Development of a Statistical Model for Household Electrical Appliances: A Case Study Hillingdon Borough of London in the UK

By

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ABSTRACT

Many studies have conducted in the past that related to the domestic energy sector and households' appliances. These previous studies have explained the energy trends in the United Kingdom. In addition to this, the past studies have also provided wealth of information. However, all of these studies had some limitations. In addition, there were many gaps in the past studies regarding to the timing of usage the household's appliances and their daily contribution to the daily and peak demand. In this study, the researcher intended to overcome the limitations and gaps regarding the appliances time of use in the UK.

In the present study, the data collected from Hillingdon Borough of London to ensure the study use the most reliable and valid data. Most importantly, suitable sampling and data collection technique applied in this study, which helped to obtain the appropriate data and outcome. All respondents were from the domestic sectors of the United Kingdom. Apart from this, to measure energy consumption in a more accurate manner, home appliances were categorised into several categories based on their functionality. Moreover, the household's appliances were categorised into time categories based on the time of use the appliances in order to determine the contribution of individual appliances at a certain time slot of the day to the total household consumption. Finally, the recommendations that have suggested in this study based on the current study as well as past studies. This means that the recommendations are a combination of all the major studies conducted.

Additionally, based on the time a category of the household's appliances, a model was introduced that helped to determine how much of electrical appliances energy consuming in the UK households. Based on this model, the appliances consumption can managed and controlled. Thus, the model will help in mitigating the chances of the energy peak demand and will contribute towards energy and cost savings. Further, this study provides a valuable contribution to the field of smart homes as through the developed model, people can design a more efficient smart home. This specific method of determining energy demand has made the study more appropriate to forecast the 24h electricity demand and electricity price.

DEDICATION

I dedicate this work, to my great mother (Salma M. Ali), may Allah forgive her, to my wonderful father (Ali M. Sheboniea), may Allah protect him, to my fabulous brothers and sisters, for their love and support.

I am truly grateful for your endless support.

Mussa Ali M. Sheboniea

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Finally, I would like to thank my family for their continued support and encouragement.

Author's declaration

I, Mussa Ali M. Sheboniea, declare that this research completely my effort, except where otherwise acknowledged. In addition, I certify that this thesis contains no material that has submitted previously, in whole or in part, for the award of any other academic degree or diploma except where otherwise are indicated.

Mussa Ali M. Sheboniea
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Table of Contents

List of Figures

List of Tables

List of Appendixes

Abbreviations

AC/DC	Alternating current Direct current
AER	Appliances efficiency rate
ANOVA	Analysis of variance
CES	Current employment status
CATREG	Categorical regression
CFLs	Compact fluorescent lamps
DEMS	Domestic energy management system
DECC	Department of energy and climate change
DVD/CD	Digital versatile disc/Compact disc
DSM	Demand side management
EST	Energy saving trust
EPRI	Electric Power Research Institute
Euro ACE	European Alliance of Companies for Energy Efficiency in Buildings
FIT	Feed in tariff
HEUS	Household electricity use survey
HES	Household electricity survey
HDCA	Heavy-duty cooking appliances
HHS	Hillingdon household survey
HHM	Hillingdon household model
IEA	International energy agency
LED/ LCD TV	Light emitting diode/ Liquid crystal display television
LCOE	Levelied cost of electricity
LDCA	Light-duty cooking appliances
LV	Low voltage
LM	Load management
MV	Medium voltage
RG	Respondent gender
NP	Number of people
NB	Number of bedrooms
ONS	National ownerships
NTS	National transportations
NEED	National Energy Education Development Project

PV	Photovoltaics
PEV	Plug-in electric vehicle
SPSS	Statistical Package for the Social Sciences
S	Summer
TH	Type of household
W	Winter

Journal and Conference Publications

Journals Publications

1. Sheboniea Mussa Ali, Mohamed K. Darwish, and Al Janbey, Review of UK Domestic Electricity Consumption and Potential Trends in Using Renewable Energy Sources and Plug-in Hybrid Electrical Vehicles, *International Review of Electrical Engineering (IREE)* Vol. 10 N.6 (2015).

2. Sheboniea, Darwish, Janbey, Measuring Factors Affecting Use of Household Daily Appliances by Using Categorical Regression Analysis: A Case Study of UK Households, *International Journal on Energy Conversion (IRECON),* Vol 4, No 4 (2016).

3. Sheboniea, Darwish, Janbey, Load Profile of a Typical Household Electrical Appliances and Potential Load Shifting Scenario in the UK, *International Journal on Energy Conversion (IRECON),* Vol 4, No 5 (2016).

4. Sheboniea, Darwish, Janbey, Measuring Factors Affecting Use of Household Cooking Equipment and Appliances by Using Categorical Regression Analysis: A Case Study of UK Households, *International Journal on Energy Conversion (IRECON),* Vol 4, No 5 (2016).

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6. Relative Daily Contribution of Household Cooking Equipment to the Peak Period Electricity Demand: A Case Study of UK Households" *International Journal on Energy Conversion (IRECON), July 2017*.

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Chapter 1 Introduction

1.1 Overview

Energy consumption differs in different countries and depends on number of factors such as; level of development, variety of appliances, introduction and usage of renewable energy sources [1]. Given examples are from countries in Europe, which use great deal energy in households. Data shows that at least 25 % of end user energy consumption is spending within buildings in developed countries, and major proportion of it is needlessly wasted. Furthermore, at least 2-thirds of energy spent goes to small appliances, home electronics, and lighting (Figure 1.1). In order to understand this waste of energy, consumers must be well informed with exact data and use it in the direction of finding better solutions for appliances usage [2]. Additionally, concessions of users and their daily habits (lifestyle) have to be changed, in order to be more effective and not to spend energy needlessly [3].

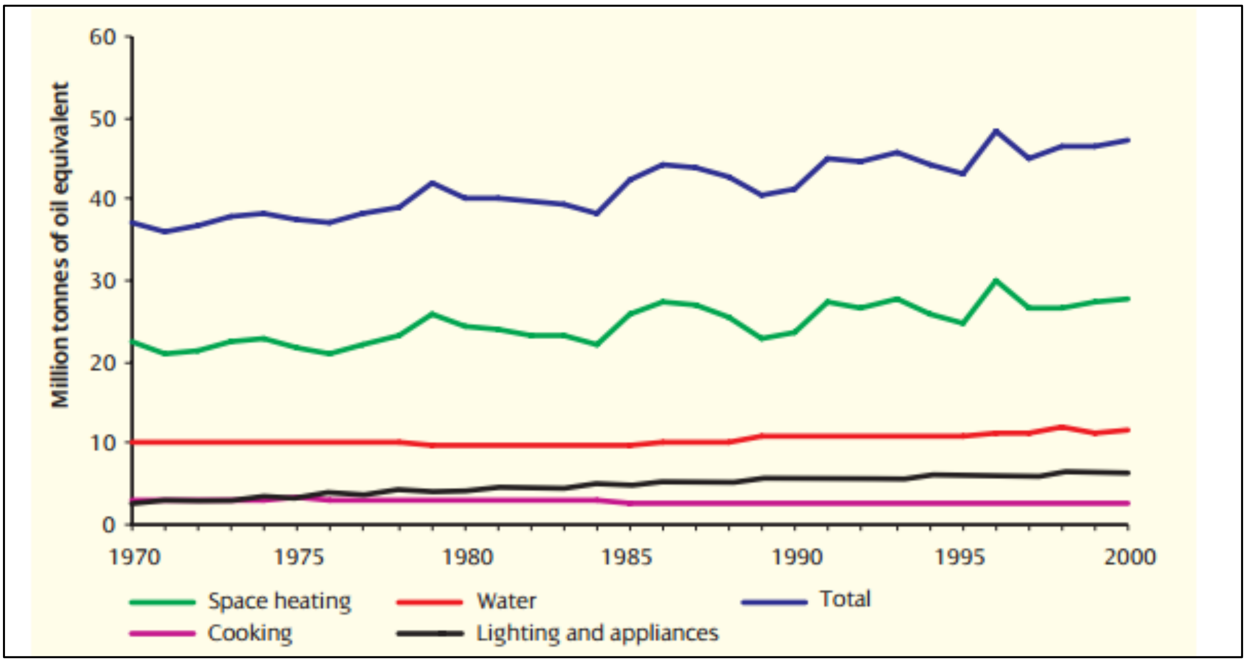


Figure 1-1 Domestic Energy Consumption Based on Space Heating, Water, Cooking and Lighting: [1]

It supposed that 70 % of the world's population will live in urban areas by the year 2030 and this will result in huge sustainable housing and energy demands [4]. Between 1974 and 2014, the world grosses electricity production increased from 6287 TWh to 23815 TWh; an average annual growth rate of 3.4 % (IEA 2016). This points us in direction of believing that a potential crisis can easily occur but before that, many things can be done to avoid such a scenario and decrease energy demands, reorganize consumption, renovate buildings and appliances-overall to improve energy efficiency as proposed by the Euro ACE and European National Strategy. Focusing in the same direction, engineers proposed centralized and distributed approaches in buildings with same goal, to improve energy efficiency [5]. Estimating number of household units, structure of families inside them and finally, inhabitants' behaviours are some of the key factors to approach these problems. Until now, we can say, what data show-energy was needlessly wasted, but the plan is to reorganize and optimize energy utilization by inhabitants "*Behaviour strongly influences energy consumption patterns and is an important factor for energy waste reduction in buildings*" [6].

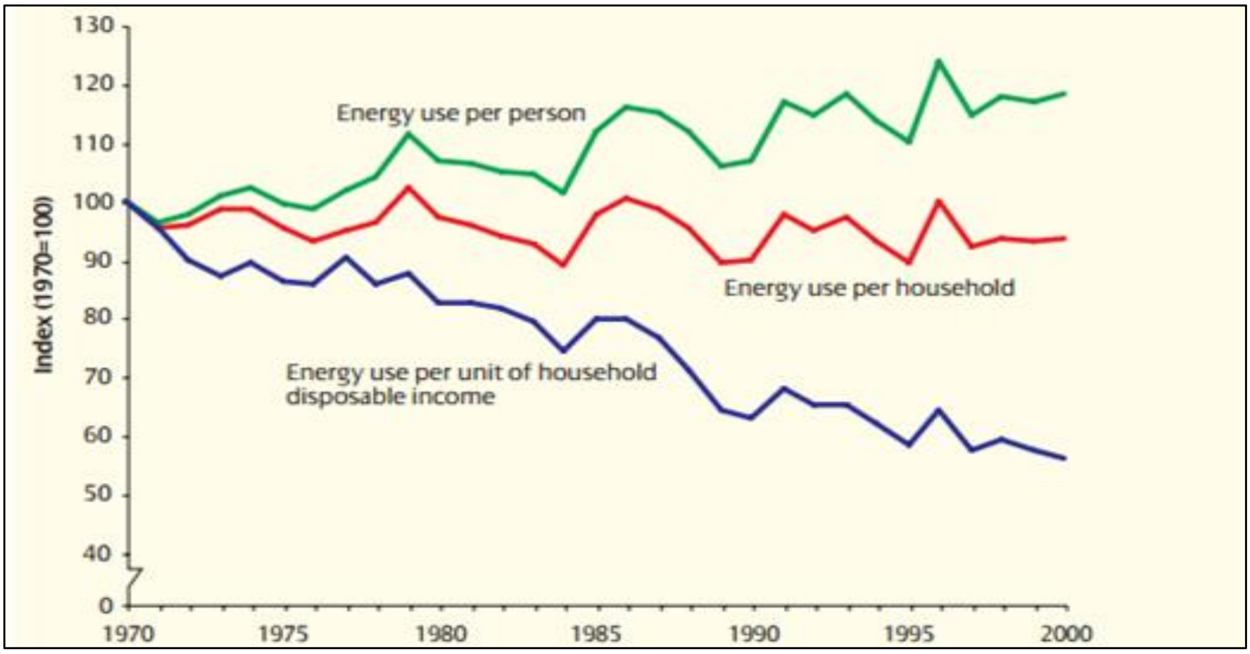


Figure 1-2 *Energy Consumption Per person, per household and per unit of Household incomes* [1]

As shown in Figure 1-2, increase the number of people those working from home affects the time of appliances usage and produced more than peak periods per day. Conversely, the high efficiency appliances rate helped to reduce the energy loads, but not the peak demand due to the high number of appliances been used in short period of time [7]. In this regard, the effects on the time-of-use of these and other factors, such as the influence of residents working from home, and the day of the week have not been studied in detail. Establishing a simple and adaptable methodology to assess appliance use over time will also prove helpful as influences on appliance use patterns change. This is particularly useful to predict the potential influence that "smart" appliances, connected to the smart electric grid, and to provide updated inputs to building energy simulation loads. Further investigation will give us exact information about domestic situation and group behaviour as a key for reliable solution in energy efficiency. According to the UK houses fact file 2012, lighting and appliances use almost 15 % of house electricity as shown in Figure 1-3. For comparison, in 1970 only 5 % was used [8]. The main objectives is to identify particularities of habitants' behaviour for energy control and later, management, next step is developing a statistical model and electricity-forecasting model, which will be able to acquire and apply data about household and appliances so that the overall understanding can improved in this particular Borough as well as in the whole country [9].

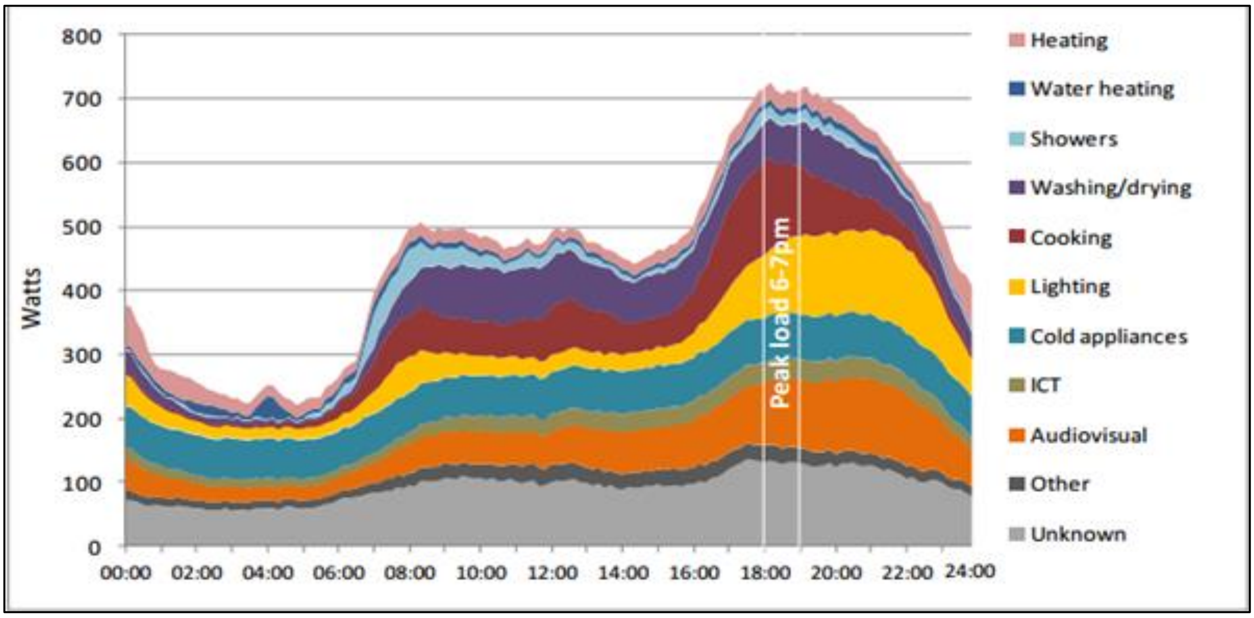


Figure 1-3 Average profile of 24-hour for 250 homes [10]

1.2 Research Motivations

Most studies have shown the significance of inhabitant's behaviour, together with demographic factors on household energy consumption [11], [12], [13] and [14]. However, the literate in this filed is yet upward presenting a lack of data concerning household's appliances. Particularly, there has been great stress on the daily consumption during a certain period of the day. Necessity of day-to-day appliances usage and lifestyle adapted raises the concern to assess the daily appliances as well as management of household's consumption to reduce such demand on the daily energy consumption. Nielsen (1993) attributed 36 % of variation in energy consumption of homes to lifestyle and occupant behaviour, and 64 % to socio-economic influences [14]. An additional fundamental concern appearing in the literature of the domestic sector is not only the requirement of reducing the peak demand. It also appears periods of high demands occur apart from the main daily peak. Even though, previous studies have contributed to the filed, there is increasing concerns from the current situation that put forward, that there are prospects to investigate when the household's appliances used and their daily consumption contributions to the household's total energy consumption.

1.3 Research Contribution

This section highlighted the main research contribution to knowledge to the research field from different aspects, including:

1- The study explored the demographic factors influence the appliances time use.
2- Also explored and determined the significant factors affecting the appliances use.
3- This study has established the difference in the appliances usage between summer and winter seasons.
4- This study has established the difference in the appliances score of different categories of demographic factors.
5- This study reveals accurate data regarding the actual peak demand contribution of the individual appliance.
6- Assess the potential peak demand shifting based on the daily appliances contribution.
7- Presented a tool to electricity demand 24 hours forecasting based on the data regarding to the appliances used in the Borough.

1.4 Study's Contribution to Knowledge

The energy demand management attitude was broken into two seasons (winter and summer), making it more realistic from a practical perception and providing the opportunity to evaluate and analyse the collected data. The synergistic effects of the time usage and appliance's physical specification on household's demand pattern are also highlighted with their potential impact in the overall daily demand and peak demand of households in UK. Hence, the uniqueness can be stated as:

This research is representing a new attempt that the household's appliances were divided into more practical time interval that can be easily used to realistically estimate the daily demand of the borough within the domestic sector. The model presented in the earlier discussion focuses on how the consumers can optimize their potential of reducing their daily demand.

The demographic factors within a household are included within this study for the first time in this study in term of time of use. This is more likely to improve the energy conservative without investing extra money and time, and the recommended models explain which factors positively influence the appliances' time usage, consequently leading to reducing the demand at a certain time interval. It contributes to the body of knowledge regarding the performance of household's appliances and how the consumer's actions can be improved to reduce the daily peak demand.

The time of use the household's appliances also, for the first time, was empirically assessed based upon quantitative approach. Therefore, this strategy fills an enormous gap in research due to the unavailability of any considerable important data regarding the timing of daily's appliances activity. The quantitative data and analyses provided evidences are valuable not only to this study, but also for energy suppliers and policy makers, helping them to encourage consumer understanding.

With its focus on a domestic sector, this research has certainly identified some valuable facts to the current literature relating to domestic appliances in UK, which links various factors that have a major influence over the repetitive of the household's daily demand.

This study investigation is in fact, one of the very limited studies of the use of household appliances in the context of ownership and daily usage within the Borough and domestic sectors of the UK.

Supporting the reliability of the research finding, this study used a quantitative approach over surveying many households from various family components within the borough.

This particular research has also developed an integrated household model for appliances daily usage, which can simply be used as a managing record for consumers to help them to perceive and enhance their overall daily routine.

This study offers significant key points within the energy suppliers in the UK on how to enhance the peak demand and electricity price forecasting.

Also, the outcomes of this study provide various implications for researchers who are concerned about household's appliances and the factors that influence the daily usage of these appliances and their contribution to the daily and peak demand for the borough or individually within domestic sector. Furthermore, the study gathered and presented quantitative data relating to the household's appliances ownership and newly introduced appliances to the UK households, while revealing the potential demand reduction by using more efficient appliances.

This study, offers a practical indication for providing a great agreement of literature which is related to household's appliances, while understanding the phenomena of changeable demand pattern within UK domestic sector.

The application of this study is a very significant since the research integrated very vital factors for practical estimation of the daily demand for the UK's households by the integration of appliances physical specification and appliances' time of use.

Finally, the results which have been achieved from the Borough can be applied to other Boroughs, as this study has considered the categorization of domestic appliances which are nationally common within the UK.

1.5 Research Aim and Objectives

The aim of this research is to develop a model for household's appliances. In order to achieve the research aim, the following objectives have to be accomplished:

1- Assess the status of the appliances ownership and usage.
2- Design a questionnaire to collect data regarding to the area of study.
3- Determine the contribution of the demographic factors to the appliances time of use.

1.6 Research Questions

This study aims to address the need for a more detailed, understanding and analysis of daily households' appliances usage patterns and several of the factors that influence them. More specifically this study will explore the following questions:

1- Why do we need accurate data of household electrical appliances consumptions?

2- Why do we need a breakdown of this data?
3- What are the significant factors affecting the appliances usage?

1.7 Research Methodology

The methodology followed in this research is to achieve the research aim and to validate the model developed. Choosing the appropriate methodology is critical in addressing specific research questions, in that collecting primary data for the entire research relies on the type of methodology, strategy and approach. This study uses a *quantitative method* as the appropriate strategy to answer the research questions, and meet the objectives by collecting reliable and valid data. The research method applied in this is household surveys (quantitative), where several stages of data analysis applied to answer the research questions and objectives.

- Firs: involved reviewing the domestic sector overall energy consumption and particularly appliances consumption and ownership.
- Second: data collection process, involve designing a questionnaire, which will be based on the previous study and recommendations regarding to the household's appliances and demographic factors.
- Third: creates a load profile for the household's appliances and estimate the daily appliances electricity demand.
- Four: SPSS analysis will be applied for further investigation of the demographic factors and appliances time of use.

1.8 Thesis Structure

The thesis consists of 7 chapters;

Chapter One: The thesis content presented in this chapter, including the research motivations, aim and, objectives accomplished in order to fulfil the research aim. An overview for energy consumption by domestic sector in UK has presented in this chapter.

Chapter Two: Objectives 1 and 2 accomplished in this chapter, focus on UK domestic sector history and trends, including the review of previous studies in the domestic sector. Appliances ownership and consumption pattern highlighted as well as the potential trends of domestic sector with respect to the renewable energy source and electrification of the transportation sector.

Chapter Three: explains the research methodology and the methods adopted in this research. In this regard, positivism philosophy adopted and justified as well as the data collection method.

Quantitative method used to collect the main data used in this research to investigate the main factors affecting the appliance time use and develop the household's model.

Chapter Four: Objectives 3 and 4 accomplished in this chapter; the statistical means used in this research presented and discussed

Chapter Five: Objectives 5 and 6 were accomplished in this chapter; the method of estimating the daily demand was presented and the appliances consumption calculated based on the time interval classification.

Chapter Six: A statistical method and analysis techniques used to analyse the collected data was explained in this chapter, and the quantitative analysis was carried out in chapter five. 381 household surveys collected from London Borough of Hillingdon were analysed in different stages using Statistical Package for the Social Sciences (SPSS version 20).

Chapter Seven: objective 7 was accomplished in this chapter; a relative importance index (Pratt 1987) used to determine the importance and contribution of demographic factors to the household's appliances.

Chapter Eight: finding of the research outcomes discussed in this chapter and the recommendation.

Chapter Nine: conclusions of the research summaries in this chapter and future work.

Chapter 2 Literature Review and Background

2.1 Introduction

The consumption of energy all over the world is continually increasing at a fast pace specifically across the UK where the energy demand is increasingly high [15]. Consequently, varying electricity price has come up as the most challenging public issue for the government as well as for the residents of the UK [16]. Therefore, investigations of an innovative energy management system, which can manage sources, appliances and storages in smart homes, have come to be a necessity. However, the end use users are much concerned about their comfortable and daily habits, which linked directly to the daily appliances usage [13]. In this regard, several studies have performed in this area, but most of them considered only a single aspect of the home energy management that is limited to understanding the consumption pattern. None of the studies focused on determining the factors that determine individual house consumption or individual appliances. This has encouraged the current study in the UK for the identification of the usage of electrical appliances. The appliances ownership as well as their patterns with the use of gathered data from the households of the electric energy users within a specific period for the purpose of reduce the daily peak demand and overall household's consumption [17], [18]. Projected quantity of the electricity that is used is organized in the form of data and the developed system which can analyses the electricity usage through specific households [19]. This scheme has seemed to be proper and promising as it may be predictable that the bill might be read with care and it will create increased interest as compared to added material [20]. Also, they can use options for feedback which could be applied in real life and also offer a comprehensive documentation for their method, approach and results [21]. Future trends in electric consumption will completely rely on renewable energy sources and smart appliances. [22]. Prospective trends may involve personalized services of energy and developing various systems related to energy with the ultimate objective to reduce the amount of electricity and switch using the sources of renewable energy. This research aims at understanding various significant points like features that influence the time's usage of the household electrical appliances and their part in the entire consumption of the household. Possibility for the change in demand of electricity in its size and efficiency and in ways through which the socio-economic ages and groups consume electricity is examined and inspected in this study.

2.2 Domestic Energy Management System

Energy management system consists of several components. However, Figure 2-1 represents all the components that generally comprise an energy management system. DEMS are required to achieve a few goals, which include energy consumption management and security of energy supply, without impeding comfort of the residents [23]. Through the DEMS, the end consumers are able to monitor and control the energy consumption in homes via decision support tool along with enhancements to the energy services. Hence, this tool's purpose is to minimise the energy consumption and reduce the bill for the domestic consumers by scheduling the load and supply. Further, it will also minimise the human interaction with daily appliance and hence will change the human behaviour towards electric appliance [24], [25]. Management system has transformed into a control system, which operates automatically according to pre-defined conditions such as turning on and off switches, which ultimately provides flexible control to the user [26]. The subsequent paragraph explains each of the components of the energy management system:

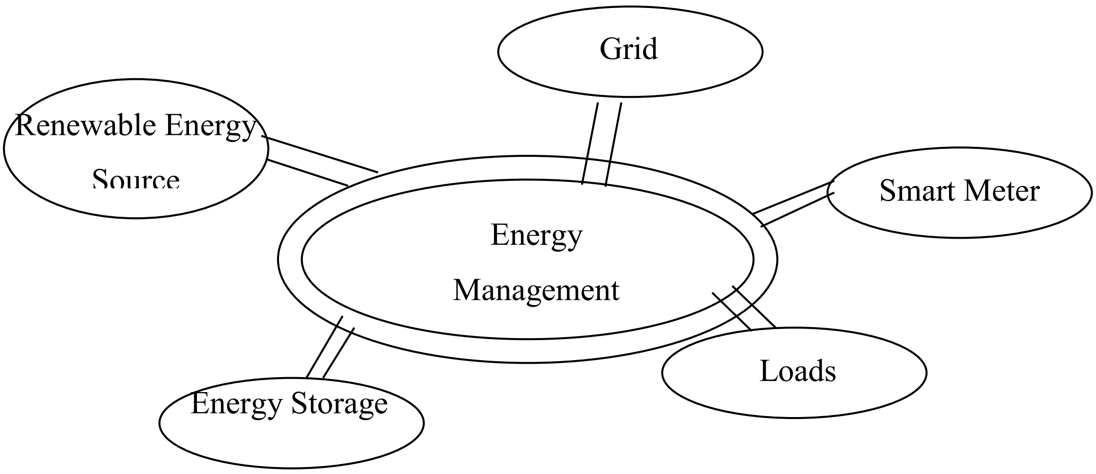


Figure 2-1 Domestic Energy Management System's Core Components

2.2.1 Utility Grid/AC Source

It is a commercial power distribution system that supplies electricity generated from the generator (water turbine, wind turbine, diesel generator, fossil fuel boiler and generator, etc.) and supplies to a certain distance to the end consumers. The supply is done through the distribution centre, and the entire system, which is known as the grid.

2.2.2 Utility/Secure Meter

A special electric meter automatically provides power from the utility grid at the nights and even in the daytime when the demand exceeds the capacity of solar electric power. Once the energy generation from the solar panel exceeds the household energy demand, the utility meter spins back allowing the household to credit the excess electricity against future utility bills [27].

2.2.3 Renewable Energy Source

The functioning of any smart home starts with panelling of solar cells. These solar cells, also known as photovoltaic or PV modules act as energy converter by converting light into electric energy. The size of a solar panel depends on the amount of energy needs to be generated. If there is the higher demand for electric energy, a large number of modules connected to generate more electricity, which referred as solar array [28]. Once the light converted into electric energy, the generated energy is in the form of DC. Thus, to convert the DC into AC, the inverter used so that AC can supplied to the home appliances, which work on AC. Moreover, inverter also synchronises the AC power from the renewable sources of utility power, whenever the electrical grid is distributing electricity [29].

2.2.4 Batteries / Energy Storage

Batteries attached to the system for storing excess of energy coming in so that excess energy does not go waste. Later, whenever, there is excess demand, the energy stored in the batteries distributed back. In order to keep the batteries charged, the solar PV panel keeps recharging the batteries continuously to maintain battery charge [23].

2.2.5 Loads

Loads that require AC power for their operations are known as AC loads, whereas, those loads which, are require DC power are known as DC loads. The common examples of AC loads are washing machine, microwave over, television, common lighting, etc. On the other hand, the common DC loads are DC powered LED lights, cell phone batteries, laptop batteries, etc. [30]. With enhanced advance technology of optimisation the use of renewable energy sources, the energy management central unit becomes capable of assisting the consumer and costly effective. Therefore, the energy management system moved towards personalized system, which is able to assist the user to save energy and reduce the bill. Such systems can easily adjust to the daily routine and act on behave of the occupants in terms switching ON / OFF the loads and supplies [31].

2.3 Development of Domestic Energy Management System

With the passage of time, more and more households are installing solar PV panels in their houses and converting their house from an ordinary house to smart homes. In smart homes, solar PV panels installed on the roof of the houses that utilise light energy to generate renewable electricity for the house. The generated renewable electricity can be used for two purposes; firstly, for home usage and reducing electricity bill, and secondly, an excess of generated renewable energy can be exported to the national grid to earn money. The size of such solar PV panels systems recorded in Kilowatt peak units (kWp). On an average, a size of domestic PV panels system is around 2.2 kWp, which saves fuel bills of approximately £100 each year. Moreover, by exporting excess of energy to the National Grid, a household can earn up to £900 per year [32]. Importantly, smart homes able to schedule the domestic loads of the household in particular the appliances where the household's appliances can be categorised into three main categories [33].

2.3.1 Appliances with Periodic Energy Consumption Mode

The energy consumption of home appliances is periodic and fluctuates when they are in operation. For example refrigerator, air conditioners, etc. Such home appliances operate at a set value of temperate and need to energise only when the temperature violates the upper or lower limit [34].

2.3.2 Appliances with non-periodic Energy Consumption Mode

This category of home appliances is those who consume energy in non-periodic nature, there is no specific time for their operation. An example of such devices includes pool pumps and plug-in hybrid electric vehicles.

2.3.3 Appliances with Real-time Energy Consumption Mode

Appliances with real-time energy consumption mode are the consumers put on those appliances in which energy consumption related to the consumer behaviour, that is, they need to be put off once. Thus, it is not possible to schedule energy consumption of such kind of appliances as they operate immediately to satisfy the demand of the consumers. This category of appliances includes wet appliances, cooking appliances, fan, television, desktop computer, light, and so on [35]. Thus, it can be say that home appliances that are included in the third category are completely dependent on consumer behaviour, whereas, the other two kinds of home appliances are schedulable loads.

The present research focuses on third category (appliances with real-time energy consumption mode). The study investigates the factors linked to the human behaviour regarding interaction with such load appliances in particular time of use these appliances. The reason behind focusing on such appliances is that, among all the categories, operations of these appliances cannot be postponed. For example, in the case of appliances with periodic non-real-time energy consumption mode, and appliances with non-periodic non-real-time energy consumption mode one can postpone the operation as one can down the cooling of refrigerator for some time as to save electricity and money. Similarly, one can postpone the operation of pool motor if there is a limited supply of electricity during peak hours. However, in the case of appliances with real-time energy consumption mode, it is necessary for the people to operate such an appliance. That is, one cannot postpone the operations of such appliance because of high tariff rate during peak hours. Thus, the present study will try to investigate the time usage of appliances with real-time energy consumption mode to customise the load.

2.3.4 Potential Peak Demand Reduction

Based on above categorisation of home appliances, load prioritisation of scheduling can be performed. For example, using a different tariff policy (economy 7) and smart meter, when load consumption and tariff rates are high, the operation of home appliances (smart appliances) can scheduled to non-peak hours. In this way, peak demand can be rescheduled to keep it below a given threshold and energy consumption can be reduced during peak hours as shown in Figure 2-2. Further, in this way consumers will be able to save both; electricity consumption and electricity bill [35], [36]. Figure 2-2 illustrates the concept of load shifting or scheduling, saving energy can be beneficial to individual consumer by reducing the bills. Therefore, there is a real need to individually investigation to optimize the energy saving techniques based on the household's factors.

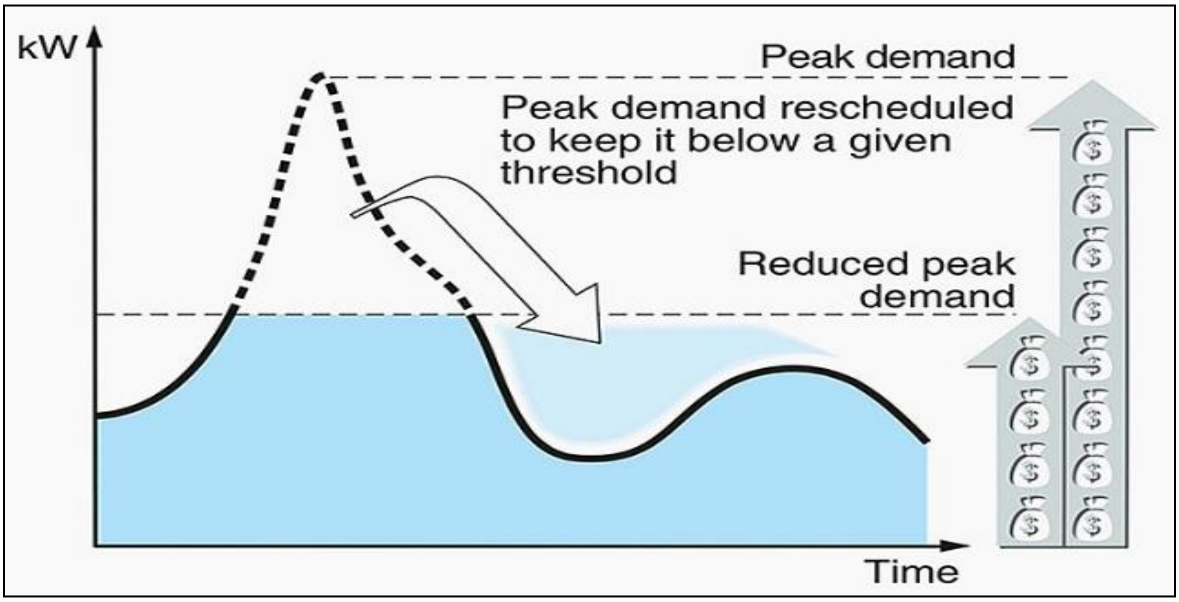


Figure 2-2 Load Scheduling Strategy to Save Energy [36]

2.4 UK Population, Household and Potential Trends

As a fact, the raised local demand is directly proportional to the number of households and population [8]. As per this, the UK fact file has arranged the data related to the spending of the household on energy as this is related to the household factors (National Statistics, 2016). Increase in population on average is 0.28 % annually whereas, the average increases per year in number of households is 0.86 %. In 1970, the population in the UK was 55.6 million and then later in 2010 the population was almost 62.2 million. Furthermore, this figure was expected to rise by another 10 million by 2050. According to the modern trend, the people of today, prefer to live in small families, due to this, the quantity of houses are increasing [22], [37]. Furthermore, since 1970 the energy consumed by lighting and household's appliances has increased by 157 % [1]. The gathered data shows that the use of energy is directly proportional to the growing number of households and population with their energy use through various appliances. The trends in demographics indicate that the growing number of aging population, increased pensioners and various approaches to number of hours worked and all such elements influence the use of energy. According to the latest studies, an increased amount of people work from their homes, in this way, there is seen growth in electricity and heat usage generally from 9 am to 5 pm in weekdays. Therefore, in this period the energy usage grows significantly [38]. *"Without improving the energy efficiency of homes, or the ways people use energy at home, growth in* *household numbers and smaller average household size would lead to higher per capita energy use"* [15].

The profiles of geography of homes define how climate influence the energy usage for heating particular areas of the UK specifically when talking about energy use for heating purpose [39], [40]. On the basis of this development, the researchers have divided households in different sorts of region and characteristics such as, any household that has children, increased amount of electricity will be used for cooking, heating, washing and cleaning. On the other hand, if one household has full time employed people, during the daytime the demand for electricity will be low. In this way, this has concluded that based on the daytime activities of the residents, households can be categorised into different types [8]. According to the nationwide statistics, the growth of the UK's new households is not evenly shared as shown in Figure 2-3 [22].

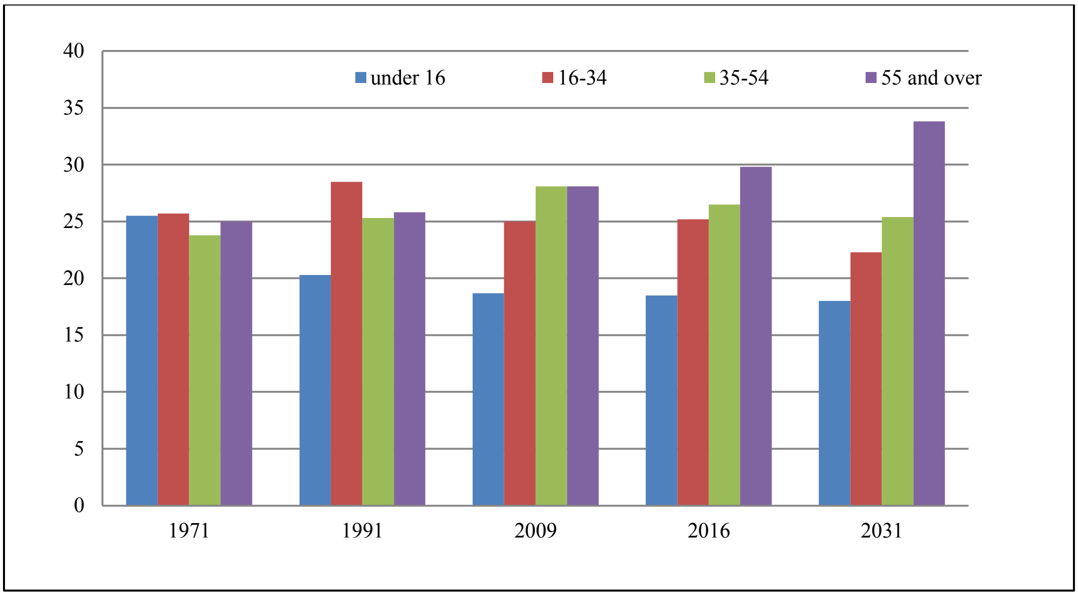


Figure 2-3 UK population age percentage trend [22]

2.5 Domestic Sector Electricity Consumption

There are many drives for domestic energy consumption in the UK. Some of the most common drivers are the climate drive, technical drive, economic drive, social and demographic drive, and the personal attitude as drivers. The economic drivers are the prices and the income of individual household. Conversely, the non-economic drivers are policies, technological factors and others such as institutional and cultural factors. Figure 2-2 is showing the prices of electricity P / kWh in the UK, while Figure 2-4 shows the entire electricity consumption of the household in TWh. All the consumers have various plans and sources of energy that involves various sorts of methods for payment, energy sources and various tariff structures, Therefore, this may be said that the suppliers of energy go to the personalized use and it is perhaps the best method [41], [42]. As an example, various providers charge low prices of electricity at night time and for this, they serve other meters which are installed for this purpose [43], [44]. In addition, Table 2-1 indicates the gathered data of electricity usage in UK. In any condition, there is a necessity for counting on the period of the year during energy monitoring *(heating require much more energy consumption during colder period of the year)* [37]. In the last decades of the human civilization, there was seen fast progress in economy, frequently on the resources of fossil fuels. This allows us to link exchanges and increase fast in all the sectors of developing human. Newly, this has identified all the incorrect aspects of the resources for renewable energy which is nearly expire, energy in the fuel form which needs to be replaced with various other energy forms [45].

Figure 2-4 UK household electricity consumption TWh and Electricity prices P / kWh [46]

Table 2-1 Household type and electricity usage [37]

Household type	Sample size	Mean electricity use per year
All HES homes	250	4,093 kWh
Homes with primary electric heating	9	7,318 kWh
Homes without primary electric heating	241	3,973 kWh
ECUK estimate for all UK homes	27 million	4,154 kWh

The NEED Project 2016, has explained that a lot of energy is consumed in heating a room during the winter days. It has concluded that around 48 % of the total energy consumed in heating and cooling a room in the households. Furthermore, electricity and natural gas have found to be the two most commonly used fuels for heating. It has also mentioned in this study that more than half of the households nowadays use the natural gases for the heating purpose. Additionally, according to EPRI under a moderate evolution by 2020, 35 % of total vehicles will be PEVs, this figure will increase up to 51 % between 2030 and 2040 and it is estimated that 62 % of total vehicles in the UK will be electric by 2050 [47]. Crucial to the existence of cars with electric vehicles the UK authority owes allegiance to managing the power consumption by these cars because of two reasons. First, that is the electric vehicle usage as the last product of technology has practical value. The second is ecological aspect, which is the decreasing of CO2 emissions and protection of the environment [48]. Electric vehicles, PHEVs will have great influence on the power distribution system, whether it is about design or distribution [49]. "*There is enormous scope for retiming of the charging to better suit overall power system operation, thus acting as responsive load providing demand side services*". In the practical meaning, electrical vehicles reach huge progress and are getting charged immediately on return to the home [50].

In 2000, 56 % of the domestic consumption of energy in the UK for space heating, 24 % for local hot water, 20 % for local energy was used for lighting and appliance [4], [51]. The appliance usage has little or no relation to the climate but it is much related to the human factor of the household. The pattern of usage changes based on various factors, like composition of the household, cultural background, income of the family, and human factors etc. For producing local load profile with considering different factors, a method of cluster analysis implemented. The demand of energy can be classified into two sorts of determinants:

2.5.1 Behavioural Determinants

These are the determinants in which the consumed energy has non-related/little-related with the climate but very much linked to the human factors of the household. This is highly correlated with the habits of people and are somewhat impacted by season like washing machine, cooker, kettle, dishwasher, television, fridge-freezer, microwave oven etc. The link between the electricity usage in households and the behaviour of the users discussed comprehensively [52]. These types of determinants more likely usage frequency of each appliance include comparatively flexible solutions and decisions that are to be made based on hourly, daily, weekly schedule [53].

2.5.2 Physical Determinants

Such consumed energy like lighting energy and heating / cooling are highly correlated with the building design and climate though carries low co-relation with the habits of people. This determinant of the energy usage like building deigns, dwelling's size and system of space-heating are the outcomes of the comparative fixed decisions. The usage of the heating systems and cooling systems for thermal relief is also linked with the pattern of occupancy and the income levels of the households. The majority of people will arrange internal temperature comfort on low when their dwellings are unoccupied and at night. The people who prefer warm temperature may fix a higher temperature comfort though other people may also set the temperature to low.

2.6 Households Energy Consumption

The need of the conformability and suitability in households is services for energy, heating, lighting and appliances. The energy quantity is directly proportional to the home types, lightings, heating systems and used appliances and the capacity of the household appliances are increasing and stirring in proportional to the size of households [54], [55]. In fact, regardless of the size of the household each household is consuming a minimum energy for basic appliance usage such as kettle, lightning, TV, fridge as the use of the appliance is based on the demographic elements like age of the occupants and the size of the family [37]. The pattern of use differs and diverges on a number of factors like composition of household, weather, behaviour patterns and income patterns of the households etc. The occupants impact on using the electricity of the houses with respect to the extent of the appliances that they own and all over their pattern of usage of the appliance [56]. Appliances are specific to the study interest as of their high rate of penetration and their higher penetration rates in the UK [1]. Additionally, for any predicting action of potential load shifting, for energy management is flexible on the appliance's usage routine. The peak demand of electricity is based on the daily usage time of the appliance and the appliance category that has been used as the occupants are probably switching them ON and OFF. Various households have distinguished lifestyle which means that the shape of load profile will be changeable and will vary from one house to another and from one day to another. Because of the data deficiency related to the patterns of occupancy, it is essential to create assumptions for the most usual consequences and cases of the occupancy patterns of the households in the UK. Hypotheses for the activity and the accessibility of the household occupancy were created on the basis of the prior researches, studies and public reports [8].

It has been seen that the behavioural as well as physical determinants associated with the consumption of the energy are more or less subjective by the pattern of occupancy. In spite of efforts to reduce the consumption of energy or at least for using it in an effective manner, the present data represents that the energy bills per annum has surpasses £1,500 for the average UK households [57]. Future production of the observing devices like smart meters which are linked with the stores of online data resulted can suggest tariffs for energy and load shifting as per the personalized and customized needs [58]. Appliances may also be swapped for using at different periods of time that can result in increased benefits, followed by the variations in behavioural goals which are monetary and saving of energy [59]. *"Changes are made to the behavioural and engineering functions, in order to reproduce end use variations resulting from technological innovations affecting appliances and the socio-economic evolution of households"*[51].

Today, developed nations are applying ecological political, social and above all scientific and technological initiatives for responding to the challenges for being energy efficient [60]. For example, in the UK, the initiatives for rolling out the smart meters, is a technology that is linked with the concept of smart grid that will be serving the consumer as the backbone of the information technology [15]-[17] . The power management in the UK is presently going through restructuring for enhancing its effective offering and delivery of power and increased billing [15]. Additionally, the government of the UK is dedicated to the technology of smart grid that involves dual flow of information among the consumers and the suppliers, developing the grid to be more energy conservative with two methods "time of use" and "dynamic" for decreasing increased demand through encouraging the shifting of load over the increased prices at peak demand periods to off-peak demand time [61]. An interactive and intelligent system like this is developed to assist the consumers for understanding and for controlling their use of energy with the ultimate goal of reducing the consumption of energy [60]. Diverse efforts have emphasized on the influential technologies for creating response and feedback on raising the awareness and consumption [44].

2.7 Domestic Energy Load Profiling

A load profile may be explained as the pictorial presentation of the changes that happen between electrical load and time. The load profile may change based on the season of holidays, consumer types and temperature. The load profile is used by the producers of power so that they can develop a plan for the amount of electricity or energy which will be needed for the availability at a given point of time. Hence, it can be stated that load profile is a prior planned process in order to determine the energy requirements for the future. In a system of power generation, the changes in the demand of energy can be shown to load profiling. More, this specific section of the study will determine the techniques for load profiling comprehensively and will also be explaining the uses of these techniques for meeting the needs and requirements of the energy in the coming time.

2.7.1 Bottom-up Approach

For establishing the residential area's load profiling the common strategy is the bottom-up approach which involves a synthesis process. The study shows obtaining data from examination in the residential area via synthesis process which involves accumulation of the contribution from the individual appliances to the demand profiling of the households and aggregation of several related demand profiles of the households [62], [63]. The probability function involves two features engineering and behavioural. Research in gathering and collection of specific data for various types of household dissimilar residential areas, with current houses can be adopted. The residential model in the UK used to motivate the area of research and records the demand of energy and its consumption. The demand of energy for each type of household are gathered carefully. Therefore, the researcher should look in to adaptation of innovative solutions for finding enhanced ways of the management of the energy consumption as concluded that today appliances are consuming increased amount of electricity and energy the postpone or shift the operation of some appliances will be the solution in near future.

2.7.2 Household Load Profile

Initially, the profiling process considered the links of appliances usage to the related home activity such as washing, leisure, cooking, personal hygiene, housework etc. Next to this constraint, the operational modes are being considered, in which the appliances are separated on the basis of automated, used and activation like hair dryers, juices, blenders etc. and the activation of successive usage like clothes washer, PC etc. other parameters involves the limitation of power demand and duty/working cycle typical duration [47]. Specific observations devoted for the profile usage, profile per hour of any particular home activity, consumption of unitary energy and the likelihood of routine usage, deferability that is the likelihood of transforming the time of usage along with the duty cycle of specific appliances. Estimated and observed is the base load of the global demand figure of the household [64].

Accumulation of the elementary units of each household receives a greater amount of data that considers very small details, mentioned as under:

1. Inhabitant's types: age and activities etc. of the inhabitants,
2. In case of working persons: the income levels and leisure life, post working activities, their daily routine,
3. Availability of the inhabitants at homes, their profile along with the percentage of their entire routine availability at home [65].

For obtaining the data, studies consider the statistic of demographic or deterministic processes may also be used. The profiles explained above recognises just the inhabitants after these data, estimations depend upon:

1. Type and number of households, with respect to their members and types of inhabitants,
2. Household with respect to their building in particular areas,
3. Average consumption of electricity of households,
4. Ownership of appliances [6].

Such an approach identifies the socio economic and the demographic characteristic of the society having the purpose of form of load construction of a particular area. Data and statistics are closely linked with the consumption of energy and the profile of load of each appliance of the household [37]. There is demand of customers as well as various psychological factors of the behaviours of consumers and individuals [66]. For investigating the energy usage of the house hold, the model can be implemented as simulation model of the household in which the field measurements of the demand of power are presented in a particular time frame, such as 15 mins. Here is shown the conducted and combine mail survey and then the consumption of energy are calculated. The foremost reason for the adoption of such models in order to ascertain the load profile is the option of cost effectiveness due to the minimization of individual load examination in utilities of electricity. There is the specific reflection in the modification of technology and in evolution of behaviour in using energy when models like these are implemented, particularly those models that provides such consideration [67].

2.7.3 District Load Profile

In order to calculate energy consumption within specific behaviour of inhabitants of different households, researchers have made and developed different approaches: econometric-statistical, engineering approaches as well as combined types. Estimated customer's response model can, during implementation, be included in evaluation and prediction of the different rate policies. When good results are gained, it means that the model allows reproduction of the load diagram of an end-use area by a process of synthesis of different aspects; behavioural and engineering components as well as macroscopic, socioeconomic and demographic aspects. Later it leads to aggregation of load diagrams, concerning every household in the researched specific area.

The first approach is dealing with a very specific behavioural factor, where energy consumption is the most difficult to estimate because of specific psychological impact on behaviour and further, behaviour of consumer. Difficulties occur when life-style related psychological factors are considered, as they are subjective but yet, they can be estimated until certain point through statistical correlations. This includes load research and surveys, familiarity with type of family (activities of inhabitants, their age etc.) and all this is a certain time frame, consecutive days or longer periods. After all, it must be admitted that many factors are essential and therefore must be taken into consideration. Such, load-shape synthesis approach is based on the two levels as below presented:

1. Aggregation of individual appliance demand so as to produce an individual household demand profile;
2. Aggregation of the load shapes of various households so as to derive the end-use area load profile by synthesis [63].

The load shape's end use may also be explained as the link between the appliance and the household members. The result may also vary for various profiles based on the residents, their lifestyle, their activities and their age etc. The function that shown in this manner shows the tendency of the residents and their tasks and activities in night as well as daytime, very broadly, particularly activities along with the consumption of energy. The researchers have also separated the activities into various types. First, of the behavioural functions which means that all the members of the family are present at home, home-based activities. Using appliances, tendency for activities at home, appliance-ownership, human-resources and the other one, is the engineering function which, involves the mode of operation of the appliance, activation or the cycle time, demand for power, average consumption each year, demand limit of the households, technological penetration, appliance saturation exemplifying the technological innovation.

2.8 Consumption patterns and consumer behaviour

In any case, there is a absence of information about the usage illustrations and customer lead of the individual appliances. Therefore, the acts of the consumer as to the demand utilize is also a surprising issue and a noteworthy investigation for the researchers in the present. Understanding the key learning of the overall public as for the essentialness usage; rather than simply measuring the genuine demand use, may be basic as it can define the demand shape. Generally, the expenses of some efficient appliances derive the consumer to rely with lower efficiency. Feasibly, this is the main reason that consumers generally tend to purchase the less costly and less adequacy appliances. A bottom-up approach used to gather a data and generated load profile on hourly basis [11]. In another study conducted in UK, proposed in order to evaluate any responsive demand there is a need to identify the demand shape of a particular consumer [68]. The behaviour for using energy in the UK showed that the public is attracted to development and information regarding the household energy consumption and suggested to devise a comprehensive energy policy to achieve high-energy efficiency [69]. In this regard, it has been found that minimum monitoring period of 12 months, 14 Out of 31 households achieved energy savings of greater than 10 % and six of these achieved savings of greater than 20 % by providing them with consumption feedback. The average reduction for households employing an ECI was 15 %, whereas those given antecedent information alone reduced their electricity Consumption, on average, by only 3 % with an average daily consumption for electric cooking of 1.30 kWh [70]. Furthermore, the consumption of energy in UK has increased by 18 % in last few years and will keep increasing each passing year and the study stated that, the use of electricity is linked to the behaviour of UK's residents. Thus, there is a need to investigate the UK households' factors in order to understand the individually consumer's behaviour [71].

2.8.1 Household Demand Fluctuation

The study by Palmer, and Cooper, (2013), stated that the demand for energy increases during the winters. Additionally, that the heating demand is less during the summer than that of the winters explains that the energy consumption during the winter is more than the energy consumption during the summers in the household sectors. The findings of the recent studies show that since 1970, there has been an increase in demand of energy in household sector by 0.4 percent per year in the United Kingdom [72]. This shows that the people in the United Kingdom require more energy every year (Carbon Trust, 2006). On the other hand, according to the study by Carbon Trust (2006), the demands of energy in the households of the United Kingdom have changed with time. Overall, it can say that the energy demand has increased over the last few decades. Furthermore, the study conducted by Carbon Trust (2006), has explained that almost 30 % of the total energy consumed by the household sectors in the United Kingdom in the year 2004 [73]. Additionally, according to the study conducted by DECC, it has been found that almost one-third of the total national energy is consumed by the household sectors in the United Kingdom. The studies carried out by Rory V. Jones, Alba Fuertes and Kevin J. Lomas (2015), had stated that, in the UK usually expenditure is related to the income of people and it incurs the use of resources [74]. Both of these studies were in line with the study conducted by Carbon Trust (2006), as this study has also related the use of resources to the income. In addition, all of these studies have stated that the use of resource usually increases if the income of a family increased. Furthermore, another study carried out by Jones, et al (2015), concluded that the UK households own more than 30 appliances and there is a growing probability that there will be increased demand of electrical energy [75]. Thus, all of the above studies have proven the energy consumption increased in the United Kingdom because the income of people increased which leads to increase the number of household appliances per household. Furthermore, they have suggested some of the recommendations for minimising the energy consumption in the United Kingdom. The most important and the common recommendation were to decrease the energy demand. It means these studies have explained that the energy consumption in the United Kingdom can be controlled if people stop demanding a lot of energy. Thus, the local government should think about reducing the energy demand and not the energy consumption. Most importantly it has been mentioned in the latest studies that this recommendation has been delivered by the Department of Energy and Climate Change (DECC) as well.

In 2012, the study conducted by Zimmermann, et. al. calculated some figures which explained the energy consumption in the households which had multiple persons and there were no children. It has calculated from this study that around 13.9 % energy consumed in these households by the cold appliances during the holidays. On the other hand, during the workdays, the cold appliances consumed only 13.7 % of the total energy. These figures show that the cold appliances consume more energy during the holidays than the workdays. Furthermore, it has calculated that if some additional electric heating appliances introduced, then the cold appliances consume only 7.2 % of the total energy during the holidays and around 7.7 % of the total energy during workdays. On the ongoing, the inhabitant's activities are link to the increase and decrease the energy consumption per household. Most importantly, it has found that the additional heating appliances consume most of the total energy during the holidays as well as the workdays. Thus, it can be said that the additional heating appliances consume most of the energy in the household. This usually happens during the winter days because demand for heating is much more during the winters. Hence, it can also be said that the heating appliances have a greater impact on the energy consumption during the winters than the summers.

During 2010 and 2011, a survey was conducted across London on 250 households. From the survey, it was found that the mean annual power consumption in 2010 was 4093 kW and in 2011 was 4154 kW. The number of appliances monitored by the study ranged from 13 to 85. The appliances were categorised as wet appliances, cold appliances, information and communication technology equipment, lighting and, consumer electronics. Further, according to the study conducted by Zimmermann, et. al. (2012), the mean annual power consumption in the year 2010 and 2011 was almost near 4000 kW in the United Kingdom. Furthermore, it has been included in the existing studies that although the household sector only consumes a quarter of the total electricity in the UK, it accounts for nearly 50 percent of household emission, which comes around to 60 million tonnes of CO_2. It has also been mentioned that over the past 44 years, the energy consumption in UK homes has increased by two-fifths. On the other hand, according to a survey carried out by Palmer and Cooper, (2013), the energy consumed by households in the UK is almost one-third of the total energy. Further, the study explained that whatever is the size of a household, the power consumption and energy consumption do not increase. They have given an example that there is a house in which a 100-watt bulb fitted which used to enlighten the house. There was only one person in the house. If there are 2-3 more people to live in the house, the bulb will remain the same and also the house will be similarly enlightened. It means that the energy consumption will not be affected by the size of the household. Apart from this, it has been found from the study conducted by Shimizu, Palmer, and Terry, (2014), that during the year 2012, the high contribution of cold appliances consumption was in the month of May. [76].

In 2009/2010 a study carried out by Jones and Lomas, (2015) offers a comprehensive evaluation of the ownership as well as use factor of appliances which are participating in increased electricity demands in homes in the UK [75]. The data collection for this survey involves data gathering citywide on a broader scale in Leicester, UK, from 2009 to 2010. This was also the notable survey for appliance and energy on citywide scale in the UK. The influence of the ownership of the appliances and the usability factor on the consumption of electricity in the UK for 183 homes was investigated. Majority of the ownership of appliances and the factor of use have not been researched and assessed in the context of the UK. The outcomes of the study have recommended that the UK households own more than 30 appliances and there is a growing probability that there will be increased demand of electrical energy. It has been found that if fewer people have been provided with the access to electricity, then the electricity consumption within the country will also be less, and vice versa. Also, Jones, Fuertes and Lomas (2015), analysed the factors related to the socio-economic, appliances and dwelling which are significant and non-significant influencing the local consumption of electricity. They identified the factors that influence the demand of the electricity in number of ways; a detailed evaluation with stocks of all the prior research findings is undertaken [74]. They stated that, more than 62 factors have been analysed in the literatures that have an influence on the local consumption and use of electric power. This involves 13 factors for socio-economic, 12 for dwelling and 37 for appliances. From the total of 62 factors, 4 from socio-economic, 7 from dwelling while 9 from appliances factors are found to have significant positive influence on the usage of electricity.
According to the Heus (2013), 99 % of households have at least one cold appliance kettle and a TV. 91 % of houses have a washing machine and 91 % have a microwave. The remaining types of appliance are from 48 % to 74 % of houses. Compared with the statistics of ONS national ownership, the HES sample had been found to have slightly lower values of ownership in all types of appliance, apart from for dishwashers, which were slightly higher. In addition, cool appliances, dryers, clothes washers and TVs possessed by more seasoned or resigned individuals were observed to be fundamentally more established. This proposes that there might be validity in focusing on data advancing the advantages of purchasing efficient appliances [37]. Consumption in various houses might have a greater influence on 24 hours profiles as compare to dwelling types. In this regard, most of the above-explained studies have said that the demand of energy has kept increasing in the last few years. It has also been mentioned that the energy consumption has also increased every year in the United Kingdom as well as the other countries. Most importantly, these studies have concluded that most of the energy is consumed by the

heating appliances in the households in the UK during the winter days, and most of the energy is consumed by the cooling appliances in the UK households during the summer days. Thus, on the basis of the above-discussed studies, it can be concluded that the households in the United Kingdom consume most of the total national energy in the country, and the heating and the cooling appliances are the most common appliances for the energy consumption in the United Kingdom.

2.8.2 Base and Peak Demand

In all the households in the UK, the electrical devices, cooking and appliances are the prime consumers of electricity and their share is shown in Figure 2-6 [17]. This is the primary reason for the importance of the policies of energy efficiency and the development of the methodologies for energy modelling for understanding philosophies of running and operating these household appliances and for solving the consumption of the electricity in an enhanced manner [55]. The outcome of the ownership and the pattern of usage have shown in survey report of The Energy Follow-Up and Mansouri, Newborough, Probert. The outcome derived from the comprehensive monitoring demand of electricity shows these electrical appliances as the prime consumers in the households of the UK which are the refrigeration appliances, cooking appliances, laundry appliances, dishwashers, televisions, base electricity demand and cooling equipment. The median base load for the dwellings is 90 Watts in the UK. Base loads are explained as the demand of power of the households for the degree of the consumption of the electrical power in Watts that surpassed 90 % of the observing period, when evaluated within the data of higher frequency [10]. The lowest power demand on average is 121 Watts while the highest power demand on average is at 2,438 Watts. The optimal power demand for all the dwellings in the UK ranges from 483 Watts to above 13 kW, whereas the minimum range is effective from zero to 632 Watts. In the entire characteristics of the median, demand of power is 447 Watts. Furthermore, more data expose more facts for the consumption of the households in the UK;

- Demand per month is less in the summer season and is more in the winter season. This usually because of the use of lighting for long winter nights and the whole use of electricity is high as for the other appliances such as heaters, tumble dryers [77].
- The peak demand for power is almost similar to all the days. The electrical demand is not more than 1000 Watts, 90 % of the time and this is from 100 to 1000 Watts for almost 75 % times [10].

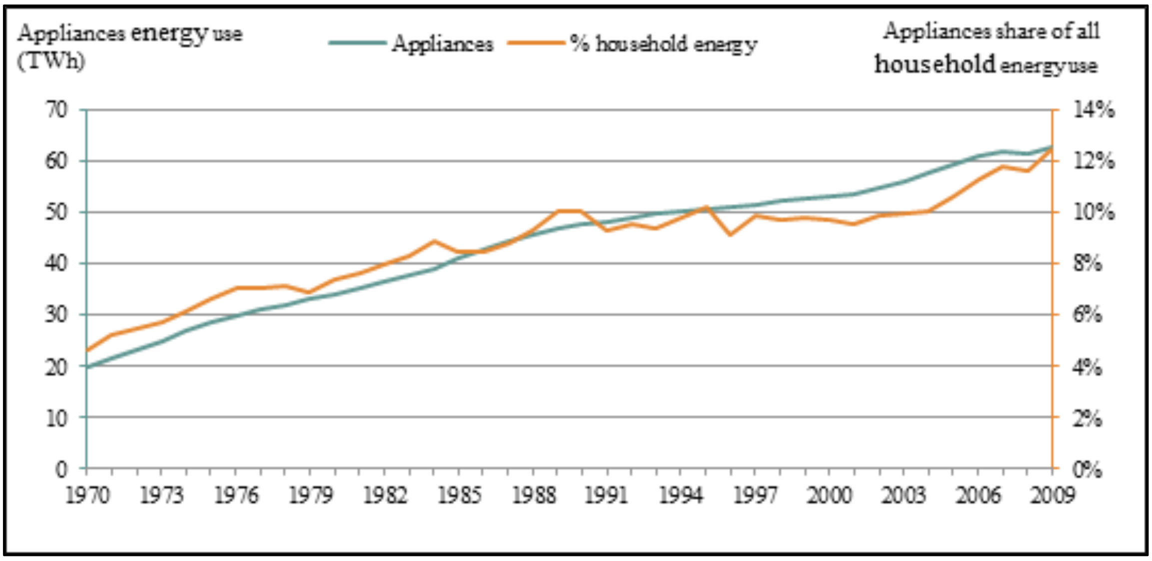


Figure 2-56 Appliances' consumption share to the total household's consumption [78]

2.9 Electrical Appliances Categories, Consumption and Ownership

2.9.1 Appliances Categories

The classification of the household's appliances represented Table 2-2. This classification is subjective to the functionality of the appliances and does not represent the time when the appliances were used [54]. The key to the upcoming solution for the demand for electricity is the time when the appliances are being used. The peak demand on a daily basis is a consumption combination and timings. An additional drawback of this classification is not providing the personalized information on each appliance. The entire consumption is the combination of the consumption of the household appliances [79]. Presently, the consumers of the UK are not properly informed and aware of the individual consumption of their appliances. Consequently, the relation and link among the time of use and appliance need to be increasingly explored for identifying the major factors which influence the patterns of usage [56], [80]. Identifying and predicting the potential saving of energy in the household appliances is the major aspect for this study. Though, the procedure of explaining what requires to be completed for realizing any specific target is not direct. From the audit findings of the important areas of consuming may also be recognized, whether the activity for end-use is taken into consideration is based on the extent to which the evaluation has been taken and the procedure of handing over importance is not achieved and not direct [81]. Through choosing the scope of the increased demand of energy in each household as an important topic, that is worthy of the comprehensive focus and attention.

Consequently, the important areas of consumption can be exposed, and then potential savings may be predictable. However, there are dual facets of this, first is that there are possible savings in this ideal world and obtainable if present best practice and most suitable technology reaches 100% saturation all over the end uses then there are also real savings which are probably achievable and obtainable and that operates the technological availability, consumer's behaviour.

Table 2-2 household appliances categories [82]

Category	Appliances	Consumption classification
Cooking equipment	Microwave, Kettle, Toaster, Cooker (hop and oven)	Unpredictable
Wet appliances	Washing machine, clothes dryer and dishwasher	Unpredictable
Entertainment	TV, Laptop, desktop and DVD, CD	Moderately predictable
Instantaneous	Fridge-freezer, fire detector, standby mode	Predictable
other	Vacuum cleaner, Iron, Hair dryer, Hair St. & Curlers	Unpredictable

2.9.2 Appliances Ownership

The domestic sector having higher ownership levels of unrestricted quantity of the appliance types enables the potentiality of the savings to be measured through recognizing the efficient model for each type of appliances and then implement these models all over the district [54]. For estimating the real potential of savings, the probable level of penetration of these effective models should be evaluated as shown in Table 2-3. The level of ownership is based on a number of factors involving the availability and cost of the appliances, the common life period of every type of appliance and the reality of any sort of motivation scheme. All these are tangible and may also be defined with a reasonable level of accuracy. However, other associating to human nature are nor much freely quantifiable. Like, CFLs, compact fluorescent lamps which are very efficient are available for almost 15 years now but these are not broadly and commonly approved from the common people. Conversely, double glazing that is highly expensive per kWh saved is highly in demand and can be implemented in the houses of the UK. Human factors like this may intensify the activity of forecasting the take-up rates for the local sector. In this way, the researcher can determine that as the local sector, the achievable savings rate for meeting the given objective [83].

2.9.2.1 Laundry or Wet Appliances

More than 97 % of the UK households have a washing machine, 62 % own tumble dryer and almost 50 % are reported using dish-washer in UK houses [82]. However, based on the structure of the households, more or less of these households will own such electrical appliances like if people living in specific houses are pensioners with no children, they will likely to be using tumble dryers and washing machine, apart from households with working individuals and children. The degree of consumption of energy is influenced significantly by the temperature in the washing process, next to the weekly loads. Such as the quantity of the washing loads in a week is 4 and the number of drying loads in a week is 3 in winter season, more, 59 % of the reports of the house hold are commonly operating their personal washing machines at a temperature of 40^{o} Centigrade, while 27 % of the reports are operating their washing machines at 30^{o} Centigrade and 8 % of them are using increased temperature for washing purposes. Summer seasons are different from winter season', therefore, in summer people are less likely to use dryer while in winters there is observed least loads of washing per week comparative to a summer season. The peak of consumption of electricity for washing is attained in weekends especially for those houses in which working people are living with their children.

Table 2-3 household appliances ownership and usage period [1], [54] and [82]

Appliances	Ownership %	Appliance category	Usage Pattern	Observation & consumption's predictability
Washing machine	97	Wet appliances	Irregular	Depend on consumer's habit & unpredictable
Tumble dryer	62	Wet appliances	Irregular	Frequently used & unpredictable
Dishwasher	46	Wet appliances	Irregular	Depend on consumer's habit & unpredictable
Refrigeration	99	Cold appliances	Regular	24/7 & predictable
Cooker	80	Cooking	Regular	Dinner time & unpredictable
microwave	75	Cooking	Regular	Depend on consumer's habit & unpredictable
Kettle	90	Cooking	Regular	Depend on consumer's habit & unpredictable
Television	98	Entertainment	Regular	5-6 hours & moderately predictable
CD and DVD	100	Entertainment	Regular	2-3 hours & moderately predictable
Cooling	17	Cooling	Irregular	Frequently used in summer & unpredictable
Iron	100	Other	Irregular	Depend on consumer's habit & unpredictable
Vacuum cleaner	100	Other	Irregular	Depend on consumer's habit & unpredictable

2.9.2.2 Refrigeration Appliances

The electricity used in such appliances is somewhat similar as appliances used in all the households since such appliances work in parallel with each other, over summer and winter, day and night, making use of the same amount of electricity. Almost 99 % of the UK household owns some sort of freezer or refrigerator [83]. Still this is the fact that a greater amount of washing machine, dryers as well as refrigerators are old beyond 10 years of more. This is an important fact from the viewpoint for the households to use a new range of appliances that will help in decreasing the consumption of energy.

2.9.2.3 Dishwashers

In the UK, less than half of households owns dishwasher so this can be said that dishwasher is not a famous appliance in the UK homes as shown in Figure 2-7. There are also popular facts that such households have a similar pattern of electric usage for washing machine and as well as for dishwashers. Additionally this can be observed that such appliances are not more than 6 years old [52].

2.9.2.4 Cooking Appliances

In the UK households, more than 80 % owns microwave and grill but the majority of them own various other appliances for cooking like hob, oven [83]. Electricity is considered as the main source of fuel that is used in ovens, about 70 % of the UK households that owns ovens are electric powered and among them just 30 % are gas ovens. Gas is considered as the dominant source of fuel for hobs, 38 % of the UK households are electric while 61 % of them are gas. Above 22 % of the houses are using ovens for 10 years [52]. The average usage of microwaves and hobs are greater in those households in which those people live who are working from homes or they spent the majority of their time in their houses including those households which have children. Higher demands of electricity of such households are at dinnertime around 6 pm. This is the calculated peak of the consumption of the electricity from cooking appliances [81].

2.9.2.5 Televisions

As shown in Figure 2-7, almost 98 % of the UK households also have television and the highest energy consumption is evening hours when the whole family is gathered. The majority of households own plasma TV and only 10 % have LCD or LED flat screen. Average hours when TV is switched on is 5-6 hours, usually in late evening and afternoon. After television presently there are a number of other appliances such as cell phones, computers, tablets, laptops and other similar gadgets and devices are operated with the use of electricity. The usage of such electric appliances is increasing day by day and so is the demand for electric consumption specifically in the evening when all the family members are gathered [8].

2.9.2.6 Cooling Equipment

Around 17 % of households use portable fans on a daily basis during summer; around 40 % of households with portable fans use them more than once per week. Peak in electricity consumption for cooling equipment is reached during hot summer nights but overall, air conditioning as fixed or portable air conditioning is used in less than 3 % of households [54].

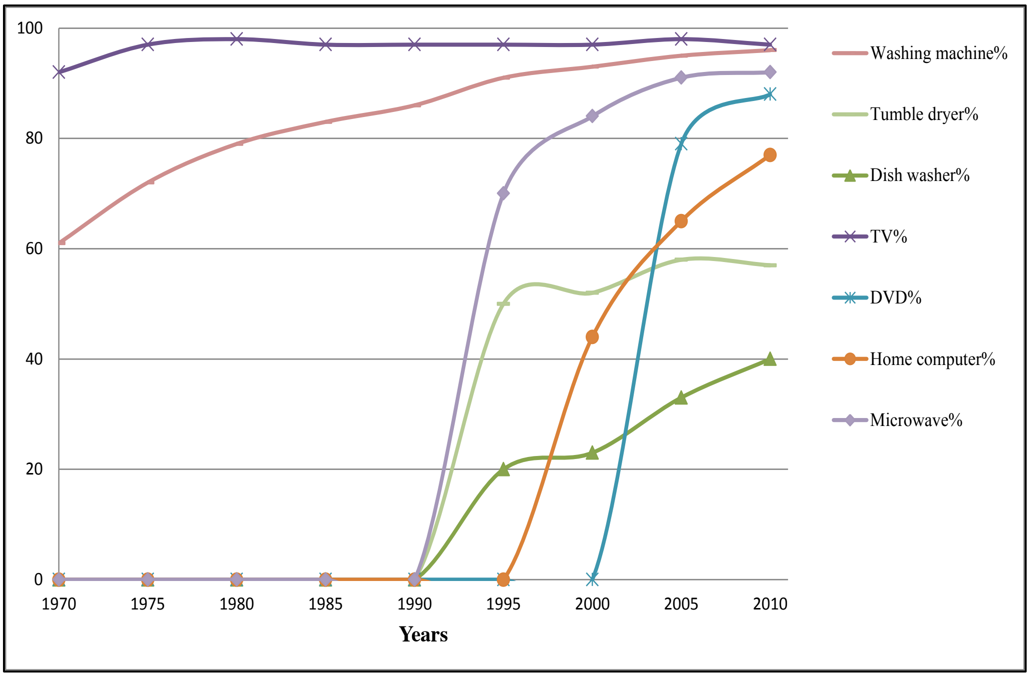


Figure 2-67 Percentage of UK household appliances ownership, 1970 to 2010 [8]

2.10 Renewable Energy, Domestic Sector and the Potential Trend

The UK government is committed to raising the development and growth of the renewable resources of energy all over the UK and has identified the important role of this innovative solution. From this point of view they have assumed that the participation of renewable energy can light the 15 % of the renewable energy by 2020 [45]. The PV system application needs to have an effective design residential area for determining the load requirement of particular consumers as it is linked with the consumer habit [84]. Regarding this, PV is considered as rapidly developing the technology of renewable energy. Moreover, here is a drastic increase in renewable energy of 11 % that can be considered all over the electricity supply in the UK [85]. Data for constructing such assumption is subjective to the researcher and the study carried out from 2003 till 2012. The contribution of the PV system is just the 3 % of the entire supply of renewable energy in the UK but the penetration of solar photovoltaics, PV, in the market of the UK has faced elevated demands, innovative solutions for the supply of energy which will be inexpensive, having better ecological solutions, has made PV as desirable solution for the all the households [46]. In Figure 2-8, it has been indicated that electricity generated in the UK from renewable sources will be playing a vital part in future of supply of energy. In the UK, the average radiation is 1000 W/m2, all across the country so it can be concluded that the UK has strong solar radiation within a certain period of the year and this can be used constructively [39]. The PV installations were very expensive but there has been observed a significant reduction in its prices as presently they can be produced for less amount of money as compare to prior times. However, The PV demand has shown an installation increasing due to the increasing in electricity prices [86].

On ongoing, an analysis published by National grid has confirmed that 10 GWp of renewable energy can be accommodated with without altering the functional in the Great Britain grid. With great support from the government the penetration of PV in UK market. The standard estimation of electricity cost is LCOE, (Levelized Cost of Electricity) that can be defined as the average cost for electricity generation over the entire life of the system. For encouraging the deployment and development of the renewable source of energy, different strategies, approaches and policies are designed to encourage the public to install PV system. Therefore, the feed in tariff (FIT) is the primary source for financial incentive, which was designed to support and encourage the technologies that generate electricity in the UK [41]. In this way increased number of households qualifies for this scheme, seems to be using solar electricity generated PV in the UK [87]. Today in the UK almost half a million dwellings have installed solar panels and this is considered as the biggest sector of the solar PV in the UK market [88]. There is an interesting fact that the supplier of the electricity pays a generation tariff for the generation of electricity along with the export tariff for surplus exports of electricity to the grid [43].

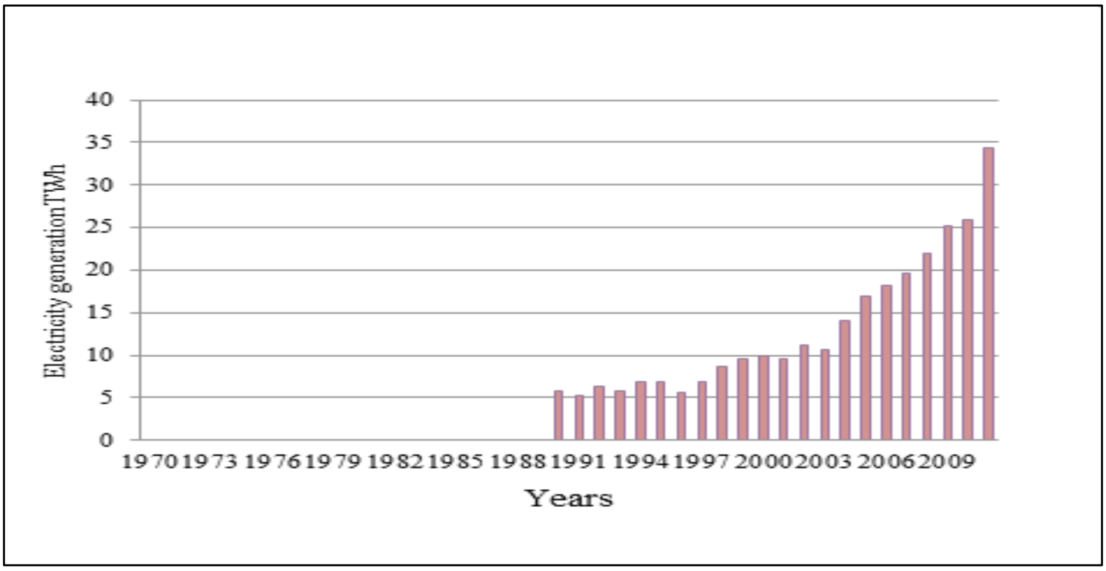


Figure 2-78 Renewable share of UK electricity [89]

2.10.1 Benefits of using Alternative Sources of Energy

Power companies in the UK comply with the regulations specified in tariff policies, such as the Feed-in Tariff (FIT), which is a government programme designed with the purpose to uptake various small-scale renewable generation electricity generation technologies [90]. Nowadays, households can get payment from generating own energy with the help of solar panels or wind turbine and supplying it to electricity supplier. This phenomenon is known as feed-in-tariff (FIT). As per the DECC report (2009), the expected return on investment is almost 8 percent or higher in the initial period of the program for a typical 3.5 kW PV system that cost near about £10,000 [91]. Moreover, according to EST (Energy Saving Trust), the owners of small-scale renewable energy installations can expect around 5 percent per year at the time of writing. Thus, it is highly motivating the consumer towards load shifting. As the cost of generating electricity is much higher in comparison to the exporting the electricity, the rewards are designed in such a manner that installation owners get highly benefitted for consuming their own generated electricity rather than exporting it to the grid. In other words, it can be said that FIT scheme is somewhat similar to a 'production' tariff rather than 'feed-in or export' tariff [92].

2.11 Hybrid Plug in Electrical Vehicle PHEV

In coming few years, a great projected of development in the use of the electric vehicle may be seen. The main reason is the inhabitants will follow the advanced developments, specifically if this is related to the technology [48]. This is estimated to see how major impacts will be seen of the PHEVs on the household's electricity loads and moreover, the way through which the raised risk of the excess power system is an innovative solution for not adjusting elevated demand of energy [47]. The major reason for this investigation and examination is to accomplish to what extent the demands of electricity will reach in the households of the UK with respect to increasing the penetration of PHEVs in the domestic sector. The electrification of transport sector delivers the opportunity to existing national energy emission and energy supply security which aims to minimize the petroleum dependency and reduced global and national CO_2 emissions [50]. The infrastructure of electricity in the UK can be handled and regulated for providing considerable amount of driving energy for increased number of electrical vehicles [93]. Today the UK is opting for charging the electric vehicles from their domestic grid. These potential impacts for national grid would have an influence on the cost of electricity production and the resultant emissions from this sector. The charging of electric vehicles battery in peak periods may double the impact of the cost as compare to charging at night. Specific question and inquiries for the new domestic loads and potential solutions are: what are the influences of likely penetration of these plug in electric and hybrid vehicles on the production cost of the electricity? And what are the influences on the intensity of carbon dioxide at the regional level in relation to the chosen charging approaches? [94].

Recent stats have shown that 20 % of the local carbon emission in the UK from passenger cars and the transportation accounts to almost 58.3 %. The government of the UK is aiming to target 80 % minimization till 2050 depending upon the level of 1990 [48]. Use of electric vehicles running on battery and plug in hybrid vehicle shows better solution from ecological and social perspectives, for reducing the consumption of fuels and restructuring the use of energy to the renewable energy. Comprehensive evaluations of the present domestic consumption in the UK and the use of cars can assist in understanding and accurately predicting the PHEV's usage along with the effects of their electrical systems. Another perspective is handling with understanding and forecasting the use of PHEV's along with the impact of their electrical system, automotive producers, and electricity utilities. In NTS 2009, it has been concluded that 34.2 m of the licensed vehicles are registered in the UK and almost 28m licensed cars, 89 % of which are privately owned as shown in Figure 2-9. Additionally, it is accustomed that such cars are being driven just 5 % of the time so most of them were parked and it is measured that such cars remain parked 96 % of the time, this offers an important secondary function being responsive load [95].

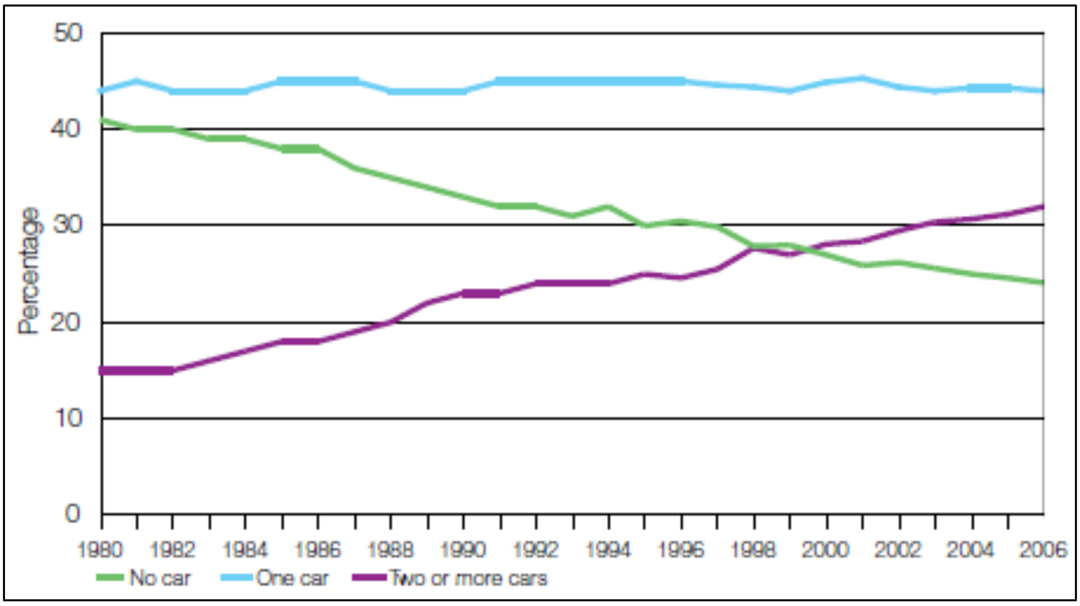


Figure 2-89 Cars owned by household: 1980 to 2006, Great Britain [48]

2.11.1 Charging PHEV

In case, the user of PHEV begins to charge their cars instantly after they got home *“has been considered here as PHEV are only charged at home”* and the procedure for measuring the driving time in round trips is presented below with measuring single charging time once the vehicle reached home. The state of the charging of the battery can be measured by using the battery as the source of electricity within the peak hours that is coincident with the vehicle arriving time at the household as shown in Figure 2-10. So, there can be two ways for charging consideration:

- Domestic point of charging, positioned in parking or residential areas, specially designed for slow rates of charging which directly linked with the LV networks of distribution.
- Charging station is similar to today’s gas station, it could comprise several connection points for fast charging; these fast charging points will be connected to MV distribution networks. [94].

Calculating the time of charge with the assumption that the car will be charged once get home:

$$E = T * U * K = 1.15\ kWh \qquad (1)$$

where;

E is the total amount of energy use;

T is the journey duration which is 10 minutes;

U is the driving speed on which is 30 mph;

K is the consumption coefficient of energy which is 0.23 kWh / mile.

According to the calculations the driving time of 10 minutes consumed by the car is 1.15 kWh and with electric vehicle in which the size of the battery is 5 kWh with the available capacity of 60 % for driving, the battery will not be completely discharge until the drive is over [1].

$$T = \frac{E}{P} * N \qquad (2)$$

where;

P is a level of charging (2.99 kW) subject to the configuration of the 13 Ams charger @230 volts [6];

N is the efficiency of the charging, considered at 90 % [6].

Thus, plug-in hybrid electric vehicles can also play a huge and important role in making a home smarter. By using vehicle-to-home technology, households can get temporary power for operating essential home appliances for a limited period. This again will help in saving energy cost as such plug-in hybrid electric vehicles can be used during peak demand hours when the price of electricity is high [97]. Moreover, such vehicles can also be used during outage until the battery reaches its lower state-of-charge threshold. In fact, automobile giant Toyota claims that they have developed a system that enables their electric vehicles to power households.

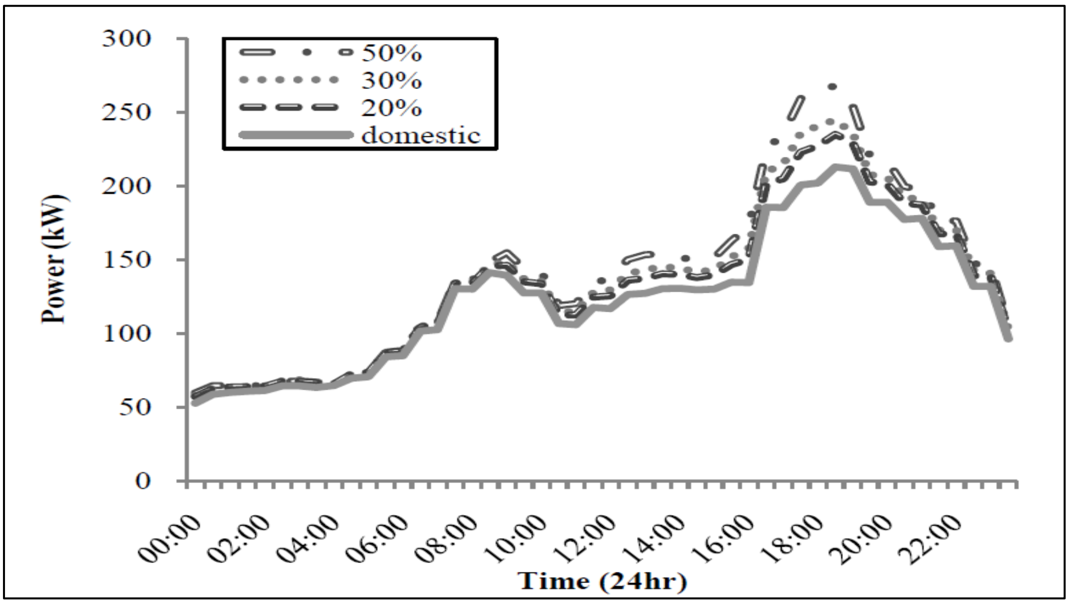


Figure 2-9~~10~~ Domestic Load with 20%, 30%, 50% EV take up levels [96].

2.12 Factors Affecting Energy Consumption in the UK Domestic Sector

There is an immense need for reducing the energy consumption in the United Kingdom. Several factors have been found to be the reason behind greater energy demand in the domestic sectors of the UK. Due to the increased energy demand in the country, the energy consumption has also increased. This is the major factor responsible for the greater energy consumption in the domestic sectors in the United Kingdom and global. The lower mean temperature was also one of those factors which led to more energy consumption. Most importantly, the weather conditions have been found to be another factor that affects the energy consumption in the domestic sectors of the UK. In addition with this, the characteristics of the house and the equipment used in the house also affect the energy consumption [54], [70], [74]. The habit of the people consuming the energy can have significant impacts on the energy consumption. Furthermore, there is also a big role of the number of the occupants or the size of the household in the energy consumption in the domestic sectors of the United Kingdom [98]. The relationship between electricity use in households and the behaviour of end-users has been discussed widely [99], [100] and [101]. The studies concluded that the behaviour of the domestic consumer is influenced by three categories of factors:

- Factors are related to the consumer personality such as; their values and beliefs towards energy conservative and environmental issues.
- Factors are linked to the regulations and social perspective.
- Factors are linked directly to the consumer habits and routine, which is the act during the daily activity where the inhabitants are acting without thinking.

Monitoring and evaluating time of use and behaviour of users is very useful in estimating the effect on the energy bill in a particular household i.e. evaluating the habits and routine of the consumer that influence the timing of using their appliances. This is important because electrical appliances and cooking are major end uses of energy in the home [102]. Consequently, ensure that households have access to the necessary information to manage their electricity bills and making better use of electricity which are the key challenges in the United Kingdom and across the globe. Therefore, knowing how, when and why households use electricity is a key challenge to achieving both these goals. In addition, previous literature also has indicated that factors such as occupant behaviour and socio-economic status are important in energy use as shown in Table 2-4 [103]. Nielsen suggested that about 36 % of energy consumption at homes is attributable to lifestyle and occupant behaviour, and 64 % to socio-economic influences. Other factors such as climate zone, the number of occupants, income level, age of home, and size of home have also been correlated with home energy use were suggested in [104]. However, the energy use of appliances such as dishwashers, clothes washers and clothes dryers is more highly influenced by occupant behaviour since they depend solely on the user for operation. The effects on the time-of-use of these and other factors, such as the influence of residents working from home, and the day of the week, the gender, the number of bedrooms in a house, the type of the household, the number of people living in a house, current employment status, the age, have not been studied in detail [105]. As influencing the time-of-use of energy becomes increasingly important to control the increasing demand stress. The factors that linked to the consumer habits and behaviour are investigated in this research. As a result, it could be beneficial if the researcher can identify some statistically significant factors that influence the time of use of the household appliance and build statistical models for associating these factors with each appliance.

Table 2-4 factors linked to the consumer's daily routine and behaviour

Factor	Description
Occupants	Increasing the times of appliances been on
Income	Increasing the appliances owned
Household size	Increasing the appliances owned
Household type	The type can affect certain appliances.
The age	There is a different need of usage based on the consumer age, adult, children and senior

2.13 Summary

The chapter focuses on assessing the factors that determine the individual consumption pattern. The UK population is extending in time interval, parallel with energy demand and experts tend to develop a new course of actions to move towards the renewable energy sources. However, a crucial solution here deals with the impacts of high penetration of domestic appliances at a short period. Tackling such a challenge, regulate the usage time of domestic loads is the proper approach. Thus, there is a need to look at the individual usage and shape the individual demand to individual hybrid power supply. In addition, the data about PHEVs control usage investigated from point of domestic consumer's view and need further investigation on how it influences the domestic consumption. However, along these lines, lack of disaggregation of individual data is keeping us away from the suitable response. Finally, the review of the fields has pointed very interesting facts regarding to the households demand;

- The consumer habits and daily routine is the major driving towards the use of households' appliances.
- Absence of appliances categorization based on their time of use in order to get accurate picture of individual appliances daily consumption contribution.
- Absence any measurements of the factors affecting the appliances usage time.
- Absence any measurements to the appliances contribution of influences.
- Most previous studies considered only the factors affecting the overall household consumption and lack of studies focus on the factors affecting the appliances time of use.

Based on the mentioned finding, there is a need to investigate the domestic factors that influencing the user's behaviour towards the household appliances in terms of the time. Therefore, the following chapter will present the research methodology adopted in this research to look in-depth into the factors and gather any additional information and data that might needed for further investigation in the future.

Chapter 3 Research Methodology

3.1 Introduction

This chapter has comprehensively presented the methodology adopted in this study, which is very important for achieving the aim and objectives of the research that are meant to validate and justify the findings and, the results of the research. The methodology selection of any research is a crucial element for addressing the approach, research strategy and designed questions. For investigating and explaining the factors influencing the usage of the household appliances to measure any potential of energy demand reduction and electricity price forecasting, the research questions designed and developed included the major elements derived from the literature review of the available data from the prior related studies and government data. Also, the focus of the survey on the future is followed by the anticipated and elevated electricity demand.

Section 3.2, has explained the research approaches; deductive and inductive and the reasons for chosen the quantitative approach for this research. In section 3.3, the research philosophies are discussed and the reasons for choosing the positivism in order to demonstrate critical problems and issues of this research. Followed by this, ection 3.4 explains the design of the research and the stages involved in various processes incorporated in this research study. Section 3.5 identifies the strategies for the quantitative design of the research. Section 3.6 represents and explains the collection of the data methodology includes the primary and secondary methods of data collection. Section 3.7 shows comprehensively choosing the quantitative population for the survey and the developments of the sample frame. Section 3.8 demonstrates the analysis and evaluation method of the quantitative data and its needs and requirements. In the end, section 3.9 summaries the entire chapter, however, this section shows the method and approach that are involved in data collection and analysis and evaluation for answering the research questions, mentioned below:

3.2 Research Approach for Domestic Sector

Saunders (2011) states that prior to selecting the data collection methods, four facets or aspects should be considered carefully, the approach and philosophy of the research, its design and strategy with defining each of this concept [106]. As per the Singleton and Straits, the two approaches of the research are qualitative and quantitative; in which each of the approaches can answer different or specified problems of the research, its aims and objectives and questions [107].

The quantitative approach of a research study is concerned related to respondents and dealing with the samples of the study, its experiences and research background of specified phenomena. A deductive approach is associated to the quantitative research and is valuable for making experiments and tests of the theory. It is based on the objectivism and positivism and depends greatly on numerical data as well as statistics [108]. On the other hand, concern for the qualitative approach investigates and demonstrates deeply into the details related to attitudes, behaviours, thoughts and opinions. It greatly depends on the verbal or worldly responses from the participants. The research that follows a qualitative approach depends on interpretivism as well as constructionism, so, the results can be achieved via words instead of numbers like interviews. As stated by Cohen and Manion (2013), quantitative as well as qualitative approaches of research are the broadly used in various fields [109]. Various scholars and research experts highlighted that the phases of the research process depend importantly on the sort of the selected research approach [110]. In chapter 2 of this study, that is the factors and household's electricity with changing market pricing, increasing the demand at certain period of the day, introduction smart solutions and the response of the demand, which is a newly arising phenomenon, particular to the individual household to enhanced energy conservative. Domestic consumption of energy includes various multidisciplinary elements because of the differential of the habits of the consumers like commitment with the management, knowledge and awareness of the consumer and level of understanding related to the consumption of energy of various devices and appliances. However, for achieving and accomplishing the anticipated degree of managing and reduce energy usage at the peak period, there must not be any sort of complexity in examining the entire elements directly for it, depending on the suitable approaches that are being selected for the research. So, it is very important to get the whole knowledge and making clear the components, upsetting its time usage through questions like 'when', 'what' and 'why', that can be achieved through the implementation and application of the inductive approach.

3.3 Research Philosophy

It is essentially significant to investigate the most suitable philosophy of research which assists the answers of the formulated questions of the research for the phenomenon which is been studied in this study. The selected philosophy of the research in this study adapts positivism. As stated by Saunders as well as Dewey (2003), such philosophy of the research is certainly suitable for explaining the exclusive problem of the research that lack sufficient information [111]. Therefore, the suitable philosophy for this research context is positivism because of the accessibility of the descriptive variable for extent. Section 3.6 of this study defines the theoretical structure that consists of the major elements of the household factors and proposed model that control and manages the key success elements, needs and requirements for the aim and objectives of this research. The entire factors and elements can also support and control the knowledge of the reasons for the implement the research philosophy which has been applied and adopted in this research study as presented in Table 3-1. In this regard, the deductive approach tends to discover the association and the connection among the factors influencing the time of use domestic appliances [106]. The motivation for selecting this research philosophy is due to the behaviour of the consumers which involves various multidisciplinary factors because of the different habits of the consumers, their level of appreciative, and the responsiveness of the end user and the level of understanding related to the conservation of energy. However, the inductive research approaches tend to clarify the importance of the factors that are engaged in particular appliance been investigated in this research through understanding the perspective and standpoint on the occurrences and phenomena and through gathering the quantitative type of data, discussing carried out in groups and through individuals. This is also possible to enable and to permit the advancement and progress or the elimination of the various construction of research through the procedures of the research and as it gets less focus and concentration for generalization [106].

Table 3-1 Research Philosophies [108], [112]

Philosophy	Description	Approach
Positivism	Observations and evaluate facts that are not controlled by human thinking and thoughts, which is use statistical analyses and representative of these facts. Positivism is used in this study by adapting the deductive approach to investigate the factors associated to the daily time usage of the household's appliances.	The deductive approach used for quantitative data and highly controlled. Adopt all fits in one
Interpretivism	Determining implications of the thoughts and opinion that can contribute to explain phenomenon knowledge with a smaller number of samples.	The inductive approach used for more flexible data collection and discuss deeply the thought and beliefs. Adapt one fits in all

3.4 Research Design

As stated by Blaikie (2000), the design of the research is a technical and mechanical document which involves integration and assimilation and the statements for validation that are developed as a plan or as a guide for carrying out a project of the research [113]. Also, Yin (2013) has explained that the design of the research as an action plan for obtaining from here and there [114]. Boris (1982) has also demonstrated the design of the research as the plan, strategy or structure of examination to get answers of the questions of the research [115]. This defines that the design of the research should encounter the requirements of the research question for obtaining the appropriate sampling features and choosing suitable methods for using for data collection to answer the research question. This technique relies on the sort of the strategy and approach that is selected for collecting and gathering and also for analysing the main or primary data. So, the design of the research shows the entire process for collection and gathering of data and analysing [108]. Bell and Bryman (2011) have recommended that the process of the research is a reflection that shows the type of the importance and dimension of the priority which are arranged for addressing the expressed and developed questions of the research and issues and for clearing the organizational nature and sampling from where the collected data are gathered. Creswell (2008) has declared that a good research with successful research is based on selecting the suitable and appropriate design of the research and succeeding the process of the research steps for completion [110].

3.5 Research Strategies

As stated by Robson (1997), the strategy of the research and the research process should be suitable for the questions generated, which the researcher wants to answer [116]. This research has designed the strategy that able to validate and backing the results and achieve a high accuracy outcome. This has been accomplished and validated from the instrument of the survey design which is been developed for collecting and gathering information and data. This research has adopted the quantitative approach to accomplish the aim of this study. The strategies of the research, which have implemented have validated and justify every research question as shown below:

- Comprehensive reviews of the energy domestic sector that get to answer the questions, which related to the domestic consumption and households.
- Questionnaire design is the suitable methodology for the bottom-up approach.

- Comparing the results with previous studies for ensuring the validity of the household's model.
- Investigate the influencing of the demographic factors on appliances usage's time.
- Chose a suitable analysis technique and tools for measuring the reliability and the validity of the questionnaire instrument.
- Additionally, applying an analysis of variance with the use of SPSS V 20 among the formulated groups of the respondents carried out in order to examine and investigate the existence of significant variations or differences among the several demographic factors that related to appliances usage in the households.

Moreover, the researcher has contributed by publishing the results and finding as well as the related topic in national and international journals. This is had improved the knowledge and experience of the researcher in the research field by contacting and communicating field's experts, which are related to the current study. The researcher also has attended number of training courses along with the developmental and learning sessions at Brunel University London for understanding the tools, procedures and techniques, which adopted and followed throughout this research study.

3.6 Research Methods Employed in this Study

Generally, the research methods can be classified into qualitative and quantitative methods [108]. The comparison of these two main methods presented in Table 3-2. As stated earlier, this research study has adopted the quantitative approach methods for achieving and accomplishing the objectives of the research, explained in the subsection below.

Table 3-2 Research methods comparison [117]

method	Approach	Respondents contact	analysing	implementation
Qualitative	Open and unstructured. Based on interview	Direct contact with the participants	Tests related to thoughts and beliefs	Finding can be generalize
Quantitative	Non-open and structured. Based on questionnaire	Indirect can by posted/emailed or handled	Statically and numerically data representation	Finding can be personalized

3.6.1 Quantitative Method

The quantitative methodology is used for generating the data which can be statistically evaluated for determining the entire problem or idea through estimating and testing the parameters from a huge number of samples. In addition, the quantitative methodology can defined as the numerical analysis and representation of the observations for describing and defining the phenomena that have reflected by the observations [118]. Quantitative methodological approach commonly carried out as surveys that enable the researcher to collect the data needed for testing a certain set of hypothesis or assumptions. As stated by Tanur (1982), the survey method explains the information collected related to the opinions, actions and characteristics of an extensive group of individuals, which known as respondents [119]. The questionnaire instrument collects and gathers data for testing, calculating and projecting attitudes, knowledge, experiences, preferences and beliefs from people of a wider population. Survey instruments or questionnaires must developed with care for providing meaningful information and evidence related to the problems, which have examined. Carrying out a survey depends on the time, budget and availability of the resources that contributes in explaining the hypothesis that reflects the behaviour of the selected sample. Hence, the quantitative methodology of surveys acquires a deductive form through asking questions that support developing and testing the theory or the hypotheses because of the capability of addressing a critical situation and rich demonstration of the research study [120]. The advantage of quantitative methods over the qualitative is that in qualitative methods the outcome can be personalized. In this case, the model derived can be applied individually to each case in order to achieve more energy conservative and understand the increasing demand per household. Several scholars and experts of research methodology have categorised certain elements of the quantitative research which, discussed below [114], [121]:

- The aim and the objectives for implementing quantitative approach is to allow the researcher to clarify, comprehend and project particular phenomena which have been derived from the theory.
- The variable has been developed with care from reviewing the literature prior to the data collection from a particular sample that must be appropriate and suitable statistically and reliable.
- It grants the capability for producing figures graphs and charts and is not difficult for measuring reliability as well as validity.

In this way, the survey instrument is not just used in social sciences but also used widely in energy management, consumption and electrical engineering. They are also an effective tool for gathering data and measuring the influence of the parameters and identifying the elements and difficulties of applying domestic energy conservation measurements. Quantitative data collected has been presented through figures and charts in the 4th Chapter for justifying the selection of the research subject and household survey. The survey's questions developed for identifying the current status of appliances ownership and their percentage share to the total household electricity consumption during a certain period of the day.

3.7 Data Collection Methods

Several methods and approaches for gathering data for this research were used. As stated by Bryman and Yin (2011), selection of several data sources such as; archival articles, case studies, reports, and survey questionnaire will back up the finding and results of the research with increasing reliability and validity [108], [122]. However, every method of collecting data has certain strengths and shortcomings and has highlighted those methods for generating the data is a way through which the researcher produces subjective data field or evidence [123].

3.7.1 Secondary Data Collection Method

For gathering the research's data, various sources for producing enough information and background for the local sectors used in this research. This involves journal articles, books, conferences proceedings, and on-line databases. Furthermore, the secondary data gathering also continued along with the primary collection of the research data. Additionally, types of the reviewed documents, presentations, annual reports, seminars, journal articles, and technical reports, all are very important as the researcher has determined the early objectives and the aims of these resources influencing the research design. In addition, household's national records and survey and the data on stats which are kept by various supply utilities, related to the local consumption and the rate of penetration of the appliances [124].

3.7.2 Primary Data Collection

3.7.2.1 Case Study

For achieving and accomplishing the aim and objectives, two resources are utilized. Initially, a comprehensive review for better understanding and benefitting of the application and techniques that can be applied domestic sector. The major and prime purpose of the developed model is for guiding the borough's consumers, to the most appropriate way for improvising their customs for making use of the household appliances. Additionally, the model that enables the consumer to initiates and to handle any elevated problems regarding to the price of the electricity at the high demand through arranging a clear and lasting strategy with complex objectives through associating the demographic factors and set priorities for appliances usage, which is related directly to increased consumption of the households [125]. In this way, the Household Survey was selected as case study in order to evaluate deeply the demographic factors that influence the using time of the household appliances [123]. The majority of the customers are associated with the daily routine. Therefore, the respondents share a number of conditions in relation to routine habits that elevates the demand because of the economic development and the increased demand for electricity from the population of the same borough. Additionally, the essential lack of knowledge and increased use of appliances from the residents are the elements which have formed the peak demand [13]. Consequently, parallel and comparable conditions validate the research through permitting direct relative analysis and evaluation among the various households and demographics' factors. This assists in categorizing the contribution of each appliance in peak period demand. In replying to these facts, the Household Survey carried out at the Hillingdon Borough for investigating and examining the major factors, which influences the use of the appliance and their contribution to peak demand.

3.7.2.2 Questionnaire

The questionnaire instrument is among the methods of data collection that have largely used in various science fields for a long time. Earlier studies on the consumption of energy, its issues, the penetration rate of appliances and the efficiency of energy have used questionnaire [54], [37], [126]. The prime objective of this research study is to develop a statistical model and an evaluation the demographic factors for projecting the demand of electricity in two ways.

- The first way is to recognize the prime important factors that would have an important influence on the individual use of appliance in the UK.
- Secondly, develop a model, which able to motivate and guides the consumers to obtain a clear visualization approach for preventing or minimizing the peak demand.

This enables to demonstrate the levels of peak demand from the perspectives of consumers. However, one of the major challenges for designing the model is to associate the entire difficulty of the objectives as well as the strategies. In this way, it is essential to categorize the factors influence increasing electricity demand in two aspects; Technical and Non-technical [127].

As stated by Oates (2005), one of the many benefits of a questionnaire is that can be managed and administered in several ways such as, phone, post, or via e-mail [123]. For this research, the household questionnaire distributed to the residents of Borough, and then gathered by the researcher. This approach is appropriate for the problem and its nature, which discussed in this study.

3.8 Quantitative Survey: Population and Sample Frames

3.8.1 Populations

There are two kinds of populations, target population and survey population. The target population is assumed as units that collect data from which it has been gathered, whereas the survey population are those units from which the research's survey [128]. For this research study, the target population is used in parallel with the methods of probability sampling for gathering data that comprise of the entire categories of the household.

3.8.2 Sampling and Sample Size

Sampling is a process for choosing units, so, among others; a consideration in developing the samples is a sample has a larger or wider size, so that maximum accuracy can be obtained. Sarndal (2007), has claimed that there exist various techniques for choosing sample like systematic random sampling, simple random samplings, cluster sampling, convenience sampling and simple random sampling, whereas, the convenience sampling is the method which has been used because of the multiple categories of participants used in the study [129]. As stated by Sekaran and Uma (2011), it is very difficult to survey the entire population and involving all of them in a single study, it is time consuming and extremely costly. Also, they have demonstrated statistical tools and technique for generalizing the ratio of the sample [130]. As per their estimation, the entire sample required for this research study which is carried out in Borough of Hillingdon calculated as; the number of households in the borough is 74924 excluding the one person family according to the 2011 census Factsheet which is required 283 samples [131].

3.8.3 The Total Survey Error

The total error of the survey means that the estimated percentage which varies from the mean of the actual value of the major magnitude point and the parameters of the population [132]. Moreover, even if the selected sample developed correctly then an error in the survey is likely to occur and influence the entire rate of response, if some of the replies not gotten from insufficient respondents. The error that has obtained from non-response results in the least consistent and valid. In addition, Groves (1989) has stated that any error that is non-sample must be allocated in order to elevate the accuracy of response through careful follow up of the instrument of the survey, instructions and guidelines and the process or procedures for minimizing the variance as well as bias that will increase the reliability as well as the validity [133]. According to Blaikie (2000), with the increase of the sample size, the sampling error also declines and the reliability of the sample increases and with the decrease in the homogeneity of the population, the error of the sample increase and the reliability of the sample decreases [134]. Furthermore, there are major points that need more attention whenever carrying out a research in orders to reduce the error of the samplings, which are:

1- Choosing the suitable and appropriate time for carrying out the survey.
2- Developing the research survey and selecting the precise frame for sampling.
3- Increase the abilities and skills for using the method of survey.
4- Selecting the factors, which require careful examination?
5- Considering the underlying reasons for the non-sampling responses.

In this regard, this study has reduced the error of the non-sampling overall the design of the survey, gathering data and analysing procedure stages [121].

3.8.4 Response Rate and Non-Response

For this research, the targeted population is Household of Hillingdon Borough, was selected and the probability sampling was also used for the data collection and so anticipate the rate of response. Moreover, the rate of response may also can be calculated from the appropriate responses [121]. Also, see this outcome in various arguments given by a number of researchers that recommended; the replies from all the survey questionnaires should filtered depending on the responses of the sample. The questionnaire is presented in Appendix A, which given to the total sample of 450 candidates in the Borough. At the time of collecting back the questionnaire, the data have entered in SPSS V 20. The total size of the respondents, those who have accomplished the survey is 381, with having a greater rate of response that is 84%. Therefore, 57 of the questionnaires from the total respondents were not able to complete the questionnaire and therefore have excluded. Additional 12 respondents have completed the questionnaires were also excluded as they were not usable, with multiple answers. These immediately left out from the set of data and the maximum number of the responses 381 that was greater than the sample size of 284, depending on the estimation of the Krejcie and Morgan's [135].

This research study has applied postal and personal handle survey, from which this may be very simple to identify the non-responses. As stated by Dillman (2000), the greater the rate of response, greater will be the outcomes [121]. As an outcome, this research study carries a measured rate of response that is highly effective at 84%. This higher rate of response received as the researchers consider put more efforts and used all resources available to get a higher response rate. In addition, with care the mentioned below considerations while carrying out the preparation of the survey:

- Paying higher attention to the design of the survey.
- Directing the developed questionnaire for making sure it is more understandable.
- Brief introduction for the entire questionnaires.
- All the questionnaires distributed to represent the targeted population (households).

3.8.5 Questionnaire Design

Questionnaire Design is translating the aims and the objectives of the research into clear statement. These statements are the questions of the research that the researcher seeks to answer through gathering required data from the Borough residents. So, the planning, preparing and the designing development of a well-structured questionnaire can be reflected from the results of the research and also needed process steps in devising the questions from the literature review which is the foundations of the of this research that clearly recognizes and demonstrates the crucial and essential factors which influencing the usage of the household's appliance. It has been claimed by Fowler (2013) that the elements for the development of a well-structured questionnaire it must be:

1- Clear, specific, focused, easy and short.
2- Encourage and motivate the respondents for filling and providing relevant data.
3- Not aggressive to the respondents for obtaining the reliable and consistent data.
4- Respect in keeping the privacy of the respondent confidential [136].

In this research study, the survey of the household questionnaire was developed to provoke the genuine requirements of the use of time and the demographic factors, with respect to the penetration of the household appliances, the level of ownership and the peak period demand's contribution of the individual appliance. Also, for investigating the demographic factors influencing the usage of the appliance phenomena that leads to the increase in the demand of the household's electricity at a certain period. Therefore, the design of the questionnaire has five parts to be filled out by the participants, which are;

1- Collecting data regarding to the household's demographic factors.

2- Appliances that involve the daily use of coffee maker, toaster, kettle and microwave.
3- Cooking appliances consist of electric pressure cooker, electrical cooker and electrical frying pan.
4- The wet and weekly appliances like washing machine, dishwasher, Vacuum cleaner, Iron and dryer.
5- The office and entertainment like Desktop, TV, CD players and DVD etc.

3.8.6 Coding of Responses

The coding of the answers is a crucial step of the process that needs the researcher pays more attention and concentration when coding every individual factor in the entire survey. De Vaus (2001) has recognized six key factors for coding the questionnaire of the survey:

1- Classifying responses.
2- Allotting codes to every variable.
3- Specifying numbers of the columns to each variable.
4- Producing a codebook.
5- Examining the errors of coding.
6- Entering the data of the respondents [137].

The quantitative approach of data was passed in and analysed statistically by SPSS (Statistical analysis software package) with five point's scale that transforms the responses to numbers. When the 381 questionnaires are collected from the respondents, then every respondent given a reference number, from which it becomes very easy for referencing. A set of database for the collected information developed post completing the coding of the entire variables of the questionnaire.

3.8.7 Questionnaire Formulation

Developing and designing the questionnaire was an additional critical stage in this research, relying on widely studying the related literature on the survey of the household. This has assisted the research in understanding the entire level of the household appliances, their classification and structural patterns from several studies carried out in various regions all over the world and measuring their experience. Zikmund (2006) has recognized various phases of the process of designing the questionnaire:

- Description the objectives of the questionnaire.
- Developing the questions of the questionnaire.

- Conducting the questionnaire.
- Revising and allowing for the changes in the questionnaire.
- Supervising the questionnaire.
- Data analysis and evaluation.
- Reporting the findings of the questionnaire [138].

However, such a process in devising the questionnaire that helps in obtaining the valid results and the elevated rate of response with respect to legal responses through developing the appropriate and suitable questionnaire. Furthermore, the questionnaire was arranged and formatted with care for making the respondents excited and keen for filling out the questionnaire. For developing the questionnaire in a professional manner, this is clearer that this will raise the rate of response. Certain critical recommendations were also obtained after directing the questionnaire from the Brunel University Research Students 2014 / 2015 for making the design of the questionnaire in an attractive manner.

3.8.8 Questionnaire Pilot Test

After designing and developing the questionnaire, the step to follow is the pilot testing. As stated by Zikmund (2006), carrying out the pilot testing of the questionnaire is an important step prior to the collection of the primary data. The pilot testing of the questionnaire promotes the validity and the consistency of the primary data and overpowers any shortcoming depending on the feedback of the respondents [138]. The pilot test, could disclose certain important points above the questions that may never be identified by the authors and can influence the research findings like testing the words question, layout, rate of responses, familiarity with respondent, analysis process, completion time for questionnaire sequence [139]. This has been explained further that the sample size for pilot testing the questionnaire must be in ranges 10 - 30 research participants. In this research, the sample size for pilot testing was 33. The required estimated time for completing the questionnaire was 10 to 15 minutes. The rate of the response in the pilot testing was 100 per cent where all questionnaires were handled in person to the respondents and collected. Moreover, the data and load profiling technique was presented and published as showed a great agreement with national data [140].

3.8.9 Study Covering Letter and Guidelines

The researcher has also developed a covering letter that defines clearly the instructions for explaining and demonstrating the survey purpose. The covering letter prepared the questionnaire that has been printed on the official paper of the College of Engineering, Physical Sciences, Design, Electronic and Computing Engineering Department, Brunel University. The covering letter was developed for introducing the research purpose to the participants. All the participants were provided with clear guidelines for filling the research questionnaires. All the instructions were mentioned in the covering letter of the questionnaire for defining the research purpose of the importance of their participants. At the start of every part of the questionnaire, there is clear written description of all statements.

3.8.10 Research Ethical Considerations

There is certain ethical reflections that the researcher must consider like personal information must be kept strictly confidential, demonstrating the research purpose and also that the researcher must receive consent before putting effort for data collection. Considerations including, defining the research purpose, notifying the participants that the gathered data in this research is a part of the degree of PhD thesis, the gathered data in this research will be printed in national as well as international conferences and journals [130]. Also, a letter from the Brunel University College of Engineering, Design and Physical Sciences Research ethics committee prior to the gathering of the data was obtained.

3.9 Summary

This chapter has provided the outlook on the methods of the research; this involves approaches, design, philosophies and strategies in this research. With respect to this, the philosophy of positivism has been validated and justified due to its choice and its power for more evaluation and explanation with respect to remarkable problems of the research in the domestic sector. Besides, the procedural perspectives were also implemented for collecting data method which is the quantitative approach which is used for bottom-up approach. They can be used in collecting primary data for understanding and exploring deep factors which influence and affects the using time of the household's appliances. The methodology of the research is commonly accepted in researches related to electrical engineering as well as electronic engineering. The method for gathering secondary data used in the documentation review, reports, archival records, journal articles and books, that later allowed the factors for recognizing to test and then to examine a survey questionnaire of the households.

Chapter 4 Quantitative and Initial Data Analysis

4.1 Introduction

This is the chapter where the statistical means used in this research are discussed. It provides some assumptions and information on the statistical means utilized in this investigation. It is structured as follows. First, it starts with a discussion regarding the choices of statistical software. The discussion is then followed by an overview outlining the factors influencing the statistical techniques choices, data presentation and distribution. The statistical techniques procedures for the analysis of the survey data are presented next. This chapter provides a statistical description of the whole samples developed through the use of the demographic and appliances data collected in this study and analysis of data related to the time of using the household's appliances.

4.1.1 Choice of the Statistical Software

In this investigation, SPSS version 20 has been chosen for data analysis. SPSS is popular statistical analysis software in social science studies, such as sociology, anthropology, management and is used by many organizations and universities. The popularity of SPSS is attributed to its highly sophistication, wide availability and comprehensive statistical computer packages [141].

4.1.2 Factors Influencing the Statistical Techniques Choices

Some factors influence the choices of statistical tests. These factors might include issues such as the analysis objectives, the analysis focus, type and size of the sample and type of tests (parametric and nonparametric) and variable measurement level. First, the analysis objectives aim to guide and direct the analytical processes and are key parts in managing the credibility of a research. In this research, one of the main objectives is to investigate if there is an impact of appliance consumption between summer and winter time of use (and whether this is connected to the household occupier habits). The analysis will look to find if there is a relationship between appliance's time of use in the summer, winter and demographic factors of the household. This leads to the selection of statistical techniques, such to find out whether such causal relationships exist [142].

4.2 Statistical Methods and Techniques

4.2.1 Statistical Methods

Statistical procedures can be divided into descriptive and inferential statistics. The descriptive statistics used to represent and report the measures of central tendency (mean, median and mode), measures of dispersion (range and standard deviation), and measures of position (quartiles, deciles and percentiles) graphical or table representation of the data will be used [143]. The inferential statistics used to generalize the sample findings to the broader target population from which the sample data was collected. Statistical inference can be performed through parameter estimation or hypothesis testing. This research will use the latter, which aims to examine whether a particular proposition concerning the population is likely to be true or false. It is essential to select the most appropriate statistical technique for every hypothesis to be tested [144].

4.2.2 Statistical Techniques

The hypotheses formulated to address the research problem will be tested by using Mann-Whitney U test and Kruskal-Wallis test, and Spearman's chi-square test and correlation analysis as shown in Figure 4-1. The Spearman’s correlation coefficient (Spearman’s rho) is a measure of association between rank orders. This is a measure of linear association between the variables. Spearman’s is used for categorical or Ordinal data where both rows and columns contain ordered values. Mann-Whitney test is a non-parametric alternative to independent sample t-test and it’s used if the means of two unrelated groups of data are significantly different from one another. To test if the means of three or more unrelated groups of data are significantly different, the Kruskal-Wallis test was used. The Spearman's chi-square test was used to test for association between two variables. A Mann-Whitney U test is used to compare two independent groups when the independent variable is not normally distributed. Mann-Whitney U test, Kruskal-Wallis test and Spearman’s Chi-square tests and analysis will be used from the Statistical Package for the Social Sciences Software (SPSS).

4.3 Initial Analysis of Data

Prior to starting the analysis of the data, there are measurements have to be taken to prevent any error. Screening and cleaning the collected data to ensure input process is correctly, and ready. In exploring the suitable technique to use for this type of data in terms of accuracy, outliers and normality are investigated in order to gain good results [211], [212].

4.3.1 Screening and Cleaning Data

According to Pallant (2010), there are steps to take for screening and cleaning the data before it was analysed, accuracy, outliers and normality. For the accuracy, there were 381 questionnaires collected. SPSS was used to configure the data. The total questionnaires completed and collected is 381 with response rate (84 %). However, approximately 69 of the questionnaires were excluded. Multiple answers were the main reason to exclude these questionnaires where the participants tick more than one answer for the same appliance. There were promptly excluded from the data collections and the final number was 381 responses. So, there are enough samples to carry on conducting the research according to Krejcie and Morgan's concept [145]. According to Malhotra, statistical analysis was re-running for every factor to detect any missing responses [146]. Then for the outliers, there are four causes for outliers which are; incorrect data record, failure to detect missing values, error in the sampling, and finally extreme values than the normal distribution [147].

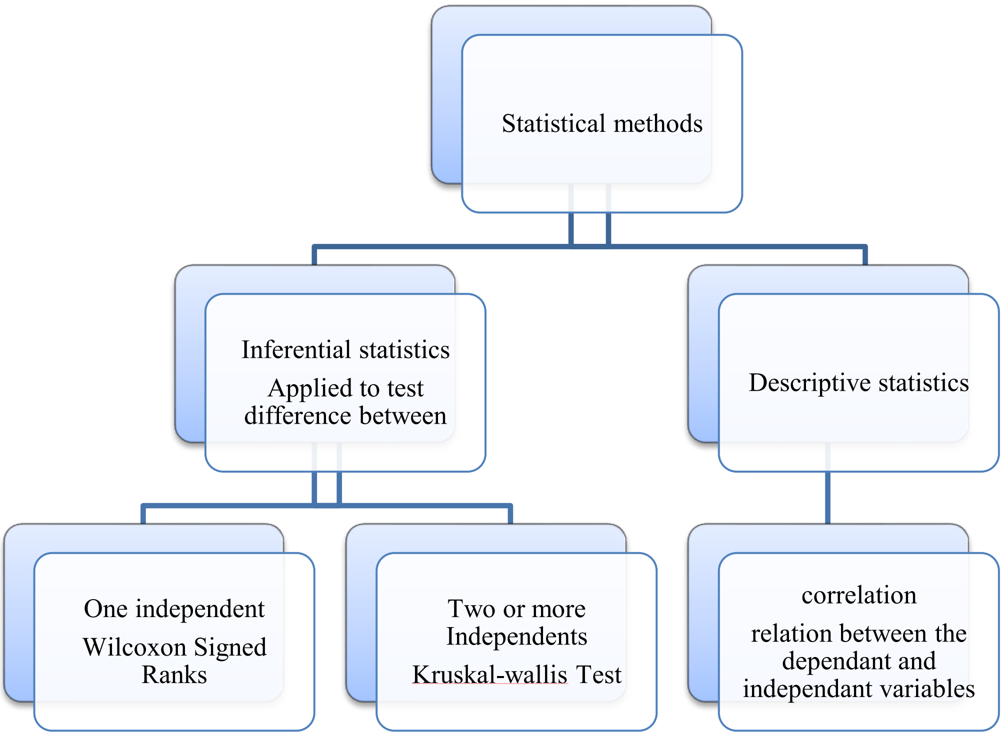


Figure 4-1 statistic methods and techniques

4.4 Representation of Respondents

This section based on the collected data of household's demographic factors from the samples located in London Borough of Hillingdon [131]. The data, indicates that the frequency distribution of respondents were 55.4 % male and 44.6 % female. Also, represent the number of bedrooms in a house, illustrates that 33.1 % of the respondents had 2 bedrooms in a house, 43.3 % had 3 bedrooms in a house, 14.2 % had 4 bedrooms in a house, 9.5 % had 5 bedrooms or more in a house respectively. On the other hand, in terms of the type of the household, appendix B displays the frequency distribution of household ownership and shows that 23.1 % of the respondents own their house outright, 48.8 % of the respondents bought their house on a mortgage, and the remaining respondents rented their house or used other methods (28.1 %). Appendix B, the frequency distribution of the household as; 34.9 % of the respondents said that there are only 2 people living in the house, 32.3 % of the respondents said that there are 3 people living in a house, 23.6 % of the respondents said that there are 4 people living in a house, 7.1 % of the respondents said that there are 5 people living in a house, 1.8 % of the respondents said that there are 6 people living in a house and the remaining respondents said that there are 7 people living in a house (0.3 %). Additionally, the data indicates the current employment status of the respondents, 30.2 % of the respondents are employed full time, 26.0 % are employed part time, 13.4 % are retired and unemployed respondents, 11.0 % are full time and retired respondents, 12.1 % are full time and part time respondents and 7.3 % are part time and retired respondents. Also, the data illustrates the family components, 26.0 % of the household residents are 2 adults, 9.7 % of the household residents are 1 adult and 1 child, 21.0 % of the household residents are 2 adults and 1 child, 11.3 % of the household residents are 1 adult and 2 children, 17.3 % of the household residents are 2 adults and 2 children, and 14.7 % of the household residents are other types of residents. Finally, the appliances rate, 22.0 % of the respondents are using efficient appliances in their household, 52.5 % of the respondents are using normal appliances in their household, 18.6 % of the respondents do not know, and 6.8 % of the respondents do not care whatever appliances are using.

4.5 Grouping the Appliances Based on Functionality

In this section, the data grouped into categories based on the functionality. As illustrated in the Table 4-1, the appliances grouped into five different groups based on their functionality [67], [54]. For simplicity of the analysis, the kitchen appliances and equipment divided into two different groups, light-duty and heavy-duty cooking appliances.

Table 4-1 Categorization of the Household's appliances

Category	Appliances consist
Light-Duty Cooking	Kettle, Coffee maker, Toaster, Microwave, Blender, Popcorn popper, Waffle-iron.
Heavy-Duty Cooking	Hotplate, Electrical frying pan, Bread Maker, Electrical food steamer, Electrical rice cooker, Electrical pressure cooker, Electrical cooker.
Office and Entertainment	Laptop, Desktop, Printer, Scanner & Photocopier, Shredder, Electrical hard drive, TV, CD player, DVD player, Radio, Home cinema.
Wet	Dishwasher, Washing machine, Clothes dryer.
Other or weekly	Vacuum cleaner, Iron, Kitchen extractor, Celling & table fans, Hair Dryer, Hair straightener and curlers, Electrical Shaver & Electrical Tooth Brush.
Seasonal	Electrical Shower, Electrical Heater, Electrical Blanket, Electrical Mower, Electrical Hedge Trimmer, Electrical Drill, Electrical Saw, Electrical Grinder.

4.6 Reliability Test

One of the main difficulties concerning reliability is the internal accuracy represented by consistency, stability and repeatability. This refers to the degree to which one or more variables being assessed are homogeneous, and can provide a good degree of reliability in presenting the right score on a specific dimension. Reliability is a measure of the capacity to gain reliable measurements, and can be estimated using a reliability coefficient, such as Cronbach's alpha correlates [148]. The estimation of Cronbach's alpha calculated for each item against more items in the same group, which gives the total score. Items less than the Cronbach's alpha can be removed to make an instrument with a high degree of, and total score of, homogeneity. The difficulty concerning the reliability is the accuracy of the consistency, to which extent the factors are homogeneous. In SPSS, the measurement of reliability can be measured or estimated using Cronbach's alpha coefficient. The estimation calculation of the coefficient is presented in total score. As "*Coefficient alpha absolutely should be the first measure one calculates to assess the quality of the instrument*" [148]. Alpha's coefficient of 0.70 or higher is reflected to be a good reliability. Therefore, the reliability test was performed to all factors included in this study and the overall of the Cronbach's alpha is 0.854 [149].

4.7 Normality Test

It is assumed in a statistical inference that as sample size increases, distributions will approximate normal. Most statistical tests rely on the assumption that the data is "normal". Tests that rely on the assumption or normality are called parametric tests. If the data is not normal, then statistical tests that do not rely upon the assumption of normality would be used, and these tests are called non-parametric tests. The Kolmogorov-Smirnov test (K-S) and Shapiro-Wilk (S-W) test are designed to test normality by comparing the data to a normal distribution with the same mean and standard deviation of the sample. Table 4-2 shows the data variables are not normally distributed, since the sig. values are less than 0.05 then all the variables above are not normally distributed. Table 4-3 provides the K-S and S-W test results. If the test is not significant, then the data are normal, so any p-value from K-S and S-W test that is above 0.05 indicates normality. If the test is significant (p-value less than 0.05), then the data are non-normal.

Table 4-2 Normality Test for the appliances

Tests of Normality	Kolmogorov-Smirnov[a]						Shapiro-Wilk					
	Statistic		df		Sig.		Statistic		df		Sig.	
	winter	summer	winter	summer	winter	summer	winter	summer	winter	summer	winter	summer
Light-duty cooking	.11	.11	381	381	.00	.00	.97	.95	381	381	.00	.00
Heavy-duty cooking	.21	.26	381	381	.00	.00	.82	.78	381	381	.00	.00
Entertainment and office	.14	.17	381	381	.00	.00	.96	.95	381	381	.00	.00
Wet appliances	.13	.21	381	381	.00	.00	.94	.91	381	381	.00	.00
Other appliances	.09	.07	381	381	.00	.00	.98	.98	381	381	.00	.00

4.8 Appliances Usage

This defines the type of appliance in possession in the households surveyed, and it assumed that an appliance is in use if it exists. A multiple ownership is not considered, as the ownership is only one unit per household. As shown in Figure 4-2 and Table 4-3, the data indicated that 68.7 % (262 households) are using more appliances during winter than summer. Conversely, only 52 households (13.64 %) stated that are using more appliances during summer than winter. Besides, only 67 households (17.5 %) indicated that are using same appliances during winter and summer. Additionally, the table below indicates the number of households divided into five categories showing the overall total number of appliances owned. However, this is indicating that there is uncertainty in exact appliances owned by the households in the UK [150].

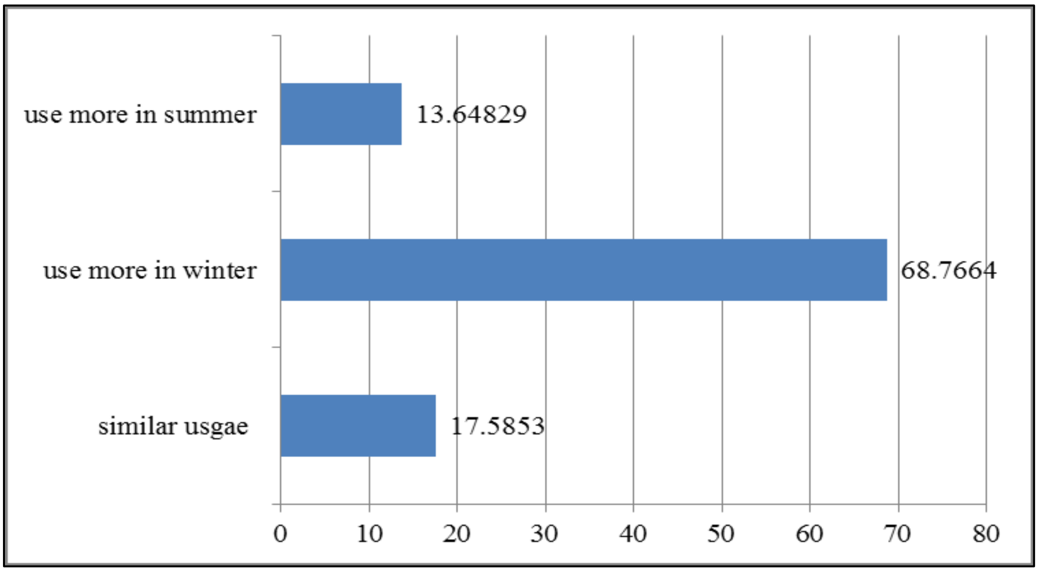


Figure 4-2 Percentage appliances usage winter-summer

Table 4-3 Number of Appliances per Household

Appliances	Number of households with the stated appliance's number			
	winter	Winter percentage	summer	Summer percentage
30 or less	130	34.1	196	51.44
31-35	79	20.7	65	17
36-40	25	6.5	21	5.5
41-45	51	13.3	42	11
46 or more	96	25.1	57	14.9

4.8.1 Light-duty Cooking Appliances Usage

4.8.1.1 Kettle

The data reveals there is not much difference in the time of use of the kettle in winter and summer as can be seen in Figurer 4-3. The majority of people (more than 55 %) use the kettle between 5 am-9 am, both in winter and summer. In addition, there is a high number of people (n = 85, 22.3 % & n = 62, 16.3 %) who use it during peak period (4-9 pm). In the study done by Frith et al. (2007) the kettle used a great deal after 8am in the morning and until 5 pm there were several peaks of usage above 1000 W caused by the use of a kettle [151].

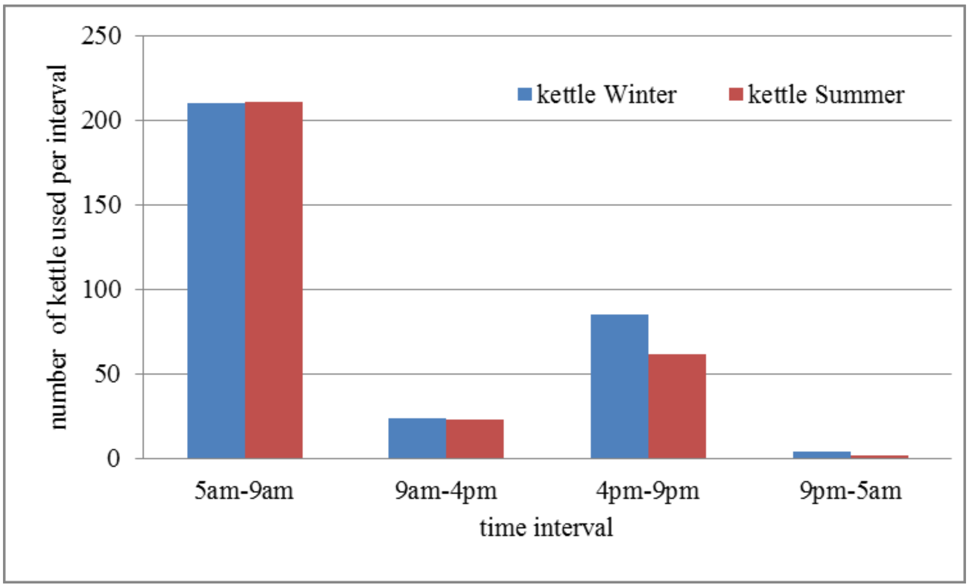


Figure 4-3 Kettle Usage

4.8.1.1 Coffee Maker

The bar chart in Figure 4-4 shows there is no much difference in use of a coffee maker during winter and summer. Most of the participants (more than 80 %) they do not use a coffee maker. However, almost 17 % 1nd 13 % of the households are using a coffee maker between the hours of 5 am and 9 am during winter and summer respectively. In addition, the usage during the peak period (4-9 pm) is low, where only two households (0.5 %) reported that they are using the coffee maker during peak periods.

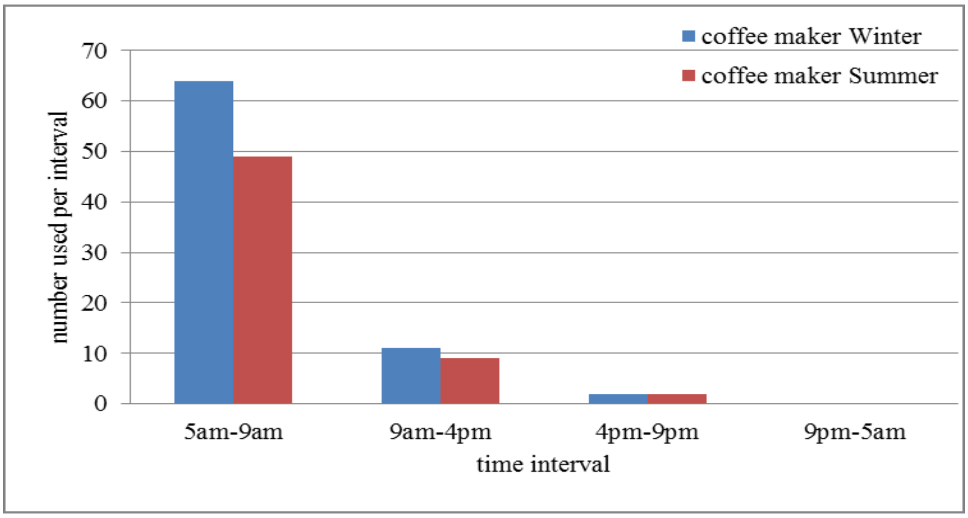


Figure 4-4 Coffee Maker Usage

4.8.1.2 Toaster

The collected data reveals there is 13 % of the households use more toasters in winter than summer as shown in Figure 4-5. However, toaster usage in summer is a slightly higher than winter in the morning (2 %). In fact, many of the participants (25 % & 37.8 %) do not use a toaster at all. For those who do, the most common time to use one is between 5 am and 9 am (42.8 % & 39.4 %). During the peak period (4-9 pm) the usage of a toaster is about 18 % and 10 % for winter and summer. In the study conducted by Jones and Lomas (2016), the findings suggested that the use of toasters was the same all year round, regardless of the time of year [150].

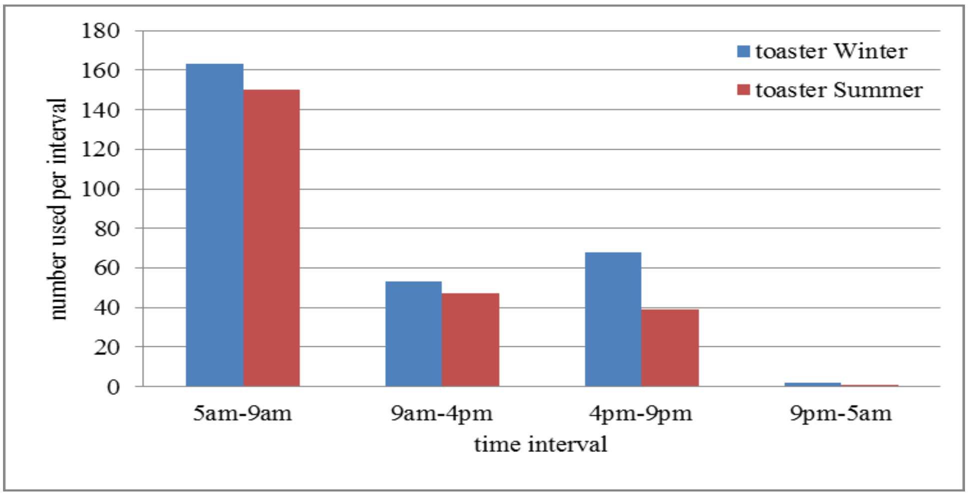


Figure 4-5 Toaster Usage

4.8.1.3 Microwave

From the data analysis, it revealed there is more than 80 % and 73 % in winter and summer is using a microwave during the day. As shown in Figure 4-6, the most popular time to use the microwave in both the winter and summer is peak time (4-9 pm) where out of all the 381 participants more than 58 % and 48 % are using a microwave. Moreover, around a third of the participants (n = 103) never use the microwave in summer. In the study done by Jones and Lomas (2016), the findings suggested that the use of microwaves was the same all year round, regardless of the time of year [150].

4.8.1.4 Popcorn Maker

The analyses reveal most of the 381 participants never use a popcorn popper either in the winter of summer (85 % & 88.5 %). As shown in Figure 4-7, there was low use of a popcorn popper in both winter and summer during certain times of the day 4-9 pm (6.8 % & 4.7 %).

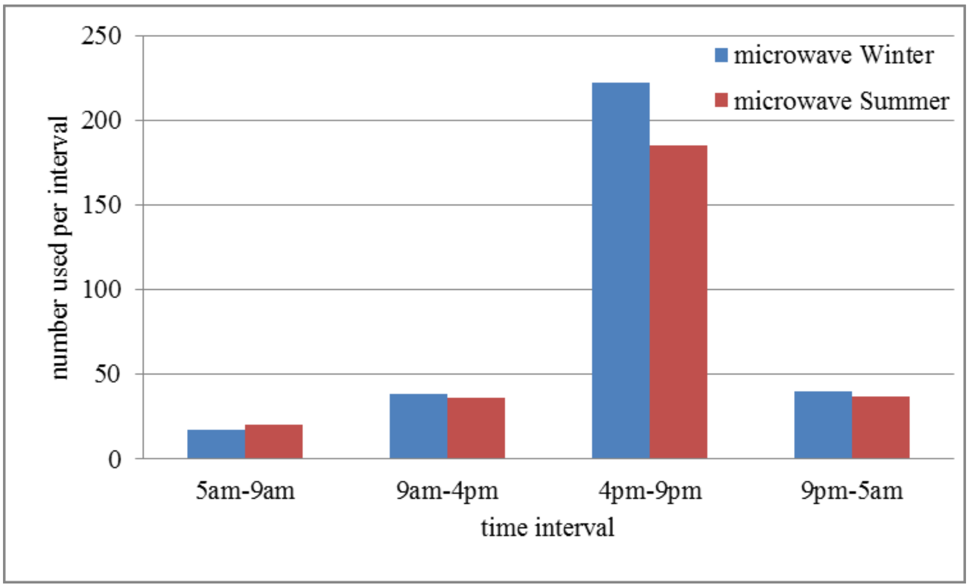


Figure 4-6 Microwave Usage

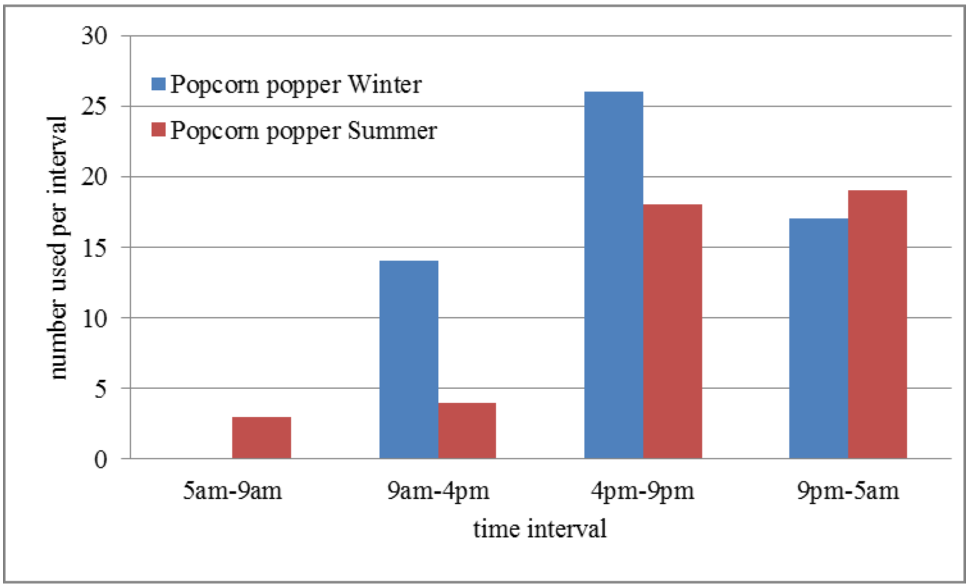


Figure 4-7 Popcorn Popper Usage

4.8.1.5 Food Blender/Juicer

As shown in Figure 4-8, the majority of the 381 participants do not use a blender either in the summer of winter (78 %). There was a low usage of a blender at other times of the day during the winter and summer and during the peak period (4-9 pm) 5 & 6 % and a considerably higher in the morning time (4-9 am) where more than 12 % reported using the blender in summer and winter.

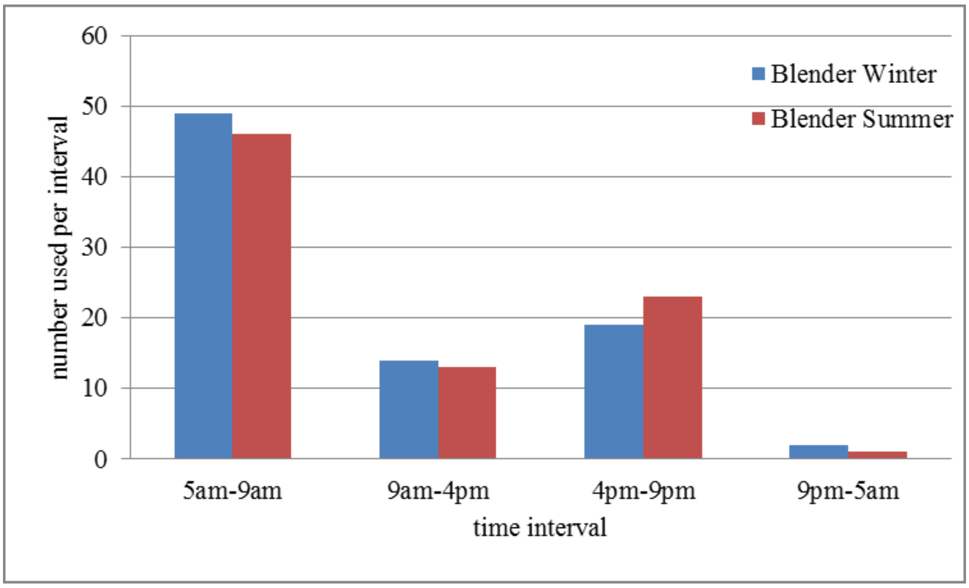


Figure 4-8 Food Blender/Juicer Usage

4.8.1.6 Waffle Iron/Sandwich maker

The analyses reveal there is very low use of a waffle iron amongst the 381 participants. In fact, many of them never use them in winter or summer (324 & 346), more than 85 %. As shown in Figure 4-9, there was some use, albeit very low uses of a waffle iron during the other times of the day. During the peak period, only 4.2 % of the participants are using it in winter and only 1.8 % in summer.

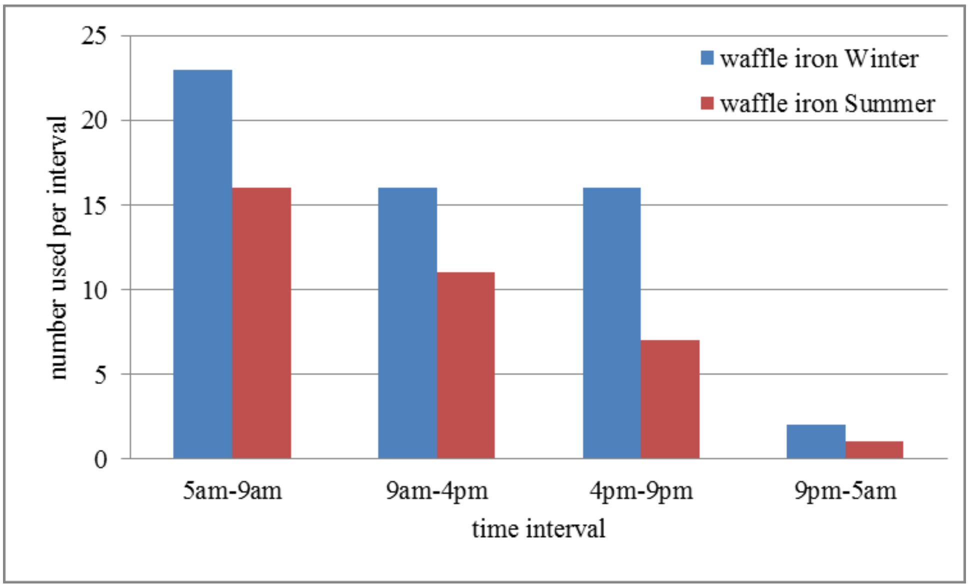


Figure 4-9 Waffle Iron/Sandwich Maker Usage

4.8.2 Heavy-duty cooking appliances usage

4.8.2.1 Hotplate

The analyses show there is no difference in use of a hotplate amongst the 381 participants during the winter and summer. In fact, the majority of them never use one. However, as shown in Figure 4-10, there was some use (7.65 & 6 %) reported during peak period (4-9 pm).

4.8.2.2 Deeper Frying Pan

According to Figure 4-11, the analyses show that for the most part, the participants never use one (84.5 % & 89.8 %). Very few use one during peak period (4-9 pm).

4.8.2.3 Bread Maker

The analyses reveal there is very low use of bread maker in both summer and winter as shown in Figure 4-12. In fact, the majority of the 381 participants never use one (91.3 % & 95.8 %). Very few of the participants used one between 4- 9 pm (4.5 % & 2.9 % of the participants) and between 9 am and 4 pm (1.6 % & 1.3 %). The finding is in line with that of Jones and Lomas (2016) who found bread makers were used very infrequently and therefore consume little to no energy [150].

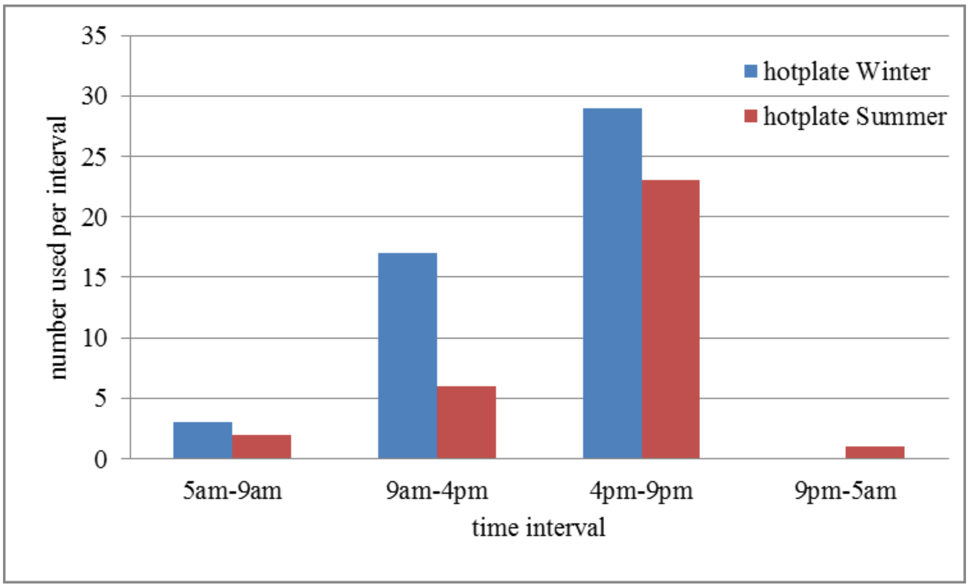


Figure 4-10 Hotplate Usage

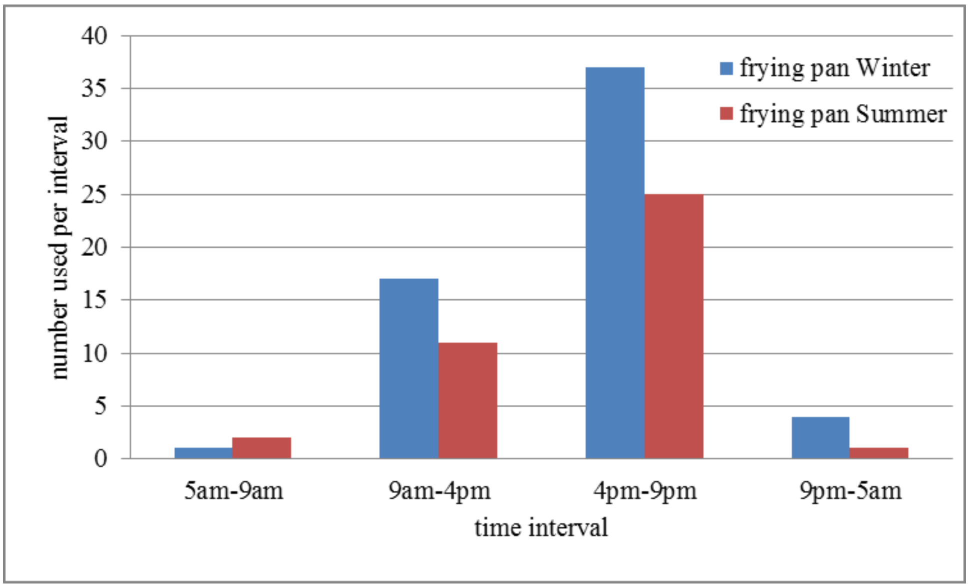


Figure 4-11 Deeper Frying Pan Usage

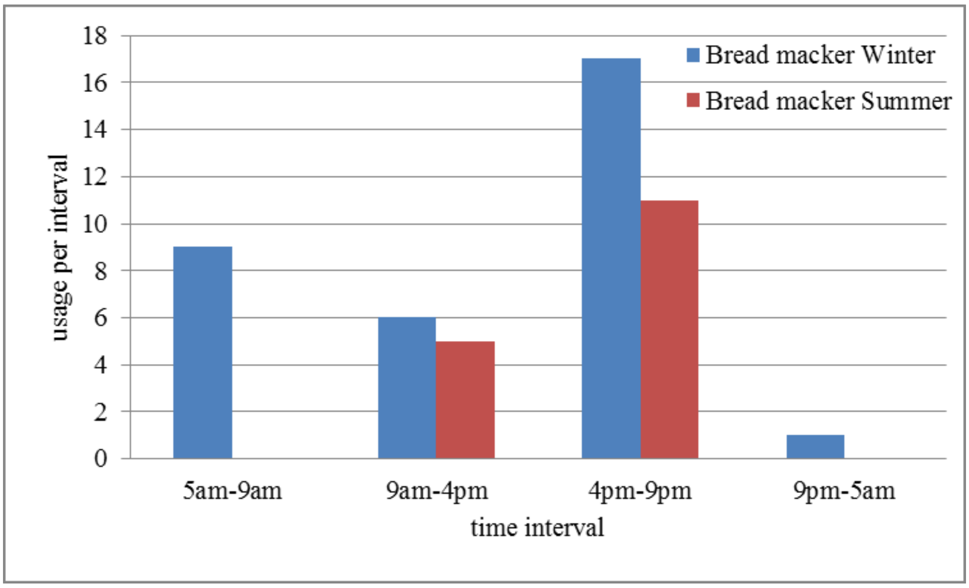


Figure 4-12 Bread Maker Usage

4.8.2.4 Electrical Food Steamer

From the analyses, it can be inferred there is low use of a food steamer in winter and summer amongst the 381 participants in the study. Many of them never use a food steamer either in winter or summer (80.3 % & 85.6 %) as shown in figure 4-13. There was some use during peak period (4-9 pm), 16.8 % in winter and 11.5 % in summer and a very low use between 9 am and 4 pm (2.9 % & 0.5 %).

4.8.2.5 Electrical Rice Cooker

As can be seen in figure 4-14, the majority of the 381 participants never use an electrical rice cooker in winter or summer (67.7 % & 78.7 %). There was some use during peak hours (4-9 pm) (24.7 % & 13.9 %), low use between 9am and 4pm and between 9 pm and 5 am.

4.8.2.6 Electrical Pressure Cooker

The majority of the participants do not use an electrical pressure cooker in either the winter or summer. However, a considerable usage during peak hours in winter was reported amongst the participants (8.1 %) as shown in Figure 4-15.

4.8.2.7 Electrical Cooker

It can be deduced from the analysis and Figure 4-16 that use of electrical cookers in both winter and summer are very uncommon due to the use of gas as the main cooking process that is a very common in the UK. However, for 18.9 % & 21 % they are most likely to use it between 4pm and 9pm. It can be seen here that the number of households reported in summer are a slightly high than winter. A study by Jones and Lomas (2016) was reported around half of their participants (54 %) used an electric cooker, and in this study, around 25 % of the participants reported that are using electricity for their main daily cooking which is unfortunately happening during peak periods.

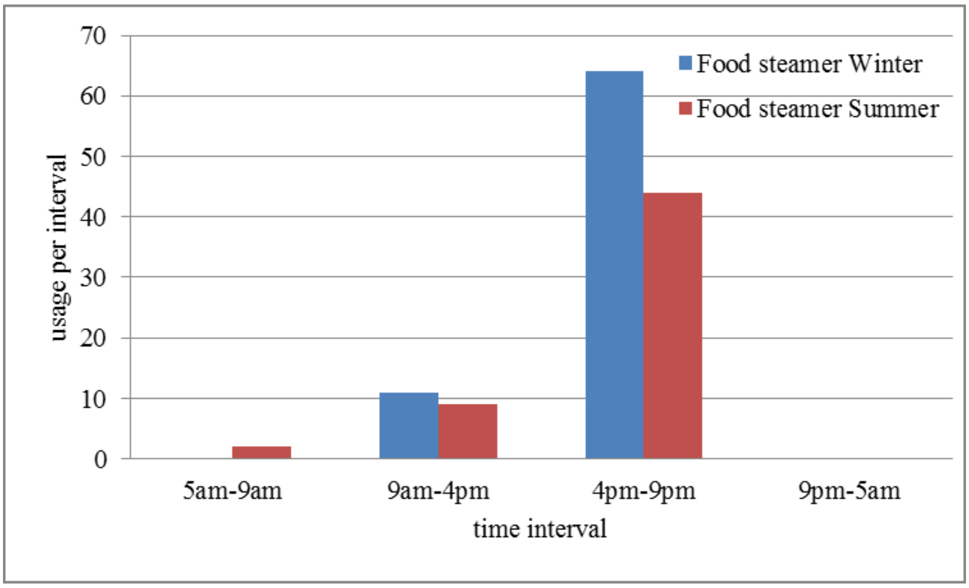


Figure 4-13 Food Steamer Usage

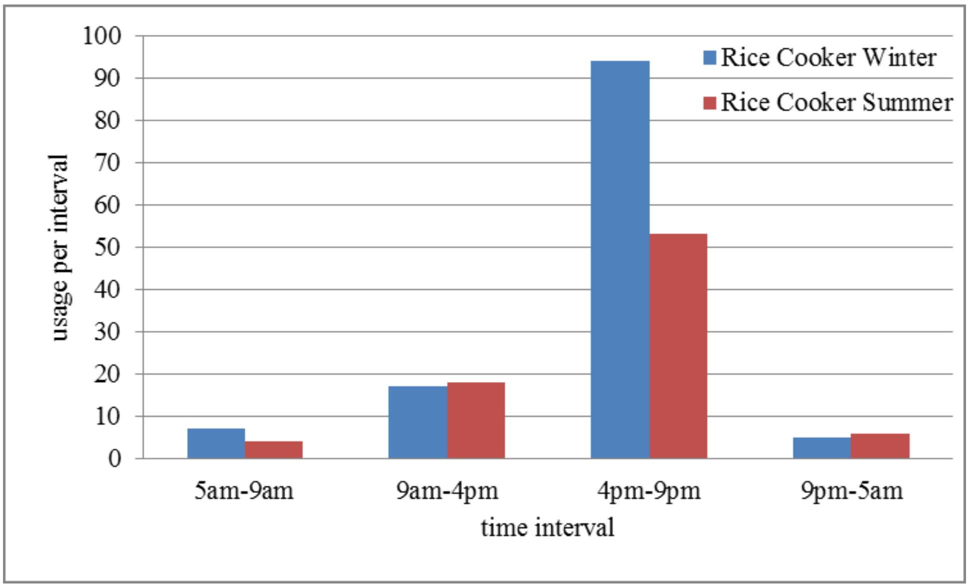


Figure 4-14 Rice Cooker Usage

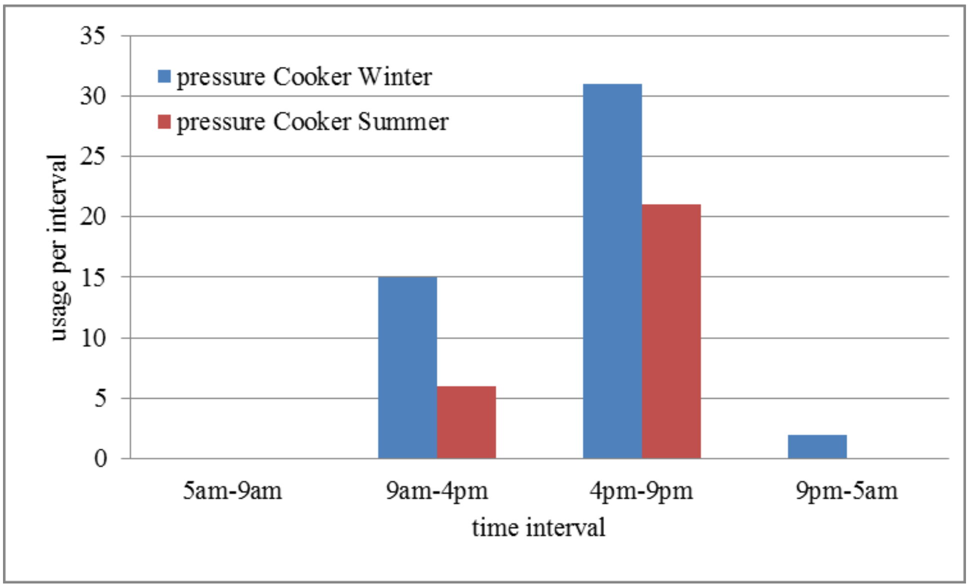


Figure 4-15 Pressure Cooker Usage

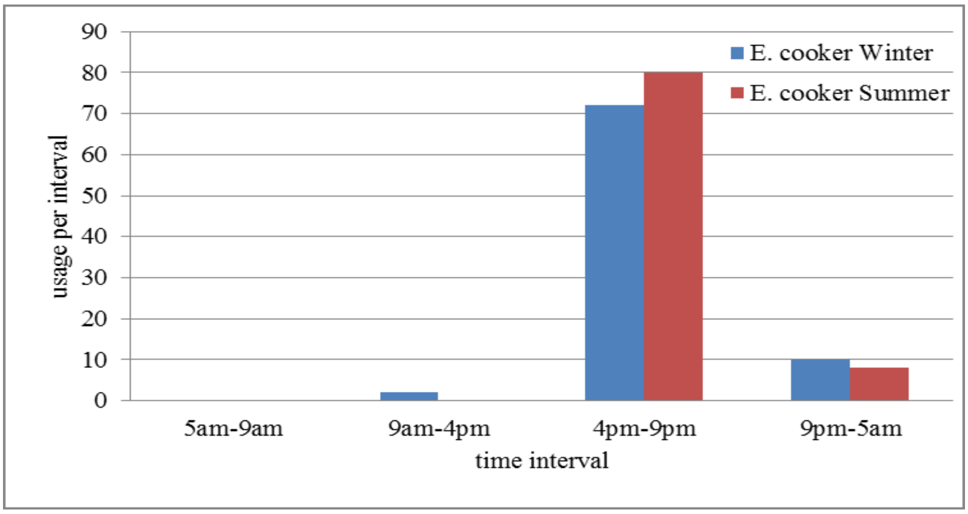


Figure 4-16 Electrical Cooker Usage

4.8.2.8 Kitchen Extractor

As shown in Figure 4-17, the usage of the kitchen extractor occurs during the peak period of the day where more than 50 % of the participants reported that are using it.

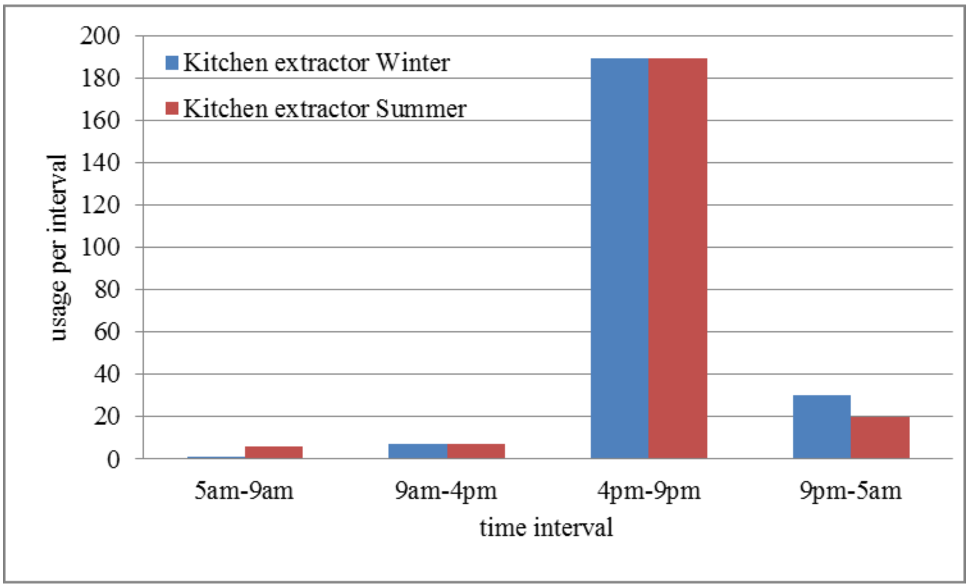


Figure 4-17 Kitchen Extractor Usage

4.8.3 Office and Entertainment Usage

4.8.3.1 Laptop

From the analyses as shown in Figure 4-18, just over 90 % of the participants, use a laptop in either winter or summer. However, participants reported that are using laptop slightly higher in summer than winter. In the study by Lomas and Jones (2016), there was a low use of laptops for 1 and 2 hours a day. It also found in the study that as laptop ownership increased, so did the likelihood of high electrical demand. Loams and Jones (2016) inform only the households using their main laptop for more than two hours on a weekday were more likely to be high consumers of electric. In this study, in total, only a third used a laptop during the peak period and more than 50 % of the participants reported that they use a laptop after 9 pm.

4.8.3.2 Desktop Computer

The analyses show there is more than 50 % amongst the participants are not using a desktop computer. During summer, high use between 4 pm and 9 pm (11.3 %) and a slightly higher after 9 pm (21.8) as shown in Figure 4-19. In winter, the majority of desktop users reported that are using a desktop computer after 9 pm and in winter there is 17.8 % using during the peak period and more than 16 % using after 9 pm. In the study conducted by Lomas and Jones (2016) it was found there was less use of a desktop computer amongst the participants (49 %) did not use one. However, 45 % had at least one desktop in the house and would mainly use it for between zero and two hours. Jones and Lomas (2016) argue for households that had three or more desktop computers “were significantly more likely to be high electricity consumers”.

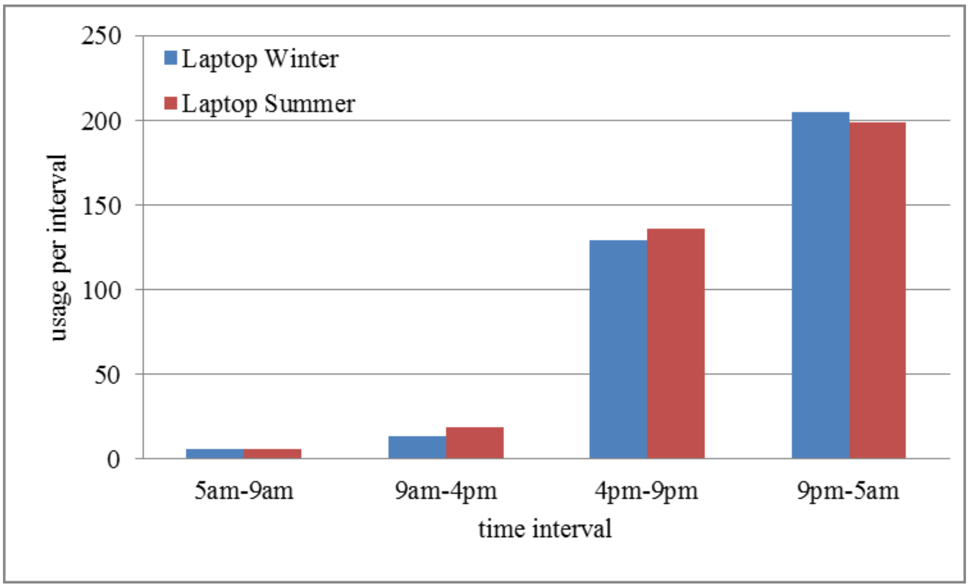


Figure 4-18 Laptop Usage

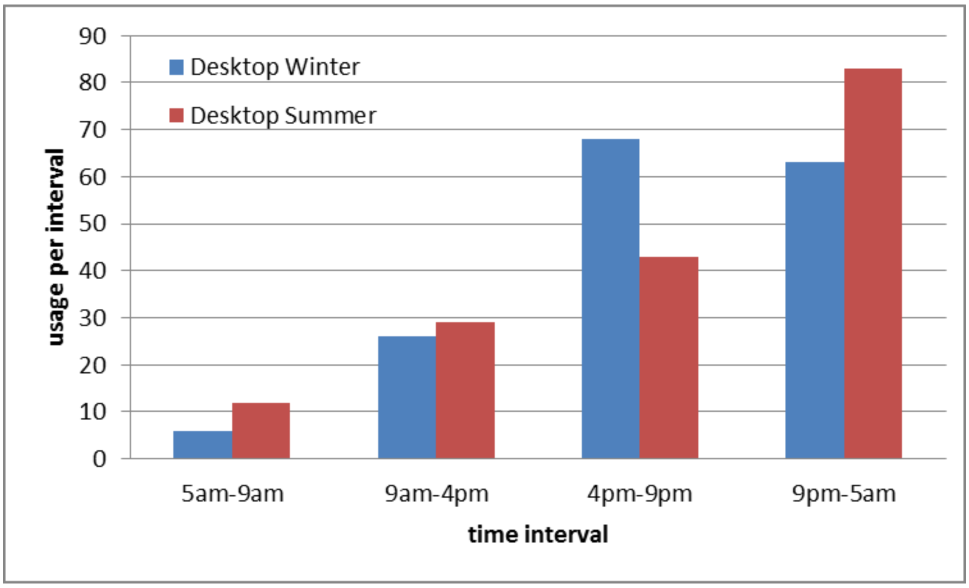


Figure 4-19 Desktop computer Usage

4.8.3.3 Printer, Scanner and Photocopier

The data revealed many of the participants do not use a printer, scanner or photocopier either in the winter or in the summer. Only 12 % reported using a printer in summer and winter as shown in Figure 4-20. Out of those who do, the most common times to use them are either between 4-9 pm or after 9 pm (6.6 % & 7.6 %). According to Firth et al. (2007) many households are purchasing poorly designed IT equipment such as printers and scanners etc., which are always on standby and therefore they are using electricity even when they are not being used.

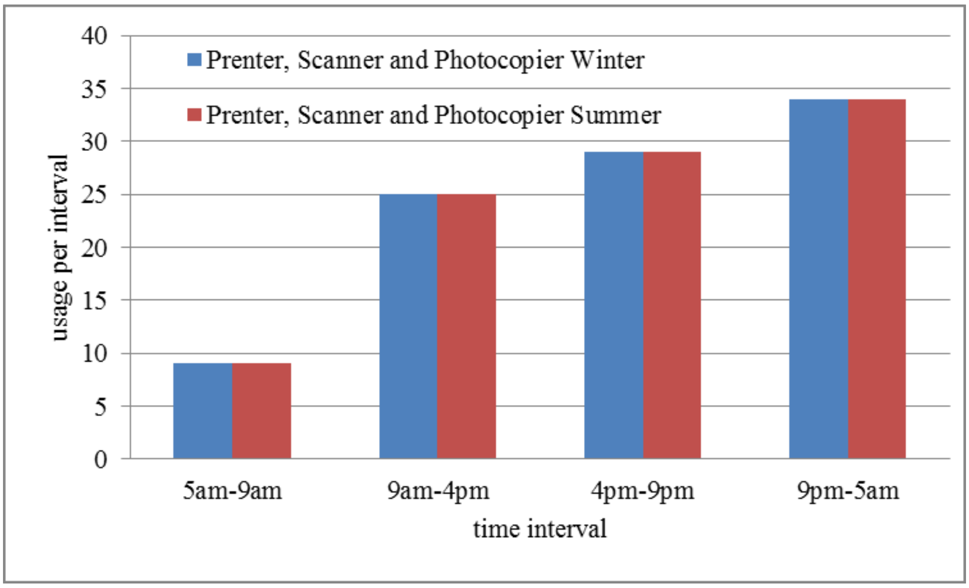


Figure 4-20 Printer, Scanner and Photocopier Usage

4.8.3.4 Shredder

The analyses reveal many of the participants do not use a shredder in either the winter or the summer as shown in Figure 4-21. Out of those who do use one, the most popular time to use one is between 9 pm and 5 am (5 %). However, no noticeable differences were reported between winter and summer usage.

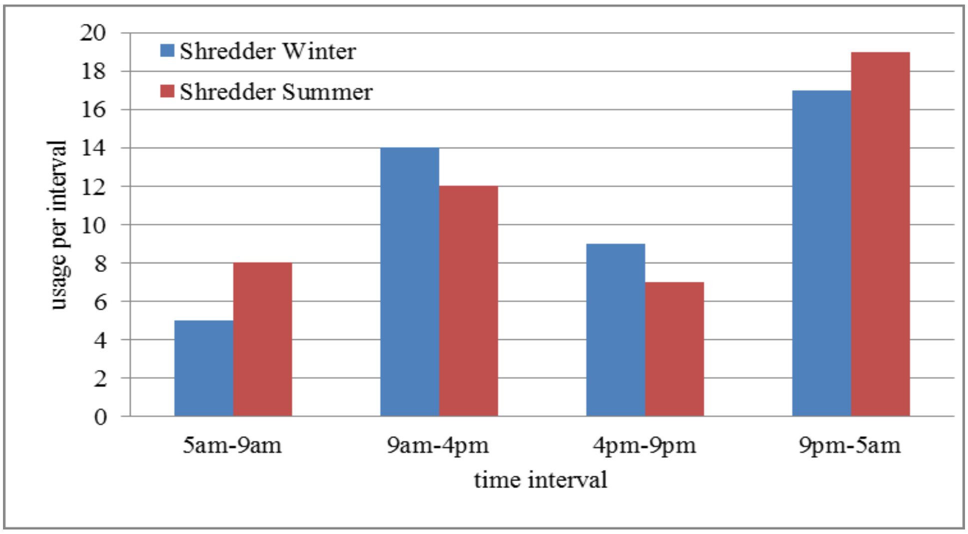


Figure 4-21 Shredder Usage

4.8.3.5 Electrical Hard Drive

As shown in Figure 4-22, the use of electrical hard drives is not very common amongst the participants. Most of them (more than 80 %) never use one in either winter or summer. However, out of those who do use one, the most common time to use one between 9 pm and 5 am (less than 8 %).

4.8.3.6 TV

The data revealed that just over 90 % in winter and nearly 90 % in summer of the participants reported that are using TV as shown in Figure 4-23. More than 80 % of the users indicate that are using the TV in the peak period, and after 9 pm. The data show a similarity in using a TV during both winter and summer, which reflects the daily habit of the residents.

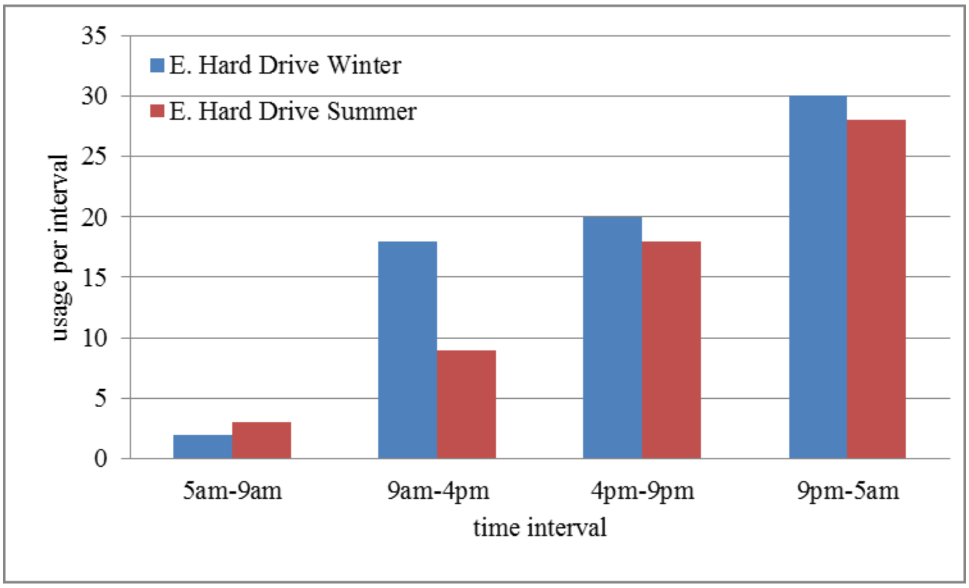


Figure 4-22 Electrical Hard Drive Usage

4.8.3.7 DVD/CD Players and Radio Set

It can be seen in Figure 4-24, nearly 50 % of participants use DVD/CD players or Radio set both in the winter and summer. The most popular time to use them is after 9 pm (28.3 % & 29.1 %). However, around 20 % of the participants reported that are using them at the peak period.

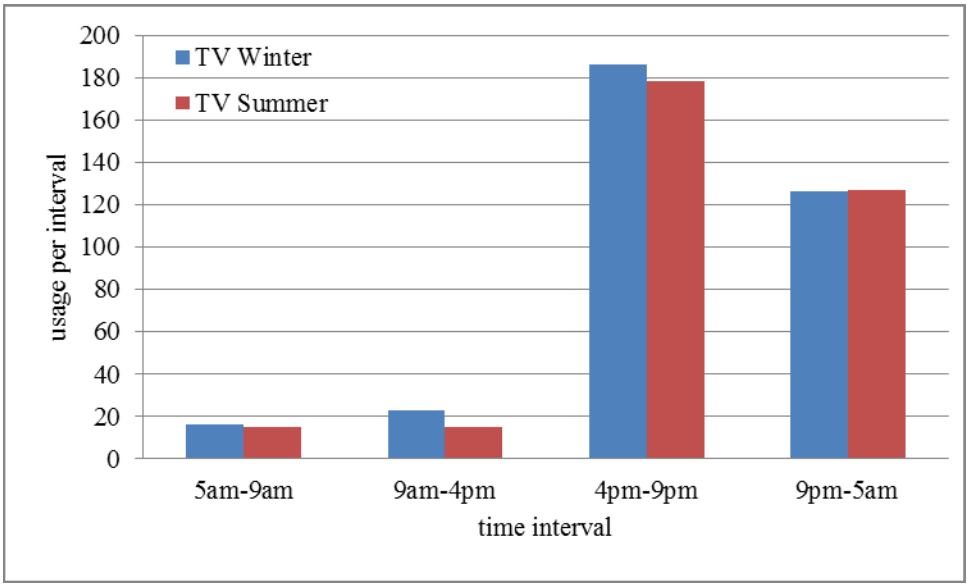


Figure 4-23 Television Usage

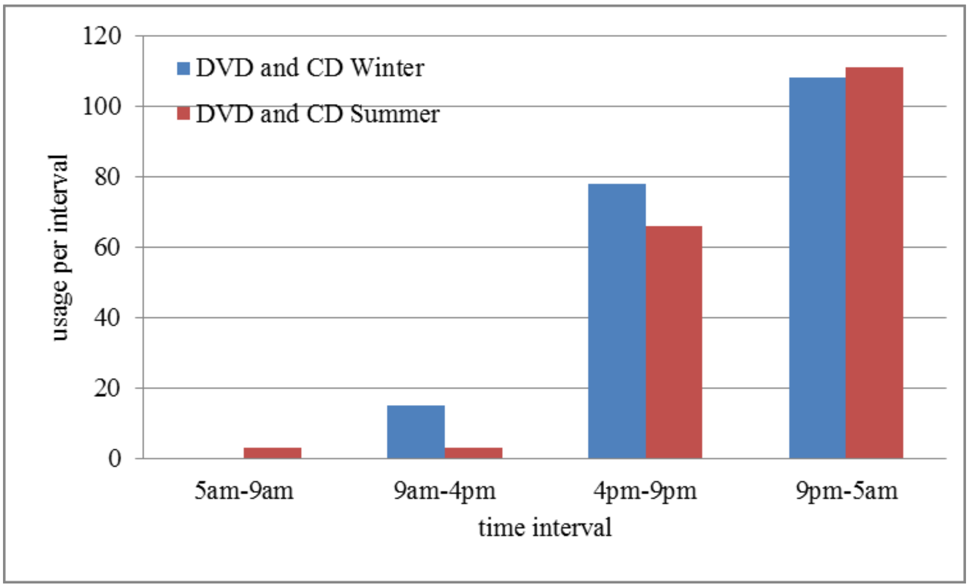


Figure 4-24 DVD/CD and Radio Usage

4.8.3.8 Home Cinema

The majority of participants are not using a home cinema (90 %) as shown in Figure 4-25, only 10 % reported that are using it during winter after 9 pm and 6 % in summer.

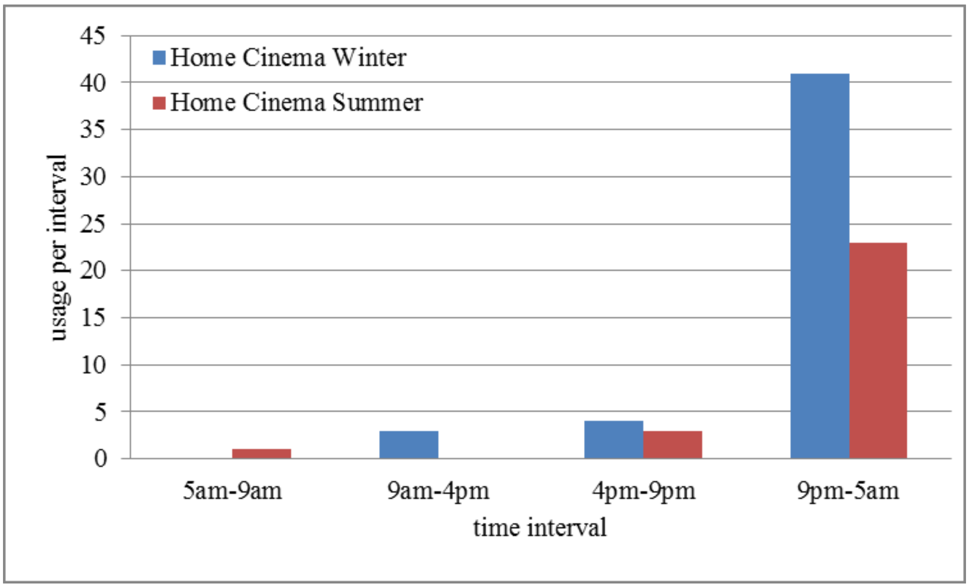


Figure 4-25 Home Cinema Usage

4.8.4 Wet Appliances Usage

4.8.4.1 Dishwasher

Most of the participants reported use a dishwasher during winter and summer after 9 pm as shown in Figure 4-26. Hence, around 55 % of participants do use one in winter and around 40 % do use one in summer. However, there are more than 18 % reported do use one during the peak period in winter and more than 8 % in summer.

4.8.4.2 Washing Machine

The data reveals the most common time to use a dishwasher in both winter and summer is between 4 pm and 9 pm and after 9 pm as shown in Figure 4-27. The data show no differences in winter and summer usage and more than 40% do use one at peak period. (n = 158 which is 41.5 %). In the study of Lomas and Jones (2016), most of the participants (89 %) had a washing machine. They argue households are more likely to be high consumers of electricity if they use their washing machine for more than four or five loads a week. Jones, Fuertes (2015), also argues this who state the greater the use of washing machines results in increased electricity use [74].

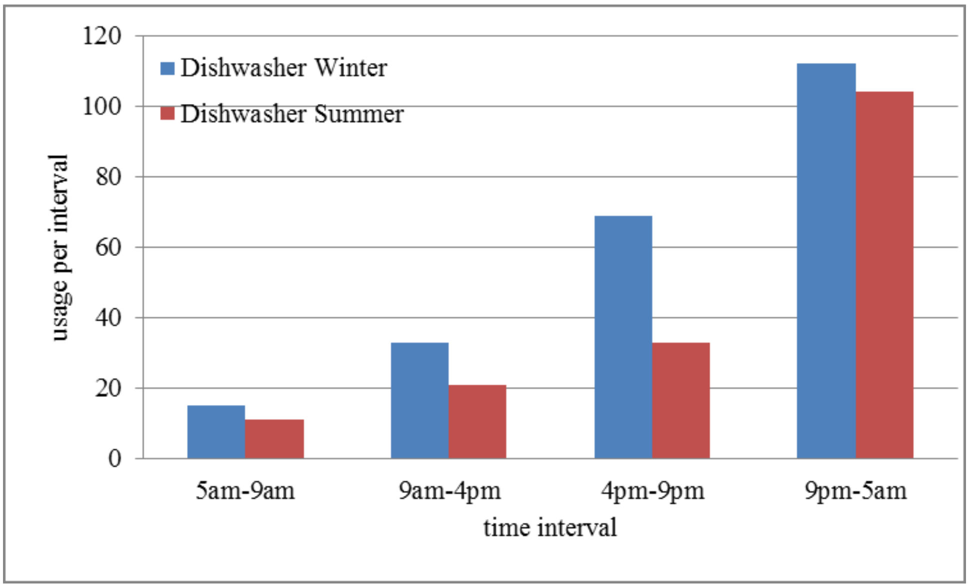


Figure 4-26 Dish-Washer Usage

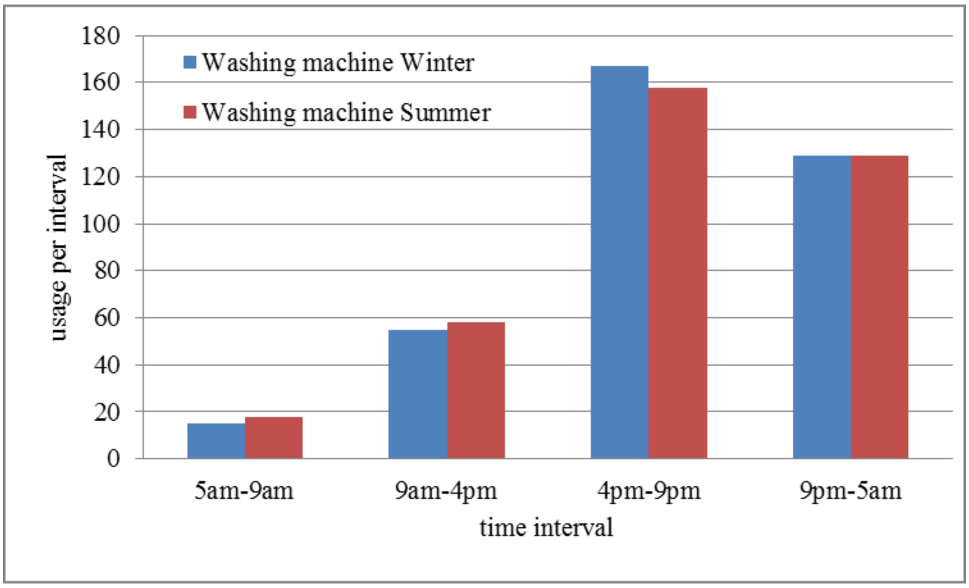


Figure 4-27 Washing Machine Usage

4.8.4.3 Clothes Dryer

As shown by the data in Figure 4-28, more than 70 % of the participants are do use one during winter and most likely will be used during the peak period (34.4 %) as well as after 9 pm (27.6 %). Conversely, there are only 17.6% reported are do use one during summer and it will most likely be used during peak hours. In the study by Jones and Lomas (2016) it was also found most of the participants do not use a clothes dryer (90 %). However, they inform the use of clothes dryer can significantly increase electricity consumption.

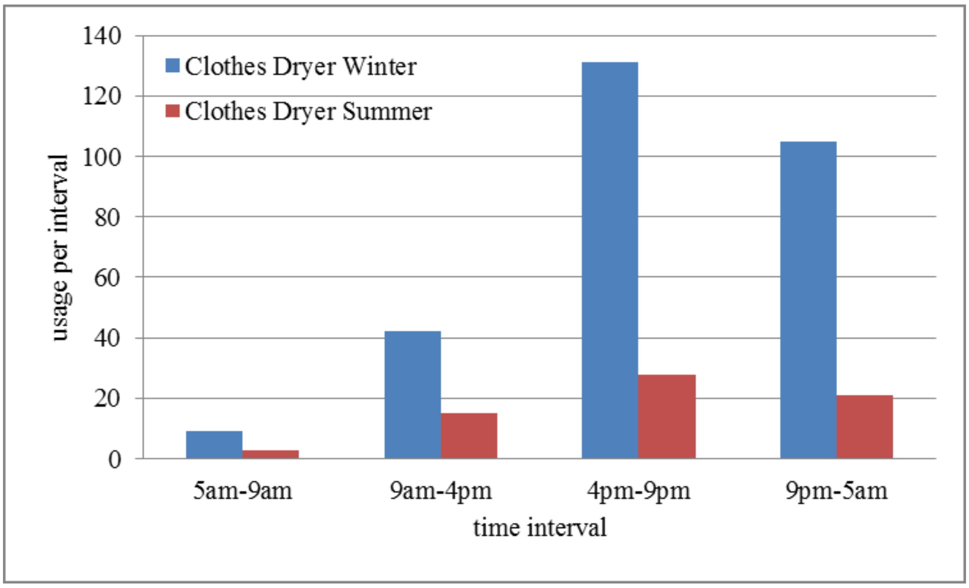


Figure 4-28 Clothes Dryer Usage

4.8.5 Other Appliances Usage

4.8.5.1 Electrical Shower

According to Jones and Lomas (2016), the ownership of electrical shower found significantly increases the consumption of electricity. In addition to this, Yohanis et al. (2007) found an electric shower was the appliance that used the most electricity. The collected data reveals that more than 50 % do use an electrical shower in winter and nearly 25 % do use in summer as shown in Figure 4-29. The most common time of use is morning period.

4.8.5.2 Hair Dryers, Straighteners and Curlers

As shown in Figure 4-30, more than 50 % reported do use one during winter and most likely will be used in morning period despite nearly 10 % reported do use one after 9 pm. On the other hand, only 25 % reported do use one in summer and commonly time use is morning period.

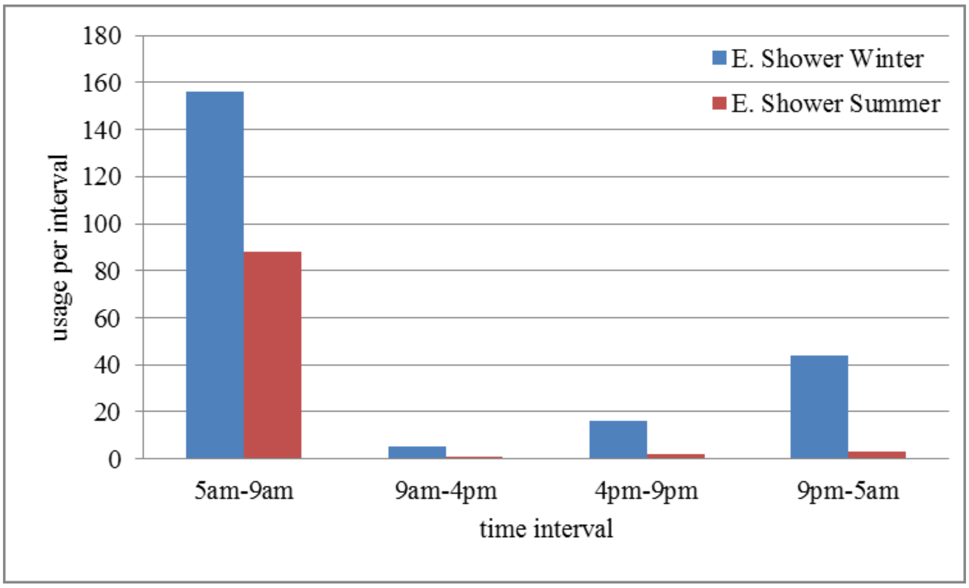


Figure 4-29 Electrical Shower Usage

4.8.5.3 Electrical Shaver and Toothbrush

The analyses reveal many of the participants do not use an electrical shaver or toothbrush as shown in Figure 4-31. Out of those who do, the most common time to use them is between 5 am and 9 am (30 %). There is also some use between 9 pm-5 am (3.1 %) and show no differences in use during winter and summer.

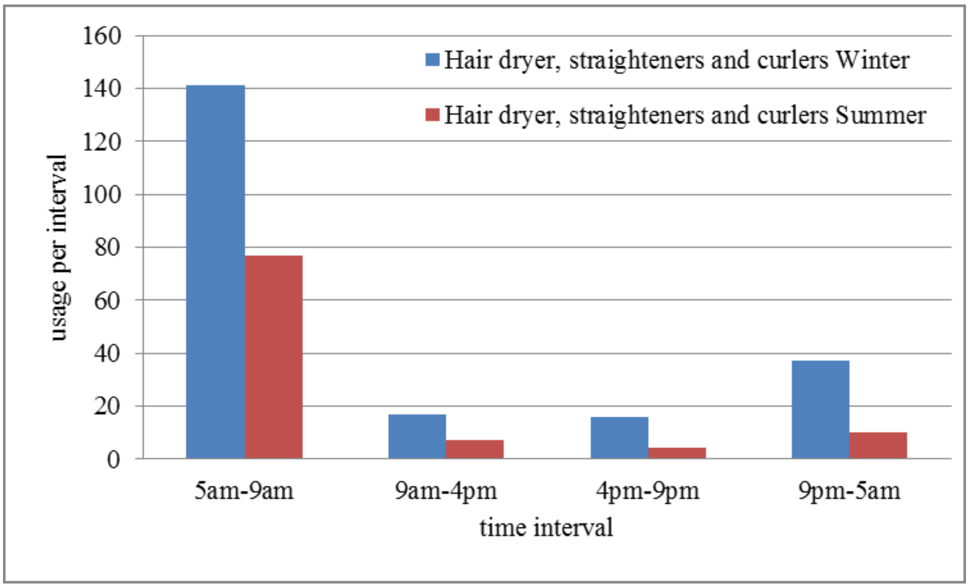


Figure 4-30 Hair Dryer, Straighteners and Curlers Usage

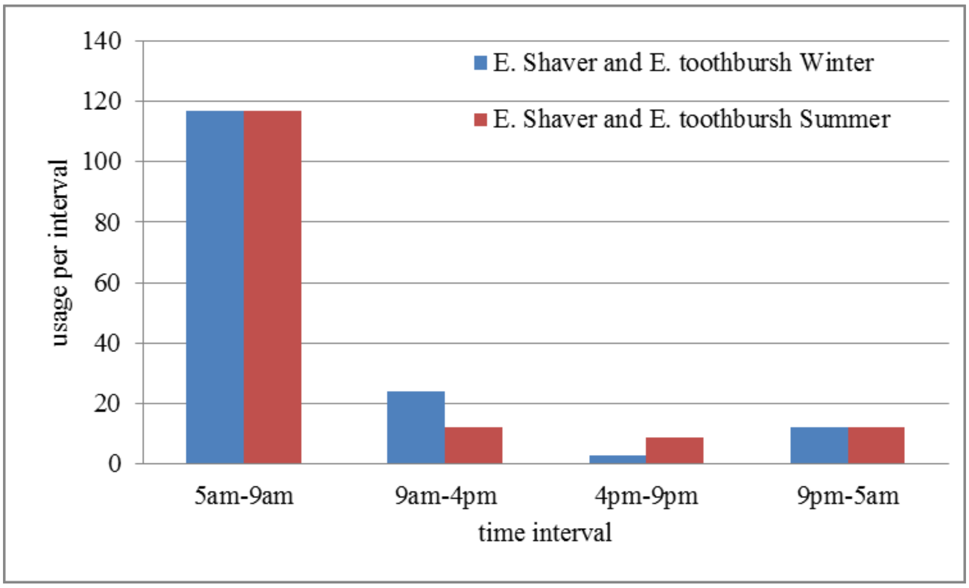


Figure 4-31 Electrical Shaver and Tooth Brush Usage

4.8.5.4 Vacuum Cleaner

In the winter and the summer, the most popular time to use a vacuum cleaner is between 4 pm and 9 pm (45.9 % & 42.5 %) as shown in Figure 4-32. There is also moderate use between the hours of 9 am-4 pm and between 9pm and 5am (n = 53 (13.9 %)) and between 5 am and 9 am (n = 38 (10 %)).

4.8.5.5 Iron

The analyses reveal the times the participants use the iron varied as shown in Figure 4-33. The most popular time for use is during peak hours, and then followed by morning for the winter usage. In the summer, a considerable percentage (28.6 %) reported that do use an iron at peak hours.

4.8.5.6 Electrical Garage Door Opener

As shown in Figure 4-34, the majority of the participants never use an electrical garage door opener. A very low percentage does use one (10.5 %).

4.8.5.7 Electrical Blanket

Nearly 12 % of the participants reported using electrical blanket during winter and only 2.4 % are do use electrical blanket during peak hours. Nevertheless, more than 2% reported they do use an electrical blanket during summer as shown in Figure 4-35.

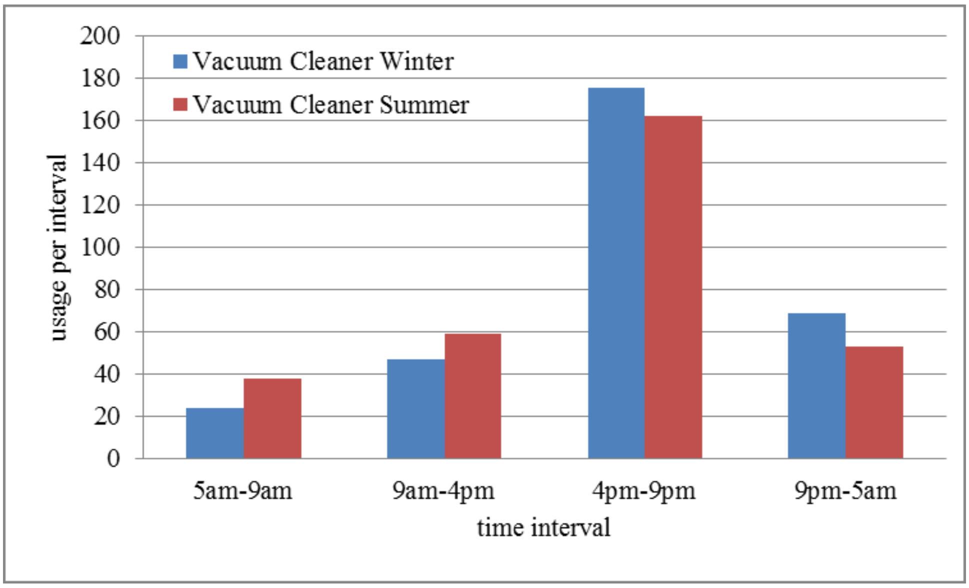


Figure 4-32 Vacuum Cleaner Usage

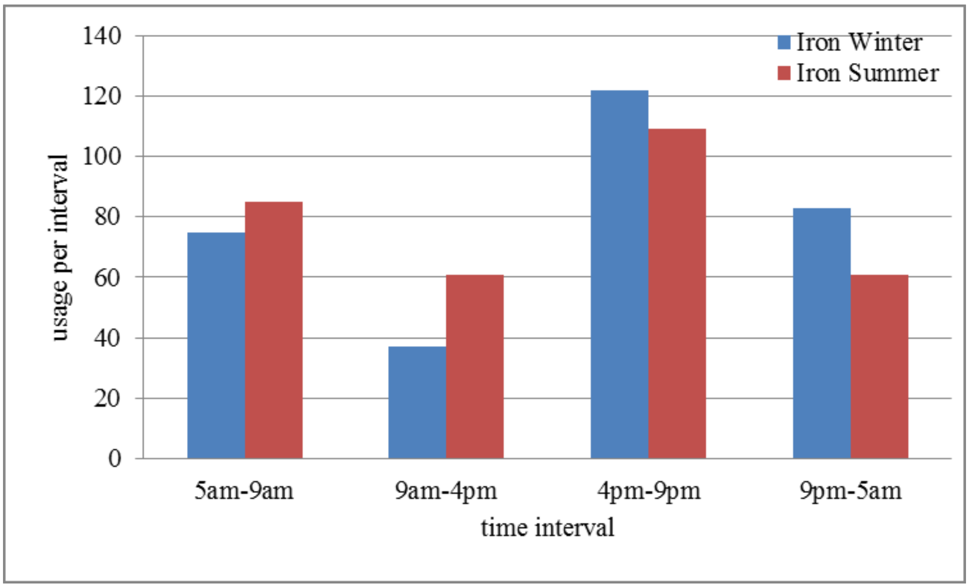


Figure 4-33 Iron Usage

4.8.5.8 Ceiling and Table Fans

More than two thirds of the participants reported that do not use any fans. However, out of those who do use one 18.1 % use it during peak hours in summer. Conversely, less than 20 % do use a fan during winter and there is varied time usage as shown in Figure 4-36.

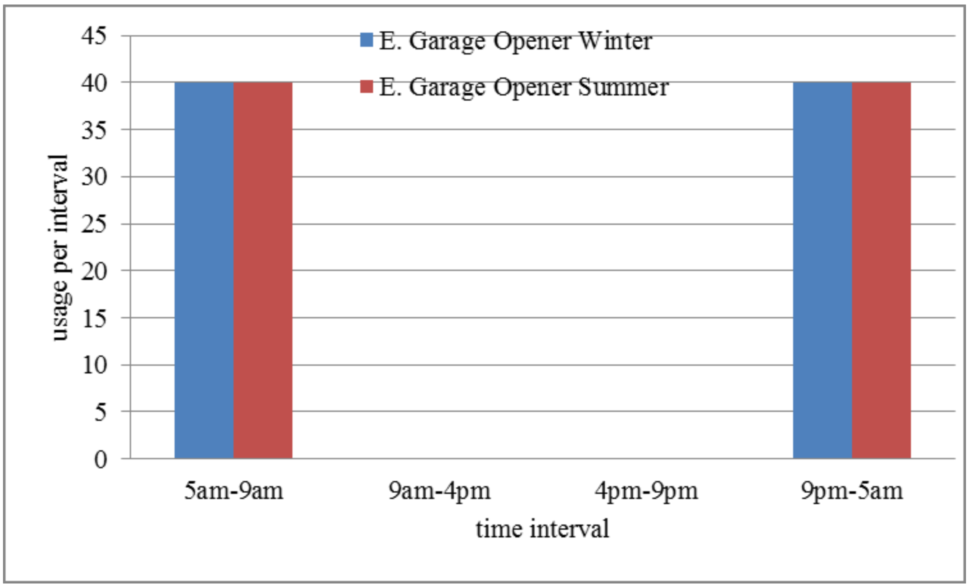


Figure 4-34 Electrical Garage Door Opener Usage

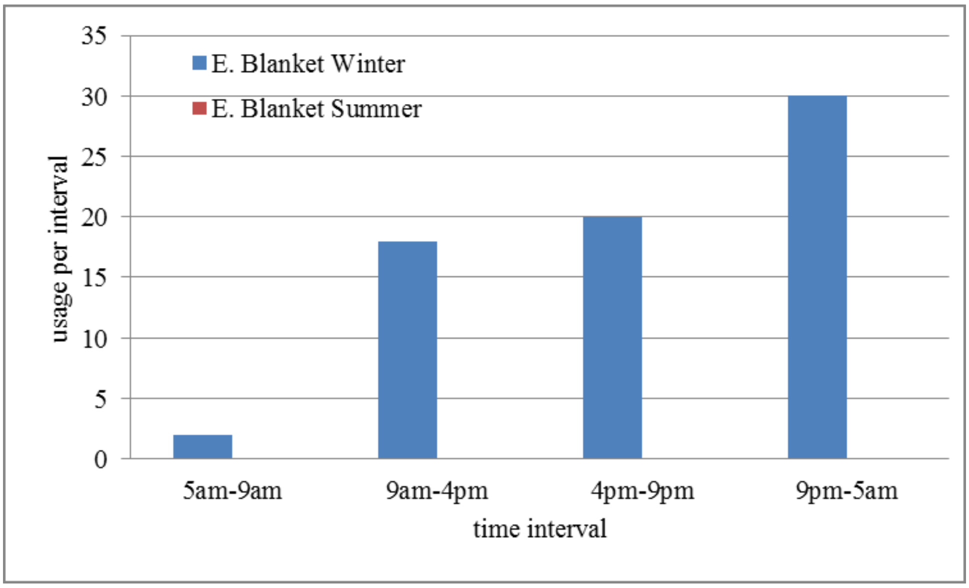


Figure 4-35 Electrical Blanket Usage

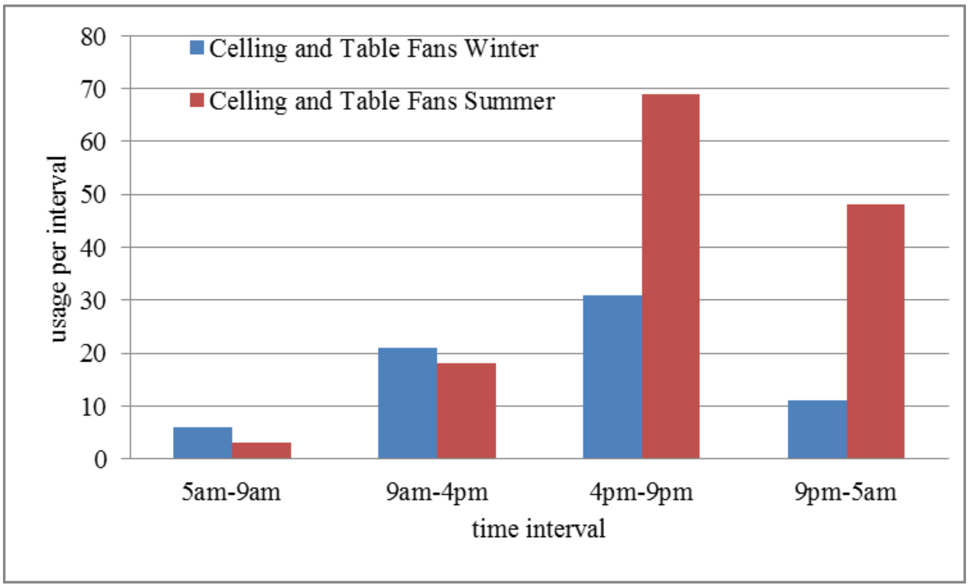


Figure 4-36 Table and Celling Fan Usage

4.9 Summary

This chapter has discussed the statistical means used in this research. It has provided some assumptions and information on the statistical means utilized in this investigation. The chapter has presented the choice of statistical techniques in the analysis of survey data, data presentation and distribution. The next chapter will interpret and present findings. In the preceding chapter, the researcher has described the analytical procedures followed in analysing the survey data and the assumptions of each technique used. It helped to provide a technical guide for the researcher in conducting the statistical analysis. The chosen techniques included univariate analysis of descriptive statistics, correlation, Kruska-Walis test, Mann-Whitney and Wilcoxon test. This is the chapter where the results of statistical analysis in Chapter 4 will be discussed and interpreted in relation to research questions and hypothesis. In the first step, a demographic profile of the respondents was analysed using the descriptive statistics in Chapter 4.

Chapter 5 Hillingdon Household Electricity Demand

5.1 Introduction

This chapter presents a household model for estimated the daily average demand for a UK household located in London Borough of Hillingdon. Patterns associated with different sections of the population and the variations in consumers' knowledge/attitudes needs to be identified. Possible links between daily lifestyles and energy use explored in order to identify feasible means for promoting energy-rational behaviour [56]. Only electrical appliances considered and the daily appliances from the data collected categorized based on time interval. A good agreement with published data was observed [140]. The share of appliances category during the peak period presented in percentage and potential load-shifting scenario explored. However, the time shifting is managing the loads instead of reducing the total daily consumption [152]. Moreover, the wet appliances show great potential load shifting due to their high electricity demand particularly in winter where clothes dryers are most likely be used [78].

5.2 Bottom-Up Approach

A home profile is taken for hourly activities, and then considers uniform energy consumption and occasionally usage appliances. Here occasional use of appliances means infrequent use of home appliances. The global household diagram is based on estimated and observed figures [63]. A cluster of information or data derives from following points of fundamental unit per household:

1. Inhabitant kind or type along with age and activities.
2. Employee information according to daily activities and daily obligations.
3. Person's availability at home total time and routine spend at home.

For data gain purpose, it can be categorized according to the demographic points of view, individual household inhabitant profile observes with distinctions points while further data will relate to calculations:

- Members of household in numbers.
- Identify the targeted area and the numbers of households
- Average electricity consumption of household.
- Appliances ownership, etc.

The above-mentioned points belong to demographic and socioeconomic data or information, it helps to construct from a particular area. The extracted data is purely for individual (profile) domestic energy consumption and domestically usable appliances [153]. It can be observed from the data that two distinct data, one from residential customers and other from the psychological behaviour of an individual consumer with specific area belonging, the model can be applied for the simulation of a residential area where field measurements of power demand are in a certain time frame, for example, 15 minutes. Models are adopted because it asserts that load shape is a cost effective option and causes a reduction of single inhabitant load investigation in electric utilities. Specifically, the advance technologies and behaviour, evolution are the considerable point of energy usage. Application of the model is provision based. *"Models provide extremely interesting possibilities where load shaping is concerned, particularly as regards evaluation of the diverse Load Management (LM) options available to the utility within the framework of various Demand side management (DSM) programs"* [53].

5.3 Load Profile

Researchers established many approaches to calculating energy consumption within the specific behaviour of the inhabitants of different households. Developed approaches are: econometric to calculate economic statistics and engineering along with other combined techniques. Implementation responses of the estimated customer model can be evaluated and after this, it can be predicted for different rate policies. When a positive response is received, then ultimately a model allows for the reproduction of load diagram of the end user by different aspects of the synthesis process, behaviour and engineering combined components besides this macroscopic, socioeconomic and demographic are also the factors for each household for specific research area [9]. However, load shapes synthesis approach based on two levels as follows:

1. The collective response of individual demand can predict an average profile.
2. The aggregative response of load shapes from different types of household, it derives end use area load by synthesis.

End-use area load shape can be determined by studying the connection between household members and appliances. Results of different profiles depend on single household age, activities, lifestyle etc. "In order to reproduce the psychological factors which form the very basis of domestic energy usage, the interrelations in question have been expressed as rules and constraints affecting certain functions which have been introduced in the model" [9].

Fundamentally, there is some function related to the inhabitant activities, tendency to consume energy in day and night time. Studies show that the researcher has categorises them into two types: Behavioural functions (availability at home of each member of the household; home-activities; appliance usage; tendency for home activities; human-resources; appliance-ownership). Engineering functions (appliance mode of operation: cycle or activation time, power demand, average annual consumption; household demand limit; technological penetration, saturation of appliances embodying technological innovation).

However, the different households have different life-styles. The total load profile shape, will of course, varies from day to day and house to house. The factors influencing the occupancy pattern are as follows:

- The number of occupants.
- The time of getting up in the morning and the going to sleep.
- The period of the house unoccupied during the day.

It is important to identify the cluster of households when analysing the load profile, because the load profile depends very much on the occupancy pattern as shown in Table 5-1. In the case of a lack of information about household occupancy pattern, five most common scenarios of household occupancy patterns in the UK were proposed. Moreover, the following assumptions have been made in order to generate appliances load profile:

- Only one appliance considered for each household.
- The weekend hourly load curves have been equalized to those for the workdays for calculation simplicity.
- The space heating and hot water systems are provided by means of natural gas.

Table 5-1 Household Occupancy Profile [56]

Employment status	Employed	Part time		Retired and unemployment	Family with part time
Occupancy pattern	08:30-18:00	Morning	Afternoon	Occupied	08:30-13:00
		08:30-14:00	13:00-18:00		

5.3.1 Appliances Usage and Consumption Pattern

The information of the average daily consumption of major appliances in the UK household carried out by [54], [70] and [150]. The information in Table 5-2, gives the type and the average annual consumption per household per day, the average annual consumption per capita per day and the ownership level. The daily energy consumption of electrical appliances for different types of households can be calculated based on Average annual consumption per day (per capita or household).

Table 5-2 Domestic Appliances Categories [51], [8] and [154]

Appliances category	Appliances	Consumption contribution
Cold	Refrigeration, freezers and combined fridge-freezer	22.2%
Brown good	Electronic consumer goods such as; TVs, CDs and DVDs	14.3%
Cooking	Oven, kettle, toaster, and microwave	18.8%
Wet appliances	Washing machine, tumble dryers, and dishwasher	16.5%
Miscellaneous/other	Vacuum cleaner, iron, electric shower, and heating	5.6%

5.4 London Borough of Hillingdon Households Electricity Demand

Hillingdon household electricity demand estimated and the forecasting tool based on disaggregated approach of 381 households surveyed which outlines the electricity demand of households based on number of appliances and daily time usage. The data collected on the household are appliances ownership and usage pattern. From these data, scenarios of electricity demand can run and the influence of certain appliances can be defined. An Excel platform has been developed to generate a typical domestic load profile representing a scenario of occupancy pattern [155]. The following points were taken into consideration:

- Firstly, identification of the labels has connectivity with home routines (e.g. cooking, washing, personal hygiene and leisure).
- Secondly, operational automatic home appliances (for example, food processor, hair dryer, etc.) along with activation machines like (e.g. PC, washing machines and others).
- Other parameters include power demand and working/duty cycle typical duration [9].

Therefore, the households can be classified into different daily functions, such as, routines which include cooking, washing and personal hygiene, then the operational automatic appliances such as, food processor and hair dryer and then activation machine such as, PC, washing machine, etc. These functionality appliances are used on an hourly basis and some are occasionally used according to the inhabitants need. To this end, the household estimation is based on observation and estimation to generate a household's diagram and then create the daily profile for that household as mentioned earlier. There are different factors might have an effect on mentioned parameters, the inhabitant age which is defined the inhabitant activities and need. Also, the activities are linked to the daily obligation such the career and kind of job the inhabitants are executing which is outlining the inhabitant availability at the household and profile their routine.

To simulate the load shape of a residential area, main influencing data are; demographic and socioeconomic, data related to lifestyles and their usage of energy consumption habits, engineering data for operation of appliances. Load profiles are obtained from measurements of a large sample of appliances produced by the main manufacturers [52].

The literature review is based on previous work or secondary data (usage of electricity) taken from government reports and previous studies. This source is used to estimate the daily appliance, electricity demand for the samples in [37], [69], [156], [157]. Pilot study conducted and a positive agreement observed between the estimated demand and the national load profile on a typical winter day which is 13.4 kWh and 13 kwh respectively [67]. Another agreement of the peak demand period where the estimation is between 17:00 and 22:00 [156], [158].

Hourly estimated demands along with one-minute separate slots were calculated. Minor and major peaks of morning and evening time are calculated whereas, minimum demand has been occurring when there was not any activity identified. It is shown through a statistical diagram that energy consumption once again goes down at day time and gets a peak in evening. It gives more accurate figures of power consumption at the interval of particular minute (appliances usage in minutes). Furthermore, changes are made to the behavioural and engineering functions, to reproduce end use variations resulting from technological innovations affecting appliances and the socioeconomic evolution of households [37].

5.5 Model Data and Structure

The key dataset used for HHM: appliances data and pattern usage data for the UK. Appliances data, the model uses data from the HHS, which is available in shape of ownership and time of use individually. There is four times interval for 24h a day define the time of use the appliances surveyed. Pattern usage data, data collected from government reports and previous studies which are presented as occupancy scenario, power rate and total power consumption. For an accurate estimation of household demand, there is a need to cover physical and social parameters which provide deeper insights details which would otherwise be easily missed [159].

5.5.1 Household Data

The key dataset used for this model (HHM) was the 2015 Hillingdon Housing Survey conducted in London Borough of Hillingdon. The survey conducted to collect data on the usage time of household's appliances in the borough. So, the 24 hours where divided into time interval as explained in Table 5-3 according to household occupancy profile Table 5-1. Therefore, the appliances were categorized according to their time of use. In general, no data were available on the disaggregated level, such as; the power rate for the appliances and pattern usage. In practice, this led to assumptions for the Borough. This was considered appropriate since the samples are equivalent to the Borough. Moreover, the appliance's physical specifications are available in the market. In practise, the average was considered in order to apply the specification to all samples.

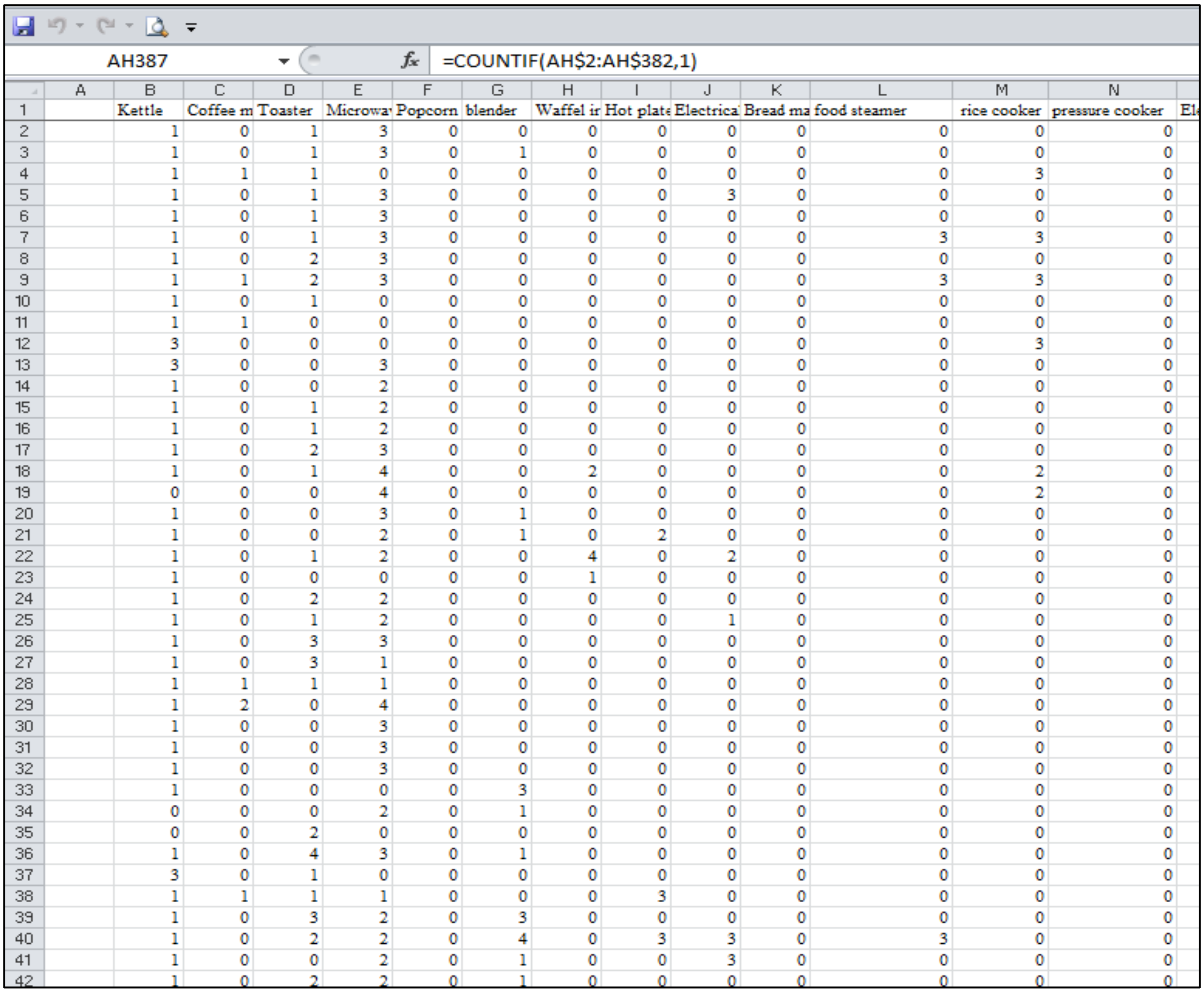
Table 5-3 24 hours' time interval for appliances daily usage [71]

Periods of daily	description	Hours	Code
5 am-9 am	Getting up and ready to leave the house	4	1
9 am-4 pm	This is the time mostly no activity	7	2
4 pm-9 pm	Tripling back from work and schools and main mail preparing time	5	3
9 pm-5 am	Getting ready to get into bed and some activity still on	8	4
Total		24	

The model uses an interactive dataset with 2 internal files: One for winter usage and another for summer. These data are composed of different household's appliances such as cooking, wet, office's equipment, etc., which together give 36 appliances with unique combinations for each interval.

5.5.2 Household's Appliances

The increase in electricity consumption for the house appliances since 1970 is due to increasing the level of appliances penetration in overall. However, cooking and appliances are only considered in this study due to the high penetration for the last three decade and their future's potential [36]. The end use energy consumption is influenced by different factors, and only these are linked to the user's behaviour is been investigated such as; the number of household' members, their age and income. The peak consumption is occurring at the time when a maximum number of appliances are being used [160].



AH387 | =COUNTIF(AH$2:AH$382,1)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1		Kettle	Coffee m	Toaster	Microwa	Popcorn	blender	Waffel ir	Hot plate	Electrica	Bread ma	food steamer	rice cooker	pressure cooker
2		1	0	1	3	0	0	0	0	0	0	0	0	0
3		1	0	1	3	0	1	0	0	0	0	0	0	0
4		1	1	1	0	0	0	0	0	0	0	0	3	0
5		1	0	1	3	0	0	0	0	3	0	0	0	0
6		1	0	1	3	0	0	0	0	0	0	0	0	0
7		1	0	1	3	0	0	0	0	0	0	3	3	0
8		1	0	2	3	0	0	0	0	0	0	0	0	0
9		1	1	2	3	0	0	0	0	0	0	3	3	0
10		1	0	1	0	0	0	0	0	0	0	0	0	0
11		1	1	0	0	0	0	0	0	0	0	0	0	0
12		3	0	0	0	0	0	0	0	0	0	0	3	0
13		3	0	0	3	0	0	0	0	0	0	0	0	0
14		1	0	0	2	0	0	0	0	0	0	0	0	0
15		1	0	1	2	0	0	0	0	0	0	0	0	0
16		1	0	1	2	0	0	0	0	0	0	0	0	0
17		1	0	2	3	0	0	0	0	0	0	0	0	0
18		1	0	1	4	0	0	2	0	0	0	0	2	0
19		0	0	0	4	0	0	0	0	0	0	0	2	0
20		1	0	0	3	0	1	0	0	0	0	0	0	0
21		1	0	0	2	0	1	0	2	0	0	0	0	0
22		1	0	1	2	0	0	4	0	2	0	0	0	0
23		1	0	0	0	0	0	1	0	0	0	0	0	0
24		1	0	2	2	0	0	0	0	0	0	0	0	0
25		1	0	1	2	0	0	0	0	1	0	0	0	0
26		1	0	3	3	0	0	0	0	0	0	0	0	0
27		1	0	3	1	0	0	0	0	0	0	0	0	0
28		1	1	1	1	0	0	0	0	0	0	0	0	0
29		1	2	0	4	0	0	0	0	0	0	0	0	0
30		1	0	0	3	0	0	0	0	0	0	0	0	0
31		1	0	0	3	0	0	0	0	0	0	0	0	0
32		1	0	0	3	0	0	0	0	0	0	0	0	0
33		1	0	0	0	0	3	0	0	0	0	0	0	0
34		0	0	0	2	0	1	0	0	0	0	0	0	0
35		0	0	2	0	0	0	0	0	0	0	0	0	0
36		1	0	4	3	0	1	0	0	0	0	0	0	0
37		3	0	1	0	0	0	0	0	0	0	0	0	0
38		1	1	1	1	0	0	0	3	0	0	0	0	0
39		1	0	3	2	0	3	0	0	0	0	0	0	0
40		1	0	2	2	0	4	0	3	3	0	3	0	0
41		1	0	0	2	0	1	0	0	3	0	0	0	0
42		1	0	2	2	0	1	0	0	0	0	0	0	0

Figure 5-1 Appliances Ownership and Time of Use Sheet

5.5.3 Appliances Sheet

Household's appliances specification and time pattern usage are flexible to run different scenarios for the same set of data. As shown in the appliances sheet, data can be re-entered according to the preferred scenario as shown in Figure 5-1.

5.5.4 Time of Use Sheet

The primary input to the model is the data contained within the worksheet Time of Use as shown in Figure 5-2. This sheet contains one row for each appliance, with columns representing power rating, appliance consumption, and usage in minute and actual power consumption per minutes. A full list of the information contained within the Time of Use sheet is shown in Figure 6-3. The input data can be entered directly into the Time of Use sheet from colum2 onwards. The appropriate data must be placed in the corresponding column for each case. Colum1 in this sheet is held for the list of household appliances and row 1 and row 2 are headers for each minute and each hour. Most of the cells in the consumption sheet are active cells.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
1	Household appliances	Power rating KWh				Consumption per c		Power rating per minute			Ownership													Pattren usage in minutes		
2		min.	max.	average							winter				Total	Percent	summer				Total	Percent		min.	max.	average
3	Kettle	2.2	2.2	2.2		0.78	0.04875	0.03667			210	24	85	4	323	84.7769	211	23	62	2	298	78.2152		3	5	4
4	Coffee maker	0.2	0.2	0.2				0.00333			64	11	2	0	77	20.21	49	9	2	0	60	15.748		10	10	10
5	Toaster	0.8	0.8	0.8				0.01333			163	53	68	2	286	75.0656	150	47	39	1	237	62.2047		5	5	5
6	Microwave	0.6	0.6	0.6		0.23	0.0115	0.01			17	38	222	40	317	83.2021	20	36	185	37	278	72.9659		5	5	5
7	Popcorn Popper	1.4	1.4	1.4				0.02333			0	14	26	17	57	14.9606	3	4	18	19	44	11.5486		5	5	5
8	Blender/Juicer	0.3	0.3	0.3				0.005			49	14	19	2	84	22.0472	46	13	23	1	83	21.7848		2	10	6
9	Waffle Iron/Sandwich maker	0.7	0.7	0.7				0.01167			23	16	16	2	57	14.9606	16	11	7	1	35	9.18635		15	25	20
10	Hot plate	1.2	1.2	1.2				0.02			3	17	29	0	49	12.8609	2	6	23	1	32	8.39895		15	45	30
11	Electrical Frying Pan	1.2	1.2	1.2				0.02			1	17	37	4	59	15.4856	2	11	25	1	39	10.2362		10	30	20
12	Bread maker	0.55	0.55	0.55				0.00917			9	6	17	1	33	8.66142	0	5	11	0	16	4.19948		30	60	45
13	Food Steamer	0.65	0.65	0.65				0.01083			0	11	64	0	75	19.685	2	9	44	0	55	14.4357		30	60	45
14	Rice Cooker	0.6	0.6	0.6				0.01			7	17	94	5	123	32.2835	4	18	53	6	81	21.2598		15	15	15
15	Pressure Cooker	1	1	1				0.01667			0	15	31	2	48	12.5984	0	6	21	0	27	7.08661		30	60	45
16	Electrical cooker	1.3	1.3	1.3		1.33	0.02956	0.02167			0	2	72	10	84	22.0472	0	0	80	8	88	23.0971		30	60	45
17	Kitchen extractor	0.005	0.005	0.005				8.3E-05			1	7	189	30	227	59.5801	6	7	189	20	222	58.2677		30	60	45
18	Laptop	0.02	0.02	0.02		0.5	0.00079	0.00033			6	13	129	205	353	92.6509	6	19	136	199	360	94.4882		159	159	159
19	Desktop	0.08	0.08	0.08				0.00133			6	26	68	63	163	42.7822	12	29	43	83	167	43.832		159	159	159
20	Printer, scanner and photocopier	0.3	0.3	0.3				0.005			9	25	29	34	97	25.4593	9	25	29	34	97	25.4593		20	20	20
21	Shredder	0.146	0.146	0.146				0.00243			5	14	9	17	45	11.811	8	12	7	19	46	12.0735		5	5	5
22	Electrical hard drive	0	0	0				0			2	18	20	30	70	18.3727	3	9	18	28	58	15.2231		159	159	159
23	TV set	0.2	0.2	0.2		0.91	0.00431	0.00333			16	23	186	126	351	92.126	15	15	178	127	335	87.9265		211	211	211
24	DVD, CD players and Radio set	0.02	0.02	0.02		0.3	0.00142	0.00033			0	15	78	108	201	52.7559	3	3	66	111	183	48.0315		211	211	211
25	Radio	0	0	0				0			56	2	9	16	83	21.7848	58	2	4	7	71	18.6352		58	58	58
26	Home cinema	0	0	0				0			0	3	4	41	48	12.5984	1	0	3	23	27	7.08661		211	211	211
27	Dish washer	1.05	1.05	1.05		1.72	0.043	0.0175			15	33	69	112	229	60.105	11	21	33	104	169	44.357		40	40	40
28	Washing machine	1.2	1.2	1.2		0.8	0.016	0.02			15	55	167	129	366	96.063	18	58	158	129	363	95.2756		40	60	50
29	Clothes dryer	2	2	2		0.78	0.0156	0.03333			9	42	131	105	287	75.3281	3	15	28	21	67	17.5853		40	60	50
30	Electrical shower	7	7	7				0.11667			156	5	16	44	221	58.0052	88	1	2	3	94	24.6719		15	30	22.5
31	Hair dryer, straightener and curlers	1	1	1				0.01667			141	17	16	37	211	55.3806	77	7	4	10	98	25.7218		5	10	7.5
32	Electrical shaver and tooth brush	0.015	0.015	0.015				0.00025			117	24	3	12	156	40.9449	117	12	9	12	150	39.3701		3	5	4
33	Vacuum cleaner	0.5	0.5	0.5		0.15	0.005	0.00833			24	47	175	69	315	82.6772	38	59	162	53	312	81.8898		20	40	30
34	Iron	1	1	1		0.3	0.01	0.01667			75	37	122	83	317	83.2021	85	61	109	61	316	82.9396		20	40	30
35	Electrical garage door opener	0.22	0.22	0.22				0.00367			40	0	0	0	40	10.4987	40	0	0	40	80	20.9974		2	2	2
36	Sewing machine	0.03	0.03	0.03				0.0005			0	0	0	0	0	0	0	0	0	0	0	0		10	30	20
37	Electrical heater	0	0	0				0			0	2	11	61	74	19.4226	0	0	0	0	0	0		0	0	0
38	Electrical blanket	0	0	0				0			2	18	20	30	70	18.3727	0	0	0	0	0	0		0	0	0

Figure 5-2 Appliances Sheet of the Household's Electricity Model

5.5.5 Consumption Sheet

The electricity consumption of appliances in HHM is based on the HHS and appliances specification as shown in Figure 5-4. One advantage of the model is can be improved relatively simple by changing the existing appliances' specification to adopt other scenarios. The model is based on theoretical events of what actually happens in a household. It is theoretically based but it also contains realistic measures. The HHM model benefits from measurements made according to data accumulated from the borough. Even so, the model can be updated whenever a significant change in the data becomes available.

A56 | fx 37 refrence is Demand-side management opportunities for the UK

	A	OY	OZ	PA	PB	PC	PD	PE	PF	PG	PH	PI	PJ	PK	PL	PM	PN	PO	PP	PQ	PR	PS	PT	PU	PV	PW	PX	PY	PZ	QA	QB	QC	QD
1																										7							
2	Appliances	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	1	2	3	4	5	6	7
3	Kettle																																
4	Coffee maker	1	1	1	1	1																											
5	Toaster	1	1	1	1																												
6	Microwave	1	1	1	1	1	1	1	1	1																							
7	Popcorn popper																																
8	Blender										1	1	1	1	1	1																	
9	Waffle-iron	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1													
10	Hotplate																																
11	Electrical frying pan	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1													
12	Bread machine																																
13	Electrical food steamer																																
14	Electrical rice cooker																				1	1	1	1	1	1	1	1	1	1	1	1	
15	Electrical pressure cooker																																
16	Electrical cooker																																
17	Kitchen extractor																																
18	Laptop	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
19	Desktop	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
20	Printer, Scanner & Photocopier	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
21	Shredder																																
22	Electrical hard drive	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
23	TV	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
24	DVD and or CD player	1	1	1	1	1	1	1	1	1	1																						
25	Radio	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
26	Home cinema																																
27	Dishwasher																																
28	Washing machine	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1						
29	Clothes dryer																											1	1	1	1	1	
30	Electrical shower																																
31	Hair dryer, Straightnere and Curlers																																
32	Electrical shaver & Electrical tooth brush																																
33	Vacuum cleaner																										1	1	1	1	1	1	
34	Iron																										1	1	1	1	1	1	
35	Electrical garage door opener																																
36	Sewing machine																										1	1	1	1	1	1	
37	Electrical heater	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
38	Electrical blanket																																
39	Air conditioner																																
40	Ceiling & table fans	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	

Figure 5-3 Time of Use the Household's Appliances

The first and second rows are used to identify the time of day, hours and minutes respectively. The third row, cells (B2-S2) is used to identify the column associated with the appliances specification, time of use and actual consumption per a single use. For use when only a single case run is performed, by entering the appropriate certain appliance data from the list of Hillingdon Housing Survey Data into the applicable cell at the appliances sheet. The appliances consumption is automatically populated when the customer enter the appliances specification and time of use. The top two rows and the first column are inactive and used to identify the time and appliances names.

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	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1																			
2	Appliances	rating	rating	Power	Power rate p	Quantity	ercentag	consumption	N1	P1	N2	P2	N3	P3	N4	P4	age mi	age max	Average usage in minut
3	Kettle	1.8	1.8	1.8	0.03	298	85	8.94	211	6.33	23	0.69	62	1.86	2	0.06	3	5	4
4	Coffee maker	0.36	0.36	0.36	0.006	60	20.5	0.36	49	0.294	9	0.054	2	0.012	0	0	10	10	10
5	Toaster	0.8	0.8	0.8	0.013333	237	74.5	3.16	150	2	47	0.6266667	39	0.52	1	0.0133333	5	5	5
6	Microwave	1	1	1	0.016667	278	83.2	4.633333	20	0.3333333	36	0.6	185	3.0833333	37	0.6166667	5	15	10
7	Popcorn popper	0.25	0.25	0.25	0.004167	44	14.7	0.183333	3	0.0125	4	0.0166667	18	0.075	19	0.0791667	5	5	5
8	blender	0.15	0.15	0.15	0.0025	83	22.3	0.2075	46	0.115	13	0.0325	23	0.0575	1	0.0025	2	10	6
9	Waffel iron	1.2	1.2	1.2	0.02	35	15	0.7	16	0.32	11	0.22	7	0.14	1	0.02	15	25	20
10	Hot plate	1	1	1	0.016667	32	12.9	0.533333	2	0.0333333	6	0.1	23	0.3833333	1	0.0166667	15	45	30
11	Electrical frying pan	1.8	1.8	1.8	0.03	39	15.5	1.17	2	0.06	11	0.33	25	0.75	1	0.03	10	30	20
12	Bread maker	0.65	0.65	0.65	0.010833	16	8.7	0.173333	0	0	5	0.0541667	11	0.1191667	0	0	90	90	90
13	food steamer	0.8	0.8	0.8	0.013333	55	19.7	0.733333	2	0.0266667	9	0.12	44	0.5866667	0	0	60	60	60
14	rice cooker	0.65	0.65	0.65	0.010833	81	32.3	0.8775	4	0.0433333	18	0.195	53	0.5741667	6	0.065	15	15	15
15	pressure cooker	1.3	1.3	1.3	0.021667	27	12.3	0.585	0	0	6	0.13	21	0.455	0	0	40	40	40
16	Electrical cooker	1.75	1.75	1.75	0.029167	88	22.8	2.566667	0	0	0	0	80	2.3333333	8	0.2333333	30	90	60
17	Kitchine extractor	0.1	0.1	0.1	0.001667	222	59.6	0.37	6	0.01	7	0.0116667	189	0.315	20	0.0333333	60	60	60
18	Laptop	0.3	0.3	0.3	0.005	360	96.1	1.8	6	0.03	19	0.095	136	0.68	199	0.995	40	60	50
19	Desktop	4	4	4	0.066667	167	76.1	11.13333	12	0.8	29	1.9333333	43	2.8666667	83	5.5333333	60	90	75
20	Printer, scanner and pho	0.5	0.5	0.5	0.008333	97	83.5	0.808333	9	0.075	25	0.2083333	29	0.2416667	34	0.2833333	20	40	30
21	Shredder	1	1	1	0.016667	46	84	0.766667	8	0.1333333	12	0.2	7	0.1166667	19	0.3166667	20	40	30
22	Electrical hard drive	1.3	1.3	1.3	0.021667	58	57.7	1.256667	3	0.065	9	0.195	18	0.39	28	0.6066667	15	30	22.5
23	TV	0.1	0.1	0.1	0.001667	335	8.7	0.558333	15	0.025	15	0.025	178	0.2966667	127	0.2116667	10	30	20
24	DVD nad Cd players	1.5	1.5	1.5	0.025	183	0	4.575	3	0.075	3	0.075	66	1.65	111	2.775	300	360	330
25	Radio	0.2	0.2	0.2	0.003333	71	0	0.236667	58	0.1933333	2	0.0066667	4	0.0133333	7	0.0233333	300	420	360
26	Home cinema	1	1	1	0.016667	27		0.45	1	0.0166667	0	0	3	0.05	23	0.3833333	180	360	270
27	Dish wsher	0.05	0.05	0.05	0.000833	169	93.2	0.140833	11	0.0091667	21	0.0175	33	0.0275	104	0.0866667	120	240	180
28	Washing machine	0.25	0.25	0.25	0.004167	363	41.7	1.5125	18	0.075	58	0.2416667	158	0.6583333	129	0.5375	120	240	180
29	Clothes dryer	0.2	0.2	0.2	0.003333	67	25.5	0.223333	3	0.01	15	0.05	28	0.0933333	21	0.07	120	240	180
30	Electrical shower	0.1	0.1	0.1	0.001667	94	11.8	0.156667	88	0.1466667	1	0.0016667	2	0.0033333	3	0.005	2	4	3
31	Hair dryer, straightner an	0.8	0.8	0.8	0.013333	98	13.1	1.306667	77	1.0266667	7	0.0933333	4	0.0533333	10	0.1333333	90	120	105
32	Electrical shaver and too	1.5	1.5	1.5	0.025	150	60.1	3.75	117	2.925	12	0.3	9	0.225	12	0.3	0.76	0.95	0.855
33	Vacuum cleaner	0.25	0.25	0.25	0.004167	312	92.1	1.3	38	0.1583333	59	0.2458333	162	0.675	53	0.2208333	250	310	280
34	Iron	0.1	0.1	0.1	0.001667	316	52.8	0.526667	85	0.1416667	61	0.1016667	109	0.1816667	61	0.1016667	30	180	105
35	Elctrical garage door ope	1	1	1	0.016667	80	10.5	1.333333	40	0.6666667	0	0	0	0	40	0.6666667	5	15	10
36	Sewing machine	0.03	0.03	0.03	0.0005	33	40.7	0.0165	2	0.001	21	0.0105	10	0.005	0	0	3	5	4
37	Electrical heater	0.015	0.02	0.02	0.00025	0	18.4	0	0	0	0	0	0	0	0	0	120	240	180
38	Electrical blanket	0.001	0	0	1.67E-05	0	22.3	0	0	0	0	0	0	0	0	0	30	150	90
39	Air Conditioner	0.01	0.01	0.01	0.000167	16	17.3	0.002667	0	0	5	0.0008333	4	0.0006667	7	0.0011667	1440	1440	1440
40	Celling and table fan	0.8	0.8	0.8	0.013333	138	55.4	1.84	3	0.04	18	0.24	69	0.92	48	0.64	5	15	10

	A	OV	OW	OX	OY	OZ	PA	PB	PC	PD	PE	PF	PG	PH	PI
1															
2	Appliances	33	34	35	36	37	38	39	40	41	42	43	44	45	46
3	Kettle	6.33	6.33	0	0	0	0	0	0	0	0	0	0	0	0
4	Coffee maker	0.294	0.294	0.294	0.294	0.294	0.294	0.294	0.294	0	0	0	0	0	0
5	Toaster	0	0	2	2	2	2	2	0	0	0	0	0	0	0
6	Microwave	0	0	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0.333	0	0
7	Popcorn popper	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	blender	0	0	0	0	0	0	0	0	0	0	0	0	0.115	0.115
9	Waffel iron	0	0	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
10	Hot plate	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	Electrical frying pan	0	0	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
12	Bread maker	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	food steamer	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	rice cooker	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	pressure cooker	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	Electrical cooker	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	Kitchine extractor	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	Laptop	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
19	Desktop	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
20	Printer, scanner and pho	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075
21	Shredder	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	Electrical hard drive	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
23	TV	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
24	DVD nad Cd players	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0
25	Radio	0.193	0.193	0.193	0.193	0.193	0.193	0.193	0.193	0.193	0.193	0.193	0.193	0.193	0.193
26	Home cinema	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	Dish wsher	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	Washing machine	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075
29	Clothes dryer	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	Electrical shower	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	Hair dryer, straightner an	1.027	1.027	1.027	0	0	0	0	0	0	0	0	0	0	0
32	Electrical shaver and too	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	Vacuum cleaner	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	Iron	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	Elctrical garage door ope	0	0	0	0	0	0	0	0	0	0	0	0	0	0
36	Sewing machine	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	Electrical heater	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38	Electrical blanket	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39	Air Conditioner	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	Celling and table fan	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04

Figure 5-4 Calculation of Appliances Consumption

5.6 Appliance Electricity Demand of the Sampled Surveyed

The cumulative data from 381 samples was analysed and the appliances demand was calculated based on the appliances ownership and physical specifications. As expected there is a morning peak and evening. However, due to the different household compositions being investigated, there is a midday minor peak due to the minor activity expected during the daytime.

Furthermore, a peak expected to occur after 9 pm due to the increasing of wet appliances usage. The load profile was estimated in two different time intervals; a one-hour interval to determine the hourly appliances demand and a one-minute interval to illustrate the individual electricity demand which is a very significant factor in changeable electricity market [160]. Therefore, the clear picture of individual demand shaping will contribute to understanding the scheduling of the daily usage of appliances. The profiling was done based on two different scenarios of household's appliances power rate. Firstly, an average of power rate was used in the calculation as explained in the consumption sheet in Section 5.5.3. Secondly, the lowest power rate of appliances was used in order to simulate the usage of efficient appliances for same of set of data. Total demand comparison and relative daily contribution for two scenarios was done and presented in the following sections.

5.6.1 Appliances Daily Demand

For the first scenario, the daily appliances demand, the total daily demand for winter usage is 3447.42 kWh / day, whereas in summer is 2401.88 kWh / day with annual average 2081.64 kWh / year. Noticeably, more than 1000 kWh / day is the difference between winter and summer demand. The hourly peak demand reported more than 900 kWh in winter and this peak dropped to nearly 50 % in summer. For the second scenario, by examining Figures 5-5 to 5-12, the demand fluctuation has considerably changed when power rate of the household's appliances improved. However, the usage pattern of the daily appliances fixed for both scenarios as the daily activity is linked to the resident's habits [13]. Overall daily demand reduction of 26.87 % can be achieved in winter and 32.68 % in summer by using more efficient appliances.

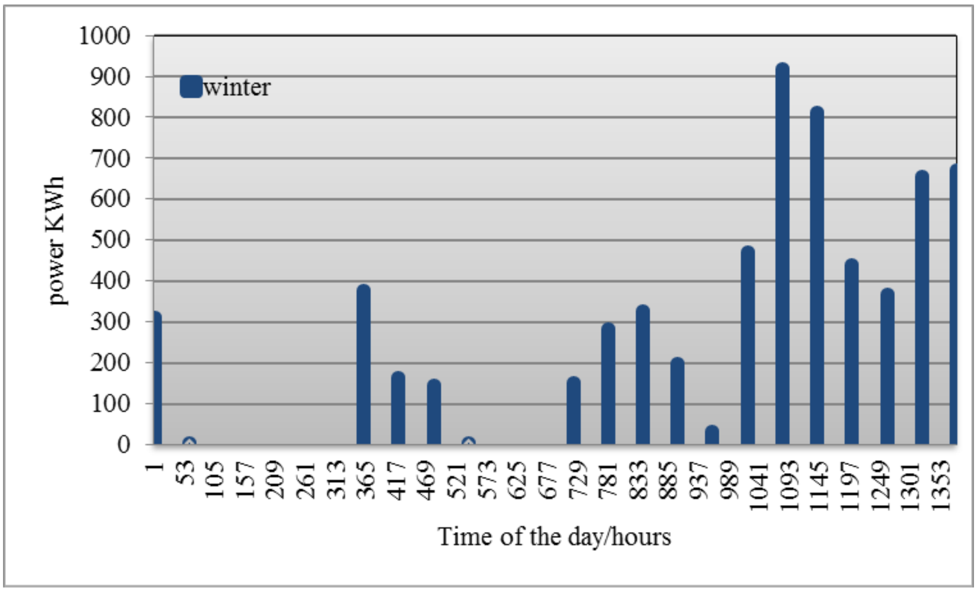

Figure 5-5 Hourly appliances demand winter profile (average power rate)

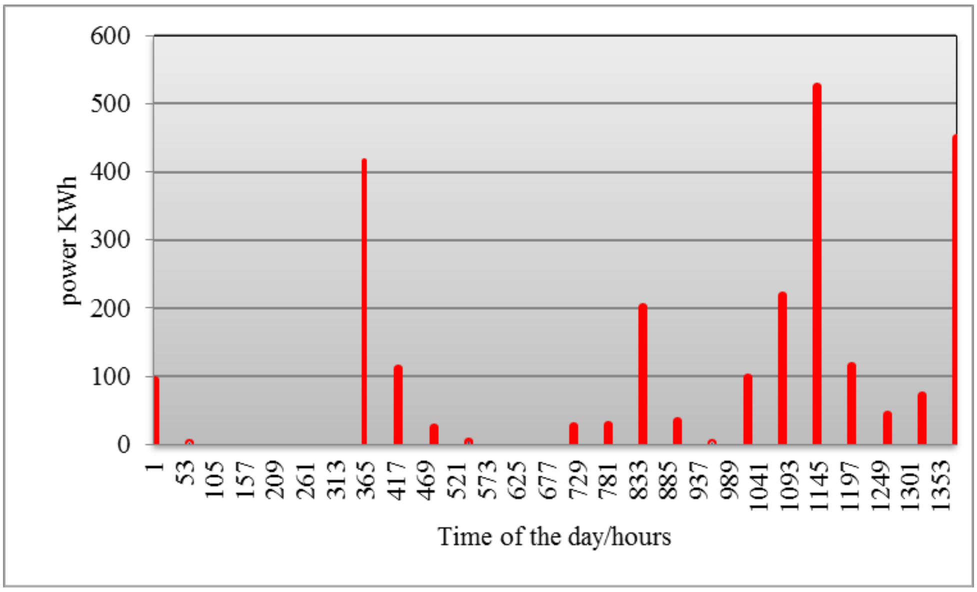

Figure 5-6 Hourly appliances demand summer profile (average power rate)

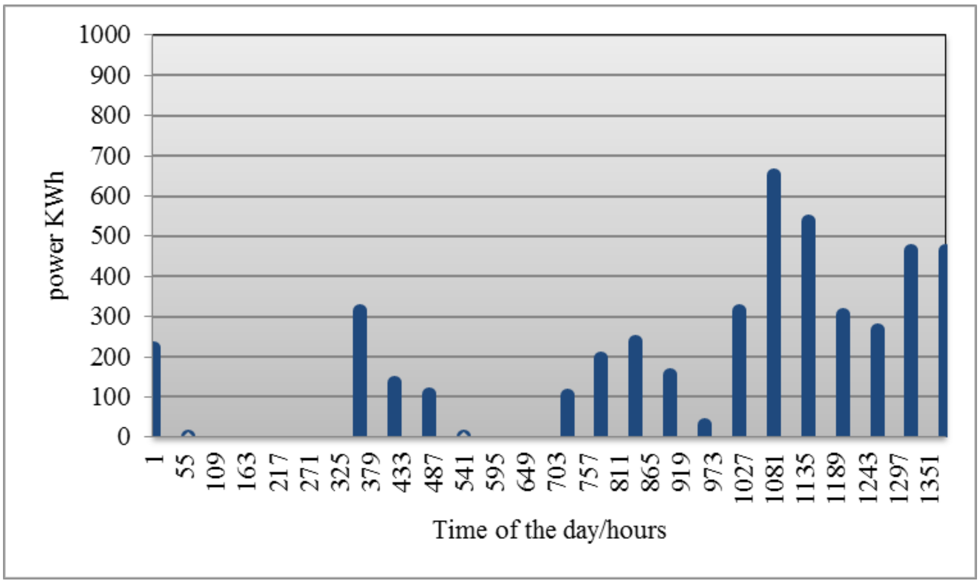

Figure 5-7 Hourly appliances demand winter profile (efficient power rate)

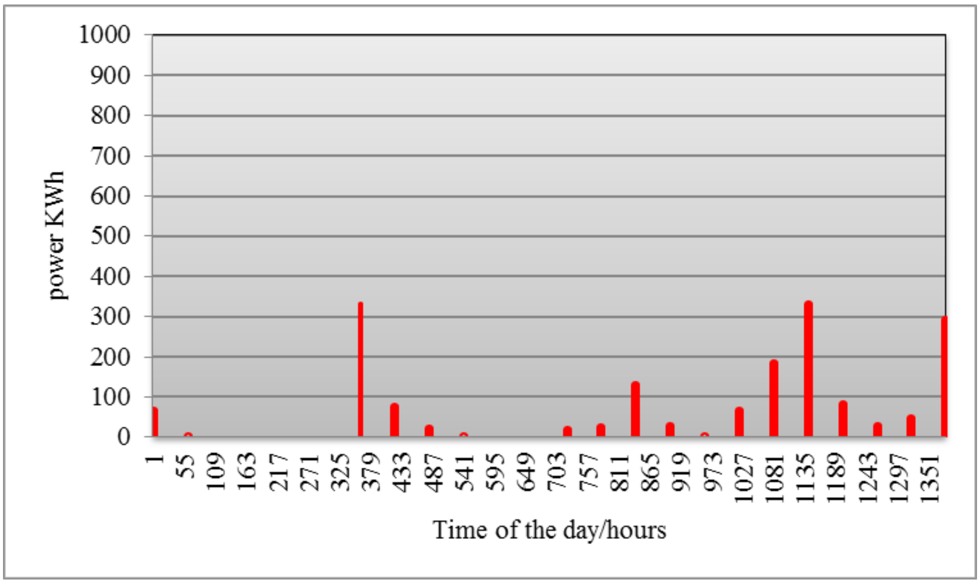

Figure 5-8 Hourly appliances demand summer profile (efficient power rate)

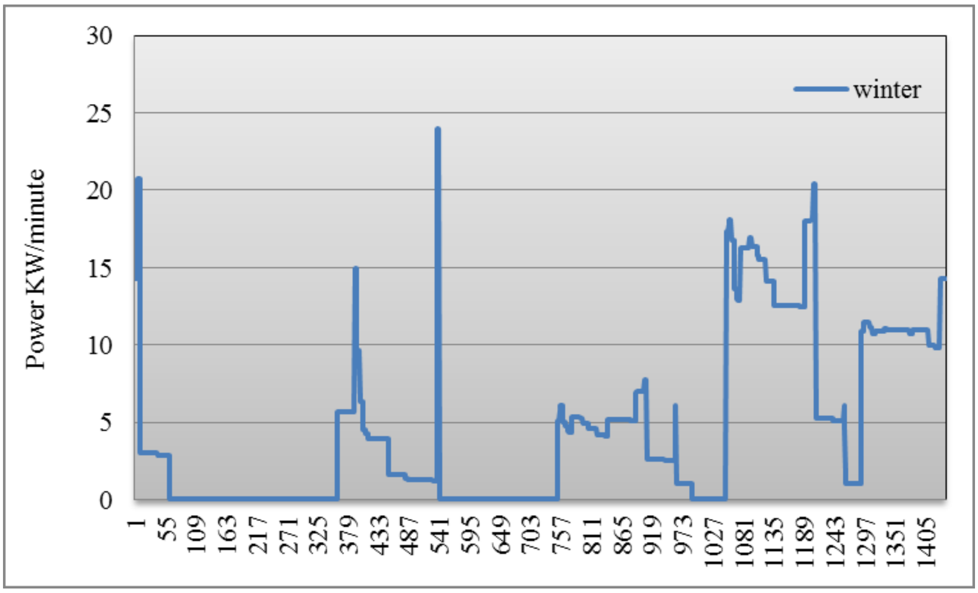

Figure 5-9 one-minute appliances demand winter profile (average power rate)

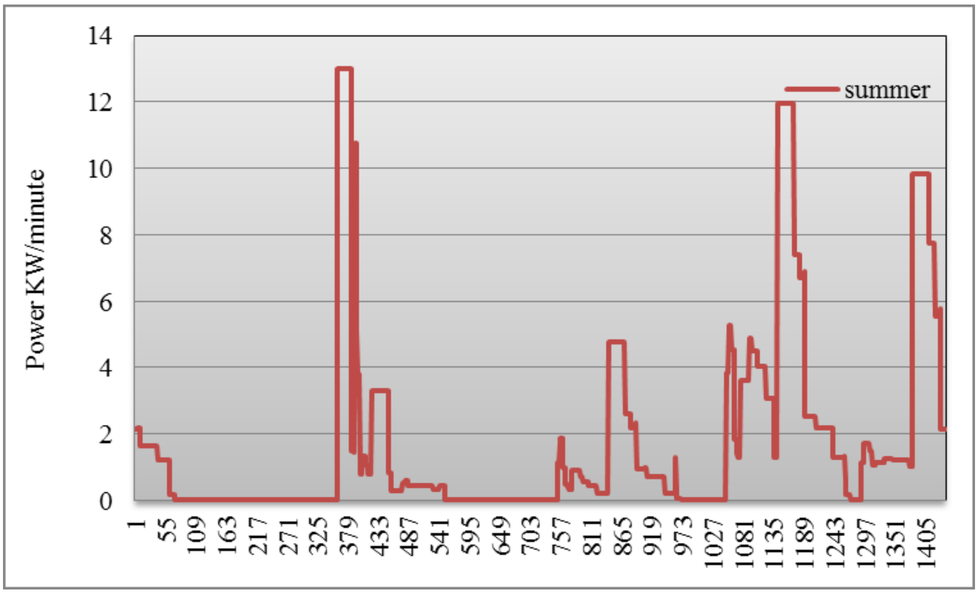

Figure 5-10 one-minute appliances demand summer profile (average power rate)

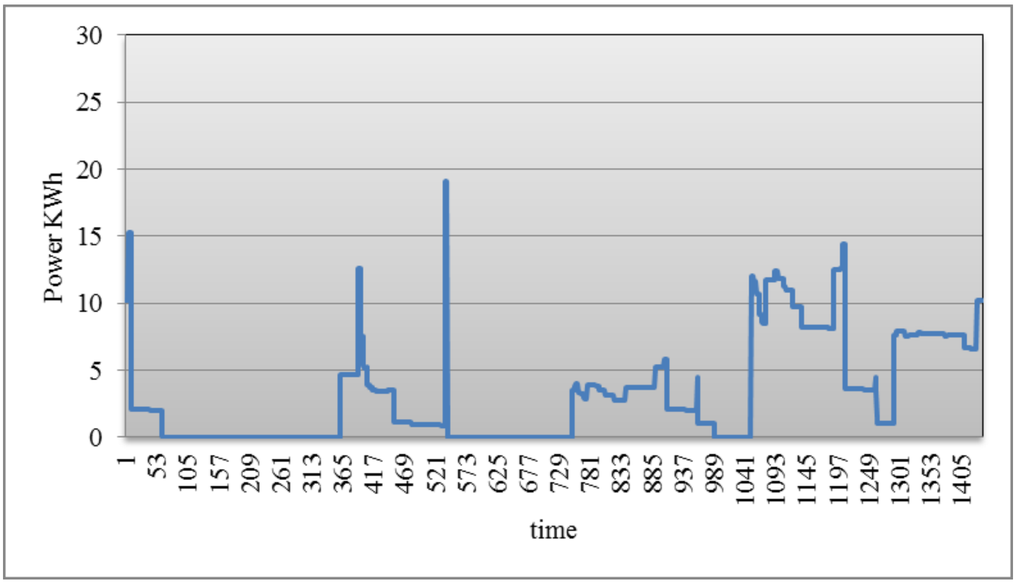

Figure 5-11 one-minute appliances demand winter profile (efficient power rate)

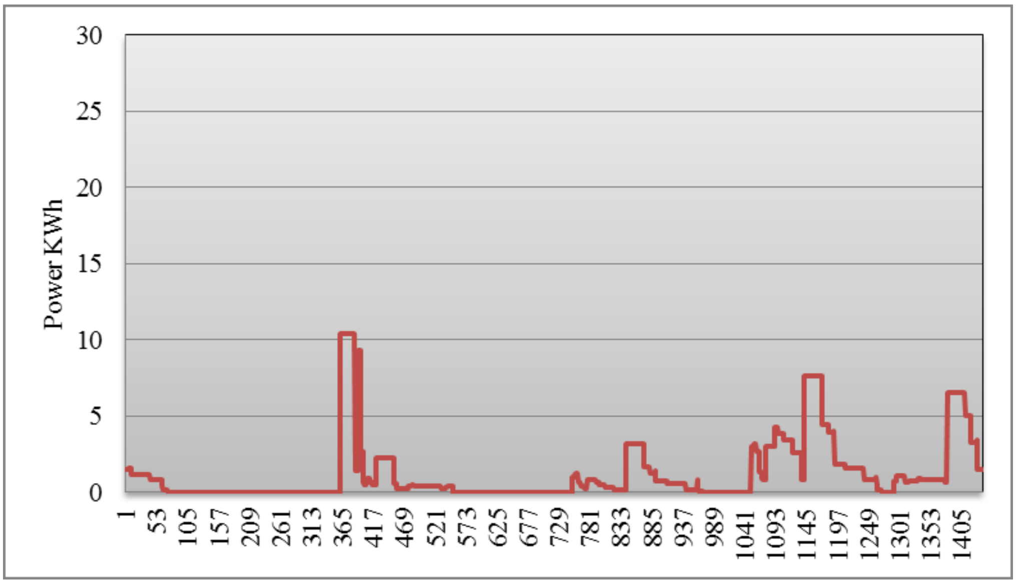

Figure 5-12 one-minute appliances demand summer profile (efficient power rate)

5.6.2 Appliances Demand and Relative Contribution per Period

As can be seen, the majority of the appliances demand is happening during the peak period (4 - 9 pm). The daily contribution of each period is presenting in the Figure 5-8. The peak period (4 - 9 pm) is responsible for more or less on 40 % of the daily demand. Although there is a significant difference between winter and summer demand, still the daily contribution is similar. Similarly, the reduction of peak demand can be achieved by using more efficient appliances. 30 %

reduction was observed in winter and nearly 31 % in summer. However, the relative contribution of the individual interval to the total daily demand was virtually the same, except in the morning period where a miniature increasing can be observed. Moreover, the following figure illustrates each appliances category's demand, it is clear that wet appliances demand during winter is virtually double the summer demand. Also, the other appliances usage has a significant change. The maximum demand expected per period is 1329 kWh / period which the peak period demands for the borough is in winter. Conversely, the demand for the same period in summer is 945.7 kWh / period.

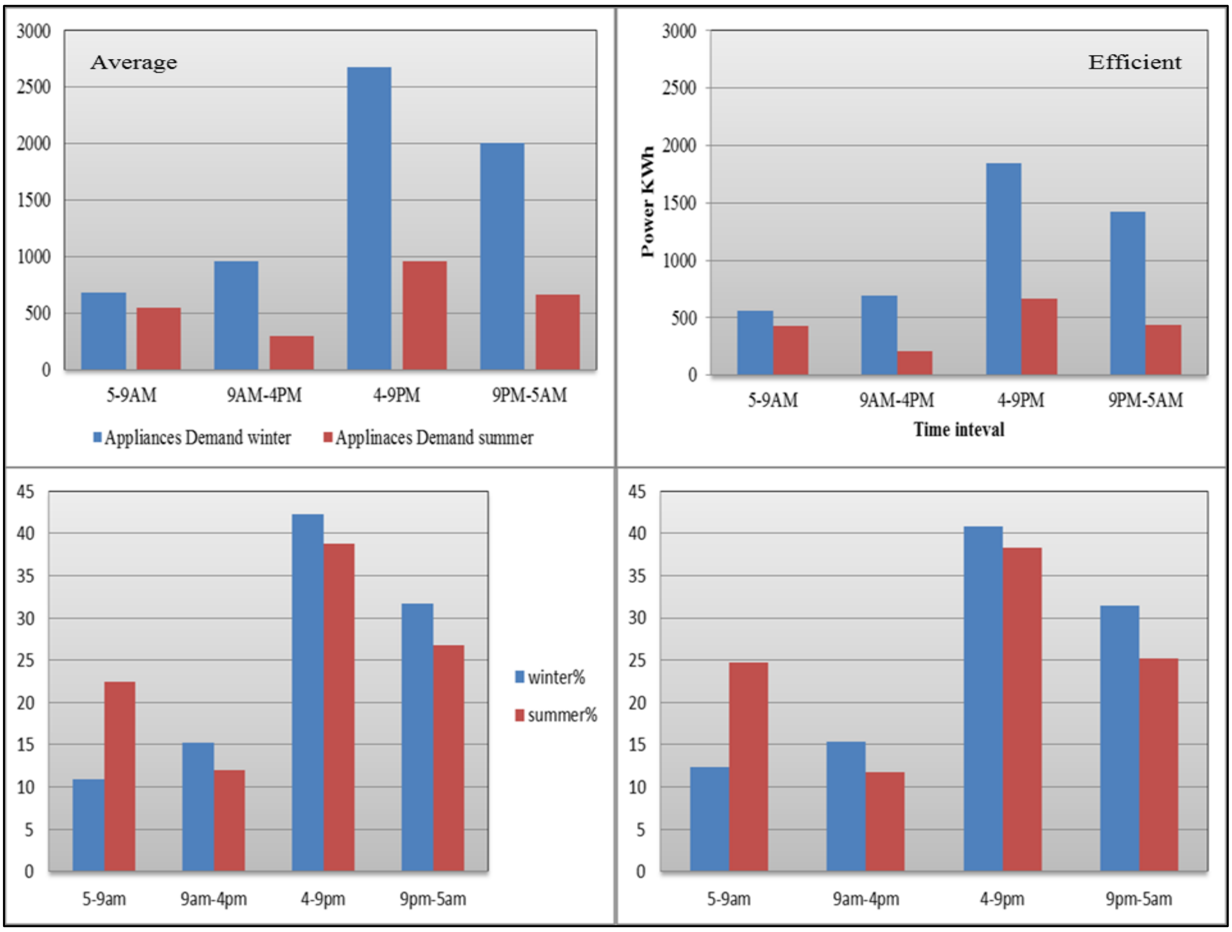

Figure 5-13 Hourly and One-Minute Appliances Demand Profiles

5.7 Cooking Appliances Daily Demand and Relative Daily Contribution

This category consists of 15 appliances, the total demand of the cooking appliances and equipment is 397 kWh / day in winter, whereas in summer is 317.4 kWh / day. However, a noticeable difference has been observed due to increased usage of some of these appliances in winter over summer. According to [160], the main use of cooking appliances is occurring at peak period where the main meals are prepared. However, other cooking appliances reported to be used throughout the day. In summer usage the cooking appliances contribution is a higher than winter usage, where in the summer the daily relative contribution of the cooking appliances to the total daily demand is 14 %,while in winter the relative daily contribution is 11.5 %. The overall daily reduction in cooking appliances and equipment can be achieved is just over 12 % for winter and summer.

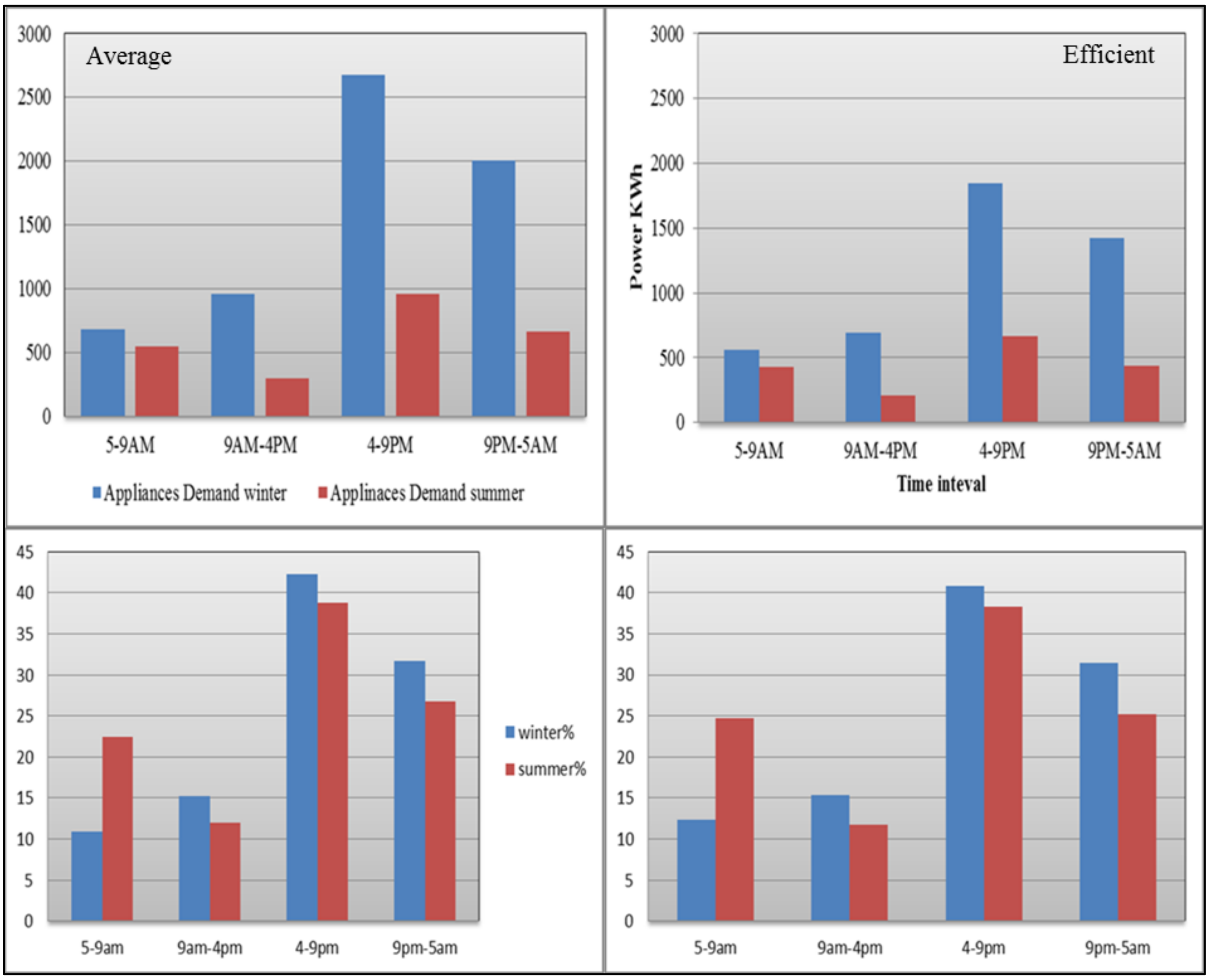

Figure 5-14 Appliances Electricity Demand and Relative Contribution

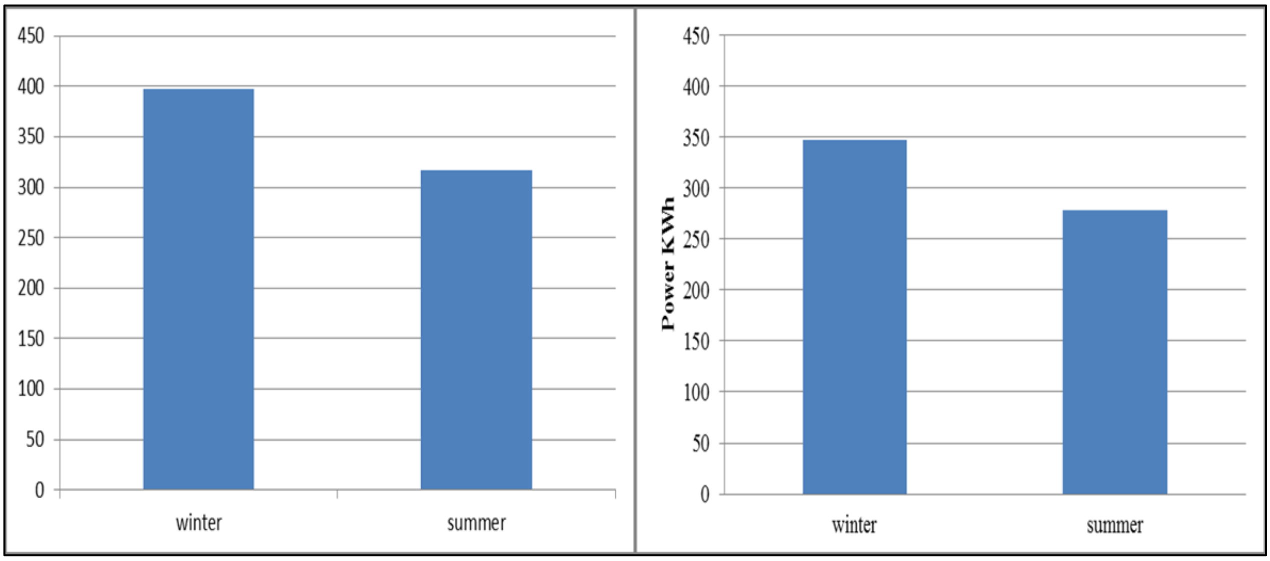

Figure 5-15 cooking appliances daily demands

5.7.1 Daily Demand per Period and Relative Daily Contribution

Figure 5-12 illustrates the cooking appliances demand of each time interval. The demand is at it is peak during (4 - 9 pm), where the winter demand during this period in winter is 239.3 kWh while, in summer it is 196.3 kWh. The relative daily contribution of this period to the daily demand is slightly over 60 %. However, in this category has been noticed that the summer contributions slightly higher than winter. In fact, the winter demand is higher, as mentioned above, but the contribution to the total demand is lower. The potential reduction in cooking appliances demand is 10.5 % and 9.5 % for winter and summer respectively during the peak period.

5.7.2 Cooking Appliances Usage During Peak Period and Relative Contribution

As mentioned the total number of appliances investigated is 15 and are illustrated in Figure 5-16. The usage of an electrical cooker is significant comparing to other appliances, the use of electrical cooker in summer is slightly higher than winter for the sample surveyed. Though, only 18.9 % in winter and 21 % in summer are reported using electricity cooker amongst the total samples surveyed. The relative contribution of each of these appliances shown in Figure 5-13, the electrical cooker is responsible for 30 % and 40 % in winter and summer respectively, and then food steamer comes second and followed by the microwave as are responsible for 15 % and 10 %. Figure 5-15 shows the relative contribution of individual appliances during the peak period, a significant reduction in microwave usage during this period reported by using an efficient appliance.

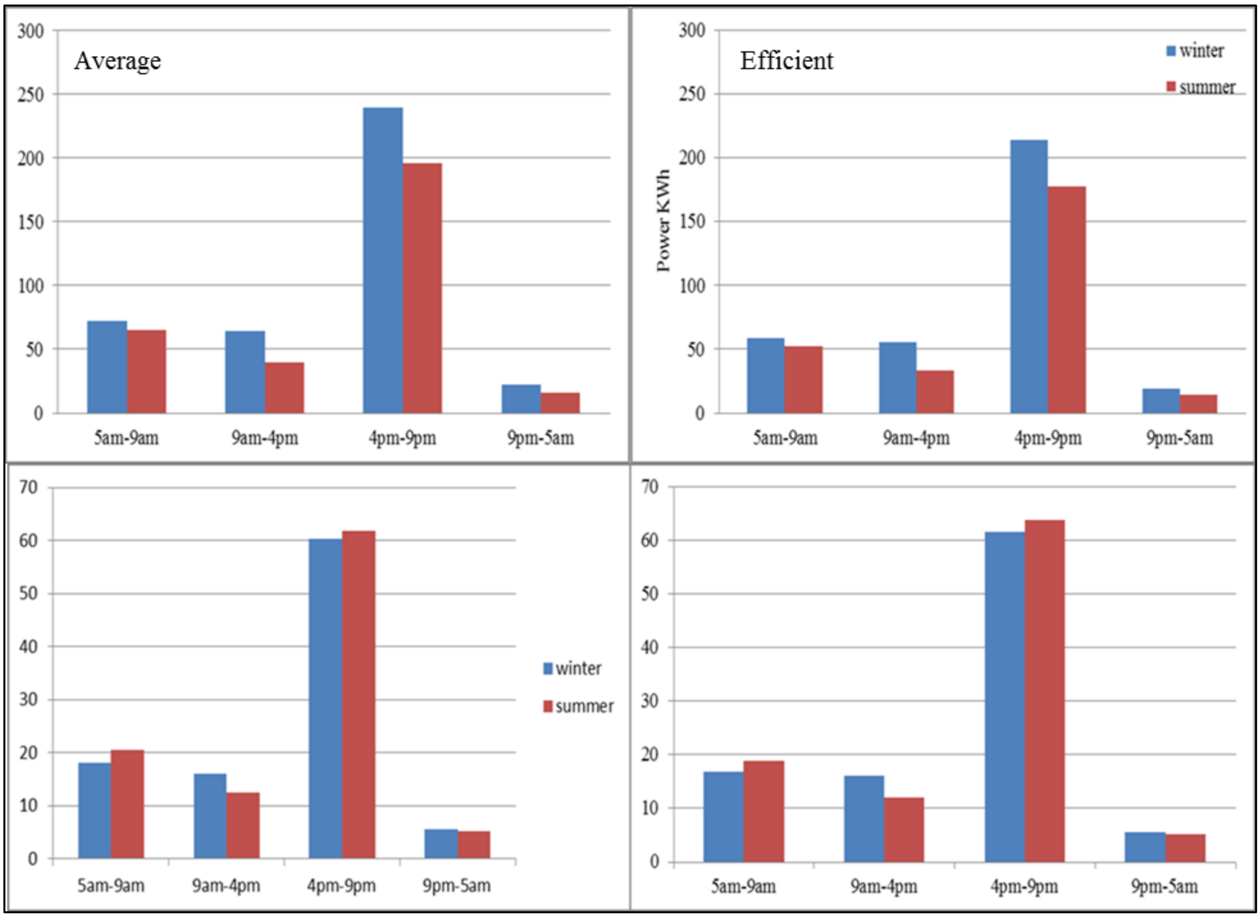

Figure 5-16 cooking appliances daily demand and relative daily contribution

5.8 Entertainment and Office Appliances

This category of household appliances contains 6 different entertainment and office pieces of equipment. The total demand of this category is 525.3 kWh / day in the winter, whereas in the summer is 506.5 kWh / day. However, a visible difference has been observed due to increasing usage of some of these appliances in winter over summer. Based on the data trends, the usage of this category of household's appliances is during the occupancy periods. As people tend to watch TV and entertain themselves during their stay at home, either for relaxing, or when doing other activities such as cooking or working. The relative daily contribution of entertainment and office appliances to total daily demand is different during summer and winter. It has been observed that the contribution of this category to the total daily demand just over 22 % while in winter the relative contribution is 15 % of the total daily demand. For both usage (winter and summer), more than 38 % reduction in the daily demand of this appliances category can be achieved by using more efficient appliances.

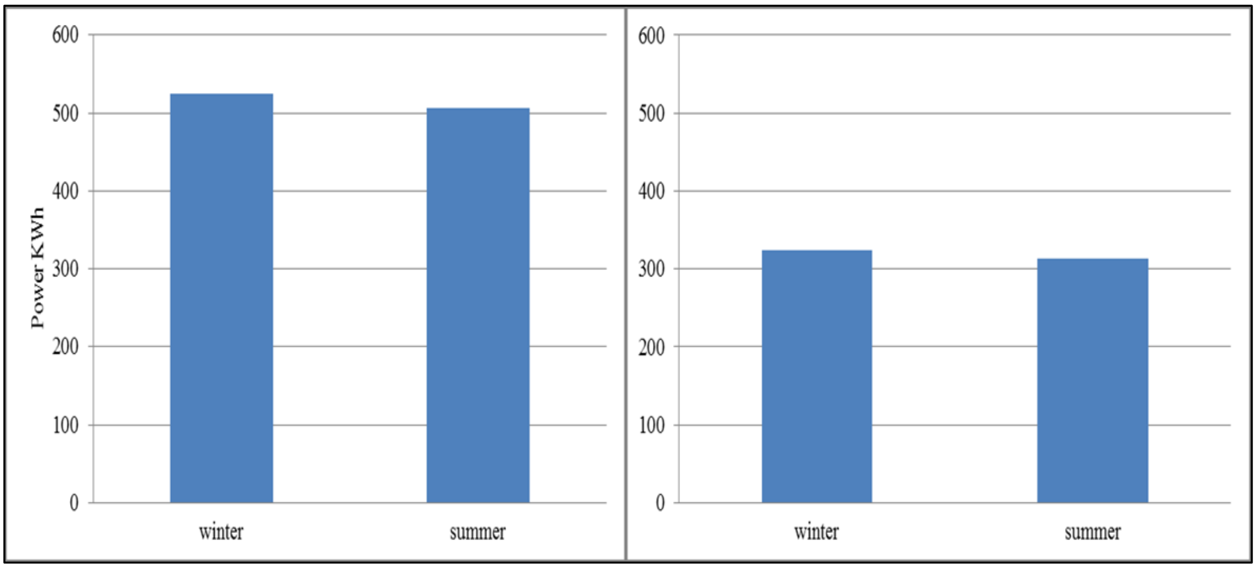

Figure 5-17 Entertainment and Office Appliances Daily Demand

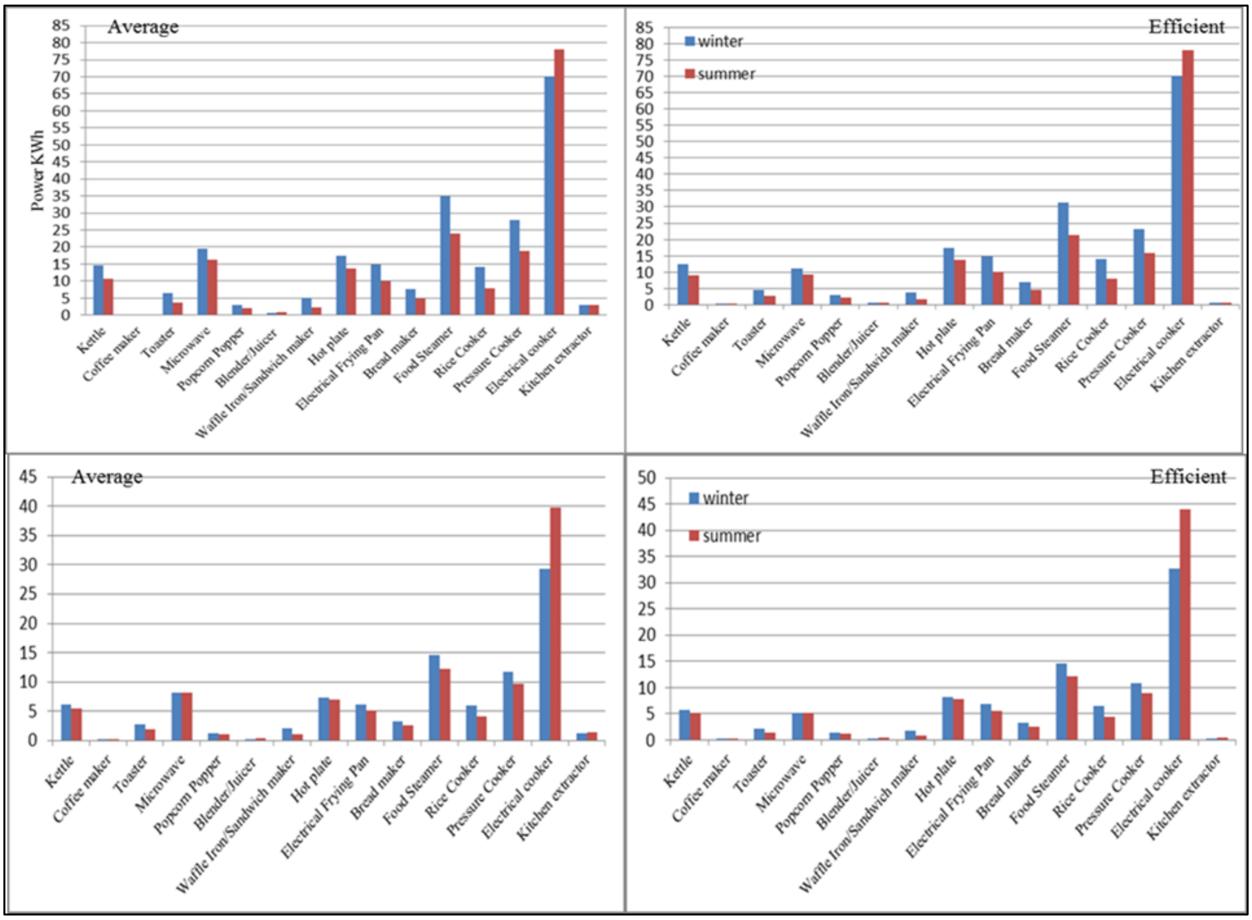

Figure 5-18 Peak Period Cooking Appliances Demand and Relative Contribution

5.8.1 Daily Demand per Period and Relative Daily Contribution

Looking to Figures 5-16 and 5-17, the entertainment and office appliances are very much used in the two intervals. The peak period as well as 9 pm - 5am, the demand range is (200 to 250 kWh / interval) for both winter and summer usage. It is observed that during summer the usage is slightly higher than winter for the 9 pm - 5 am period. The relative daily contribution of peak period and 9 pm - 5 am to the daily demand is nearly 50 % and 40 % respectively. This category shows a massive potential reduction as the relative contribution to the peak period can be cut by more than 38 %. However, the relative contribution to the total demand remains almost similar as shown in Figure 5-18.

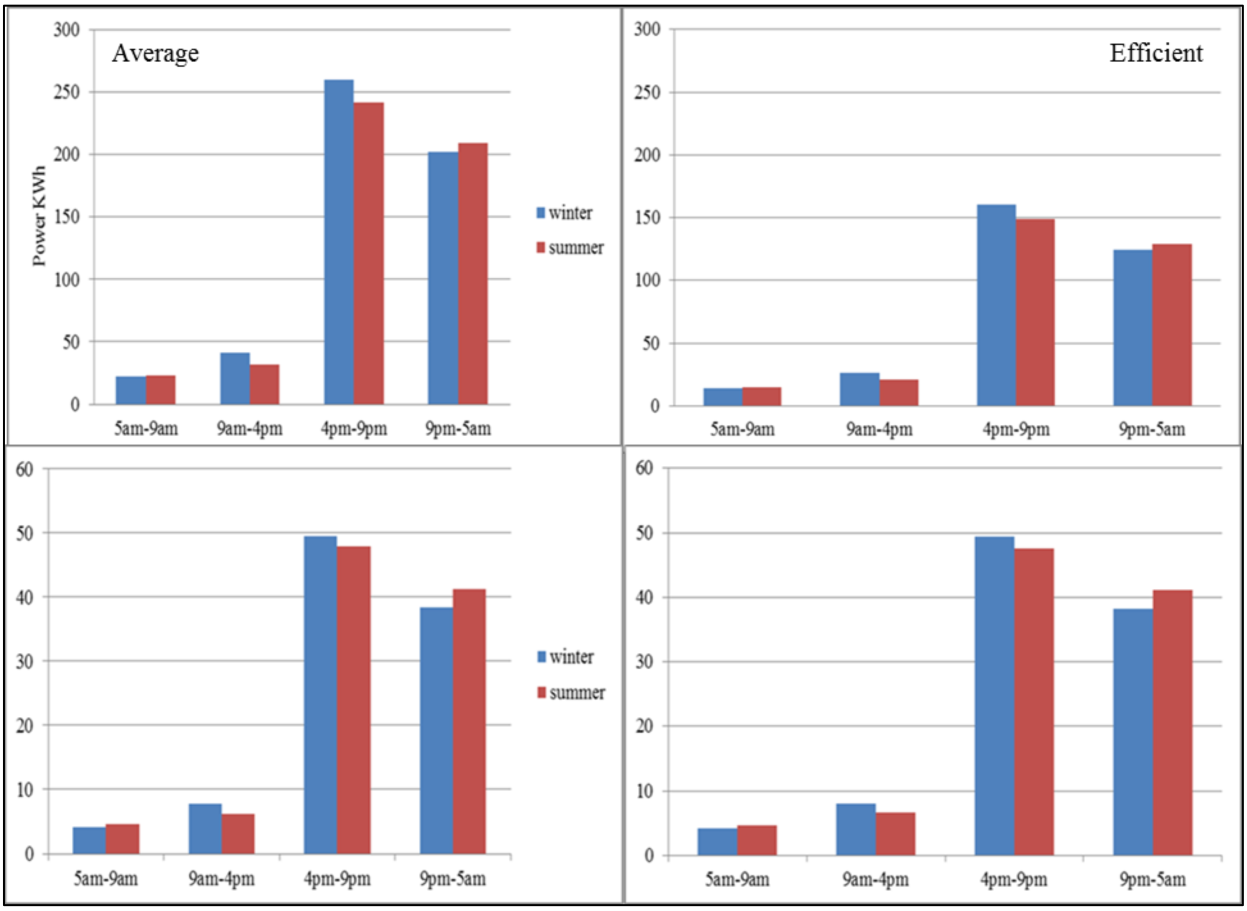

Figure 5-19 Entertainment and Office Daily Demand and Daily Relative Contribution

5.8.2 Demand Peak Period and Relative Contribution to Peak Demand

As stated in Section 5.6, the total entertainment and office during the peak period is about 250 kWh. However, TV set appears to consume most of the demand which is slightly just over 80 %

for each period. According to [54] and [22], the average TV set watching time is 3 - 5 hours a day in the UK which explains the high relative contribution amongst the investigated appliances in this category. The daily relative contribution to the peak demand of the entertainment and office appliances remains similar. In this category, the majority of demand is due TV set which is responsible on over 80 % of the category demand during peak demand period.

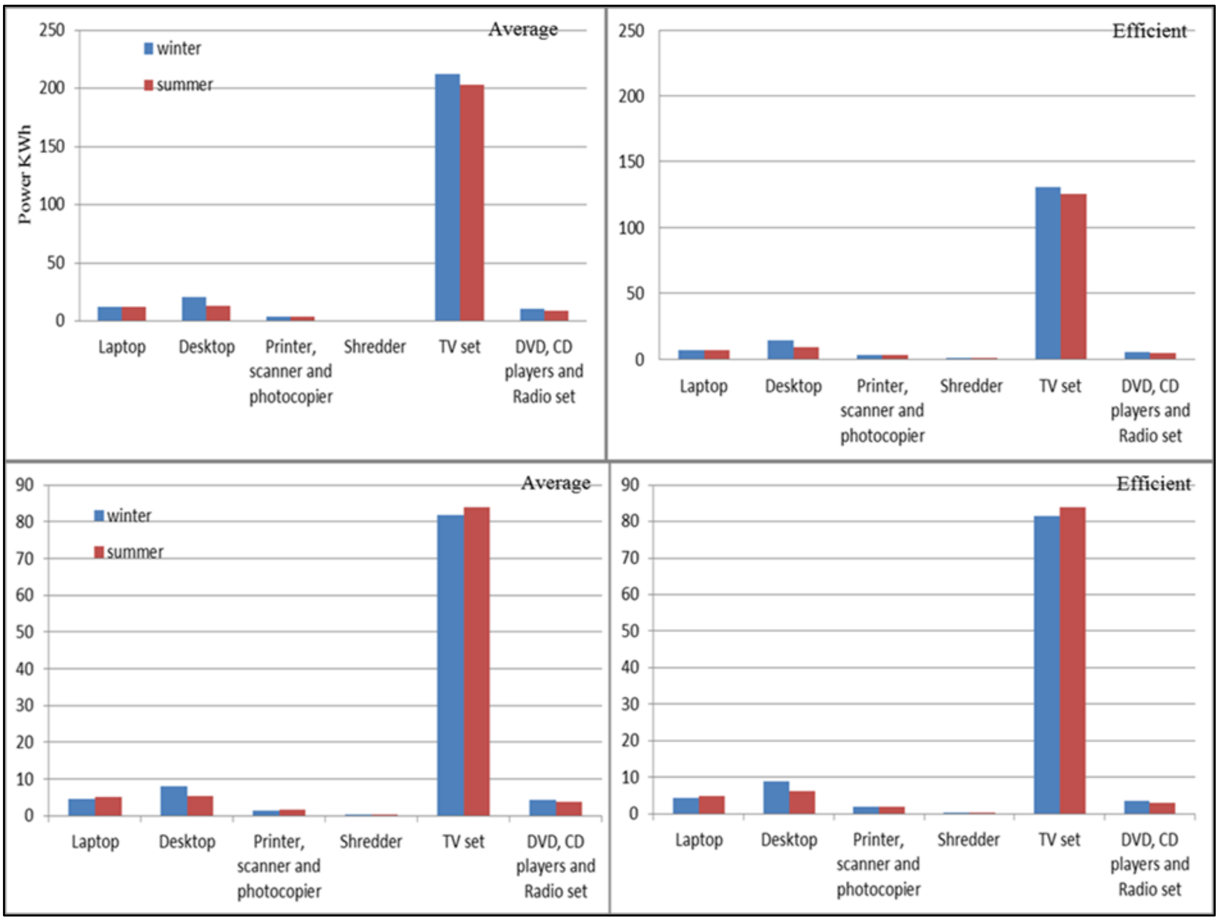

Figure 5-20 peak period entertainment and office demand and relative contribution

5.9 Wet Appliances Daily Demand and Relative Daily Contribution

This category of household appliances contains 3 different appliances which are considered to use a high level of energy by consumers. Figure 5-22, indicates the demand of the wet appliances which is over 1400 kWh / day in the winter (41 % of the total daily demand of the borough). Conversely, in summer the demand drops to just above 900 kWh / day (40 % of the total daily demand) as an insignificant number of households use the clothes dryer. It has been observed the relative daily contribution is identical for both winter and summer. Regardless of any load shifting scenario, in winter nearly 30 % demand reduction can be achieved by using an efficient wet appliance and more than 35 % in summer.

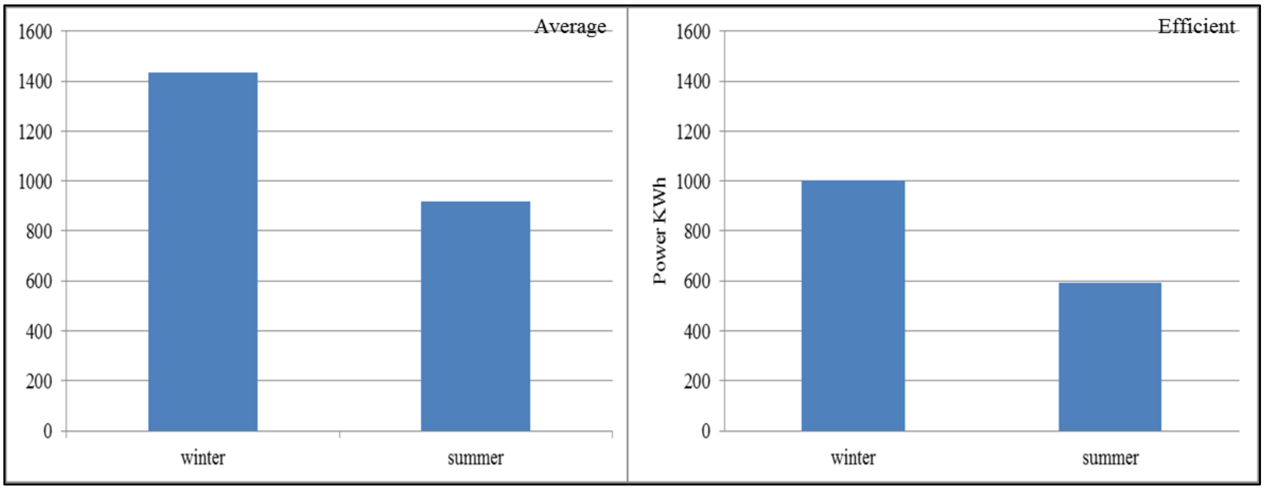

Figure 5-21 wet appliances daily demand

5.9.1 Daily Demand per Period and Relative Daily Contribution

By looking at Figure 5 - 24, the wet appliances demand during the peak period is slightly over 600 kWh in winter and just over 350 kWh. Also, the figures indicate that a considerable number of wet appliances are reported been used after 9 pm which explains another peak occurs after 9 pm. The relative daily contribution of wet appliances is just about 40 % for the both periods during winter and summer. There is less than 5 % of the demand that taking place in the morning and another 15 % during the 9 am – 4 pm period.

5.9.2 Peak Period Demand and Relative Daily Contribution to the Peak Period

Giving the fact, the washing machine is consuming just over 40 % of the total peak period demand for winter, as the ownership level of a washing machine is higher than the other appliances of this category. Whereas, in summer, the daily contribution jumps to more than 70 % as less clothes dryer been used during summer. The relative contribution has shown some changes in this category, washing machine share has reduced by 6 % in summer and more than 8 % in winter. Conversely, the clothes dryer share has shown an increase of nearly 8 % where a slight increase of dish-washer contribution to the peak demand period was observed.

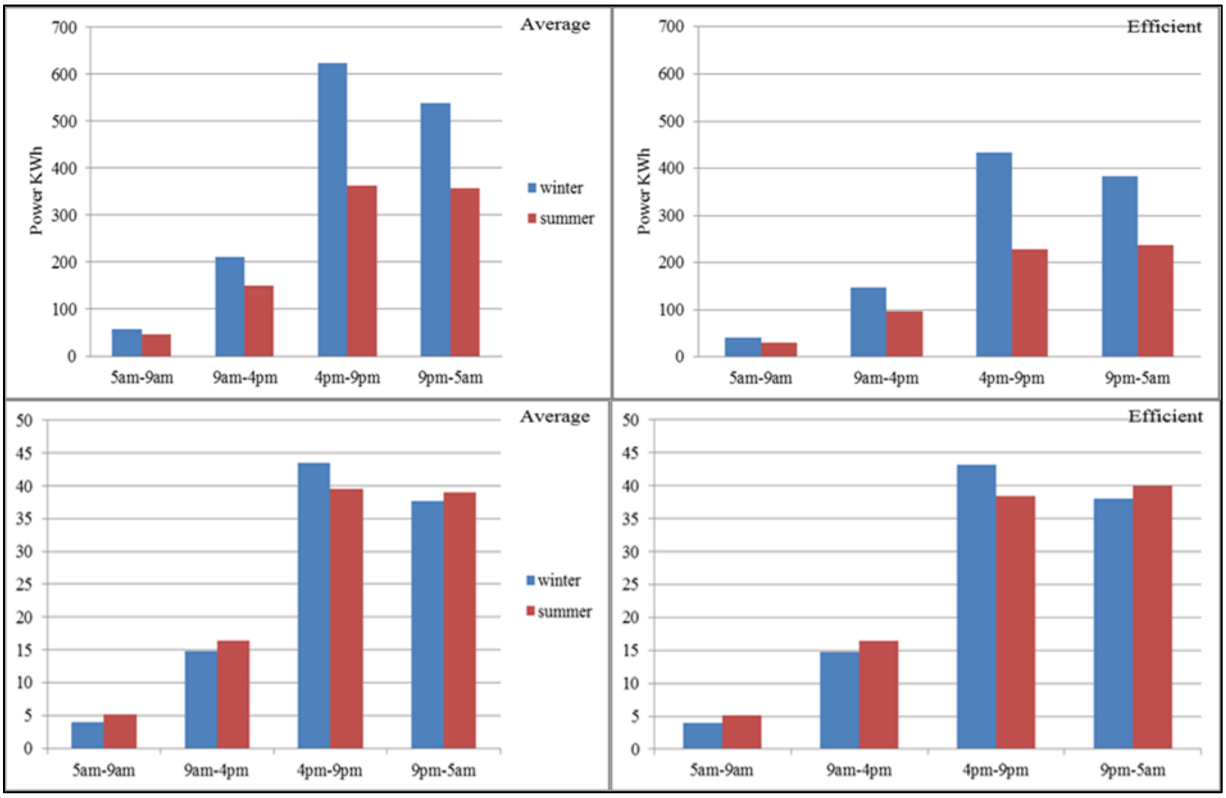

Figure 5-22 Wet Appliances Daily Demand and Relative Contribution

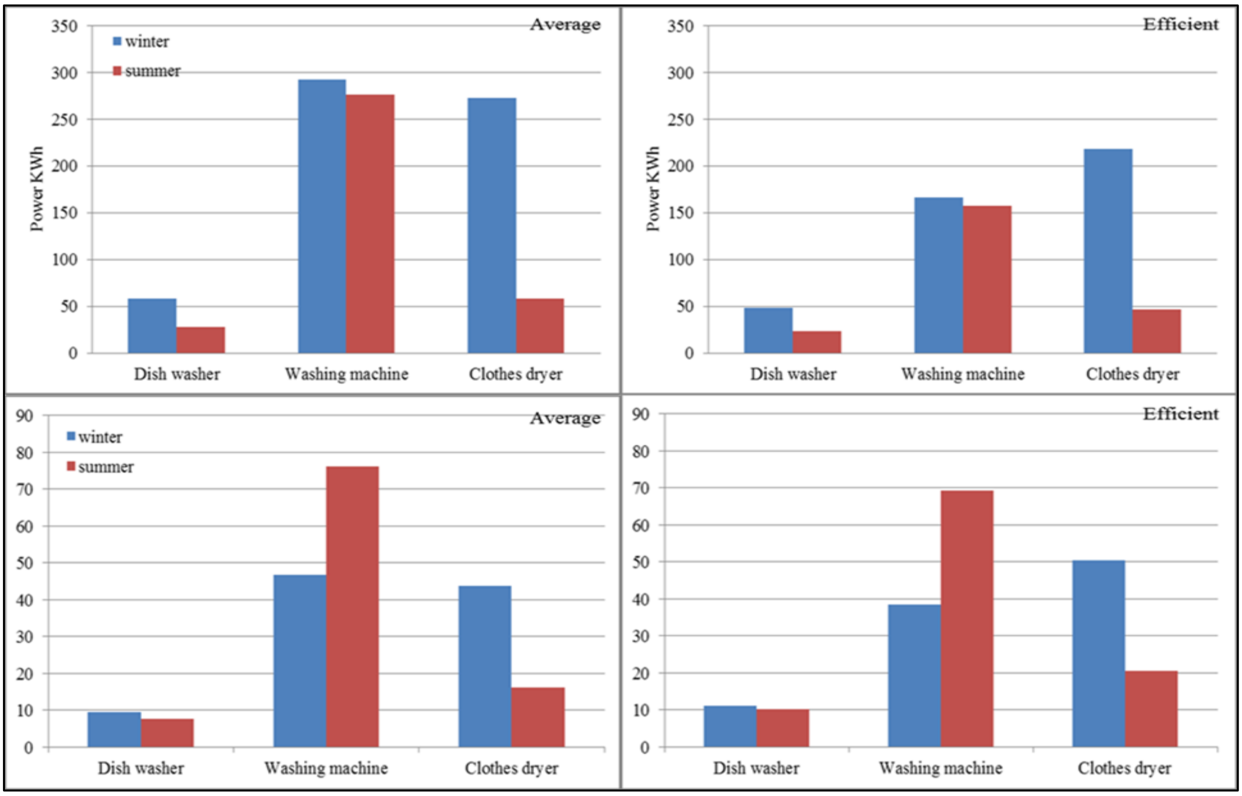

Figure 5-23 Wet Appliances Demand In Peak Period and Relative Contribution

5.10 Other Appliances

This category of household appliances contains 5 different appliances, which are also, to an extent, three of them are considered to have high-energy consumption. Figures 5-28, shows the daily demand of the other appliances and relative daily contribution to the total daily demand. Although, there is a noticeable difference in the usage due to increasing use of an electrical shower in the winter still the daily contribution similar in winter and summer. Can be expound the high contribution of this category (31 % in winter and 29 % in summer to the total daily demand) is due to electrical shower and iron as explained below. The potential demand reduction can be achieved when more other efficient appliances used. There was 22.69 % and 24.85 % in winter's demand and summer's demand respectively, the potential of the demand reduction of this category.

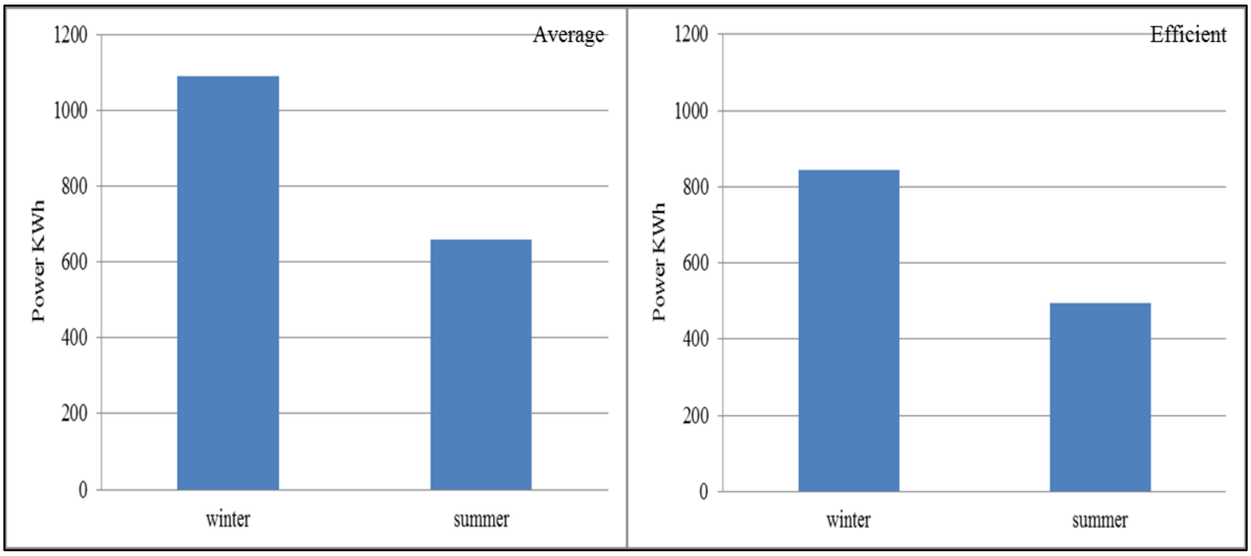

Figure 5-24 Other Appliances Daily Demand

5.10.1 Daily Demand per Peak Period and Relative Daily Contribution

Contradictory to the previous categories, the other appliances peak demand occurs in the morning. For instance, the majority of the residents of the borough intend to use the electrical shower in the morning. The daily demand in the winter is almost 600 kWh and just over 350 % in summer. Additionally, the relative daily contribution to this period is nearly 55 %. There is a great potential demand reduction (25 kWh & 20 kWh) in this category just use more efficient appliances. However, the daily contribution shows a fixed share for both. The other interesting fact is that electrical shower holds a significant share of daily demand in this category.

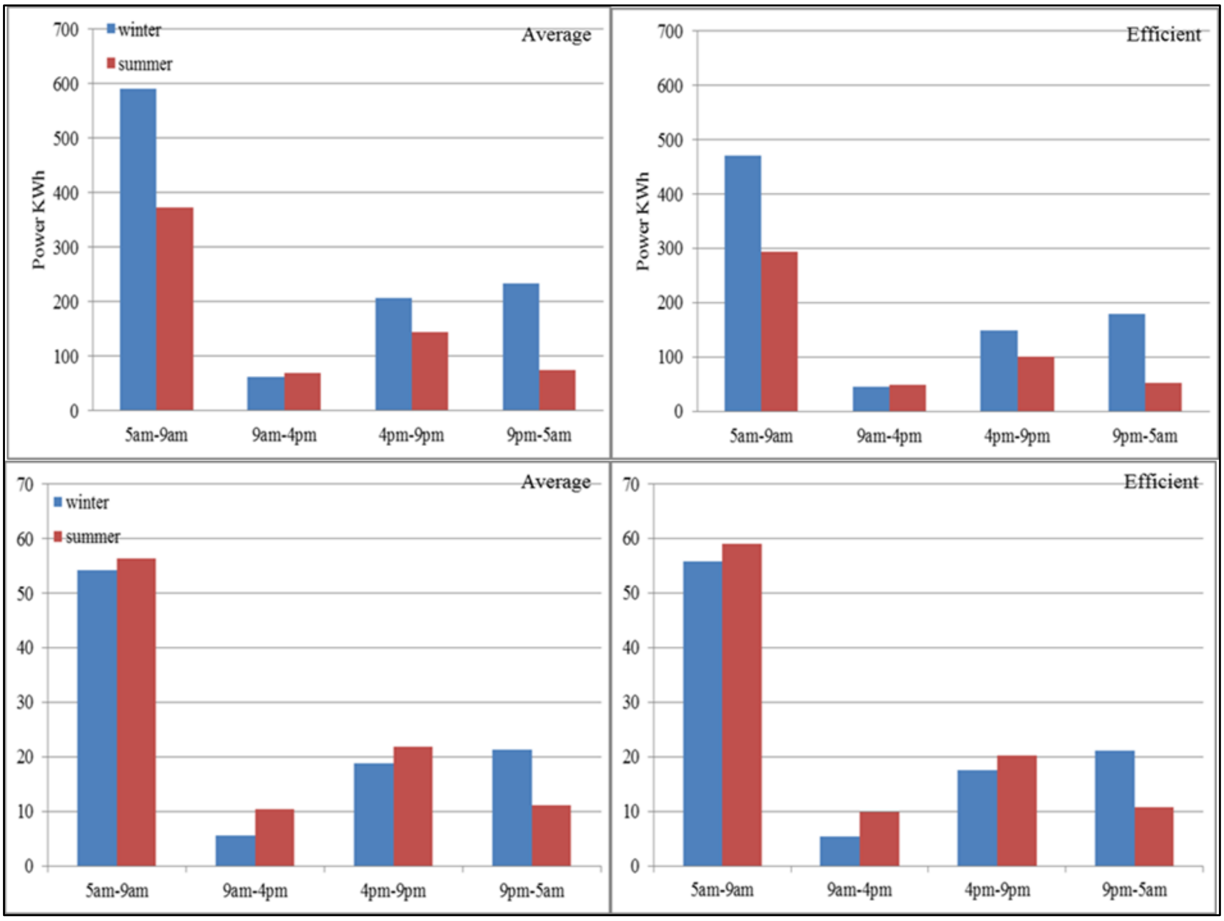

Figure 5-25 Other Appliance's Daily Demand per Period and Relative Contribution

5.10.2 Peak Period Demand and Relative Peak Contribution

Given the fact, this category reached its peak during the morning period; the usage of electrical shower in winter contributes more than 25 % to the peak demand. However, the results show a significant reduction in appliances demand when more efficient appliances were used.

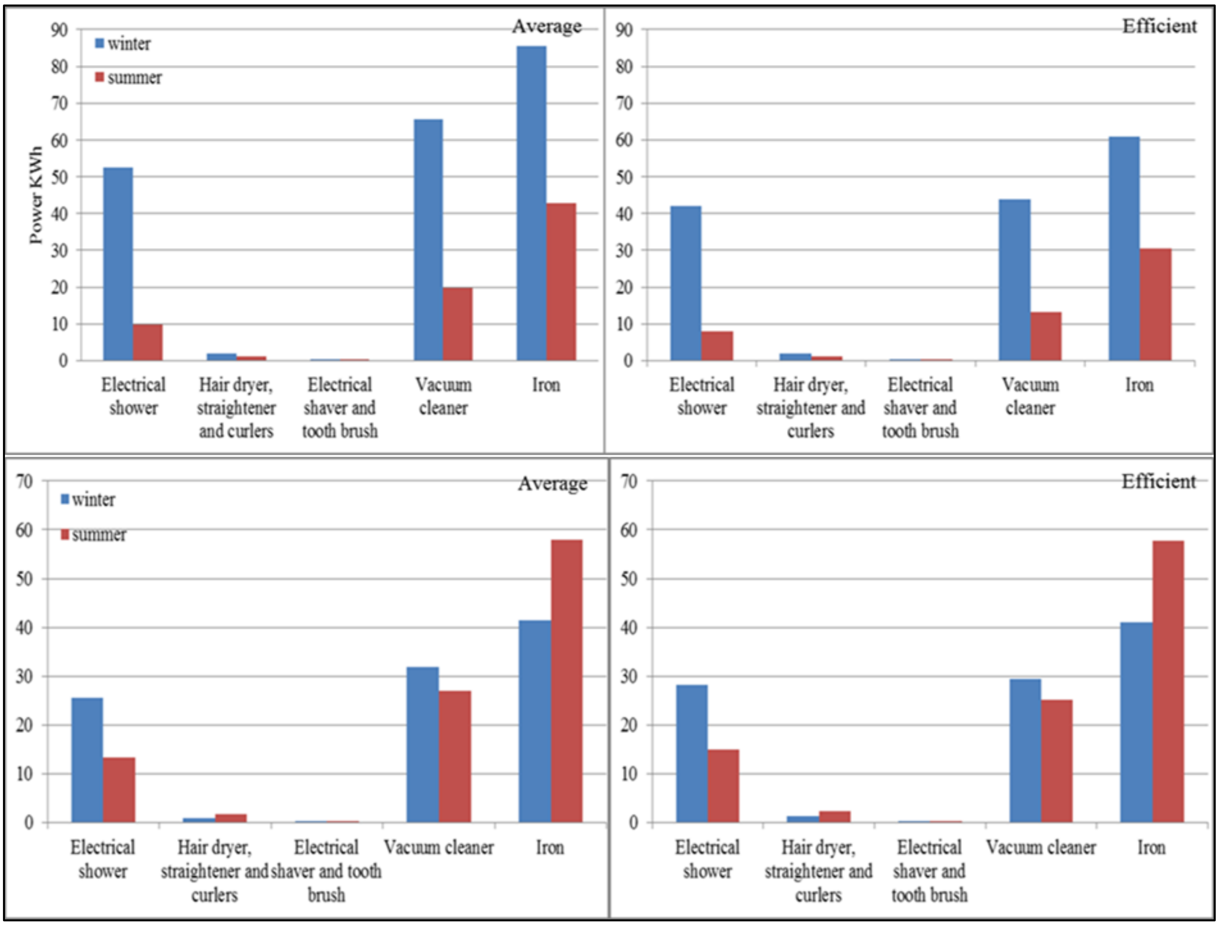

Figure 5-26 Other Appliances Demand Of Peak Period and Relative Contribution

5.11 Summary

This chapter has presented an estimation of the household electricity demand. The results show that it can be forecasted the daily consumption based on available data collected from the end-use of the electricity. Gathering, these data, the appliances power rate and pattern usage used to calculate the average consumption per household for the Hillingdon borough. The average consumption derived was compared to the data collected and shows a great agreement with the data [140]. The peak period consumption can be reduced by (13 %) by shifting only wet appliances usage to off-peak period as shown in Table 5-4. The data presented show that the wet appliances and cooking equipment are responsible for 13 % and 15 %, of peak period demand respectively. The results provide a strong indication that of the method's capability to estimate the domestic electricity consumption. A valuable use for such a technique is to compare the different category of appliances consumption and their share of household consumption. Investigating the household individually consumption which is expected to grow due growth in the number households in the future.

In the preceding chapter, energy consumption and usage of the household inhabitant are observed along with load profile. Different approaches are used for critical to quality. The process of synthesis approach is used and that is part of the bottom-up approach. Research data are obtained from investigation of a residential area by using quantitative mechanism, which itself includes two types of aggregation. The first was related to individual appliances to the household demand profile and the other was from various appliances of household demand. Moreover, two functions also discussed related to probability, for example, behaviour and engineering. Through behaviour research, particular data is collected from the different residential area and their different households.

UK residential model is chosen for survey and sample purposes. Data is collected and estimations are made on the basis of the research area, energy consumption or demand records, etc. Each household inhabitant has different criteria of consuming energy by drawing a conclusion with facts figures. Along with this, by encouraging consumers to change their normal lifestyles to cost effective and energy sustainability, researchers and scientists are developing techniques and solution in order to find a better way of consumption.

Table 5-4 Appliances Demand and Potential Reduction

Appliances	Average Power rate KWH/Day		Efficient Power Rate KWh/Day		Potential Reduction	
	winter	summer	winter	summer	winter	summer
Daily Demand	3447.416	2401.884	2521.055	1616.855	26.87%	32.68%
Cooking	397.010	317.382	347.702	278.44	12.4%	12.3%
Cooking peak period	239.26	196.29	214.174	177.63	10.5 %	9.5 %
Entertainment and Office	525.334	506.382	324.52	313.258	38.23 %	38.15 %
Peak period	260.218	242.393	160.569	149.145	38.29 %	38.47 %
Wet	1433.07	918.483	1004.63	592.967	29.9 %	35.44 %
Other	1092.01	659.624	844.199	495.737	22.69 %	24.85 %

Chapter 6 Statistical Data Analysis

6.1 Descriptive Statistics

The descriptive statistics is used to analyse the coded data, and sort it in a way which is more easily to understand and get better indication of the data trends. Tables are used to present the measure and calculation of various descriptors. The Descriptive statistics table is used to describe the appliances score during summer and during winter. As a nonparametric test used it is most likely that the quartiles information to describe the groups should use as shown in Table 6-1 [161].

Table 6-1 descriptive statistics analysis

Appliances	Std. Deviation		Maximum		Percentiles					
					25th		50th (Median)		75th	
	winter	summer	winter	summer	winter	summer	winter	summer	winter	summer
LDCA	2.91	2.88	16.00	15.00	5.0000	4.000	6.0000	5.0000	8.000	7.000
HDCA	3.89	3.12	21.00	18.00	.000	.000	3.0000	2.0000	6.000	4.000
Ent. and office	3.08	2.91	15.00	15.00	3.000	3.000	6.0000	4.0000	8.000	7.000
Wet appliances	3.06	2.51	12.00	12.00	6.0000	3.000	7.0000	4.0000	9.5000	7.0000
Other	3.84	3.84	21.00	23.00	6.0000	5.0000	8.0000	8.0000	11.000	11.000

6.2 Wilcoxon Signed Ranks Test

The Wilcoxon signed-rank test is the nonparametric test equivalent to the dependent t-test that does not assume normality in the data. It is used to compare two sets of scores that come from the same participants. This can occur when investigating any change in scores from one time point to another, or when individuals are subjected to more than one condition. Thus, Wilcoxon signed-rank test can be used to understand whether there was a difference in light-duty cooking appliances summer's usage time and light-duty cooking appliances winter's usage time, and the two related groups would be the light-duty cooking appliances values recorded during the "summer" and "winter". Thus, Wilcoxon signed-rank test can be used to understand whether there was a difference in response times under these two different lighting conditions (*i.e., the dependent variable is "response time", recorded in categories, and the two related groups would be response times in a "summer" versus "winter"*).

6.2.1 Light-Duty Cooking Appliances

The ranks table provides some interesting data on the comparison of participants' LDCA score during summer and winter. It can be seen from the Table 6-2 that 181 participants had higher light-duty cooking appliances score during winter than during summer. However, 43 participants had a higher LDCA score during summer than during winter and 157 participants saw no change in their LDCA score during summer and winter.

Table 6-2 Light Duty Cooking Appliances Ranks and Statistics Test

Ranks		N	Mean Rank	Sum of Ranks
Light-duty Cooking appliances (Summer) - Light-duty Cooking appliances (Winter)	Negative Ranks	181[a]	116.79	21139.00
	Positive Ranks	43[b]	94.44	4061.00
	Ties	157[c]		
	Total	381		
Test Statistics[a]	Light-duty cooking appliances (Summer) – (Winter)			
Z	-8.856[b]			
Asymp. Sig. (2-tailed)	.000			

By examining the final test statistics table, we can discover whether these changes, due to timing during winter and summer, led overall to a statistically significant difference in light duty cooking appliances scores. Asymp. Sig. (2-tailed) value, in this case, is 0.00. This is the *p*-value for the test. We report the Wilcoxon signed-ranks test using the *Z* statistic. A Wilcoxon signed-rank test showed that there is a statistically significant change in light-duty cooking appliances score during summer and winter ($p = 0.00$). Indeed, median light duty cooking appliances score or rating was 6.0 during winter and 5.0 during summer (Section 4.10, Table 4-10). Thus, there is higher light-duty cooking appliances score or rating during winter than during summer.

6.2.2 Heavy-Duty Cooking Appliances

The ranks table provides some interesting data on the comparison of participants' heavy-duty cooking appliances (HDCA) score during summer and winter. It can be seen from the table's legend (Table 6-3) that 113 participants had higher heavy-duty cooking appliances score during winter than during summer. However, 35 participants had higher Heavy-duty cooking appliances score during summer than during winter and 233 participants saw no change in their heavy-duty cooking appliances score during summer and winter. A Wilcoxon signed-rank test showed that there is a statistically significant change in heavy-duty cooking appliances score during summer and winter (p = 0.00). Indeed, median heavy-duty cooking appliances score or rating was 3.0 during winter and 2.0 during summer. Thus, there is higher heavy-duty cooking appliances score or rating during winter than during summer.

Table 6-3 Heavy-duty cooking appliances rank and statistics test

Ranks		N	Mean Rank	Sum of Ranks
Heavy duty-cooking appliances (Summer) – Heavy-duty cooking appliances (Winter)	Negative Ranks	113[a]	79.29	8959.50
	Positive Ranks	35[b]	59.04	2066.50
	Ties	233[c]		
	Total	381		
Test Statistics[a]	Heavy-duty cooking appliances (Summer) – (Winter)			
Z	-6.672[b]			
Asymp. Sig. (2-tailed)	.000			

6.2.3 Entertainment and Office

The ranks table provides some interesting data on the comparison of participants' Entertainment Score during summer and winter. It can be seen from the table's legend (Table 6-4) that 101 participants had a higher entertainment score during winter than during summer. However, 62 participants had a higher entertainment score during summer than during winter and 218 participants showed no change in their entertainment score during summer and winter. A Wilcoxon signed-rank test showed that there is a statistically significant change in entertainment score during summer and winter (p = 0.00).

Table 6-4 Entertainment and office rank and statistics test

Ranks		N	Mean Rank	Sum of Ranks
Entertainment and office (Summer) – Entertainment and office (Winter)	Negative Ranks	101[a]	95.34	9629.00
	Positive Ranks	62[b]	60.27	3737.00
	Ties	218[c]		
	Total	381		
Test Statistics[a]	Entertainment and office (Summer) - (Winter)			
Z	-4.920[b]			
Asymp. Sig. (2-tailed)	.000			

6.2.4 Wet Appliances

The Ranks table provides some interesting data on the comparison of participants' wet appliances score during summer and winter. It can be seen from the table's legend that 234 participants had higher wet appliances score during winter than during summer. However, 24 participants had higher wet appliances score during summer than during winter, and 114 participants saw no change in their wet appliances score during summer and winter. A Wilcoxon signed-rank test showed that there is a statistically significant change in wet appliances Score during summer and winter (p = 0.00). The median wet appliances Score or rating was 7.0 during winter and 4.0 during summer. Thus, there is higher wet appliances Score or rating during winter than during summer.

Table 6-5 Wet Appliances Rank Score and Statistics Test

Ranks		N	Mean Rank	Sum of Ranks
Wet appliances (Summer) - Wet appliances (Winter)	Negative Ranks	243[a]	142.70	34675.00
	Positive Ranks	24[b]	45.96	1103.00
	Ties	114[c]		
	Total	381		
Test Statisticsa	Wet appliances (Summer) - Wet appliances (Winter)			
Z	-13.359[b]			
Asymp. Sig. (2-tailed)	.000			

6.2.5 Other Appliances

The Ranks table provides some interesting data on the comparison of participants' other appliances score during summer and winter. It can be seen from the table's legend that 151 participants had higher other appliances score during winter than during summer. However, 96 participants had higher other appliances score during summer than during winter and 134 participants saw no change in their other appliances score during summer and winter. A Wilcoxon signed-rank test showed that there is a statistically significant change in other appliances score during summer and winter (p = 0.029). The median other appliances score or rating for both winter and summer was 0.8. Thus, there is higher other appliances score or rating during winter than during summer.

Table 6-6 Other Appliances Rank Score

Ranks		N	Mean Rank	Sum of Ranks
Other appliances (Summer) - Other appliances (Winter)	Negative Ranks	151[a]	117.59	17756.50
	Positive Ranks	96[b]	134.08	12871.50
	Ties	134[c]		
	Total	381		

6.3 Mann-Whitney and Kruskal-Wallis Test

The nonparametric tests of difference are used to test the significance of the difference between two or more variables. The nonparametric tests do not make assumptions about the parameters of a distribution, nor do they assume that any particular distribution is being used. Mann-Whitney and Wilcoxon statistics tests the null hypothesis that two independent samples come from the same population. Essentially, the researcher is exploring the mathematical belief differences between two different groups (summer & winter). Thus, the Mann-Whitney test is used for comparing an independent variable with two categories. It is an alternative to an Independent sample t-test when the data are not normally distributed. Whereas an Independent sample t-test is a test of population means, the Mann-Whitney test is a test of population medians. Whereas, the Kruskal-Wallis test is the nonparametric test equivalent to the one-way ANOVA, and it is used to compare three or more sets of scores that come from different groups.

6.3.1 Type of Household

Do the responses from the grouped appliances differ significantly among the categories of type of the household regarding the time of use household appliances?

The Kruskal Wallis Test results indicate that there is statistically significant difference in the heavy-duty cooking appliances (summer) scores among the three types or categories of the household (Chi-square = 7.33, p-value = 0.026). However, the Kruskal Wallis Test results also indicate that there is no statistically significant difference in the other groups of the appliances scores among the three types or categories of the household (p-value > 0.05).

6.3.2 Current Employment Status

By looking at the Kruskal-Wallis Test, the results indicate that there is no statistically significant difference in the group of the appliances scores among the six categories of the Current employment status (p-value > 0.05).

6.3.3 Age Group of the Household's Resident

The Kruskal-Wallis Test results indicate that there is a statistically significant difference in the Light-duty cooking appliances scores among the six age groups of the household residents (chi-square = 21.81, p-value = 0.001) and (Chi-square = 29.92, p-value = 0.00) for the winter and summer respectively. However, the results indicate there is no statistically significant difference among the group scores.

6.3.4 Appliances Efficiency Rate

The Kruskal-Wallis Test results indicate that there is no statistically significant difference in the group of the appliances scores among the four categories of appliances efficiency rate (p-value > 0.05) as shown in Table 6-7.

Table 6-7 Kruskal-Wallis Test

Test Statistics	Chi-Square		df		Asymp. Sig.	
	winter	summer	winter	summer	winter	summer
Type of the household						
Light-duty cooking appliances	0.05	0.33	2	2	0.97	0.84
Heavy-duty cooking appliances	3.29	7.33	2	2	0.19	0.02
Entertainment and office	1.17	2.03	2	2	0.55	0.36
Wet appliances	3.25	.49	2	2	0.19	0.78
Other appliances	.18	.004	2	2	0.91	0.99
employment status						
Light-duty cooking appliances	0.86	2.77	5	5	0.97	0.73
Heavy-duty cooking appliances	5.09	4.06	5	5	0.40	0.54
Entertainment and office	3.73	1.81	5	5	0.58	0.87
Wet appliances	0.96	4.14	5	5	0.96	0.52
Other appliances	1.47	2.91	5	5	0.91	0.71
age categories						

Light-duty cooking appliances	21.81	29.92	5	5	0.001	0.000
Heavy-duty cooking appliances	2.66	3.66	5	5	0.751	0.598
Entertainment and office	6.92	6.78	5	5	0.226	0.237
Wet appliances	11.10	3.64	5	5	0.049	0.602
Other appliances	2.05	1.67	5	5	0.841	0.892
appliances efficiency rate						
Light-duty cooking appliances	0.23	2.93	3	3	0.97	0.402
Heavy-duty cooking appliances	2.62	3.82	3	3	0.45	0.28
Entertainment and office	2.73	1.53	3	3	0.43	0.67
Wet appliances	3.62	1.63	3	3	0.30	0.65
Other appliances	0.90	1.60	3	3	0.82	0.65

6.4 Correlation

Spearman Correlation test was used to measure how strongly the demographic factors are related to the household's appliances. A Spearman Correlation is used because it is assumed that demographic factors are not normally distributed but assumed to be ordinal/nominal. The values of the variables are converted in ranks and then correlated by the SPSS. Spearman's 'non-parametric correlation' between demographic factors and household appliances were tested at 5 % level of significance. The main hypothesis is: can the demographic factors of the households considered as vital source of motivation for time of use of the household's appliances?

6.4.1 Correlation with Number of Bedrooms in the Household

Can the number of bedrooms in a house be considered as a vital source of motivation for the time of use of appliances?

The results suggest a very weak relationship between numbers of bedrooms in a household. However, few significant relationships have been observed between number of the bedrooms in a house and light-duty cooking appliances, other appliances usage in the winter and office equipment according to the results indicated in the correlation table.

6.4.2 Correlation with Type of the Household

Appliances times of use are motivated by type of the household. Can type of the household be considered as a vital source of motivation for time of use of appliances?

The results suggest a very weak relationship between types of the household.

6.4.3 Correlation with Number of People Live in the Household

The results suggest a very weak relationship between the number of people who live in a house and the time of use of appliances. However, few significant relationships have been observed between the number of people living in a house and light-duty cooking appliances, as well as entertainment and office appliances as shown in Table 6-8.

6.4.4 Correlation with Current Employment Status

Spearman's is 'non-parametric correlation' between current employment status and household's appliances usage time. The results suggest a very weak relationship between current employment status and household's appliances as no significant relation have been observed as shown in Table 6-8.

6.4.5 Correlation with Age category of the Household's Inhabitant

Spearman's is 'non-parametric correlation' between the age category and the household's appliances. The results suggest a very weak relationship between age group and household's appliances. However, few significant relationships have been observed between age group and light duty cooking appliances, and office appliances as shown in Table 6-8.

6.4.6 Correlation with Appliances' Efficiency Rate

Spearman's is 'non-parametric correlation' between appliances efficiency rate and household's appliances. The results suggest a very weak relationship between appliances' efficiency rate and households' appliances, as no significant relationships have been observed as shown in Table 6-8.

Table 6-8 Correlation of The Demographic Factors and The Household's Appliances

Appliances	r value		p value		statistically	
	winter	summer	winter	summer	winter	summer
The Number of Bed Rooms						
Light-duty Cooking appliances	0.10	0.13	0.04	0.00	sig.	sig.
Heavy-duty cooking appliances	0.05	-0.02	0.31	0.57	Not sig.	Not sig.
Entertainment and office	0.00	-0.03	0.00	0.00	sig.	sig.
Wet appliances	-0.00	-0.05	0.91	0.33	Not sig.	Not sig.
Other appliances	-0.10	-0.04	0.03	0.38	sig.	Not sig.
The Household's Type						
Light-duty Cooking appliances	0. 002	-0.03	0.968	0.56	Not sig.	Not sig.

Heavy-duty cooking appliances	-0. 02	-0.06	0.760	0.21	Not sig.	Not sig.
Entertainment and office	-0. 05	-0.04	0.295	0.36	Not sig.	Not sig.
Wet appliances	-0. 03	-0.00	0.596	0.91	Not sig.	Not sig.
Other appliances	0. 01	0.001	0.893	0.99	Not sig.	Not sig.
The Number of People						
Light duty Cooking appliances	0. 15	0.19	0.002	0.001	sig.	sig.
Heavy duty cooking appliances	0. 000	0.02	0.99	0.69	Not sig.	Not sig.
Entertainment and office	-0. 01	0.03	0.000	0.000	sig.	sig.
Wet appliances	-0. 03	-0.01	0.49	0.79	Not sig.	Not sig.
Other appliances	0. 03	0.01	0.52	0.76	Not sig.	Not sig.
Employment Status						
Light-duty Cooking appliances	0. 04	0.04	0.463	0.42	Not sig.	Not sig.
Heavy-duty cooking appliances	-0. 03	-0.04	0.512	0.40	Not sig.	Not sig.
Entertainment and office	0. 05	0.02	0.316	0.64	Not sig.	Not sig.
Wet appliances	-0. 02	-0.07	0.640	0.12	Not sig.	Not sig.
Other appliances	-0. 05	-0.08	0.342	0.11	Not sig.	Not sig.
Age						
Light-duty Cooking appliances	0. 13	0.15	0.007	0.003	sig.	sig.
Heavy-duty cooking appliances	0. 004	0.006	0.934	0.900	Not sig.	Not sig.
Entertainment and office	-0. 02	0.05	0.000	0.000	sig.	sig.
Wet appliances	-0. 06	-0.03	0.20	0.60	Not sig.	Not sig.
Other appliances	0. 01	-0.003	0.81	0.95	Not sig.	Not sig.
Efficiency Rate						
Light-duty Cooking appliances	0. 01	0.04	0.9	0.42	Not sig.	Not sig.
Heavy-duty cooking appliances	-0. 06	-0.04	0.21	0.37	Not sig.	Not sig.
Entertainment and office	0. 02	0.02	0.63	0.60	Not sig.	Not sig.
Wet appliances	0. 01	-0.01	0.90	0.85	Not sig.	Not sig.
Other appliances	-0. 03	-0.04	0.60	0.41	Not sig.	Not sig.

6.5 Multiple Regression Analysis

Multiple linear regression analysis used to determine if there will be a relationship between each of the appliances and demographic factors. It is referred to as multiple linear regression model because there are multiple predictors' variables. Multiple regression analysis was used to determine if there is an effect of demographic factors on the appliances groups in terms of time of use. This section on multiple linear regression by using ordinary least squares (OLS) linear regression method will focus on the general interpretation of multiple regressions which involves:

1- Whether or not the regression model is meaningful, and
2- Which variables contribute meaningfully to the model as stated above?

6.5.1 Assumptions of Multiple Linear Regression Analysis

In multiple regression analyses we assess or measure the impact of the demographic factors on the appliances usage time. The appliances usage should be measured on a continuous scale and have two or more demographic factors. There is a need for a linear relationship between (a) the appliances and each of the demographic factors, and (b) the appliances and the demographic factors collectively [162]. Also, the data needs to show homoscedasticity and must not show multicollinearity. In multiple regression, there should be no significant outliers, high leverage points or highly influential points. Finally, in multiple regression, the residuals (errors) are approximately normally distributed. In this regard, the several assumptions of multiple regression are “robust” to a violation (e.g., normal distribution of errors), and others are fulfilled in the proper design of a study (e.g., independence of observations) [163].

The results of the test for normality showed that all the variables failed the test of normality, but there are four principal assumptions which justify the use of linear regression models for purposes of inference or prediction. These four principal assumptions of linearity, statistical independence, homoscedasticity and normality must be violated together to satisfy the efficiency of a regression model. Violations of normality assumption only create problems for determining whether regression model coefficients are significantly different from zero and for calculating confidence intervals for forecasts. We can violet the normality assumption because independence and homoscedasticity assumptions are more important assumptions than normality.

Osborne & Waters (2002) suggests that the assumptions of linearity, reliability of measurement, homoscedasticity, and normality are not robust to a violation and can be dealt with if violated. Importantly, we can determine the linearity assumption through the regression analysis which assumes that variables have to be normally distributed. Moreover, the collinearity statistics tell us the extent to which there is multicollinearity between our variables. If the value for the tolerance is less than 10 and the value of the VIF is close to 1 for each explanatory variable then there is probably no cause for concern. The use of the variance inflation factors (VIF) is the most reliable way to examine multicollinearity [163].

6.5.2 Regression Analysis Techniques

To get an accurate data analysis, the running of data analysis generated four tables; Variables Entered/Removed table, which as the name implies, reports which variables were entered into the model then, the model summary table. This table provides the multiple correlation (R, the multiple correlation squared (R^2), the adjusted multiple correlation squared (adj.R^2), and the Standard Error of the Estimate.

- The multiple correlations are the combined correlation of each predictor with the outcome.
- The multiple correlation squared represents the amount of variance in the outcome which is accounted for by the predictors.
- Additionally, *(Multicollinearity is a problem in multiple regressions that develops when one or more of the demographic factors are highly correlated with one or more of the other demographic factors)* [164].

If one demographic factor is a perfect linear combination of the other demographic factors, then the matrix of intercorrelations among the demographic factors is singular and there exists no unique solution for the regression coefficients.

6.5.3 Regression Analysis of Light-Duty Cooking Appliances

The model summary shown in Table 6-17 provides the multiple correlation (R = 0.179), the multiple correlation squared (R^2 = 0.032), the adjusted multiple correlation squared (adj.R^2 = 0.014), and the Standard Error of the Estimate; here, 1.4 % of the variance in time use of LDCAW is accounted for by predictors. Following this, there is the ANOVA summary Table 6-18, which indicates that our model-'s R^2 is not significantly different from zero, $F(7, 373) = 1.773$, $p > 0.05$. Based on the above discussion, the regression model is not significant and there is no linear relationship between the variables in the regression model.

Similarly for the summer, the model summary provides the multiple correlation (R = 0.194), the multiple correlation squared (R^2 = 0.038), the adjusted multiple correlation squared (adj.R^2 = 0.02), and the Standard Error of the Estimate; here, 3.8 % of the variance in LDCAS is accounted for by the predictors. This shows that all the predictors can only explain 3.8 % variation in the light duty cooking appliances (summer). In addition, the ANOVA summary Table 6-17, indicates that the model's R^2 is significantly different from zero, $F(7, 373) = 2.089$, and $p < 0.05$.

Therefore, the regression model is significant and there is a linear relationship between the variables in the regression model which means has met another assumption of multiple regression analysis. Furthermore, Beta expresses the contribution of each independent variable in standardized terms while the B coefficients are un-standardized coefficient that express the importance or contribution of each independent variable.

The null hypothesis can clearly be rejected and the alternative hypothesis can be accepted. Thus, a formulation of a regression equation is used here to analyse whether light-duty cooking appliances (summer) are influenced by the demographic variables, which can be written as:

LDCAS = α + β1 * RG + β2* NB + β3*TH + β4* NP + β5* CES + β6* Age + β7* AER

LDCAS = 2.655 + 0.279RG + 0.051NB -0.108TH + 0.829NP + 0.115CES -0.218Age + .088AER

Table 6-9 Light-duty cooking Appliance's Multiple Regression ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	104.07	7	14.87	1.773	.091[b]
	Residual	3127.04	373	8.38		
	Total	3231.11	380			
a. Dependent Variable: Light-duty Cooking appliances winter						
b. Predictors: (Constant), AER, NPTH, CES, RG, NB, Age						
1	Regression	119.45	7	17.06	2.09	.044[b]
	Residual	3047.54	373	8.17		
	Total	3166.99	380			
a. Dependent Variable: Light-duty Cooking appliances summer						
b. Predictors: (Constant), AER, NPTH, CES, RG, NB, Age						

Table 6-10 Coefficients for Light-duty Cooking appliances (summer)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	2.65	1.02		2.61	.01	.65	4.65					
	RG	.279	.3	.05	.93	.35	-.30	.86	.03	.04	.04	.97	1.03
	NB	.051	.16	.02	.30	.75	-.27	.37	.08	.01	.01	.80	1.24
	TH	-.11	.21	-.023	-.51	.60	-.51	.30	-.00	-.02	-.02	.97	1.03
	NP	.83	.40	.3	2.04	.04	.03	1.62	.16	.10	.10	.12	8.17
	CES	.11	.09	.06	1.26	.20	-.06	.29	.05	.06	.06	.97	1.02
	age	-.22	.23	-.13	-.94	.34	-.67	.23	.14	-.04	-.04	.12	7.97
	AER	.09	.18	.02	.48	.62	-.26	.44	.02	.02	.02	.97	1.02
a. Dependent Variable: Light duty Cooking appliances (Summer)													

The scatter plot in Figure 6-1, reflected the relationship between all gender and light duty cooking appliances (summer). The slope (0.18) of the linear approximation of their values shows that it is a positive relationship. Its shows that higher scores on the light duty cooking appliances (summer) axis are associated with higher scores on the gender axis and lower scores on the light duty cooking appliances (summer) axis are associated lower scores on the gender axis.

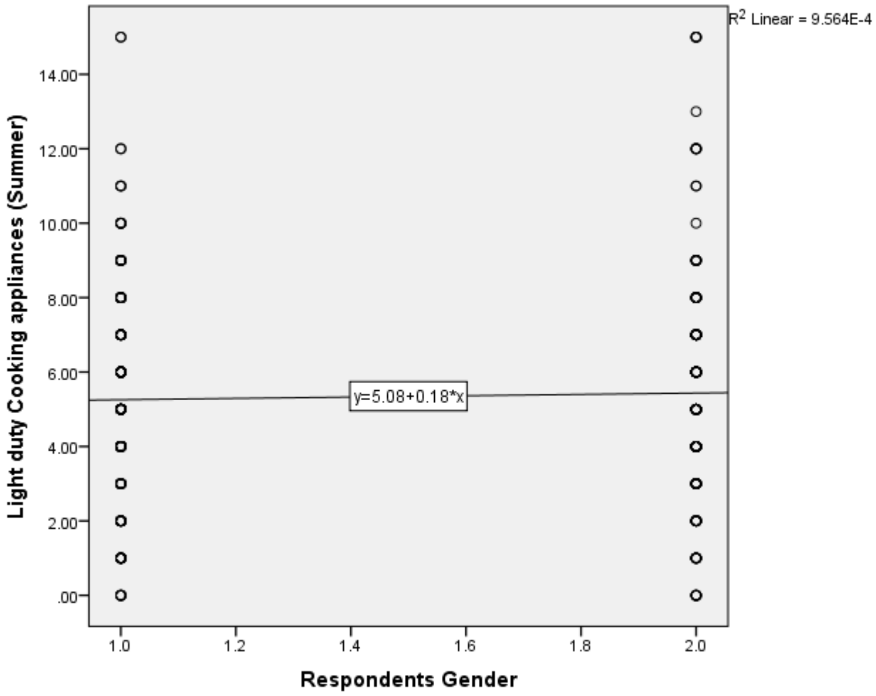

Figure 6-1 Scatter plot of the respondent gender and LDCAS

The scatter plot in Figure 6-2, reflected the relationship between number of bedrooms in a house and light duty cooking appliances (summer). The slope (0.25) of the linear approximation of their values shows that it is a positive relationship. Its shows that higher scores on the light duty cooking appliances (summer) axis are associated with higher scores on the number of bedrooms in a house axis. Lower scores on the light duty cooking appliances (summer) axis are associated lower scores on the number of bedrooms in a house axis. Conversely, the scatter plot as shwon in Figure 6-3, reflected the relationship between type of the household and light duty cooking appliances (summer). The slope (-0.02) of the linear approximation of their values shows that it is a negative relationship. Its shows that higher scores on the Light duty cooking appliances (summer) axis are associated with lower scores on the type of the household axis. Lower scores on the light duty cooking appliances (summer) axis are associated higher scores on the type of the household axis.

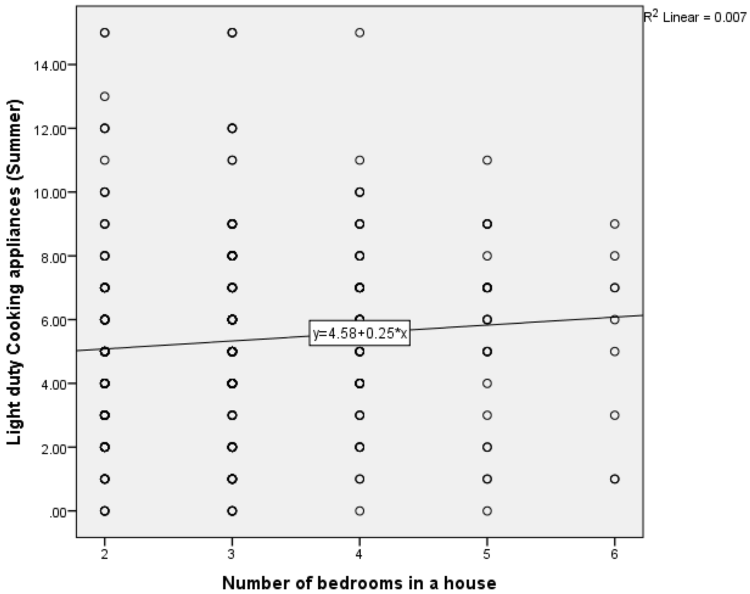

Figure 6-2 Scatter plot of number of bedrooms and LDCAS

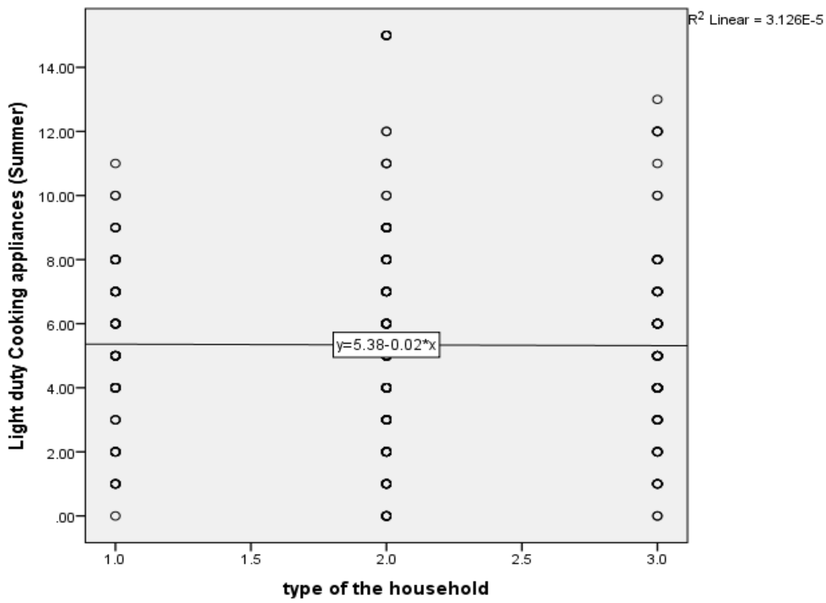

Figure 6-3 Scatter plot of type of the household and LDCAS

The scatter plot shown in Figure 6-4, reflected the relationship between number of people live in a house and light duty cooking appliances (summer). The slope (0.47) of the linear approximation of their values shows that it is a positive relationship. Its shows that higher scores on the light duty cooking appliances (summer) axis are associated with higher scores on the number of people live in a house axis. Lower scores on the light duty cooking appliances (summer) axis are associated lower scores on the number of people live in a house axis.

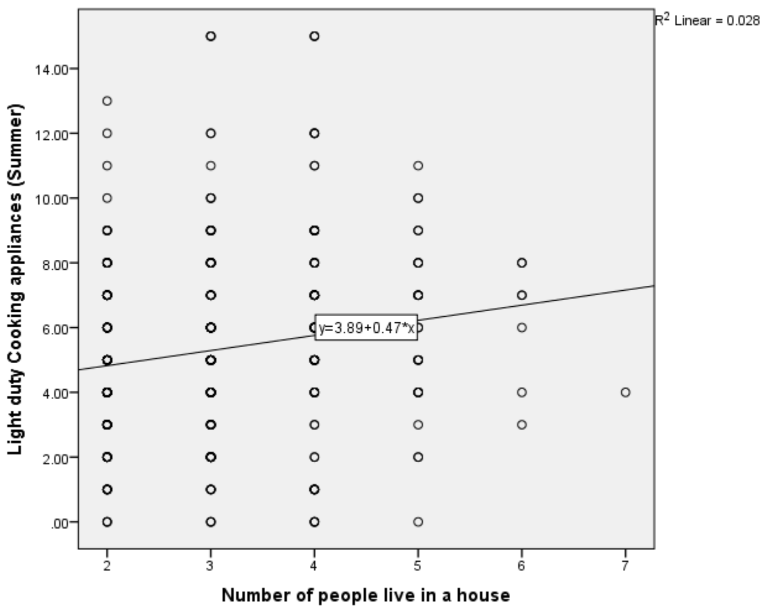

Figure 6-4 Scatter plot of number of the people and LDCAS

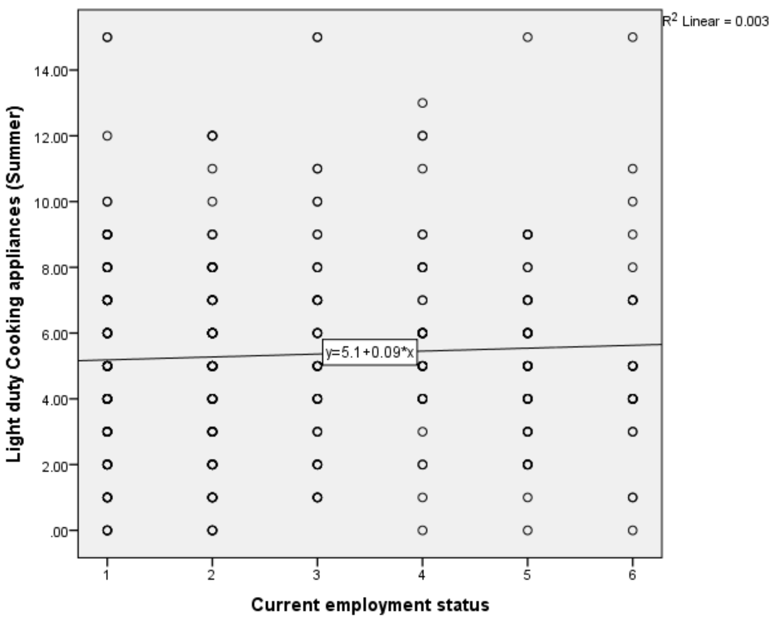

Figure 6-5 Scatter plot of employment status and LDCAS

Figure 6-5, shows the scatter plot reflected the relationship between current employment status and light duty cooking appliances (summer). The slope (0.09) of the linear approximation of their values shows that it is a positive relationship. Its shows that higher scores on the light duty cooking appliances (summer) axis are associated with higher scores on the current employment status axis. Lower scores on the light duty cooking appliances (summer) axis are associated lower scores on the current employment status axis. In addition, Figure 6-6, shows the scatter plot reflected the relationship between age group of the household resident and light duty cooking appliances (summer). The slope (0.23) of the linear approximation of their values shows that it is a positive relationship. Its shows that higher scores on the light duty cooking appliances (summer) axis are associated with higher scores on the age group of the household resident axis. Lower scores on the light duty cooking appliances (summer) axis are associated lower scores on the age group of the household resident axis.

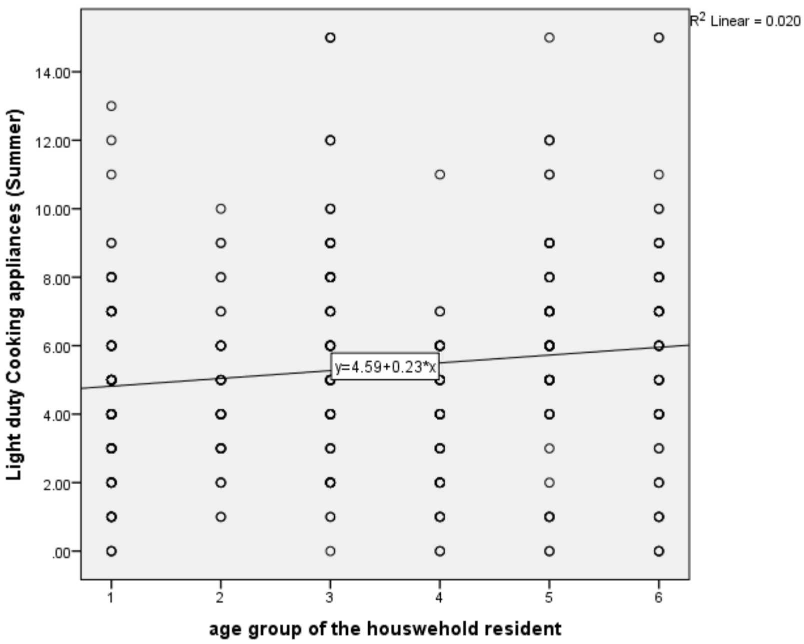

Figure 6-6 Scatter plot of age group and LDCAS

The scatter plot in Figure 6-7 reflected the relationship between appliances efficiency rate and light duty cooking appliances (summer). The slope (0.09) of the linear approximation of their values shows that it is a positive relationship. Its shows that higher scores on the light duty cooking appliances (summer) axis are associated with higher scores on the efficiency rate axis. Lower scores on the light duty cooking appliances (summer) axis are associated lower scores on the efficiency rate axis.

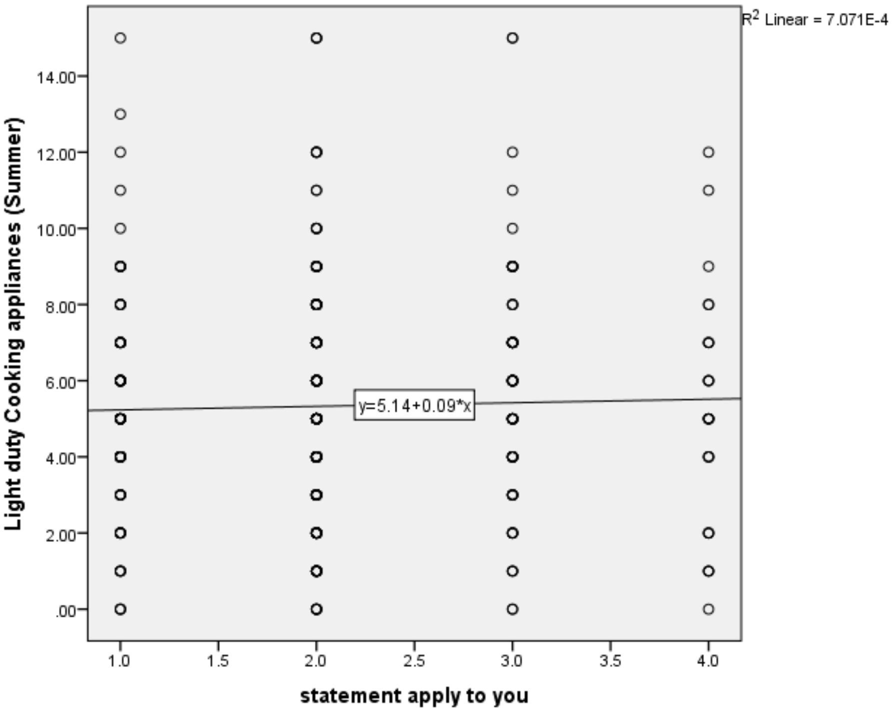

Figure 6-7 Scatter plot of appliances efficiency and LDCAS

6.5.4 Multiple Regression Analysis of Heavy-Duty Cooking Appliances

Data appendix 6-22, provides the multiple correlation (R = 0.101), the multiple and adjusted multiple correlation squared ($R^2 = 0.00$) ($adjR^2 = -0.01$), and the Standard Error of the Estimate; here, 1.0 % of the variance in time of use the heavy-duty cooking appliances (winter) is accounted for by predictors. Then, the ANOVA summary indicates that the model's R^2 is not significantly different from zero, $F(7, 373) = 0.55$, $p > 0.05$. Therefore, the regression model is not significant and there is no linear relationship between the variables in the regression model. However, the use of the variance inflation factors (VIF) is the most reliable way to examine multicollinearity. As a rule of thumb, if any of the VIF is greater than or equal to 10 there is a multicollinearity problem [165]. Hence, variance inflation factors (VIF) has shown that there is no problem of multicollinearity as it is less than 10 for the predictors as indicates in table 6-10.

By examining summer model summary, which indicates that our model's R^2 is not significantly different from zero, $F(7, 373) = 0.55$, $p > 0.05$. Therefore, there is no linear relationship between the variables in the regression model.

6.5.5 Multiple Regression analysis of Entertainment and Office

The model summary table provides the multiple correlation (R = 0.32), the multiple correlation squared (R^2 = 0.10), the adjusted multiple correlation squared (adj.R^2 = 0.08), and the Standard Error of the Estimate; here, 10.5 % of the variance in entertainment and office winter usage is accounted for by predictors. Furthermore, the ANOVA summary table indicates that the model's R^2 is significantly different from zero, $F(7, 373) = 6.2$, $p > 0.05$. Therefore, the regression model is not significant and there is a linear relationship between the variables in the regression model as shown in Table 6-11.

Table 6-11 Entertainment and Office Appliance’s Multiple Regression ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	95.32	7	13.61	1.44	.18b
	Residual	3510.40	373	9.41		
	Total	3605.73	380			
a. Dependent Variable: Entertainment and office winter						
b. Predictors: (Constant), AER, NP, TH, CES, RG, NB, AGE						
1	Regression	415.78	7	59.39	4.40	.000b
	Residual	5033.47	373	13.49		
	Total	5449.26	380			
a. Dependent Variable: Entertainment and office summer						
b. Predictors: (Constant), AER, NP, TH, CES, RG, NB, AGE[b]						

Summer usage, model summary provides the multiple correlation (R = 0.3), the multiple correlation squared (R^2 = 0.08), the adjusted multiple correlation squared (adj.R^2 = 0.06), and the Standard Error of the Estimate; here, 7.6 % of the variance in entertainment and office (summer) is accounted for by predictors. Moreover, the ANOVA summary Table 6-11 indicates that the model's R^2 is significantly different from zero, $F(7, 373) = 4.40$, $p < 0.05$. Therefore, the regression model is significant and there is a linear relationship between the variables in the regression model. In addition, Beta expresses the relative importance or contribution of each independent variable in standardized terms while the B coefficients are unstandardized coefficient that expresses the importance or contribution of each independent variable as shown in Table 6-12 [165].

The results revealed that the number of bedrooms in a house and number of people who live in a house are significant predictors. Additionally, the number of bedrooms in a house has a higher impact than number of people live in a house (beta =3 .01 and beta = 1.96). According to the coefficients table we can reject the null hypothesis and accept the alternative hypothesis that there is relationship between the predictors and the dependent variable in the model. A formulation of a regression equation can be written as:

Entertainment and office summer = α + β1 * RG + β2* NB + β3* TH + β4* NP + β5*CES + β6* age + β7* AER

Entertainment and office summer = 2.35 + 0.15*RG + 0.64*NB - 0.08*TH + 1.02*NP - 0.07*CES -0.29 Age -0.06AER

Table 6-12 Entertainment and office summer's Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	2.35	1.31		1.8	.07					
	RG	.15	.38	.02	.39	.69	.01	.02	.019	.97	1.03
	NB	.64	.21	.16	3.01	.00	.23	.15	.150	.80	1.24
	TH	-.08	.26	-.01	-.29	.77	.00	-.01	-.015	.97	1.03
	NP	1.02	.52	.27	1.96	.05	.22	.10	.098	.12	8.17
	CES	-.06	.12	-.03	-.56	.57	-.05	-.03	-.028	.97	1.02
	age	-.29	.29	-.14	-.99	.32	.19	-.05	-.049	.12	7.97
	AER	-.06	.23	-.01	-.26	.79	-.02	-.01	-.013	.97	1.03

The scatter plot in Figure 6-8, reflected the relationship between all gender and entertainment (summer). the slope (-0.23) of the linear approximation of their values shows that it is a negative relationship. Its shows that higher scores on the entertainment (summer) axis are associated with lower scores on the gender axis. Lower scores on the entertainment (summer) axis are associated higher scores on the gender axis.

The scatter plot reflected the relationship between number of bedrooms in a house and entertainment (summer) is shown in Figure 6-9. The slope (0.09) of the linear approximation of their values shows that it is a positive relationship. Its shows that higher scores on the entertainment (summer) axis are associated with higher scores on the number of bedrooms in a house axis. Lower scores on the entertainment (summer) axis are associated lower scores on the number of bedrooms in a house axis.

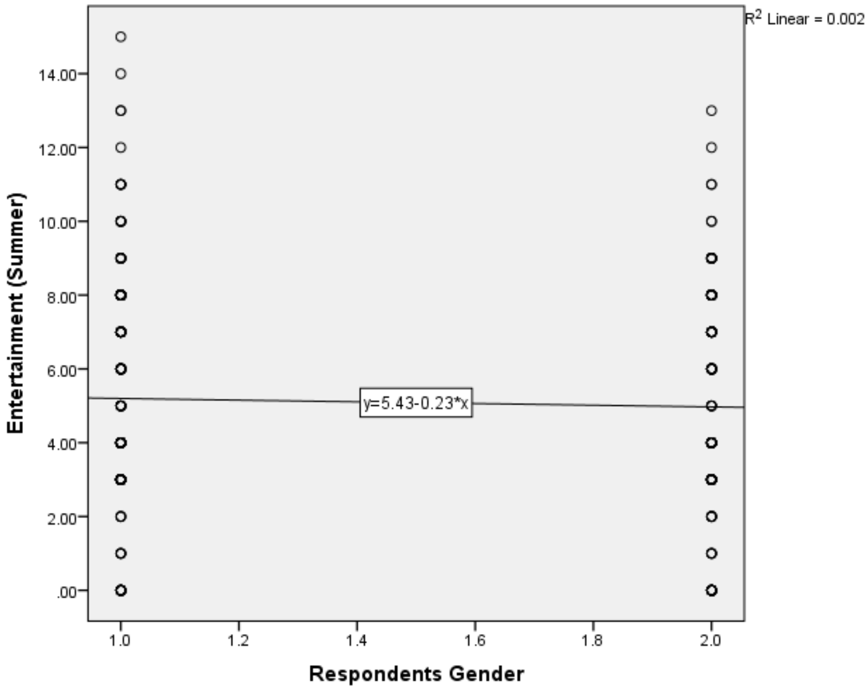

Figure 6-8 scatter plot of gender and entertainment

The scatter plot shown in Figure 6-10, reflected the relationship between type of the household and entertainment (summer). The slope (-0.2) of the linear approximation of their values shows that it is a negative relationship. Its shows that higher scores on the entertainment (summer) axis are associated with lower scores on the type of the household axis. Lower scores on the entertainment (summer) axis are associated higher scores on the type of the household axis.

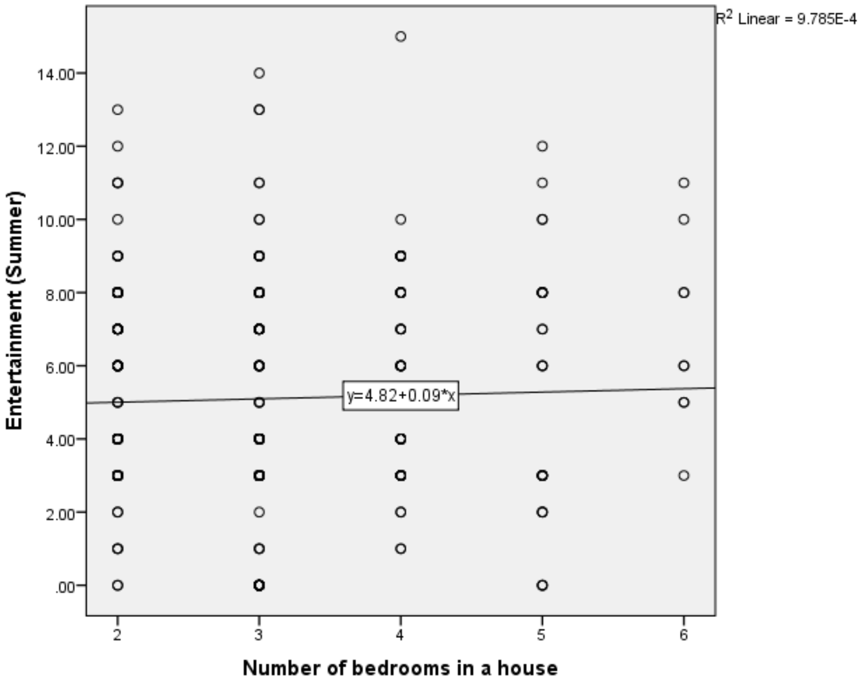

Figure 6-9 scatter plot of number of bedrooms and entertainment

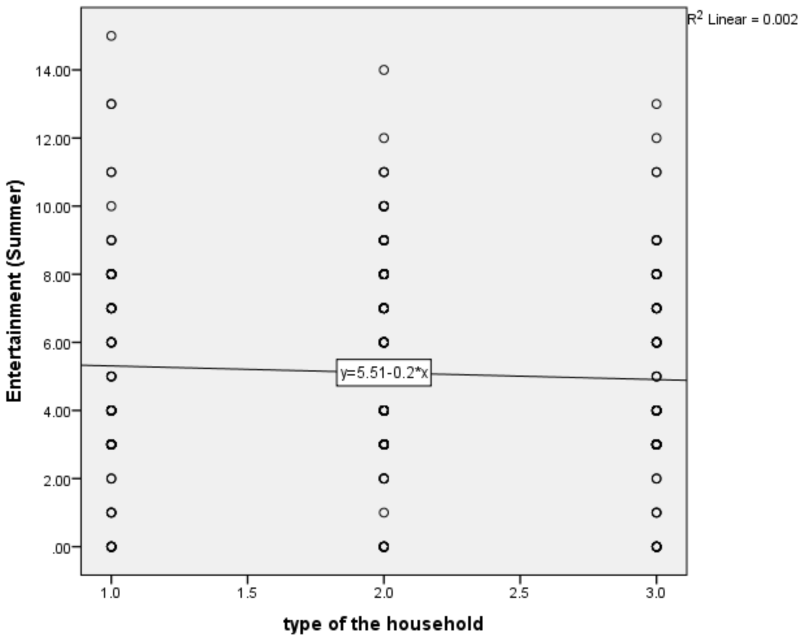

Figure 6-10 scatter plot of type of the household and entertainment

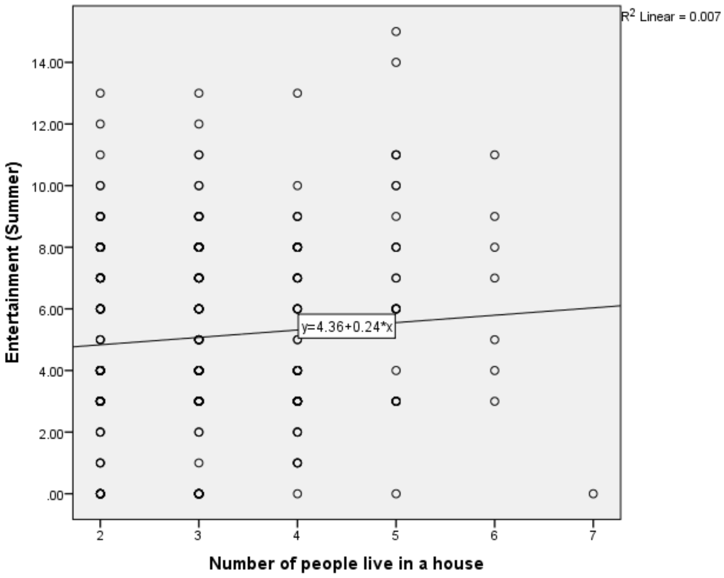

Figure 6-11 scatter plot of number of people and entertainment

The scatter plot reflected the relationship between number of people live in a house and entertainment (summer). The slope (0.24) of the linear approximation of their values shows that it is a positive relationship as shown in Table 6-11. Its shows that higher scores on the entertainment (summer) axis are associated with higher scores on the number of people live in a house axis. Lower scores on the entertainment (summer) axis are associated lower scores on the number of people live in a house axis. Moreover, the scatter plot reflected the relationship between current employment status and entertainment (summer) is presented in Figure 6-12. The slope (0.03) of the linear approximation of their values shows that it is a positive relationship. Its shows that higher scores on the entertainment (summer) axis are associated with higher scores on the current employment status axis. Lower scores on the entertainment (summer) axis are associated lower scores on the current employment status axis.

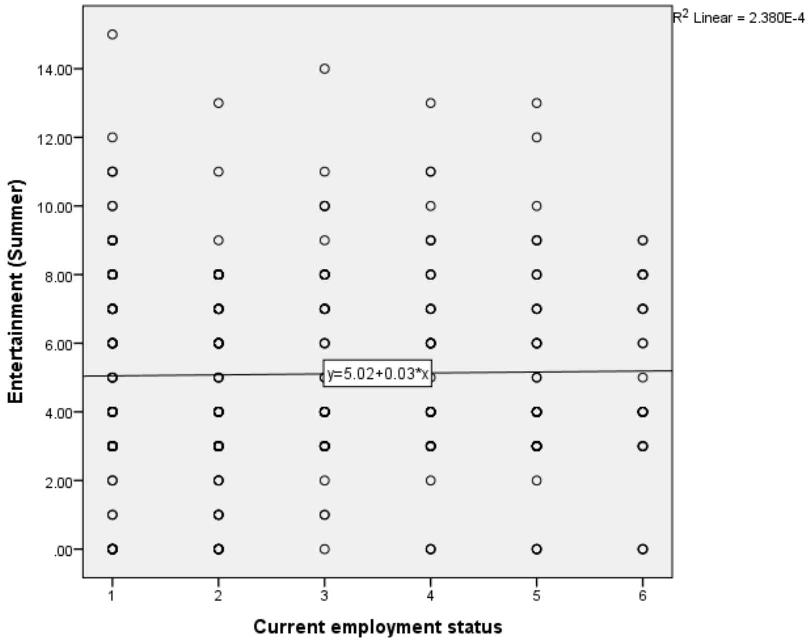

Figure 6-12 scatter plot of employment status and entertainment

The scatter plot in Figure 6-13, reflected the relationship between age group of the household resident and entertainment (summer). The slope (0.14) of the linear approximation of their values shows that it is a positive relationship. Its shows that higher scores on the entertainment (summer) axis are associated with higher scores on the age group of the household resident axis. Lower scores on the entertainment (summer) axis are associated lower scores on the age group of the household resident axis. In addition, Figure 6-14 the scatter plot reflected the relationship between appliances efficiency and entertainment (summer). The slope (0.15) of the linear approximation of their values shows that it is a positive relationship. Its shows that higher scores on the entertainment (summer) axis are associated with higher scores on the appliances efficiency axis. Lower scores on the entertainment (summer) axis are associated lower scores on the appliances efficiency axis.

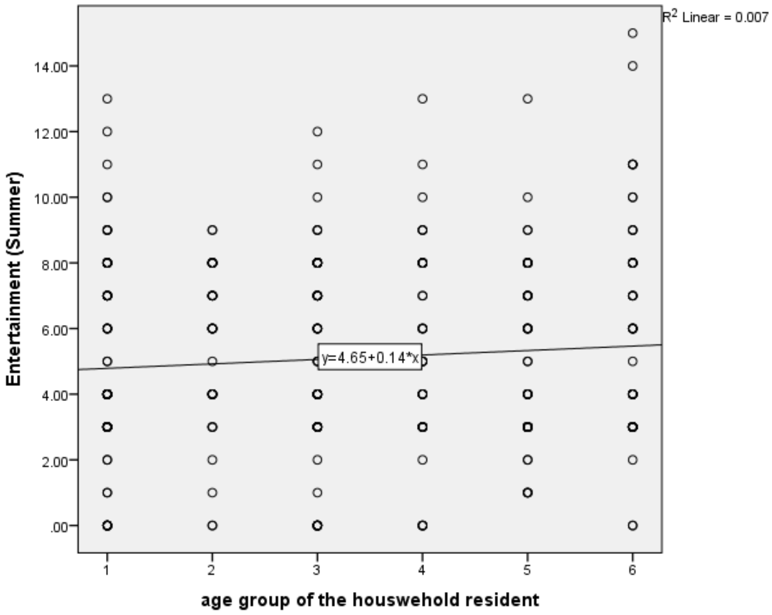

Figure 6-13 scatter plot of age group and entertainment

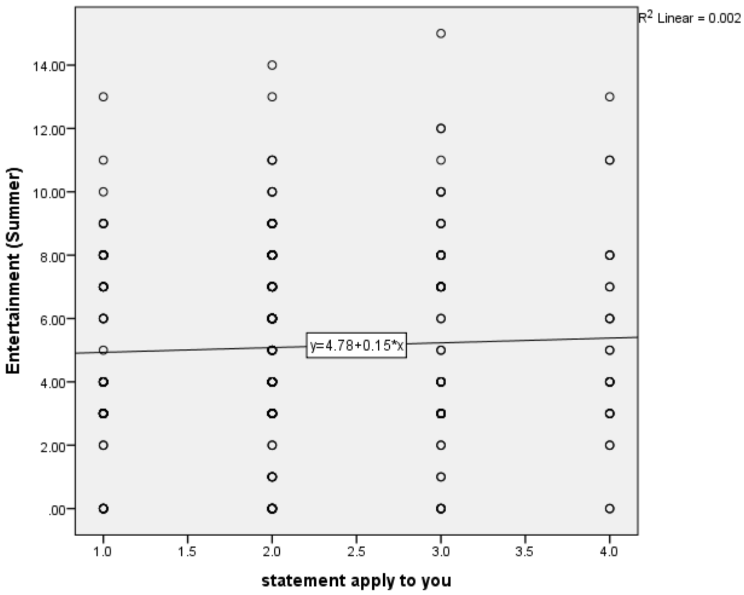

Figure 6-14 scatter plot of appliances efficiency and entertainment

6.5.6 Multiple Regression analysis of Wet appliances

The summary model provides the multiple correlation (R = 0.14), the multiple correlation squared (R^2 = 0.02), the adjusted multiple correlation squared (adj.R^2 = 0.001), and the Standard Error of the Estimate; here, 1.9 % of the variance in wet appliances (winter) is accounted for by predictors. Additionally, the ANOVA summary table indicates that the model's R^2 is not significantly different from zero, $F(7,373) = 1.06$, $p > 0.05$. Therefore, the regression model is not significant and there is no linear relationship between the variables in the regression model. Summer usage, the model summary provides the multiple correlation ($R = 0.14$), the multiple correlation squared ($R^2 = 0.02$), the adjusted multiple correlation squared (adj.$R^2 = 0.001$), and the Standard Error of the Estimate. Here, 2.0% of the variance in wet appliances summer is accounted for by predictors. In addition, we have the ANOVA summary table which indicates that the model's R^2 is not significantly different from zero, $F(7,373) = 1.08$, $p > 0.05$. Therefore, the regression model is not significant and there is no linear relationship between the variables in the regression model.

6.5.7 Regression Analysis Between other Appliances and the Demographic Factors

The results provides the multiple correlation ($R = 0.17$), the multiple correlation squared ($R^2 = 0.03$), the adjusted multiple correlation squared (adj.$R^2 = 0.01$), and the Standard Error of the Estimate; here, 2.9 % of the variance in other appliances (winter) is accounted for by predictors. Furthermore, the ANOVA summary indicates that the model's R^2 is not significantly different from zero, $F(7, 373) = 1.60$, $p > 0.05$. Therefore, the regression model is not significant and there is no linear relationship between the variables in the regression model. This has not met another assumption of multiple regression analysis between the dependent variable and the demographic factors. However, the variance inflation factors (VIF) has shown that there is no problem of multicollinearity. The data analyses provides the multiple correlation ($R = 0.13$), the multiple correlation squared ($R^2 = 0.02$), the adjusted multiple correlation squared (adj.$R^2 = -0.002$), and the Standard Error of the Estimate. Here, 1.6 % of the variance in other appliances summer time usage is accounted for by predictors. Next, we have the ANOVA summary, which indicates that our model's R^2 is not significantly different from zero, $F(7, 373) = 0.87$, $p > 0.05$. The regression model is not significant and there is no linear relationship between the variables in the regression model.

6.5.8 Summary

The p-values suggest that the correlation coefficients stated above are significantly different from zero. Thus, the first null hypothesis cannot be rejected. Therefore, by referring to these findings, the first hypothesis (Can demographic factors be considered as a strongly related to use of appliances?) has shown a weak correlation and is significantly different from zero at 5 % level of significance. Similarly, the p-values suggest that the correlation coefficients stated above are significantly different from zero. Thus, the second null hypothesis cannot be rejected. Therefore, by referring to these findings, the first hypothesis (Can number of bedrooms in a house be considered as a vital source of motivation for time of use of appliances?) has proven to have a very weak correlation and is significantly different from zero at 5 % level of significance.

Chapter 7 Relative Importance of Demographic Factors

7.1 Introduction

Monitoring of factors that can influence the use of household appliance in every study may not be practicable frequently since the cost required will be naturally much higher. This section will investigate factors that influence time scale towards the use of household appliances and rely on those factors that influence the use of household appliances due to the limited time resources the researcher encounter. All the factors investigated in this study are essentially categorical in nature. As a result, it could be beneficial if the researcher can identify some statistically significant factors that influence time scale towards use of household appliances to build statistical models for associating these factors with each appliance used. In this research, the researcher will use statistical models based on categorical regression with optimal scaling technique (CATREG) to investigate what factors that influence the use of particular household appliances.

7.2 Regression for Categorical Data

Since the relationship between the times, scale of use of household appliances and the demographic factors is not linear. One approach that can be used in such a case is a regression with transformation [166]. In this approach, the relationship between the response and the predictors is linearized through a separate nonlinear transformation of the variable. In particular, by using optimal scaling it is possible to quantify categorical variables (nominal or ordinal) and at the same time optimizes the relationship between response and predictors [167]. Even if, many preliminary decisions have to be considered before performing this model (as the properties of the original variable to be preserved with the transformation), the results are more similar to those of linear regression. The squared multiple regression coefficient R^2 and the regression coefficients assume the same form that in the case of linear regression analysis. The beta coefficients are the standardized regression coefficients and are highly influenced by misspecification of the model. [168]. Although, the standardized coefficients (Beta) cannot fully explain the impact of these predictors since the original variables were transformed. Therefore, CATREG reports the measures of relative importance that are useful to further explore the relative importance of explanatory variables (Pratt, 1987). The Pratt's measure of relative importance (Pratt, 1987), the final column of coefficients table displays the importance of these variables. The additive importance of the demographic factors accounts for about 100.0 %. Furthermore, the relative importance is only displayed since no regularization is applied. In addition, the relative importance measures (Pratt, 1987) of the demographic factors show that the most influential household's demographic factors predicting the household's appliances.

7.3 CATREG model for light-duty cooking appliances

The categorical regression was used in determining which of the demographic factors that influence the light-duty cooking appliances. The models summaries and ANOVA tests are presented in Table 7-1. The results revealed that only five out of seven appliances in this category are significant during winter usage. Conversably, only three are significant during summer use. The Sig. P value indicates the significant of the models tested and the variance in the dependent value by independent variable explains by (R square).

Table 7-1 CATREG model and ANOVA for light-duty cooking appliances

	Model summery				ANOVA			
appliances	Multiple R		R Square		F		Sig. **P** value	
	winter	summer	winter	summer	winter	summer	Winter	summer
Kettle	0.35	0.38	0.12	0.14	1.71	1.87	0.02	0.008
Coffee maker	0.67	0.70	0.44	0.49	1.76	1.44	0.04	0.16
Toaster	0.43	0.35	0.18	0.12	2.15	1.26	0.00	0.19
Microwave	0.36	0.36	0.13	0.13	1.73	1.57	0.02	0.04
Popcorn popper	0.72	0.92	0.53	0.85	1.51	4.71	0.13	0.001
Blender/Juicer	0.65	0.61	0.42	0.38	1.79	1.48	0.03	0.11
Waffle/sandwich	0.74	0.82	0.56	0.67	1.82	0.98	0.05	0.53

7.3.1 Categorical Regression of the Kettle

The winter and summer models are significant (ANOVA p = 0.02 /0.008) and 12.6 % / 14.7 % of the variance in the dependent variable is explained by the demographic factors. The results show that five demographic factors included in the winter model and only two in the summer model are significant as explained by its standardized Beta coefficient

- Number of bedrooms in a house β = 0.106, p = 0.001;
- Type of the household β = 0.158, p = 0.001;
- Number of people live in a house β = 0.359, p = 0.000 / β = 0.341, p = 0.009;
- Current employment status β = 0.143, p = 0.00) / β = 0.126, p = 0.001;

- Age group of the household resident β = 0.299, p = 0.00).

The coefficient of determination above had shown the extent to which the total variation of the kettle is explained by the demographic factors in the regression. The standardized coefficients displayed in Table 7-2 indicate the effects of each factor on the kettle. The relative importance measures (Pratt, 1987) of the demographic factors show that the most influential factors predicting the kettle correspond to 'number of people live in a house' (accounting for 35.8 % / 71.7 %), followed by 'age group during winter' (accounting for 23.6 %) and appliances efficiency rate in summer (accounting for13.5 %). The additive importance of the seven factors accounts for about 100 %. Furthermore, having accepted the consistency of the demographic factors used in the CATREG, the models yielded a multiple regression coefficient (R) of 0.355 / 0.383, indicating a moderate relation between the 'Kettle and the demographic factors, and 12.6 % / 14.7 % of the variance in the rankings is explained by the regression of the optimally transformed variables used. The F statistic of 1.871 with the corresponding a p-value = 0.08 also indicates that this model is performing well.

Table 7-2 Categorical Regression's coefficients of the Kettle

Demographic factors	Standardized Coefficients		F	Sig.	Importance
	Beta	Bootstrap (1000) Estimate of Std. Error			
Winter					
Respondents Gender	0.074	0.049	2.235	0.136	0.041
Number of bedrooms in a house	0.106	0.049	4.780	0.001	0.084
type of the household	0.158	0.059	7.192	0.001	0.103
Number of people live in a house	0.359	0.132	7.393	0.000	0.358
Current employment status	0.143	0.054	6.991	0.000	0.148
age group	0.299	0.126	5.669	0.000	0.236
Appliances efficiency rate	0.062	0.051	1.519	0.210	0.032
Summer					
Respondents Gender	0.048	0.073	0.435	0.510	.003
Number of bedrooms in a house	0.104	0.069	2.221	0.067	.030
type of the household	0.058	0.049	1.393	0.250	-.005
Number of people live in a house	0.341	0.192	3.163	0.009	.717
Current employment status	0.126	0.062	4.191	0.001	.113
age group	0.050	0.163	0.094	0.993	.009
Appliances efficiency rate	0.139	0.064	4.709	0.003	.135

7.3.2 Categorical Regression of the Coffee Maker

The winter model is significant (ANOVA p = 0.044) and 49.7 % of the variance in the coffee maker is explained by the demographic factors. The results show that two demographic factors included in the model are significant as explained by its standardized beta coefficient as shown in Table 7-3;

- Number of people β = 0.982, p = 0.001;
- Age group β = 1.096, p = 0.000.

The relative importance measures (Pratt, 1987) of the demographic factors show that the most influential factors predicting the coffee maker correspond to 'age group' (accounting for 46.9 %), followed by 'current employment status' (accounting for 23.2 %).

Table 7-3 Categorical Regression's coefficients of the coffee maker

Demographic factors	Standardized Coefficients		F	Sig.	Importance
	Beta	Bootstrap (1000) Estimate of Std. Error			
Respondents Gender	0.111	0.165	0.451	0.506	0.051
Number of bedrooms in a house	0.204	0.175	1.347	0.272	0.113
type of the household	0.152	0.145	1.102	0.343	0.058
Number of people live in a house	0.982	0.409	5.779	0.001	0.063
Current employment status	0.398	0.254	2.449	0.053	0.232
age group of the household resident	1.096	0.363	9.118	0.000	0.469
Appliances efficiency rate	0.187	0.179	1.089	0.366	0.013

7.3.3 Categorical Regression of the Toaster

The winter model is significant (ANOVA p = 0.00) and 18.9 % of the variance in the toaster is explained by the demographic factors. The results show that three demographic factors in the model are significant as explained by its standardized beta coefficient as shown in Table 7-4;

- Number of bedrooms in a house β = 0.384, p = 0.003;
- Type of the household β = 0.109, p = 0.022;
- Appliances efficiency rate β = 0.154, p = 0.00.

The relative importance measures (Pratt, 1987) of the demographic factors show that the most influential factors predicting the toaster correspond to 'number of bedrooms in a house' (accounting for 73.8 %), followed by 'appliances efficiency rate' (11.8 %).

Table 7-4 Categorical Regression's coefficients of the toaster

Demographic factors	Standardized Coefficients		F	Sig.	Importance
	Beta	Bootstrap (1000) Estimate of Std. Error			
Respondents Gender	.012	.040	.085	.770	.002
Number of bedrooms in a house	.384	.191	4.028	.003	.738
type of the household	.109	.055	3.862	.022	.063
Number of people live in a house	.144	.160	.804	.548	.004
Current employment status	.082	.061	1.780	.117	.018
age group of the household resident	.133	.151	.769	.573	.057
Appliances efficiency rate	.154	.058	7.142	.000	.118

7.3.4 Categorical Regression of the Microwave

The models are significant (ANOVA P = 0.018 / P = 0.043) and 13.0 %/13.5 % of the variance in the microwave is explained by the demographic factors. The results show that five demographic factors included in the winter model and two in the summer model are significant as explained by its standardized beta coefficient as shown in Table 7-5;

- Number of bedrooms in a house $\beta = 0.236$, $p = 0.00$/ $\beta = 0.256$, $p = 0.00$;
- Number of people live in a house $\beta = 0.196$, $p = 0.001$;
- Current employment status $\beta = 0.175$, $p = 0.00$/ $\beta = 0.148$, $p = 0.000$;
- Age group of the household resident $\beta = 0.225$, $p = 0.00$;
- Appliances efficiency rate $\beta = 0.131$, $p = 0.002$.

The relative importance measures (Pratt, 1987 Table7-5) of the demographic factors show that the most influential factors predicting the microwave correspond to 'number of bedrooms in a house' (accounting for 45.5 % / 46.2 %), followed by age group of the residents (accounting for 27.3 % / 38.1 %), and 'current employment status' (accounting for 23.5 % / 17.4 %).

7.3.5 Categorical Regression of the Popcorn Popper

The summer model is significant (ANOVA p = 0.001) and 85.6 % of the variance in the popcorn popper is explained by the demographic factors. The results show that two demographic factors included in the model are significant as explained by its standardized beta coefficient as shown in Table 7-6;

- Number of people live in a house $\beta = 0.883$, $p = 0.038$;
- Age group of the household resident $\beta = 1.061$, $p = 0.004$.

The relative importance measures (Pratt, 1987) of the demographic factors show that the most influential factors predicting the popcorn popper correspond to 'number of people live in a house' (accounting for 46.8 %), followed by 'age group of the household resident' (accounting for 40.0 %).

Table 7-5 Categorical Regression's coefficients of the microwave

Demographic factors	Standardized Coefficients		F	Sig.	Importance
	Beta	Bootstrap (1000) Estimate of Std. Error			
Winter					
Respondents Gender	.045	.046	.950	.330	.010
Number of bedrooms in a house	.236	.071	10.914	.000	.455
type of the household	.014	.043	.106	.899	.002
Number of people live in a house	.196	.095	4.230	.001	-.083
Current employment status	.175	.051	11.737	.000	.235
age group of the household resident	.225	.097	5.425	.000	.273
Appliances efficiency rate	.131	.057	5.230	.002	.106
Summer					
Respondents Gender	.035	.068	0.261	.610	.002
Number of bedrooms in a house	.256	.071	12.989	.000	.462
type of the household	.063	.049	1.659	.192	.020
Number of people live in a house	.115	.170	0.459	.807	-.087
Current employment status	.148	.062	5.597	.000	.174
age group of the household resident	.292	.195	2.246	.050	.381
Appliances efficiency rate	.080	.064	1.570	.197	.048

Table 7-6 Categorical Regression's coefficients of the Popcorn popper

Demographic factors	Standardized Coefficients		F	Sig.	Importance
	Beta	Bootstrap (1000) Estimate of Std. Error			
Respondents Gender	.086	.179	.231	.636	.020
Number of bedrooms in a house	.432	.385	1.257	.321	-.026
type of the household	.150	.250	.358	.703	.028
Number of people live in a house	.883	.498	3.150	.038	.468
Current employment status	.203	.297	.469	.795	.057
age group of the household resident	1.061	.476	4.964	.004	.400
Appliances efficiency rate	.170	.253	.453	.718	.053

7.3.6 Categorical Regression of the Blender/Juicer

The winter model is significant (ANOVA p = 0.035) and 42.2 % of the variance in the blender/juicer is explained by the demographic factors. The results show that five demographic factors included in the model are significant as explained by its standardized beta coefficient as shown in Table 7-7;

- Number of bedrooms in a house β = 0.261, p = 0.018;
- Type of the household β = 0.259, p = 0.016;
- Number of people live in a house β = 0.508, p = 0.000;
- Current employment status β = 0.223, p = 0.005;
- Age group of the household resident β = 0.605, p = 0.00.

The relative importance measures (Pratt, 1987) of the demographic factors show that the most influential factors predicting the Blender/Juicer used correspond to 'age group of the household resident' (accounting for 41.3 %), followed by 'number of bedrooms in a house' (accounting for 20.6 %).

7.3.7 Categorical Regression of the Waffle Iron/Sandwich Maker

The models are significant (ANOVA p = 0.056 / p = 0.534) and 56 % / 67.4 % of the variance in the waffle iron/sandwich maker is explained by the demographic factors. The results show that only two from the demographic factors included in the winter model are significant as explained by its standardized beta coefficient as shown in Table 7-8;

- Number of bedrooms in a house β = 0.629, p = 0.001;
- Age group β = 0.448, p = 0.017.

The relative importance measures (Pratt, 1987) of the demographic factors show that the most influential demographic factors predicting the waffle iron/sandwich maker correspond to 'number of bedrooms in a house' (accounting 52.6 % / 27.1 %), followed by age group in winter (accounting for 32 %) and 'number of people live in the household in summer' (accounting for 23.2 %).

Table 7-7 Categorical Regression's coefficients of the blender/juicer

Demographic factors	Standardized Coefficients		F	Sig.	Importance
	Beta	Bootstrap (1000) Estimate of Std. Error			
Respondents Gender	.236	.126	3.512	.066	.160
Number of bedrooms in a house	.261	.137	3.634	.018	.206
type of the household	.259	.123	4.415	.016	.075
Number of people live in a house	.508	.218	5.426	.000	.058
Current employment status	.223	.114	3.796	.005	.016
age group of the household resident	.605	.195	9.618	.000	.413
Appliances efficiency rate	.189	.116	2.648	.057	.069

Table 7-8 Categorical Regression's coefficients of the Waffle iron/sandwich maker

Demographic factors	Standardized Coefficients		F	Sig.	Importance
	Beta	Bootstrap (1000) Estimate of Std. Error			
Winter					
Respondents Gender	.028	.126	.049	.826	-.001
Number of bedrooms in a house	.629	.256	6.047	.001	.526
type of the household	.249	.179	1.930	.161	.032
Number of people live in a house	.290	.276	1.103	.362	.037
Current employment status	.308	.211	2.139	.085	.037
age group of the household resident	.488	.271	3.245	.017	.320
Appliances efficiency rate	.158	.164	.932	.436	.048
Summer					
Respondents Gender	.045	.288	.024	.879	.008
Number of bedrooms in a house	.454	.344	1.745	.210	.271
type of the household	.303	.309	.965	.411	.154
Number of people live in a house	.452	.483	.874	.484	.232
Current employment status	.262	.366	.511	.763	.204
age group of the household resident	.368	.369	.997	.463	.158
Appliances efficiency rate	.280	.342	.671	.587	-.027

7.4 CATREG Model for Heavy-Duty Cooking Appliances

The categorical regression was used in determining which of the demographic factors that influence the light-duty cooking appliances. According to the ANOVA test and model summary of each individual heavy-duty cooking appliances, only three appliances are significant. The model summaries and ANOVA test are presented in Table 7-9. The results revealed that only three out of seven appliances in this appliances category are significant during winter usage. Conversably, only two are significant during summer.

Table 7-9 CATREG model and ANOVA for cooking-duty cooking appliances

appliances	Model summary				ANOVA			
	Multiple R		R Square		F		Sig. **P** value	
	winter	summer	winter	summer	winter	summer	Winter	summer
Hot plate	0.791	0.902	0.626	0.813	1.675	1.780	0.107	0.187
Frying pan	0.951	0.866	0.905	0.749	13.459	1.948	0.000	0.092
Bread maker	0.868	1.000	0.754	1.000	1.198	1.691	0.408	0.364
Food steamer	0.663	0.678	0.439	0.460	1.630	1.148	0.073	0.355
Rice cooker	0.613	0.670	0.376	0.449	2.463	1.899	0.001	0.025
Pressure cooker	0.796	0.848	0.634	0.718	1.661	0.607	0.114	0.808
Cooker	0.753	0.558	0.567	0.311	3.634	1.257	0.433	0.000
Kitchen extractor	0.447	0.596	0.200	0.355	2.106	4.525	0.003	0.000

7.4.1 Categorical Regression of the Deeper Frying Pan

The winter model is significant (ANOVA p = 0.00) and 90.5 % of the variance in the deeper frying pan is explained by the demographic factors. The results show that one factor included in the model is significant as explained by its standardized beta coefficient as shown in Table 7-10;

- Number of bedrooms in a house β = 0.88, p = 0.001.

However, the relative importance measures (Pratt, 1987) of the demographic factors show that the most influential factors predicting the deeper frying pan correspond to 'number of bedrooms in a house' (accounting for 85.9 %), followed by 'age group of the household resident' (7.2 %).

7.4.2 Categorical Regression of the Rice Cooker

The models are significant (ANOVA p = 0.001 / p = 0.03) and 37.6 % / 44.9 % of the variance in the rice cooker is explained by the demographic factors. The results show that five demographic factors included in the winter model and three in the summer model are significant as explained by its standardized beta coefficient as shown in Table 7-11;

- Number of bedrooms in a house β = 0.297, p = 0.007;
- Number of people live in a house β = 0.50, p = 0.001 / β = 0.962, p = 0.00;
- Current employment status β = 0.23, p = 0.000 / β = 0.37, p = 0.00;
- Age group of the household resident β = 0.358, p = 0.002 / β = 0.66, p = 0.00;

- Appliances efficiency rate β = 0.33, p = 0.00).

The relative importance measures (Pratt, 1987) of the demographic factors show that the most influential factors predicting the rice cooker correspond to 'number of people live in a house' (accounting for 37.8 % / 76.0 %), followed by 'appliances efficiency rate' (accounting for 27.1 %), 'number of bedrooms in a house' (accounting for 19.2 %), and 'current employment status' (accounting for 15.3 % / 28.6 %).

Table 7-10 Categorical Regression's coefficients of the deeper frying pan

Demographic factors	Standardized Coefficients		F	Sig.	Importance
	Beta	Bootstrap (1000) Estimate of Std. Error			
Respondents Gender	.161	.117	1.892	.178	.036
Number of bedrooms in a house	.876	.356	6.067	.001	.859
type of the household	.130	.114	1.315	.282	.004
Number of people live in a house	.256	.408	.394	.811	.014
Current employment status	.167	.159	1.100	.379	.015
age group of the household resident	.224	.241	.861	.517	.072
Appliances efficiency rate	.048	.216	.049	.986	-.001

Table 7-11 Categorical Regression's coefficients of the rice cooker

Demographic factors	Standardized Coefficients		F	Sig.	Importance
	Beta	Bootstrap (1000) Estimate of Std. Error			
Winter					
Respondents Gender	.109	.073	2.230	.139	-.004
Number of bedrooms in a house	.297	.153	3.742	.007	.192
type of the household	.118	.078	2.309	.105	.049
Number of people live in a house	.503	.222	5.124	.001	.378
Current employment status	.232	.081	8.210	.000	.153
age group	.358	.178	4.043	.002	-.038
Appliances efficiency rate	.329	.099	11.060	.000	.271
Summer					
Respondents Gender	.234	.131	3.173	.080	.037
Number of bedrooms in a house	.142	.236	.361	.835	.044
type of the household	.119	.097	1.501	.232	.051
Number of people live in a house	.962	.275	12.26	.000	.760
Current employment status	.372	.162	5.293	.000	.286
age group	.658	.236	7.813	.000	-.251
Appliances efficiency rate	.199	.143	1.945	.133	.073

7.4.3 Categorical Regression of the Electrical Cooker

The winter model is significant (ANOVA p = 0.00) and 56.7 % of the variance in the cooker is explained by the demographic factors. The results show that three demographic factors included in the model are significant as explained by its standardized beta coefficient as shown in Table 7-12;

- Number of bedrooms in a house β = 0.37, p = 0.007;
- Number of people live in a house β = 0.66, p = 0.01;
- Current employment status β = 0.212, p = 0.03.

Table 7-12 Categorical Regression's coefficients of the electrical cooker

Demographic factors	Standardized Coefficients		F	Sig.	Importance
	Beta	Bootstrap (1000) Estimate of Std. Error			
Respondents Gender	.024	.076	.096	.757	0.100
Number of bedrooms in a house	.371	.175	4.469	.007	0.300
type of the household	.115	.110	1.100	.339	0.033
Number of people live in a house	.662	.325	4.153	.010	.100
Current employment status	.212	.130	2.665	.030	.120
age group of the household resident	.142	.307	.216	.954	.284
Appliances efficiency rate	.130	.109	1.440	.240	.063

The relative importance measures (Pratt, 1987) of the demographic factors show that the most influential factors predicting the cooker correspond to 'number of bedrooms' (accounting for 30 %) and followed by 'age group (28.4 %).

7.4.4 Categorical Regression of the Kitchen Extractor

The models are significant (ANOVA p = 0.003 / p = 0.00) and 20.1 % / 35.5 % of the variance in the kitchen extractor is explained by the demographic factors. The results show that four demographic factors included in the models are significant and as explained by its standardized beta coefficient as shown in Table 7-13;

- Number of bedrooms in a house β = 0.285, p = 0.000 / β = 0.474, p = 0.00;
- Type of the household β = 0.117, p = 0.026 / β = 0.897, p = 0.024;
- Current employment status β = 0.153, p = 0.00/age group β = 0.199, p = 0.00;
- Appliances efficiency rate β = 0.091, p = 0.049 / β = 0.897, p = 0.001.

The relative importance measures (Pratt, 1987) of the demographic factors show that the most influential factors predicting the kitchen extractor correspond to ‘number of bedrooms in a house’ (accounting for 41.4 % / 68.8 %) and followed by ‘age group’ (32.9 % / 12.8 %).

Table 7-13 Categorical Regression’s coefficients of the kitchen extractor

Demographic factors	Standardized Coefficients		F	Sig.	Importance
	Beta	Bootstrap (1000) Estimate of Std. Error			
Winter					
Respondents Gender	.046	.049	.881	.349	-.005
Number of bedrooms in a house	.285	.093	9.514	.000	.414
type of the household	.117	.061	3.705	.026	.072
Number of people live in a house	.335	.559	.360	.837	.060
Current employment status	.153	.065	5.444	.000	.101
age group of the household resident	.397	.537	.548	.739	.329
Appliances efficiency rate	.091	.056	2.665	.049	.029
Summer					
Respondents Gender	.087	.055	2.460	.118	.012
Number of bedrooms in a house	.474	.148	10.327	.000	0.688
type of the household	.121	.062	3.784	.024	.044
Number of people live in a house	.073	.071	1.072	.372	.017
Current employment status	.106	.071	2.208	.055	.031
age group of the household resident	.199	.080	6.166	.000	.128
Appliances efficiency rate	.152	.066	5.335	.001	.080

7.5 CATREG Models for Wet Appliances

The categorical regression was used in determining which of the demographic factors that influence the wet appliances. The model summaries and ANOVA test are presented in Table7-14. The results revealed that the dish-washer and clothes dryer are significant in winter and all three models are significant in summer. The Sig. P value indicates the significant of the models tested and the variance in the wet appliances by demographic factors explains by (R square).

7.5.1 Categorical Regression of the Dish Washer

The models are significant (ANOVA p = 0.00 / 0.004) and 24.5 % / 9 % of the variance in the dish-washer is explained by the demographic factors. The results show that five demographic factors included in the winter model are significant and four in the summer model, as explained by its standardized beta coefficient as shown in Table 7-15:

- Number of bedrooms in a house β = 0.295, p = 0.00/ β = 0.384, p = 0.00;
- Number of people live in a house β = 1.691, p = 0.000/ β = 0.857, p = 0.002;
- Current employment status β = 0.112, p = 0.001;
- Age group β = 1.743, p = 0.00/ β = 0.641, p = 0.029;
- Appliances efficiency rate β = 0.184, p = 0.001 / β = 0.188, p = 0.002.

Table 7-14 CATREG model summary and ANOVA for wet appliances

appliances	Model summary				ANOVA			
	Multiple R		R Square		F		Sig. **P** value	
	winter	summer	winter	summer	winter	summer	Winter	summer
Dish washer	0.495	0.469	0.245	0.220	2.633	1.609	0.000	0.044
Washing machine	0.300	0.372	0.090	0.138	1.344	2.160	0.128	0.001
Clothes dryer	0.469	0.804	0.220	0.647	2.941	3.205	0.000	0.000

Table 7-15 Categorical Regression's coefficients of the dish-washer

Demographic factors	Standardized Coefficients		F	Sig.	Importance
	Beta	Bootstrap (1000) Estimate of Std. Error			
Winter					
Respondents Gender	.009	.047	.041	.841	.002
Number of bedrooms in a house	.295	.102	8.331	.000	.362
type of the household	.053	.049	1.163	.315	.015
Number of people live in a house	1.691	.670	6.368	.000	.072
Current employment status	.112	.054	4.271	.001	.056
age group of the household resident	1.743	.707	6.084	.000	.294
Appliances efficiency rate	.184	.077	5.677	.001	.155
Summer					
Respondents Gender	.091	.077	1.392	.240	.030
Number of bedrooms in a house	.384	.092	17.464	.000	.400
type of the household	.057	.064	.792	.455	-.002
Number of people live in a house	.857	.425	4.072	.002	.418
Current employment status	.092	.071	1.670	.146	.044
age group of the household resident	.641	.400	2.570	.029	-.020
Appliances efficiency rate	.188	.083	5.165	.002	.124

The relative importance measures (Pratt, 1987) of the demographic factors show that the most influential factors predicting the dish-washer in winter correspond to 'number of bedrooms in a house' (accounting for 36.2 %) and followed by 'age group' (29.4 %). Whereas in summer, correspond to 'number of people live in a house' (accounting for 41.8 %) and followed by 'number of bedrooms in a house' (40.0 %).

7.5.2 Categorical Regression of the Washing Machine

As indicated in Table 7-15, the summer model is significant (ANOVA p = 0.001) and 13.8 % of the variance in the washing machine is explained by the demographic factors. However, the results in Table 7-17 show that none of the demographic factors included in the model are significant as explained by its standardized beta coefficient (β and p). However, the relative importance measures (Pratt, 1987) of the demographic factors show that the most influential factors predicting the washing machine correspond to 'number of people in a house' (accounting for 103.5 %).

Table 7-16 Categorical Regression's coefficients of the washing machine

Demographic factors	Standardized Coefficients		F	Sig.	Importance
	Beta	Bootstrap (1000) Estimate of Std. Error			
Respondents Gender	.032	.049	.423	.516	-.001
Number of bedrooms in a house	.085	.062	1.906	.109	.051
type of the household	.052	.041	1.590	.205	.015
Number of people live in a house	.499	.350	2.034	.073	1.035
Current employment status	.061	.057	1.165	.326	.035
age group of the household resident	.281	.290	.939	.455	-.152
Appliances efficiency rate	.031	.042	.556	.644	.011

7.5.3 Categorical Regression of the Clothes Dryer

The models are significant (ANOVA p = 0.00) and 22.0 % / 64.7 % of the variance in the clothes dryer is explained by the demographic factors. The results show that five demographic factors included in the winter model are significant and three in the summer model, as explained by its standardized beta coefficient as shown in Table 7-17;

- Number of bedrooms in a house β = 0.258, p = 0.00;
- Type of the household β = 0.113, p = 0.010;

- Number of people live in a house β = 1.169, p = 0.012 / β = 1.997, p = 0.00;
- Current employment status β = 0.115, p = 0.000;
- Age group of the household resident β = 0.853, p = 0.045 / β = 1.877, p = 0.000;
- Appliances efficiency rate β = 0.345, p = 0.039 (summer).

The relative importance measures (Pratt, 1987) of the demographic factors show that the most influential factors predicting the clothes dryer correspond to 'number of people live in a house' (accounting for 149.2 %) and followed by 'number of bedrooms in a house' (accounting for 20.7 %). In the summer model, the most influential factors predicting the clothes dryer correspond to 'number of people live in a house' (accounting for 47 %) and followed by 'appliances efficiency rate (accounting for 12.7 %).

Table 7-17 Categorical Regression's coefficients of the clothes dryer

Demographic factors	Standardized Coefficients		F	Sig.	Importance
	Beta	Bootstrap (1000) Estimate of Std. Error			
Winter					
Respondents Gender	.020	.043	.210	.647	.000
Number of bedrooms in a house	.258	.076	11.61	.000	.207
type of the household	.113	.052	4.667	.010	.052
Number of people live in a house	1.169	.674	3.007	.012	1.492
Current employment status	.115	.050	5.297	.000	.045
age group of the household resident	.853	.561	2.311	.045	-.818
Appliances efficiency rate	.034	.063	.284	.837	.010
Summer					
Respondents Gender	.099	.162	.372	.545	.026
Number of bedrooms in a house	.115	.249	.213	.930	.010
type of the household	.144	.153	.882	.421	.002
Number of people live in a house	1.997	.715	7.800	.000	0.470
Current employment status	.272	.180	2.294	.062	.082
age group of the household resident	1.877	.696	7.276	.000	-.292
Appliances efficiency rate	.345	.198	3.045	.039	.127

7.6 CATREG Models for Other Appliances

The categorical regression was used in determining which of the demographic factors that influence the other appliances. The model summaries and ANOVA test are presented in Table 7-

19. The results revealed that the iron, vacuum cleaner, electrical blanket and shaver/toothbrush models are significant, where the hair dryer winter model and celling fan summer are significant.

7.6.1 Categorical Regression of the Vacuum Cleaner

The models are significant (ANOVA p = 0.00) and 19.2 % / 20.7 % of the variance in the vacuum cleaner is explained by the demographic factors (adjusted R square = 0.12). The results show that five demographic factors included in the winter model and two in the summer model are significant, as explained by its standardized beta coefficient as shown in Table 7-19;

- Number of bedrooms in a house β = 0.292, p = 0.00 / β = 0.390, p = 0.000;
- Number of people live in a house β = 1.189, p = 0.00;
- Current employment status β = 0.162, p = 0.00;
- Age group of the household resident β = 1.188, p = 0.000;
- Appliances efficiency rate β = 0.124, p = 0.00 / β = 0.148, p = 0.000.

The relative importance measures (Pratt, 1987) of the demographic factors show that the most influential factors predicting the vacuum cleaner in winter correspond to 'number of bedrooms in a house' (accounting for 42.1 % / 72.5 %) and followed by 'age group' (accounting for 26.2 % / 18.2 %).

Table 7-18 CATREG model summary and ANOVA for other appliances

appliances	Model summary				ANOVA			
	Multiple R		R Square		F		Sig. **P** value	
	winter	summer	winter	summer	winter	summer	Winter	summer
E. shower	0.352	0.541	0.124	0.293	1.103	1.128	0.342	0.339
E. heater	0.658	-	0.433	-	1.561	-	0.093	-
E. blanket	0.83.8	-	0.702	-	2.150	-	0.041	-
Vacuum cleaner	0.438	0.455	0.192	0.207	2.745	2.989	0.000	0.000
Iron	0.378	0.407	0.143	0.166	1.945	2.308	0.005	0.001
Hair dryer	0.511	0.517	0.261	0.268	2.609	1.111	0.000	0.354
shaver/toothbrush	0.540	0.567	0.291	0.322	2.241	2.472	0.002	0.001
Celling fan	0.811	0.582	0.657	0.339	3.295	2.411	0.343	0.000

Table 7-19 Categorical Regression's coefficients of the vacuum cleaner

Demographics factors	Standardized Coefficients		F	Sig.	Importance
	Beta	Bootstrap (1000) Estimate of Std. Error			
Winter					
Respondents Gender	.046	.042	1.225	.269	.008
Number of bedrooms in a house	.292	.069	18.007	.000	.421
type of the household	.024	.043	.298	.742	.002
Number of people live in a house	1.189	.353	11.340	.000	.084
Current employment status	.162	.051	9.970	.000	.149
age group of the household resident	1.188	.383	9.612	.000	.262
Appliances efficiency rate	.124	.054	5.383	.001	.049
Summer					
Respondents Gender	.004		.012	.914	.000
Number of bedrooms in a house	.390		19.634	.000	.725
type of the household	.077		2.612	.075	.024
Number of people live in a house	.188		.472	.797	-.023
Current employment status	.057		1.704	.134	.012
age group of the household resident	.246		.810	.543	.182
Appliances efficiency rate	.148		7.592	.000	.079

7.6.2 Categorical Regression of the Iron

The models are significant (ANOVA p = 0.005 / p = 0.001) and 14.3 % / 16.6 % of the variance in the dependent variable is explained by the demographic factors. The results show that six demographic factors included in the models are significant as explained by its standardized beta coefficient as shown in Table 7-20;

- Number of bedrooms in a house β = 0.24, p = 0.00 / β = 0.25, p = 0.00;
- Type of the household β = 0.114, p = 0.009 / β = 0.113, p = 0.016;
- Number of people live in a house β = 0.84, p = 0.00 / β = 0.895, p = 0.00;
- Current employment status β = 0.12, p = 0.00 / β = 0.148, p = 0.00;
- Age group of the household resident β = 0.858, p = 0.00/ β = 0.957, p = 0.00;
- Appliances efficiency rate β = 0.11, p = 0.003 / β = 0.079, p = 0.04.

The relative importance measures (Pratt, 1987) of the demographic factors show that the most influential factors predicting the iron correspond to 'number of bedrooms in a house' (accounting for 38.7 % / 33.8 %), followed by 'number of people in winter' (accounting for 17.6 %) and 'age group of the household resident' (accounting for 29.4 %).

Table 7-20 Categorical Regression's coefficients of the iron

Demographic factors	Standardized Coefficients		F	Sig.	Importance
	Beta	Bootstrap (1000) Estimate of Std. Error			
Winter					
Respondents Gender	.008	.038	.043	.835	.000
Number of bedrooms in a house	.243	.063	14.691	.000	.387
type of the household	.114	.052	4.799	.009	.097
Number of people live in a house	.840	.298	7.928	.000	.176
Current employment status	.123	.050	6.086	.000	.100
age group of the household resident	.858	.312	7.560	.000	.129
Appliances efficiency rate	.113	.052	4.728	.003	.087
Summer					
Respondents Gender	.006	.037	.027	.870	-.001
Number of bedrooms in a house	.250	.058	18.609	.000	.338
type of the household	.113	.055	4.172	.016	.081
Number of people live in a house	.895	.294	9.279	.000	.107
Current employment status	.148	.052	8.130	.000	.123
age group of the household resident	.957	.299	10.280	.000	.294
Appliances efficiency rate	.079	.048	2.730	.044	.041

7.6.3 Categorical Regression of the Electrical Blanket

The model is significant (ANOVA p = 0.041) and 70.2 % of the variance in the electrical blanket is explained by the demographic factors as shown in Table 7-21. The results show that two demographic factors included in the model are significant as explained by its standardized beta coefficient; (number of bedrooms in a house β = 0.55, p = 0.025 and number of people live in a house β = 0.670, p = 0.006.

The relative importance measures (Pratt, 1987) of the demographic factors show that the most influential factors predicting the electrical blanket correspond to 'number of people live in a house' (accounting for 35.0 %) and followed by 'age group' (23.0 %).

7.6.4 Categorical Regression of the Hair Dryer, Straightener and Curlers

The model is significant (ANOVA p = 0.00) and 26.1 % of the variance in the Hair dryer, straightener and curlers is explained by the demographic factors. The results show that five demographic factors included in the model are significant as explained by its standardized beta coefficient as shown in Table 7-22;

- Number of bedrooms in a house β = 0.445, p = 0.00;
- Type of the household β = 0.123, p = 0.026;
- Current employment status β = 0.13, p = 0.00;
- Age group of the household resident β = 0.237, p = 0.026;
- Appliances efficiency rate β = 0.19, p = 0.00.

The relative importance measures (Pratt, 1987) of the demographic factors show that the most influential factors predicting the Hair dryer, straightener and curlers correspond to 'number of bedrooms in a house' (accounting for 70.2 %), followed by 'age group of the household resident' (accou8nting for 13.9 %) and 'appliances efficiency rate' (accounting for 10.1 %).

Table 7-21 Categorical Regression's Coefficients of the Electrical Blanket

Demographic factors	Standardized Coefficients		F	Sig.	Importance
	Beta	Bootstrap (1000) Estimate of Std. Error			
Respondents Gender	.080	.175	.208	.653	.010
Number of bedrooms in a house	.555	.297	3.488	.025	.189
type of the household	.190	.241	.623	.546	.066
Number of people live in a house	.670	.301	4.966	.006	.350
Current employment status	.406	.290	1.966	.126	.156
age group of the household resident	.315	.370	.724	.613	.230
Appliances efficiency rate	.041	.196	.044	.957	-.002

Table 7-22 Categorical Regression's Coefficients of the Hair Dryer, Straightener and Curlers

Demographic factors	Standardized Coefficients		F	Sig.	Importance
	Beta	Bootstrap (1000) Estimate of Std. Error			
Respondents Gender	.047	.049	.919	.339	.002
Number of bedrooms in a house	.445	.072	37.630	.000	.702
type of the household	.123	.064	3.739	.026	.041
Number of people live in a house	.137	.147	.864	.506	-.008
Current employment status	.132	.057	5.349	.000	.023
age group of the household resident	.237	.147	2.605	.026	.139
appliances efficiency rate	.191	.066	8.477	.000	.101

7.6.5 Categorical Regression of the Electrical Shaver / Toothbrush

The models are significant (ANOVA p = 0.002 / p = 0.001) and 29.1 % / 32.2 % of the variance in the Electrical shaver/toothbrush is explained by the demographic factors. The results show that two demographic factors included in the winter model and three in the summer model are significant as explained by its standardized beta coefficient as shown in Table 7-23:

- Number of bedrooms in a house β = 0.416, p = 0.00 / β = 0.495, p = 0.00;
- Current employment status β = 0.152, p = 0.00 / β = 0.164, p = 0.00;
- Appliances efficiency rate (summer model) β = 0.4396, p = 0.049.

The relative importance measures (Pratt, 1987) of the demographic factors show that the most influential factors predicting the electrical shaver/toothbrush correspond to 'number of bedrooms in a house' (accounting for 43.3 % / 54.4 %), followed by 'age group of the household resident' (21.3 % / 33.9 %).

Table 7-23 Categorical Regression's Coefficients of the Shaver/Toothbrush

Demographic factors	Standardized Coefficients		F	Sig.	Importance
	Beta	Bootstrap (1000) Estimate of Std. Error			
Winter					
Respondents Gender	.115	.076	2.308	.131	.031
Number of bedrooms in a house	.416	.088	22.281	.000	.433
type of the household	.055	.062	.802	.451	.009
Number of people live in a house	.337	.371	.823	.513	.155
Current employment status	.152	.068	4.978	.000	.106
age group of the household resident	.326	.326	.999	.421	.213
appliances efficiency rate	.114	.075	2.275	.083	.052
Summer					
Respondents Gender	.085	.074	1.326	.252	.007
Number of bedrooms in a house	.495	.106	21.803	.000	.544
type of the household	.082	.069	1.436	.242	.008
Number of people live in a house	.171	.300	.323	.862	-.003
Current employment status	.164	.072	5.259	.000	.097
age group of the household resident	.396	.261	2.300	.049	.339
appliances efficiency rate	.062	.062	.995	.397	.009

7.6.6 Categorical Regression of the Celling and Table Fans

The summer model is significant (ANOVA p = 0.001) and 33.9 % of the variance in the celling and table fans is explained by the demographic factors. The results show that five demographic factors included in the model are significant as explained by its standardized beta coefficient as shown in Table 7-24;

- Number of bedrooms in a house β = 0.38, p = 0.00;
- Number of people live in a house β = 1.43, p = 0.00;
- Current employment status β = 0.23, p = 0.00;
- Age group of the household resident β = 1.487, p = 0.00;
- Appliances efficiency rate β = 0.37, p = 0.00).

The relative importance measures (Pratt, 1987) of the demographic factors show that the most influential factors predicting the celling/table fans correspond to 'number of people in a house' (accounting for 48.4 %) and followed by 'number of bedrooms in the household (accounting for 35.3 %).

Table 7-24 Categorical Regression's Coefficients of the Celling/Table Fan

Demographic factors	Standardized Coefficients		F	Sig.	Importance
	Beta	Bootstrap (1000) Estimate of Std. Error			
Respondents Gender	.030	.060	.256	.614	-.001
Number of bedrooms in a house	.381	.098	14.995	.000	.353
type of the household	.027	.066	.167	.846	.001
Number of people live in a house	1.427	.473	9.120	.000	.484
Current employment status	.233	.086	7.371	.000	.057
age group of the household resident	1.487	.433	11.773	.000	-.217
appliances efficiency rate	.370	.109	11.449	.000	.311

7.7 CATREG Models for Office and Entertainment Appliances

The categorical regression was used in determining which of the demographic factors that influence the other appliances. The model summaries and ANOVA tests are presented in Table 7-25. The results revealed that eight models are significant.

Table 7-25 CATREG model summary and ANOVA for Office and Entertainment appliances

appliances	Model summary				ANOVA			
	Multiple R		R Square		F		Sig. **P** value	
	winter	summer	winter	summer	winter	summer	winter	summer
Laptop	0.319	0.341	0.102	0.116	1.485	1.760	0.066	0.015
Desktop computer	0.481	0.446	0.231	0.198	1.731	1.465	0.027	0.769
Printer, scan. and photo.	-	0.692	-	0.479	-	2.612	-	0.001
Shredder	0.821	0.848	0.674	0.720	1.722	2.246	0.110	0.033
TV	0.286	0.343	0.082	0.118	1.212	1.724	0.228	0.020
DVD&CD and radio	0.501	0.634	0.251	0.403	2.464	4.436	0.000	0.000
Home cinema	0.761	1.000	0.579	1.000	1.319	417.656	0.255	0.002

7.7.1 Categorical Regression of the Laptop

The summer model is significant (ANOVA p = 0.015) and 11.6 % of the variance in the laptop is explained by the demographic factors. The results show that five demographic factors included in the model are significant, as explained by its standardized beta coefficient as shown in Table 7-26;

- Number of bedrooms in a house β = 0.11, p = 0.003;
- Number of people live in a house β = 0.34, p = 0.00;
- Current employment status β = 0.15, p = 0.00;
- Age group of the household resident β = 0.24, p = 0.001;
- Appliances efficiency rate β = 0.17, p = 0.00.

The relative importance measures (Pratt, 1987) of the demographic factors show that the most influential factors predicting the laptop correspond to 'number of people live in a house' (accounting for 50.9 %) and followed by 'appliances efficiency rate' (accounting for 24.3 %).

7.7.2 Categorical Regression of the Desktop Computer

The winter model is significant (ANOVA p = 0.027) and 23.1 % of the variance in the desktop computer is explained by the demographic factors. The results show that two demographic factors included in the model are significant as explained by its standardized beta coefficient as shown in Table 7-27;

- Number of bedrooms in a house β = 0.415, p = 0.00;
- Appliances efficiency rate β = 0.138, p = 0.019.

The relative importance measures (Pratt, 1987) of the demographic factors show that the most influential factors predicting the desktop computer correspond to 'number of bedrooms in a house' (accounting for 70.9 %), followed by 'number of people live in a house' (accounting for 15.5 %).

Table 7-26 Categorical Regression's Coefficients of the Laptop

Demographic factors	Standardized Coefficients		F	Sig.	Importance
	Beta	Bootstrap (1000) Estimate of Std. Error			
Respondents Gender	.079	.052	2.317	.129	.041
Number of bedrooms in a house	.113	.055	4.184	.003	.106
type of the household	.015	.040	.136	.872	-.004
Number of people live in a house	.342	.125	7.454	.000	.509
Current employment status	.150	.049	9.462	.000	.181
Age group of the household resident	.242	.117	4.275	.001	-.078
Appliances efficiency rate	.171	.061	7.913	.000	.243

Table 7-27 Categorical Regression's Coefficients of the Desktop Computer

Demographic factors	Standardized Coefficients		F	Sig.	Importance
	Beta	Bootstrap (1000) Estimate of Std. Error			
Respondents Gender	.056	.067	.700	.404	.021
Number of bedrooms in a house	.415	.174	5.713	.000	.709
type of the household	.082	.075	1.219	.299	.008
Number of people live in a house	.232	.299	.604	.660	.155
Current employment status	.103	.087	1.414	.223	.019
age group of the household resident	.104	.291	.127	.986	.003
Appliances efficiency rate	.138	.075	3.410	.019	.083

7.7.3 Categorical Regression of the Printer, Scanner and Photocopier

The model is significant (ANOVA p = 0.001) and 47.9 % of the variance in the printer, scanner and photocopier is explained by the demographic factors. The results show that four demographic factors included in the model are significant as explained by its standardized beta coefficient as shown in Table 7-28:

- Number of bedrooms in a house β = 0.50, p = 0.00;
- Number of people live in a house β = 0.66, p = 0.00;
- Current employment status β = 0.25, p = 0.00;
- Age group of the household resident β = 0.40, p = 0.001.

The relative importance measures (Pratt, 1987) of the demographic factors show that the most influential factors predicting the printer, scanner and photocopier correspond to 'number of bedrooms in a house' (accounting for 47.2 %) and followed by 'number of people live in a house' (accounting for 28.4 %).

Table 7-28 Categorical Regression's coefficients of the printer, scanner and photocopier

Demographic factors	Standardized Coefficients		F	Sig.	Importance
	Beta	Bootstrap (1000) Estimate of Std. Error			
Respondents Gender	.050	.072	.473	.494	.006
Number of bedrooms in a house	.501	.114	19.365	.000	.472
type of the household	.046	.076	.368	.694	.005
Number of people live in a house	.660	.192	11.794	.000	.284
Current employment status	.254	.099	6.587	.000	.119
age group of the household resident	.403	.188	4.616	.001	.065
Appliances efficiency rate	.137	.097	2.007	.121	.049

7.7.4 Categorical Regression of the Shredder

The summer model is significant (ANOVA p = 0.033) and 72 % of the variance in the shredder is explained by the demographic factors. The results show that two demographic factors included in the model are significant as explained by its standardized beta coefficient as shown in Table 7-29;

- Number of people live in a house β = 0.95, p = 0.004;
- Age group β = 0.78, p = 0.007.

The relative importance measures (Pratt, 1987) of the demographic factors show that the most influential factors predicting the shredder correspond to 'number of people' (accounting for 46.7 %) and followed by 'number of bedrooms (accounting for 28.4 %).

Table 7-29 Categorical Regression's coefficients of the Shredder

Demographic factors	Standardized Coefficients		F	Sig.	Importance
	Beta	Bootstrap (1000) Estimate of Std. Error			
Respondents Gender	.058	.158	.135	.717	.016
Number of bedrooms in a house	.470	.281	2.809	.052	.213
type of the household	.356	.213	2.781	.085	.051
Number of people live in a house	.947	.413	5.266	.004	.467
Current employment status	.381	.269	2.001	.120	.099
age group of the household resident	.778	.372	4.377	.007	.021
Appliances efficiency rate	.370	.221	2.819	.064	.131

7.7.5 Categorical Regression of the TV

The summer model is significant (ANOVA p = 0.02) and 11.8 % of the variance in the TV is explained by the demographic factors. The results show that three demographic factors included in the model are significant as explained by its standardized beta coefficient as shown in Table 7-30;

- Number of bedrooms in a house $\beta = 0.264$, $p = 0.00$;
- Current employment status $\beta = 0.111$, $p = 0.00$;
- Appliances efficiency rate $\beta = 0.107$, $p = 0.002$.

The relative importance measures (Pratt, 1987) of the demographic factors show that the most influential factors predicting the TV correspond to 'number of bedrooms in a house' (accounting for 57.9 %) and followed by 'age group' (accounting for 13.0 %).

Table 7-3030 Categorical Regression's Coefficients of the TV

Demographic factors	Standardized Coefficients		F	Sig.	Importance
	Beta	Bootstrap (1000) Estimate of Std. Error			
Respondents Gender	.108	.057	3.541	.061	.095
Number of bedrooms in a house	.264	.078	11.379	.000	.579
type of the household	.028	.043	.436	.647	.005
Number of people live in a house	.062	.131	.221	.927	-.003
Current employment status	.111	.045	5.954	.000	.095
age group of the household resident	.122	.105	1.340	.247	.130
Appliances efficiency rate	.107	.048	5.015	.002	.100

7.7.6 Categorical Regression of the DVD/CD Player and Radio

The models are significant (ANOVA p = 0.00) and 25.1 % / 40.3 % of the variance in the DVD/CD player and radio is explained by the demographic factors. The results show that four demographic factors included in the winter model and there in the summer model are significant as explained by its standardized beta coefficient as shown in Table 7-31;

- Type of the household $\beta = 0.192$, p = 0.00 / $\beta = 0.107$, p = 0.02;
- Number of bedrooms $\beta = 0.595$, p = 0.00 summer model;
- Number of people live in a house $\beta = 0.625$, p = 0.00 winter model;
- Current employment status $\beta = 0.100$, p = 0.008;
- Age group of the household resident $\beta = 0.640$, p = 0.00.
- Appliances efficiency rate $\beta = 0.147$, p = 0.005 summer model.

The relative importance measures (Pratt, 1987) of the demographic factors show that the most influential factors predicting the DVD/CD player and radio correspond to 'age group' (accounting for 48.0 %), followed by 'number of people live in a house' (26.1 %) and 'type of the household' (11.6 %). For the summer model the most influential factors predicting the DVD/CD player and radio correspond to number of bedrooms in a house' (accounting for 83.7 %) and followed by 'appliances efficiency rate' (6.0 %).

7.7.7 Categorical Regression of the Home Cinema

The summer model is significant (ANOVA p = 0.002) and 100.0 % of the variance in the home cinema is explained by the demographic factors. However, the results show that none of the demographic factors included in the model are significant as explained by its standardized beta coefficient as shown in Table 7-32. The relative importance measures (Pratt, 1987) of the demographic factors show that the most influential factors predicting the home cinema correspond to 'number of bedrooms in a house' (accounting for 95.6 %).

Table 7-31 Categorical Regression's coefficients of the DVD/CD player and radio

Demographic factors	Standardized Coefficients		F	Sig.	Importance
	Beta	Bootstrap (1000) Estimate of Std. Error			
Winter					
Respondents Gender	.006	.060	.010	.921	.001
Number of bedrooms in a house	.129	.083	2.423	.050	.098
type of the household	.192	.070	7.559	.001	.116
Number of people live in a house	.625	.266	5.519	.000	.261
Current employment status	.100	.055	3.236	.008	.020
age group of the household resident	.640	.259	6.089	.000	.480
Appliances efficiency rate	.093	.059	2.430	.067	.023
Summer					
Respondents Gender	.053	.080	.433	.512	.008
Number of bedrooms in a house	.595	.213	7.781	.000	.837
type of the household	.107	.055	3.831	.024	.030
Number of people live in a house	.168	.154	1.180	.322	.038
Current employment status	.089	.077	1.329	.254	.002
age group of the household resident	.096	.128	.558	.732	.026
Appliances efficiency rate	.147	.070	4.413	.005	.060

Table 7-32 Categorical Regression's coefficients of the home cinema

Demographic factors	Standardized Coefficients		F	Sig.	Importance
	Beta	Bootstrap (1000) Estimate of Std. Error			
Respondents Gender	.019	.310	.004	.958	.004
Number of bedrooms in a house	1.383	.330	17.531	.055	.956
type of the household	.056	.370	.023	.977	-.006
Number of people live in a house	1.492	.611	5.969	.149	-.142
Current employment status	.094	.456	.042	.997	.011
age group of the household resident	.965	.507	3.617	.231	.173
Appliances efficiency rate	.025	.371	.004	.999	.005

7.8 Summary

The main findings as per the regression analysis are summarised in the Table 7-34 to 7-38. The relative importance measures (Pratt, 1987) of the independent variables demonstrate the most influential factors predicting the time usage of the household's appliances. The accountability of each of demographic factors was investigated. Generally, the number of bedrooms in the house and number of people living in the household are the most influential factors of appliances usage. The number of people, size of the household are the age group the most influential factors for most of the cooking appliances. In addition, the employment status comes next in this category as has the most influential of using coffee maker and food blender/Juicer. Obviously, these two types of appliances are linked to age; different ages have different needs. The relative importance (Pratt, 1987) of the age group (the most influential factor) to use the coffee maker is 46.9% and to use food blinder/juicer is 41.3 %. Conversely, then most influential factor of using the wet appliances is the number of people and then, the house size (number of bedrooms). Also, the house size is the most influential factor amongst all demographic factors is influencing the usage of this category. However, the age group found to be the influential factor of using DVD/CD in the winter and noticeably the summer is more influential by the demographic factors than winter, where only the desk top computers and printers are influential by the house size in winter.

Table 7-31~~34~~ summary of cooking appliances relative importance

Appliances	Number of people		Number of bedrooms		Household type		Employment status		Age group		Efficiency rate	
	W	S	W	S	W	S	W	S	W	S	W	S
Kettle	✓ 1	✓ 1	✓		✓		✓ 3	✓ 3	✓ 2			2
Coffee maker	✓						2		✓ 1			
Toaster			✓ 1		✓						✓ 2	
Microwave	✓		✓ 1	✓ 1			✓ 3	✓ 3	✓ 2	2	✓	
Popcorn popper		✓ 1								✓ 2		
Blender/juicer	✓		✓ 2		✓		✓		✓ 1			
Waffle/sandwich		2	✓ 1	1					✓ 2			
Deeper frying			✓ 1						2			
Rice cooker	✓ 1	✓ 1	✓ 2				✓ 3	✓ 2	✓		✓	
E. Cooker	✓		✓ 1				✓		2			
Kitchen ext.			✓ 1	✓ 1	✓	✓	✓ 3		2	✓ 2	✓	✓

Table 7-32~~35~~ summary of wet appliances relative importance

Appliances	Number of people		Number of bedrooms		Household type		Employment status		Age group		Efficiency rate	
	w	s	w	s	w	s	w	s	w	s	w	s
Dish-washer	✓	✓ 1	✓ 1	✓ 2			✓		✓ 2		✓ 3	✓ 3
Washing M.		1										
Clothes dryer	✓ 1	✓ 1	✓ 2		✓		✓		✓	✓		✓ 2

Table 7-33~~36~~ summary of other appliances relative importance

Appliances	Number of people		Number of bedrooms		Household type		Employment status		Age group		Efficiency rate	
	w	s	w	s	w	s	w	s	w	s	w	s
Vacuum cleaner	✓		✓ 1	✓ 1			✓ 3		✓ 2	2	✓	✓
Iron	✓ 2	✓	✓ 1	✓ 1	✓	✓	✓	✓	✓	✓ 2	✓	✓
E. blanket	✓ 1		✓						2			
Hair dryer			✓ 1		✓		✓		✓ 2		✓ 3	
Shaver/tooth brush	3		✓ 1	✓ 1			✓ 4	✓	2	2		✓
Celling/table fans		✓ 1		✓ 2				✓		✓		✓ 3

Table 7-34~~37~~ summary of entertainment and office appliances relative importance

Appliances	Number of people		Number of bedrooms		Household type		Employment status		Age group		Efficiency rate	
	w	s	w	s	w	s	w	s	w	s	w	s
Laptop		✓ 1		✓ 4				✓ 3		✓		✓ 2
Desktop computer	2		✓ 1								✓	
Printer	✓ 2	✓ 2	✓ 1	✓ 1			✓ 3	✓ 3	✓	✓		
Shredder		✓ 1		2						✓		
TV				✓ 1				✓		2		✓ 3
DVD/CD and Radio	✓ 2			✓ 1	✓ 3	✓	✓		✓ 1			✓ 2
Home cinema				1								

Table 7-35~~38~~ summary of relative importance

Appliances	Predicting factor (most influential)		Relative importance %	
	winter	summer	winter	summer
Cooking equipment and appliances				
Kettle	Number of people		71.7 %	
Coffee maker	Age group		46.9 %	
Toaster	Number of bedrooms		73.8 %	
Microwave	Number of bedrooms		45.5 %	
Popcorn popper	Number of people		46.8 %	
Food blender/Juicer	Age group		41.3 %	
Waffle iron/Sandwich maker	Number of bedrooms	Number of bedrooms	52.6 %	27.1 %
Deeper frying pan	Number of bedrooms		85.9 %	
Electrical rice cooker	Number of people	Number of people	37.8 %	76%
E. cooker and kitchen extractor	Number of bedrooms	Number of bedrooms	30 %	41.4 %
Wet appliances				
Dish washer	Number of bedrooms	Number of people	36.2%	41.8%
Washing machine	Number of people		103%	
Clothes dryer	Number of people		149.2 %	47.4 %
Other appliances				
Vacuum cleaner	Number of bedrooms	Number of bedrooms	42.1 %	72.5 %
Iron	Number of bed rooms	Number of bedrooms	38.7 %	33.8 %
Electrical appliances	Number of people		35%	
Hair dryer, str. and curlers	Number of bedrooms		70.2 %	
E. shaver/E. tooth brush	Number of bedrooms	Number of bedrooms	43.3 %	44.4 %
Celling and table fan		Number of people		48.4%
Office and Entertainments				
Laptop computer		Number of people		50.9 %
Desk top computer	Number of bedrooms		70.9 %	
Printer, scanner and photo.	Number of bedrooms		47.2 %	
Shredder		Number of people		46.6 %
TV		Number of bedrooms		57.9 %
DVD/CD players	Age group	Number of bedrooms	48%	83.7%
Home cinema		Number of bedrooms		95.6%

Chapter 8 Finding and Discussion

8.1 Overview

This study aimed to provide a wider range of data regarding to the household appliances, with a clearer understanding of key factors involved in selecting the time of usage. In addition, it presented how technology and efficient appliances decrease the daily demand and reduce the energy cost. In order to calculate the appliances demand and assess their contribution to the daily demand, a household electricity model for the Borough designed to provide the consumers with a clear picture of individual appliance or set of appliances, impact on the household daily demand. The appliances data collected based on a designed questionnaire to assess the appliances ownership and estimate the daily demand of the borough. Demographic factors investigated and the factors relative importance affecting the time of use of individual appliance was determined.

For the purpose of this research project, devoted excel spread sheets (model) created to allow the consumer to test and compare the impact of the demographic factors and their habit on the daily demand. So, that practical investigation of the appliances usage can be attempted. The regression analysis of the data results showed that the overall the time of use the daily appliances were less influenced by some of the demographic factors. However, individual investigation of the household's appliances showed that there is an effect on the appliances in matter of usage by the demographic factors. The examination of the number of people living in the household showed an influence on the appliances, as well as the age of the household's residents. The efficient appliances showed interesting and encouraging results towards reducing the daily demand and peak demand, which is promising to relief the stress on the electricity suppliers during peak period demand.

8.2 Significant of the Demographic Factors

The three categorical predictor variables found significant in the model for predicting Kettle used in a single summer day were Number of people live in the house, current employment status and appliances efficiency rate. The five categorical predictor factors found significant in the model for predicting Kettle used in a winter day were number of bedrooms in a house, type of the household, number of people live in a house, current employment status and age group of the household resident.

The CATREG model tested for Kettle used in a summer day and Kettle used in a winter day are both significant. The coefficient of determination had shown the extent to which the total variation of the kettle. The demographic factors could explain more of the variation in Kettle used in a summer day than the variation in Kettle used in a winter day. Meanwhile, appliances efficiency rate has statistically significant effect on both Kettle used in a summer day and Kettle used in a winter day. The relative importance measures of the demographic factors show that the number of people lives in a house' is the most influential factor predicting both the Kettle used in a summer day (accounting for 71.7 %) and Kettle used in a winter day (accounting for 35.8 %).

The relative importance measures of the demographic factors show that the 'appliances efficiency rate' is the least influential factor predicting the Kettle used in a winter day (accounting for 3.2 %) while the 'type of the household' is the least influential factor predicting the Kettle used in a summer day (accounting for less 0.5 %).

Meanwhile, The CATREG model tested for Microwave used in a summer day and in a winter day, Electrical rice cooker used in a summer day and a winter day, washing machine used in a summer day and TV used in a summer day show that these are statistically significant models. The CATREG model tested for Washing machine used in a single winter day and TV used in a single winter day show that these are not statistically significant models. The results show that number of people live in a house, current employment status and appliances efficiency rate have statistically significant effects on the kettle used in a single summer day. It shows that number of bedrooms in a house, type of the household, number of people live in a house, current employment status and appliances efficiency rate have statistically significant effects on the kettle used in a single winter day.

The results show that number of bedrooms in a house and current employment status have statistically significant effects on the microwave used in a summer day. it shows that number of bedrooms in a house, number of people live in a house, current employment status, age group of the household resident and appliances efficiency rate have statistically significant effects on the microwave used in a winter day. On another hand, the results show that number of people live in a house, current employment status and age group of the household resident have statistically significant effects on the electrical rice cooker used in a summer day. In addition, it shows that number of bedrooms in a house, number of people live in a house, current employment status, age group of the household resident and appliances efficiency rate have statistically significant effects on the electrical rice cooker used in a single winter day.

The results show that none of the demographic factors shows statistically significant effects on the washing machine used in a summer day. It shows that model tested for Washing machine used in a winter day shows that it is not statistically significant models.

The results show that number of bedrooms in a house, current employment status and statement apply to you has statistically significant effects on the TV used in a single summer day. It shows that model tested for TV used in a single winter day shows that it is not statistically significant models.

8.3 Research Findings

The wide range of household's appliances was evident in the UK household. Suppliers put the difference in the appliances functions core, when it concerns the peak demand period of domestic sector, forward. While the consumer's prime concern was to reduce the energy bill and maintain their zone of comfort.

The consumers have a daily habit when it comes to the appliances daily usage, while the daily demand is an aggregation of the consumer activity. The increasing number of people in the household increases the opportunity of increasing the demand of a particular appliance. Typical, all appliances were evidently affected by the demographic factors, though there is a relative contribution of these factors to the particular appliance based on their function and association to other household's appliance.

The size of the household is also a very significant factor when it concerns cooking equipment and entertainment appliances. The demand of electricity is remarkably different for the large and small households in terms of appliance's ownership. Similarly, daily demand also varies greatly according to the size of the household. When the classification of the household's appliances is used to examine the daily contribution, the difference between the four major partitions is clearly functional. Physical specifications and pattern usages (in minutes) are included as main of the prime concerns for the daily demand within the individual household, while the peak demand period of the borough focuses more on the increasing the number of appliances been used during this period.

The household type also differentiates the ownership of certain appliances in terms of the relative contribution of daily demand and relative importance of demographic factors. Households owned by the consumers generally have a higher level of appliance's ownership, which leads to increasing the daily demand.

The rented households are least likely to use heavy-duty cooking appliances (electrical cooker). However, in terms of the usage of the light duty-cooking appliances, the rented households are more likely to use them during the daytime. In regards to the preparing meals, the younger and people, have completely different needs. In terms of winter versus the summer usage, was found that in the survey that winter usage has a higher usage of appliances regardless of the demographic factors. Summer usage data shows a fewer number of households are using more appliance in summer than winter while 17 % are shoe a similar usage throughout the year.

All the correlation tables show that there is a very weak relationship between demographic factors and the appliances. However, few significant relationships have been observed between the number of bedrooms in a house and Light-duty cooking appliances, and number of bedrooms in a house and the other appliances (winter) as shown in Table 8-1. The Wilcoxon signed-rank test showed that there was a statistically significant difference in the score of the appliances between summer and winter. It was observed that there is higher appliances score or rating during winter than during summer. It can be concluded that the significance of the difference between the two distributions is not due to their different locations on the scale and not to any differences in shape. It can be attributed to difference in score. Thus, so it's not likely to be motivated by winter or summer time of appliance use.

Table 8-1 Demographic Factors Correlation Summary

Appliances category	Number of people		Number of bedrooms		Age group	
	winter	summer	winter	summer	winter	summer
Light-duty cooking	✓	✓	✓	✓	✓	✓
Heavy-duty cooking						
Office and Entertainment	✓	✓	✓	✓	✓	✓
Other			✓			

8.4 Summary

This chapter has presented the research finding, which clearly demonstrate the relation between the daily appliances usage and the household's demographic factors in the UK. Approximately 22 % respondents, who were surveyed, were using efficient appliances, which reflect lack of awareness of impact of the daily appliances usage on the daily and peak demand. Lack of such information was found responsible for increasing the demand during the peak period. This lack of detailed individual information regarding to the daily usage has led to 25 % to 32 % increasing the daily demand. A strategy is needed to accommodate the demand growth, and for designing, the management system based on each consumer type and load. It shows that there are statistically significant differences in number of people, number of bedrooms and age of the residents on the combined appliances along with all participants. In addition, the relative importance index method (RII) was involved to identify the importance of each demographic factor on household's appliances usage. It revealed that number of bedrooms was the most important factor, which leads to higher appliances usage in the household, as it was ranked the first amongst most of relative index. The following chapter presents the conclusion for the whole thesis and creates recommendations, limitations and future work.

Chapter 9 Conclusion, Recommendation, and Future Work

9.1 Introduction

The major aim of the research is to develop a statistical model of the household electrical appliances in Hillingdon Borough of London in the UK. Functioning and routine appliances usage as examine in order to get a better understanding of household's appliances management for domestic energy conservative.

The regression analysis of the survey results showed that the overall daily usage of household's appliances is less influence by some demographic factors. However, number of people and household's size has an influence on all the household's appliances.

As per the first research question (Why do we need accurate data of household electrical appliances consumptions?), the study identifies all elements, which have a major influence on the household's appliances.

As per the second research questions (Why do we need a breakdown of this data?), the study provides a worthy evidence for an individual household's appliances daily consumption contribution to the total daily consumption and the importance of each demographic factors, where an effective quantitative analysis was conducted through SPSS via the correlation, regression test and relative importance index. Factors like number of people and household's size have influences over appliances usage showed some fruitful insights, which would help in controlling and managing the household's daily demand of UK domestic sector.

As per the third research question (What are the significant factors affecting the appliances usage?), the Pratt index (relative importance) analysis of the data helped in identified the most importance demographic factors per each appliance.

9.2 Importance of the Research Outcomes

In this study, the overall criteria for the time of use have been divided into practical time intervals to evaluate the performances of consumers towards the daily appliances. The study also examined different demographic factors that influence the daily appliances usage time and performance of using more efficient appliances for daily activity, including the relative contribution of daily performance for the household's appliances. Considering the ownership level and type of the household's appliances within the UK domestic sector, this study provides a domestic-level model of routine, managing and measurement of household's appliances. This model is most likely to help consumers to gain a better understanding of their habits of using appliances, and then they can change their habit or adopt a different life style to reduce their energy bills and decrease the daily and peak demand. Objectives have exposed to be a great importance in aggregation with daily activity together play a significant role in the overall prediction and manging the use of the household's appliances. Other than this, the performance of daily activity is relatively complex and combined; hence, different demographic factors are influencing the performance of household's daily demand. The study highlighted factors that can be merged within the household's electricity model to achieve better energy conservative and efficiency. It will help the consumers achieve better performance and reduce their energy bills without impeding their routines. Most importantly, the research also delivers energy suppliers with an on-hand breakdown and findings of the household's appliances within the UK.

9.3 General Conclusion

In addition to the mentioned importance of this research, there are other conclusions that have emerged from this study are as follows:

- ❖ A comprehensive literature review was conducted to highlighting the main household electricity consumption along with an investigation of the critically significant demographic factors, and to understand derives of increasing the daily household's demand, which has been defined for the purpose of this research. The main purpose of the developed the model is to update the domestic consumer awareness, which have not previously investigated.
- ❖ A household survey questionnaire was distributed to respondents and 381 were collected, comprising two bedrooms houses, three bedrooms houses, four bedrooms houses, conducted during academic year 2014 / 2015 with a response rate of 84 %.
- ❖ The quantitative data were analysed by using Statistical Package for Social Science (SPSS) software, version 20.
- ❖ Household's appliances usage was investigated empirically based on the quantitative approach. The need for understand the consumer usage in the UK is significantly important for energy suppliers, especially with increasing the penetration of daily appliances, electric vehicle, and deployment of using renewable energy sources. The peak demand period plays a significant role in increasing the daily demand and increasing the stress on the distribution networks. The purpose of implementing energy

conservative policy is associated with completing and developing management systems to achieve the energy demand reduction in the domestic sector.

- The outcome of this research showed that many studies do not give enough attention to increasing the household's appliances penetration. This was due to lack of detailed on disaggregated appliances usage data.
- The domestic energy conservative requires significant attention from bottom to up to help the energy policy maker to achieve their goals, by converting the recommendations into practice, and apply energy conservative strategy practically.

In addition, the essential future challenge for the domestic sector in the UK contains two main reciprocally decisive goals; as technologies are increasing constantly, there should be a clear strategy, which would support the increasing appliances efficiency demands and the future requirements in order to reduce the daily demand. Yet, it appears that the rapid growth of the penetration of electrical appliances will be highly recommended to be under efficiency measurements. According to the real current level of domestic demand in the UK and the new trends faced in terms of peak periods, it is vital for the domestic consumers to ensure that any additional reforms would be to reduce the demand during the peak period, and accommodate renewable energy sources development in the domestic sector.

9.4 Recommendations

In the discussion chapter, more details about the research findings gained from the data collected, which were illustrated in-depth in chapters 5, 6, and 7. However, there should be important recommendations in the direction of improving and evaluating household's appliances for the UK domestic sector especially where this study was conducted.

- Expound the increasing demand due to the highly penetration of household's appliances.
- Highlight the benefits of using more efficient appliances and the use of renewable energy sources in domestic sector.
- Get updated and complete information about customer behaviour and the connections with the appliances usage and how they are using the appliances on daily bases.
- Classify household appliances based on usage time rather than their functionality.
- Provide consumers with detailed information based on their daily habits and usage.
- Establishing a household's appliances database to contribute to the improvement and development of information that are related to daily demand and peak demand.

- ❖ Gradually eliminating the usage of poor efficient highly demand appliances such as wet appliances for more efficient to avoid associated electricity theft by faulty connection to the distribution networks, which lead to PQ issues.
- ❖ Allow easier identification of efficiency rate labelling.
- ❖ Apply more visual persuasion to increase the consumer's awareness regarding to the daily demand.

Therefore, employing these recommendations among domestic consumers will facilitate tackling increasing the domestic demand. Increasing the daily demand among household's appliances are thought to be caused by increasing the appliances penetration at certain period (peak periods demand). Therefore, the domestic sector seems to be in much need of physical and behaviour enhancements.

On the other hand, about managing the loads, households are required to provide loads record, and ensure cost-effective replacements of users' appliances. Therefore, adequate investment in efficient appliances or smart energy management systems needs to be made to reduce demand increasing of households and to ensure a high level of energy efficiency in managing energy.

9.5 Research Limitations

Data regarding the household's appliances availability was a vital problem in this study. There is no efficient data mechanism in domestic sector. Although, this study has followed a quantitative research method, there are expectedly limitations in every such study. Firstly, daily habits of consumers regarding using the appliances are mainly a complicated and any particular study mainly targets on the perception of the borough rather than the individual perception. This study did not encompass the level of education of the consumers, even though the perspective of the individual consumer was similarly important within this study of household's appliances as it can give a better understanding and a bigger image of how appliances might boost their demand. Therefore, would have been better to consider including both ownership-level and individual-usage pattern. However, in such case the study objectives would become unattainable due to time limitation and resources.

9.6 Future Work

The concept of appliance time of use is considered as a new phenomenon due to insufficient data from previous studies. This requires more consideration and studies to be undertaken to raise the importance of the phenomena and highlight the directions of better solutions. Moreover, this research attempts to highlight the main demographic factors influencing the usage of the household's appliances and lack of disaggregated data. Therefore, the findings would be useful to researchers and students, who are interested in knowing the factors associated with household's appliances.

This study was conducted in Hillingdon Borough of London. However, this study can be nationally generalized, if all households included and studied, which can lead to focusing on the overall household's appliances daily demand, in terms of guidelines in order to draw more recommendations and conclusions. This study focused on the household's appliances only. Future researches work can be carried out to cover overall demand by considering both the electricity and gas as they are the main power sources for the domestic sector. This can lead to a comparative analysis and studies between demographic factors and daily demand of the households by taking into account the household categories in terms of size, type, age and number of people live in the household.

Future work should be undertaken to focus on the increasing the penetration of the household's appliances. This can lead to providing in depth data in how to establish clear strategy for domestic management and involving all potential trends. Future research is needed to reveal the significant impact of the end user behaviour and habits on the daily demand. This can provide a widespread data regarding to understanding and to discover relationships when household's appliances used. More future research work can be undertaken on how the consumers and suppliers can play significant roles and influence on short time changes in energy pricing, and how their cooperation is important to reduce the demand. The household's appliances model was developed and validated for the Hillingdon borough of London in the UK. Future work needs to be undertaken to apply this model practically on real performance in the UK, and to assess its efficacy along with increasing the penetration of EV and PHEV.

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Appendix A

Dear Participant

This survey is being conducted to determine the load requirement of UK typical houses. You are invited to participate in this research survey study by completing the attached questionnaire. The attached questionnaire will take approximately 5 to 10 minutes to complete. In order to ensure that all information will remain confidential, please do not include your name, or any contact details. It will remain anonymous.

If you choose to participate in this research, please answer all questions as honestly as possible and return the completed questionnaires promptly. Should you have any quires or comments regarding this questionnaire, please do not hesitate to contact me.

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SURVEY ON DETERMINATION OF THE LOAD REQUIREMENT OF THE UK TYPICAL HOUSES

Kindly note: This questionnaire has separate entries for a typical **summer** and **winter** power consumption days.

- Please be aware that the table should be completed according to daily appliances usage.
- Please note that the table need to be filled according to family resident, not for sharing or students.
- A complete day hours is divided into 4 intervals (5am-9am. 9am-4pm, 4pm-9pm and 9pm-5am).
- You can include other electrical devices or appliances not mentioned in the list.
- Only electric items are considered (For example, electric cookers are considered but not gas cookers).

Q1. Including yourself, how many people are living in your household ☐

Q2. How many bedrooms in your household ☐

Q3. Which of the following best describes the household?

1- The household owned outright ☐

2- The household being bought on a mortgage ☐

3- The household being rented ☐

Q4. Which of the following best describe the household's occupant's employment status?

Full time ☐ Part time ☐ Retired ☐ Unemployment ☐

Q5. Which of the following describe the age of the household's residents (please indicate the number of adults and children)

Adult ☐ Child ☐

Q6. Which of the following is applying to you?

1- Using normal appliances ☐

☐

2- Using efficient appliances

3- I don't know ☐

Q7. Please tick the appropriate box according to the appliances usage in winter.

1- Cooking appliances

Appliances	Time of use			
	5am-9am	9am-4pm	4pm-9pm	9pm-5am
1. **Example:** Electrical kettle	☑	☐	☐	☐
2. Electrical Kettle	☐	☐	☐	☐
3. Coffee Maker	☐	☐	☐	☐
4. Toaster	☐	☐	☐	☐
5. Microwave	☐	☐	☐	☐
6. Popcorn popper	☐	☐	☐	☐
7. Blender/Juicer	☐	☐	☐	☐
8. Waffle/Sandwich maker	☐	☐	☐	☐
9. Hot Plate	☐	☐	☐	☐
10. Electrical Frying Pan	☐	☐	☐	☐
11. Bread Machine	☐	☐	☐	☐
12. Food Steamer	☐	☐	☐	☐
13. Rice Cooker	☐	☐	☐	☐
14. Pressure Cooker	☐	☐	☐	☐
15. Electrical cooker	☐	☐	☐	☐
16. Kitchen extractor	☐	☐	☐	☐

2- Entertainment and office

Appliances	Time of use			
	5am-9am	9am-4pm	4pm-9pm	9pm-5am
1. Laptop	☐	☐	☐	☐
2. Desktop	☐	☐	☐	☐
3. Printer, scanner and photocopier	☐	☐	☐	☐
4. shredder	☐	☐	☐	☐
5. TV set	☐	☐	☐	☐
6. DVD,CD players and radios et	☐	☐	☐	☐

3- Wet appliances

Appliances	Time of use			
	5am-9am	9am-4pm	4pm-9pm	9pm-5am
1. Dish washer	☐	☐	☐	☐
2. Washing machine	☐	☐	☐	☐
3. Clothes dryer	☐	☐	☐	☐

4- Other appliances

Appliances	Time of use			
	5am-9am	9am-4pm	4pm-9pm	9pm-5am
1. Electrical shower	☐	☐	☐	☐
2. Hair dryer, straightener and curlers	☐	☐	☐	☐
3. Electrical shaver and tooth brush	☐	☐	☐	☐

4. Vacuum cleaner	☐	☐	☐	☐
5. Iron	☐	☐	☐	☐
6. Electrical Garage opener	☐	☐	☐	☐

Q8. Please tick the appropriate box according to the appliances usage in summer.

1- Cooking appliances

Appliances	**Time of use**			
	5am-9am	**9am-4pm**	**4pm-9pm**	**9pm-5am**
1. **Example:** Electrical kettle	☑	☐	☐	☐
2. Electrical Kettle	☐	☐	☐	☐
3. Coffee Maker	☐	☐	☐	☐
4. Toaster	☐	☐	☐	☐
5. Microwave	☐	☐	☐	☐
6. Popcorn popper	☐	☐	☐	☐
7. Blender/Juicer	☐	☐	☐	☐
8. Waffle/Sandwich maker	☐	☐	☐	☐
9. Hot Plate	☐	☐	☐	☐
10. Electrical Frying Pan	☐	☐	☐	☐
11. Bread Machine	☐	☐	☐	☐
12. Food Steamer	☐	☐	☐	☐
13. Rice Cooker	☐	☐	☐	☐
14. Pressure Cooker	☐	☐	☐	☐
15. Electrical cooker	☐	☐	☐	☐
16. Kitchen extractor	☐	☐	☐	☐

2- Entertainment and office

Appliances	Time of use			
	5am-9am	9am-4pm	4pm-9pm	9pm-5am
1. Laptop	☐	☐	☐	☐
2. Desktop	☐	☐	☐	☐
3. Printer, scanner and photocopier	☐	☐	☐	☐
4. shredder	☐	☐	☐	☐
5. TV set	☐	☐	☐	☐
6. DVD,CD players and radios et	☐	☐	☐	☐

3- Wet appliances

Appliances	Time of use			
	5am-9am	9am-4pm	4pm-9pm	9pm-5am
1. Dish washer	☐	☐	☐	☐
2. Washing machine	☐	☐	☐	☐
3. Clothes dryer	☐	☐	☐	☐

4- Other appliances

Appliances	Time of use			
	5am-9am	9am-4pm	4pm-9pm	9pm-5am
1. Electrical shower	☐	☐	☐	☐
2. Hair dryer, straightener and curlers	☐	☐	☐	☐
3. Electrical shaver and tooth brush	☐	☐	☐	☐
4. Vacuum cleaner	☐	☐	☐	☐

5. Iron	☐	☐	☐	☐
6. Electrical Garage opener	☐	☐	☐	☐

Thank you for taking a part of this survey.

Ethical approval

Brunel University London

Brunel University London
Uxbridge UB8 3PH
United Kingdom

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14 January 2015

STATEMENT OF ETHICS APPROVAL

Proposer : Mussa Sheboniea

Project Title: Investigating Energy Management System for Smart Home Usage

Under delegated authority from the College Research Ethics Committee I have considered the proposal recently submitted by you. I am satisfied that there is no objection on ethical grounds to the proposed study.

Approval is given on the understanding that you will adhere to the terms agreed with participants and to inform me of any change of plans in relation to the information provided in the application form.

Yours sincerely,

John Park
College Research Manager
T +44(0)1895 266057| E John.Park@brunel.ac.uk

Brunel University London
College of Engineering, Design and Physical Sciences

Appendix B

Appendix A: Representation of the Respondents

Gender	Frequency	Percent	Valid Percent	Cumulative Percent
male	211	55.4	55.4	55.4
female	170	44.6	44.6	100.0
Total	381	100.0	100.0	
Number of bedrooms				
2	126	33.1	33.1	33.1
3	165	43.3	43.3	76.4
4	54	14.2	14.2	90.6
5 & more	36	9.5	9.5	100.0
Total	381	100.0	100.0	
Type of the household				
owned outright	88	23.1	23.1	23.1
Bought on a mortgage	186	48.8	48.8	71.9
Rented and Other	107	28.1	28.1	100.0
Total	381	100.0	100.0	
Number of people live in the household				
2	133	34.9	34.9	34.9
3	123	32.3	32.3	67.2
4	90	23.6	23.6	90.8
5	27	7.1	7.1	97.9
6	7	1.8	1.8	99.7
7	1	.3	.3	100.0
Total	381	100.0	100.0	
Current employment status				
full time	115	30.2	30.2	30.2
part time	99	26.0	26.0	56.2
Retired and Unemployment	51	13.4	13.4	69.6
Full time and retired	42	11.0	11.0	80.6
full time and part time	46	12.1	12.1	92.7
Part time and retired	28	7.3	7.3	100.0
Total	381	100.0	100.0	
Age category				
2 adults	99	26.0	26.0	26.0
1 adult and 1 children	37	9.7	9.7	35.7
2 adults and 1 children	80	21.0	21.0	56.7
1 adult and 2 children	43	11.3	11.3	68.0
2 adults and 2 children	66	17.3	17.3	85.3
other	56	14.7	14.7	100.0
Total	381	100.0	100.0	
Appliances efficiency rate				
using efficient appliances	84	22.0	22.0	22.0
using normal appliances	200	52.5	52.5	74.5
don't know	71	18.6	18.6	93.2
don't care	26	6.8	6.8	100.0
Total	381	100.0	100.0	

Appendix B: Household's appliances usage pattern [69], [54], [156], [17]

appliances	Power rating			Usage pattern		
	Min.	Max.	average	Min.	Max.	average
Kettle	2.2	3	2.6	3	5	4
Coffee maker	0.2	0.2	0.2	10	10	10
Toaster	0.8	1.5	1.15	5	5	5
Microwave	0.6	1.5	1.05	5	5	5
Popcorn popper	1.4	1.4	1.4	5	5	5
Blender/juicer	0.3	0.4	0.35	2	10	6
Waffle iron and sandwich maker	0.7	1.2	0.95	15	25	20
Hot plate	1.2	1.2	1.2	15	45	30
Electrical frying pan	1.2	1.2	1.2	10	30	20
Bread maker	0.55	0.65	0.6	30	60	45
food steamer	0.65	0.8	0.725	30	60	45
rice cooker	0.6	0.6	0.6	15	15	15
pressure cooker	1	1.4	1.2	30	60	45
Electrical cooker	1.3	1.3	1.3	30	60	45
Kitchen extractor	0.005	0.036	0.0205	30	60	45
Laptop	0.02	0.05	0.035	159	159	159
Desktop	0.08	0.15	0.115	159	159	159
Printer, scanner and photocopier	0.3	0.5	0.4	20	20	20
Shredder	0.146	0.146	0.146	5	5	5
TV set	0	0	0	159	159	159
DVD CD players and radio	0.2	0.45	0.325	211	211	211
Dish washer	0.02	0.06	0.04	211	211	211
Washing machine	0	0	0	58	58	58
Clothes dryer	0	0	0	211	211	211
Electrical shower	1.05	1.5	1.275	40	40	40
Hair dryer, straightener and curlers	1.2	3	2.1	40	60	50
Electrical shaver and tooth brush	2	3	2.5	40	60	50
Vacuum cleaner	7	10.5	8.75	15	30	22.5
Iron	1	1	1	5	10	7.5
Electrical garage door opener	0.015	0.015	0.015	3	5	4

Appendix C: Scores of the household type categories

Ranks	Type of the household	N		Mean Rank	
		winter	summer	winter	summer
Light-duty Cooking appliances	owned outright	88	88	189.20	195.50
	Bought on a mortgage	186	186	192.33	191.47
	Rented and Other	107	107	190.17	186.49
Heavy-duty cooking appliances	owned outright	88	88	182.58	186.41
	Bought on a mortgage	186	186	201.07	204.58
	Rented and Other	107	107	180.43	171.17
Entertainment	owned outright	88	88	197.70	191.40
	Bought on a mortgage	186	186	193.17	197.77
	Rented and Other	107	107	181.72	178.91
Wet appliances	owned outright	88	88	184.56	187.57
	Bought on a mortgage	186	186	201.10	194.97
	Rented and Other	107	107	178.75	186.93
Other appliances	owned outright	88	88	187.36	190.54
	Bought on a mortgage	186	186	193.27	191.34
	Rented and Other	107	107	190.06	190.79

Appendix D: Scores of the current employment categories

Ranks	Current employment status	N		Mean Rank	
		winter	summer	winter	summer
Light-duty Cooking appliances	full time	115	115	183.66	185.83
	part time	99	99	194.33	185.38
	Retired and Unemployment	51	51	190.75	196.58
	Full time and retired	42	42	195.86	215.37
	full time and part time	46	46	197.65	187.85
	Part time and retired	28	28	191.63	190.59
Heavy-duty cooking appliances	full time	115	115	189.90	191.01
	part time	99	99	206.82	199.57
	Retired and Unemployment	51	51	171.59	190.17
	Full time and retired	42	42	197.21	205.44
	full time and part time	46	46	175.13	170.24
	Part time and retired	28	28	191.70	174.63
Entertainment	full time	115	115	183.56	190.08
	part time	99	99	189.22	183.26
	Retired and Unemployment	51	51	192.37	198.41
	Full time and retired	42	42	215.00	204.80
	full time and part time	46	46	179.82	183.67

	Part time and retired	28	28	207.73	199.98
Wet appliances	full time	115	115	193.90	196.94
	part time	99	99	191.13	197.02
	Retired and Unemployment	51	51	196.07	200.96
	Full time and retired	42	42	179.77	182.21
	full time and part time	46	46	194.62	178.59
	Part time and retired	28	28	180.29	160.77
Other appliances	full time	115	115	201.18	204.21
	part time	99	99	187.19	188.22
	Retired and Unemployment	51	51	184.55	188.80
	Full time and retired	42	42	184.69	185.96
	full time and part time	46	46	188.54	182.10
	Part time and retired	28	28	187.89	172.77

Appendix E: Scores of the appliances efficiency rate

Ranks	appliances efficiency rate	N		Mean Rank	
		winter	summer	winter	summer
Light duty Cooking appliances	using efficient appliances	84	84	191.57	189.76
	using normal appliances	200	200	189.96	185.37
	don't know	71	71	189.69	210.69
	don't care	26	26	200.73	184.52
Heavy duty cooking appliances	using efficient appliances	84	84	197.58	199.43
	using normal appliances	200	200	193.57	188.97
	don't know	71	71	187.01	199.06
	don't care	26	26	160.92	157.37
Entertainment	using efficient appliances	84	84	179.71	179.71
	using normal appliances	200	200	197.60	196.69
	don't know	71	71	180.51	187.58
	don't care	26	26	205.38	193.04
Wet appliances	using efficient appliances	84	84	178.38	186.49
	using normal appliances	200	200	200.80	195.30
	don't know	71	71	178.90	192.58
	don't care	26	26	189.42	168.15
Other appliances	using efficient appliances	84	84	191.07	197.68
	using normal appliances	200	200	194.25	190.58
	don't know	71	71	188.29	193.13
	don't care	26	26	173.23	166.85

Appendix F: Score of the age categories

Ranks	age categories	N		Mean Rank	
		winter	summer	winter	summer
Light-duty Cooking appliances	2 adults	99	99	170.60	167.32
	1 adult and 1 children	37	37	184.45	170.24
	2 adults and 1 children	80	80	203.55	213.70
	1 adult and 2 children	43	43	140.80	136.62
	2 adults and 2 children	66	66	222.43	228.98
	other	56	56	214.96	211.15
Heavy-duty cooking appliances	2 adults	99	99	188.84	186.64
	1 adult and 1 children	37	37	193.23	177.46
	2 adults and 1 children	80	80	187.74	199.50
	1 adult and 2 children	43	43	213.65	206.14
	2 adults and 2 children	66	66	181.17	197.44
	other	56	56	192.19	176.29
Entertainment	2 adults	99	99	186.56	175.10
	1 adult and 1 children	37	37	217.16	215.53
	2 adults and 1 children	80	80	190.83	194.24
	1 adult and 2 children	43	43	206.59	203.05
	2 adults and 2 children	66	66	166.07	176.67
	other	56	56	199.22	205.91
Wet appliances	2 adults	99	99	198.10	197.41
	1 adult and 1 children	37	37	159.89	175.61
	2 adults and 1 children	80	80	217.31	198.57
	1 adult and 2 children	43	43	198.86	196.27
	2 adults and 2 children	66	66	176.02	172.61
	other	56	56	173.04	196.66
Other appliances	2 adults	99	99	184.53	188.35
	1 adult and 1 children	37	37	186.57	193.41
	2 adults and 1 children	80	80	199.03	201.34
	1 adult and 2 children	43	43	196.83	184.67
	2 adults and 2 children	66	66	199.86	180.51
	other	56	56	178.99	196.54

Appendix G: Light-duty cooking appliance's Models summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.179[a]	.032	.014	2.89543	.032	1.773	7	373	.091	1.785
a. Predictors: (Constant), AER, NPTH, CES, RG, NB, Age										
b. Dependent Variable: Light-duty Cooking appliances winter										
1	.194[a]	.038	.020	2.85838	.038	2.089	7	373	.044	1.640
a. Predictors: (Constant), AER, NP,TH, CES, RG, NB, Age										
b. Dependent Variable: Light-duty Cooking appliances (Summer)										

Appendix H: Heavy-duty cooking Appliance's Multiple Regression Models Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.101[a]	.010	-.008	3.91485	.010	.552	7	373	.795	1.569
a. Predictors: (Constant), AER,NP, TH, CES, RG, NB, Age[b]										
b. Dependent Variable: Heavy-duty cooking appliances (Winter)										
1	.101[a]	.010	-.008	3.13804	.010	.554	7	373	.793	1.689
a. Predictors: (Constant), AER, NP, TH, CES, RG, NB, age										
b. Dependent Variable: Heavy duty cooking appliances (Summer)										

Appendix I: Heavy-duty cooking Appliance's Multiple Regression ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	59.175	7	8.454	.552	.795[b]
	Residual	5716.625	373	15.326		
	Total	5775.801	380			
a. Dependent Variable: Heavy-duty cooking appliances winter						
b. Predictors: (Constant), AER,NP, TH, CES, RG, NB, Age						
1	Regression	38.196	7	5.457	.554	.793[b]
	Residual	3673.038	373	9.847		
	Total	3711.234	380			
a. Dependent Variable: Heavy-duty cooking appliances summer						
b. Predictors: (Constant), AER, NP, TH, CES, RG, NB, age[b]						

Appendix J: Entertainment and Office Appliance's Multiple Regression Models Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.324a	.105	.088	3.76117	.105	6.268	7	373	.000	1.808
a. Predictors: (Constant), AER, NP, TH, CES, RG, NB, AGE										
b. Dependent Variable: Entertainment and Office winter										
1	.276a	.076	.059	3.67350	.076	4.402	7	373	.000	1.907
a. Predictors: (Constant), AER, NP, TH, CES, RG, NB, AGE										
b. Dependent Variable: Entertainment and Office summer										

Appendix K: Wet Appliance's Multiple Regression Models Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.139[a]	.019	.001	3.05878	.019	1.057	7	373	.391	1.768
a. Predictors: (Constant), AER, NP, TH, CES, RG, NB, AGE										
b. Dependent Variable: Wet appliances (Winter)										
1	.141[a]	.020	.001	2.51106	.020	1.081	7	373	.375	1.717
a. Predictors: (Constant), statement apply to you, Number of people live in a house, type of the household, Current employment status, Respondents Gender, Number of bedrooms in a house, age group of the household resident										
b. Dependent Variable: Wet appliances (Summer)										

Appendix L: Wet Appliance's Multiple Regression ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	69.222	7	9.889	1.057	.391[b]
	Residual	3489.849	373	9.356		
	Total	3559.071	380			
a. Dependent Variable: Wet appliances (Winter)						
b. Predictors: (Constant), AER, NP, TH, CES, RG, NB, AGE[b]						
1	Regression	47.705	7	6.815	1.081	.375[b]
	Residual	2351.917	373	6.305		
	Total	2399.622	380			
a. Dependent Variable: Wet appliances (Summer)						
b. Predictors: (Constant), AER, NP, TH, CES, RG, NB, Age[b]						

Appendix M: Other Appliance's Multiple Regression Models Summary#

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.171[a]	.029	.011	3.82292	.029	1.601	7	373	.134	1.645
a. Predictors: (Constant), AER, NP, TH, CES, RG, NB, AGE										
b. Dependent Variable: Other appliances (Winter)										
1	.127[a]	.016	-.002	3.84690	.016	.869	7	373	.531	1.702
a. Predictors: (Constant), AER, NP, TH, CES, RG, NB, AGE										
b. Dependent Variable: Other appliances (Summer)										

Appendix N: Other Appliance's Multiple Regression ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	163.809	7	23.401	1.601	.134[b]
	Residual	5451.293	373	14.615		
	Total	5615.102	380			
a. Dependent Variable: Other appliances (Winter)						
b. Predictors: (Constant), AER, NP, TH, CES, RG, NB, AGE						
1	Regression	90.066	7	12.867	.869	.531[b]
	Residual	5519.887	373	14.799		
	Total	5609.953	380			
a. Dependent Variable: Other appliances (Summer)						
b. Predictors: (Constant), AER, NP, TH, CES, RG, NB, AGE						

Appendix O: Sample of household details

RECORD No.	Gender	House size	House type	No. ppl	Employment status	Age group	Statements apply
1	male	2	owned outright	2	full time	2 adults	using normal appliances
2	female	2	Bought on a mortgage	3	full time	1 adult and 1 children	using normal appliances
3	female	2	Bought on a mortgage	3	Full time and retired	2 adults and 1 children	using normal appliances
4	male	2	Rented and Other	3	full time and part time	1 adult and 2 children	don't care
5	male	2	Bought on a mortgage	2	Part time and retired	2 adults	don't care
6	female	2	owned outright	3	part time	2 adults and 1 children	don't know
7	male	2	owned outright	2	full time	2 adults	using normal appliances
8	female	2	Bought on a mortgage	2	Retired and Unemployment	1 adult and 1 children	don't know
9	female	2	Rented and Other	3	part time	2 adults and 1 children	using normal appliances
10	female	2	Rented and Other	2	full time	1 adult and 1 children	using efficient appliances
11	female	2	Rented and Other	2	full time and part time	1 adult and 1 children	using normal appliances
12	male	2	Rented and Other	2	full time	2 adults	using efficient appliances
13	male	2	Rented and Other	2	Full time and retired	2 adults	don't know
14	male	2	owned outright	2	part time	2 adults	using normal appliances
15	female	2	Bought on a mortgage	2	Part time and retired	1 adult and 1 children	using normal appliances
16	male	2	Rented and Other	3	full time and part time	1 adult and 2 children	using normal appliances
17	male	2	Rented and Other	3	part time	2 adults and 1 children	using normal appliances
18	male	2	Bought on a mortgage	3	Retired and Unemployment	2 adults and 1 children	using normal appliances
19	female	2	Rented and Other	2	full time	2 adults	using normal appliances
20	male	2	owned outright	3	full time	2 adults and 1 children	using efficient appliances
21	male	2	Bought on a mortgage	2	Full time and retired	1 adult and 1 children	using normal appliances
22	male	2	Bought on a mortgage	3	full time	2 adults and 1 children	using normal appliances

Appendix C: samples of data coding

Appliances time of use.sav [DataSet2] - IBM SPSS Statistics Data Editor

File Edit View Data Transform Analyze Direct Marketing Graphs Utilities Add-ons Window Help

	KettleW	CoffeemakerS	CoffeeMakerW	ToasterS	ToasterW	MicrowaveS	MicrowaveW	PopcornPopperS	PopcornPopperW
1	1	0	0	1	1	3	3	0	0
2	1	0	0	1	1	3	3	0	0
3	1	1	1	1	1	0	3	0	0
4	1	0	0	1	1	3	3	0	0
5	1	0	0	1	1	3	3	0	0
6	1	0	0	1	1	3	3	0	0
7	1	0	1	2	2	3	3	0	3
8	1	1	1	2	2	3	3	0	0
9	3	0	0	1	2	0	0	0	0
10	3	1	1	0	0	0	0	0	0
11	3	0	1	0	0	0	0	0	0
12	3	0	0	0	0	3	3	0	0
13	1	0	0	0	1	2	2	0	3
14	1	0	0	1	1	2	2	0	4
15	1	0	0	1	1	2	2	0	0
16	1	0	0	2	2	3	3	0	0
17	1	0	0	1	1	4	1	0	0
18	0	0	0	0	0	4	4	0	0
19	1	0	0	0	0	3	4	0	0
20	1	0	0	0	0	2	2	0	0
21	3	0	0	1	1	2	2	0	0
22	1	0	0	0	0	0	0	0	0
23	3	0	0	2	2	2	2	0	0
24	1	0	0	1	1	2	2	0	0
25	3	0	0	3	3	3	3	0	0
26	3	0	0	3	3	1	1	0	0
27	1	1	1	1	1	1	1	0	0
28	3	2	2	0	0	4	3	0	0
29	3	0	0	0	0	3	3	0	0
30	3	0	0	0	0	3	3	0	0
31	1	0	0	0	0	3	3	0	0
32	1	0	1	0	0	0	0	0	0

*Appliances ownership.sav [DataSet1] - IBM SPSS Statistics Data Editor

File Edit View Data Transform Analyze Direct Marketing Graphs Utilities Add-ons Window Help

	Gender	housesize	housetyoe	Noppl	employment	age	statementsapply	kettleS	KettleW	CoffeemakerS	CoffeeMakerW	ToasterS
349	2	3	1	3	1	3	3	1	1	1	1	0
350	2	3	2	2	2	2	3	1	1	0	0	0
351	1	4	3	5	3	6	1	1	1	0	0	0
352	2	2	1	2	6	1	3	1	1	0	0	0
353	1	5	2	3	5	3	3	1	1	0	0	0
354	1	6	3	6	4	6	1	1	1	0	0	1
355	2	4	2	4	1	6	4	1	1	1	1	1
356	2	2	1	2	2	1	4	1	0	0	0	0
357	1	2	2	3	2	3	2	1	1	0	0	1
358	1	2	2	4	1	5	3	1	1	0	0	1
359	2	3	2	4	3	6	3	1	1	0	0	0
360	1	2	2	2	2	1	4	1	1	0	0	1
361	1	2	1	3	1	4	4	1	1	0	0	0
362	1	3	2	2	6	1	4	1	1	0	0	1
363	1	3	2	3	3	4	3	1	1	0	0	1
364	1	4	1	5	1	6	3	1	1	0	0	1
365	2	4	2	3	1	4	2	1	1	0	0	1
366	2	3	1	3	1	3	3	1	1	0	0	1
367	1	3	2	4	1	5	3	1	1	0	0	1
368	2	2	3	2	4	1	1	1	1	0	0	0
369	2	3	3	4	1	6	2	0	0	0	0	1
370	1	3	2	2	4	1	2	0	0	0	0	1
371	1	2	1	4	1	5	4	1	1	0	0	1
372	1	2	1	3	2	4	4	0	0	0	0	0
373	1	2	2	4	1	6	2	0	1	0	0	0
374	2	3	2	4	2	6	3	0	0	0	0	0
375	1	3	3	3	1	3	2	0	0	0	0	1
376	1	5	3	4	2	5	3	0	1	1	1	1
377	1	3	2	3	1	3	4	0	1	0	0	1
378	1	3	3	4	2	5	4	0	0	0	0	0
379	1	3	3	3	1	4	4	1	1	0	1	0
380	2	5	1	4	3	5	2	1	1	0	0	0