IMPACTS OF SOCIO ECONOMIC AND URBAN FORM ELEMENTS ON DOMESTIC ELECTRICITY CONSUMPTION, A CASE STUDY OF ISLAMABAD

By

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THESIS ACCEPTANCE CERTIFICATE

Certified that final copy of MS thesis titled "*Impacts of socio economic and urban form elements on domestic electricity consumption, a case study of Islamabad*" written by Mr. Syed Imran Ali (Registration No. 2014NUST63366MSCEE15814F), of Urban and Regional Planning (NIT - SCEE) has been vetted by undersigned, found complete in all respects as per NUST Statutes / Regulations, is free of plagiarism, errors, and mistakes and is accepted as partial fulfillment for the award of MS degree. It is further certified that necessary amendments as pointed out by GEC members of the scholar have also been incorporated in the said thesis.

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DECLARATION

I, Syed Imran Ali, declare that this research study "*Impacts of socio economic and urban form elements on domestic electricity consumption, a case study of Islamabad",* submitted for the Master of Science in Urban & Regional Planning is my own evolutionary and creative work both in conception and execution. All the theoretical information's and related sources which are used or quoted have duly acknowledged by means of complete references. Furthermore, such a dissertation has not previously been submitted to any institution for degree purposes to date.

Syed Imran Ali

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In the name of Allah, the compassionate. All praises are for Allah. All salutations to his Prophet Muhammad (PBUH). By the grace of Almighty I completed this research work.

I am infinitely grateful to my Uncle Mr. Syed Liaqat Ali and Aunt Ms. Syeda Riffat Fatima for everything they did throughout my life. No doubt their contribution is beyond payback in any conceivable term.

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Syed Imran Ali

DEDICATION

تو کیا ہے اور کیا ہے   تیرے علم کی بساط

تجھ پر کرم نصیرؒ   یہ سارا علیؑ (کرم اللہ وجہہ) کا ہے

I am imperfect and so is my knowledge

All this achievement is a blessing of Saint Ali (R.A)

(Peer Syed Naseer ud deen Naseer, Golra Shareef)

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ABSTRACT

The global energy scarcity and exceptional increase in energy consumption pushed energy optimization in the ambit of inevitable tasks. Meanwhile, the ambience of urban life is reliant on energy availability. Energy crisis of 1970s gave rise to the energy conservation principles but the idea of regulating domestic electricity demand through socio economic and urban form elements gained popularity in the early 2000s.Pakistan has 39% urban population while urbanization rate in Pakistan is 2.81% which means cities are expanding faster and will claim more energy in future. The country is facing electricity shortage hence beside production, optimum regulation of electricity demand is imperative.

This research investigates the effect of socio economic features and urban form elements on domestic electricity demand in context of Islamabad, Pakistan. Four residential areas of Islamabad are selected as the case study. Income level, household size, house ownership are taken as socio economic characteristics. Street pattern, land cover, house size, no of storey, basement, tree plantation, open to sky area are taken as elements of urban form. Electricity billing data is collected from the electric supply company, IESCO and questionnaire survey is conducted in four residential areas of case study. Satellite imagery is obtained through Google earth and plans are downloaded from official website of CDA. A total no of 200 households are surveyed. The data is coded and analyzed in SPSS. Multivariate analysis techniques including correlation and regression analysis are employed. The major trends of electricity consumption are highlighted. The key findings of this study shows that two of the socio economic features including income and household size significantly affect electricity consumption. Moreover electricity consumption is largely dependent on the micro elements of urban form including open to sky area, tree plantation, basement and house size.

This research concludes that significant reduction in electricity demand is possible through socio economic and urban form changes. It is recommended to ensure basements provision in the buildings, maximize open area, promote tree plantation, incorporate natural ventilation and minimize household size for reduction in electricity consumption.

CHAPTER 1 INTRODUCTION

1.1 BACKGROUND

The alarms related to energy resources depletion started beeping in the late 1920s but these were responded merely through conservation strategies till 1970s. In 1970 energy crises pushed planners to pay attention towards energy efficiency at building and neighborhood level. Subsequently, many design and planning principles emerged regarding the optimum association of urban development and energy usage in the 1970s but most of these concepts remained unimplemented. Once again the energy and economic crunch in the last few decades brought our focus to this subject.

"Being the engine of economic activity, cities drive the majority of the world's energy use and are major cause of global greenhouse gas (GHG) emissions. currently, around half of the world's population lives in urban areas, and this share is rising over time, anticipated to reach 60% by 2030. Cities are responsible for the largest consumption of energy resources globally – between 60 to 80% – and account for a roughly equal share of global CO2 emissions. Today, European cities claim about 70% of the overall primary energy consumption, and this share is likely to swell to 75% by 2030." (European Institute for Energy Research, 2011).

Pe´rez-Lombard et al. (2008) reported that in developed countries such as the United States and the European Union, the energy demand of buildings is higher industry or transportation. Mitchell (2005) narrated that in the City of London, buildings claim 2.2 times more energy as compare to transportation systems.

Considering these facts, more persistent efforts are required to regulate domestic energy consumption. Over the last few decades, urban from emerged as a factor that potentially influence domestic energy consumption and many studies are conducted on the usefulness of urban form elements as a tool to regulate energy consumption in different parts of the world.

The bulk of research in this area has increased significantly since the 2000, with a main focus on the impacts of urban form elements on energy consumption. Urban planners propose multiple solutions for the energy efficiency including going vertical through compact development and green construction technologies. Some of the formerly conducted popular research studies are briefly discussed in the under given paragraphs.

Ewing & Rong (2008) investigated the cities of the United States and computed the association of urban form and domestic electricity usage. They concluded that compact development is associated with least domestic energy consumption. Jones (2015) investigated the mutual dependence of energy consumption on urban form elements and found out that housing characteristics are notably influencing the domestic energy consumption. Ratti et al. (2005) calculated the association of urban geometry of cities with their energy consumption. He considered façade distance, its orientation, specific angles and sky line as variables. The association was found positive and the study concluded reliance of energy consumption upon the geometry of cities.

According to CIA (2015) urban population comprises approx 39% of total population of Pakistan while urbanization rate in Pakistan is 2.81% which means cities are expanding faster and will claim more energy in the coming years. Meanwhile Pakistan is facing an energy shortage. Hence, optimum regulation of energy demand is imperative. Along with the construction of new dams, there is another facet to deal with this issue. i.e. reducing domestic energy consumption through elementary improvements in urban form.

This research studies the effect of urban form elements on domestic electricity consumption in context of Islamabad, Pakistan. Islamabad has a diverse range climate with five seasons. The hottest month is June with average temperature 38 °C (100.4 °F). Four residential areas of Islamabad are selected as the case study. Both the micro and macro level elements of urban form are incorporated in this study. Macro level elements include street pattern, land composition and topography. The micro level elements include demographic, housing characteristics and environmental characteristics. Demographic characteristics are represented by household size, household type and household income. Housing characteristics are represented by house size, no of storey, basement provision, no of rooms, house age and house ownership. The percentage open to sky area and no of plants in house represent are considered as environmental characteristics. Domestic energy consumption is represented through electricity bills and occupant behavior. To conduct this study, both the primary and secondary source data is acquired from the case study and relevant departments i.e. CDA, IESCO. Descriptive and correlation analysis technique is employed to generate results.

This research collects electricity billing detail and conducts a questionnaire survey from the residents of case study area. The major trends of electricity consumption are highlighted. Considering these trends, this research concludes that micro level elements of urban form remarkably affects the domestic energy consumption and suggests the improvements that can play vital role for optimum regulation of domestic electricity demand.

The potential contribution of this dissertation is expected be in the following direction:

- This study is expected to unfold the impacts of socioeconomic features and urban form elements on domestic electricity consumption. Thus it may enable city planners to understand their role in minimizing domestic energy demand.

- The findings of this study are expected to generate vital results for the future research in the field of domestic energy efficiency.

- This research is expected to recommend the improvement in bylaws/rules regulating development.

1.2 PROBLEM STATEMENT

Energy crisis is a global concern and more attention is being paid on energy safety, energy equity and energy sustainability. Cities have almost two-thirds share in the primary energy consumption around the globe and by the year 2050 half of the world will be urbanized in term of population. It is imperative to take demand side measures to maintain balance between energy supply and its demand. Modern urban planning methods are in particularly needed to get advantage from energy efficiency measures. Urban form may play an essential role in reducing energy consumption to optimum level. Currently, less work is conducted on this subject and a significant research gap exists in this direction.

Pakistan is facing energy crisis that has more or less, hampered all the sectors of national machinery and it is hindering national progress drastically. The exponential population growth, rapid expansion of urban areas and lack of effective energy policies have caused phenomenal gap in our energy demand and its supply which entails to be properly addressed.

Traditionally, the concept of energy efficiency is explored in one dimension I.e. technological innovation. Enhancing energy efficiency via technological means is analogous to more service per set quantity of energy distributed. Contemporarily, urban form emerged as a useful tool for energy efficiency at broader scale. Studying the areas based on the socio economic and of urban form features using the data obtained from development plans, electricity billing records and surveys can potentially explain the electricity consumption behavior and the factors significantly affecting electricity demand.

This paper aims to explore the electricity consumption pattern in the residential neighborhoods of Islamabad. Identify the link of electricity consumption with urban form elements and socioeconomic features and provide recommendations to reduce domestic electricity consumption.

1.3 RESEARCH OBJECTIVES

The objective formulation is vital component of any research methodology. This study primarily focuses on the achievement of four objectives. These objectives are as follow.

1. To generate the profile of selected areas with respect to socio economic and urban form features.

2. To identify relationship between electricity consumption and socioeconomic features.

3. To identify relationship between electricity consumption and urban form elements.

4. To provide recommendations for reduction in electricity consumption.

1.4 RESEARCH QUESTIONS

The research questions and objectives go side by side. The development of research question is inevitable task to achieve any objectives. In this study, four research questions are formulated corresponding to the objectives. These questions are as follow.

1. What is the profile of selected areas according to socioeconomic and urban form features?

2. Is there any relationship between electricity consumption and socio-eco features?

3. Is there any relationship between electricity consumption and urban form elements?

4. What are the recommendations for reduction in electricity consumption?

1.5 SCOPE & LIMITATIONS

For a fine reflection of scenario, it is better to select as many neighborhoods as possible from the case study i.e. Islamabad city. However, taking into consideration the limited nature of financial resources and time constraints four areas are selected as case study. For convenience of primary data collection, a moderate sample size of 10 % is selected.

1.6 THESIS STRUCTURE

The standard structure is adapted to write this thesis. The thesis write up comprises of six chapters. The brief of each chapter is under given.

Chapter I contains the backdrop scenario of topic, a brief statement of problem, objectives of research, research questions and scope & limitations of the study.

Chapter II provides the literature review for this study. It provides a chronological review of the significant research work done so far on this topic. It also discusses few selected relevant studies for better understanding of the research dimension.

Chapter III includes the methodology adapted to carry out this study. It defines the urban form and classification of its components. It explains parameters for selection of case study, urban form variables, data collection sources and analysis techniques employed.

Chapter IV is named as data analysis chapter. It presents the data and the results in the form of tables, charts and graphs.

Chapter V covers the aspect of results and discussion. It narrates the results in detail and discusses the logical connections with the results of formerly conducted studies.

Chapter VI It includes conclusions and recommendations. It is the final chapter which concludes the findings of every chapter and also gives clear recommendations. It also points out the constraint of the research defines the scope of future research. Annexure are attached in the end along with the questionnaires.

CHAPTER 2 LITERATURE REVIEW

2.1 BACKGROUND

Discoveries do not emerge out of the blue; rather, they are founded upon the findings of previous research work and investigations. In order to develop deep insight about the background of our research topic and to be acquainted with what has gone before, we conducted a thorough literature review. The prominent derivation in this connection is that this topic attained attention of researchers for short span of time in the past century. During the quest of literature exploration, ample research work conducted after 2000 was found on this subject. In this chapter, I provide a review of the existing literature on the theme of this research. This chapter explains basic principles of energy efficiency through urban form elements, analyzes the outcomes of previous work and addresses the missing spots.

The warnings of energy concerns first surfaced in 1920s but less attention was paid on to this subject. The energy crises in 1970 brought this subject into mainstream attention worldwide which resulted in significant research work in the field of energy efficiency at building and neighborhood level. Researchers contributed various design and planning principles to link urban development and energy usage in the best efficient manner including project of Homes in village area of Davis, California in the late 1970s. These efforts did not last longer as it lost attention with the settlement of energy crisis. In late 2000s the energy and economic crisis reawakened our attention to this subject. Traditionally, the efficacy of layouts in the conservation of energy is least calculated. City planners are now exploring the urban form elements as a factor of and domestic electricity consumption.

Many of studies conducted to investigate the subject of energy expenditure after 2000 have a close focus on regulating energy consumption through urban form changes and the researcher have done work on domestic electricity consumption mostly in context of European countries.

2.2 FORMER PROMINENT STUDIES

Susan Owens (1986) investigated urban form impact on urban energy performance. Owens floated the idea that the spatial structure (i.e. Urban form) determines energy demand and consumption (i.e. space conditioning and transport) and provides opportunities for alternative energy systems. Owens investigated the energy-efficient characteristics of the spatial structure and found compactness, integration of land uses, self-contained urban units of variable size as the most influential characteristics. Owens described the 'compact city', the 'archipelago pattern and the 'linear grid structure' as the fundamental types of energy-efficient urban forms.

Nielsen L (1993) used regression analysis technique to investigate the implications of socio economic features including household size, monthly income and electrical devices on the electricity consumption. The study considered 1500 households of Denmark. The outcome of research showed that two third of energy usage is directly associated with the socio economic features of household.

Patrick Moriarty (2002) studied the electricity and transport energy demand of prominent capital cities of Australia. He reported that per capita energy consumption increases as we move from core of city to its sub urban areas unless the income group is our control variable. The study findings revealed that within the large cities, inner area households directly useless domestic than households of similar size and income in the outer area of the same city. These differences appear greatest for Sydney and Melbourne, the largest and densest cities. The higher density living does depicted that they need both less residential energy per capita. The study concluded that a little change in domestic energy demand can be brought through efficiency improvements.

Perkins (2003) generated the energy profile of household of Australia. He followed an outward approach from the city center while conducting this research. The scope of his work incorporated the energy profiles of domestic units and transport sectors as well. He reported that a notable change occurs in the level of energy consumption as we move outwards. The prime observation states that energy consumption increases outwards. The statistical analysis indicated that the urban form factors including house location, semi detached nature of houses, and the building design greatly affect the energy consumption. This researcher concluded that household socio-economic characteristics act as prime factor in defining the energy consumption.

Gordon Mitchell (2005) studied urban development; form and energy use in buildings. The study indicated that energy demand of buildings in cities is two times the energy demand of transport sector, meanwhile building stock energy use is sufficiently responsive to urban form to make from a significant determinant of energy demand within a city. The study reviewed urban and regional energy modelling and identified the research gap that existing literature lacks any models of energy related to urban form. However the comparatively unripe nature of urban energy modelling is illustrated by recent ample funding from EPSRC to the academic community for model development within the Carbon Visions Buildings Project. The study adopted different assessment methods at the scale of city and neighborhood. These methods have separate conceptual basis, sensitive to multiple metrics of urban form.

Bartiaux et al. (2005) conducted a comparative analysis between Denmark and Belgium regarding the domestic electricity consumption profile. He took a sample size of 50,000 households in Denmark and Belgium. The purpose of study was to identify the vital factors of electricity consumption from socio-economic and dwelling characteristics. The researcher also considered the role of electrical appliances in electricity consumption. He reported that nearly two third of energy consumption is dependent on the house size, its type and household size in Denmark while 10–30% of electricity usage is depended on the same variables in case of Belguim. He also reported that with the increase in number electrical appliances households electricity consumption increases in linear way.

Ewing & Rong (2008) calculated the impact of urban form elements on domestic electricity usage of the US cities. They reported that vertically packed development leads to less residential energy consumption in comparison with horizontal development. They identified that the energy demand positively relies on household income, and differ with respect to ethnicity and is robustly related to the physical characteristics of housing units. Old houses are less energy efficient than new ones. Energy demand of detached houses is higher than attached ones. Urban form and housing mix changes County wise. Out of 448 counties, the top share of multifamily housing is 99 percent in New York County with a county sprawl index of 352 while the modest is 0.6 percent in New Kent County, VA, with an index of 73. It reveals that compact places are energy efficient.

Ali Soltani et al. (2012) studied the urban features and energy consumption at local level in context of

Iran. Their research investigated the effects of urban features on residential energy consumption at neighborhood level using data gathered through household questionnaires. Two residential districts in the metropolitan Shiraz, Iran, were selected as case study. Different features of the two areas including building density, typology, housing location, parcel size, floor area and construction materials were compared. Ordinary linear regression was used to discover the impact of explanatory variables on energy consumption. It was found that some physical variables such as parcel size, setback, and the number of floors played significant roles in explaining the variances existing in energy use level. The findings of study confirmed that role of high density plays a vital function towards reduction in energy demand. Although, energy demand remained more or less the same by change in age of building and type of façade.

Yekang Ko. (2013) studied the effect of urban form features on residential energy use through the literature review. The study examined climate responsive design principles and linked to research on how several factors affect residential energy use. I.e. housing type, density, community layout and plantation. The researcher summarized study under three categories of experiments followed by simulation modelling and finally statistical analysis of the empirical data. The study indicated that increasing urban density and reducing the sizes of units and lots can contribute to the reduction of energy use for residential neighborhoods. Energy-related incentives and regulations for community design and planning should be introduced. Form-based codes can be implemented to reduce the energy used for space-conditioning. More trees should be planted through municipal tree-planting programs, to reduce the energy demand for cooling. The study suggested an interdisciplinary approach with smart planning, design, and technology can play an essential role in overcoming the challenges of energy in the communities of the twenty-first century.

Arnab & Dustin (2015) explored the links between urban form, land use planning, and energy use. They reviewed existing literature on potential energy savings from compact development; achieving compact development through land use regulations and approaches for coordinating land use regulations regionally. The study findings showed that a clear link between regional governance, urban form outcomes, and energy use exist but questions remain on measuring the impact and communicating the degree to which energy use benefits can offset other real and perceived costs associated with greater land use regulation and regional coordination. The study suggests the ways through which researchers, practitioners, and policymakers can better leverage these connections. The study confirms clear connections between urban form and energy use, and its link to land use planning at a regional scale. Although land use plans and policies may promote more compact development through density minimums, smaller lot sizes, and infrastructure investment for energy efficiency but they remain relatively minor contributor in the discourse on energy planning, primary because regional scale coordination is a necessary aspect of gaining energy efficiency. The study indicated research gap in understanding the pathways and processes along which local governments prioritize regional sustainable development goals and under what conditions it results in more sustainable outcomes over the long term.

Juliane Grobeet al. (2016) studied the association among Urban Structure, Energy and Planning in context of cities in Sweden, Finland and Estonia. This study took stock of the state of energy in urban policy and planning and disclosed potentials of energy-efficient urban development. This study presents relationship between energy and urban structure as an outline to confer the role of urban planning in increasing energy efficiency of cities through three comprehensive case studies of medium-sized cities in Northern Europe: Eskilstuna in Sweden, Turku in Finland and Tartu in Estonia. The research findings shows that in several ways these cities go ahead when it comes to their national climate and energy policies and aspire to set up urban planning as a regulatory instrument to manipulate the city's transition sustainably. Simultaneously, the cities are facing challenges of regional enlargement vs compact urban development. Julian concluded that considering urban form and spatial structure along with the policy context as well as regional drivers and functional relations is a suitable approach for addressing the challenges of energy-efficient urban development.

CHAPTER 3 METHODOLOGY

3.1 INTRODUCTION

In this chapter, the methodology of research work is discussed. To conduct this study, I selected four residential neighborhoods of Islamabad. The definition of urban form and classification of its elements is made through literature. Both primary and secondary data sources are used. Random sampling technique is used for survey. Based on the pre-selected parameters of urban form elements through literature, I created profile of each of the four selected areas of Islamabad. I incorporate the variables of macro & micro level elements of urban form including street pattern, land composition, topology, demographic, housing and environmental characteristics. The energy consumption is reflected by monthly electricity bill. Cross tabulation technique is applied to generate profile of areas. Multivariate analysis is employed to identify the relationship between urban form elements and domestic electricity consumption. The outcome is presented in the form of tables and charts and graphs.

3.2 RESEARCH DESIGN

The definition of urban form and classification of its elements are studied through the literature. Articles related to the definition and elements of urban form, energy impact of urban form, determinants of residential energy consumption and strategies for regulating domestic electricity consumption through urban form features were studied from recognized online journal-repositories.

Kropf (1996) stated that cities and their tissues are constituted by a set of elements of urban form i.e. street pattern, block type, open spaces and buildings combined in a particular way, originating different types of tissues. At low resolution (macro level), the urban tissue includes only the street pattern and blocks. At a high level of resolution (micro level), the tissue include some details such as the open spaces and buildings.

Luz et al. (1982) narrated that the urban form is a combination of macro & micro level elements of urban system. Urban form represents the relation between the outdoors space and buildings, which exist in a given landscape/soil. These are then the elements to be analyzed by themselves, between themselves, and in their relation with other urban elements.

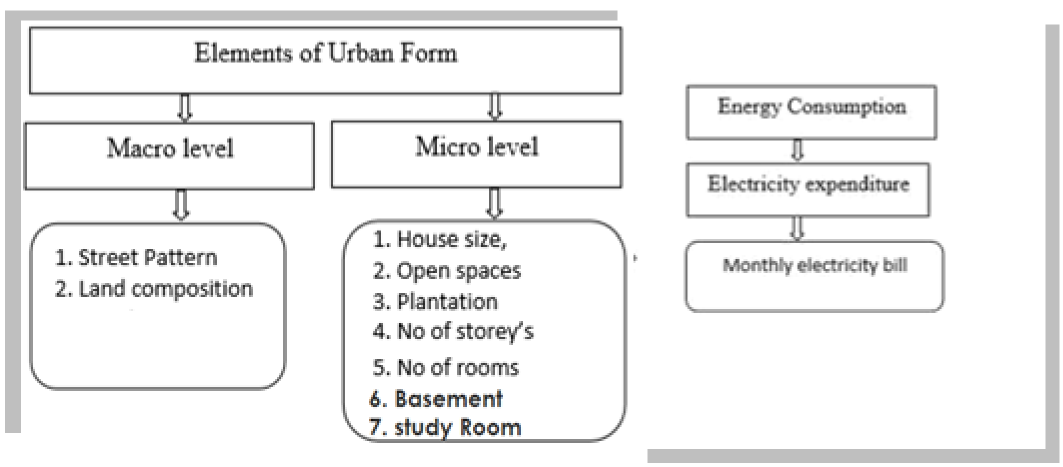


Figure 3.1: The bifurcation of urban form elements

I formulate a site selection parameters and the basis include varied climate range, availability of satellite imagery & departmental layout plans, accessibility to energy billing data and socio-economic data. On the basis of above criteria and considering the proximity, I select the city of Islamabad. Considering the time and financial constraints, I will limit my study site to the few neighborhoods of Islamabad.

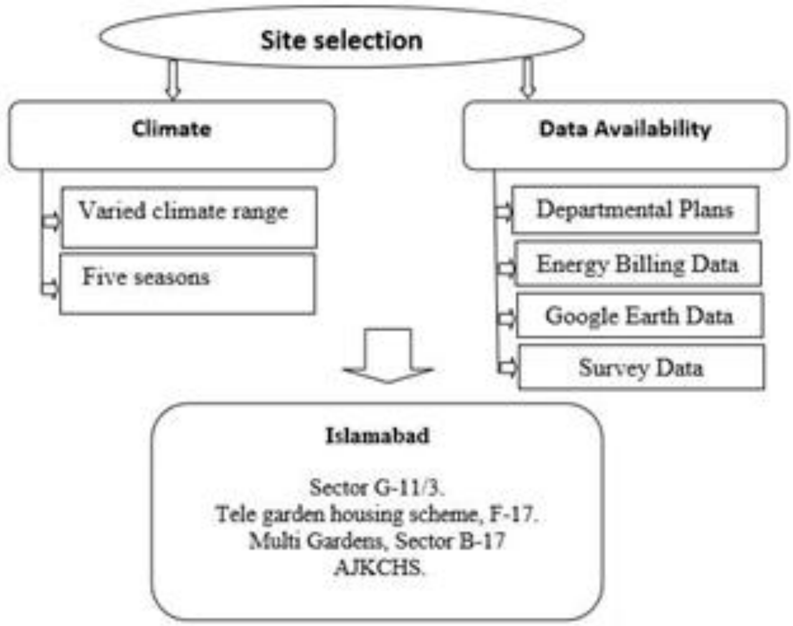


Figure 3.1: The basis of site selection.

3.3 DESCRIPTION OF THE STUDY AREA

The City of Islamabad is the capital city of Pakistan and is located at the northern edge of the Pothohar Plateau and at the foot of the Margalla Hills. Its elevation is 540 meter (1,770 ft). The city of Islamabad has area of 906 square km (350 sq mi). A further 2,717 square km (1,049 sq mi) area is known as the Specified Area, with the Margala Hills in the north and northeast. The southern portion of the city is an undulating plain. It is drained by the Kurang River, on which the Rawal Dam is located. It is comprised of 906.00 km2 area and has a population of 2 million.

The city is administered by Capital Development Authority (CDA). The city's master-plan divides the city into eight basic zones, including administrative, diplomatic enclave, residential areas, educational sectors, industrial sectors, commercial areas, and rural and green areas Islamabad has a diverse range climate with five seasons including winter, spring, summer, rainy monsoon and autumn. The hottest month is June with average temperature 38 °C (100.4 °F).

Fragments of four selected area are studied including sector G-11/3, B-17, F-17 and JKCHS. These areas lie at different locations of the capital city. The location and detail layout of study sites is shown in the figures below.

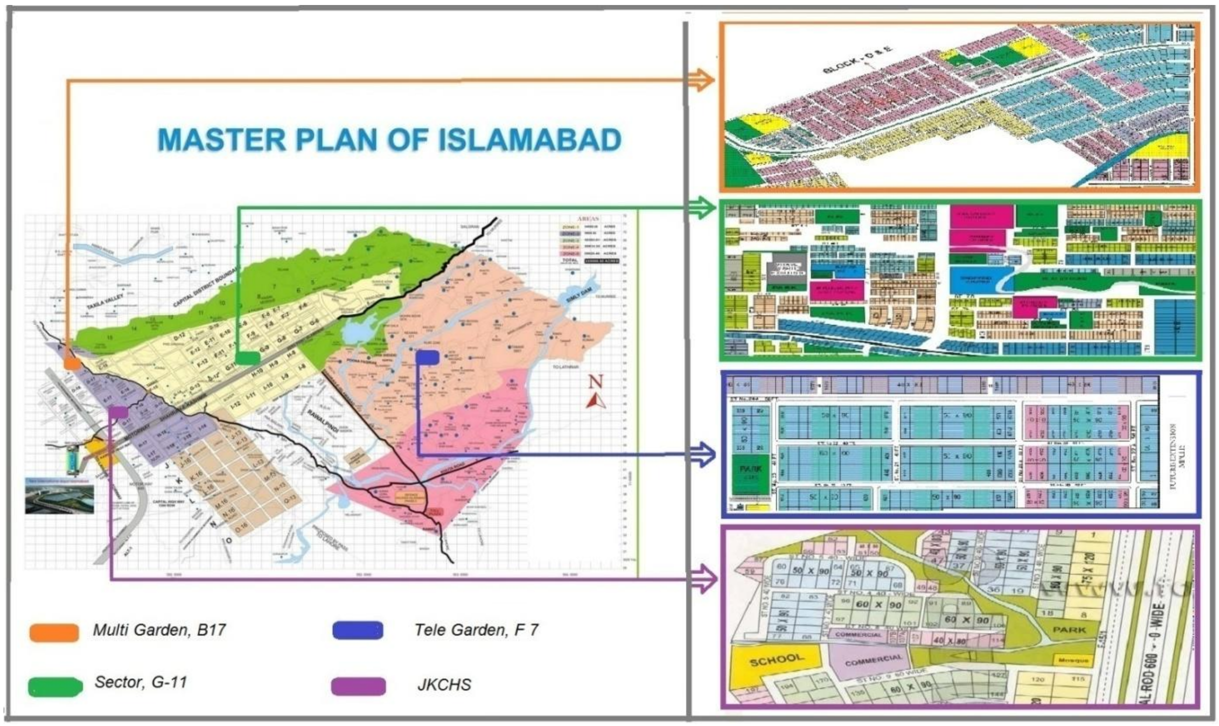


Figure 1.3: The map of Islamabad along with case study areas

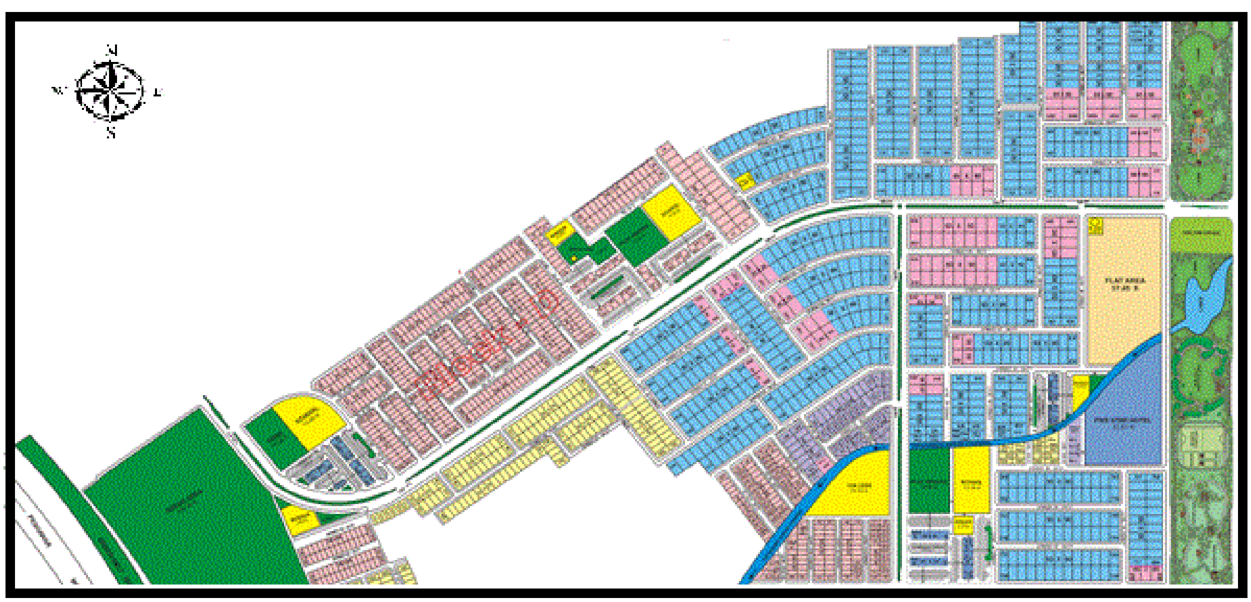


Figure 3.4: The layout plan of Multi garden housing scheme, B-17

Figure 3.5: The layout plan of Tele garden housing scheme, F-17

Figure 3.6: The layout plan of sector G-113

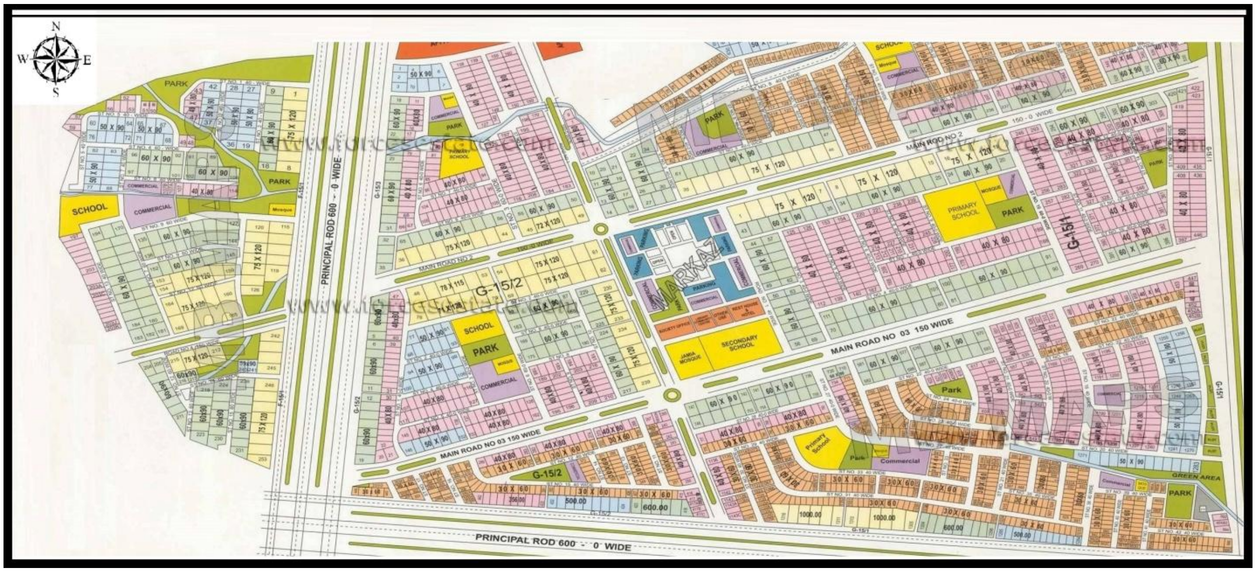
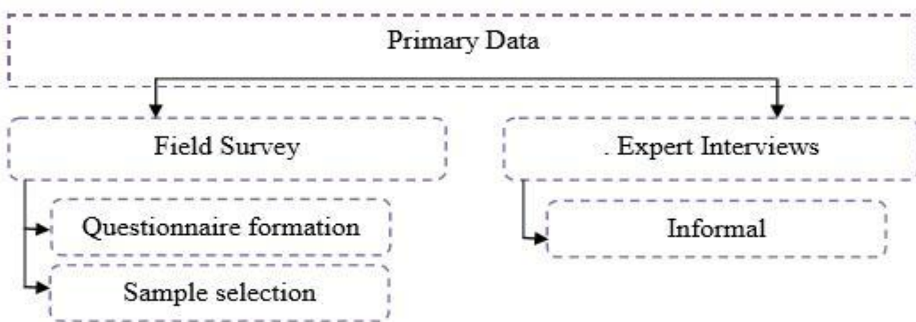


Figure 3.7: The layout plan of JKCHS

In order to conduct this study, an amalgamated data collection method is adopted in which the data requirement is fulfilled through both the primary and secondary sources.

4.1 PRIMARY DATA

The data regarding the pre selected variables of micro elements of urban form is extracted through primary data instruments as illustrated in the figure below. The informal interviews are conducted to formulate questionnaires.



Interviews

To incorporate the deep insight of relevant stakeholders, interviews of experts is conducted. Detail of interviewees and stakeholders are under given in the table:

Field/Sector	**Description of Interviewees**	**Frequency**
Intellectuals	Academicians Practitioners	10
Government Officials	CDA Officers IESCO Officers	10
Private Consultants	City Pulse pvt ltd, Shehar-Saaz pvt ltd, etc.	5
Total		25

Figure 4.1: The mechanism of data collection

4.2 SECONDARY DATA

The data requirement of this study is fulfilled through secondary sources as well in addition to the primary data instruments. The detail of secondary sources is under given.

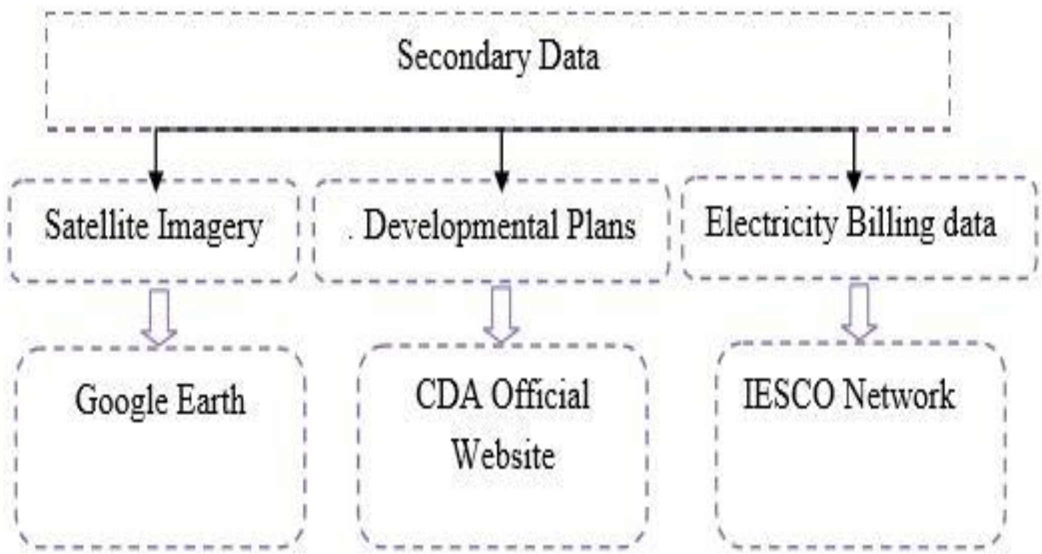


Figure 4.2: The sources of secondary data

4.3 SAMPLING

The number of housing units in selected areas is roughly estimated up to 2200. A 10% sample size is selected. Total no of 200 households were surveyed. Random sampling technique was employed to collect primary data from each of the four selected areas. Questionnaire survey was conducted from all of the four selected areas in even manner with 50 questionnaires from each case study area respectively.

The questionnaire mainly comprised of demographic, housing, environmental and occupant behavioral characteristics. These include specifications like type of household, size of house, building, age and condition, open spaces; plantation etc. some questions were also incorporated related to occupant's energy behavior including major electricity consumption activity, average monthly expenditure on electricity etc. All the relevant dimensions were taken into account while preparing the questionnaire.

4.4 VARIABLE SELECTION

This section describes the process of creating variables to conduct this study. It also provides detailed insight about the level of investigation in the case study area. The elements of urban forms are classified into micro and macro level. I assembled the variable into the factors of occupant behavior, urban form and socio- eco features.

It provides detailed insight about the level of investigation in the case study area. The elements of urban forms are classified into micro and macro level. The individual variable and its indicator source are given in the table below.

Table 4.1

Selection of Variables

Dimension	Variables	Indicator Source
Urban Form	Street pattern	*Downs A, 1994*
(Macro level)	Land composition	*TBR, 2009*
Urban Form	House size	*Mc Loughlin et al., 2012*
(Micro level)	Basement Opens pace percentage	*O' Doherty et al., 2008*

	No of floors	
	No of rooms	
	Plantation	
Socio economic	Income	*Zhou & Teng, 2013*
	Household type	*Bartusch et al., 2012*
	Household size	
	House ownership status	*Sardiano, 2007*
		Chen et al., 2013
Electricity consumption	Average monthly bill	*Yekang Ko, 2013*
	Solar panel installation	

4.5 DATA ANALYSIS

The primary data collected from questionnaire survey and secondary data gathered from Islamabad electricity supply company IESCO is organized and processed in statistical package for social sciences SPSS. Multivariate analysis is employed. The cross tabulation technique, correlation analysis and regression analysis is conducted to generate results. The descriptive statistics and the model outcomes are explained with reference to the findings of formerly conducted research studies. The results obtained from analysis are presented in the form of charts, tables and sheets and are discussed for better understanding.

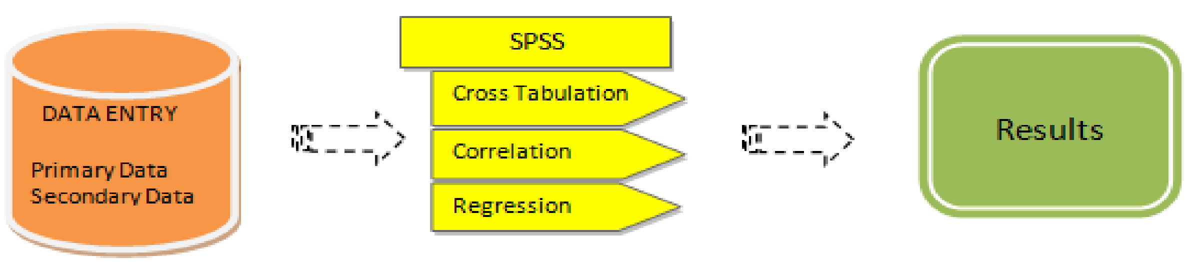


Figure 4.3: The techniques of data analysis

In order to study the correlation between variables, correlation analysis is performed and a matrix is generated representing the r-value of each correlation. The significance level of correlations is assessed through the correlation coefficient scale as shown below. The r values above 0.8 reflect strong correlation, values below 0.5 shows weak correlation and the moderate correlation exists if r value falls in the range 0.5-0.8.

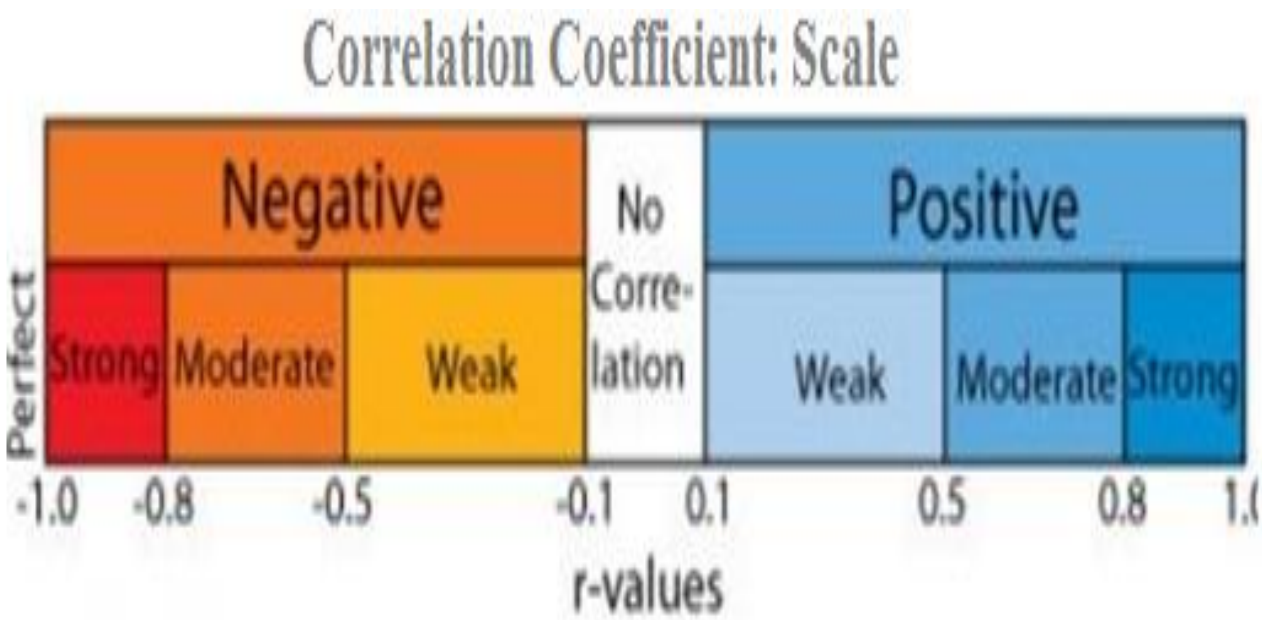


Figure 4.4: The correlation Coefficient Scale

4.6 RESEARCH FRAMEWORK

Adoption of an inclusive research framework is mandatory for a quality research outcome. The following research framework is formulated and followed to conduct this research study.

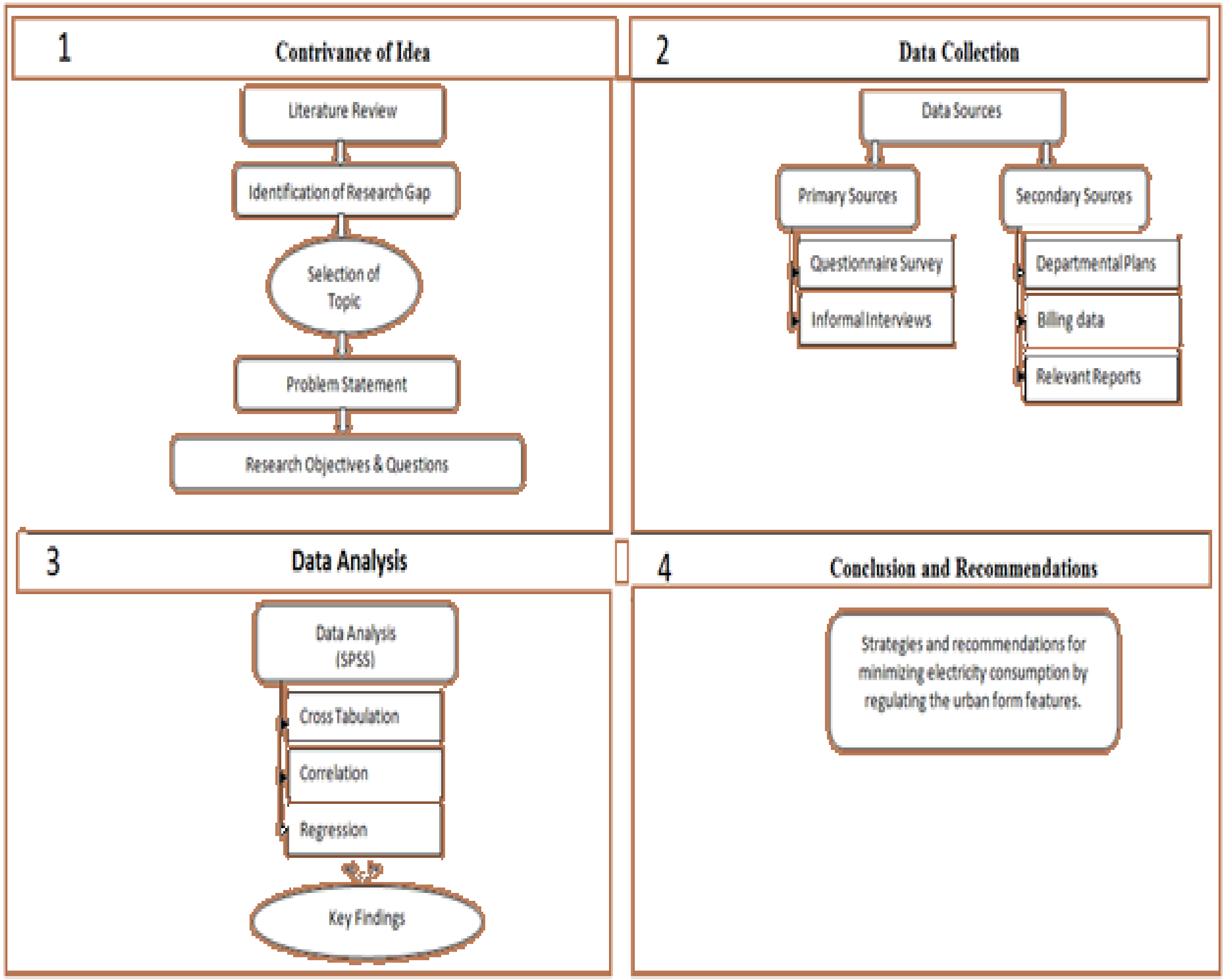


Figure 4.5: The flow chart of research framework

CHAPTER 5 RESULTS & DISCUSSIONS

5.1 DESCRIPTIVE STATISTICS

All the four selected areas of Islamabad are cross examined against the socio economic features and micro characteristics of urban form. The crosstab technique in SPSS is used to carry out this analysis. The individual result is discussed and presented in the form of table.

5.1.1 STREET PATTERN

Cities and their tissues are comprised of multiple elements of urban form including street pattern, blocks, and buildings. The combination of these elements in a particular way, results in different types of tissues. Street pattern gives an area a unique character and makes it identify able.

The four different areas of Islamabad are examined via Google earth to recognize street pattern. The area of G-11/3 with its rigorous grid iron pattern has a central and very compact urban occupation. It shows an extremely regular alignment of blocks with a proportionate more building height. Such street geometry leads to restricted natural ventilation. Givoni (1998) found out that the geometry of high buildings with contracted streets along the direction of wind creates street canyon effect. It produces equal air pressure on both sides of the building and resultantly natural ventilation is restricted. The street pattern in Multi garden, B-17 is predominantly curve linear. More circulation space and clear vista is observed at turning points due to chamfering of lot. It allows more natural ventilation which may reduce load on mechanical ventilation. Golany (1996) concluded that wider streets promote air circulation and improve the natural flow of air inside the building. The JKCHS area shows fragmented linear street pattern having higher percentage of open space compared to build form which results in scattered development with varied heights. It may enhance the ventilation of buildings.

Aggarwal (2006) suggested that the spread out and irregular building height along the slim streets along the wind direction redirects heavy wind to the streets and helps natural ventilation. The Tele garden F-17 comprised of linear street pattern which enables a continuous regular development in this area with most of houses of large size and less no of floors. It may increase the cooling demand. Sharlin and Hoffman (1984) reported that linear street pattern having small aspect ratio ensures additional space for solar access.

Figure 5.1: The street pattern of case study areas

5.1.2 LAND COVER

The land cover refers to the physical material at the surface of the earth. Land covers include grass, asphalt, trees, bare ground, water, etc. The land cover of four selected areas is analyzed according to major broad categories including built space, open space, vegetation and water bodies. The information on land cover is captured through field survey and analysis of remotely sensed imagery.

The vegetation cover is found maximum in JKCHS. Relatively higher vegetation is observed in-tele garden compared multi garden. The G-11 contains least area under vegetation. Yekang (2013) compared the urban form elements and admitted that vegetation plays vital role in the reduction of energy demand for space conditioning through solar access regulation, evaporation transpiration phenomenon and restraining urban heat island effect etc. The built up area ratio is observed maximum in case of G-11 as it is compactly developed. Least built up area is found in JKCHS in scattered manner. A relatively higher share of built space is observed in tele garden compared to multi garden.

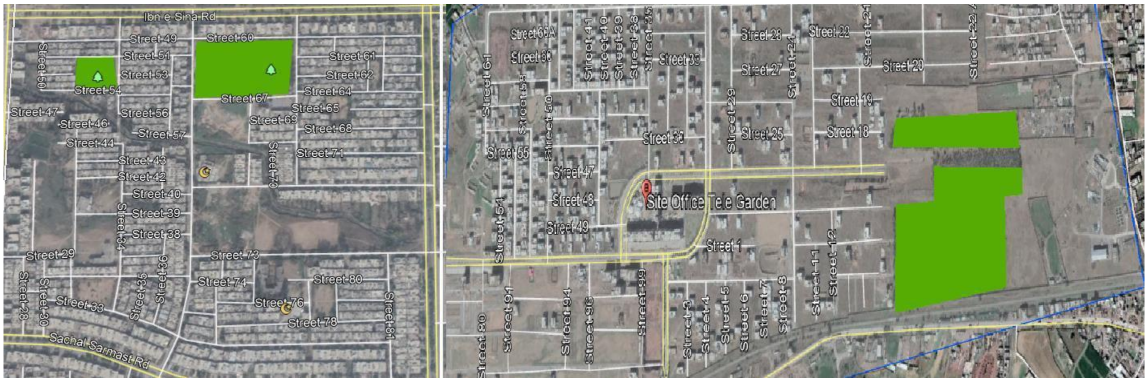


Figure 5.2: The green spaces of case study areas.

5.1.3 SOCIO-ECONOMIC FEATURES

The area wise distribution of household type shows that the overall tendency of nucleus family unit is higher compared to single or joint system in all areas. A higher trend of joint family is observed in G-11 & Tele garden F-17 while in multi garden B-17 & JKCHS the single household type is frequently found.

The distribution of household size reflects that G-11 has the maximum household size and is followed by Tele garden. The minimum household size is found in case of JKCHS which is slightly lower than the household size of Multi garden.

Table 5.1

Socio Economic Features

	Frequency (G-11)	Frequency (Tele garden)	Frequency (Multi garden)	Frequency (JKCHS)
Household Type				
Single	9	7	25	18
Nucleus	23	25	22	27
Joint	18	18	3	5
Dominant Age Group				
Youngster	10	11	6	5
Mature	33	31	37	38
Elder	7	8	7	7
Average Household Size	4.34	3.94	3.68	4.1
Average Monthly Income	94,120	67,860	68,820	64,780

5.1.4 URBAN FORM ELEMENTS

The area wise breakdown of house size shows that maximum ten marla house size is the most frequent in nearly all areas while the least found is one kanal. A trend of smaller house size is observed in Multi garden and JKCHS as compare to G-11 and Tele garden. A low tendency of basement provision in house is observed in all areas. However, least number of basement is found in Multi garden. The minimum ratio of single to multiple floors of houses in case of Tele garden shows that it has maximum number of multistory buildings and each house has four bedrooms on an average. However, majority of single storey houses are observed in JKCHS with least average of bedrooms i.e. 3.38. A moderate blend of single and multistory buildings is found in Multi garden with an average of 4.14 bedrooms per house. Three quarter houses are more than single storey in G-11 having maximum no of bedrooms on an average exceeding 4.5-bed rooms.

The house condition, ownership states and age of building shows remarkable variations. Majority of houses in G-11 and Tele garden are found in normal condition. However, a balanced distribution of houses is observed regarding good and normal condition in case of Multi garden and JKCHS. Only one house out of complete sample is noted in poor condition. The age of house is highest in case of G-11 and that is closely followed by JKCHS. However, the average age of houses drops remarkably in case of Tele garden and Multi garden as compare to G-11.

The result shows that the maximum no of houses in Multi garden lack plantation. The houses in Tele garden have maximum plantation. A mixed trend of plantation is observed in case of G-11 while limited plantation is observed in case of JKCHS. Houses in nearly all the areas are properly ventilated. However, the percentage of open space in JKCHS is observed a bit lesser compared to other areas.

Table 5.2

Table of Urban Form Elements

	Frequency (G-11)	Frequency (Tele garden)	Frequency (Multi garden)	Frequency (JKCHS)
House Size				
3 Marla	1	7	2	7
5 Marla	4	14	21	36
6 Marla	2	1	1	0
8 Marla	7	8	3	1
10 Marla	34	20	20	6
12 Marla	2	0	2	0
Basement				
Exists	17	19	16	19
Doesn’t Exist	33	31	34	31
Single / Multi Floor Ratio	(0.25)	(0.190)	(0.66)	(1.77)
Average No of Bed Rooms	4.58	4.0	4.14	3.38
No of Big Plants				
0	17	11	20	11
1	17	10	17	30
2	15	19	10	9
3	1	9	2	0
4	0	1	1	0
Open Area in House				
15%	1	7	2	7
20%	12	20	24	36
25%	36	22	23	7

G-11	
Frequent Household Type (Joint)	46%
Average Household Size	4.34
Average Monthly Income	94,120
Frequent House Size 10 Marla	68%
Underground Facility/ Basement	34%
Multi Floor Houses	75%
Average No of Bed rooms per House	4.58
Frequent House Condition (Normal)	78%
Houses with big plants	66%
Frequent Open Area in House (20%)	72%
Max. Electricity Consuming Activity Air Conditioning	60%
Willingness to Install Solar Panel	18%

JKCHS	
Frequent Household Type (Nucleus)	54%
Average Household Size	4.1
Average Monthly Income	64,780
Frequent House Size 5 Marla	72%
Underground Facility/ Basement	38%
Multi Floor Houses	25%
Average No of Bed rooms per House	3.38
Frequent House Condition (Normal)	54%
Houses with big plants	78%
Frequent Open Area in House (20%)	72%
Max. Electricity Consuming Activity Lighting & Fan	66%
Willingness to Install Solar Panel	32%

Multi Garden	
Frequent Household Type (Single)	50%
Average Household Size	3.68
Average Monthly Income	68,820
Frequent House Size 5 Marla	42%
Underground Facility/ Basement	32%
Multi Floor Houses	66%
Average No of Bed rooms per House	4.14
Frequent House Condition (Good)	56%
Houses with big plants	60%
Frequent Open Area in House (25%)	48%
Max. Electricity Consuming Activity Lighting & Fan	54%
Willingness to Install Solar Panel	14%

Tele Garden	
Frequent Household Type (Nucleus)	50%
Average Household Size	3.94
Average Monthly Income	67,860
Frequent House Size 10 Marla	40%
Underground Facility/ Basement	38%
Single / Multi Floor Ratio	81%
Average No of Bed rooms per House	4.0
Frequent House Condition (Normal)	70%
Houses with big plants	78%
Frequent Open Area in House (25%)	44%
Max. Electricity Consuming Activity Air Conditioning	32%
Willingness to Install Solar Panel	20%

Figure 5.3: The detailed profile of case study areas

5.1.5 ENERGY BEHAVIORAL CHARACTERISTICS

The residents of houses in G-11 consider air-conditioning as the maximum energy consuming activity while the same is considered as least energy consuming activity by the residents of JKCHS. A trend of high usage of Air conditioner is also observed among the G-11 residents. However maximum usage of fans & lights is observed in case of JKCHS. None of the house in complete sample is found with installation of solar panel. The residents of JKCHS and Tele garden are more inclined towards installation of solar panel in future. The least willingness to install solar panel is observed in case of G-11.

Table 1.3

Electricity Consumption Behavior

	Frequency (G-11)	Frequency (Tele garden)	Frequency (Multi garden)	Frequency (JKCHS)
Max. Electricity Consuming Activity				
Food prep& Preserve	4	11	2	0
Washing & Cleaning	8	13	1	3
Air Conditioning	29	16	20	14
Lighting & Fans	9	10	27	33
Frequently used Electrical Appliance				
Fridge, Freezer, Microwave	4	10	2	0
TV, LCDs, Radio	0	1	0	0
Water Pump, Cloth Cleaner,	29	16	20	14
Air Conditioner, Split Unit	8	13	1	3
Bulbs, Fans	9	10	27	33
Solar Panel Installed				
Yes	0	0	0	0
No	50	50	50	50
Willingness to Install Solar Panel				
Yes	9	10	7	16
No	41	40	43	34

5.2 CORRELATION ANALYSIS

To identify the correlation of socio economic, physical, environmental and behavioral characteristics with the electricity expenditure correlations analysis is employed on a total no of fifteen variables. Data set collected against each variable represents 200 respondents. The results suggest that 24 out of 105 correlations were statistically significant with a p value greater than 0.5. A total of 68 correlations are found positive while rest of correlations is negative out of total 105 correlations. Some of vital values of correlation are discussed below in the matrix shown in landscape.

Table 5.4

Correlation

	AMEE	HT	HS	MI	ALS	DAG	HS	TFs	UF/BH	TBs	SSR	OSH	AH	PCH	TBP	OAP	MECA	FUEA	WISP	TSP
AMEE		.626**	.575**	.878**	.114	.095	.554**	.439**	-.363**	.530**	-.093	-.234**	.360**	.275**	-.441**	.526**	-.416**	-.639**	.226**	-.399**
HT			.679**	.646**	.147*	.121	.468**	.501**	-.105	.506**	.025	-.360**	.167*	.246**	-.163*	.427**	-.390**	-.516**	.226**	-.307**
HS				.586**	.126	-.006	.499**	.418**	-.105	.561**	.116	-.234**	.169*	.126	-.180*	.451**	-.266**	-.403**	.236**	-.063
MI					.139*	.089	.602**	.522**	-.251**	.624**	.016	-.315**	.283**	.213**	-.418**	.589**	-.406**	-.649**	.286**	-.318**
ALS						-.030	.101	.141*	-.057	.150*	.087	-.076	.031	.069	.006	.099	-.134	-.138	-.090	-.094
DAG							.022	-.021	-.073	-.058	-.179*	.061	.103	.015	-.098	.067	-.049	-.089	-.074	.078
HS								.639**	-.011	.798**	.234**	-.307**	.133	.287**	-.155*	.931**	-.345**	-.452**	.095	-.427**
TFs									.046	.796**	.225**	-.349**	.104	.306**	-.121	.605**	-.401**	-.430**	.089	-.370**
UF/BH										.051	.488**	-.094	-.053	-.141*	.271**	.018	.114	.288**	-.142*	.014
TBs											.313**	-.353**	.145*	.229**	-.199**	.750**	-.331**	-.434**	.110	-.304**
SSR												-.228**	.107	-.089	.267**	.230**	-.029	.047	-.003	-.096
OSH													.024	.204**	.095	-.302**	.205**	.249**	-.064	.219**
AH														.320**	-.065	.113	-.027	-.066	.040	-.229**
PCH															-.052	.241**	-.190**	-.209**	.014	-.231**
TBP																-.224**	.015	.245**	-.066	-.082
OAP																	-.279**	-.390**	.040	-.376**
MECA																		.820**	-.128	.413**
FUEA																			-.250**	.367**
WISP																				.108
TSP																				

Notes: This table shows the correlation among all the variables. * and ** shows the significance level at 1% and 5%. The total number of observations are 200. AMEE = Average Monthly Expenditures of 3 Years, HT = Type of Household, HS = Size of Household, MI = Monthly Income, ALS = Average Life Spam of Family Member, DAG = Dominant Age Group Among Family Member, HS = House Size, TFs = Total No. of Floors, UF/BH = Underground Facility/Basement in House, TBs = Total No. of Bedrooms in House, SSR = Separate Study Room in House, OSH = Ownership Status, AH = Age of House in Years, PCH = Physical Condition of House, TBP = Total No. of Big Plants in House, OAP = Open Area percentage MECA = Maximum Electricity Consumption Activity in House, FUEA = Frequently Used Electrical Appliances in House, WISP = Willingness to Install Solar Panel in House in Future, TSP = Type of Street Pattern.

.5.2.1 ELECTRICITY EXPENDITURE AND SOCIO-ECONOMIC FEATURES

Majority of formerly conducted studies endorse that demographic characteristics create significant impacts on residential electricity consumption. The socio-economic features upon which correlation analysis is computed are household size, household type, income group, average life span of family members and dominant age group.Through the correlation analysis, this study reveals that energy consumption keeps a high relationship with the demographic attributes. The electricity expenditure is strongly correlated with the majority of pre-selected characteristics in positive manner.

Income appeared to be big influencer of electricity expenditure as per results. A strong positive correlation exists among monthly income and electricity bill which reflects that the electricity demand of rich domestic units is much more than those falling in lower income group. It also points towards affordability and energy behavior of different income groups. A possible explanation for this trend could be high living standard and comfort priority of high income group. The rich households are normally composed of larger number of occupants inclusive of servants and live in big houses. It shows that high income group is less inclined to compromise comfort living and hence consumes more electricity as compare to the low income group. Similar findings have been reported by Paatero and Lund (2005) in their research to predict electricity consumption using household income and other explainable variables. Another study on the energy-saving features and determinants of ownership conducted by O'Doherty et al. (2008) in context Ireland regards income as a leading factor in determining the electricity expenditure. McLoughlin et al. (2012) also concluded in his study that the variable of disposable income has a significant impact on electricity consumption.

The household size and domestic electricity use are significantly correlated positively. It indicates that joint family household consumes more electricity compared to nucleus and single households. With the increase in dwelling occupants, the concurrent usage of electrical devices also increases that increases the electricity demand. In a study conducted to determine the multiple causes of electricity demand in context of Mumbai, Tiwari (2000) claimed that electricity expenditure is dependent correlated with the household size and recognized that families with five members consume 23% more electricity than two-member families.

The higher or lower life span of residents of a house does not affect the electricity expenditure to much extent as average life expectancy has very weak positive correlation with average electricity bill with a P value of 0.114 only. This result might be explained by analyzing the correlation of life span with household size which is quite weak and insignificant. It shows that longer or smaller life span does not necessarily cause rapid change in the number of residents and resultantly energy expenditure remains unaffected. The statistics shows that electricity expenditure is very weakly correlated with dominant age group and this correlation is statistically insignificant. This finding is in concurrence with the former studies of similar nature. Bedir M et al. (2013) studied the determinants of electricity demand in Dutch houses and reported that family composition in term of age do not influence electricity demand. Cramer JC et al. (1985) also found no significant correlation among dominant age group and electricity expenditure while investigating the equity implications of social and engineering determinants on domestic electricity usage. However, some researchers believe that presence of teenagers as dominant group affects electricity consumption. Bartiaux et al. (2005) while studying the influence of Socio-political factors on household electricity consumption reported the significant impact of teenage group on electricity consumption.

A significant negative correlation exists between house ownership status and electricity expenditure. The electricity expenditure of privately owned housing units is more than the rented units. One logical explanation of this outcome might be financial. Ownership is something associated with the wealth and it is predominantly observed that the size of houses on rent are lesser than owned houses. It is common observation that lower income families are more engaged in rented housing so they prefer electricity conservation measures because of financial constraints. Yohanis et al. (2008) established significant correlation between ownership of house and domestic electricity usage in context of Northern Ireland. In a comparison between rented and owned homes Waytt. Et al. (2013) found out owned homes to have high electricity demand.

The findings show low domestic electricity consumption in newer houses. A moderately negative correlation prevails among house age and electricity consumption with a value of 0.36 statistically significant. It is because of the heat loss due to poor insulation as older houses contain outdated insulation techniques. Wiesmann et al. (2011) studied residential electricity consumption in Portugal and reported that new houses have less electricity demand because of improved insulation facilities.

5.2.2 ELECTRICITY EXPENDITURE AND URBAN FORM ELEMENTS

The impact of house size on electricity expenditure is generally linked to its requirement for space conditioning. The correlation is statistically significant with a value of 0.554.

A statistically significant, positive correlation between the size of house and electricity consumption is observed. The electricity demand of house is positively dependent upon its size because more area requires space conditioning in bigger houses. Moreover it might be due to a common assumption that bigger residential units implies larger number of residents and thus, the electricity demand for air-conditioning, cooking and cleaning is higher. Another justification for this result is that bigger houses have more number of rooms as compared to smaller houses. No of rooms and energy expenditure are positively correlated with a value of 0.530 and highly significant statistically. It implies that due to more no of rooms, more electrical appliances are used in bigger houses which elevate the electricity expenditure in comparison with small houses. This result is in line with the previous studies. Nielsen (1993) reported that if floor area of a housing unit increases by 1%, it will elevate the electricity demand by 0.61% in context of Denmark. While studying the domestic electricity consumption in context of Indiana, Filippini (2004) recognized that electricity consumption raised 0.2% with an addition of 1% floor area of household.

The no of floors in a house and its electricity expenditure are found to be positively correlated with high statistical significance as per results. This effect can be explained by the effect of no of floors on space cooling. The houses with multiple floors protects ground floor from heat & sunlight exposure which is likely to reduce its cooling demand. Moreover the common pattern of shifting from upstairs to ground floor in summer and vice versa in winters might also be a positive contributor towards reduction of electricity expenditure. The correlation matrix shows that the presence of basement in a house is moderately correlated to energy expenditure with a high statistical significance. It implies that due to underground nature basements provide best shelter from the exposure of extreme weather and their demand space cooling is low. Hence it is cognitive to assume that residents of houses with basement avail this facility in summer due to which their energy expenditure drops. Fidero (2015) endorsed the positive effect of basement on reduction of space cooling expenditure.

The number of big plants and percentage of open area in house are found to have moderate correlation with the electricity expenditure with high statistical significance. The results shows that percentage open space in house has r =0.526 and p= 5 and is correlated with energy expenditure. This effect might be explained through the space conditioning demand of floor area. More the floor area of house, more will be its cooling demand. Furthermore the natural ventilation of house through more open space is likely to reduce the expenditure incurred on mechanical ventilation.

The no of plants in house is negatively correlated with energy expenditure with a high level of statistical significance. Houses with greater number of big plants are likely to have less electricity expenditure. The results shows that no of big plants in the house has r =(0.441) and p= 5 and is correlated with energy expenditure. The rationale behind this finding is the eco friendly nature of plants and their positive effect on the surrounding area. The plants in house produce cooling effect which lowers the demand of space cooling. Haggag (2017) reported that plants has a significant effect on the cooling demand of house and reported an energy saving of up to 23.96% in hottest month by mitigation of heat gain in indoor spaces as a strategy to lower cooling demand through the optimum placing of plantation.

5.3 SOCIAL STATUS CLASS

Income is generally considered as key indicator of social status but it does not reflect the complete picture of social status of respondent. To ensure a comprehensive representation of all the potential indicators affecting social status of respondent, a separate variable of social status is generated by computation and z value of relevant variables. Income level, house ownership status, appliances ownership is mainly considered to formulate social status class. This variable of social status class is then analyzed against the prime indicators of electricity expenditure, socio economic features and elements of urban form.

5.3.1 SOCIAL STATUS CLASS AND ELECTRICITY EXPENDITURE

The willingness level of mediocre is highest regarding installation of solar panel. Rich showed least concern about solar panel while poor is moderately attracted to the benefits of solar panel. The possible explanation for this trend could be financial constraints.

Table 5.5

Solar Panel Willingness

	No	Yes	Total
Poor	83	16	99
Mediocre	70	25	95
Rich	3	3	6
	156	44	200

The analysis revealed that air conditioner is the prime electricity consuming appliances among the mediocre group. The poor group showed more inclination towards the light and fan as the most frequently used appliance in the house. All the social class, each group rated cleanliness related electrical appliances at low rate.

Table 5.6

	Fridge & microwave	AC & Heater	Water Pump	Lights Fan	Total
Poor	6	13	19	60	99
Mediocre	10	60	6	19	95
Rich	0	6	0	0	6
	16	79	25	79	200

5.3.2 SOCIAL STATUS CLASS AND URBAN FORM ELEMENTS

A higher trend of study room facility is observed in mediocre group while the inclination of rich group is found least towards provision of separate study room in the house. Poor group closely follow the trend of mediocre.

Table 5.7

House Size

	No	Yes	Total
Poor	79	20	99
Mediocre	72	23	95
Rich	3	3	6
	154	46	200

The poor group has least no of rooms in house with only few houses having more than five rooms. Majority of houses have three rooms per house. Moderate number of rooms are observed in case of mediocre group with maximum houses having five rooms while a trend of maximum number of rooms up to eight rooms prevail among the rich. These trends are possibly due to the differences in living style and financial well being of residents.

Table 5.8

Total No of Rooms in House

	2	3	4	5	6	7	8	9	Total
Poor	23	44	17		12	3	0	0	99
Mediocre	4	8	14		60	7	2	0	95
Rich	0	0	0		3	0	2	1	6
Total	27	52	31		75	10	4	1	200

Grid iron pattern is observed to have maximum number of mediocre households which is closely followed by linear curve pattern. Fragmented linear accommodates majority of poor households. Ina addition, Grid iron also accommodates rich.

Table 5.9

Type of Street Pattern

	Grid Iron	Linear	Curve Linear	Fragmented Linear	Total
Poor	12	29	23	35	99
Mediocre	33	21	26	15	95
Rich	5	0	1	0	6
	50	50	50	50	200

Overall trend of basement provision is low among all social classes. The provision of basement facility in poor is maximum which is weakly followed by the mediocre. However the rich shows a total negative trend of basement provision in the house.

Table 5.10

Basement in House

	Doesn't exist	Exist	Total
Poor	54	45	99
Mediocre	69	26	95
Rich	6	0	6
Total	129	71	200

The majority of houses of mediocre are double storey. All the houses of rich are double storey while a mixed trend of single and double storey houses is observed in case of low social class which is closely led by single storey houses.

Table 5.11

Total no of Floors

	1	2	3	Total
Poor	59	40	0	99
Mediocre	11	81	3	95
Rich	0	6	0	6
Total	70	127	3	200

5.4 REGRESSION ANALYSIS

Regression analysis is more decisive in studies where cause and effect relationship are desirable. On the other hand, it is different from correlation analysis in the sense that correlation analysis can only tell the relationship among two variables. However, regression analysis not only describes the relation between two variables, it also shows the direction of variables i.e. cause and effect. We have data from 200 households. Regression analysis is employed to develop a model for predicting changes in energy consumption from eight predictor variables. The dependent variable is average monthly electricity expenditure of 3 years. Before conducting the regression analysis, the data normality test is executed to generate the normality curve and to know the distribution of our data set.

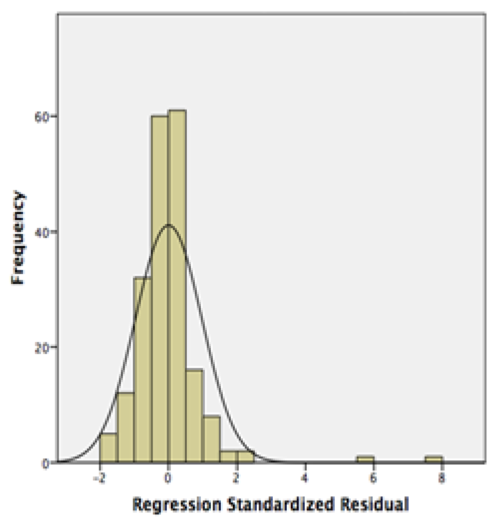


Figure 5.4: The histogram of regression

The graph depicts that normal distribution range is between -3 and +3. Standard deviation value is 0.969 which lies in the middle of range and shows that the data is normally distributed. The dependent variable is continuous. One of the assumptions of regression analysis is that the residuals from the regression should normally be distributed with mean of zero and constant variance. The graph shows that the regression analysis is suitable for this data set and results are likely to be conclusive.

Table 5.12

Model Summery

R	R Square	Adjusted R Sq	Std. Error of the Estimate
.740[a]	.548	.519	2213.34794

Dependent Variable: Average Monthly Energy Expenditure of 3 years.

Predictors: (Constant), Total No of Big Plants in House, Physical Condition of House, Basement in House, Age of house, Separate Study room, Open Area %age, Total Number of Floors, Total Number of Bedrooms, Size of House.

The R square value is about 54.8% which shows the variations in energy consumption explained by the independent variables. However, simple R square values might be misleading because this value is not adjusted for the inclusion of more variables. It is quite possible that the simple R square may increase by including irrelevant or redundant variable in the model. To resolve this issue the adjusted R square is a more reliable statistic. The adjusted R square value shows that 51.9% variations in energy consumption are explained by the dependent variables. This means that a significant portion of the energy consumption is well explained by the independent variables.

Moreover, since our data is cross sectional which varies across households therefore, normally the R square values are not that high. The F- statistic shows the overall fit of the model. Df shows the degree of freedom.

Table 5.13

ANOVA Statistics

	Sum of Squares	df	Mean Square	F	Sig.
Regression	1111540152.860	12	92628346.072	18.908	.000b
Residual	916096001.806	187	4898909.101		
Total	2027636154.667	199			

Basic descriptive statistics and regression coefficients are shown in below table. Each of the predictor variables has a significant ($p < 0.1$) zero-order correlation with energy consumption. The eight predictor model was able to account for 54.8% of the variance in electricity consumption. Diagnostic tests show that the regression model is statistically good. The F-statistics shows are 18.908 with corresponding P-Values of 0.00. It shows that the overall model is statistically stable and good. Moreover, the adjusted R-square value is .519. It implies that 51.9% of the variations in average energy consumption are explained by the independent variables.

Table 5.14

Regression Model

		B	Std. Error	Beta	T	Sig.
Constant	A	3252.519	2047.498		1.589	.114
Size of House	SH	30.222	150.347	.027	-.201	.841
Physical Condition of House	HC	510.117	386.164	.079	1.321	.188
Age of house	HA	349.089	103.075	.191	3.387	.001
Total Number of Floors	TF	1574.721	538.405	-.249	-2.925	.004
Basement in House	BH	-1726.25	393.709	-.259	-4.385	.000
Total Number of Bedrooms	TB	749.022	275.377	.301	2.720	.007

Study room	SR	477.740	486.590	.063	.982	.327
Open Area %age	OA	39.512	113.020	.041	.350	.727
Total No of Plants	TP	-716.504	194.904	-.210	-3.676	.000

Whereas:

t = T- Statistics,

β =*Beta Coefficient of independent variable*

Sig = Percentage of doubt.

Based on this analysis, we have recommended that the electricity consumption is closely related to urban form elements. Hence they require to be optimized to minimize the electricity demand. Six out of eight predictor variables affect electricity consumption in positive manner while two variables have negative impact on energy consumption. For example, the Size of house positively affects the electricity consumption. The results are statistically significant at 1% level. The coefficient value is 0.027. It implies that as the size of house increases by 1 unit, it will lead to increase the electricity consumption by .02 units. Moreover, the larger the size of the household the more the energy consumption would be. This is quite logical as the demand for energy increases with an increase in the number of members in the house.

The results indicate that there is linear association between physical condition of house and average energy expenditures. It is found that the better the physical condition of the house is the greater are the expenditures on energy. However, the results are not statistically significant as the p-values exceed the standard limit of 10%. So, it asserts that although there is positive relationship between the physical condition of house and energy expenditures, but this relationship is not very important.

The age of the house has a statistically significant relationship with average energy expenditure. It implies that as the house getter older it will lead to an increase in average energy expenditures. Alternatively, consumers will spend more as the age of the house increases. This relationship is stronger statistically as the T-Stats are 3.387. The average energy expenditures is negatively related to the number of floors in a house. Intuitively, there should be a positive association among these two. However, results show the contrary. It is observed that as the number of floors increases the energy expenditures decreases. Again, this relationship is significant at 1% level.

Consistent with the above results regarding number of floors, it is also observed that there is negative relationship between houses in which basement facility is available and energy expenditures. This is logical since basements are normally less warm therefore appliances such as fans and air conditions are randomly used, it leads to reduce the cost on energy. This relationship is also statistically very strong.

Next, we test the impact of the number of rooms in a house on average energy consumption. It is found that there is direct relationship between these two variables. It shows that people will consume more on energy as the number of rooms increases. These results are significant at 1% level. It is also explored that how the energy expenditures are affected if there is a separate room is allocated for study purposes in the house. Although, results show that houses in which separate room is allocated for study purpose increases the energy expenditures, but these results are uncertain as the statistical association is weak.

In equation one the dependent variable is energy consumption denoted by Eci. Where i is for the household which ranges from 1 to 200. The right hand sided of the regression shows the independent variables. Intercept is donated by α which captures the average energy consumption of the house hold if all other factors effect is held constant. Betas are the coefficients to be estimated using the ordinary least squares method.

Moreover, beta shows the sensitivity between the dependent and independent variables. The error term is donated by Ei. In this model we test the following hypotheses.

H1: There is significant relationship between energy consumption and size of house.

H2: There is significant relationship between energy consumption and age of house.

H3: There is significant relationship between energy consumption and number of floors in house.

H4: There is significant relationship between energy consumption and basement in house.

H7: There is significant relationship between energy consumption and no of bedrooms in house.

H8: There is significant relationship between energy consumption and big plants in house.

Equation 1

Model Equation

$$Eci = \alpha + \beta i(SH)i + \beta i(HA)\, i + \beta i(TF)i + \beta i(BH)i + \beta i(TB)i + \beta i(TP)I + Ei$$

Whereas: SH represents size of house, HA represents house age, TF represents total number of floor, BH represents basement in house, TB stand for total number of bedrooms, TP represents total number of big plants., α is constant, β is beta coefficient of independent variable and Ei is the error term.

CHAPTER 6 CONCLUSION & RECOMMENDATIONS

6.1 CONCLUSION

This study concludes that micro elements of urban form have a significant influence over the domestic electricity consumption. The size of house and no of rooms are positively correlated with the electricity consumption as with each additional room the no of energy consuming appliances and the space cooling requirement also increases. The presence of underground basement and trees in the house negatively affect the electricity consumption. It is found that the houses with basements and trees have relatively less electricity expenditure. It is due to the cooling effect of plantation.

This research concludes that the macro level elements of urban form also influence the energy consumption in a lighter way. The electricity expenditure is dependent on the composition of land cover and street pattern. The areas with more green space and plantation require slightly less space cooling due to cooling effect of vegetation while in the curvilinear pattern the natural ventilation is maximum as compare to the evenly spaced grid pattern because of wind canyon effect which reduces load on its mechanical ventilation system and resultantly affects the energy expenditure. The rigorous grid iron pattern in G-11 has a central and very compact urban occupation having regular alignment of blocks with a proportionate more building height. Such street geometry leads to restricted natural ventilation as it creates a straight wind tunnel (street canyon) increases wind speed. High wind speed exposes buildings to the same air pressure on both sides, thus reducing the natural ventilation of the buildings.

Due to curvilinear street pattern Multi garden, B-17 has more air circulation space and clear vista is observed at turning points due to chamfering of lot. It allows more natural ventilation which may reduce load on mechanical ventilation. The fragmented linear street pattern of JKCHS with higher percentage of open space enables the natural ventilation of buildings. The linear street pattern of Tele garden, F-17 with continuous regular development of large size houses and less no of floors makes it moderately ventilated.

The descriptive analysis concludes that the residents of houses in G-11 consider air-conditioning as the maximum energy consuming activity while the same is considered as least energy consuming activity by the residents of JKCHS. A trend of high usage of Air conditioner is also observed among the G-11 residents. However maximum usage of fans & lights is observed in case of JKCHS. None of the house in complete sample is found with installation of solar panel. The residents of JKCHS and Tele garden are more inclined towards installation of solar panel in future. The least willingness to install solar panel is observed in case of G-11.

This study concludes that the social class of residents (inclusive of Income level, house ownership status, electrical appliances ownership) affects the socio economic features and elements of urban form both of which are prime factors of electricity expenditure. The air conditioning is the prime electricity consuming activity among the mediocre group while the poor group uses fans for the same purpose with additional cooling effect of trees. All the social class rated cleanliness related electrical appliances at low rate. The poor group has least no of rooms in house with only few houses having more than five rooms. Majority of houses have three rooms per house. Moderate number of rooms are observed in case of mediocre group with maximum houses having five rooms while a trend of maximum number of rooms up to eight rooms prevail among the rich. These trends are possibly due to the differences in living style and financial well being of residents. The mediocre households are abundant in Grid iron pattern with majority of double storey houses which is closely followed by curve linear pattern. Fragmented linear accommodates majority of poor households with a mixed trend of single and double storey houses. In addition, Grid iron also accommodates rich with all the houses having more than storey. On the whole, among all social classes the trend of basement provision is low. The mediocre is already at the moderate level of electricity consumption with moderate number of rooms and blend of multi storey buildings while the potential of reduction in electricity consumption is high in rich class.

It is concluded that the social class and energy expenditures increase with an increase in the size of the household. As it is obvious bigger the size of the household more would be the energy expenditures. It implies that smaller families consume less energy and have less expenditure.

6.2 RECOMMENDATIONS

This research recommends that by regulating micro elements of urban form decrease in domestic electricity consumption can be achieved. Some of the electricity demand reduction steps entail socio economic changes which require long term workout including changes in household characteristics. In addition, the changes in the micro level elements of urban form may require relatively less duration and create significant impact of electricity demand reduction.

Basement provision in the houses is one of the prime recommendations for reduction in domestic electricity consumption as it provides well insulated environment and reduces the exposure to harsh external weather which in turn reduces the energy demand for space conditioning. Incorporated more open to sky area in the building design is also recommended as electricity demand reduction measure as with proper geometry it enables natural ventilation and reduces the per square foot area of space cooling. It is also recommended to keep number of rooms proportionate to the occupants and avoid any unnecessary rooms in the house design as each additional room adds lighting, cooling and other electrical appliances into the electricity consumption list. The regulatory body should incorporate basement provision and upper limit of rooms as mandatory element in the building by laws.

It is highly recommended to pay special focus on the plantation of trees suitable to the local climate and maximize the number of trees inside the house along the boundary wall as it is a natural and free of cost method of natural cooling whose continuous effect supports noticeable reduction in mechanical cooling demand. However, selecting the ideal position for tree plantation is very important. It is recommended to plant maximum trees on north side and avoid plantation on southern side as both the rise and set positions of sun are displaced towards the north in the mid summer towards south in winter hence it will reduce sun exposure during summer and allow maximum sunlight in the winter season. Municipal tree plantation programs at household level should be announced to encourage plantation among the residents.

It is also recommended to pay focus on reduction in household size to reduce load of electricity consumption as the electricity demand is correlated with the number of occupants. The less number of occupants will require lesser electricity. Overcrowding of housing stock should be avoided by curtailing haphazard urban rural migration on the analogy of Chinese urban migration policy. Based upon the electricity demand implication of macro level urban form elements, it is recommended to promote curvilinear pattern as it enhances natural ventilation. The development authorities should encourage the developers of housing schemes to adopt curvilinear layout by introducing tax concession policy.

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ANNNEXURE

NATIONAL UNIVERSITY OF SCIENCES & TECHNOLOGY, PAKISTAN.

RESEARCH QUESTIONNAIRE

Master's Thesis Survey

"Impact of urban form elements and socio economic features on domestic electricity consumption."

A case study of Islamabad.

Respondents Information:

Name ________________________________ Address: ________________________________

Occupation ____________________________ Gender: _______________ Age: ____________

Meter Reference No____

Socio Economic Characteristics

Q.1. What is the type of your household?

a. Single b. Nucleus c. Joint d. Other __________

Q.2. What is the size of your household?

a. 1 to 3 Members b. 4 to 6 Members c. 6 to 8 Members

d. 8 to 10 Members e. other __________

Q.3. What is the average life expectancy of your family?

a. Below 35 b. 35 to 45 c. 46 to 60

d. 61 to 80 e. Other__________

Q.4. What is the dominant age group in your family? (Please specify ratio _________)

a. Youngsters (<30) b. Mature (31-50) c. Elders (>51)

Q.5. In which of the following income group your family falls?

a. Below 30 k b. 31k to 50k c. 51k to 75 k

d. 76k to 99k e. 100k to 150 k f. Other ________________________

Housing Characteristics

Q.1. What is the size of your house?

a. < 5 M b. 5 -10 M c. 11 -20 M d. >1 K e. Other ________________

Q.2. What is the condition of your house?

a. Good b. Normal c. Poor d. Worst

Q.3. What is the ownership status of your house?

a. Owned b. Rented c. On Lease d. Other___________

Q.4. What is the age of your building?

a. < 5 years b. 5 -10 years c. 11 -20 years d. Other ___________

Q.5. What is the number of floors in your house?

a. Only G- floor b. G+1 c. G+2 d. Other____________

Q.6. Is there any basement in your house?

a. Yes b. No c. Yes, but not operational

Q.7. Is there any study room in your house?

a. Yes b. No c. Pls specify no ______

Q.8. What is the percentage of open area (open to sky) in your house?

____

Q.9. Is there any big plant/tree in your house?

a. Yes Please specify number _________________ b. No

Electricity Consumption Characteristics

Q.1. What is your average electricity bill per month? Please specify a range.

a. In Summer ____

b. In Winters ____

Q.2. What are the major contribution appliances in energy consumption in your house?

a. Fridge/ freezer b. TV c. AC/ Electric Heater d. Water Pump

e. Microwave Oven f. Other _______________

Q.3. Which activity do you consider consumes maximum electricity in your house in normal days?

a. Food preparation b. Cloth Washing c. Air conditioning d. IT based social activates e. TV/Music f. Other activity ______________________

Q.4. Do you have solar panel installed in your house?

a. Yes Please specify capacity _______________ Dominant usage ____________________

b. No Are you willing to install in future ____