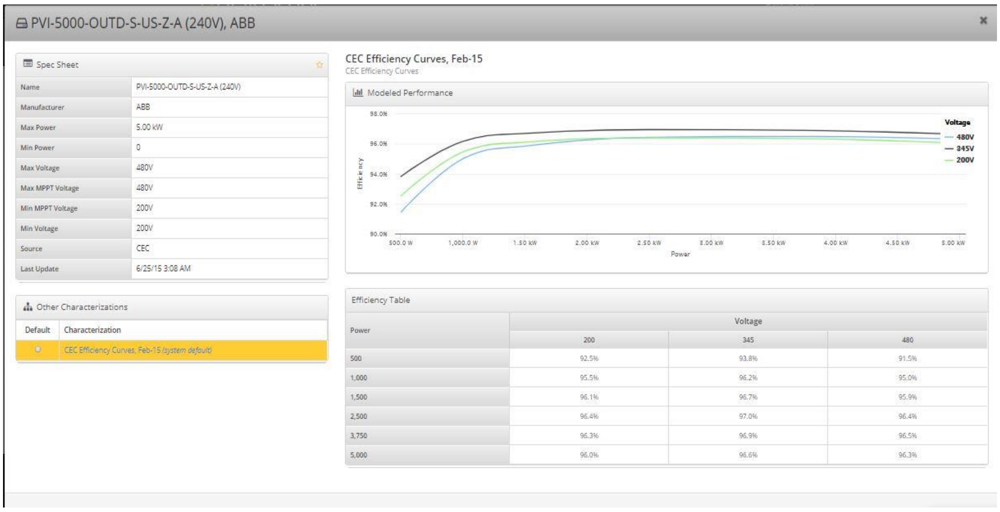

Figure 4-21 Invertor Parameters

The detailed single line diagram of designed system using 10AWG copper wires is shown (Figure4.22)

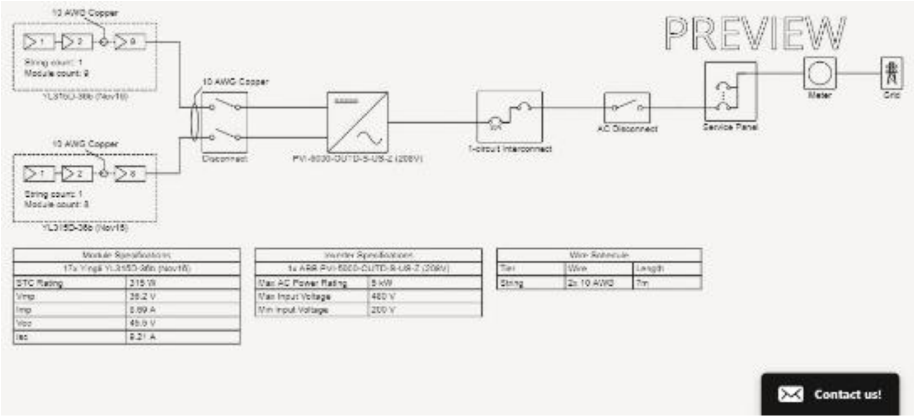

Figure 4-22 Single Line Diagram of Designed System

After completing the design, shading analysis and climate conditions run the simulation and generate the results file. Figure shows the monthly kWh production of system.

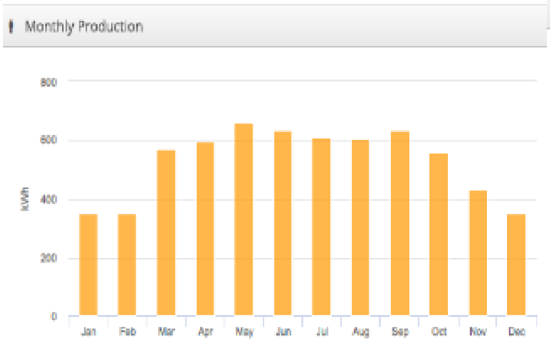

Figure 4-24: Monthly Solar Production

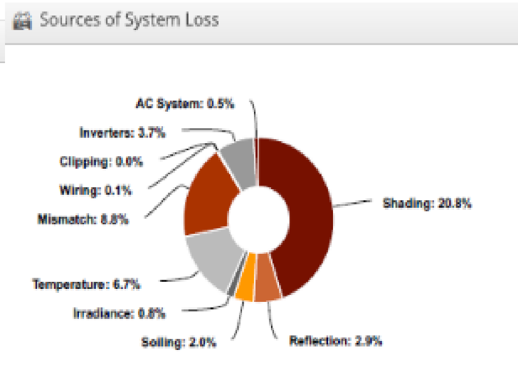

Figure 4-23 Losses in System

It also indicates the losses due to soiling climate direction and other factors affecting the output of system. (figure 4.24). It also displays the brief results of shading analysis in final report.

Figure 4-25 Shading Analysis based on keep out time zone

Similarly, Solar PV potential for each sample i.e. 100 household were calculated. It was observed that Residential sector of Pakistan has huge potential of going NZEH and NZEPH, if designed and operated efficiently. (Figure 4-26)

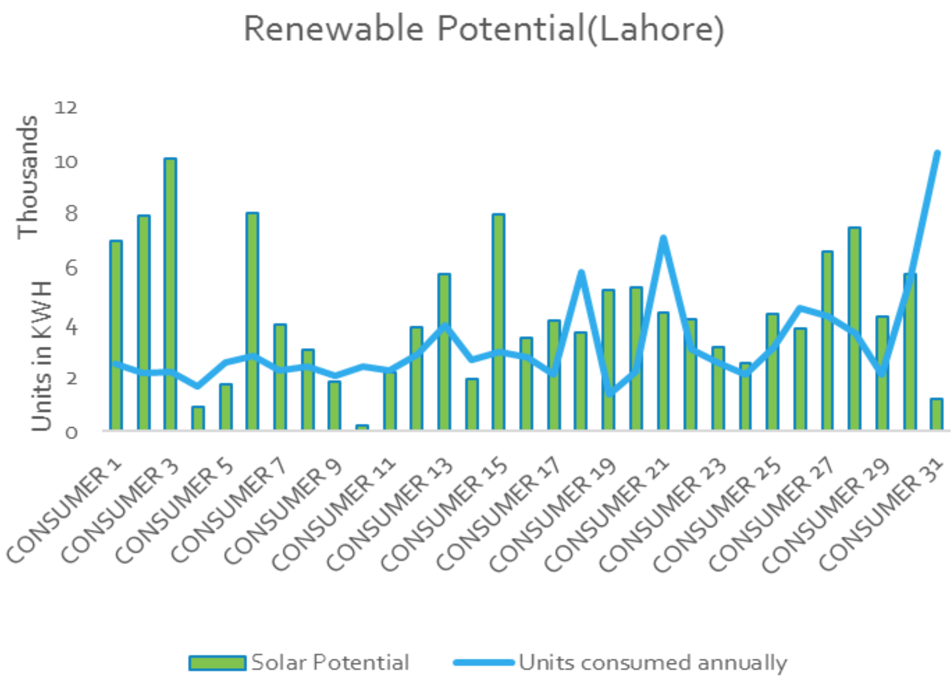

Figure 4-26 Renewable Potential of Houses in Lahore

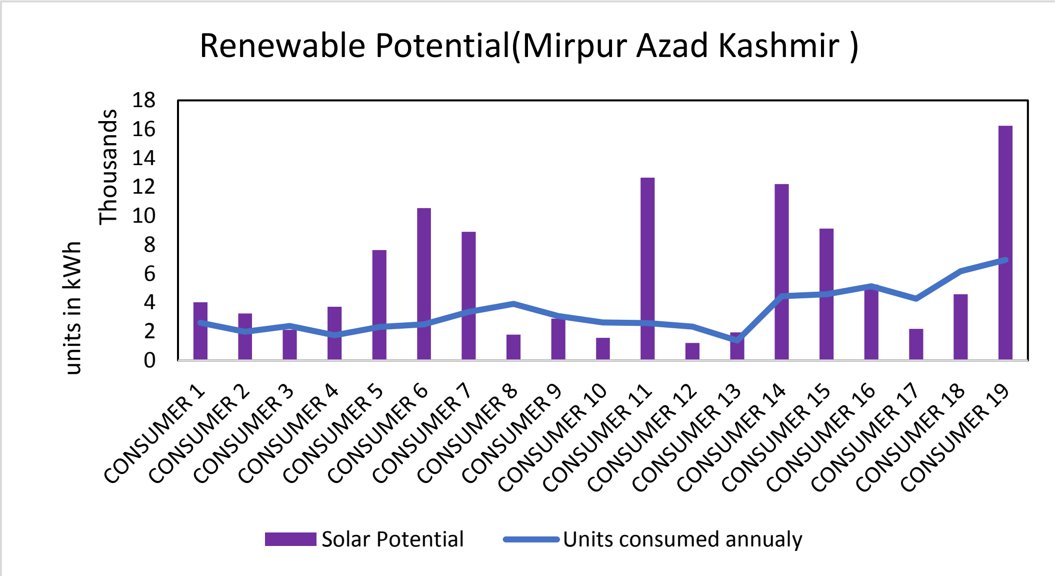

Figure 4-28 Renewable Potential of Houses in Mirpur AK

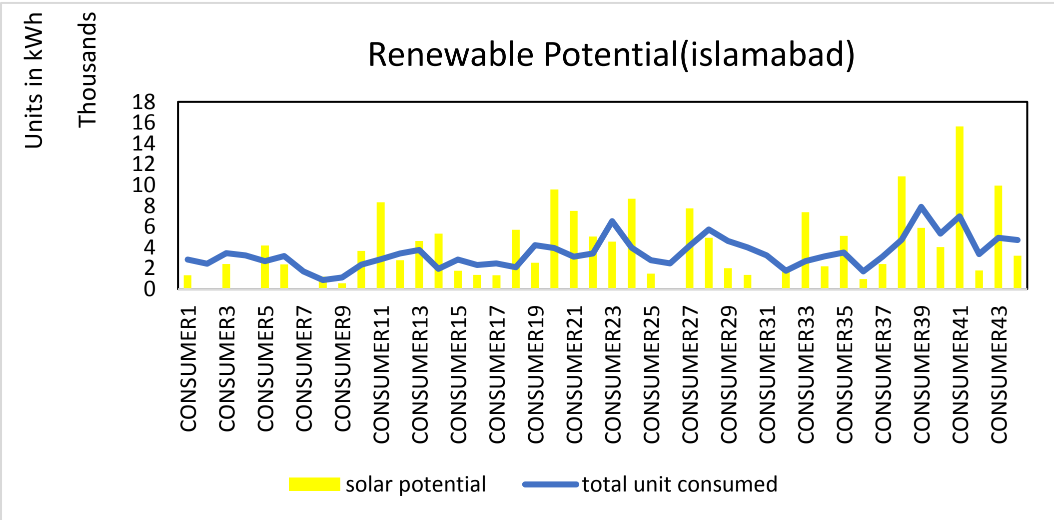

Figure 4-27 Renewable Potential of Houses in Islamabad

4.11 Potential Challenges

There are few main constrains in the adoption of sustainable development such as

- Financial issues
- Occupant awareness
- Building infrastructure

Financial support from government is one of the significant factors in promoting energy conservation as retrofitting of house increases the initial cost hence restrain the owner. Government or banks should take such initiatives to encourage them. Whereas Sui Northern Gas Pakistan Limited(SNGPL) is putting its valuable share towards conservation of natural gas as well as for reducing greenhouse gas emissions by introducing different energy conservation devices including solar water heaters, geyser timer devices and baffles. Company has installed a number of these devices at the premises of its consumers saving emissions as well as conserving valuable resource i.e. natural gas. Another important factor is building infrastructure as all studied houses have numerous air infiltrations, single glass windows, poor ventilation system and no insulation. Moreover, awareness among the occupants is hurdle toward the progress as average person has no or minimal concept of green building and energy conservation techniques. EE measures were also included in Pakistan Building Energy Codes 2011 but no implementation has been seen as no clear law & policies are being made or imposed on people to oblige them to practice green ideas. Significant efforts have been made to implement green building policies and innovative energy conservation technologies in country through collaboration with organizations like National Energy Efficiency and Conservation Authority (NEECA), Punjab Energy Efficiency and Conservation Authority (PEECA) and Alternative Energy Development Board (AEDB).

Summary

This chapter include detailed analysis of the results of the survey conducted in Pakistan and discusses all the possible low and high cost measures for improving energy efficiency and promote energy conservation. It also indicates the challenges faced by the adaption of NZEH in Pakistan along with the effect of climate change and inevitability of its adoption for sustainable future.

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Chapter 5 Conclusion &Recommendations

5.1 Conclusion

Currently Pakistan is facing huge energy crisis and shortfall of energy has reached upto 6000MW approximately. However, new energy generation projects have been installed but the demand of energy also increased especially in residential sector, with the rise in GDP growth rate. Apart from that, Pakistan is also combating with serious climate change issues. This study is conducted to analyze the energy consumption pattern in residential sector and evaluate the potential of Net Zero Onsite Energy Homes concept in Pakistan. For this purpose,100 samples were collected from the households of three major cities of Pakistan. Questionnaire focused on the building structure, occupant behavior, appliances usage and their annual utility bills. 17% households don't have the natural gas connection. However, only 22 % users consume natural gas for cooking purpose.

Results showed that the penetration of conventional appliances is very high. This study also insight currently introduced energy efficient appliances in the market which have reduced environmental footprint and are also economically beneficial. Furthermore, adoption of solar technology for clean generation and balancing net energy use is also viable option, due to high solar isolation and low cost of system. Also, dependence on natural gas should be reduced as it has high carbon footprint whereas cost factor of electricity is of high concerns. Potential of renewable energy on homes is modelled on HelioScope Software by Folsom , which is similar to PVSyst but also include the complemented feature of AutoCad. The software is highly efficient and user-friendly and can be used in industry for exhibiting true potential of PV system.

Net zero energy homes can reduce the energy demand along with significant reduction in utility bills and carbon footprint. Having an arid climate Pakistan has huge potential of energy saving and solar energy integration hence NZEB. The result showed 32% electricity can be saved only through implementing no/low cost retrofitting measures to conserve energy. Availability of national data and lack of trust are the main hurdles in its adaption in domestic market along with lack of awareness. National Standards or policies regarding green building should be designed & implemented to promote NZEH concept. Few energy conservation measures were incorporated in Building Energy Code 2011 but no proper execution of policy has been made since to ensure efficient energy use.

5.2 Future Recommendations

- Implementation of Net Zero Energy Homes on residential sector of Pakistan, through collaboration with Solar industry and organizations e.g. National Energy Efficiency and Conservation Authority (NEECA), Pakistan Green Building Council (PakGBC) and Alternative Energy Development Board (AEDB).
- Creating Awareness of NZEH through campaign for the households
- Obtain Certifications to guarantee the net zero performance
- This study could also help in achieving Energy Plus Homes through Net Metering
- Explore other definitions of NZE for residential sector of Pakistan
- Make new green policies and upgrade Pakistan Building Energy Codes (2011) and make sure their implementation.

Acknowledgment

All praise to the great **Allah Almighty** who has bestowed me with the opportunity to seek knowledge and enabled me to fulfil the obligation to explore the world of science up to my maximum limits.

I would like to express my sincere gratitude to my **research supervisor Dr. Muhammad Bilal Sajid** for his motivation, continuous support, patience and immense knowledge. They guided me completely through-out my research work. Working under their supervision has indeed broadened my vision.

I am also thankful to my GEC members, Dr. Kafait Ullah and Dr. Nadia Shahzad and Dr. Adeel Javed for sparing precious time from their busy schedules, for suggestions as well as moral support.

A special thanks to my group members at solar lab and friends including Rafia Akbar, Akhter Abbas, Anum Ameer, Bushra Khattak, Awais Amin, Waqas Ahmed Khalil, Sahar Zafar, Wajiha Ateeq for their unlimited support, valuable advice and guidance in my research work.

Last but not the least, I would pay my regards to my parents for their un-parallel love and encouragement throughout my research work.

APPENDIX

Survey Questionnaire

A zero-energy home, net-zero energy building (NZEB), is a house with zero net energy consumption, meaning the total amount of energy used by the building on an annual basis is roughly equal to the amount of renewable energy created on the site,

Kindly fill the form carefully as my master's research based on it. Information provided will only be used for educational purpose.

For any queries
Contact no 03133752111
Moeezowaisbhatti@gmail.com

USPCASE,NUST

Survey for Net Zero Energy Homes

N**<u>ame(optional):</u>**

<u>Contact no:</u>

<u>Address:</u>

Kindly attach the copy of utility bills (Electricity & Gas bills) of last month with the Account ID given on bill

1. Are you aware of global warming effects in Pakistan?

- Yes
- No

2. Your House Status

- Rented
- Self-owned

Govt owned

3. Type of House

- ( ) Bungalow
- ( )
- ( )

Flat/Apartment

Town house

4. Total Size of House (covered portion and uncovered)

____

5. Number of Storey

____

6. Total Number of Rooms in House

____

7. Number of Families

- ( ) 1
- ( ) 2
- ( ) 3
- ( ) 4 or more than 4

8. Total Family Members

____

9. Total Monthly Family Income

- ( )
- ( )
- ( )
- ( )

<50,000 50,000-

70,000 70,000-

100,000

>100,000

10. Total Expenditures of the Family(approx.)

APPLIANCES USAGE

11. Ceiling Fans in *numbers*

Old (conventional)	New (energy efficient)	Energy Star Rated	total number of fans

12. Number of Lights *Check all that apply.*

	total number		Time of use (Hr)
Tube lights			
Bulbs(100w if other sizes do mention			
Energy savers (size)			
Others			

size

13. Number of Air Conditioners and their size

Window	Conventional (split)	Invertor

14. Other Appliances *Check all that apply.*

	total number	Wattage
Microwave		
Oven		
Refrigerator		
Deep freezer		
Printer		
Laptops		
Iron		
Television		

15. Heating Appliances *Check all that apply.*

If electric then mention that too.

	Total number	Wattage/ Gas Consumption
Geysers	☐	☐
Heaters	☐	☐

BUILDING ENVOLOPE

Type of material used in the construction of roof windows and walls also play an important role in energy efficiency of house along with its construction design

16. Glazing Windows (on glass windows glazing is done used to prevent heat transfer to room)

- ◯ Single glaze
- ◯ Double glaze
- ◯ Not Glazed

17. Type of Glaze in windows

- ◯ Glass (high performance glass)
- ◯ Gas Filled (double glazed)
- ◯ Insulation
- ◯ Reflective Coating
- ◯ N/A

18. Roof top Surface Area Type (for estimating the solar potential)

Flat

Slide/Tilted

N/A

19. Does Your house exterior walls have insulation (some materials are used on exterior walls for thermal insulation)

Yes

No

Response toward Energy saving

20. Do you want to reduce the energy consumption of your house?

Yes

No

21. Have you heard about Net Zero Energy Home concept and interested in making your home one?

Yes
No

22. Available Energy Sources other than Grid (kindly mention if more than 1 and their specifications) Check *all that apply.*

- [ ] Generator
- [ ] UPS
- [ ] Solar Panels
- [ ] Another Source Mention Please
- [ ] None

23. What do you think/know about renewable energy technology (Solar Panels, Solar Heaters for water and space) and would you like to adopt one?

Publication in Journal/ Conference

Energy Consumption in Residential Sector of Pakistan

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Abstract
Energy consuming buildings account for 30-40% of the overall energy consumption in the world and are responsible for more than one third of greenhouse gases emissions. In Pakistan Residential building sector has around 47% share in total energy consumption. Study is conducted to identify the energy consumption pattern and the areas of energy wastage in residential sector of Islamabad. From the analysis of its annual energy usage it can be clearly seen that electricity consumption dominates in term of cost but natural gas has major share in annual energy consumption. Recommendations are provided which include required energy retrofit measures for improving building performance and financial assistance from Government officials. Through these energy efficiency measure significant reduction in carbon footprint can be achieved.

Keywords
Energy Conservation , Energy Consumption , Residential Sector, Pakistan

1. INTRODUCTION

Increasing energy demand makes fossil fuel the most feasible option to obtained energy. Around 80% of world energy is obtained by burning fossil fuels that play drastic role in increasing global warming i.e. responsible for one-third of the world total greenhouse gas emissions. Among the total world energy, 40% is consumed by building sector so they play critical role in global climate change. Majority of that energy is consumed in residential buildings(Cao, Dai, & Liu, 2016). Due to the rapid increase in world population energy consumption in residential sector also increases. In US, residential sector also contributes around 22% of their total energy. Depletion in fossil fuel sources along with increase in their prices and their negative impact on earth environment urged to exploit the renewable and non-conventional sources for energy production. Studies are conducted and implemented for energy conservation in residential sector around the world. But in Pakistan besides having potential of energy conservation, still no useful study has been carried out in this area.

Pakistan is facing severe energy crisis nowadays. Energy gap between supply and demand is widening with every passing year. The current electricity production including all energy sources is of 19000MW with installed capacity of around 25000MW and shortfall of almost 4000 MW. Residential sector of Pakistan plays crucial role in its energy consumption i.e. 47% of the total energy consumption(Figure 1)(Sohail & Qureshi, 2011). Pakistan being located near to equator has temperate climate in most of the regions due to which most of its total energy consumed by building cooling system. Whereas other factors also affect the building performance such as building envelope, weather conditions, occupancy level, their behavior and so forth(Hu, Yan, Guo, Cui, & Dong, 2017). In the current scenario, energy conservation in buildings is only viable option to bridge the energy gap between energy demand and supply.

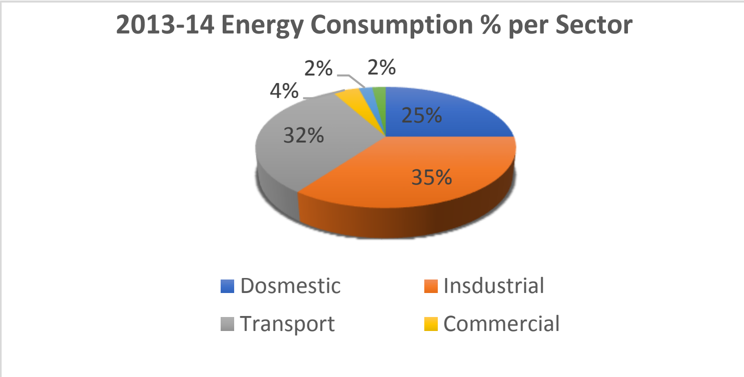

Figure 1.1: Energy Consumption % per Sector

2. RESIDENTIAL SECTOR OF PAKISTAN

The research is carried out in the capital of Pakistan i.e. Islamabad to understand the impact of energy conservation. Islamabad lies in the temperate zone. The climate is generally arid, characterized by hot summers and cold winters. However, the average solar irradiance in Islamabad is 4.5 kwh/m2/day. Total population of city is 2.1 million whereas number of urban households are 169918. Detailed climate analysis is obtained from NASA's satellite database through RETScreen software.

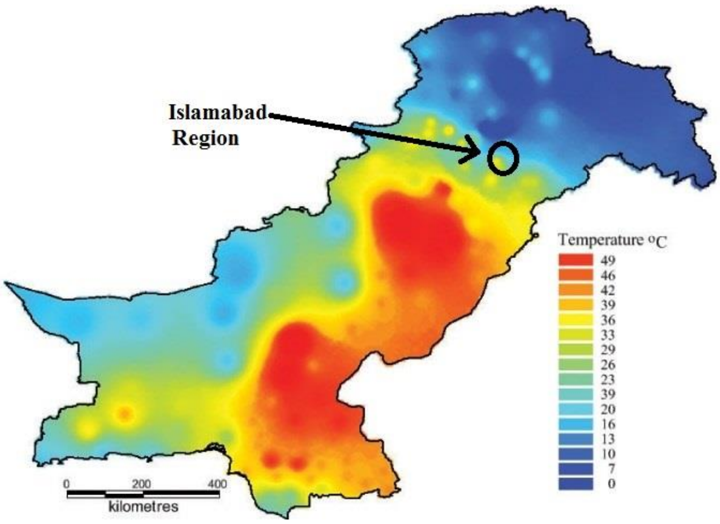

Figure 1-2:Climatic Condition in Pakistan

Average temperature and other parameters of this city are shown (Table 1). The temperature data showed that monthly average values of air temperature vary from minimum 14°C to a maximum value 31.3°C; the low annual average values represent the severity of heating requirement; while the high solar radiation values indicate enormous potential for solar energy technologies. ("Pakistan Statistical Year Book 2016 | Pakistan Bureau of Statistics," n.d.)

Table 10: General Parameters of Islamabad

Total area	906sq.Km
Number of household	335408
Houses having natural gas	56%
Average household size	6 persons
Average low temperature	14.1
Average high temperature	31.3
Heating degree days	101
Cooling degree days	264

2.1 Data Collection of Residential Sector

Under ambient temperature Islamabad requires more cooling than heating. As we considered 6 houses from which 5 of them have access to natural gas whereas 1 uses LPG supply for cooking, heating purposes. The electrical appliances detail in table 2 shows load profile used to estimate energy consumption.

Table 11: Load Profile of Houses

Electrical Appliances	Tubelight	LED	Energy Saver	Fans	New Fans	Ac	Invertor	Tv	Washing Machine	Iron	Refrigerator	Motor	Bulbs
consumer 1	6	2	4	6	0	2	0	1	2	1	2	1	0
consumer 2	6	0	6	4	0	2	0	0	1	1	2	1	0
consumer 3	4	1	2	2	1	0	0	1	0	1	1	0	0
consumer 4	4	0	3	3	0	0	1	1	1	1	1	1	0
consumer 5	1	0	6	5	0	1	0	0	0	1	1	0	1
consumer 6	3	0	2	4	0	0	0	1	1	1	1	0	0

2.2 Energy Consumption

In Islamabad 87% of the houses are cemented among which 38% have 3 to 4 rooms. The major sources available for energy other than electricity are natural gas and LPG. Only 56% have the access to natural gas for their cooking and heating purpose.

2.2.1Electricity and natural gas

The energy consumption of the houses has been analyzed along with their load pattern and plotted in term of mega joule(MJ) of energy consumed per month (Figure 3). It can be seen in data that electricity demand is high in summers i.e. from May to August. Unit consumption per home for air-conditioned homes is significantly higher than non-air-conditioned homes.

Similarly, Natural gas consumption increases during October to January (Figure 4). Houses with conventional gas heater have high energy utilization ratio and contribute majorly in polluting the environment. In addition, Infrastructure of these houses is old and standard lack insulation and glazing on windows which also effect the cooling and heating requirement of house.

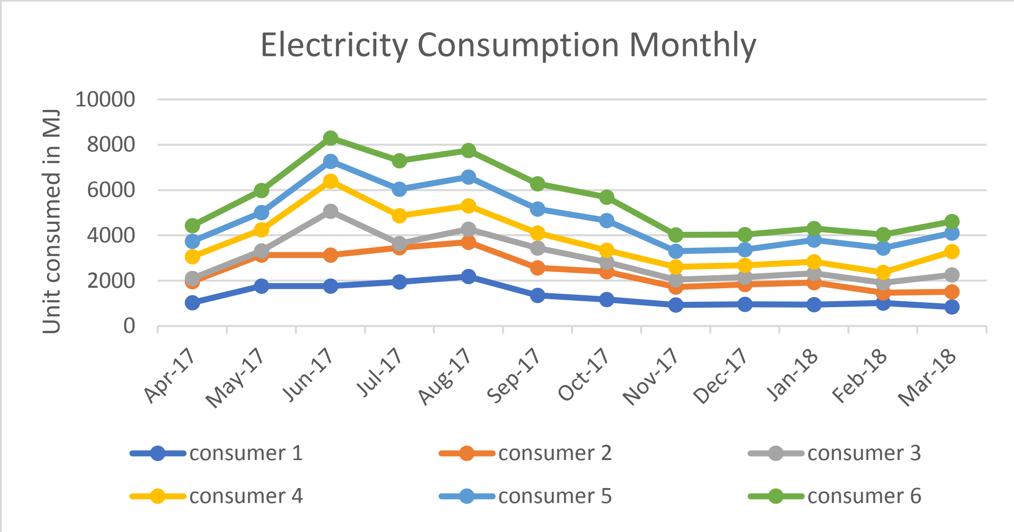

Figure 1-3:Monthly Electrical Energy Consumption

As seen (Figure 4) consumer 5 uses liquid petroleum gas due to lack of natural gas connection and uses LPG cylinder of approx. 15 kg per month consuming average energy of 375 MJ per month.

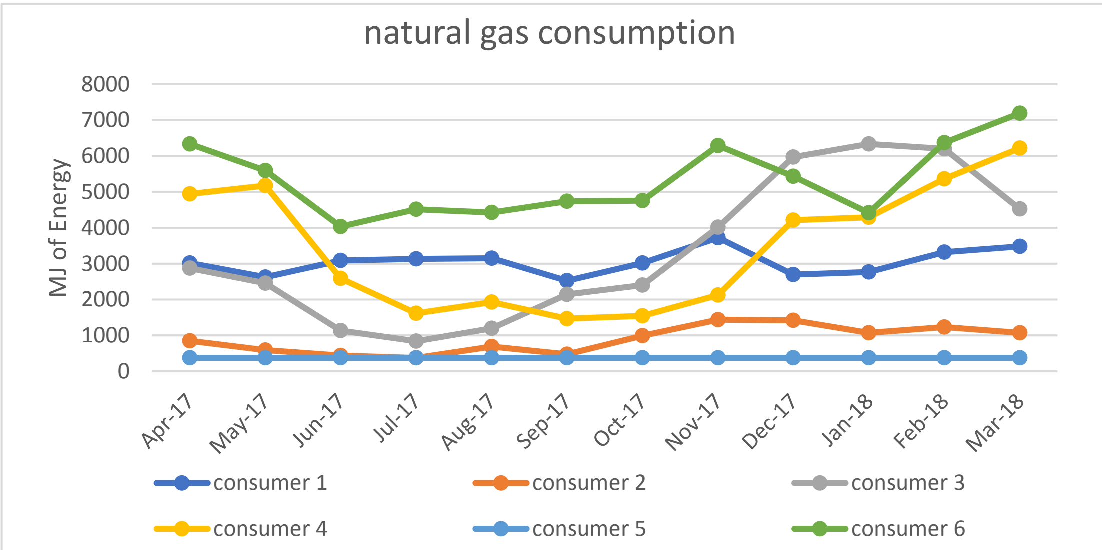

Figure 4: Monthly Natural Gas & LPG Consumption

2.2.2 Total cost of electricity and natural gas

Electricity per unit cost increases as number of units cross certain threshold value, limiting the units to low cost slab through energy conservation significant reduction in residential electricity bill can be achieved. Although the cost of electrical energy is high as compared to the natural gas but carbon footprint of natural gas is comparatively higher than electrical energy and adversely effects the environment. Monthly data of their energy consumption bill is shown (Figure 5 & 6).

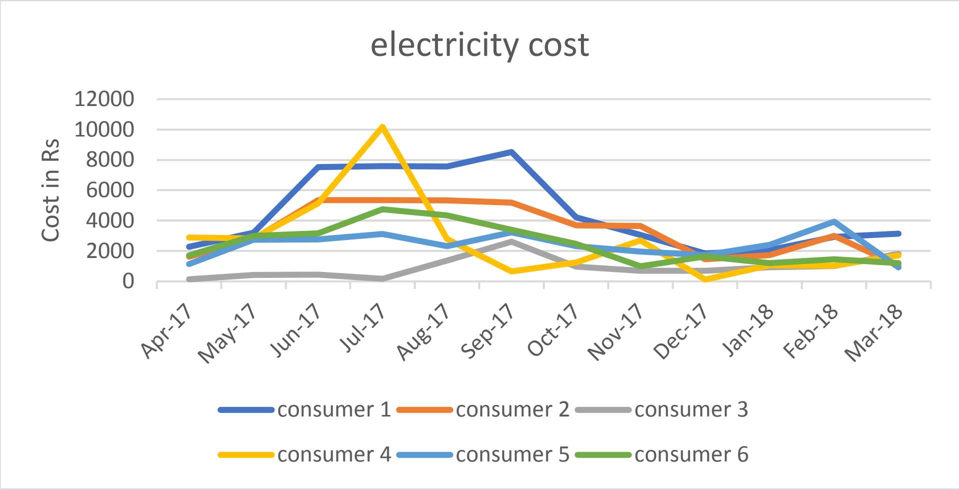

Figure 5: Monthly Cost of Electricity

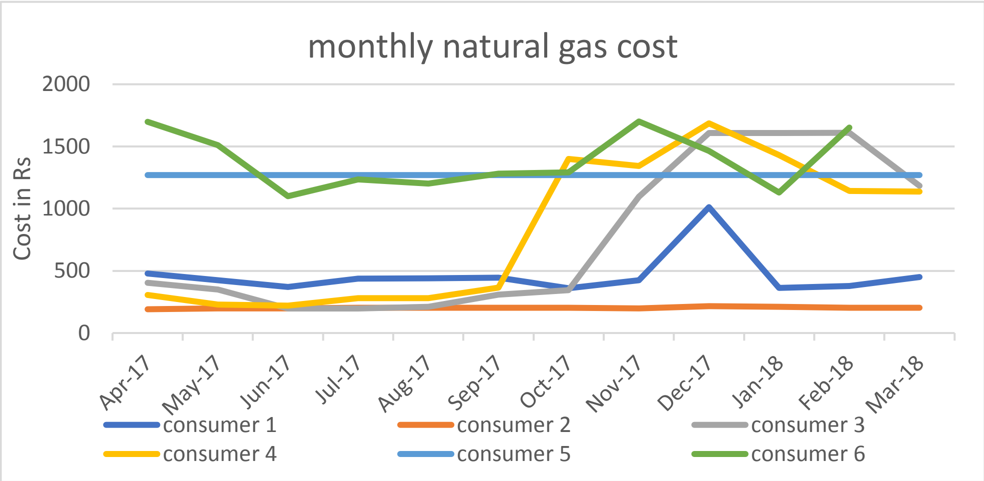

Figure 6: Monthly Cost of Natural Gas & LPG

3. RESULTS & DISSCUSSION

Annual consumption of electricity and natural gas consumption is determined in term of MJ. It can be seen from the graph that total energy consumption of consumer 3 ,4 and 6 are high whereas cost graph shows the peak occur with consumer 1 and 2. (Figure 7&8)

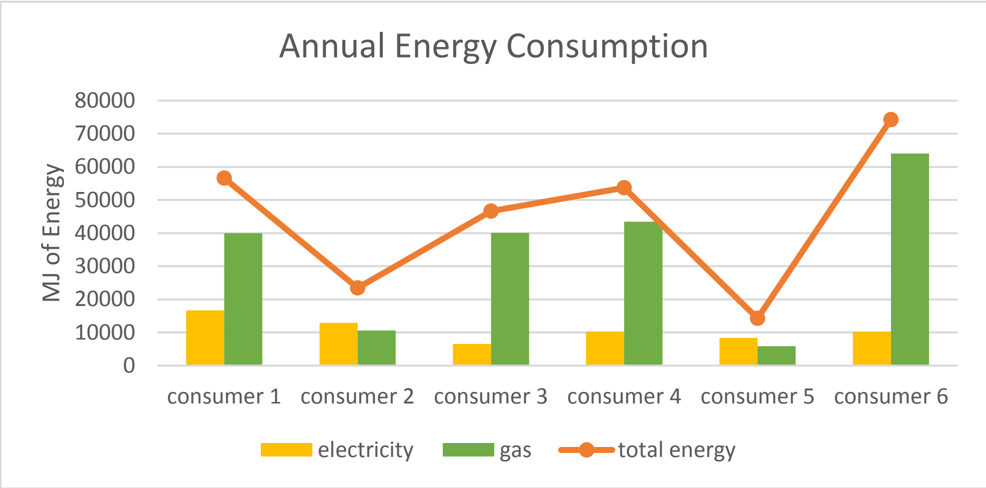

Figure 7: Annual Energy Consumption

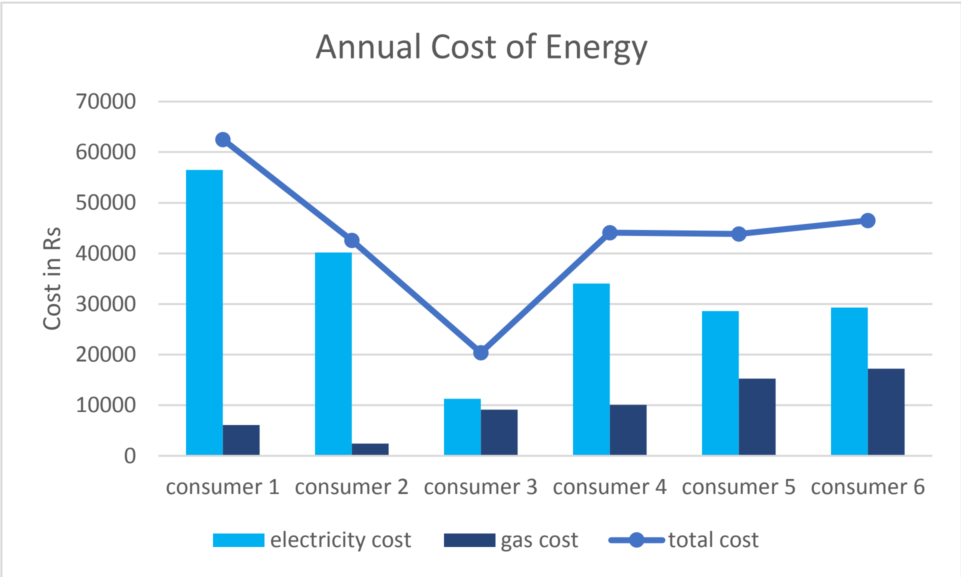

Figure 8: Annual Cost of Energy Consumed by Houses

Consumers having higher natural gas consumption gives high energy comsumption annually whereas consumers with high electricity usage have high cost. It is clear that electricity dominates in term of cost whereas natural gas does offer low cost but adversely effects the environment. Due to Abundant resources of natural gas, lack of awareness about energy shortfall and environmental changes people are not concerned about usage of natural gas. Natural gas might be cleaner than coal burning but still have carbon impact and a threat on living environment.

4. RECOMMENDATIONS

Energy consumed by the buildings play a key role in global energy requirements; generating more energy cannot be solution as demand of energy is increasing day by day. Energy conservation is only feasible option under this scenario. Factors which effect the energy savings within buildings are

- Design and construction of houses

- Lighting equipment and appliances installed
- Occupant behaviour

By walk through analysis we obtained that they are using inefficient tubelights which share upto 30%of their lighting load whereas their fans are also old and highly inefficient which contribute 50% of total electrical load during summers.(Jones, Li, Perisoglou, & Patterson, 2017)(Giusti & Almoosawi, 2017)

Significant efforts have been made to implement green building policies and innovative energy conservation technologies in country through collaboration with organizations like National Energy Efficiency and Conservation Authority (NEECA), Punjab Energy Efficiency and Conservation Authority (PEECA),Alternative Energy Development Board (AEDB) and few other(Qazi & Jahanzaib, 2018). There are number of ways through which energy can be conserved and reduce the carbon foot print. Ranging from no/low cost measure to high cost measure. Some are discussed below

4.1 Replacement of Lights

Replacing the old inefficient tubelights, incandescent bulbs with new LED are the easiest way to conserve electricity as they are designed to provide the same lumens in less power along with long lifespan and short payback period. The average life of a LED is about 10 times that of an incandescent lamp. Further Motion sensor sensors can also be installed.

4.2 Efficient Fans

Islamabad being in arid climate zone require more cooling and fans are main source of cooling in residential areas. Replacing the old fans with 5-star energy rated fans can also reduce the electrical load of house as energy efficient fans which consumes approximately 50% less energy. Without compromising the indoor comfort of occupants.

4.3 Energy star Air Conditioners

Conventional air conditioners have sizeable share in energy consumption of houses. By replacing, them with new energy rated highly efficient air conditioners can reduce the electrical bill to great extent. Also, R22 refrigerant used in old AC have negative impact on environment whereas new Conditioners uses R410, R404. R407 which are certified environmental friendly gases. According to Enercon 18 % energy can be saved from air conditioners. Replacing air conditioners may have high initial cost but their payback period is within 2 seasons.

4.4 Controlled devices

Programmable thermostat should be installed in all devices as they will turn off the heating and cooling appliance when the required temperature attained

4.5 Install solar water heater

Conventional gas heaters play major role in natural gas consumption and increases carbon emissions by installing solar water heater along with gas geyser can give 50% reduction in energy consumption also reduce the greenhouse gas emissions. The efficiency and reliability of solar water heating systems have significantly increased over the last few decades while the cost has also come down.(Sadiq, 2018)

All the energy consuming equipment in the building including air-conditioners, water heaters, refrigerators, freezers, washing machines, cloth dryers, television sets, computers, light bulbs, etc. is available in a wide range of high-efficiency versions. Choose high-efficiency appliances. This requires no special skills, and it adds very little or no to the price of the house but have immense impact on earth climate.

5. POTENTIAL CHALLENGES TOWARDS ENERGY EFFICIENCY

There are few main constrains toward the adaption of sustainable development such as

- Financial issues
- Occupant awareness
- Building infrastructure

Financial support from government is one of the significant factors in promoting energy conservation as retrofitting of house increases the initial cost hence restrain the owner. Government or banks should take such initiatives to encourage them. Whereas Sui Northern Gas Pakistan Limited(SNGPL) is putting its valuable share towards conservation of natural gas as well as for reducing greenhouse gas emissions by introducing different energy conservation devices including Solar water heaters, Geyser timer devices and baffles. Company has installed a number of these devices at the premises of its consumers saving emissions as well as conserving valuable resource i.e. natural gas("Sui Northern Gas Pipelines Limited - Official Website," n.d.). Moreover, Awareness among the occupants is hurdle toward the progress as average person has no or minimal concept of green building and energy conservation techniques. Another influencing factor and most important factor is building infrastructure as all case studied houses have numerous air infiltrations, single glass windows, poor ventilation system and no insulation.

6. CONCLUSIONS

Pakistan is currently facing a huge electricity crisis in terms of its short fall. This is due to both increase in demand and reduction in supply. Faced with increasingly constrained oil supplies and global warming challenges, we must exploit other options to meet the energy demand. And using energy efficient measures in buildings can reduce the reliance on electricity supply and can result in significant operational cost saving. In the near future improving the architectural design creating awareness in people about energy utilization techniques is only feasible option to reduce the electricity demand and relieve the environmental pressure on earth. However, Government should seriously focus on providing attractive packages along with creating awareness among the households to promote energy conservation. Implementing energy conservation concept will provide benefits that extend far beyond energy cost savings like improved health, increased productivity, sustainable future and amplification effect on other buildings along with reduced carbon footprint.

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