ESTIMATION AND COMPARISON OF CARBON FOOTPRINT WITH AND WITHOUT USE OF SOLAR PHOTOVOLTAIC SYSTEM AND THEIR SOCIAL ACCEPTANCE IN ISLAMABAD

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A thesis submitted to Bahria University, Islamabad in partial fulfillment of the requirement for the degree of BS in Environmental Sciences

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Abstract

Pakistan is dealing with a significant energy crisis and the problems of climate change, all while confronting rising fossil fuel prices. Meeting the rising demand for electricity becomes increasingly difficult. This situation emphasizes the necessity for research and development methods to apply alternative green energy solutions. By addressing these difficulties, Pakistan hopes to reduce the effects of the climate catastrophe while moving to a more sustainable energy future.

The goals of this research are to: (i) give a comparison of a household's carbon footprint from grid energy usage against solar photovoltaic - grid electricity mix; and (ii) investigate the social acceptability of solar technology in Islamabad. Data from a selected family in Islamabad were collected to calculate the carbon footprint. These records contained power bills and information about the solar photovoltaic system placed in the home. To assess the social acceptability of solar technology in Islamabad, a specially constructed questionnaire-based study was conducted in several residential areas of the city.

The investigation showed a 95.29 percent reduction in carbon footprint at the consumption endpoint. As a result, installing solar technology for power generation reduces carbon emissions more effectively than using grid electricity alone. Although 85 percent of the selected families want to improve the city's environment and switch to solar technologies, they are hesitant to invest in solar technology due to financial and operational complexity. The thesis concludes by making policy proposals to address identified barriers.

Dedication

This thesis is dedicated to our beloved parents, whose everlasting love, encouragement, and unending support have brightened our academic path.

ACKNOWLEDGEMENT

In the name of Allah, the Most Beneficent, the Most Merciful. All praises to Him for the strength and blessings endowed upon us in completing this thesis. We would like to express our profound appreciation to our supervisor, Dr. Aansa Rukya Saleem, for her invaluable guidance, and persistent support. We are especially grateful to our senior Assistant Professor and cluster Head, Dr. Umair Ullah Jamil, for his mentorship, engaging discussions, and persistent drive. We are also grateful to our friends whose encouragement, support, and companionship provided us with inspiration and strength during challenging times. Lastly, we want to express our heartfelt gratitude to our parents and family for their unwavering love, encouragement, and sacrifices during our academic journey. Their continuous support has been the foundation of our successes and accomplishments.

ABBREVIATIONS

CF	Carbon Footprint
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
DC	Direct current
GHGs	Greenhouse Gases
GWP	Global Warming Potential
kWh	Kilo Watt hour
MW	Mega Watt
PV	Photovoltaic
UPS	Uninterrupted Power Supply
WAPDA	Water and Power Development Authority

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CHAPTER 1
INTRODUCTION

Pakistan is facing immense challenges due to the rising energy crisis and the negative effects of climate change. These challenges are intimately linked to Pakistan's energy production and consumption patterns. The country's energy sector is presently in crisis due to a lack of energy producing capacity, which has failed to keep up with increasing demand over the last few decades. This predicament highlights the urgent need for long-term solutions to both the energy problem and the effects of climate change. Pakistan's current energy mix is heavily dependent on costlier resources such as oil (35.3%) and gas (48%). It also has a share of hydro (29.9%) and others (5.8%). The total electricity generation capacity in Pakistan is 41,557 MW in comparison to average demand of 31,00 MW. The demand is predicated to increase by further 19% over the next decade. Only about 22,000 MW of transmission and distribution capacity is available. This results in shortfall of about 9,000 MW (Awan et al., 2012). These figures portray the areas which receive an electricity connection, whereas many areas in Pakistan are still vacant of grid electricity.

The use of fossil fuels is the greatest contributor to global carbon emissions, accounting for around two-thirds of total emissions. The carbon emissions hence play a crucial role in ongoing climate change (Marchal et al., 2011). Currently, Pakistan is one of the smallest contributors of GHGs the carbon emission per capita in Pakistan in fiscal year 2019-2020 was approximately 0.81 ton. It seems to be low in compared to industrialized countries such as the United States of America, that has an average of 13 ton per capita in 2020.Furthermore, in Pakistan the energy sector contributes 76.1% of the total CO_2 emissions (Raza et al., 2022). This implies that Pakistan's energy consumption has the largest carbon footprint.

Even making only a small contribution to CO2 emissions, Pakistan is observing the widespread impacts of climate change. Evidence of this can be observed through the occurrence of harsh and unpredictable weather patterns across the country. Looking ahead, Pakistan may encounter various challenges soon. These include unseasonal rains and flooding, increased temperatures particularly in coastal areas leading to rising of sea levels, glacial melting, reduced crop yields, higher commonness of diseases, and increased social inequality within the country. For instance, it is projected that temperatures could rise by approximately 1.0 degree Celsius by the year 2030 (Khan et al., 2008).

Renewable energy sources like solar, wind; water-based energy generation and biofuels are considered as wealthy, sustainable, and secure energy alternatives for the whole world. (Chu &Majumdar, 2012). Significance of solar power is noticeable from intense continuing threat posed by the global climate change and this global climate change is consequent to huge emission of carbon dioxide from fossil fuels. The ratio of carbon dioxide emissions to global energy use must be lessened substantially to control this issue without compromising global economic growth (MIT study). In addition, solar energy is the most plentiful, inexhaustible, and clean of all the renewable energy resources till date (Kalogirou&Tripanagnostopoulos, 2006).

It has been showed from the previous studies that half percent of the desert land if used for solar energy purpose it would fulfill the energy demand of the entire world because the radiations obtained from the sun in one hour are more than entire world's total energy per year. As far as Pakistan is anxious, electricity can be delivered to 90% of its rural areas because Pakistan has a potential to obtain 19 mega joules per square meter per year (Israr, 2010).

Post Kyoto Protocol, there has been a greater pressure on reduction of carbon emissions in order to reduce or terminate climate change. Renewable sources of power generation can play a crucial role in the success of this objective (conick et al., 2008)

Pakistan inaugurated many projects on renewable energy such as Thatta power plant and the Quaid-e-Azam Solar Park in Bahawalpur, but their proper management and operation has never been done. In order to improve and involve local businesses in energy sector, we need to bring funds into such projects (Ashraf,2014).

There is a myth that solar power does not worth it because it is not efficient in cloudy/cold regions. Clouds may affect efficiency of solar panels but not to very much extent as they can still produce enough power to be a viable source of electricity. One of the obvious examples is of Germany, being located in colder region on earth yet known as the world leader in solar energy. Solar power is considered as the most reliable and cost-effective source because life expectancy of almost all solar panels is over 20 years or more. In fact, the solar system installed some 40 years ago are still in working conditions (Solar panels facts,2015).

In order to lessen the expenditure and dependency on imported fuel (that has a greater impact on country’s economy), attain the country’s gap for energy and its circular debt, and explore into a more dependable and renewable green technology to fuel Pakistan’s solar power systems provide a greater a place for suppliers and consumers.

1.2 Solar energy mechanism

Solar panels work on the basic idea of harnessing sunshine, which consists of photons with varied energy that interact with the placed panels. When photons impact the surface of a photovoltaic cell, they shift electrons from the atoms, resulting in an electrical current. These electrons then pass through the photovoltaic cell and eventually reach the metal wire attached to a direct current (DC) battery, where they can be stored to power household items.

Solar panels are consistently made of doped silicon, which has impurities such as phosphorous and boron added to improve its conductivity. When these p-type and n-type semiconductors mix, they form a p-n junction at their interfaces, generating an ideal condition for the production of an electric field and electron migration towards battery storage.

Thus, solar energy is a practical source of electricity for household use assisted by the installation of properly positioned solar panels, an inverter, and a rechargeable battery system. This system moves as a conduit between the solar panels and domestic appliances allowing for the effective use of renewable energy resources. (Khan etal.,2016).

1.3 Significance of work

This research helps us to understand the distinction in carbon emissions between utilizing only grid electricity and a combination of grid and solar power systems. By undertaking this research, we want to obtain useful insights into the viability of using solar-powered devices as an alternative to standard grid electricity for household purposes.

This investigation's findings will be valuable to both potential solar electricity customers and sellers. We desire to improve public awareness about the environmental impact of traditional energy sources by measuring the carbon footprint related with grid-supplied domestic electricity. This information can motivate and encourage people to shift towards renewable energy sources such as solar power, helping to create a more sustainable and environmentally friendly energy landscape.

1.4 Study objectives

Main objectives of this study are to examine the socio-environmental feasibility of solar PV system for households. More specifically the objectives are:

(i) To compare the Carbon Footprint produced by use of grid electricity with that of a combined use of solar powered electricity and grid electricity.

(ii) To assess the social acceptability of solar powered electricity in households of Islamabad.

1.5 Literature review

1.5.1 Carbon footprint

In the study conducted for Turkey's Energy Policy in 2011, CO, emissions calculations were made because of electricity generations, with respective "fuel-specific" CO, emission factors for fossil fueled power plants operational between the periods 2001 - 2008 in Turkey. Furthermore, calculations of carbon emissions from 2009 - 2019 have also been undertaken in the study with projected values of electricity generation capacity of power plants in the selected time frame. The study divided the estimation of carbon footprint (CO2 emission) calculation into four varying scenarios, each scenario withholding a selective fuel-mix. The carbon footprint was thus inferred by the product of total electricity generation and fuel-specific emission factor. The results produced from the research indicated that the Renewable Energy Scenario proves to contribute the lowest CO, emissions (smallest footprint) for the projected years of 2009 - 2019. Study concludes by quoting an approximate figure of 192 million tons decrease in carbon emissions during the time frame under observation in comparison to fossil fuel powered electricity generators (Izzet, 2011).

The objective of the paper by Ismail (2013) is to calculate how the reduction of power and electrical carbon footprint can convert computing to a pro-environment and greener practice in the Department of Computer & Information Systems Engineering in NED University. This involves the calculation of the carbon footprint of data center and power usage efficiency. The study calculates the carbon footprint in four distinct phases: i) calculation of total power consumption by data center; ii) calculation of IT load; iii) calculation of PUE; and iv) CO2 footprint. The said carbon footprint was calculated with the assistance of an electricity emission factor, which varies from country to country. With, the complete calculation of the two variables under observation in the study, the results indicate that the Department of Computer & Information Systems Engineering (NED) has power usage efficiency (PUE) of 7.34 and producing 675t of annual carbon footprint. According to the study, the ideal PUE for a data center range between 2 - 4, thus the case under observation shows highly inefficient power usage (high PUE figure), and therefore the carbon footprint calculated is exceptionally high. The concluding remarks of the paper regarded the importance of converting such centers towards efficient systems, and avoiding infrastructural losses of energy (Ismail, 2013).

In research published by the royal society, conducted at Department of Electronics and Electrical Engineering, University of Edinburgh, UK, about the alternatives electricity generation options to reduce carbon emission, stated that the bulk production of electricity has been achieved by burning fossil fuels, with unavoidable gaseous emissions, including large quantities of carbon dioxide: an average-sized modern coal-burning power station is responsible for more than 10 Mt of CO2 each year. In Britain, each square meter of a south-facing roof can receive up to 1000 kWh of solar radiation during a year. Roofs represent an energy source for both space heating and hot water by using solar collectors to capture some of this solar radiation. As a consequence, there is a reduction in the consumption of fossil fuels. (Whittington, 2002)

Research conducted in United states' Missouri University of Science and Technology, calculating the electricity bill savings for solar residential solar panel adopters in the US, states that solar adopters in Arizona have on average 13.27% and 19.08% savings in summer and winter respectively. The amount of electricity generated from distributed solar photovoltaic (PV) systems in the United States (U.S.) residential sector has increased from 401-million-kilowatt hour in 2008-to-17,105-million-kilowatt hour in 2018 (Energy Information Administration, 2019). local jurisdictions may have standards on how PV is to be installed at a residential premise (standards on size, position, roof space, visibility, etc.). Cities and towns may have ordinances on the use of energy storage devices, additional energy efficiency codes, and laws that allow the community to procure electricity from cheaper sources. These factors directly affect a solar adopter's electricity bill and may either create or remove opportunities to maximize savings (Fikru, 2020).

Research conducted in department of mechanical engineering, higher technical institute on the Environmental benefits of domestic solar energy systems, states that All nations of the world depend on fossil fuels for their energy needs. However, the obligation to reduce CO_2 and other gaseous emissions to be in conformity with the Kyoto agreement is the reason behind which countries turn to non-polluting renewable energy sources. In this paper the pollution caused by the burning of fossil fuels is initially presented followed by a study on the environmental protection offered by the two most widely used renewable energy systems, i.e. solar water heating and solar space heating. The results presented in this paper show that by using solar energy, considerable amounts of greenhouse polluting gasses are avoided. For the case of a domestic water heating system, the saving, compared to a conventional system, is about 80% with electricity or Diesel backup and is about 75% with both electricity and Diesel backup. In the case of space heating and hot water system the saving is about 40%. It should be noted, however, that in the latter, much greater quantities of pollutant gasses are avoided. Additionally, all systems investigated give positive and very promising financial characteristics. With respect to life cycle assessment of the systems, the energy spent for manufacture and installation of the solar systems is recouped in about 1.2 years, whereas the payback time with respect to emissions produced from the embodied energy required for the manufacture and installation of the systems varies from a few months to 9.5 years according to the fuel and the pollutant considered. Moreover, due to the higher solar contribution, solar water heating systems have much shorter payback times than solar space heating systems. It can, therefore, be concluded that solar energy systems offer significant protection to the environment and should be employed whenever possible to achieve a sustainable future. (Kalogirou, 2004)

1.5.2 Social acceptability

Social acceptance is important for large scale implementation of new technologies such as renewable energy technology. Positive public opinion/participation is a must for adoption of technology such as solar energy technology and implementation of government policies. The paper of social acceptance of solar energy technology in India gathered public opinion of three villages (Gajner, Kolayat and Nokha) on solar energy technology. The three villages are situated near Bikaner town of Rajasthan, India. The survey is based on "Qualitative and Quantitative" methodology to explore public opinion and impact of technology on their day-to-day life. This sample study shows that about 91.27% residents are in favor of establishment of new solar power plant near their agriculture fields and 91% respondents would like to install roof top solar panels for their domestic power needs. 89% respondents of these villages believed that this power plant provides electricity and job opportunities. However, 7% opined that solar power plant is not beneficial for them. (Patel et al., 2016).

Solar energy is abundantly available in Pakistan and is converted into electrical energy by using solar photovoltaic system. The study social acceptability of solar photovoltaic system in Pakistan shows that 46% of the households used solar PV system in the northwest Pakistan. The results show that income of the household, household's monthly cost of energy consumption, education of respondents, information about the availability of solar PV system in the market, and source of awareness about solar PV system are the key determinants of the social acceptability of solar PV system. The overall model was highly significant as shown by $p < 0.001$. The study concludes that household, community, and market related variables play a key role in the social acceptability of solar PV system. The study recommends that the government should adopt incentive-based policies that focus on solar energy promotion in Pakistan. (Jan et al., 2020).

Social acceptance is being considered as an important factor towards the increasing implementation and expansion of renewable energy, especially solar, technologies. To determine the social acceptance of renewable energy technologies in Finland research with a multiple-choice questionnaire survey was conducted. This survey consisted of questions pertaining to the background information, the awareness of renewable technologies and their willingness to invest in them. From the analysis of the survey conducted in the Finish study, it was found that 33% of the people do not see the long-term economic feasibility of using Renewable Energy Technologies in homes, but about 62% were willing to invest extra to obtain this clean energy. Also, more than half of the surveys (52%) think that the public sector should take the first step towards renewable energy production so that the public/citizens can better understand the nature and gain more knowledge regarding these technologies from public sources rather than government ones which can be biased (Moula et al., 2013).

Overview of the above studies indicate that each component being studied in the thesis, that is carbon footprint analysis and social acceptability of installation of solar panels are interlinked. The key to introduction of a new technology (in this case solar PV systems for households) is the reception of it amongst the target consumers. The two main factors that influence this acceptance include costs incurred and benefits to be reaped in terms of external costs being diminished (including environmental costs). Therefore, for a decision to install solar technology, cumulative outcome of all three components must be considered.

CHAPTER 2
METHODOLOGY

This section outlines the methodology that is used to make significant empirical results that can be analyzed to attain the study's objectives. As a result, this section is separated into two major sub-sections for the assessment of household solar PV systems in Islamabad, Pakistan, namely:

(i) Estimation of the carbon footprint.
(ii) Social acceptability of solar energy by the sampled Islamabad households.

The data used to calculate the Carbon Footprint was assembled from a specific selected residence (with a solar PV system in operation) located in G10 Islamabad. The social acceptability study was done in Islamabad across three different sectors: G8, G9, and G10.

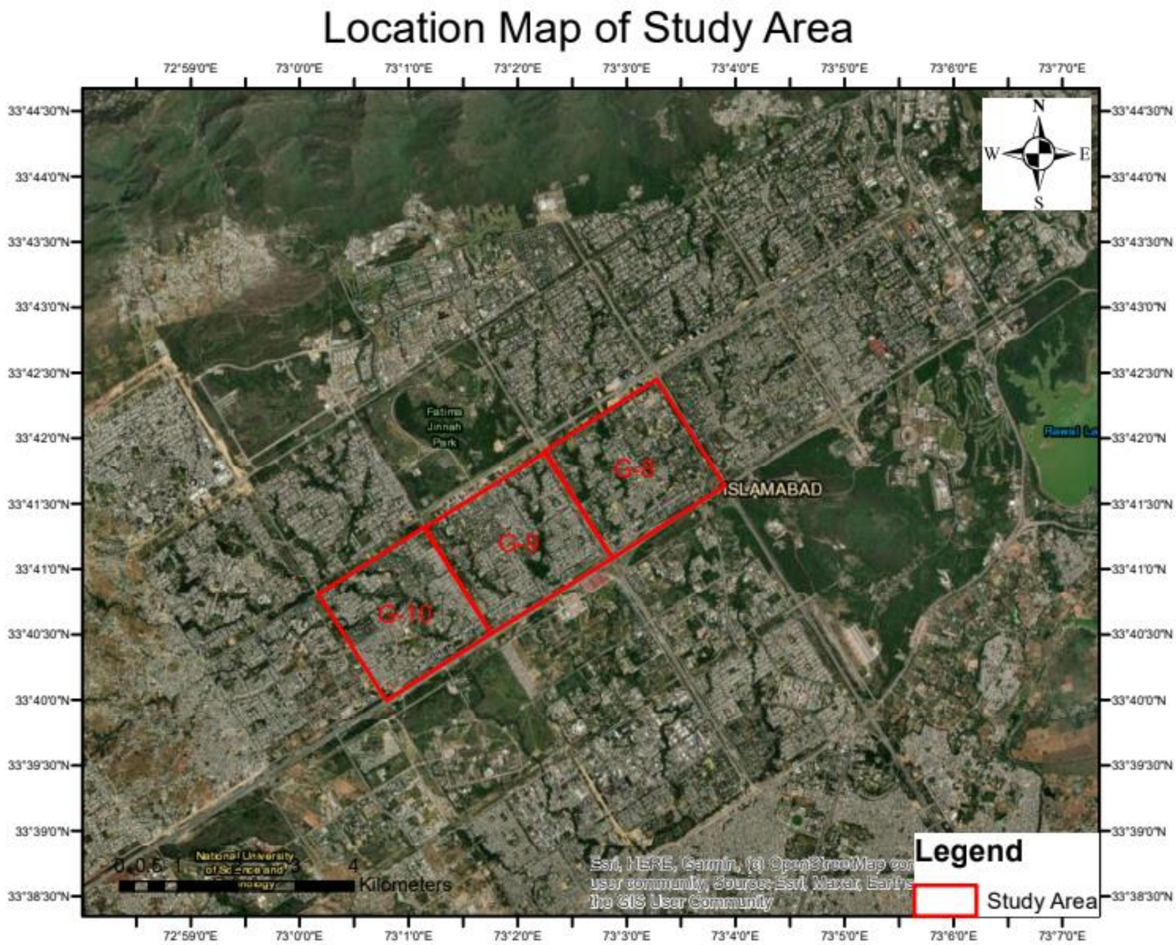


Figure 2.1: Survey and study area location

2.1Procedure for assessing household solar PV system

2.1.1 Carbon Footprint Calculation (CF)

Carbon footprint is defined as: the total amount of carbon dioxide and methane emissions caused by an individual activity under the condition that the sink, source, and storage are within the boundaries of the system or activity of interest; It is calculated as carbon dioxide equivalent (CO2e) using the applicable 100-year global warming potential. (GWP 100). (Wright, 2011)

It can also be defined as; "The measurement represented as the number of tons of carbon dioxide delivered into the atmosphere by things such as power plants, cars, or flaming heating oil" (Global Footprint Network, 2008).

In case of this study, it may be emphasized here that the activity under examination for which CO_2 emissions will be measured is the consumption of grid electricity.

Matthew et al. (2011) proposed the following formula for the calculation of Carbon Footprint for grid electricity usage:

CF = Use (kWh/month) x **EF** ($kgCO_2e/kWh$)

where,
Use = units of electricity consumed per month per person
EF = emission factor for consumption of grid electricity.

The data of two years of the household electricity bills have been recovered; Year1 is March-February 2021-2022, in which the household consumed grid electricity, and Year 2 starting from August-July, 2022-2023 is the period when the household worked on a mix of grid electricity and solar PV system. The Carbon Footprint of each of the preceding years mentioned will be calculated separately for comparison and analysis. Comparison was also made on different factors based on survey results. Factors included;

(i) Family size verses CO_2

(ii) Emissions timeframe verses CO_2 emissions and

(iii) Electricity bills before and after installation of solar PV system.

2.1.2 Social acceptability survey

Acceptability research in technology assessment refers to the analysis of the social and economic outcomes of new technologies such as solar PV systems using common empirically aligned approaches. In this sense, acceptability is a key prerequisite for the social acceptance of a technology. (Hirschl,2005).

Social Acceptability can also be defined as the acceptability of a technology as its “Capacity to be embraced in relation to its cultural frame." (Meyer-Abich, 1999)

In this study, a social acceptability field survey of 100 households is conducted to gain a better grip of existing knowledge among the local population. Moreover, it enables for a precise assessment of the target population's perception of renewable technology, namely solar PV systems in households.

Aside from the reception of solar PV systems, the survey done in this study identifies the sample population's priorities in terms of cost and environmental benefits of solar panel installation.

The survey conducted in this study consists of eighteen basic questions; the language and style of the questions have been deliberately kept simple to make them graspable for the general public. The survey was divided into sectors in Islamabad, with a random sample of 18 questionnaires being filled out in each sector. The questionnaire's primary variables include household income, house size, electricity use, availability of solar technologies, monthly income and factors influencing awareness of solar technology. Another major aspect questioned in the survey was the sample population's prior understanding of the detrimental impacts of fossil-fuel-powered electricity, and how this influences their decision to adopt solar technologies.

2.1.3 Data and data limitations

This section summarizes the data assembling techniques for each component under consideration in the research. Moreover, it includes the restrictions that have occurred in the gathering and availability of the required data.

2.1.3.1 Data collection

The data collected and used for all of the two components under consideration in the study is mostly primary data. Here is a breakdown of data collecting.

(a) Primary data:

The data used for carbon footprint calculation were acquired from selected household that converted from grid to solar electricity and acquiring their electricity bills (see Annexure A and Annexure C) for the questionnaire used to acquire this information and copies of electricity bills. The questionnaire was assembled in order to add all the required information regarding, size of plot, family, rooftop spacing, type, size and cost of solar panels. Moreover, there was acquisition of data concerning change in energy patterns, change in bills, and the advantage of solar PV system in terms of addressing load shedding hours.

A questionnaire was devised and used to gather information on the social acceptability of solar energy utilization by households in Islamabad (Annexure A contains the questionnaire). The questionnaire was filled out by households in three sectors (G-8, G-9, and G-10), with 33 questions completed in each sector for a total of 100. The sort of sampling used was random sampling. The questionnaire was produced to assess the existing knowledge of solar technology and environmental stewardship amid the sample population of Islamabad. Moreover, other variables such as age, household income, number of household members, plot size, capacity of solar PV system, initial installation cost and willingness to pay for solar technology were look- overed in order to better understand the target audience and social inference of solar PV system advocacy and installation as an alternative source of electricity generation to consuming grid electricity.

(b) Secondary data:

Additional information for Carbon Footprint calculations has been obtained from secondary sources, such as research papers and websites. In the Carbon Footprint calculation, the Emission Factor (EF) for grid energy use in Pakistan is taken as 0.75737 kg $CO2$/kWh. The EF value reported above is from the International Energy Agency (2010).

2.1.4.2 Data limitations

Due to difficulties in assigning and obtaining permission from household owners to use their personal data, only three major sectors were employed to assemble data for the calculation of Carbon Footprint (Cost Information).

The carbon footprint calculated in the study only focuses on footprint due to electricity and excludes carbon emissions of natural gas usage, transportation, and other activities in the household. This was done in order to avoid misunderstanding and keeping the center of the study according to its theme of electricity generation.

Chapter 3

Results and Analysis

3.1 Carbon footprint

For the purpose of this research a household of 7 people is taken which has already operational solar panels installed. The house is located in sector G-10/1 Islamabad, its plot size is 40 x 80 feet, and its rooftop is approximately 60 x 40 feet. There are 28 panels supported by stands installed on the roof (Annexure D), adding up to a total generation capacity of 15 kw. The panels receive sunlight optimally an hour after sunrise till an hour before dusk on a clear day. The production efficiency of the installed panels is 75%.

Figure 3.1 below shows the average monthly temperature profile in Islamabad. The city faces all four seasons, i.e., spring, summer, autumn and winter. The highest temperature can be recorded in the months of June (38◦C) and May (36◦C), whereas the lowest temperatures can be measured in December (20◦C) and January (18◦C).

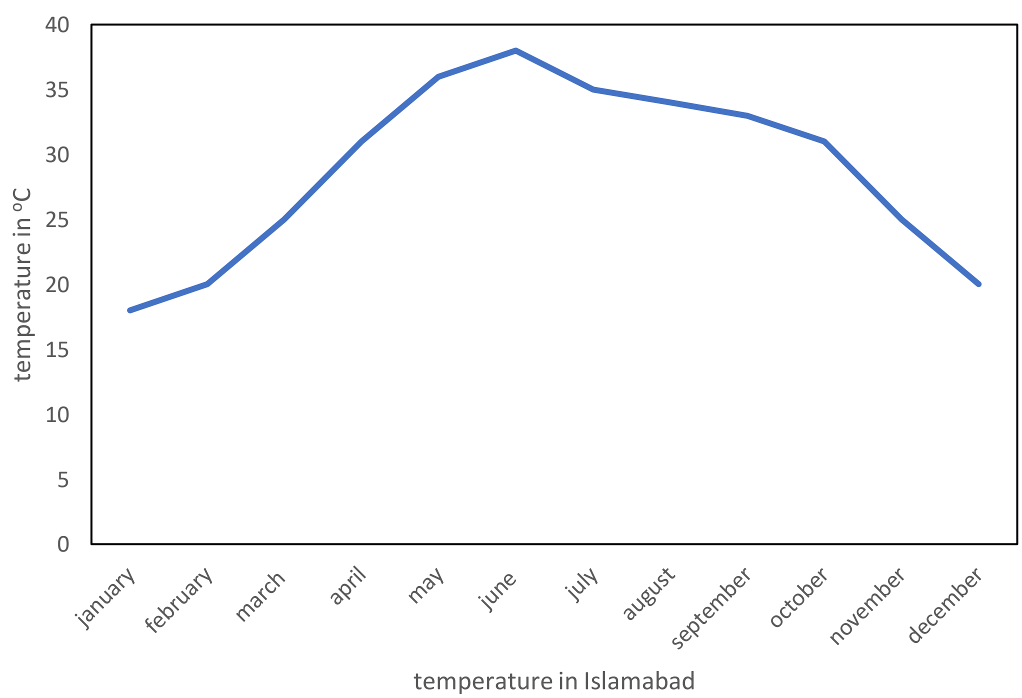


Figure 3.1: Average monthly temperature in Islamabad (source: weather2travel; 2024)

Parallel to these the monthly daylight hours illustrated in Figure 3.2; show a similar pattern with the peak daylight hour in June (14.32h) and July (14.12h), whereas the lowest daylight hours are in December (9.93h) and January (10.17h) respectively. The amount of daylight hours directly affects the amount of energy generated by the solar photovoltaic system. Long daylight hours mean greater number of hours of sunshine that can be converted into energy, similarly shorter days of daylight mean less hours of sunshine that can be utilized by the solar PV system. Therefore, seasonal variation should be evident in units of energy generated with changing daylight hours.

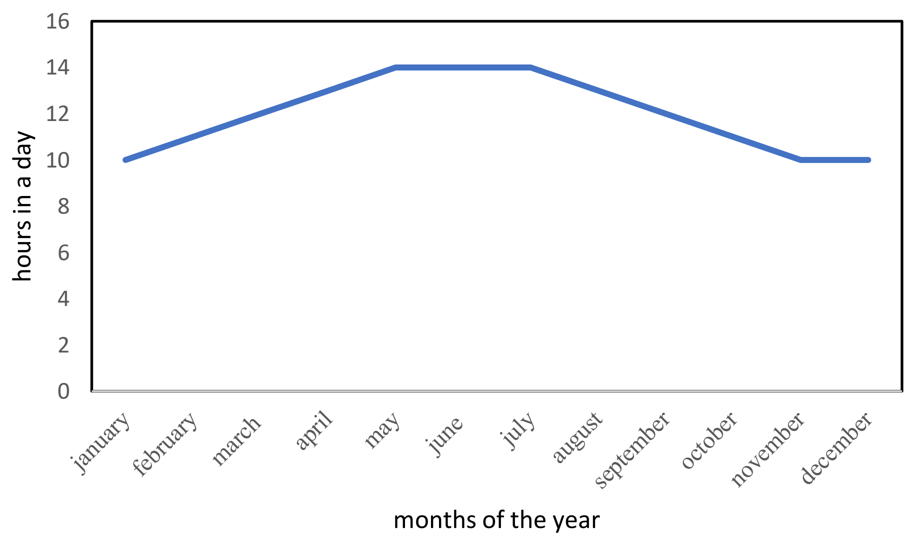


Figure 3.2: Average monthly daylight hours in Islamabad (source: weather2travel; 2024)

Tables 3.1 and 3.2 represent the units of electricity used per kWh; obtained from the WAPDA electricity bills of our selected household for the years 2021-22 and 2022-23 (Annexure C), followed by their individual computed Carbon Footprints in the last column.

Table 3.1: March 2021-February 2022; Grid Electricity

Month	Units	Calculations	Carbon Footprint of Household ($kgCO_2e$)
March	387	387× 0.75737	293.903
April	414	414× 0.75737	313.836
May	559	559× 0.75737	423.235
June	1115	1115× 0.75737	844.281
July	1268	1268× 0.75737	960.057
August	1714	1714× 0.75737	1298.086
September	1232	1232× 0.75737	933.888
October	888	888× 0.75737	672.511
November	448	448× 0.75737	339.434
December	432	432× 0.75737	327.212
January	415	415× 0.75737	314.304
February	459	459× 0.75737	347.427
Total	**9331**	**N/A**	**7067.464**

(Source: Based on Authors' estimates)

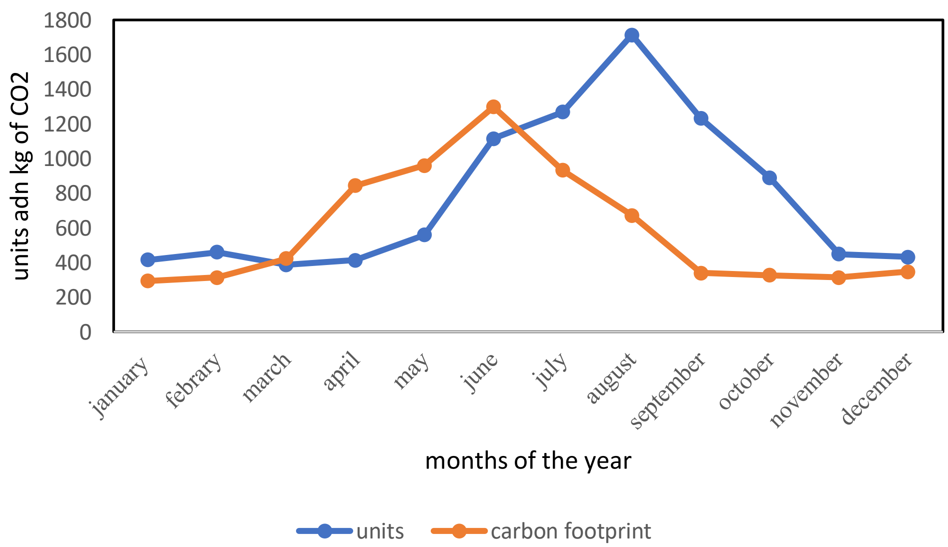


Table 3.2: August 2022-July 2023; Solar/Grid Mix Electricity

Months	**Units**	**Calculations**	**Carbon Footprint of Household ($kgCO_2e$)**
August	227	227× 0.75737	171.965
September	-695		
October	0		
November	0		
December	-3050		
January	0		
February	0		
March	-1506		
April	0		
May	0		
June	-3868		
July	211	211× 0.75737	159.791
Total		**N/A**	**331.756**

(Source: Based on Authors' estimates)

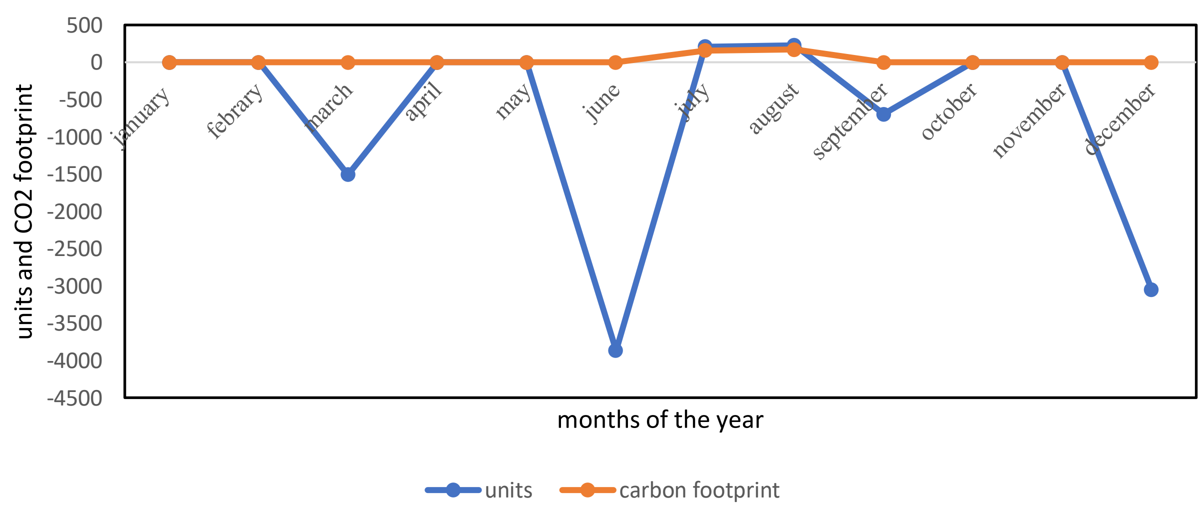


Figure 3.3: Units consumed throughout the year and their corresponding carbon footprint.

Table 3.2 illustrated the solar/grid mix electricity consumption from August 2022 to July 2023, along with the total carbon footprint for the period amounted to 331.756 kgCO2e.In the month of August, the household consumed 227 units, resulting in a carbon footprint of 171.965 kgCO2e. September, October, November, December, January, February, April, and May showed no consumption of units, implying that solar energy generation exceeded the household's demand during these months. In March and June, the household generated excess solar energy, resulting in negative consumption of units (-1506 and -3868 respectively). As a result, the WAPDA bill reflected zero values for these months due to the surplus solar energy supplied to the grid.

3.1.1 Monthly Breakdown of Carbon Footprint

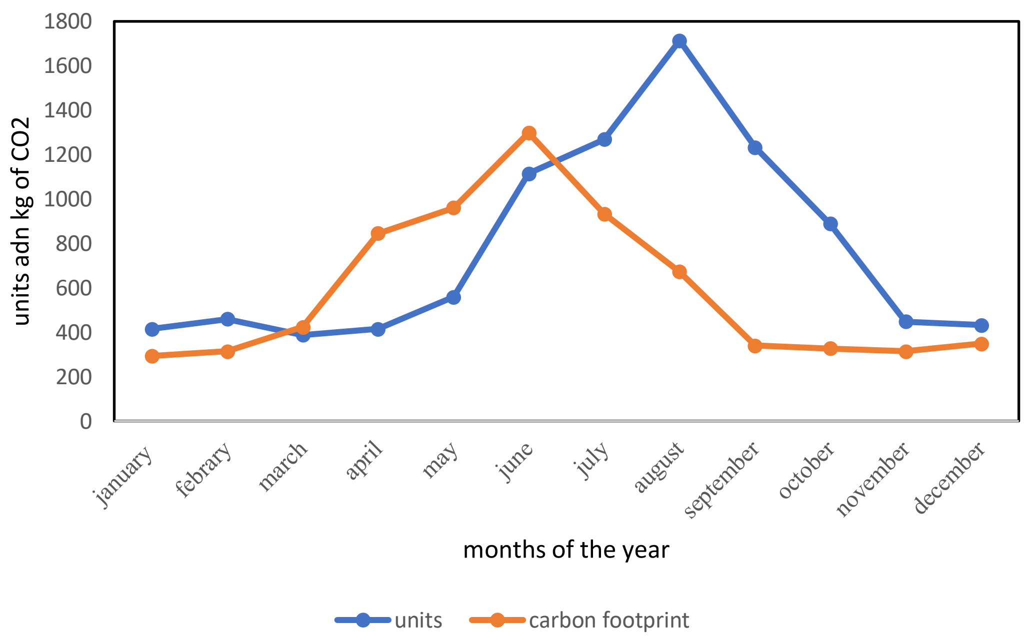


Figure 3.4: Year: March 2021-Feburary 2022; Grid Electricity

The total grid electricity units consumed by the household in 2021-22 are 9,331 kWh whereas the corresponding total Carbon Footprint of the year is 7067.464 kgCO_2e (Figure 3.4).The maximum amount of units being consumed in year 2021-2022 are through the months of July, August and September accumulating the highest number of units at(1714 kWh).Conversely, the lowest consumption of units is in the months of March, December and January (387kWh). As the amount of energy generated by grid-power plants increase, so does the amount of carbon emissions produce. Although hydroelectricity reports for around 29.9% of Pakistan's energy generation and emits no carbon dioxide during the function, the bulk, 64.4%, is manufactured from oil and gas (Kazmi, 2014). As a result, increased electricity use directly correspond with increased carbon emissions, which add to the user's computed Carbon Footprint.

March

March represents the smallest consumption of electricity units (387 kWh) along with average temperature of 26.67 ° C. This verified the factor of temperature being directly proportional to consumption of electricity. Corresponding to the low consumption of electricity in the household, the Carbon Footprint. The low consumption of electricity can be associated with relatively low average temperatures in Islamabad during these three months, thus the load on electricity is comparatively small. There is less or no usage of fans, air conditioners, motor pumps for water uprooting.

April-July

The advent increases in temperature from an average of 26.67° C in March to 33.3° C April and ahead July incorporated with greater usage of appliances such as fans, air conditioners, refrigeration, and usage of Uninterrupted Power Source (UPS) batteries to prevent longer hours of electricity load shedding in the summer months account for greater consumption of electricity units. This is evident from the graph above which shows an increase in electricity units whereby March has total units of 387 kWh, and in April this increased to 414 kWh. The Carbon Footprint followed similar pattern of rising from March

293.903to 313.836 $kgCO_2e$ in April. This shift continues on to the forthcoming months of May, June, and July.

August-October

According to the data recovered from the electricity bill of the selected household the peak and highest consumption of electricity units were recorded in August 1714 kWh coinciding with high average temperatures of 42.2° C in Islamabad and as a result of greater consumption, greater value of Carbon Footprint was received for the month:1298.086 $kgCO_2e$. The electricity unit's consumption in September is recorded as 1232 kWh with a Carbon Footprint of 933.888 $kgCO_2e$, (with an average temperature 31.67° C). Similarly, units consumed in Month of October is 888 kWh with resulting carbon footprint of at 672.511 with average temperature 27.78 ° C.

November-February

The average electricity consumption of in this quarter of year is 584 units similarly to which carbon footprints of November is 339.434 $kgCO_2e$ which gradually decrease to 327.212 $kgCO_2e$.

Thus overall, the trend shows a peak increase in electricity consumption and corresponding Carbon Footprint in the summer months (May – October), with an average Carbon Footprint of 1710.686 $kgCO_2e$, similar to which the winter months (November – January) where the average Carbon Footprint for these months is calculated to be 326.983 $kgCO_2e$. As a result, there is an obvious pattern in the increase of power consumption and the corresponding carbon footprints with seasonal variations and temperature fluctuations.

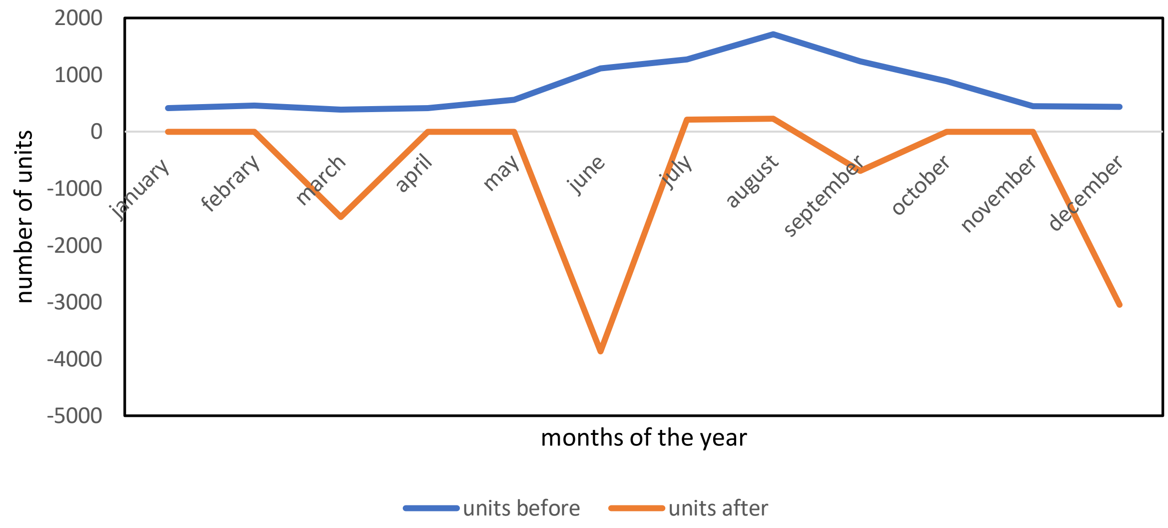


Figure 3.5: Comparison of Grid Electricity Units Consumed 2021-22 verses Solar/ Grid Mix 2022/23

Figure 3.5 illustrates the comprehensive comparison of Carbon Footprint and electricity consumption of selected household of both years 2021-2022 (Grid Electricity only) and 2022-2023 (Solar/Grid Mix). Electricity consumption and carbon footprint vary significantly during the periods March 2021-February 2022 and August 2022-July 2023.There is a sharp distinction between the two footprints, and this pattern continues throughout the year profiles. During the first year, which represents grid power usage, the total grid electricity units consumed by the household in 2021-2022 are 9,331 kWh units, whereas the corresponding total carbon footprint of is year 7067.464 kgCO_2e.

The second year, which included a mix of solar and grid electricity, saw a real shift in consumption patterns. Months like August and July have positive consumption values but much lower carbon footprints due to the combination of solar-generated electricity and little grid dependency. The negative numbers seen in September, December, March, and June indicate that the household's solar panels produced more electricity than needed, resulting in net-zero emissions during those months. The total carbon footprint of the year is 331.756 kgCO_2e.This decrease is directly associated to the installation of solar panels in the household in the latter year. This has divided the share of grid electricity units with solar photovoltaic system generated electricity units. Since, consumption of electricity by solar photovoltaic system produces essentially zero carbon emissions. This move shows a sustainable approach to energy usage, exemplifying the household's dedication to decreasing its carbon footprint while embracing renewable energy solutions.

The notable difference between the two Carbon Footprints occurs during the summer months (May - October), when daily solar exposure is high, as are daylight hours, following a greater amount of energy produced via solar photovoltaic systems for storage and use. However, greater energy generation is sometimes counterbalanced by increased energy use, especially as temperatures rise. The distinction between the two footprints is determined by the ratio of increased energy generated by the solar photovoltaic system to increasing energy demand over the same time period.

In winter months (November-February) because of winter it's colder, so people normally don't use as much electricity. Because they use less electricity, the carbon footprint tends to be lower because less CO_2 is released into the air. So, during winter, even though solar panels might not make as much electricity, the overall impact on the environment is less because people use less electricity overall.

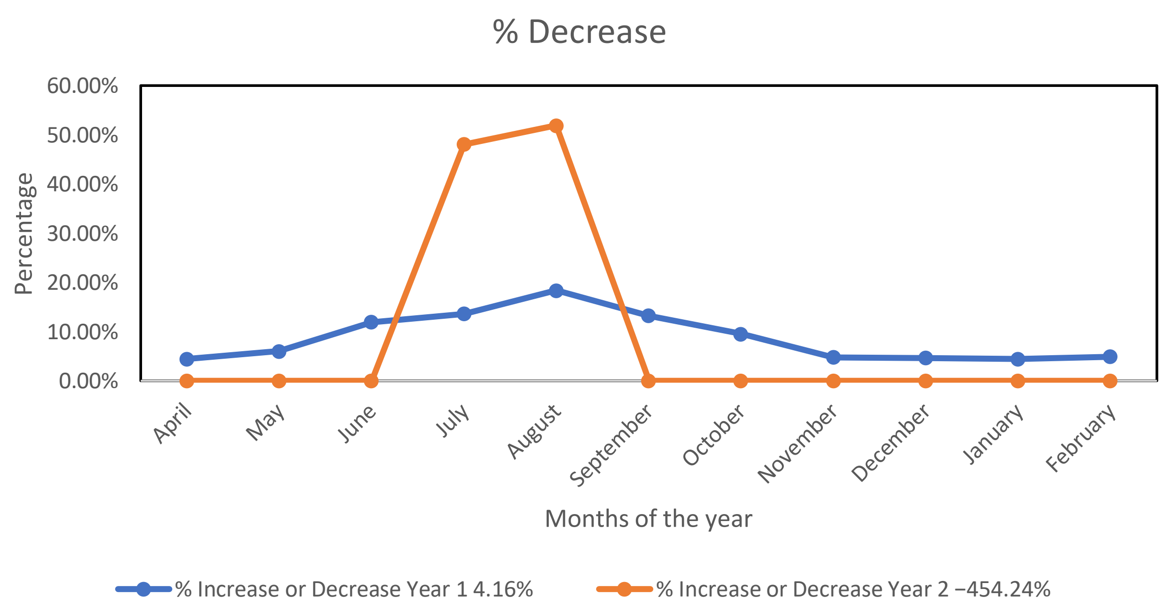


Figure 3.6: Percentage decline in carbon footprint between year 2021-22-2022-23

Figure 3.6 shows that the Carbon Footprint decreases gradually over the two years of comparison. The highest percentage decrease can be found in August, with a notable 51.91% reduction in the Carbon Footprint. The lowest percentage decline occurs in March, with a 4.16% reduction in carbon emissions. The overall percentage decrease in carbon footprint from 2021-22 to 2022-23 is 95.29%. This gives concrete evidence that the installation of solar photovoltaic systems for energy generation in houses might provide a reliable potential source of reducing carbon emissions.

3.1.2 Comparison of carbon emissions from different factors based on survey results.

Table 3.3: Number of people living in a house

Family Size	Electricity Units Consumed	Percentage of Respondents
(a) 2-3	215	15%
(b) 4-5	450	35%
(c) 6-7	885	45%
(d) More than 7	975	5%

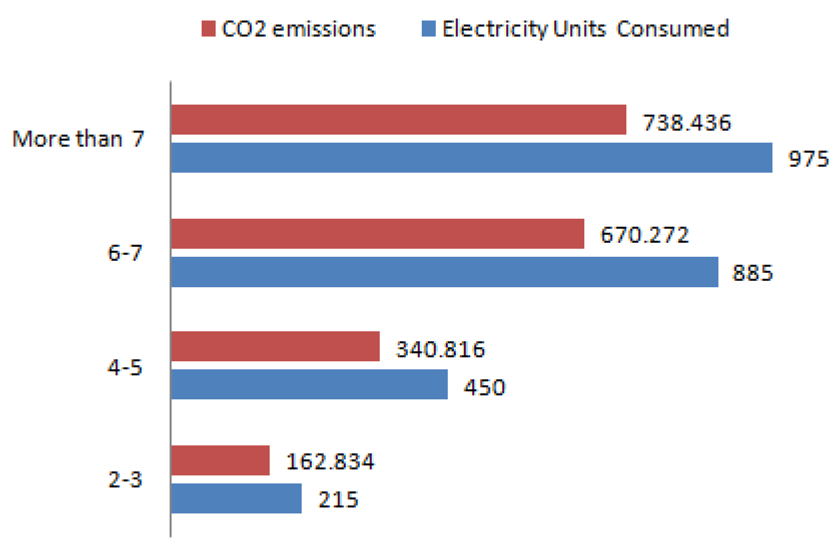


Figure 3.7: CO_2 emissions corresponding to family size.

Family size verses CO_2 emissions

Small families (2-3)

Figure 3.6 illustrates that small families commonly had lower energy consumption compared to larger families due to fewer individuals using appliances and devices. With fewer members, small families needed less electricity for daily activities, resulting in lower CO_2 emissions. The installation of solar PV system in small families led to noteworthy ductions in CO_2 emissions as they balance a larger proportion of the household's energy needs.

Moderate families (4-5)

Moderate-sized families had a counterbalance between energy consumption and the number of household members. Solar PV system installation in moderate families resulted in notable reductions in CO_2 emissions, particularly when energy-efficient practices were adopted (Figure 3.6).

Larger families (6-7 and more)

Large families often consumed more energy since more people use appliances, lighting, and devices (Figure 3.6). Large households used more electricity for cooking, heating, and other daily activities, resulting in increased CO_2 emissions. Despite greater initial emissions, larger families could profit greatly from solar PV system installation, lowering their overall environmental effect over time.

Table 3.4: When was the solar system installed.

Timeframe	**Percentage of Respondents**
Less than 1 year	15
1-2 year	21
3-5 year	9
More than 5 years	5

Timeframe verses CO_2 emissions

Less than 1 year ago (15% respondents)

Households that installed solar PV systems less than a year ago were still getting used to their new energy systems. During this first era, they saw modest reductions in CO_2 emissions as they enhanced their energy usage and adapted to solar technology. Despite the short time span, these households helped to reduce overall CO_2 emissions and began to see the benefits of using solar energy.

1-2 years ago (21% respondents)

Households having solar PV systems installed 1-2 years ago had already made changes to their energy usage patterns. During this time, they began to witness notable reductions in CO_2 emissions as they became more familiar with their solar PV systems and applied energy-efficient practices. The 1–2year timeframe permitted these households to reap major benefits from solar energy adoption, evolving in significant CO2 emissions reductions relative to pre-installation levels.

3-5 years ago (9% respondents)

Households that installed solar systems 3-5 years ago had a lot of time to improve their energy consumption and benefit from advances in solar technology. During this timeframe, they saw significant reductions in CO_2 emissions as they purified their energy usage patterns and increased the efficiency of their solar systems. These homes were able to achieve appreciable environmental benefits and long-term sustainability by adopting solar energy within a 3–5-year timeframe.

More than 5 years ago (3% respondents)

Households that installed solar systems more than five years ago were among the first to adopt solar technology. Over time, they attained significant reductions in CO_2

emissions and positioned themselves as leaders in sustainable energy techniques. With significant expertise and advanced energy systems, these households demonstrated the long-term environmental and economic benefits of solar energy adoption.

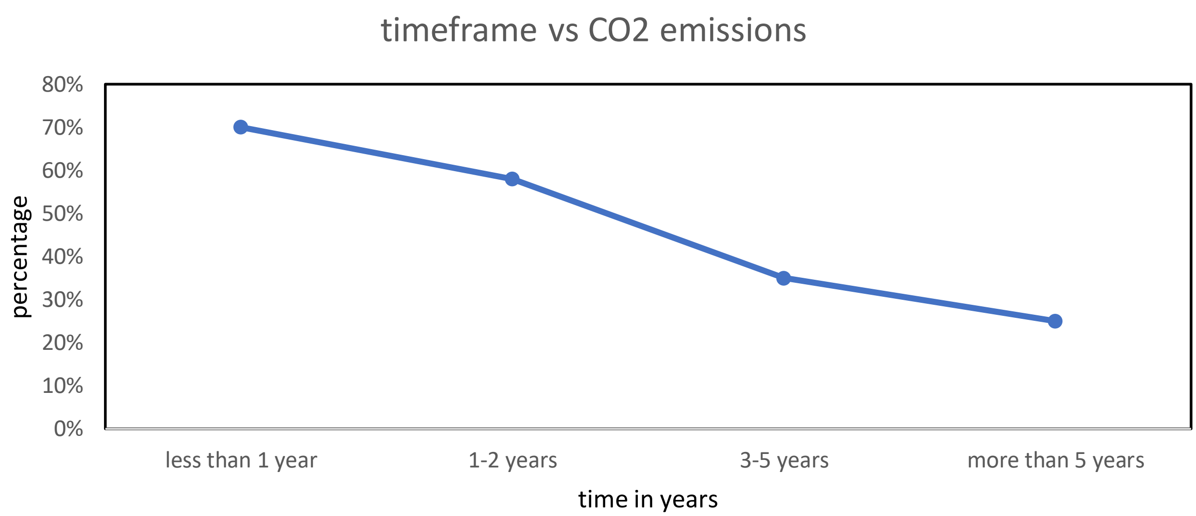


Figure 3.8: Timeframe verses CO_2 emissions

Table 3.5: Electricity bills before and after installation

Before	After	Percentage of Respondents
0-15,000 rupees	5,00-2,000 rupees	20%
16,000-30,000 rupees	1,000-5,000 rupees	45%
31,000-50,000 rupees	5,000-10,000 rupees	27%
1,00000 and above rupees	15,000-20,000 rupees	8%

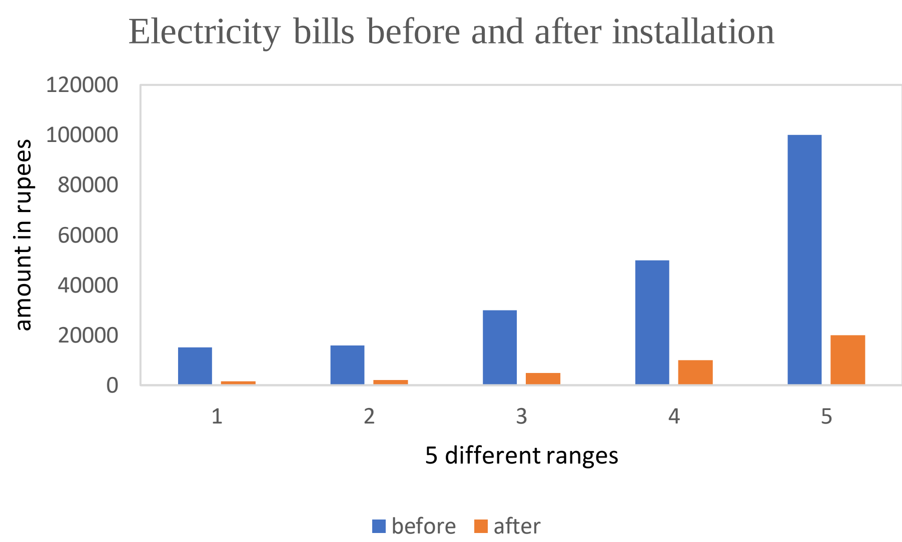


Figure 3.9: Electricity bills before and after installation of solar PV system

Before installation

Before installation, households had differing in electricity bills, ranging from 0 to 100,000+ rupees per month., Most of the respondents (45%) had electricity bills ranging from 16,000 to 30,000 rupees per month. Smaller proportions had bills below 15,000 rupees (20%), between 31,000 to 50,000 rupees (27%), and 100,000+ rupees (8%) (Figure 3.8).

After installation

Figure 3.8 shows that after installing solar PV system, households experienced notable reductions in their electricity bills. Large number of respondents (45%) reported bills between 1,000 to 5,000 rupees per month, compared to the 16,000 to 30,000 rupees range before installation.

The second most usual category (27%) reported bills between 5,000 to 10,000 rupees per month after installation. Smaller proportions reported bills below 2,000 rupees (20%) and between 15,000 to 20,000 rupees (8%).

Comparison

The findings show a noteworthy reduction in electricity bills after installing solar PV system across all income levels (Figure 3.8). For example, households that were previously paying 16,000 to 30,000 rupees per month had their charges drop to 1,000 to 5,000 rupees following installation, resulting in an immense cost savings. Likewise, those with higher starting bills of 31,000 to 50,000 rupees saw monthly reductions of 5,000 to 10,000 rupees each. The lower electricity prices specify a drop in grid energy consumption, which could donate to a reduction in CO_2 emissions related with grid electricity usage.

3.2 Social acceptability

The social acceptance questionnaire was designed to find out how people recognize solar technology and whether they are comfortable using it. To collect this information, a social acceptance questionnaire was designed (Annexure A). The questionnaire was straightforward and easy to grasp, with an introduction to what solar technology is. Survey participants who did not understand were given simple clarification to assist them understand the purpose of the survey and the questions being asked.

The survey was taken from random people from all walks of life and social standings across the sectors G-8, G-9, and G-10 in Islamabad. This was done to understand about people's perceptions on technology and whether they believe it is good or not. The questionnaire results were organized into a table (Annexure B), which is detailed below.

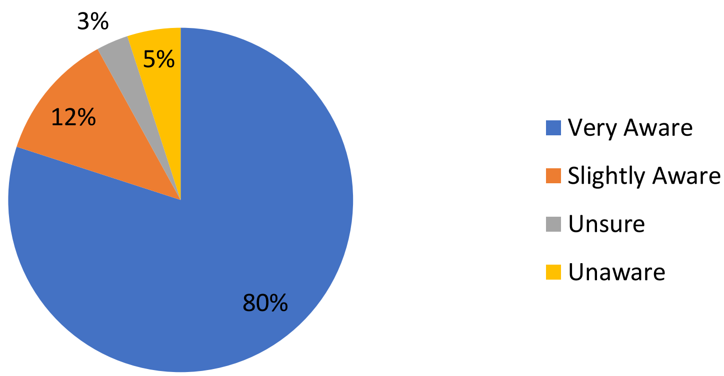
The early 9 questions were introductory questions to allow the person filling the form to get comfortable in filling the survey. Besides, it provided the compulsory information to categorize them demographically and determine what kind of background they have and whether this impact their decision about solar technology.

Majority of the respondents were young, 45% were of ages between 15-25, this percentage drops as we go higher in age, 34% in ages between 25-35, 15% in ages 35-45 and a mere 6% of ages 45 and above filled the forms. This demonstrates that when people were approached about the questionnaire, the youth were the most likely to fill out the forms, and as the age group progressed, the number of respondents decreased, designating that the older people were, the less interested they were in filling out forms about solar technology. Majority of respondents that were surveyed were the male population of about 84% only 16% of respondents were female community. The people surveyed belonged to different walks of life.

About 85% of the people live in a house which makes it easier for them to install solar panels, than when living in an apartment. And it gets easier because 75% have their own property on which they live in so they can't worry about relocating their setup every time they move.

The monthly household income reveals that some of the persons polled might afford solar panels if they saved up some money before applying for solar panel installation, as there are presently many effective solar installation alternatives available in the market, with prices starting as low as 200,000 lac Rupees. The majority of those polled have affordability issues.

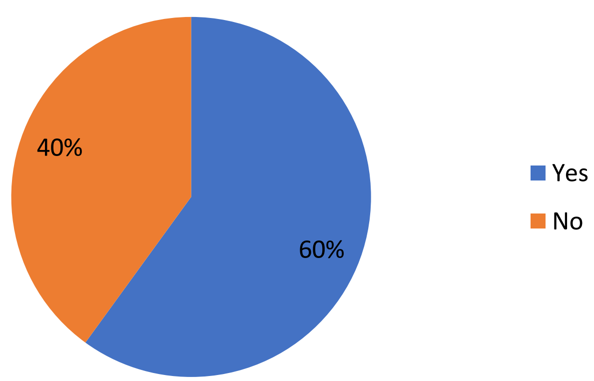
People who live in small houses with an average number of family members have a notable advantage when it comes to installing solar panels because their electricity usage is lower, and the solar installation benefits them more. 55% of people live in houses of 7-10 Marla, while around 28% have 3-5 or fewer persons in their residences, making them perfect for low-cost solar installations.



3.10 Awareness of solar panels

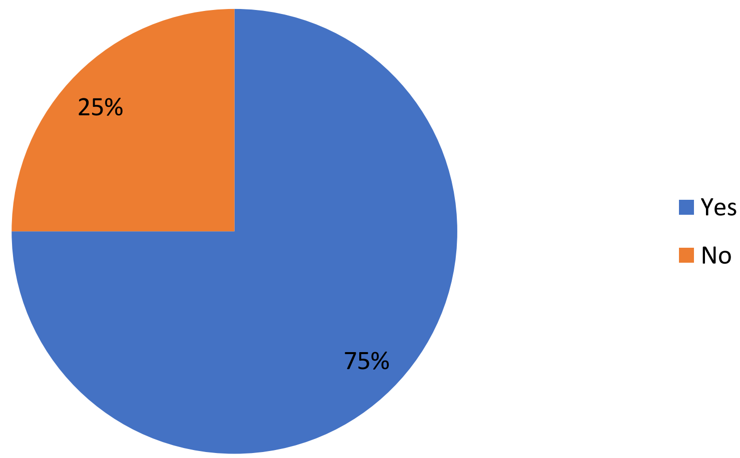
Previously, the public was less aware of solar technologies, but this has gradually increased. Approximately 80% of those polled were familiar with solar technology (Figure 3.10); they understood how it worked and what it was to some extent. This awareness trend was more widespread among younger respondents and declined with age.

Now more than ever people know about the technology and when questioned from the people surveyed how and why they know so much, most of them replied that due to current bloom in soaring electricity prices and solar advertising and the new government solar project their awareness had risen and they got to know more about it or researched about it themselves, some of them even got a solar setup installed in their homes after that.



3.11 Consideration of installing solar panels on your property

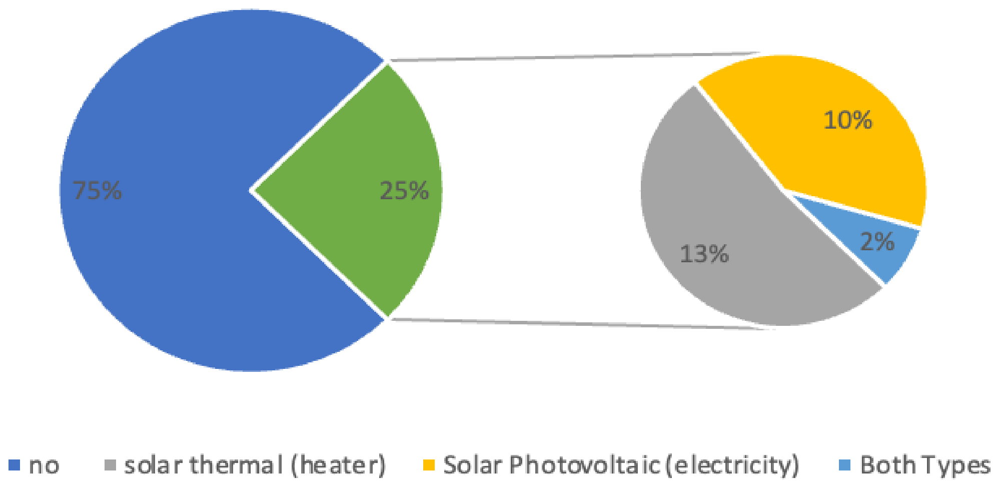
Figure 3.11 illustrates that majority, 60%, of the surveyed population have indeed considered installing solar panels on their property. This indicates a significant level of interest in solar energy among the public whereas 40 % population were seemed not interested.



3.12 Interest in reducing electricity consumption.

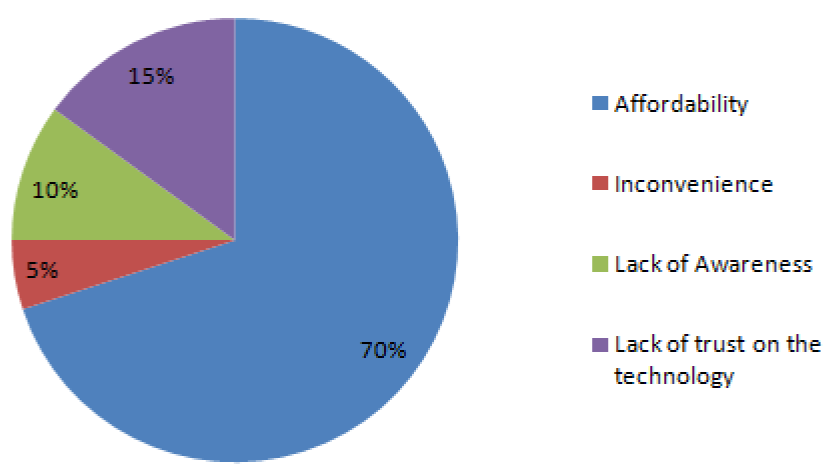
75% of the surveyed respondents expressed an interest in reducing their electricity consumption and were willing to take the necessary steps. However, a nearly identical proportion (25%) of consumers were content with their present electricity consumption (Figure 3.12).

The most common cause for this behavior was their unwillingness to cut back on their essentials. Moreover, the respondents were anxious in spending extra cash to install energy saving appliances or adopt such practices. Others were of the view that if they could afford it, they can use as much electricity as they desired**.**



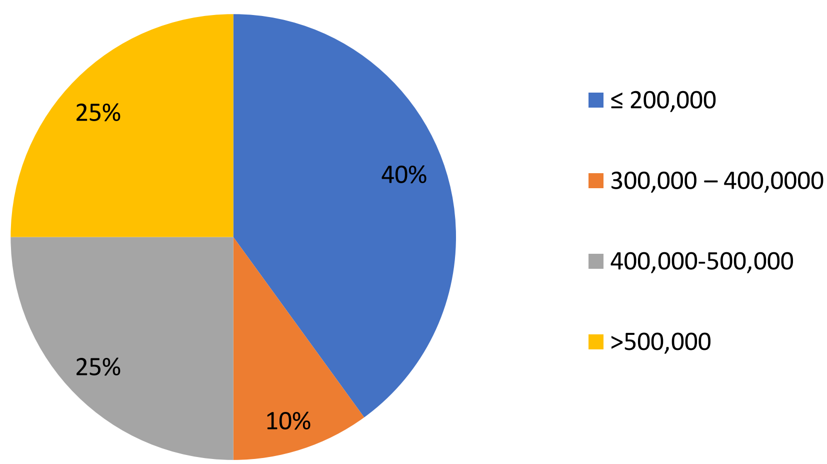
3.13 Existence solar technology installed.

As shown in Figure (3.13) respondents appeared to have adopted solar technologies at varying rates. Of the total respondents, 25% reported installing solar thermal heaters, while 10% acknowledged using solar photovoltaic systems to generate electricity. Interestingly, just 2% reported having both types of solar systems installed. Furthermore, a sizable proportion of respondents, 75%, stated that they had not yet installed any sort of solar technology.



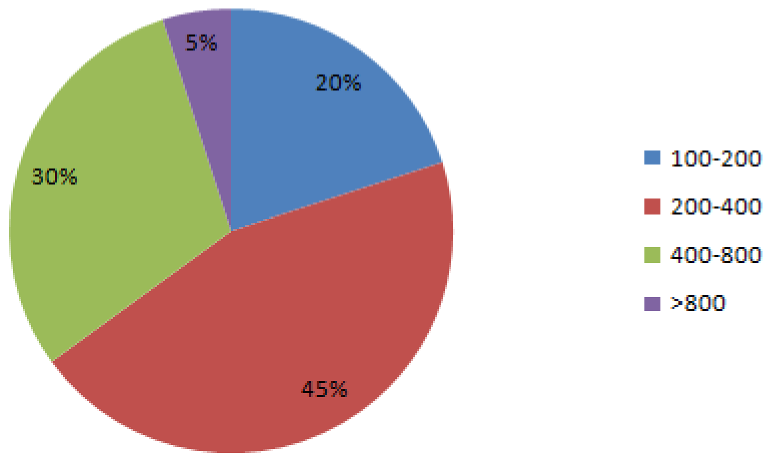
3.14 Factors preventing from installation of solar technology.

With reference to (Figure 3.14), the most prevalent barrier preventing consumers from adopting solar technology is affordability (70%), the cost of the entire set-up. According to the survey respondents, most solar setups cost more than Rs. 400,000, which is incorrect. Many solar setups can be installed for as low as Rs. 50,000-100000 depending upon the need of a person, this misunderstanding about the price is due to lack of awareness (5%) which is the next thing which stops people from adopting solar technology. This lack of awareness and skepticism of technology was particularly notable among the older generations who completed the questionnaires. These are the most usual barriers that prevent individuals from learning about and adopting new technology, including solar. Some of the people surveyed still have trust difficulties with this expanding technology. (15%)



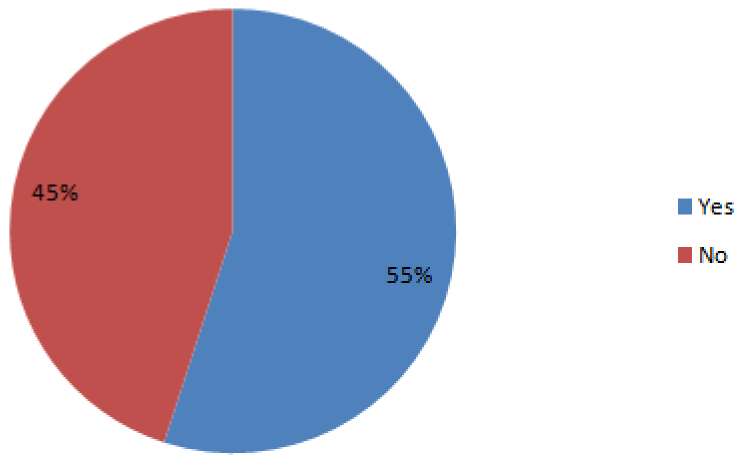
3.15 Willingness to spend on solar technology.

The people surveyed were not informed about the current price depository of solar companies, so the majority of the questions were answered honestly, and this question was no deviation because it required the person's own willingness to invest in a clean technology without regard to current prices. As shown in (Figure 3.15), 40% of those who did not have solar installations were only willing to pay a minimum of Rs. 200,000 or less.25% of the studied population were willing to pay the average price of 300,000-500,000, whereas only (10%) of the surveyed population were able to spend more than 500,000 rupees on solar technology. This is related to their affordability decision, which was previously mentioned, as well as their economic stability, which people incorrectly believed was inadequate.



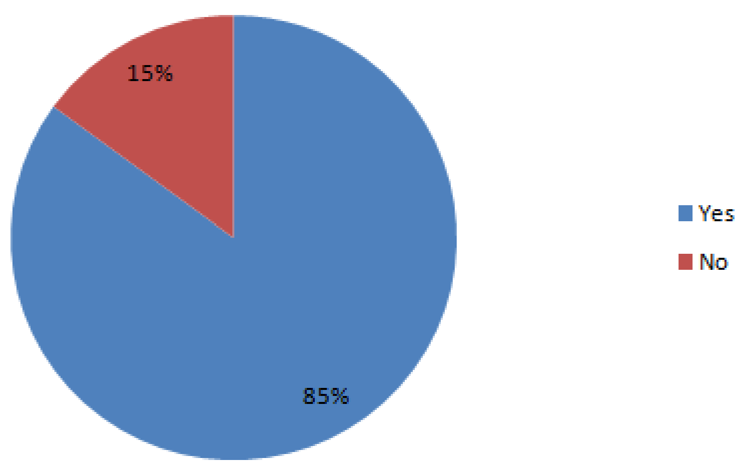
3.16 Monthly units of electricity consumed.

The survey samples consumed varying amounts of electricity every month. (Figure 3.16), a higher percentage (90%) had mainly moderate consumption between 100 and 400 units. This could be attributed to the high cost of electricity in compared to the accessibility of consumers. A small percentage of consumers (5%) consume more than 800 units of power per month. This is the part of society that is willing to pay for energy regardless of price increases.



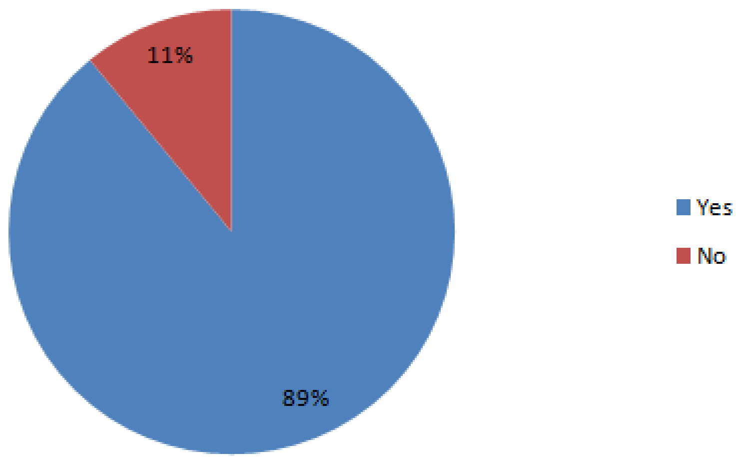
3.17 Awareness of negative effects of fossil fuel power generation

Figure 3.17 shows that 55% of the respondents surveyed were conscious of and concerned about the negative effects of fossil fuel electricity generation, such as coal-fired power plants. More than half (45%) were unaware of the negative impacts of fossil fuels on the environment, believing that the emissions were slight in comparison to the immensity of the earth.



3.18 Positive contribution of solar panel to environment

(Figure 3.18) shows that a high proportion of the population (85%) favors solar panels for their environmental benefits. The public's awareness of solar panels as environmentally friendly reflects a broader trend of increased understanding and support for renewable energy technologies such as solar power.



3.19 Consideration of solar panels in future

Solar panels are seen positively by the public because they relate to sustainability, innovation, and energy independence. (Figure 3.19) displays a high level of public support for solar panel installation or consideration in the future (89%). Some consumers were uncertain to embrace solar panels in the future due to a lack of information about the upcoming technology and its affordability.

The social acceptability survey provides perception into the general public's awareness and acceptance of solar technologies. Despite claiming to understand solar technologies, respondents were first disappointed about their benefits. Many of them believed the government and business organizations unnecessarily applaud solar technology, making it appear untrustworthy to them. People’s attitudes improved as the surveyed progressed, thanks to the information provided to them about the genuine benefits derived from this study, significantly a reduction in their carbon footprint and financial situation. Overall, the survey results varied; while many were anxious to put solar power in their houses to save their electric bills, they were alarmed to trust this new technology. It is thus critical to further spread knowledge regarding the viability and prospective benefits of solar technology as an authentic electricity generating source.

CONCLUSIONS

The significant role of solar PV systems in greatly reducing the carbon footprint of users cannot be overstated. By harnessing the power of sunlight, these systems provide a clean and renewable replacement to traditional grid electricity, thereby mitigating the environmental impact associated with fossil fuel consumption. This environmental well-being coupled with the evident enthusiasm among residents to grasp eco-friendly solutions, presents a compelling case for the universal adoption of solar technology. The benefits of investing and looking into solar technology as a source of household electricity consumption, outweighs the negatives. Solar PV system has proven to exceptionally reduce the endpoint annual carbon footprint of the user. This tallied with the willingness of the sample population of Islamabad (85% of total surveyed), who want to enhance the environment of the city.

Despite a high level of alertness regarding solar solutions, the study reveals a notable inconsistency between awareness and adoption rates, with only 25% of the sampled population currently utilizing solar technologies in their households. This inconsistency primarily stems from barriers such as the perceived high cost of installation and absence of tailored information regarding solar plans suited to individual needs. Addressing these barriers is crucial to bridge the gap between intention and action, thereby facilitating the change towards sustainable energy practices. Similarly, there was a mixed view in the willingness to lessen their electricity consumption, even though 55% of the respondents agreed to the negative impacts of fossil fuel/coal powered.

In conclusion, installing solar technology for power generation lessen the carbon emissions more effectively than using grid electricity alone. This is another reason why people are willing to switch to solar technology. Moreover, beyond the obvious environmental benefits, the use of solar technology has key ramifications for Pakistan's overall energy landscape. As the country grapples with continuous energy shortages and an expanding energy crisis, investment in renewable energy infrastructure appears as a practical and forward-thinking solution. By utilizing the copious solar resources at its disposal, Pakistan may expand its energy portfolio, reduce dependency on finite fossil fuels, and improve energy security for its populous.

RECOMMENDATIONS

(1) Policymakers should consider developing and executing laws and regulations that make it easier to combining solar energy into existing energy infrastructure. This can include net metering policies, simplified approval procedures, and grid interconnection standards.

(2) Increasing local capacity for solar energy installation, operation, and continuation is critical. Training programmes and vocational courses can be designed to provide individuals with the skills and information required to operate in the solar energy business. This has the potential to generate job opportunities and encourage the development of a trained workforce in the renewable energy industry.

(3) Financial and operational challenges have been mentioned as barrier to investing in solar technology. To address this issue, the government and related stakeholders might give financial incentives such as subsidies, tax credits, and low-interest loans to make solar systems more reachable and appealing for homes and companies.

(4) Encourage research and development projects focused at improving solar technology, efficiency, reliability, and cost. This includes funding cutting-edge research, supporting technology incubators and accelerators, and encouraging collaboration among scientists, engineers, and industry personnel.

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Annexure A

Questionnaire - Social Acceptability for Solar Devices

Solar Powered electricity generation results from panels installed on the rooftop. It converts the incoming sunlight into electricity that can be stored in a battery for household consumption. The larger the size of panels, the greater the amount of electricity generation produced. The objective of our study is to determine the receptiveness/level of acceptance of the public in Islamabad to the use of solar panels in the household, as an alternative to grid-electricity.

1. What is your age?

A. 15-25 B. 25-35 C. 35-45 D. 45 above

2. Do you own or rent your house?

A. Own B. Rent

3. What is your approximate monthly household income?

A. 20k or less B. 20 - 30k C. 30 - 40k D. 40k plus

4. What type of property do you live in?

A. Apartment/Flat B. House

5. What is the size of your house?

A. 5 Marla B. 10 Marla C. 1 Kanal D. More than 1 kanal

6. Number of people living in your home?

A. 2-3 B. 4-5 C. 6-7 D. More than 7

7. How aware are you of Solar Technologies?

A. Very aware B. Slightly aware C. Unsure D. Unaware

8. Do you have any Solar Energy technology installed in your home?

A. Yes B. No

9. If 'Yes', what type?

A. Solar Thermal (hot water) B. Photo voltaic (electricity) C. Both types

10. Are you interested in reducing your level of energy consumption?

A. Yes B. No

11. What factors would prevent you from installing Solar Energy Technology? Pleas tick all that apply.

A. Affordability

B. Inconvenience

C. Lack of awareness

D. Lack of trust

12. How much are you willing to spend on solar technology?

A. Up to 50k B. 50k - 100k C. 100k-200+k D. More than 200k

13. What is your average monthly consumption of electrical units?

A. 100-200 B. 200-400 C. 400-800 D. More than 800 units

14. If you invest in solar energy for your use then what should be the payback period for it?

A. 1-3 years B. 3-6 years C. 6-9 years D. More than 10 years

15. Are you aware of the negative effects of fossil fuel powered electricity on our environment? A. Yes B. No

16. If yes, would you be willing to convert to solar technology just to reduce this impact on our environment?

A. Yes B. No

Questionnaire for solar powered household

1. MWs capacity of solar power installed?
2. When was the solar system installed?
3. Installation (initial costs)?
4. Costs of batteries?
5. Primary purpose of solar power system
6. Difference in the billing of electricity before and after installation?
7. Size of Plot? \ Size of Rooftop?
8. Is the system entirely dependent on solar, or has a share of WAPDA electricity?
9. If yes then, what percentage?
10. Maintenance Costs and Warranty?
11. Has there been significant benefit with regards to the load shedding issue; UPS and Generator purchasing cost?
12. What are some of the precautions you would suggest if others wanted to install on the similar basis?
13. Have you ever experienced any issue or maintenance requirement with your solar panels?
14. Are you satisfied with your solar power system performance and cost saving?

Annexure B

Social acceptance questionnaires findings total answers and percentages

Question1:

Age Group	15-25	25-35	35-45	45-above
Number of Respondents	45	35	15	5
Percentage of Respondents	45%	35%	15%	5%

Question 2:

Gender	Male	Female
Number of Respondents	84	16
Percentage of Respondents	84%	16%

Question 3:

Location	G-8	G-9	G-10
Number of Respondents	33	33	34
Percentage of Respondents	33%	33%	34%

Question 4:

Do you own or rent a house	Own	Rent
Number of Respondents	75	25
Percentage of Respondents	75%	25%

Question 5:

Type of Property	House	Apartment/Flat
Number of Respondents	90	10
Percentage of Respondents	90%	10%

Question 6:

Size of House	3-5 Marla	7-10 Marla	1 Kanal	>1 Kanal
Number of Respondents	28	55	10	7
Percentage of Respondents	28%	55%	10%	7%

Question 7:

Monthly Household Income	2-3	4-5	6-7	>7
Number of Respondents	2	8	25	65
Percentage of Respondents	2%	8%	25%	65%

Question 8:

Number of people in house	2 – 3	4-5	6-7	>7
Number of Respondents	25	40	25	10
Percentage of Respondents	25%	40%	25%	10%

Question 9:

Awareness of Solar Technology	Very Aware	Slightly Aware	Unsure	Unaware
Number of Respondents	80	12	3	5
Percentage of Respondents	80%	12%	3%	5%

Question 10:

Considerations about installing solar panels on your property	Yes	No
Number of Respondents	60	40
Percentage of Respondents	60%	40%

Question 11:

<table>
<tr><td rowspan="2">Existent solar technology installed</td><td colspan="3">Yes</td><td rowspan="2">No</td></tr>
<tr><td>Solar Thermal (heater)</td><td>Solar Photovoltaic (electricity)</td><td>Both Types</td></tr>
<tr><td rowspan="2">Number of Respondents</td><td>13%</td><td>10%</td><td>2%</td><td rowspan="2">75%</td></tr>
<tr><td colspan="3">25%</td></tr>
<tr><td>Percentage of Respondents</td><td colspan="3">25%</td><td>75%</td></tr>
</table>

Question 12:

Interest in reducing level of electricity consumption?	Yes	No
Number of Respondents	75	25
Percentage of Respondents	75%	25%

Question 13:

Factors preventing from installation of solar technology	Affordability	Inconvenience	Lack of Awareness	Lack of trust on the technology
Number of Respondents	70	5	10	15
Percentage of Respondents	70%	5%	10%	15%

Question 14:

Willingness to spend on solar technology	≤ 200,000	300,000 – 400,0000	400,000-500,000	>500,000
Number of Respondents	40	10	25	25
Percentage of Respondents	40%	10%	25%	25%

Question 15:

Monthly units of electricity consumed (kWh)	100-200	200-400	400-800	>800
Number of Respondents	20	45	30	5
Percentage of Respondents	20%	45%	30%	5%

Question 16:

Awareness of negative effects of fossil fueled power generation	Yes	No
Number of Respondents	55	45
Percentage of Respondents	55%	45%

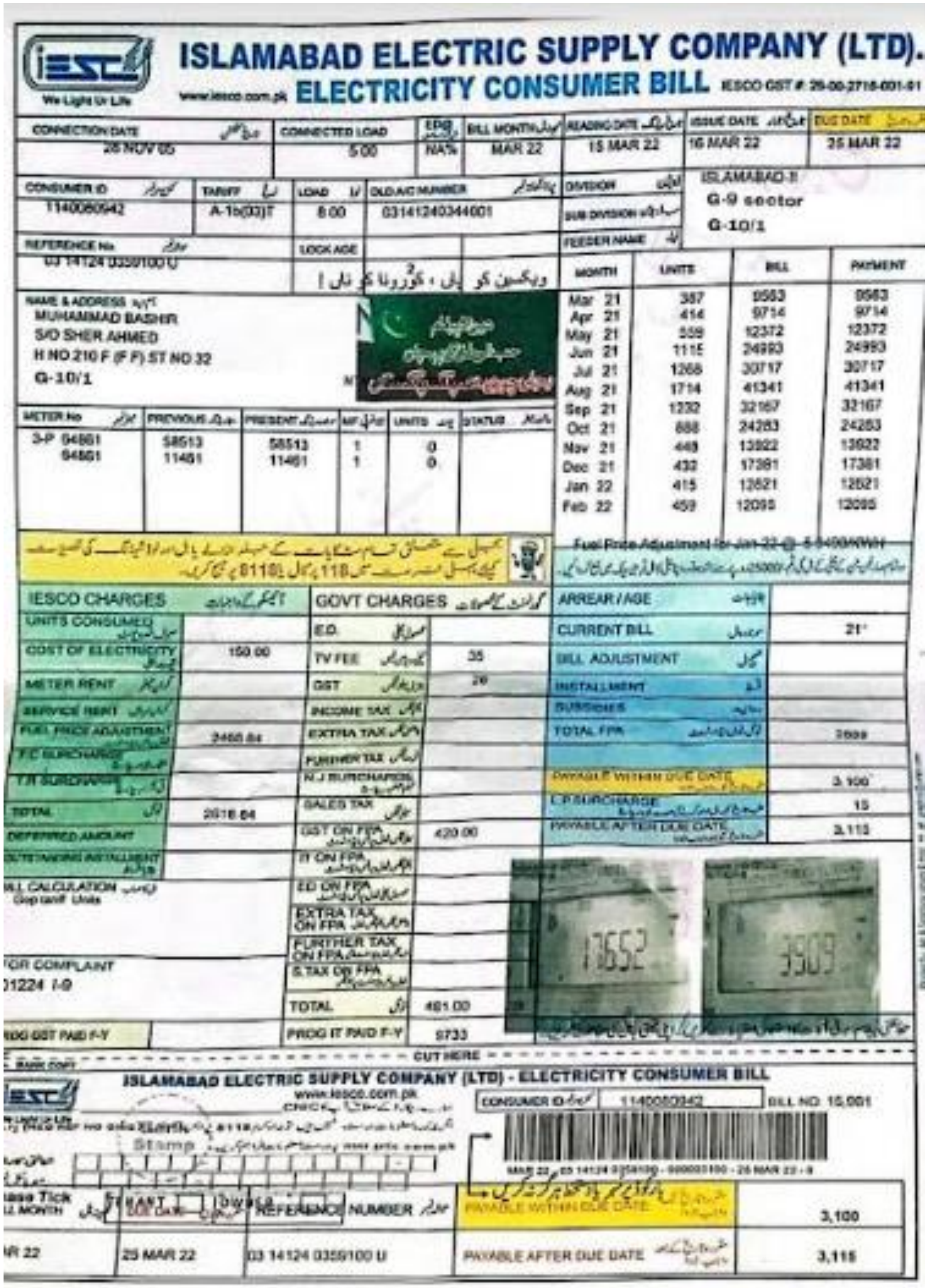
Question 17:

Do you believe solar panels contribute positively to environment	Yes	No
Number of Respondents	85	15
Percentage of Respondents	85%	15%

Question 18:

Are you likely to consider solar panels in future	Yes	No
Number of Respondents	89	11
Percentage of Respondents	89%	11%

Annexure C



ISLAMABAD ELECTRIC SUPPLY COMPANY (LTD).

www.iesco.com.pk ELECTRICITY CONSUMER BILL IESCO GST # 26-00-2716-001-01

We Light Ur Life

CONNECTION DATE	CONNECTED LOAD	ED@	BILL MONTH	READING DATE	ISSUE DATE	DUE DATE
26 NOV 05	5.00	NA%	MAR 22	15 MAR 22	16 MAR 22	25 MAR 22

CONSUMER ID	TARIFF	LOAD	OLD A/C NUMBER
1140080942	A-1b(03)T	8.00	03141240344001

DIVISION: ISLAMABAD-II
SUB DIVISION: G-9 sector
FEEDER NAME: G-10/1

REFERENCE No: 03 14124 0359100 U

LOCK AGE

NAME & ADDRESS
MUHAMMAD BASHIR
S/O SHER AHMED
H NO 210 F (F F) ST NO 32
G-10/1

METER No	PREVIOUS	PRESENT	MF	UNITS	STATUS
3-P 94861	58513	58513	1	0	
94861	11461	11461	1	0	

MONTH	UNITS	BILL	PAYMENT
Mar 21	387	9563	9563
Apr 21	414	9714	9714
May 21	559	12372	12372
Jun 21	1115	24993	24993
Jul 21	1268	30717	30717
Aug 21	1714	41341	41341
Sep 21	1232	32167	32167
Oct 21	888	24283	24283
Nov 21	449	13922	13922
Dec 21	432	17381	17381
Jan 22	415	12621	12621
Feb 22	459	12095	12095

Fuel Price Adjustment for Jan 22 @ 5.9400/KWH

IESCO CHARGES		GOVT CHARGES			
UNITS CONSUMED		E.D.		ARREAR / AGE	
COST OF ELECTRICITY	150.00	TV FEE	35	CURRENT BILL	21'
METER RENT		GST	26	BILL ADJUSTMENT	
SERVICE RENT		INCOME TAX		INSTALLMENT	
FUEL PRICE ADJUSTMENT	2466.84	EXTRA TAX		SUBSIDIES	
F.C SURCHARGE		FURTHER TAX		TOTAL FPA	2699
T.R SURCHARGE		N.J SURCHARGES		PAYABLE WITHIN DUE DATE	3,100
TOTAL	2616.84	SALES TAX		L.P SURCHARGE	15
DEFERRED AMOUNT		GST ON FPA	420.00	PAYABLE AFTER DUE DATE	3,115
OUTSTANDING INSTALLMENT		IT ON FPA			
BILL CALCULATION		ED ON FPA			
		EXTRA TAX ON FPA			
		FURTHER TAX ON FPA			
FOR COMPLAINT 01224 I-9		S.TAX ON FPA			
		TOTAL	481.00		
PROG GST PAID F-Y		PROG IT PAID F-Y	9733		

CUT HERE

ISLAMABAD ELECTRIC SUPPLY COMPANY (LTD) - ELECTRICITY CONSUMER BILL

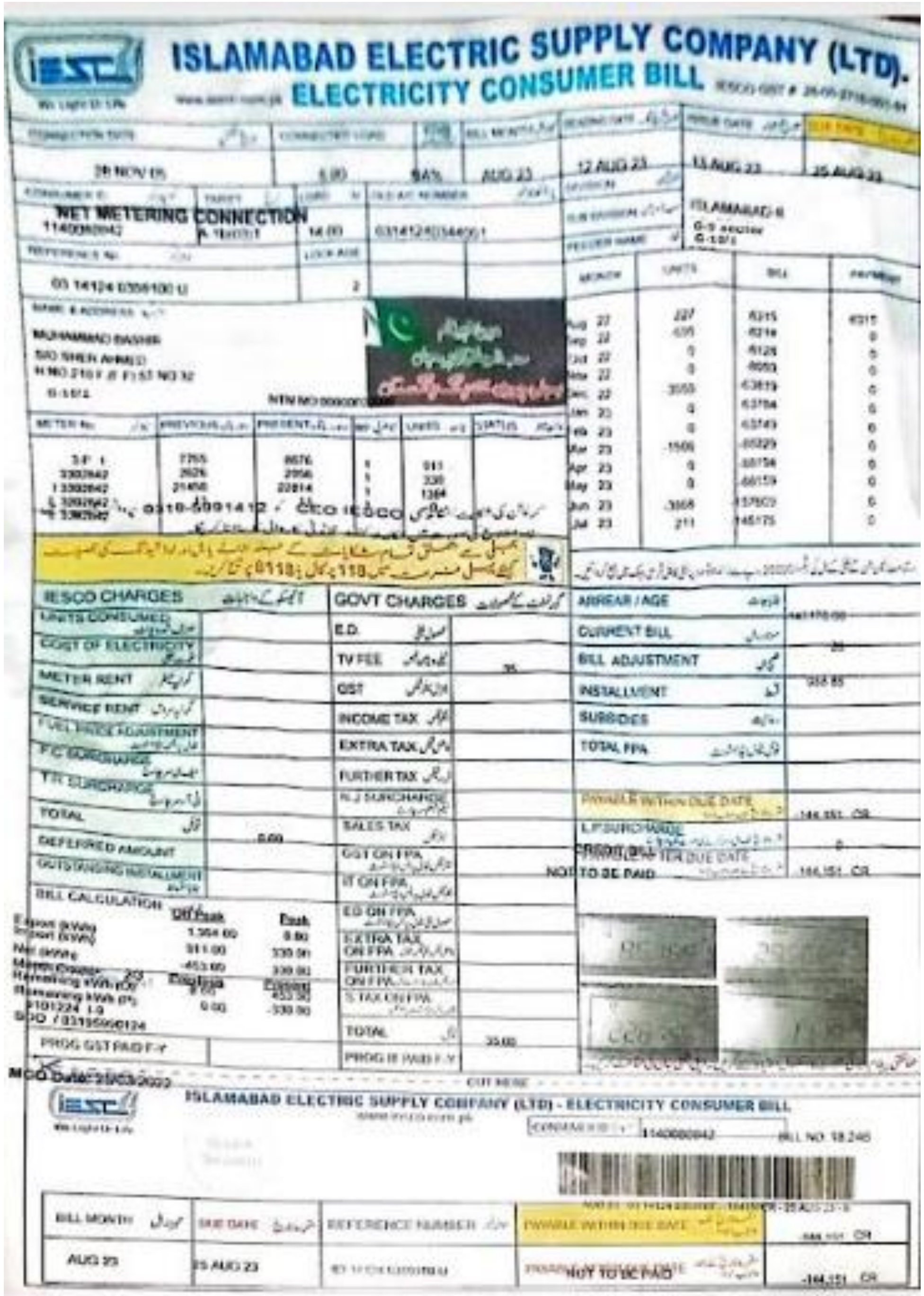
www.iesco.com.pk

CONSUMER ID 1140080942 BILL NO 15,001

MAR 22 03 14124 0359100 - 000003100 - 25 MAR 22 - 0

Stamp

BILL MONTH	DUE DATE	REFERENCE NUMBER	PAYABLE WITHIN DUE DATE	3,100
MAR 22	25 MAR 22	03 14124 0359100 U	PAYABLE AFTER DUE DATE	3,115


ISLAMABAD ELECTRIC SUPPLY COMPANY (LTD).

ELECTRICITY CONSUMER BILL

CONNECTION DATE	CONNECTED LOAD	ED@	BILL MONTH	READING DATE	ISSUE DATE	DUE DATE
28 NOV 05	6.00	84%	AUG 23	12 AUG 23	15 AUG 23	25 AUG 23

NET METERING CONNECTION

Consumer ID: 1140080042

Sub division: ISLAMABAD-II

G-9 sector, G-10/1

Reference No: 03 14124 0356100 U

MUHAMMAD BASHIR

S/O SHER AHMED

MONTH	UNITS	BILL	PAYMENT
Aug 22	227	6315	6315
Sep 22	635	-6214	0
Oct 22	0	-6128	0
Nov 22	0	-6053	0
Dec 22	3055	-63819	0
Jan 23	0	-63784	0
Feb 23	0	-63749	0
Mar 23	-1505	-85329	0
Apr 23	0	-85794	0
May 23	0	-86159	0
Jun 23	-3068	-137603	0
Jul 23	211	-145175	0

IESCO CHARGES | GOVT CHARGES | ARREAR / AGE

TV FEE 35

TOTAL 35.00

PAYABLE WITHIN DUE DATE -144,151 CR

NOT TO BE PAID -144,151 CR

BILL CALCULATION

ISLAMABAD ELECTRIC SUPPLY COMPANY (LTD) - ELECTRICITY CONSUMER BILL

BILL MONTH	DUE DATE	REFERENCE NUMBER	PAYABLE WITHIN DUE DATE	
AUG 23	25 AUG 23	03 14124 0356100 U	NOT TO BE PAID	-144,151 CR

Annexure D

ESTIMATION AND COMPARISON OF CARBON FOOTPRINT WITH AND WITHOUT USE OF SOLAR PHOTOVOLTAIC SYSTEM AND THEIR SOCIAL ACCEPTANCE IN ISLAMABAD

ORIGINALITY REPORT

16%	11%	10%	9%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

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4	Mahelet G. Fikru. "Determinants of electricity bill savings for residential solar panel adopters in the U.S.: A multilevel modeling approach", Energy Policy, 2020 Publication	1%
5	www.researchgate.net Internet Source	1%
6	rsta.royalsocietypublishing.org Internet Source	1%
7	Submitted to Choithram International School Student Paper	1%