CHANGING TEMPERATURE, ELECTRICITY CONSUMPTION AND HOUSEHOLDS' COPING MECHANISMS AGAINST ELECTRICITY SHORTFALL IN ISLAMABAD, PAKISTAN

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DEDICATION

Dedicated to the everlasting memories of my father, Shafaat Hussain (Late), my mother, my sister and my brothers: Gul Hassan, Mubashir Hassan and Mushabar Hassan who encouraged me for the course of the Higher Studies

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THANKS FOR EVERY THING YOU DID FOR ME

Kausar Abbas

Abstract

This study analyzes the impact of changes in monthly temperature on the monthly residential electricity demand for the capital city of Pakistan, Islamabad. This study also analyzed the households coping mechanisms against electricity shortfall along with their monetary and environmental costs to the society in Islamabad. This study used the primary data from the monthly billing data from June 2012 to May 2013, from 250 respondents from the residential sector of the urban Islamabad. To analyze the impact of monthly temperature on residential electricity demand, this study used simple linear regression model and log linear regression model. The coping mechanisms against electricity shortfall that are using in the residential sector and their respected monetary and environmental costs are analyzed through survey and the structured questionnaire. Results of the study revealed that the changes in monthly average temperature has a significant and positive impact on the changes in the monthly electricity consumption. All the correlations and elasticities are positive and significant. The coping mechanisms that the households are using against electricity shortfall are the small electricity generators, solar energy systems, uninterruptible power supply systems (UPS) and rechargeable fans. From the monetary standpoint, all of the coping mechanisms bring retail costs while generators, UPS and rechargeable fans bring also the operational costs. From environmental point of view, all the coping mechanisms impose the environmental costs in terms of CO_2 emissions at the time of construction while generators impose the operational environmental costs also. It is concluded that electricity consumption increases in hot months in the residential sector and it decreases in winter with a decrease in the average atmospheric temperature. At the households level, most of the electricity is generated by small thermal generators which are bringing high monetary and environmental costs to the society. The authorities should

discourage the use of generators by providing the households the required amount of electricity. New hydropower, solar power and wind power projects should be implemented. Nuclear power is also an option to minimize the gap between supply and demand for electricity.

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LIST OF ABBREVIATIONS

UPS	Uninterruptible Power Supply
KWh	Kilowatt Hour
CO_2	Carbon Dioxide
WAPDA	Water and Power Development Authority
MW	Mega Watts
GWh	Giga Watt Hour
NTDCL	National Transmission Dispatch Company Limited
IESCO	Islamabad Electricity Supply Company
PMD	Pakistan Meteorological Department

CHAPTER-1

INTRODUCTION

1.1. Introduction

Changes in weather pose significant impacts on different sectors of the economy. Electricity sector is no exception. The production and consumption of electricity responds to different weather factors, most notably the air temperature (Velor et al, 2001, Hor et al, 2005).

Residential electricity consumption changes in two ways i.e. annual or long-term changes and seasonal or short-term changes. Its use is sensitive to the economic (GDP growth), demographic (population growth) and weather factors (temperature, wind speed, rainfall etc). Economic and demographic factors are responsible for long-term changes in electricity consumption while the seasonal/short-term changes occur due to the weather factors (Lam, 1998). Among all the weather factors, temperature is the most important factors affecting the residential electricity consumption.

The seasonal changes in residential electricity consumption typically show two peaks, in winter and summer. The summer peak is becoming increasingly important in many countries in recent years due to climate change induced increases in temperature (De Cian and Lanzi, 2007). The sensitivity of each degree Celsius rise in temperature towards the residential electricity consumption at national level is 2-4 percent (Sailor and Pavlova, 2003).

When it comes to the demand for electricity, demand is largely uncontrollable and changes with the time of day and season (Strbac, 2008). Therefore, the installed generation capacity must be able to fulfill the seasonal peak demand in order to avoid electricity breakdowns. Beside this, there should be adequate capacity available to cope with the uncertainty in supply and unpredicted increases in demand. In order to fulfill the peak demand, the households should be provided with their own electricity generation capacity.

When people face electric power shortages, they use different mechanisms to cope against it. They normally use small electricity generators, uninterruptible power supply systems (UPS), rechargeable fans and lamps, small solar power panels and wind power turbines to produce or store electricity at a small scale. In some cases, they use house insulation to maintain the heat stress at comfortable level to reduce the consumption of electricity needed for cooling or heating the homes.

Uninterruptible power supply system, rechargeable fans and lamps store the electricity supplied from the central grid. Electricity generators produce its own electricity by using petrol, diesel or gas. The solar energy panels convert solar energy into electricity while the wind power turbines transform wind energy into electrical energy. House insulation reduces the electricity consumption required for space heating or cooling in order to adapt against the atmospheric temperature.

Every electricity generation and transmission method affects the environmental quality. Some electricity generation techniques i.e. the conventional generating options can damage air, climate, water, land and wildlife. On the other hand, renewable technologies for electricity generation are safer, offering a solution to many environmental and social problems associated with conventional energy sources (Tsoutsos, 2005).

The use of generators is unfriendly to environment. Generation of electricity from conventional energy sources such as petrol, diesel and gas produce Sulfur Oxides, Nitrogen oxides, Suspended Particulate Matter and Respirable Suspended Particulate matter emissions to the atmosphere (Lee et al, 2001). Remaining strategies are environment friendly, as the uninterruptible power supply system; store the electricity supplied by the electricity supplying company. Therefore, it does not emit pollution emissions in its operations. Wind turbines convert wind energy, and solar panels transform solar energy, which are considered the clean energy sources and do not pollute the environment.

Pollution emissions of any coping mechanisms used to generate or store electricity, can be divided into two phases i.e. the construction and operation phase. Among all of the discussed coping mechanisms, only generators produce pollution emissions in both the construction and operation phases, while all other coping mechanisms emit pollutants only in the construction phase. The lifecycle emissions of 1-Kilowatt hour (KWh) of electricity generated from oil produce 0.76 kg of CO_2 emissions and 1-KWh of electricity produced from natural gas produce 0.34 to 0.58 kg of CO_2 emissions (EURELECTRIC, 2003). House insulation reduce electricity consumption due to which Carbon dioxide emissions are saved from decreased consumption of electric power for space cooling or heating purposes (Erlandsson et al, 1996).

Beside environment, these coping mechanisms are imposing monetary costs to the society also. Some of these mechanisms entail both the retail and operational costs while some entail only the retail costs. Generators, UPS and rechargeable fans entail both the retail and operational costs. While, the house insulation, solar energy system and wind energy system require only one time investment and impose only the retail costs. Generators need fuel to produce electricity while the UPS and rechargeable fans extract the supplied electricity, which impose increases in electricity bills.

This study interrogates the relation between the changes in monthly residential electricity consumption and changes in monthly average temperature in Islamabad, Pakistan. This study also undertakes the household's coping mechanisms against electricity breakdowns.

1.2. Research Questions

In view of the importance of the issue under consideration, this study aims to provide answers to the following questions.

- What the relationship exists between changes in temperature and monthly residential electricity consumption.
- At the time of electricity breakdowns, how are people coping against this problem?
- What are the environmental implications of these coping mechanisms to the community?
- What monetary costs the society faces by using these coping mechanisms.

1.3. Objectives of the Study

This study aims:

- To investigate the impact of monthly temperature changes on changes in the residential electricity consumption in Islamabad.
- To assess the coping mechanisms that households are using against electricity shortfall.
- To find out the monetary costs of the coping mechanisms.
- To find out the environmental costs of the coping mechanisms to the society.

1.4. Hypotheses to be Tested

This study tests the following hypotheses.

- Electricity consumption changes with a change in temperature.
- The households use different coping mechanisms (thermal generators, UPS, rechargeable fans and solar panels) against electricity breakdowns.
- Thermal electricity generators are harmful to the environment while the rest of the coping mechanisms are not.

1.5. Contribution and Significance of the Study

This study contributes to the existing literature in the following ways:

- In Pakistan, fewer amounts of studies considered the weather determinants of electricity consumption like Khan and Qayyum, (2009), Jamil and Ahmad, (2011) and Ali et al, (2013) etc. There is a need to work on the short run changes in electricity demand or consumption. This study employs short-term changes in electricity consumption due to changes in temperature.
- This study used primary data while conducting the research while previous studies have employed secondary data while estimating the demand for electricity.
- In Pakistan, there is very less work done so far on the coping mechanisms that households are using against electricity breakdowns. Previously, Siddiqui et al, (2011) estimated the economic costs of un-served energy to the industrial sector. The cost of un-served electricity to the residential sector is unexplored. As this study explores these coping strategies and the corresponding monetary and environmental costs of these coping mechanisms, it is an important contribution towards future research on this issue.

1.7. Organization of the Study

This study is organized in the following manner.

Introduction of the study covering statement of the problem, research question and objectives are discussed in the first chapter. In second chapter, relevant literature about the electricity consumption and temperature relationship and the coping mechanisms against electricity shortfall is reviewed. Third chapter is contained with the supply and demand profile of electricity in Pakistan. Fourth chapter is comprised of the data and methodology of the study. The fifth chapter gives the results and discussion while the last chapter highlights the conclusions and recommendations of the study.

CHAPTER-2

LITERATURE REVIEW

2.1. Introduction

Literature review consists of two parts. The first part discussed studies about the relationship between electricity consumption/demand and temperature while in the second part the previous literature on the households coping mechanisms against electricity shortages and their environmental implications is reviewed.

2.2. Electricity Consumption and Temperature

There is a vast amount of literature present on the relationship between the electricity demand and temperature. The studies indicate that there is a strong relationship between the electricity demand and the temperature. Some studies have directly related the electricity demand with temperature while in some studies the two temperature indexes i.e. the heating degree days and cooling degree days are used to measure the impact of temperature on electricity demand. Following are given some studies that discussed the relationship between electricity consumption and temperature.

Le Comte and Warren, (1981) modeled the impact of summer temperature on national electricity consumption in U.S.A. for the months May- September for the years 1977-79. The study used a simple regression model. In the study, national population weighted cooling degree-days statistics were used to determine the relationship between summer temperatures and electricity output. From the regression results, it was observed that weekly cooling degree-days explained 95 percent of the variations in weekly electric power output in 1977. It explains 91 percent variations in 1978 and 1979. The study further indicated that during a typical summer week, temperature related electricity output accounts for approximately 17 percent of total electricity output.

Ranjan and Jain, (1990) analyzed the consumption pattern of electricity in Delhi for the period 1984-93 by using linear regression models for different seasons of the year i.e. winter, summer, pre monsoonal season and post monsoonal season. The study incorporated electricity consumption as a function of population and weather sensitive parameters such as temperature, rainfall. The results concluded that in winter 97 percent of the changes in electricity consumption occurred due to changes in population and temperature. In summer, 99 percent variations in electricity consumption were due to the variations in population and temperature. In the post-monsoonal season, these two factors caused 98 percent of the variations in electricity consumption.

Al-Zayer and Al-Ibrahim, (1996) modeled the impact of monthly temperature on the monthly consumption of electricity in the Eastern Province of Saudi Arabia from 1986 to 1990 by using a regression model. This study incorporated the cooling and heating degree days for temperature. Results revealed that peak consumption of electricity occurred in the month of June for the years 1986, 1987 and 1990. In 1988 and 1989, peak consumption of electricity occurred in the month of August. In first six months of the year i.e. for January to June, temperature explained 88 percent of the variations in electricity consumption. In the second half of the year i.e. July to December, 75 percent of the variations in electricity consumption were explained by temperature.

Lam, (1998) performed regression and correlation analyses to explore the relationships among residential electricity consumption, economic factors and climatic factors for Hong Kong for the period 1971-93. The study used cooling degree days, latent enthalpy days and cooling radiation days to see the impact of these weather factors on electricity consumption. The regression statistics showed that cooling degree days, latent enthalpy days and cooling radiation days explained 81-91 percent of the variations in electricity consumption. Only cooling degree days explained 74-83 percent of the variations in electricity consumption.

Yan, (1998) investigated the influence of weather variables on changing pattern of household electricity usage in Hong Kong for the period 1980 to 1994. Furthermore, the study also examined the connection between a weather stress index and residential electricity consumption. By using stepwise multiple regression analyses on climatic variables and electricity consumption, it was found that vapor pressure was not related significantly to residential electricity consumption. The mean temperature was strongly correlated with residential electricity consumption. The cloud cover was related significantly to residential electricity consumption only in the summer season.

Velor et al, (2001) investigated the impact of temperature on electricity load in four different areas of Spain namely; Madrid, Bilbao, Valencia and Seville for the period 1983-98. This study incorporated a regression model to carry out the relationship between the two. The results concluded that relationship between electricity load and temperature is non-linear. Electricity demand reaches at the peak when temperature reaches at the lower extreme or higher extreme. Similarly, the consumption starts increasing in summer when the temperature rises. This cycle was repeatedly observed.

Parkpoom et al, (2004) estimated the relationship between hourly electricity demand and temperature for Thailand for a peaked demand month. This study employed a multiple regression model. The study included two dummy variables for the "day of the week" and "hour of the day" in the model. The results revealed that electricity demand was at the peak between 1 to 3 p.m. of the day and it was lowest at 1 a.m. of the night. The outdoor temperature stays maximum between 1 to 3 p.m. The demand for electricity begins to increase from 6 a.m., reaches at its peak at 2 p.m. and then starts decreasing.

Hor et al, (2005) regressed the monthly demand for electricity under different weather factors such as cooling degree days, heating degree days, latent enthalpy days, rainfall, sunshine hours, wind speed. The study then predicted the demand for electricity for the period 1996 to 2003. The study results revealed that weather factors have significant impacts on electricity industry and that among all the weather variables, temperature is the most influencing factor affecting the electricity consumption. In England and Wales, space heating is dominant than space cooling. The study further concluded that the elasticity of electricity demand to extreme temperatures in winter and summer were weak than its responsiveness to a rise or fall in temperature in autumn and spring.

Fung et al, (2006) explored the impact of urban temperature on energy consumption of Hong Kong by applying regression model for the period 1990 to 2004. The study concluded that in Hong Kong, the electricity consumption increases as temperature rises and it decreases as the temperature falls. Furthermore, electricity consumption for both the domestic and industrial sectors varies seasonally; demonstrating that seasonal change in electricity consumption is temperature-dependent. About 90 percent of the variations in electricity consumption were explained by the variations in temperature. The study further revealed that for a 1˚C temperature rise, the electricity consumption of domestic sector would show an increase of 9.2 percent.

De Cian et al, (2007) quantified the global estimates of the future demand elasticity for coal, gas, oil and electricity with respect to temperature. The study incorporated data for 31 countries for the period 1978-2000 and by employed panel data techniques. The study investigated that energy/electricity consumption responds to changes in temperature. The results concluded that with an increase in temperature, the energy consumption would be high in warm countries and a lower consumption would occur in cold countries. For warmer countries, the elasticity of electric power demand with respect to temperature was 1.17 whereas it was -0.21 for the cold countries.

Meragedis et al, (2007) focused on the potential future impacts of global warming on the electricity demand in Greece for the 21^{st} century. For this purpose, the study modeled the historical monthly temperature and electricity demand for Greece for the period January 1993 to December 2003. The study used a binomial regression model. Results of the non-linear regression model revealed that electricity demand and temperature forms a U-shaped relationship. Electricity demand is at the minimum level at the balanced point temperature i.e. 18 ^{0}C. Its demand increases when the temperature deviates from the base line temperature either positively or negatively. The paper further projected that the gap between the summer electricity demand and winter electricity demand will further widen in the future due to the rising temperatures.

Bessec and Fouquan (2008) used the panel threshold regression model to find out the relation between the monthly electricity consumption and temperature in the 15 member states of the European Union for the period 1985-2000. For the analysis the study distributed the whole countries in to three groups i.e. a group of cold countries, a group of hot countries and a group of intermediate countries. Result of the regression revealed that the three groups of countries showed a different pattern of electricity consumption. In cold countries, only the heating effect was observed. In hot countries, the cooling effect dominated but a weak cooling effect was also visible. In intermediate countries, all the two effects were observed. This study found a non-linear relationship between electricity consumption and temperature and that the sensitivity of electricity consumption to temperature has increased in recent periods.

Franco and Sanstad, (2008) investigated the impact of climate change on California's electric power system and then compared it with a base year, 2002 electricity consumption. The study stated that climate change related temperature increases could worsen the performance of California's Electric power System in future. According to the study, there was a high correlation between daily average temperature and electricity consumption up to 90 percent. The study further revealed that peak electricity demand occurs in summer season when the temperature is high.

Lee et al, (2010) identified the correlation between the monthly variations in energy consumption and the cooling and heating degree days for Hong Kong for the period 1970 to 2009 by using regression model. Regression results revealed that electricity consumption in both domestic and commercial sector showed significant variations for cooling degree days and that the consumption per unit cooling degree days increased from 1970 to 2000, probably due to higher living standard and increased popularity of air-conditioning in that period. For heating degree-days, electricity consumption did not show significant variations in both domestic and commercial sector.

Pilli-Sihvola et al, (2010) analyzed the impact of climate change on electricity consumption in Spain, France, the Netherlands, Germany and Finland. The study used multivariate regression model and employed monthly dummy variables, heating degree days and cooling degree days to find out the seasonal changes in electricity consumption. Results of the regression revealed that for Finland, a one unit change in heating degree days changes the electricity consumption by 0.03 percent. In Netherlands, variations in temperature showed practically insignificant variations in electricity consumption. In Germany, a one unit change in heating degree days employed a change of 0.021 percent in electricity consumption. In France and Spain, the changes occurred in electricity consumption by a one unit change in heating degree days were 0.054 percent and 0.046 percent respectively. The changes in electricity consumption by changes in cooling degree days was only significant in case of Spain where a 1 unit change in electricity cooling degree days cause a change of 0.06 percent in electricity consumption which confirmed that there are two peaks in Spanish electricity consumption i.e. in summer and winter.

Gupta, (2011) quantified the impact of climate change (global warming) on the electricity demand in Delhi, India for the period 2000-09 by using a regression model. Regression results revealed that electricity demand reaches at the maximum in summer season due to high temperature and its demand decreases in winter season due to a fall in temperature.

Ahmed et al, (2012) projected the future electricity demand for the State of New South Wales, Australia by implying a multiple linear regression model on the historical electricity demand and related temperature for the period 1999 to 2010. Results of the study revealed that temperature induced variations in electricity consumption in spring (March-May), autumn (September-November), summer (June-August) and winter (December-February) were 97 percent, 91 percent, 99 percent and 83 percent respectively, which means that the responsiveness of electricity consumption towards summer temperature was more than its responsiveness towards the winter temperature. In summer, there was a positive correlation between the electricity consumption and temperature while in winter, the correlation between the two was negative.

2.2.1. Literature Regarding Pakistan

Jamil and Ahmed, (2011) analyzed the demand for electricity for Pakistan for the period 1968 to 2008 at the aggregate and sector wise level by using a log-log model. The study used Gross

Domestic Product, real price of electricity, real price of diesel, stock of capital and temperature as the factors affecting the electricity demand. The paper concluded that in the short run, most of variations in electricity consumption are explained by the price of diesel, capital stock and temperature. The short run elasticity of electricity demand and temperature at the aggregate level and commercial sector, respectively was 0.06 and 0.35.

Khan and Qayyum (2011), estimated the demand for electricity for Pakistan for the period 1970 to 2006 by using a regression model. The study incorporated real income, real price of electricity and temperature as the variables affecting the electricity demand in the short run. The study concluded that the average temperature exerts positive and significant impact on the residential demand for electricity. The elasticity of electricity demand with temperature for the residential sector was 0.98.

Ali et al, (2013) projected the impact of climate change on electricity demand for Pakistan. For this purpose, the study investigated the correlation between the monthly electricity consumption and mean monthly maximum temperature for the period 1990 to 2010. The study used the monthly seasonal variation index to capture the relationship between the two. Results of the study concluded that electricity demand starts to rise up in March. It remains high up to August and then starts declining. The highest demand occurs in July and August and the lowest occurs in January and February. The correlation between the increase in temperature and electricity demand was 0.412.

Mahmood et al (2013) estimated the impact of temperature variations on electricity demand for residential and commercial sectors for Karachi, Pakistan for the period 1998 to 2013 by using a regression model. The study used the cooling and heating degree days for temperature to capture the impact of heating and cooling on electricity demand. The study concluded that a 1 unit increase in cooling degree days increases the residential electricity demand by 0.171 GWh while a 1 unit increase in heating degree days decreases the electricity consumption by 0.146 GWh.

2.3. Households Coping Mechanisms against Electricity Shortfall and their Environmental Impacts

This section is distributed in two parts. The first part discusses the coping mechanisms that households use either to generate electricity at small scale or to reduce the consumption of electricity. The second part of this section deals with the environmental impacts of these coping mechanisms.

2.3.1. Households Coping Mechanisms against Electricity Shortfall

Electricity shortfall is a serious problem in the whole world. Many countries face electricity shortages. In many regions, households are producing their own electricity at the homes to meet the increasing demand for electricity. Some households insulate their homes to reduce the energy consumption required for space heating or cooling. Following are mentioned some studies in which the households electricity production mechanisms, the house insulation techniques and their impacts on energy consumption are discussed.

2.3.2. Electricity producing or Storing Coping Mechanisms

Standaro and Weisman, (1999) stated that a large number of electrical appliances, found in homes are inoperable when power supply from the grid fails. We need a backup power supply to operate them. An uninterruptible power supply unit mainly called as UPS, is a backup power system, that stores the power from commercial grid and then supply it to the home's electrical appliances when the incoming power supply from the central grid fails.

Entchev et al, (2004) stated that small Combined Heat and Power systems are emerging at community or at a household level because of its economic and environmental efficiency. These are economically and environmentally viable systems to fulfill the residential electrical and thermal demand for space and water heating. Two demonstration buildings were built at the Canadian Centre for Housing Technology to test the performance of Micro-Combined Heat and Power system. Results of the demonstration showed that the heat produced by the micro generation unit fulfilled all the space and water heating demand for the house. Similarly, for electricity demand, the micro generation unit provided considerable percentage of the house’s electrical requirement. In few circumstances, some of the electricity produced by the unit was exported back to the grid.

Qiu and Hayden, (2008) stated that thermoelectric generators are effective in providing on site power and electricity security in residential homes. These generators operate entirely on fuel combustion and do not need externally generated electricity. To test the performance of thermoelectric generators for heating purposes, a generator with 550-watt generation capacity was tested. Results of the study revealed that the electricity generated was sufficient to power all the residential heating equipments.

Strbac, (2008) stated that the installed electricity generation capacity must be to fulfill the peak demand for electricity. The study further stated that distributed or small-scale generation of electricity from thermal resources and other renewable resources is one of the better options in demand side management for electricity in order to ensure the efficiency and security of supply of the electricity at the peak demand time.

Gilmore et al, (2010) stated backup thermal generators is a good option to satisfy the peak electricity demand. The study further stated that as these generators are mainly operated by diesel and natural gas, therefore, beside the benefits, thermal generators produce non-negligible emissions of pollutants like suspended particulate matter and nitrogen oxides to the atmosphere.

Wollenhaup, (2010) stated that generating a portion of households required electricity is doable at homes. The study mentioned three ways to generate electricity at homes i.e. solar, wind and micro combined heat and power systems. The study stated that in the residential sector of the United States of America, solar energy is the most popular source of electricity generation followed by the wind energy and the micro combined heat and power systems.

Ali et al, (2013) projected the impacts of climate change on electricity demand in Pakistan. For this purpose, the study investigated the correlation between the monthly electricity consumption and mean monthly maximum temperature for the period 1990-2010. The study used the monthly seasonal variation index to capture the relationship between the two. Results of the study concluded that the correlation coefficient between the increase in electricity demand and temperature was 0.412.

Farooq and Shakoor, (2013) stated that in Pakistan, energy shortfall is a serious problem and its situation is rapidly getting worse. The demand for energy is rising due to growth in industrial, residential and commercial sectors. This study stated that in the presence of serious energy crises, solar-thermal energy is a better and viable option to balance the Demand-Supply gap for energy as compared to other conventional sources of energy. By shifting the industrial, residential and commercial sectors to solar-thermal power, a huge amount of conventional energy sources could be saved and better utilized by other sectors, which would result in the reduction in energy shortages of the country.

2.3.3. House Insulation

Soubdhan et al, (2005) investigated the performance of roofs thermal insulation in Guadeloupe, West Indies. For this purpose, four test cells made of wood were used. The first cell was equipped with polystyrene insulation material, the second one with fiberglass, the third one with radiant barrier and the last one with no insulation material. To measure the performance of each type of insulation material against the roof temperature, walls of each test cell were insulated with 4 cm of polystyrene with outside surfaces painted white. Beside this, all test cells were exposed to the same outdoor environmental conditions. Rooftop temperature, roof airspace temperature, roof deck temperature, insulation temperature, indoor air temperature, black globe temperature and five walls temperatures were recorded at different times of the day and then it were compared for all the test cells. Results of the study concluded that when roof absorption was at 0.3, the radiant barrier reduced the total heat flux by 37 percent, the polystyrene insulation material reduced it by 88 percent and the fiberglass reduced it by 84 percent. When the roof absorption was at 0.9, the relative heat flux reduction by radiant barrier was 33 percent, 78 percent by polystyrene insulation and 73 percent by fiberglass insulation.

Kim and Moon, (2009) quantified the impact of insulation of buildings on the buildings energy consumption in two states of United States of America namely Michigan and Florida. For building energy consumption values eQUEST was used. Results of the study revealed that wall insulation in cold climate reduce the energy consumption up to 25.5 of the heating energy while its impact on cooling energy saving is insignificant.

Suman and Srivastava, (2009) stated that thermal insulation of roof ceiling is extremely important in reduction to heat flow as about 60 percent of outdoor heat enters a house through roof in a composite climate. In order to assess the performance of thermal insulation of roof ceiling, the authors compared two rooms in Roorkee, India. One room was insulated while the other was not. The two rooms were exposed to the same environmental conditions with no shading on rooms. The field investigation was conducted in peak summer months (April-May), 2006. Hourly outdoor air temperature, indoor air temperature, upper surface temperature of roof and ceiling temperature of both treated and untreated were recorded. Results of the study concluded that for untreated roof, the maximum ceiling temperature was found higher. Net reduction in the ceiling temperature for the treated roof was recorded up to 7˚C as compared to the untreated roof. Similarly, the thermal resistance of the treated roof was found more than double as compared to the conventional untreated roof.

2.4. Environmental Impacts of the Coping Mechanisms

Proops et al, (1996) examined the lifecycle implications of eight forms of electricity generating stations i.e. super critical coal, integrated gasifier combined cycle, combined cycle gas turbine, nuclear, wave, solar and tidal electricity generating stations for three major air pollutants; carbon dioxide, sulfur dioxide and nitrogen oxides, in the United Kingdom. For this purpose, the input-output analysis is used which allows the calculation of total pollution effects for any economic activity throughout the whole economy. The study concluded that those power-generating stations, which use fossil fuels for their electricity generating operations directly produce carbon dioxide, sulfur dioxide and nitrogen oxides emissions while the construction and decommissioning of all types of electricity generating stations produce these emissions.

Troutsas et al, (2005) stated that the solar energy provide significant environmental and socioeconomic benefits as compared to the other conventional sources of energy. From environmental standpoint, its operation does not produce greenhouse gas emissions, reclaim the degraded land and improve the water quality, which are the threats from the operation of other conventional energy sources such as fossil fuels, hydropower and nuclear energy. Similarly, it also brings significant socioeconomic benefits such as diversification and security of energy supply at the micro and macro level, provision of job opportunities, restructuring energy markets, electrification of rural communities, energy balance and reduction in the use of exhaustible resources.

Palm and Tangward, (2011) investigated the status of small-scale electricity production at household level in Sweden. The study stated that during 2008, a new electricity production concept took massive media attention when companies started marketing micro wind turbines and small-scale solar cells. The study further stated that by the end of 2009, the share of micro wind turbines and solar photovoltaic was not very large. The installed capacity of wind power was 1440 mega watts and that of solar photovoltaic was 4.4-mega watt only, but that the market of micro wind turbines and solar photovoltaic was expanding and continued to grow. The study further stated that environmental protection was the basic purpose for the households that had invested in micro wind turbines and solar energy.

Leung and Yang, (2012) stated that conventional energy sources such as natural gas, coal and oil are not only facing depletion but are also imposing serious threats to the environment. While investigating the environmental impacts of wind energy, the study stated that wind power is a notable source of energy nowadays and that the world's wind power generation is increasing about 30 percent on annual bases. The study concluded that in contrast to the conventional sources of energy, wind energy is clean energy, because, wind turbines do not contribute in polluting the atmosphere with greenhouse gases and generation of radioactive wastes. However, beside its environmental benefits, wind power has some negative environmental effects also on animals and human beings like noise and visual impacts.

Pokale, (2012) carried out the environmental impacts and cost-benefit analyses for the various thermal power generation plants in India like STPS, Gandhi Nagar, Gujarat, Chandrapur, Jhenor, Ramagundam and Andra Pardesh. The study stated that due to operation of these power plants, sulfur oxides, nitrogen oxides and suspended particulate matter is discharged in the atmosphere which is bringing harmful negative environmental impacts on the local humans, animals and local water resources. Similarly, the operation of these power plants impose some negative socioeconomic impacts too in terms of land degradation, effects on local amenities, loss to agricultural sector due to land degradation and the economic losses due to health disorders.

2.5. Summary of the Reviewed Studies

From the above literature, it is clear that the short-term changes in electricity demand depend on the weather variables, mainly temperature. Demand for electricity changes with a change in temperature. In hot regions, electricity consumption increases with an increase in temperature and in colder regions; it decreases, but not proportionately, with a decrease in temperature. In regions where both summers and winters are extreme, electricity consumption forms a non-linear link with temperature. In terms of Pakistan, the literature concluded that electricity demand increases in summer and it decreases in winter.

From the second part of the literature review, it is concluded that households use electricity generators, solar panels, UPS, wind turbines and insulate their homes in order to cope with the electricity shortfall. The use of thermal generators produce harmful impacts on the environment while the other coping mechanisms are beneficial or are not harmful to the environment as these mechanisms do not produce harmful impacts on the environment.

Chapter-03

RESIDENTIAL ELECTRICITY CONSUMPTION PROFILE IN PAKISTAN

3.1. Historical Background

Electricity is one of the most important sources of energy in Pakistan. It has become a necessity in the present life, having a wide range of uses in residential as well as in commercial sector. At the time of independence, Pakistan received a power generation capacity of 60 mega watts (MW), which was then increased to 119 MW by 1959 after the establishment of Water and Power Development Authority (WAPDA) in 1958. After its first 5 years of operation, WAPDA increased the electricity generation capacity to 636 MW and increased the number of electrified villages from 609 to 1,882. This extension pulled up speed in the 1970s and 1980s with the generating capacity going up to 1,331 MW in 1970, followed by further growth to 3,000 MW by 1980 and 7,000 MW in 1990/91. Now the total generation of electricity in Pakistan is 15764 MW (NTDCL, 2013).

In case of Pakistan, main consumer of electricity is the household sector with a share of 46.54 percent of total electricity consumption. Other sectors like industrial sector, agriculture sector, commercial sector, street lights and other government institutions having share of 27.50 percent, 11.6 percent, 7.4 percent, 0.5 percent and 6.2 percent respectively (Economic Survey of Pakistan, 2011-12 and Pakistan Energy Yearbook, 2011-12).

Households are dependent on electrical appliances in their daily lives. Residential consumption of electricity in Pakistan mainly comes in form of cooling, refrigerating, entertainment and washing purposes (Nasir et al. 2008). Residential electricity consumption shows a clear seasonal effect. It starts to rise up from March and stays at the maximum from June to August. It then starts declining. The minimum consumption of electricity occurs in colder months (Ali et al. 2013). Table 3.1 shows the household sector electricity consumption of Pakistan from 1990-91 to 2011-12.

Table 3.1. Residential Sector Electricity Consumption of Pakistan from 1990-91 to 2011-12

Year	Residential Consumption (GWh)	Total Consumption (GWh)	Percentage Share (Residential)
1990-91	10,409	31,534	33
1991-92	11,458	33,878	33.8
1992-93	13,170	36,492	36.1
1993-94	14,080	37,381	37.7
1994-95	15,579	39,621	39.3
1995-96	17,125	41,924	40.9
1996-97	17,757	42,914	41.1
1997-98	18,750	44,572	42.2
1998-99	19,394	43,296	44.8
1999-00	21,455	45,586	46.9
2000-01	22,765	48,585	45.8
2001-02	23,210	50,622	45.5
2002-03	23,624	52,656	44.9
2003-04	25,846	57,491	45
2004-05	27,601	61,327	45.4

2005-06	30,720	67,603	45.8
2006-07	33,335	72,712	43.2
2007-08	33,704	73,400	42.6
2008-09	32,282	70,371	42.8
2009-10	34,272	74,348	43
2010-11	35,885	77,099	46.54
2011-12	35,589	76,761	46.4

Source: Pakistan Economic Survey, 2011-12

From the table 3.1 it is clear that household electricity demand has increased overtime. The reasons behind this increase are income and population growth (Tariq et al,). The percentage share of residential sector in total residential electricity consumption in 1980 was 21 percent. It increased to 30 percent in 1990 and 43 percent in 2000. In 2010, the percentage share of household sector electricity consumption was 42 percent while in 2011-12 it increased to 46.5 percent (NTDCL, 2013).

Beside the rapid progress in electricity sector, Pakistan has always faced the electric power shortage as compared to its demand. This situation got worst in 2008 where the electricity shortfall reached to 4000 MW. Nowadays, the electric power shortage is about 5000 MW. Electricity shortfall is creating a great disorder in the country, creating social and economic loses to the society. It has resulted in labor-hours loss, raised import bills and increased the cost of production in the industrial sector (Nasir et al, 2008 and Siddiqui et al, 2011).

The load shedding hours reaches at peak in summer, when the demand for electricity increases due to the increase in electricity demand needed for space cooling. In the hot months of summer like May, June and July, electricity load shedding reaches from 8 to 14 hours in Pakistan (Alter and Syed, 2011, Ali et al, 2013).

3.2. Situation in Islamabad

Due to electric power shortages, the large cities of Pakistan also face electricity load shedding. The capital city of Pakistan is also not an exception. Islamabad Electricity Supply Company (IESCO) supply electricity to the urban and rural areas of Islamabad. Other areas fall under IESCO, are the urban and rural areas of Rawalpindi division, Attock, Jhelum and Chakwal. The total residential customers of electricity in Islamabad are 254,712. The share of residential customers to total customers is 83.19 percent. Other sectors like commercial, industrial, tube wells, streetlights etc constitute the remaining 17 percent. Therefore, residential sector is the most dominant consumer of electricity in Islamabad (IESCO, 2013).

In 2012, the areas falling under IESCO faced 787.66 mega watts of monthly average shortfall of electricity. The shortfall was at the peak in the month of June with a 1373 Mega watts (IESCO Progress Report, 2011-12). In Islamabad, demand for electricity increases in summer when temperature rises, mainly due to the use of air conditioners, fans and air coolers. Increase in demand in summer increases the shortfall, reaches at the peak in the moths of May to July. In Islamabad, the average temperature stays above 30 ˚C in the months, May to June. In these months, consumption and shortfall of electricity stays at peak. On May 25, 2013, Kiyya Qadir Baloch reported in the newspaper “Daily Times”, that “electricity load shedding hours in many sectors in Islamabad has been increased to almost up to 16 hours”.

Electricity consumption decreases in the intermediate months like November, March and April where the air temperature is normal and the households require neither the space cooling nor heating. In cold months like December, January and February, electricity consumption slightly increases from the normal months. It is because some of the households use electricity for the space heating while others mainly use the natural gas for space heating Therefore, in Islamabad, the residential sector consumes the highest amount of electricity in hot months, intermediate amount in the cold months and the lowest in the normal months.

Although, summer temperatures increases the demand for electricity but the supply of electricity does not increase at the same pace. This situation causes the demand supply gap that results in electricity load shedding.

3.2.1. Geographical Location

Islamabad is the capital city of Pakistan. It is the ninth largest city of Pakistan in terms of population. Islamabad Capital Territory is divided into eight zones: Administrative Zone, Commercial District, Educational Sector, Industrial Sector, Diplomatic Enclave, Residential Areas, Rural Areas and Green Area. Islamabad city is divided into five major zones: Zone I, Zone II, Zone III, Zone IV, and Zone V. Zone I consists mainly of all the developed residential sectors like I, G, H, E and F. out of these sectors, the H sector is mostly dedicated to Health and educational institutions. Many foreigners and diplomatic personnel are housed in Sector E. Zone II is the under-developed residential sector consists of subsectors of sector D, I, G, H and E. Zone III is covered with most of the exempted lands and villages. Zone IV is the biggest zone of Islamabad includes Chuk Shehzad,, Banni Gala, Bahria Enclave, Park Enclave etc. Zone V consists of many societies like Bahria Town, Aghosh, Alhemra etc.

CHAPTER-4

DATA AND METHODOLOGY

4.1. Introduction

This chapter includes the data and its sources, sampling design and analytical techniques used to achieve the targeted objectives.

4.2. Data and its Sources

Both primary and secondary data is used for the analysis. Monthly temperature data for Islamabad for the period June 2012 to May 2013 is taken from Pakistan Meteorological Department (PMD). Monthly electricity consumption data is primary in nature and is collected from the monthly electricity bills of residential customers of electricity in Islamabad for the period June 2012 to May 2013. The households coping strategies are also assessed through primary data, collected from the household through structured questionnaire about the related monetary and environmental costs of these coping mechanisms. The survey was conducted during May-June 2013. The questionnaire was based on the information relevant to the coping strategies that the households are using against the electricity shortfall (see in Appendix)

4.3. Sample Size

The sample size is selected from the residential sector of the urban area of Federal Capital, Islamabad through simple random sampling technique from the F, G and I sectors[1].

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[1]The simple random sample is the unbiased surveying technique. The F, G and I sectors are selected for survey because these sectors have comparatively different socio-economic conditions which can affect the type and use of different coping mechanisms against electricity load shedding. Those households that were unwilling to respond were skipped and the next adjoint house was selected while conducting the survey. Other sectors like A, B, C and D are ignored because these sectors are residentially under developed. Similarly, Sector H is mostly dedicated to the health and educational institutions while sector E is mostly housed by many foreigners and diplomatic personnel.

The sample size is computed by a standard formula[2].The total population (residential electricity customers) of Islamabad is 254,712 households. It includes both the urban and the rural households. At 8 percent confidence interval, 95 percent confidence level and by picking the p-value as 0.5, the required sample size is 150. For econometric analysis, a sample size of 150 households is used.

For the assessment of coping mechanisms used against electricity shortfall, the confidence interval is reduced to 6 percent. The required sample size is the 266 households. It is limited to the 250 households because of the resources and time constraints.

4.4. Econometric Analysis

Two approaches are used to estimate the relation between electricity consumption and temperature. Some studies used degree-days approach to carry out the relation between the temperature and electricity consumption. Temperature is distributed in two indexes i.e. the heating degree-days and the cooling degree-days in order to remove the non- linearity of the relationship between temperature and electricity consumption. Degree-days are the temperature deviations from balanced point temperature, which is normally set between 18-22 ˚C. Heating degree-days are the negative deviations from the balanced point temperature while cooling degree-days are the positive deviations from the balanced point temperature. Some studies used temperature directly to find out the relation between temperature and electricity consumption.

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[2] $$SS = \frac{Z^2 * (p) * (1-p)}{c^2}$$

Where:
SS = Sample Size
Z = Z value
p = percentage picking a choice, expressed as decimal (0.5 used for sample size needed)
c = confidence interval, expressed as decimal.

They used trend or higher order models to remove the non-linearity of the relationship between electricity consumption and temperature. This study follows the methodology proposed by Fung et al (2006) and uses average temperature directly along with a dummy variable included for the hot months and income to estimate the relation between electricity consumption and temperature. The following two equations are estimated to achieve the first objective.

$$Y = \alpha + \beta_1 T + \beta_2 I + \beta_3 D_M \text{ ……………………………. (4.1)}$$

Where:

Y= Monthly Electricity Consumption of each households in KWh

T= Average Monthly Temperature

I= Income of the Households (income is same for all months throughout the year, but, different for different households)

D_M = Dummy variable included for hot months i.e. May, June, July, August, September and October which takes the value of “1” for these months while “0” for the rest of the months.

Equation 1 undertakes the relation between monthly electricity consumption and monthly average temperature and captures the changes in electricity consumption due to changes in temperature. Other weather variables such as rainfall, wind speed etc are excluded from the model because they have no direct impact on electricity consumption. These variables have a direct impact on air temperature and the air temperature then brings a direct impact on electricity consumption. Many studies have ignored these variables because of their negligible impact and no direct relationship with electricity consumption (Yan, 1998 and Velor et al, 2001).

A second equation is estimated taking log-log form to examine the impact of average monthly temperature, income and hot months on the monthly electricity consumption of the household sector. Consider equation 2.

$$\ln Y = \alpha + \beta_1 \ln T + \beta_2 \ln I + \beta_3 D_M \quad \text{……………………………………}(4.2)$$

where:

Y= Monthly electricity consumption of each household in KWh

T= Average monthly temperature

I= Income of the households

D_M= Dummy variable included for the hot months of May, June, July, August, September and October which takes the value of 1 for these months and 0 for the rest of the months.

ln is the natural log

The models are estimated by using the data collected from the 150 households.

4.5. Descriptive Analysis of the Coping Mechanisms

Alternative coping mechanisms used against electricity breakdowns are analyzed through descriptive statistics. Consumers that are using coping mechanisms against electricity shortfall and those that are not using any coping mechanism are shown descriptively. Similarly, the corresponding monetary and environmental costs of these coping mechanisms are also shown descriptively. Some coping mechanisms impose both the retail and operational monetary and environmental costs while some impose only the retail monetary and environmental costs. From monetary point of view, generators, UPS and rechargeable fans impose both the retail and operational monetary costs while solar panels and wind power turbines impose only the retail monetary costs. Quantification of the operational monetary costs of UPS and rechargeable fans are ignored because they are charged in the monthly electricity bills and are difficult to separate from the bill. For generators both the retail and operational monetary costs are quantified.

The retail monetary costs of the coping mechanisms used against electricity shortfall is computed by the data collected from the households. The costs mentioned by the households are simply summed up to compute the total cost and then divided by the total number of households using that coping mechanism to measure the average cost bore by 1 household. From operational monetary cost standpoint, the operational monetary cost of running generators is computed by using the following formula:

Operational Monetary cost of running generator= Total Consumption of petrol in liters x 99.7……………………………………………………………………………………… 4.1

To compute the operational monetary costs of running generators, June 01, 2013 petrol price is used. 99.7 is the price of 1 liter of petrol in PKR at June 01, 2013.

From environmental standpoint, only generators impose both the construction and operational environmental costs while the rest like UPS, rechargeable fans, solar energy systems and wind energy systems impose only the construction environmental costs. This study analyzed the environmental costs of only generators because it produces both the construction and operational environmental costs. The CO_2 emissions are calculated by using EURELECTRIC statistics, which states that the life cycle emission from 1 KWh electricity generated from oil produce 0.76 kg of CO_2 and the life cycle CO_2 emissions by 1 KWh of electricity generated by solar energy system is 0.14 kg.

Total electricity production by generators on hourly bases is calculated by using the total consumption of oil. Although 1 liter of oil is equivalent to 10.78 KWh of electricity but 1 liter of petrol produces 4.17 KWh of electricity because of the generation loses (Blujay, 2013). Total hourly consumption of petrol and per liter electricity production is used to calculate the total hourly production of electricity by generators. Consider the following formula.

Total electricity generated in KWh = Total consumption of petrol x 4.19…………. (4.3)

Total electricity generated on daily basis is the used to calculate the CO_2 emissions resulted from electricity generation. The use of generators increase in summer and it decreases in winter. To differentiate the electricity generation between the two seasons, the daily petrol consumption in summer and winter is used. Consider the following equations.

For summer:

Electricity generation in summer = Daily consumption in summer x 4.19……………… (4.4)

For winter:

Electricity generation in winter = Daily consumption in winter x 4.19………………… (4.5)

For the calculation of per hour CO_2 emissions, the following equation is used. As mentioned in the first chapter, a 1 KWh of electricity generated by petrol produces 0.76 kg of CO_2 emissions.

Total CO_2 emissions in Kg = Total electricity generated in KWh x 0.76……………… (4.6)

As the electricity generation by generators is high in summer and lower in winter, the summer and winter electricity generation is used to find out the summer and winter CO_2 emissions. Consider the following equations:

For summer:

Daily CO_2 emissions in summer = Daily electricity generated in summer x 0.76……… (4.7)

For winter:

Daily CO_2 emissions in winter = Daily electricity generated in winter x 0.76……….... (4.8)

The CO_2 emissions produced by solar energy systems is computed by multiplying 0.14 to the total electricity generated by the solar energy systems. It should be noted that the generation of electricity by solar energy systems and its consumption by the households is almost same in summer and winter. This study assumes it same in both the summer and winter.

CHAPTER-5

RESULTS AND DISCUSSIONS

5.1. Introduction

This chapter includes the descriptive and econometric analysis of the electricity consumption and temperature relationship and the descriptive statistics about the use of alternative coping mechanisms against electricity shortfall. The corresponding monetary and environmental costs of the coping mechanisms are also given.

5.2. Descriptive Statistics of Electricity Consumption and Temperature

Among all the households 86.8 percent of the households responded that electricity consumption increases in summer and decreases in winter. These households were using electricity only for space cooling. The remaining 13.2 percent of the households responded that electricity consumption increases in both summer and winter. They responded that they use electricity for both the space heating and cooling.

Statistics about the monthly electricity consumption and monthly average temperature of Islamabad from June 2012 to May 2013 is given in table 5.1. It can be observed that electricity consumption is at the peak in the hot months of summer. The average consumption of per household is above 300 KWh in the months of June-September 2012 and May 2013 when the temperature stays at peek. In June 2012, consumption of electricity is recorded at the maximum with an average of 388.40 with the average temperature of 33.92 ^{0}C. June is followed by July 2012 with an average consumption of 378.86 KWh. The average temperature in July 2012 was 33.32 ^{0}C. Other hot months like August, September and May also recorded a high average consumption above 300 KWh. This is because the space cooling effect. Other months recorded a relatively lower average consumption below 300 KWh with the lowest in March 2013 with an average consumption of 217.53 KWh. Electricity consumption was lowest in March because in months like March and November, the air temperature stays normal. There is no need for the space cooling nor heating. Therefore, these months observed the lowest electricity consumption. In cold months like December 2012 and January 2013, the consumption slightly increased. This is because of the space heating effect. Consumption in February 2013 was slightly above than March 2013 with the average consumption of 228.05 KWh.

Table 5.1: Monthly Average Electricity Consumption of the Selected Sample

Months	Average Consumption (KWh)	Average Temperature(^{0}C)
June 2012	388.40	33.92
July 2012	378.86	33.32
August 2012	360.50	29.69
September 2012	323.56	27.40
October 2012	271.68	23.74
November 2012	236.44	18.48
December 2012	261.45	13.64
January 2013	257.11	11.90
February 2013	228.05	13.88
March 2013	217.53	19.79
April 2013	258.52	23.56
May 2013	339.05	30.23

Computed by the Researcher

Table 5.2 shows the percentage change in the average electricity consumption and average temperature. For this analysis, this study takes the whole months into three categories i.e. the hot months, cold months and the months with normal temperature. Hot months include May to October. The cold months include the months of December to February. The months with normal temperature are March and November. The hot months have an average electricity consumption of 331.51 KWh with an average monthly temperature of 28.58 ^{0}C. The cold months have the average electricity consumption of 248.87 KWh with an average temperature of 13.14 ^{0}C. The months with normal temperature have the average consumption of 226.99 KWh with an average temperature of 19.13 ^{0}C. This study have taken the Hot months as base for this analysis.

Table 5.2. Percentage Change in Electricity Consumption

Months	**% change in electricity consumption**	**% change in temperature**
Cold Months	-25.1%	-54.45
Months with Normal Temperature	-31.53%	-33.69

Computed by the researcher

From table 5.2, it can be observed that in the cold months, electricity consumption decreases by 25.1 percent in comparison with the consumption in hot moths. In the intermediate months, it decreases by 31.53 percent. Therefore, the lowest consumption occurs in the months with normal temperature, where one requires neither space heating nor cooling.

5.3. Models Results

Table 5.3 presents summary of the regression models. Results of the linear regression model state that keeping other things constant, a 1^{o}C change in average temperature cause 4.393 kWh change in electricity consumption. This is the average change in electricity consumption due to a change in temperature. It may be a change in electricity consumption due to an increase or a decrease in the cooling energy requirement or an increase or a decrease in the heating energy requirement. The results also show that the dummy variable included for hot months advocate 65.673 units changes in electricity consumption. This is because in Islamabad, in six months from May to October space cooling is needed. Similarly, a 1 unit change in income causes a 0.001 kWh change in electricity consumption. The R^2 observed at 0.20[3]. Results were significant at 1 percent level of significance.[2]

Results of the log-log model presented in table 5.3, show that a 1 percent change in average temperature causes 0.197 percent change in electricity consumption. Similarly, the hot months cause a 0.342 percent change in electricity consumption and that a 1 percent change in income causes a 0.330 percent change in electricity consumption. All variables are significant at 5 percent level of significance. Results of both the models advocate that all the independent variables have a positive relation with the residential electricity consumption.

Results of this study are different from the other studies given in the literature. The temperature-induced variations in electricity consumption are quite high concluded by the other studies. For example, Le Comte and Warren, (1981) 91-95 percent of the variations in electricity consumption, Al-Zayer and Al-Ibrahim, (1996) concludes about 75-88 percent of the temperature induced variations in electricity consumption, Fung et al, (2006) states about 90 percent of the variations in electricity consumption are due to variations in temperature. The reason behind this difference may be due to the facts that other studies have used the time series and secondary data for their analyses. This study used the primary and cross-sectional data for the analysis.

Table 5.3: Summary of Models

	Linear	Log-Log

[3] The reason for a lower R^2 may be due to the cross sectional data. Typically, one obtains lower R^2 values for cross sectional data because of diversity in the units of sample (Gujrati, 2004). Similarly, Reisinger (2013) stated that studies with primary and cross-sectional data shows significantly lower R^2 values as compared to the studies with secondary and time series data.

	Coefficient	t-stat	Sig	Coefficient	t-stat	Sig
Intercept	87.325	4.425	0.000	1.078	2.676	0.008
Avg. temperature	4.393	4.145	0.000	0.197	2.352	0.019
Dummy Month	65.673	4.158	0.000	0.342	5.823	0.000
Income	0.001	10.487	0.000	0.330	11.011	0.000
R^2	0.200			0.188		
Adjusted R^2	0.198			0.186		
F-statistics	119.491			110.945		

Source: Computed by Researcher

The correlation between the monthly electricity consumption and the monthly average temperature, income and the hot months is given in table 5.4. It states that the correlation between the monthly electricity consumption and temperature is 0.359. All the correlations were significant at 0.01 level which indicates that monthly electricity consumption and the other independent variables are linearly related.

Table 5.4.Correlations

Variable	Consumption	Significance
Average Temperature	0.359	0.000
Income	0.248	0.000
Dummy Month	0.359	0.000

Source: Computed by Researcher

The elasticity of monthly electricity consumption with respect to monthly average temperature, hot months and income is given in table 5.5. It states that in linear model, a 0.35709 percent change in monthly electricity consumption occurs due to a 1 percent change in monthly average temperature and a 1 percent change in income causes a 0.225022 percent change in monthly electricity consumption. In case of log-linear model, a 0.197 percent change in monthly electricity consumption occurs due to a 1 percent change in monthly average temperature while a 1 percent change in income is responsible for a 0.330 percent change in monthly electricity consumption.

Table 5.5. Elasticities

	Linear	**Log-log**
E_T	0.35709	0.197 (0.115)
E_I	0.225022	0.330 (0.66)

Source: Computed by Researcher

5.4. Descriptive Statistics of Coping Mechanisms against Electricity Load Shedding

Statistics about the number and percentage of different coping mechanisms used against electricity shortfall in the residential sector of Islamabad is given in table 5.6. The statistics reveals that 78.8 percent of the households use different mechanisms to cope against electricity shortfall.

Table 5.6: Statistics about the Usage of Different Coping Mechanisms

Coping Mechanisms	**Frequency**	**Percentage**
Users of Coping Mechanisms	197	78.8
Non Users	53	21.2
Total	**250**	**100**

Source: Field Survey

The average daily electricity load shedding, reported by the households was 11.7 hours in summer while it 2.6 hours in winter. Households in Islamabad are using different coping mechanisms against electricity shortfall like generators, UPS, rechargeable fans, solar energy panels. A few households have insulated their homes to cope against the outdoor temperature to reduce the electricity requirement for space heating or cooling. Table 5.7 presents the information about percentage of households using different coping mechanisms.

Table 5.7: Percentage of Households Using different Coping Mechanisms

Name of Coping Mechanism	No. of Users	Percentage
Generators(G)	71	28.40
UPS	138	55.20
Rechargeable fans(R.Fans)	79	31.60
Solar Energy(S.Energy)	19	7.60
House Insulation(H.I)	6	2.40

Source: Field Survey

From table 5.7, it can be observed that majority of the households i.e. 55.20 percent are using UPS followed by the rechargeable fans and generators. Solar energy systems are used by only 7.60 percent of the households. This is because it is a new technology in Pakistan. Its limited use is due to its high retail cost. Only 2.40 percent of the households had insulated their homes against the atmospheric temperature. The reason behind this may be the unawareness of the people against house insulation. Table 5.7 gives information about the overall usage of the coping mechanisms against electricity shortfall. However, many of the households were using more than one coping mechanisms. Table 5.8 gives the information about the households that were either using one or more coping mechanism to cope against electricity shortfall.

Table 5.8: Categories of Different Coping Mechanisms at the Household Level

Name of Coping Mechanism	No. of Users	Percentage of Users

Generators	28	14.21
UPS	64	32.49
Rechargeable Fans	16	8.12
Solar Energy	4	2.03
UPS + R.Fans	34	17.26
G + UPS + R.Fans	12	6.1
G + UPS + R.Fans + S.Energy	5	2.54
R.Fans + S.Energy	2	1.02
G + UPS	14	7.12
G + UPS + S.Energy	2	1.02
UPS + R.Fans + H.I	3	1.52
UPS + S.Energy	1	0.51
UPS + R.Fans + S.Energy	2	1.02
G + R.Fans	5	2.54
G + S.Energy	1	0.51
G + S.Energy + H.I	1	0.51
G + H.I	2	1.02
G + R.Fans + S.Energy	1	0.51
Total	**197**	**100**

Source: Field Survey

5.5. Monetary Cost of Coping Mechanisms

The use of the coping mechanisms are imposing both the retail and operational economic costs to the society. The total and average retail costs beard by the society is given in table 5.9. Monetary cost of any coping mechanism can be divided into the retail and operational monetary costs.

5.5.1. Retail Costs of Coping Mechanisms

From the table 5.9. it is concluded that the average retail cost of solar energy systems are imposing the highest monetary costs on the society, followed by generators and then the UPS and rechargeable fans.

Table 5.9: Retail Costs of Coping Mechanisms

Category	Total Cost of all Households (PKR)	Average cost of per Household
UPS	3888500	28177.50
Generators	7458000	105042.25
Rechargeable Fans	629600	7969.6203
Solar Energy System	2208000	116210.53

Source: Computed by researcher based on the household’s information

The high average cost of generators is due to the presence of seven outliers that had the average cost of 559285.7 rupees. By removing these seven outliers, the total cost of sixty four generators is 35430000 rupees while the average cost of per generator is 55359.375 rupees.

5.5.2. Operational Monetary Costs of Coping Mechanisms

Although generators, UPS and rechargeable fans all the three impose operational monetary costs to the society but the operational costs of UPS and rechargeable fans are indigenous in the monthly electricity bills and are charged at the time of bill payment. Therefore, only the operational costs of only generators are quantified. The operational costs of running generators are computed by employing the total hourly and daily use and petrol consumption of these generators. Table 5.10 presents the information about the use of theses generators in summer and winter. From table 5.10, it can be concluded that the use of generators in summer is quite high than its use in winter because of the cooling energy requirement. The average use of 1 generator in summer is 6.93 hours while that in winter it is only 1.13 hours for a day.

Table 5.10: Use of Generators in Summer and Winter

Generator Use in Summer/Winter	Use in Hours
Total daily use of all generators in summer	492
Average daily use of one generator in summer	6.93
Total daily use of all generators in winter	80
Average daily use of one generator in winter	1.13

Source: Computed by researcher

In the table 5.11 the daily use of generators for different categories is given. From the table it can be concluded that in summer, the households having only generators have the maximum hours of usage followed by the households that are having generators along with the UPS.

Table 5.11: Daily Use of Generators for Different Categories in Summer & Winter

Category	Use in Summer (Hours)	Use in Winter (Hours)
Generators	224	42
Generators + UPS	112	8
Generators + R. Fans	39	19
Generators+ UPS+ R. Fans	39	2
Generators+ Solar Energy	8	4
Generators+ UPS+ R. Fans+ S. Energy	27	0
Generators+ House Insulation	14	2
Generators+ S. Energy+ H. Insulation	6	0
Generators+ R. Fans+ S. Energy	9	0
Generators+ UPS+ S. Energy	14	3
Total	**492**	**80**

Source: Computed by researcher

The hourly and daily consumption of petrol of the generators in summer and winter is given in table 5.12, which states that in summer the daily consumption of all generators is 479.6 liters while in winter the daily consumption is only 77.97 liters. The average consumption of 1 generator in summer is 6.75 liters while in winter it is only 1.10 liters.

Table 5.12: Consumption of Petrol by Generators in Summer and Winter

Daily Consumption of Petrol in Summer and Winter	Consumption (Liters)
Total hourly consumption of petrol of all generators	69.2
Average hourly consumption of petrol of 1 generator	0.975
Total daily consumption of all generators in summer	479.6
Average daily consumption of 1generator in summer	6.75
Total daily consumption of all generators in winter	77.79
Average daily consumption of 1 generator in winter	1.10

Computed by researcher

As the numbers of households that are using different coping mechanisms are different for different categories, their daily consumption of petrol to produce electricity is also different. In the table 5.13, the hourly consumption of petrol for the households using different categories is given. The highest consumption of petrol occurs by those households that are having only generators followed by the households that are having the generators and the UPS.

Table 5.13: Consumption of Petrol by Different Categories

Category	Total Consumption of petrol per hour (Liters)	Average Consumption of Petrol per hour (Liters)
Generators	37.6	1.34
Generators + UPS	11.9	0.85
Generators + R. Fans	4.2	0.84
Generators+ UPS+ R. Fans	3.8	0.32
Generators+ Solar Energy	2	2
Generators+ UPS+ R. Fans+ S. Energy	3.3	0.66
Generators+ House Insulation	2.5	1.25
Generators+ S. Energy+ H. Insulation	2	2
Generators+ R. Fans+ S. Energy	0.4	0.4
Generators+ UPS+ S. Energy	1.5	0.75

Source: Computed by researcher

From petrol consumption, the total hourly and daily monetary costs are computed in table 5.14 which present that the daily cost in summer is 47816.12 PKR while the daily costs in winter were 7796.54 PKR. Similarly, the average cost of per generator in summer was 673.50 PKR while in winter it was only 109.81 PKR.

Table 5.14: Monetary Cost of Running Generators

Monetary Cost of Generators Usage	Cost in PKR
Total hourly monetary cost of all generators	6899.24
Average hourly monetary cost of 1 generator	97.2
Total daily monetary cost of all generators in summer	47816.12
Average daily monetary cost of 1 generator in summer	673.50
Total daily monetary cost of all generators in winter	7796.54
Average daily monetary cost of 1 generator in winter	109.81

Source: Computed by researcher

5.6. Environmental Costs of Running Generators

Operation of generators produces greenhouse gas emissions. These are calculated by using the emissions produced from total electricity generated. Table 5.15 gives the summary of total and average generation of electricity in summer and winter. The total and daily generation of electricity in summer was 1999.932 KWh while in winter it was 326.1 KWh.

Table 5.15: Generation of Electricity by Generators

Production of Electricity by Generators	Production in KWh
Total hourly production of all generators	286.44
Average hourly production of 1 generator	4.06
Total daily production of all generators in summer	1999.932
Average daily production of 1 generator in summer	28.20
Total daily production of all generators in winter	326.10
Average daily production of 1 generator in winter	4.60

Source: Computed by researcher

Now, in the table 5.16, the power generation capacity of solar energy systems is computed that are used by the households.

Table 5.16: Generation of Electricity by Solar Energy Systems

Generation of Electricity by All Solar Energy Systems	**KWh**
Total hourly generation of electricity by all Solar Energy Systems	2.25
Average hourly generation of electricity by one Solar Energy System	0.12
Total daily generation of electricity by all Solar Energy Systems	12.7
Average daily generation of electricity by one Solar Energy System	0.67

Source: Computed by researcher based on household's information

5.6.1. Production of CO_2 Emissions from the Operation of Generators

Table 5.17 gives the total CO_2 production from the operation of generators. The table 5.17 reveals that 1-hour use of generators emits 217.7 Kg of CO_2 to the atmosphere. The emissions of CO_2 depend on the amount of electricity generated by generators. In summer when the generator use increases, the corresponding emissions also increase. Daily CO_2 emissions in summer are 1519.95 kg while in winter it is 247.84 kg. Similarly, the average CO_2 emissions from 1 generator in summer were 1788.1 kg while in winter, it were 292.63 kg.

Table 5.17: Production of CO_2 Emissions by Generators Operation

Production of CO_2 Emissions from Generators Use	**Kg of CO_2**
Total hourly emissions from the operation of all generators	217.7
Average hourly emissions from the operation of 1 generator	3.1
Total daily emissions from all generators in summer	1519.95
Average daily emissions from 1 generator in summer	21.41
Total daily emissions from all generators in winter	247.84
Average daily emissions from 1 generator in winter	3.5

Source: Computed by researcher using EURELECTRIC statistics

5.6.2. Production of CO_2 Emissions from Solar Energy Systems

Now, the CO_2 emissions by solar energy systems is given in table 5.18.

Table 5.18. Production of CO_2 Emissions by Solar Energy Systems

Production of CO_2 Emissions by Solar Energy System	**Kg of CO_2**
Total hourly CO_2 emissions produced by 1 Solar Energy System	0.02
Total hourly CO_2 emissions produced by all Solar Energy Systems	0.32
Total daily CO_2 emissions produced by 1 Solar Energy System	0.094
Total daily CO_2 emissions produced by all Solar Energy Systems	1.78

Source: Computed by researcher based on EURELECTRIC statistics

CHAPTER-6
CONCLUSIONS AND RECOMMENDATIONS

6.1. Introduction

This chapter includes the summary of the major findings followed by conclusions and recommendations based on the findings of the study.

6.2. Major Findings of the Study

1. 86.8 percent households responded that electricity consumption increases in summer and decreases in winter. The remaining 13.2 percent of the households were of the view that electricity consumption increases in both summer and winter.
2. Maximum consumption of electricity occurred in the hot months of summer i.e. May to August. Consumption in these months was above 300 KWh. The peak consumption occurred in June with an average consumption of 388.40 KWh. Consumption was lower in other months, as compared to the summer months. The lowest consumption occurred in the month of March with 217.53 KWh. This is because in March, there is a need for neither space heating nor cooling.
3. In the cold months, electricity consumption decreases by 25.1 percent as compared to the hot months while in the months with normal temperature, it decreases by 33 percent.
4. The households are using generators, UPS and solar energy panels to produce or store electricity and some households have insulated their homes to adapt against the outdoor temperature to reduce the electricity consumption required for space heating or cooling. Among all the households, 78.8 percent of the households were using coping mechanisms against electricity load shedding.

5. Among the households that are using coping mechanisms against electricity load shedding, 43.2 percent of the households were using one coping mechanism. The remaining 56.8 percent of the households were using more than one coping mechanisms. The usage of UPS was maximum (55.20 percent) followed by the generators, rechargeable fans, solar energy systems and house insulation. The use of solar energy systems and house insulation is very low with only 7.60 percent and 2.40 percent respectively.
6. The use and generation of electricity by generators was high in summer in comparison of its usage in winter. In summer, the average daily use of 1 generator was 6.93 hours while in winter it was only 1.13 hours. On the other hand, the daily average generation of electricity of 1 generator in summer was 28.20 KWh while in winter it was only 4.60 KWh.
7. Average operational monetary cost of 1 generator was 673.50 PKR in summer, while, in winter it was 109.81 PKR.
8. In summer, the production of CO_2 emissions from the operation of generators was high and it was lower in winter. The total daily CO_2 emissions production by all generators in summer was 1519.95 kg while in winter it was only 247.84 kg.

6.3. Conclusion

Demand or consumption of residential electricity changes with a change in temperature. This study attempts to analyze the monthly changes in residential electricity consumption due to changes in monthly average temperature and to investigate the monetary and environmental costs of the coping mechanisms that households are using against electricity shortfall. This study is based on the information collected from the residential sector of Islamabad. Relation between residential electricity consumption and temperature is investigated by using simple linear regression model. This study concluded that residential electricity changes with a change in temperature. The consumption stays at peak in summer when the atmospheric temperature is maximum. For each degree change in temperature, electricity consumption changes with 4.393 units. This increased demand leads to electricity breakdowns. The households have reported that in summer, they face electricity breakdowns up to 12 hours. To deal with the electricity shortfall they are using different coping mechanisms against it.

Households are using generators, UPS, rechargeable fans and solar energy systems to cope with the electricity shortfall. A small proportion of the households have insulated their homes to adapt against the outdoor temperature and to decrease their electricity consumption. These coping mechanisms are imposing heavy economic and environmental costs to the society.

6.4. Recommendations

1. Electricity shortfall is a serious problem that is bringing high monetary and environmental costs to the society. A considerable proportion of the households are using generators against electricity load shedding which is unsustainable in terms that it produces a considerable amount of CO_2 emissions. The government should provide clean electricity to the residential sector during the peak periods in order to discourage the use of thermal generators. This can be done by implementing new hydropower, solar power and wind power projects. Nuclear energy is also an option.
2. The use of sustainable and environment friendly practices like solar energy and house insulation is very low. Nowadays, solar energy is an expensive source. The government should subsidize solar energy panels. This will enhance the use of solar energy. Similarly, the House Insulation should be promoted in order to reduce the consumption of

electricity for space heating or space cooling. Building codes should be devised in order to conserve the energy. Households should be given awareness about the benefits of these mechanisms through advertisements and public service messages through media. Seminars and workshops should be arranged at the gross root level to raise awareness among the people. It will also play a major role in the promotion of house insulation and solar energy use.

3. According to International Energy Agency, the CO2 emissions produced per KWh of electricity in Pakistan is 0.45 kg while the electricity generated by generators at the households level produce 0.76 kg of CO_2 emissions. If the required electricity is provided by the government instead of households generating their own electricity by thermal generators, it will reduce the total CO_2 emissions of the country which can be claimed in carbon market to earn carbon credits.

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APPENDIX-A

QUESTIONNAIRE

HOUSEHOLDS COPING MECHANISMS AGAINST ELECTRICITY SHORTFALL

(Profile: Information about Households' Head)

- Name:
- Education:
- Income Group: 1) 10,000- 20,000
  2) 21,000-30,000
  3) 31,000-40,000
  4) 41,000-50,000
  5) 51,000-70,000
  6) 71,000 or above
- Resident of: Sector………………….

Please select the option(s) that corresponds to your choice(s).

1. What is your opinion about the electricity demand and summer temperature?

   1) Increases 2) Decreases 3) Neutral

2. What is your opinion about electricity demand and winter temperature?

   1) Increases 2) Decreases 3) Neutral

3. Do you agree that electricity shortfall is a serious problem?

   1) Yes 2) No

4. In which season electricity load shedding is at peak.

1) Summer (May-Aug). 2) Winter (Dec-Feb)

3) Autumn (Sep-Nov) 4) Spring (Mar-Apr)

5. Are you using any coping mechanism against electricity load shedding?

   1) Yes 2) No

6. Have you insulated your home against the outdoor temperature?

   1) Yes 2) No

7. Does house insulation reduce the electricity consumption?

   1) Yes 2) No

8. What type of coping mechanism you are using against electricity load shedding?

   1) UPS 2) Rechargeable fans and lamps 3) Generators

   4) Solar energy panels 5) Wind energy turbines

9. If you are using a UPS, then please answer the questions from “a” to “c” :

   a) What was the installation cost of UPS including battery? Please specify.

   …………………………………..

   b) For how many hours the UPS provides the backup facility.

   ………………………………….

   c) What is the normal life of UPS? Please specify.

   …………………………………..

10. If you are using rechargeable fans, then please answer the questions from “d” to “e”.

   d) What was the cost of rechargeable fans?

   …………………………………..

e) What is the normal life of rechargeable fans?

……………………………….

11. If you are using generators, the please answer the questions from “f” to “o”.

f) What type of generator you are using?

1) Run by Petrol   2) Run by diesel   3) Run by gas

g) What is the maximum power potential of the generator?

…………………………………….

h) What was the price of generator?

…………………………………….

i) When did you buy generator?

……………………………………

j) For how many hours, you are using generator in winter.

……………………………………

k) For how many hours you are using your generator in summer.

……………………………………

l) If you are using a petrol generator, how many liters of oil are consumed in one hour?

……………………………………

m) If you are using a diesel generator, how many liters of diesel are consumed in one hour?

……………………………………

n) If you are using a gas generator, how many kilo grams of gas are consumed in one hour?

……………………………………

o) What are the environmental threats of generators?

1) Generate Smoke 2) Generate noise 3) Both

12. If you have installed solar energy system, please answer the questions from "p" to "s".

p) What is the power capacity of solar energy system?

………………………………….

q) What was the installation cost of solar energy panels?

…………………………………

r) What is the normal life of solar energy system?

…………………………………

s) What are the environmental benefits of using solar energy?

1) Does not generate smoke 2) Does not create noise 3) Both

13. In which month you consume the higher amount of electricity.

……………………………….

14. Monthly electricity consumption in units for the previous 12 months:

June ,2012…………………………… July, 2012…………………………….

August, 2012………………………… September, 2012……………………..

October, 2012……………………….. November, 2012………………………

December, 2012…………………….... January, 2013…………………………

February, 2013 ……………………….March, 2013………………………….

April, 2013………………………….. May, 2013…………………………….