UNDERSTANDING RESIDENTIAL ELECTRICITY CONSUMPTION CONSIDERING EFFICIENCY POLICIES AND THE IMPACT ON THE ELECTRICITY SYSTEM

A thesis submitted to the
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by

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I, MERYEM NUR MORGÜL, declare that this thesis titled, 'UNDERSTANDING RESIDENTIAL ELECTRICITY CONSUMPTION CONSIDERING EFFICIENCY POLICIES AND THE IMPACT ON THE ELECTRICITY SYSTEM' and the work presented in it are my own. I confirm that:

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Abstract

Electricity consumption increases substantially over the years where residential use significantly contributes to the overall consumption. The growth in the population and variety of home appliances together with increasing comfort levels of the people results in higher levels of residential electricity use. In fact, nearly one fourth of Turkey's total electricity consumption is due to the domestic use. To achieve global sustainability targets and reduce the overall electricity use, focusing on the domestic consumption is crucial. In this research, the energy consumptions patterns of households are determined to identify the potential electricity savings existing in the residential sector, such as standby consumption and the potential electricity use which can be shifted to off-peak hours. Moreover, specific policy recommendations which can promote the behavioral change are driven by measuring the responsiveness of people to different measures and the combinations of measures such as information, feedback, rewards, and social influences.

A survey was conducted to determine the patterns and the responsiveness of the residential customers. The results obtained from the survey are used to depict a general view of Turkish households towards electricity consumption behaviors and their energy efficiency attitudes. Responses indicate there should be more regulations and improvements in energy policy. Moreover, clustering technique is used to characterize the groups of households. Cluster analysis proved the importance of unique and more specific interventions on energy saving among households. In the end, an electricity allocation problem is solved in order to see possible impacts of behavioral change measures on the network. Scenarios are defined for each policy and allocation problem is solved to see the possible generation cost reduction. Also, gas emissions for each scenario is recorded to understand the possible effects of policies on the environment. Results show that behavioral change studies seem to be well worth to study. In order to reach residential efficiency, possible policy alternatives are suggested for Turkish households.

Keywords: Energy efficiency, consumer behaviors, behavioral change, household survey, cluster analysis, impacts on electricity network.

VERİMLİLİK POLİTİKALARINI DEĞERLENDİREREK HANELERDE ELEKTRİK TÜKETİMİNİN ANLAŞILMASI VE ELEKTRİK SİSTEMİ ÜZERİNE ETKİSİNİN İNCELENMESİ

MERYEM NUR MORGÜL

Öz

Elektrik tüketimi yıllar içinde hızla artarken, konutlarda tüketilen elektriğin payı da hızla artmıştır. Evlerde kullanılan elektriğin artışı, nüfus artışı, kullanılan elektrikli gereçlerin sayısı ve çeşitliliği ve insanların daha konforlu yaşama istekleriyle izah edilebilir. Bugün Türkiye'de tüketilen toplam elektriğin dörtte biri konutlarda tüketilmektedir. Sürdürülebilir kalkınma için enerji verimliliği şarttır. Sürdürülebilirlik konusunda ulusal ve uluslararası hedeflerin yakalanması için evlerde enerjinin daha verimli kullanılması konusunda gerekli adımlar atılmalıdır. Bu çalışmada, hanehalkının elektrik tüketim tutum ve davranışları araştırılmış, tüketici davranışlarının değiştirilmesi neticesinde tasarruf edilebilir enerjinin önemi vurgulanmaya çalışılmıştır. Yapılan anket çalışması ile davranış değişikliğinde başarılı olmuş politikalar hanehalkına sunulmuş ve Türk tüketicilerinin olası politikalara yaklaşım ve tercihleri araştırılmıştır.

Anket sonuçları Türk tüketicilerinin evlerde elektriği nasıl kullandıkları, elektriği daha verimli kullanacak şekilde davranışlarını değiştirmede ne kadar istekli olduklarını ortaya koymuştur. Uygulanan politikaların tüketiciler tarafından bilinirliğinin çok düşük olması daha etkili politikaların geliştirilmesi gerekliliğini vurgulamıştır. Bu amaçla, ankete katılan haneler kümeleme analizi ile incelenmiş ve her hanenin her politikaya aynı oranda cevap vermeyeceği, tercihlerinin farklı olacağı analiz sonucuyla desteklenmiştir. Son olarak, geliştirilen matematiksel model ile farklı politika senaryolarının elektrik sistemi üzerindeki olası etkileri incelenmiştir.

Anahtar Sözcükler: Hanelerde elektrik tüketimi, enerji verimliliği, tüketici davranışları, davranış değişikliği, hanehalkı anketi, kümeleme analizi, elektrik sistemi.

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Chapter 1

Introduction

The world encounters many problems today and one of the largest issue of world agenda is sustainability. Therefore, efficient use of energy is accepted as a requirement to reach sustainability targets and also it is defined as additional type of energy resource in some references. Efficiency measures can be adopted in every aspect of life, such as transportation, industrial, and residential energy use.

The increase in residential electricity consumption brings a high importance to energy efficiency studies in residential areas. There are many factors influencing the increase and also many impacts of this increase. Higher number of end-users, variety of home appliances, and comfort seeking of the people are only some causes of the growth of residential energy consumption. The impact of this growth can be listed basically as unmet demand, high amount of energy import, more frequent electricity cuts, and so on.

The majority of the literature is concentrated on understanding households' energy consumption patterns to solve the problem in residential areas. In order to achieve residential efficiency, a deep research on consumer behaviors is required. Electricity consumption behaviors are a result of several factors such as demographics, economic, structural, individual, and so on. The data on the diversity and variation in electricity consumption between households is collected by surveying or monitoring households. This study does not only try to depict general information about Turkish households, but also looks at preferences of end-users for some policies via a survey. Policies promoting the efficient use of electricity through behavioral change are widely studied in the literature. The survey analysis comes up with general findings of the survey and also leads to a cluster analysis. Electricity use trends, policy opportunities, and the drivers of behavioral change are examined first. Then, clustering households into several groups according to certain variables makes it possible to estimate changes in the electricity network. A set of policies promoting behavioral change is defined and electricity dispatching problem is solved to investigate the effect of these policies on the network.

This thesis studies the impact of behavioral changes on the efficient use of electricity in residential areas. On this purpose, energy overview and understanding consumer behaviors have been researched. This chapter continues with our motivation for this research and our contribution with this thesis. Research problem is also summarized in the following section.

1.1. Motivation

World energy demand has been increasing due to population increase, industrialization, and urban development. In 2009, world primary energy demand was 12.15 Mtoe. The International Energy Agency (IEA) examined different scenarios and estimated energy demand in 2035 to reach 18.676 Mtoe with current policies. The rise in the emission rates is also obvious, and if there are not any policies adopted, it will reach 44.1 Gt CO_2 by 2035, which is 46% higher than its value in 2010.

Turkey's primary energy demand is mostly based on fossil fuels such as coal, gas, and oil. Turkey's total energy consumption increased substantially between 2002 and 2010. The increase in residential sector was much higher than in the industrial sector. Residential use in Turkey accounts for nearly one quarter of the entire electricity consumption. Moreover, unfortunately, the country's energy sector is also dependent on imports.

In addition to increasing the residential energy demand of Turkey, the share of standby power use is also higher in Turkey than the OECD average. Also, existing studies show that awareness and consciousness of Turkish consumers about energy subjects is relatively lower than Europeans. Furthermore, the Turkish electricity market is still being liberalized, which means there is a lot to develop. The number of free consumers, who have the opportunity to choose their electricity provider, has been rising steadily.

Residential energy is used for several purposes from electricity use to water use, from cooking to lightening. Energy efficiency in homes can be achieved through a better design of buildings, insulation, and also having energy efficient products. However, consumer behavior towards energy efficiency is unquestionably important to reaching residential efficiency. The higher number of residential consumers brings about the necessity to study electricity consumption in residential areas. Domestic consumption depends on a variety of factors. These factors are demographics, economic, structural, cultural, individual, and technological factors, as well as climate, life style, and public policy. Each factor has an impact on the energy demand of a household, the impact of which varies greatly between households. As much as energy consumption patterns of households, policies to be applied will depend on all of these factors, especially consumer preferences and individual factors.

Individual factors in energy efficiency studies involve the awareness, willingness, and attitudes of people. Some people can be driven by monetary measures, whereas some cannot be bothered with costs and only are motivated by the social and environmental benefits of energy savings. There are many studies around the world where successful reductions in electricity demand have been achieved through consumer behavioral change. Providing information, feedback, giving rewards, and organizing social events to change energy consumption habits or adjust energy saving behaviors are contained in some of these studies. The uniqueness of each household requires a detailed study for what will work in Turkey.

Although there are many studies around the world where successful reductions in residential energy demand have been achieved through consumer behavioral change, there are almost no behavioral change studies in Turkey to reduce energy demand. The majority of the literature is concentrated on the impact of taking some certain efficiency measures on the electricity demand and the environmental effects of these measures. In this study, we would like to obtain general information about Turkish consumers towards electricity consumption and we would like to see the possible impact of offering new policies on energy demand, the economy, and environment. On this purpose, a questionnaire is designed and used to reach the research targets given in the following section.

1.2. Problem Definition

Electricity consumption increases substantially over the years where residential use significantly contributes to the overall consumption. The growth in the population and variety of the home appliances together with the increasing comfort levels of the people results in higher levels of residential electricity use. In fact, nearly one fourth of Turkey's total electricity consumption is due to domestic use. To achieve global sustainability targets and reduce the overall electricity use, focusing on the domestic consumption is crucial.

The scope of this study: (1) Understanding the electricity use of Turkish consumers, (2) Clustering households, (3) Determining behavioral change measures promoting efficient use of electricity, and (4) Considering the impact of efficiency policies on the electricity network.

With the help of existing studies on the subject, surveying has been chosen to understand the consumption habits of Turkish households. The survey questions seek to answer the basic energy consumption behaviors of consumers, try to depict households' attitudes towards energy efficiency, and also learn their reactions to several behavioral change measures.

Similar studies on the subject indicate that consumer preferences differ a great deal among households. These differences can be explained by various factors, and understanding these factors can be challenging. For example, energy use of a household is affected by the number of people at home, the size of the house, the income of the household, and so on. However, with the same number of occupants in the same size house with an equal income, another household can consume energy differently. Internal factors such as values, intention, and attitudes explain this difference. As well as energy consumption, policies, which will succeed in efficient use of energy, will differ significantly among households. Therefore, clustering is a good technique to observe similar households in a single group. Instead of offering one single policy to all types of consumer, considering their preferences will bring much more efficiency in the residential sector.

Behavioral change measures can be summarized as information, feedback, rewards and disincentives, and also social influences. In the literature, there are numerous successful interventions of these measures. With the help of the designed questionnaire, more appropriate policy options to Turkish consumers can be determined.

Another target of the research is showing the impact of policy interventions on the electricity network. Making new policies promoting efficient use of electricity will help to reduce energy demand. However, as a requirement of sustainability, environmental impact of the policies should also be considered. The possible impact of energy efficiency policies on the electricity demand and the cost of electricity generation are determined via a general optimization problem.

These four research questions are examined through the study. Briefly, the main target is to show the importance of detailed understanding of Turkish consumers and focusing behavioral change to deal with increasing demand.

1.3. Contribution

There is not any comprehensive study focused on residential energy consumption in Turkey. Several studies have collected data on consumption habits of households and ownership rate of electrical products. However, to achieve residential energy efficiency, more detailed studies for better understanding of consumers are required. Especially, the number of academic research in this field is very limited. Although there are some studies for Turkish users, this study will be the first one to discover the general tendency of Turkish consumer groups' energy use and reactions of these groups to certain efficiency policies.

Understanding consumers is the most difficult challenge of behavioral change studies. For this reason, this study is thought of as an interdisciplinary research. Consumer behaviors were examined after a deep psychological review of behavioral theories. These theories were required not only for better understanding of consumer behaviors; they were also significant to the design of policies. In the process of survey design, we consider these theories. Questions aimed not only getting the data on energy consumption of households, but also tried to get the inner values of their behaviors. Households' motivators for energy saving are asked whether they are driven by monetary values, or environmental impacts of the saving, and so on. Secondly, theories explaining behaviors helped to create scenarios for the network analysis. For example, policy intervention in a school atmosphere or providing instant feedback is estimated to be more effective on the reduction of energy demand as the theories presumed.

Household consumption patterns and their attitudes towards energy efficiency measures can be learned via monitoring or surveying. Both methods give an idea about current consumption habits and possible changes in energy use, and allow researchers to make some estimation about the electricity network. Due to the limited budget and time, surveying has been chosen as a method to collect the residential consumption information of a sample of Turkish people. How people use the electricity in their homes, what are their preferences or what is more important for them were asked in the questionnaire. The questionnaire might also be an indication of current policies or projects. In addition to offering possible policies, this study may also give a general idea for implemented policies. SPSS is used to analyze the data obtained. Then, consumers' policy preferences were examined according to their attitudes and current consumption habits. Cluster analysis was done by using SPSS to see similar households in a group where they have energy consumptions in common and similar reactions to offered policies. Clustered households were thought as consumer archetypes and this method may be useful for policy makers or energy providers. Finally, an analysis to evaluate the effect on the electricity network was made by using GAMS to ensure the importance and the requirement of such studies on the subject.

Chapter 2

Literature Survey

Energy efficiency policies encourage behavioral change in residential areas and households are the main focus of this research. It is stated that achieving sustainability targets is globally required. Therefore, this chapter starts with giving detailed information about the sustainability and its requirements. We continue by describing behavioral theories supporting our study. These theories helped to design the questionnaire and to determine efficiency scenarios for effect analysis is given in the following chapters.

2.1. Sustainable Energy

The term of sustainable is defined as able to be maintained at a certain rate or level [8]. It is used to describe very different approaches such as development, economy, energy, agriculture etc. The desire to live in a clean atmosphere and in a secure future is the subject of sustainable energy. And, sustainable energy requires both using renewable sources and emphasizing energy efficiency both in the process of the production and consumption [9].

Renewable energy sources are environment-friendly having no emission to the atmosphere and can be replenished steadily. Sun, wind, hydro, and geothermal are renewable energy sources [10].

Energy efficiency is the reduction of the amount of energy used for a purpose. Basically energy efficiency is the conservation of the energy. As energy is used in every aspect of life, energy efficiency should be adopted methodically in industry, transportation, and also in residential areas.

There are three pillars of sustainability. These are social, economical, environmental aspects of the subject. Environmentally sustainability means: having no or low damage to the environment. Sustainability in the aspect of economics is keeping the cost less, reducing the amount of money spent in the long term. Social sustainability is defined with equality in its term. Equality covers having the same, or at least similar opportunities for people. For example, social sustainability emphasizes the right use of current resources in order next generations to use the same resources, or not to suffer from unmet demand. Social sustainability also aims to increase the quality of life [11]. It is important to consider each aspect in sustainability studies.

This study mainly focuses on energy efficiency in residential areas. Sustainability is not discussed in detail with its three pillars, or renewable energy is not examined thoroughly. However, energy efficiency in industry and transportation will be discussed briefly before going into detail of efficient use of energy in residential areas.

2.1.1 Energy Efficiency

Reducing the amount of energy required for a process or doing more work with the same amount energy is the subject of energy efficiency studies.

Energy use is divided into sub-sectors, such as industry, residential, transportation, service, agriculture etc., and industry has a large share in energy consumption. If renewable energy sources are used to meet energy demand, the process is already sustainable. However, energy is generally used from burning fuels. When fossil fuels are used, there is one way to make it sustainable. Co-generation systems are noteworthy in the manner they use heat after a fuel is burnt. Generated heat is kept and the steam is used to heat a next process or for another industrial purpose [12].

Sustainable transportation can be achieved by using clean fuels and making policies to change the way people drive. If clean fuels such as biodiesel, hydrogen etc. are used to fuel cars, emission released to the atmosphere will be reduced. Policies encouraging people to share their cars, or to use public transportation are significant tools to reduce the number of cars on the road. These solutions also require some technical improvements, such as the building of new fuel stations, improving public transport etc. Since the number of cars has been increasing steadily and the amount of energy consumed by transportation seems to increase simultaneously, implementation of energy efficiency policies is inescapable [13].

Energy is important in residential areas as well. Households need energy to cook, to warm their houses, to shower, to clean the house, and also to power entertainment systems. Fewer people live in one house, and energy needs of each house have been increasing due to the number of appliances and the comfort and entertainment needs of the people [6]. Energy efficiency can be achieved in several ways in homes. For example, building design is an important tool to reduce the energy required to warm the house. If this is considered at the building process stage, the energy required heating the house, or to cool it will be less.

Better design of houses, such as using natural light and allowing ventilation are steps for sustainable houses. Moreover, having solar energy and the storing rainwater to reuse for a specific purpose, e.g. for the garden, could add more efficiency to sustainably built houses [14]. In addition to building design, which helps heating and lightening with less energy, insulation should also be considered in the design process. Through insulation, the amount of energy is used will be considerably less.

Consumers have a responsibility for using energy efficiently in their homes. From cooking to separating waste, from avoiding unnecessary lightening to efficient use of electrical appliances, there is vast potential to make homes more sustainable. According to [14], electrical appliances use 30% of all electricity generated in OECD countries and 12% of related carbon dioxide emissions.

2.1.2 World Energy Outlook

In order to understand the importance of the behavioral changes, energy outlook of the world and Turkey should be examined first. World energy demand has been increasing due to population increase, industrialization, and urban development. This fact puts emphasize on issues such as sustainability, security of supply, alternative energy sources, and increasing national energy source potential.

In 2009, world primary energy demand was 12.15 Mtoe. The International Energy Agency (IEA) examined different scenarios and estimated energy demand in 2035 to reach 18.676 Mtoe with current policies. Current policies presume 1.6% increase yearly in demand. Figure 2.1 illustrates that new policy implementation will decrease the demand to 17.197 Mtoe and in the best scenario, where only 450 ppm greenhouse gas emission in the atmosphere, demand will be a minimum 14.793 Mtoe. Whereas new policies assume 40% increase in total demand by 2035, 450 ppm scenario considers 0.8% rise yearly, and predicts to increase 23% by 2035. These scenarios are based on the use of different energy sources. The best scenario predicts the highest share of renewable and nuclear energy use in the production process [1], [5].

Figure 2.2 shows planned investments by type in energy sector [1]. In addition to investments in renewables, transmission and distribution issues of energy are considered important to regulate, because the higher energy demand with current policies means the higher loss in transmission and distribution as well.

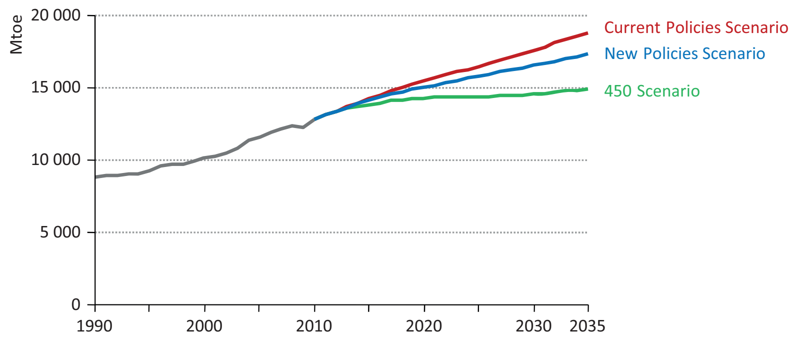


Figure 2.1: World primary energy demand by scenario [1]

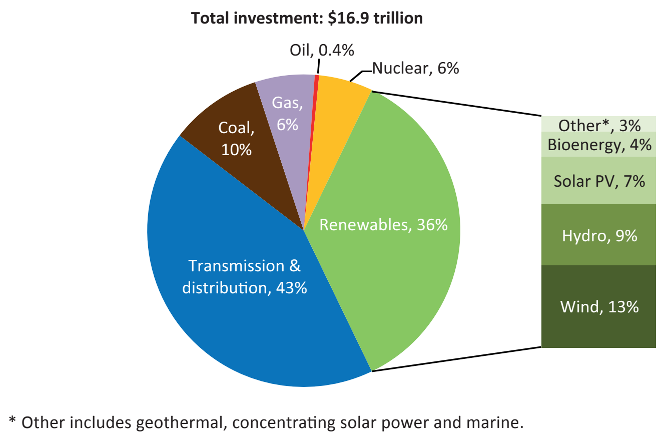


Figure 2.2: Power sector cumulative investments by type in the New Policies, 2012-2035 [1]

Figure 2.3 shows related carbon emissions in each three scenario. The rise in the emission rate is obvious, and if there are not any policies adopted, it will reach 44.1 Gt CO_2 by 2035, which is 46% higher than its value in 2010 [1].

As is seen above, energy demand and related emissions have been increasing, it is important to develop new policies emphasizing energy efficiency in the future. While global energy demand rises, the increase rate in non-OECD countries is much more important to consider. Non-OECD countries' energy demand has been increasing more rapidly than OECD countries. Between 2010 and 2030, there is only 0.11 billion toe increase predicted in primary energy demand in OECD countries. However, in the same period there is 4.85 billion toe increase in non-OECD countries [5]. Although Turkey is a member of OECD, rankings of the country are generally low in sustainable development issues.

	2000	2010	New Policies 2020	New Policies 2035	Current Policies 2020	Current Policies 2035	450 Scenario 2020	450 Scenario 2035
Total	**10 097**	**12 730**	**14 922**	**17 197**	**15 332**	**18 676**	**14 176**	**14 793**
Coal	2 378	3 474	4 082	4 218	4 417	5 523	3 569	2 337
Oil	3 659	4 113	4 457	4 656	4 542	5 053	4 282	3 682
Gas	2 073	2 740	3 266	4 106	3 341	4 380	3 078	3 293
Nuclear	676	719	898	1 138	886	1 019	939	1 556
Hydro	226	295	388	488	377	460	401	539
Bioenergy*	1 027	1 277	1 532	1 881	1 504	1 741	1 568	2 235
Other renewables	60	112	299	710	265	501	340	1 151
Fossil fuel share in TPED	*80%*	*81%*	*79%*	*75%*	*80%*	*80%*	*77%*	*63%*
*Non-OECD share of TPED***	*45%*	*55%*	*60%*	*65%*	*61%*	*66%*	*60%*	*63%*
CO_2 emissions (Gt)	**23.7**	**30.2**	**34.6**	**37.0**	**36.3**	**44.1**	**31.4**	**22.1**

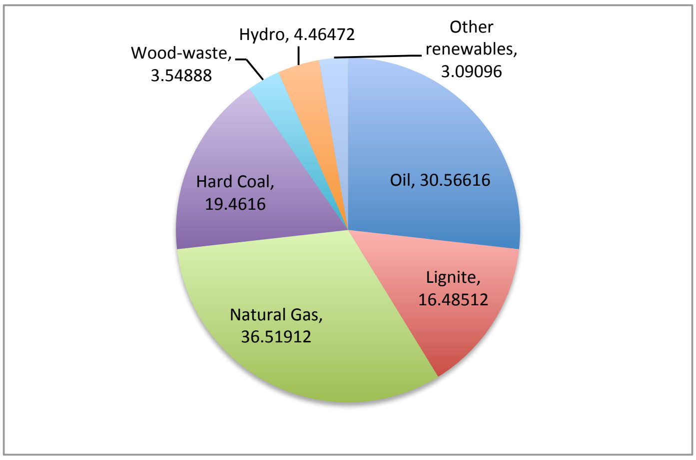
* Includes traditional and modern biomass uses. ** Excludes international bunkers.

Note: TPED = total primary energy demand; Mtoe = million tonnes of oil equivalent; Gt = gigatonnes.

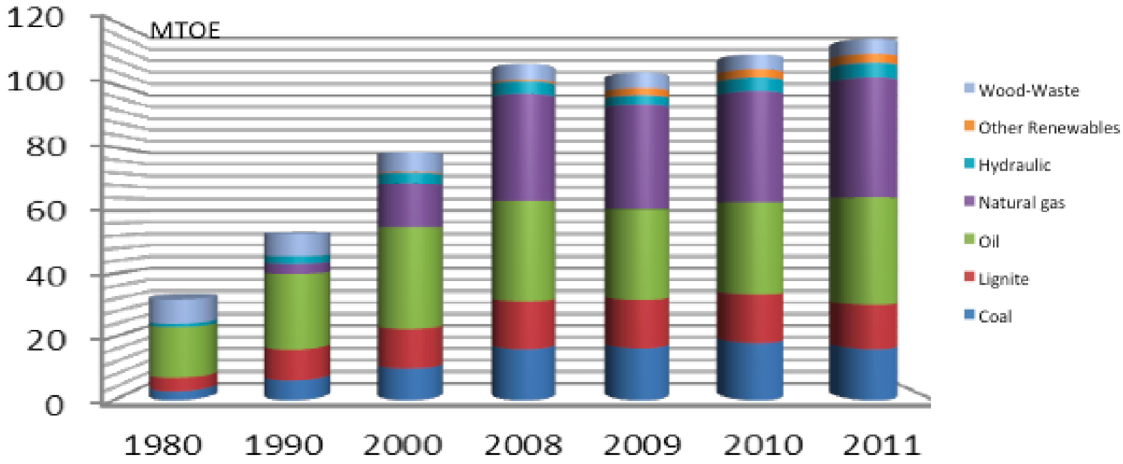
FIGURE 2.3: World primary energy demand and energy related emissions by scenario (Mtoe) [1]

2.1.3 Energy Overview of Turkey

In 2011 total primary energy demand of Turkey was 114.48 Mtoe, and it was mostly based on fossil fuels such as coal (31%), gas (32%), and oil (27%) (Figure 2.4(a)). This figure depicts the importance of energy efficiency measures in Turkey where energy is mostly based on fossil fuels and the use of renewable energy source is quite low [5]. In addition, Figure 2.4(b) shows that as demand has been inreasing remarkably, the share of renewables has not risen at the same rate of change. In 2011, Turkey met 90.3% of its energy demand by fossil fuel [2].



(a) Primary energy demand by sources (%) [5]



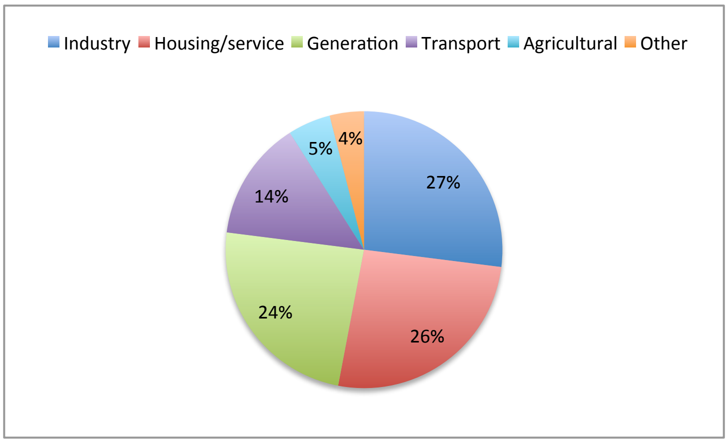
(b) Development of primary energy consumption [2]

FIGURE 2.4: Turkey's primary energy demand

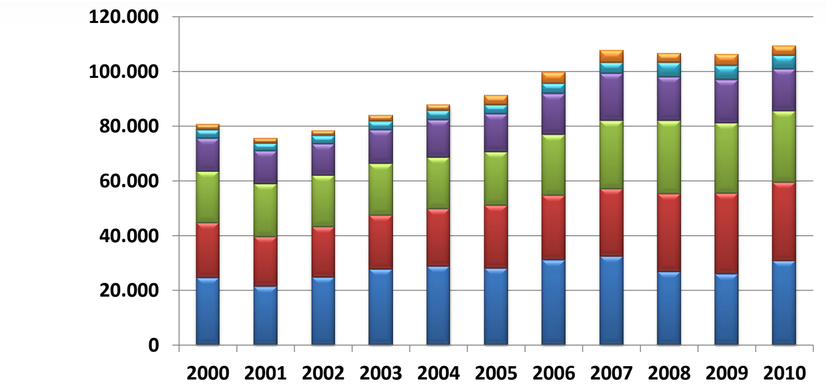
Figure 2.5(a) indicates Turkey's primary energy consumption by sector in 2010 [2]. There was a substantial increase between 2002 and 2010. The amount of increase differed from sector to sector. There was a 25% increase in industrial use, 20% in transportation, 44% in residential use, 66% in agriculture, and 37% in electricity (Figure 2.5(b)) [5].

According to TUIK data, Turkey's total import amount was 240 billion dollars in 2011. Energy import comprised of 22% of this amount, which equals to 54 billion dollar. In this amount, fuel and fuel products were 38% of all energy import [5]. Table 2.1 proves Turkey's energy sector is dependent on imports and this puts the burden on the economy.

As of end of 2012, Turkey's installed capacity was 57,071.5 MW. It is seen in Figure 2.6 most commonly built energy power plants in Turkey are thermal and hydraulic. Thermal power stations are mostly based on natural gas and lignite coal [2]. Although the number of wind power stations has increased recently, this increase cannot be considered sufficient



(a) Primary energy demand by sectors [2]



(b) Change of sectorial energy consumption (ktoe) [5]

FIGURE 2.5: Turkey's primary energy consumption

TABLE 2.1: Import numbers of Turkey (billion dollar) [5]

Years	**Total import**	**Energy import**	**Energy sector**
2002	51.5	9.2	3.79
2003	69.3	11.58	5
2004	97.5	14.41	5.77
2005	116.7	21.26	8.85
2006	139.5	28.86	12.25
2007	170.1	33.88	14.54
2008	201.9	48.28	21.25
2009	140.9	29.91	14.74
2010	185.5	38.49	17.46
2011	240.8	54.1	20.5

[5]. New energy policies for Turkey are required to achieve sustainability targets, such as encouraging investing more in renewables and adopting efficiency measures in thermal power stations.

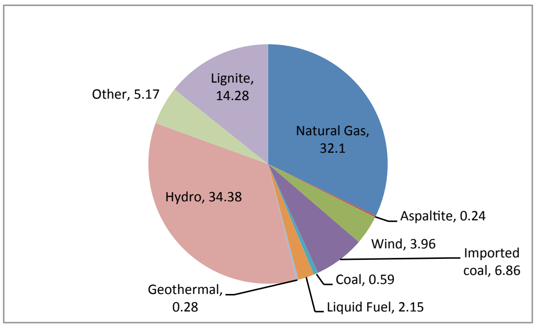


FIGURE 2.6: Installed Capacity of Turkey (%) [2]

2.1.4 Turkish Electricity Market

As this study focuses on Turkish residential electricity consumption, a very brief summary of the development of electricity market in Turkey is given in this section. Turkey's electricity generation increased from 129,400 GWh to 229,395 GWh between 2002 and 2011 [5]. The share of private electricity producers in the market started to rise in 2002, after the liberalization of the sector. As is seen in Figure 2.7, public electricity production was dominant in the sector, and then private sector investments have gradually risen. In the end there are many more private electricity producers in Turkey. In 2012, more than 60% of Turkey's electricity demand was met by the private sector [2]. However, most of investments in the private sector were made in natural gas stations (10.5 billion TL) and 7 billion TL for imported coal. Only 6.5 billion TL has invested in renewables by the private sector, which are mostly hydro and wind power [5].

Day ahead market policy is used in the Turkish electricity market since December 2011. This policy allows participants to plan their electricity trade one day ahead, and unfortunately it causes some unbalances in trade. These problems are due to prediction errors, which can be minimized by an intra-day market policy, which is still being developed. Market participants will have chance to rearrange their portfolio by considering their generation or consumption rate or the general picture of the system. An intraday policy will allow extra electricity trade between participants until a few hours ahead of the delivery and will reduce the unbalance cost [15].

The number of free consumers has been rising steadily [15]. Free consumers are defined as consumers who have the opportunity to choose their electricity provider. Reducing the required consumption amount for being a free consumer is an important step for the

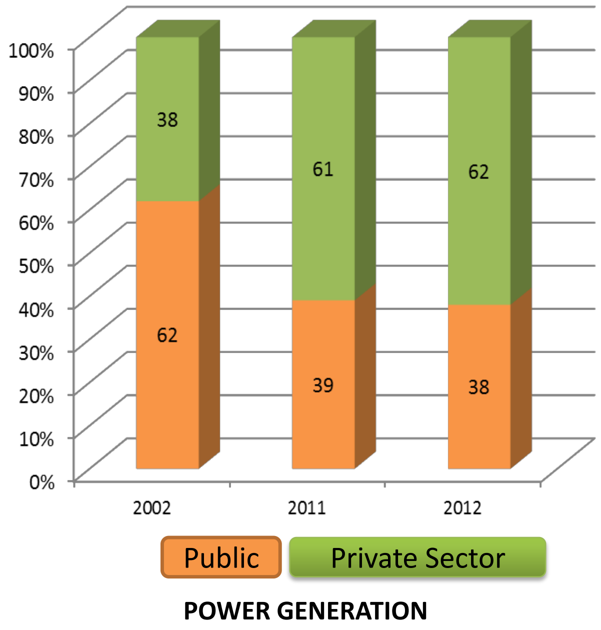


FIGURE 2.7: Electricity Generation in Turkey [2]

whole liberalization of the electricity market. By 2013, the limit for being a free consumer has been reduced to 5 thousand KWh and it approximately makes at minimum a bill for 150 TL for a month [16].

2.1.5 Household Energy

Energy is used for several purposes from electricity use to water use, from cooking to lightening in residential areas. The number of people, the size of the house, the climate in the region, household income, and some other variables have an impact on this use. This section summarizes the factors affecting household energy.

Although the fact every households needs energy, there is no valid formula for their need. Each house has its own factors that determine the consumption. In a country and between countries energy demand will be considerably different. Although behavioral change studies are quite common around Europe and the world, this diversity makes the issue worth examining for Turkey.

Haas [6] identified nine energy efficiency indicators in residential areas. These are demographics, economic factors, individual factors, culture, structure, life styles, technology, climate, and policy. All of these factors have impact on households' energy use, and they are explained briefly in Table 2.2.

Each household consumes different amounts of energy according to listed factors. Moreover, studies conducted on the subject should take into account all variables while comparing residential use of energy.

Table 2.2: Explanation of factors affecting residential energy demand [6]

Factors	
Demographics	Household growth or decline Population growth Age of occupants
Economic	Energy prices Investment cost of equipment Available income
Individual	Attitude Awareness
Culture	Cooking, washing, heating and comfort traditions
Structure	Saturation of equipment Dwelling area Share of central heating
Lifestyles	Time spent at home or work Mix of activities in and away from home
Technology	Efficiency
Climate	Differences in weather
Policy	Building and appliance standards Taxes Effect of Demand Side Management Programmes

2.1.6 Residential Electricity Consumption Trends

In 2010 electricity generation was 21,408 TWh and it is projected to be risen by 47% and to reach 40,364 TWh in 2030 with current policies. 67% of total electricity demand is met by fossil fuels [1]. New policy implementations are required both for more efficient use of electricity and investments in greener electricity generation technologies.

Figure 2.8 explains the importance of residential electricity use. There is a steady increase in OECD countries, while the rise is double in non-OECD countries [3]. Residential electricity consumption accounts for a significant share in total consumption, and it is worth to examining all around the world.

Electricity consumption increases substantially over the years where residential use significantly contributes to the overall consumption. Between 2000 and 2010, total electricity consumption of Turkey increased from $98,295.7$ GWh to $172,050.6$ GWh. In parallel to this trend, residential use increased from $23,887.6$ GWh to $41,410.7$ GWh. Domestic use accounts for nearly one quarter of the entire electricity consumption in Turkey (Figure 2.9) [4].

Total number of electricity consumers was $33,248,188$ in 2010, and 82.4% of this number ($27,400,318$) were residential consumers, and only 12.7% of all was for commercial

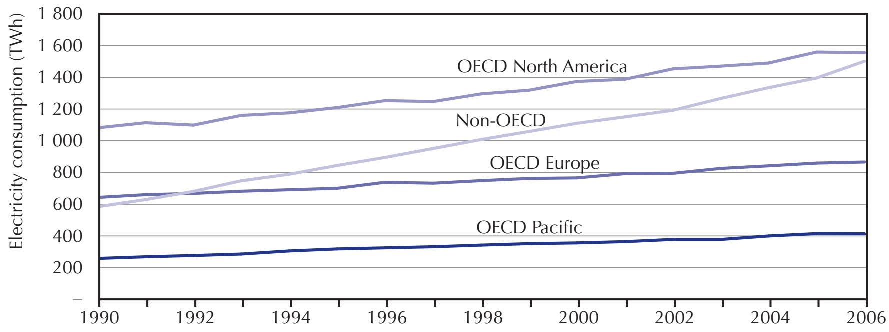


Figure 2.8: Rates of change of total residential electricty consumption beween 1990-2006 [3]

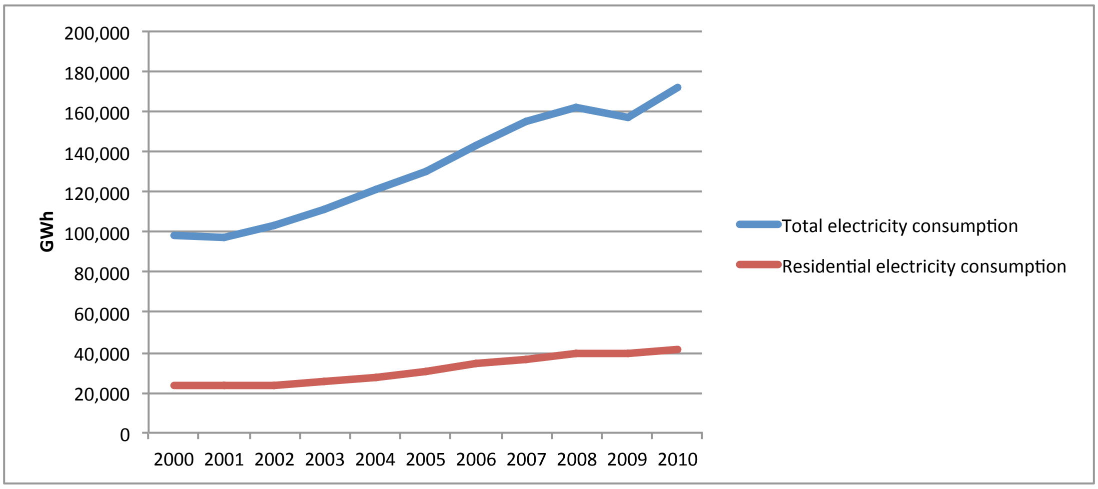


Figure 2.9: Residential Electricity Consumption in Turkey (GWh) [4]

use $(4,211,766)$[17]. The higher number of residential consumers brings the necessity to study electricity consumption in residential areas. To achieve global sustainability targets and reduce the overall electricity usage, focusing on domestic consumption is crucial. Energy consumption patterns of the households should be identified and consumer behaviors are to be understood for better policy implementation.

Table 2.3 shows the rate of use of some electrical products by Turkish consumers [7]. Data is taken from a very recent study by Ministry, and it is considered an authorized reference for our survey study that we will discuss in the following chapters.

One other thing should be evaluated in residential efficiency studies is that the standby consumption. It is 2.6 TWh/year for Turkey, and equals to 3% of national electricity consumption [18].

Table 2.3: The rate of use of some products in Turkish residential areas [7]

Product or Device	**% of Use**
Fridge	99.5
Oven	84.6
Television	99.7
Washing machine	99.6
Dishwasher	64.5
Air conditioner	21.2
Iron	95.7
Vacuum cleaner	96.8
Natural gas boiler	47
Computer	52.8
Electrical teapot	98.1
Electrical heater	95.6

2.2. Consumer Behavior

Consumers are the ones who consume electricity, but it is not easy for people to change old habits and consumption patterns. Changing electricity consumption requires implementation of new policies encouraging people to achieve sustainable consumption behavior. Before looking into developed policies, human behavior and theories used to explain this behavior will be examined.

An activity, action, performance, response, or reaction of a person can be considered in the frame of behavior. We may behave physically with our muscles or there is no physical action but there is only work of our neurons [19].

Fisbein and Ajzen [20] claimed behavior consists of four factors, which are action, target, context, and time. Performed action is a result of a directed target in a certain context and at a given time. There is a long time before the behavior and there are many factors having impact on our behaviors. Our actions, performances, or any synonyms of behavior should be evaluated together with the existence of attitudes, values, beliefs, habits, intentions, and norms. In order to understand behavior thoroughly, these terms will be explained briefly.

No matter how it is named, regular actions are considered habits or routine of someone. Even without thinking, we do the same things on a regular basis. This regularity affects our decision-making mechanism, but the behavior in the end is not rational all the time. Sometimes there could be very different reactions to similar situations. Our emotions are also another factor. We may act differently at a different time. Our mood will shape our behavior as well.

Values refer to one's principles, to what regard someone cares is a demonstration of the worth, importance of these principles [21]. Values force people to opt for a certain target among several options. Values are strong motives placed in the conscious mind and definitely direct behaviors. Personal values are in the frame of attitudes, preferences, and beliefs. Furthermore, values in the societal aspect are discussed as norms. For instance, it is a value for most of the people that younger people need to respect their elders. When we talk about a school, the expectation of how this value will work in the school becomes a norm [22].

As Becker *et al.* [23] stated, energy consumption is not a direct behavior, it is consequences of our behaviors. The way we heat our homes, fuel our automobiles, use electrical appliances draws a picture on our energy consumption [24]. Until it comes to the final consumption data, our use of electricity at homes should be meticulously evaluated.

The following theories that we define below have used to understand both consumer behaviors and effective policies promoting residential energy efficiency. In the process of survey design, we consider these theories. Questions aimed not only getting the data on energy consumption of households, but also tried to get the inner values of their behaviors. Households' motivators for energy saving are asked whether they are driven by monetary values, or environmental impacts of the saving, and so on. Second, theories explaining behaviors helped to create scenarios for the network analysis. For example, policy intervention in a school atmosphere or providing instant feedback is estimated to be more effective on the reduction of energy demand as the theories presumed.

Rational Choice Theory: This is the basic behavior theory stating consumers weigh possible benefits or costs of an action and behave in a rational way [25]. Rational Choice Theory is very close to conventional economics, which says people focus on their needs, want to maximize utility, and then make an appropriate purchase decision [26]. However both Rational Choice Theory and conventional economics are very limited to explain all behaviors of consumers. Factors influencing behaviors such as habits, values, etc. should be included in a behavior theory. Rational Choice Theory can be used in order to show the potential monetary saving and societal benefits of reduction in electricity consumption. This theory helped in giving information and increasing awareness of people in a number of studies [27].

Reasoned Action Theory: As it is stated in Rational Choice Theory, people expect some outcomes from a certain behavior, and develop an attitude after evaluation of these outcomes. According to Reasoned Action Theory, attitudes convert to intention, and this intention also includes social norms. And final behavior is a sum of all these beliefs, norms, attitudes, and intentions [27]. As mentioned, there is an expected outcome from each behavior. However, this expected outcome will differ as a result of the intention, the attitude, and the value of a person. Therefore, a behavioral change measure should decide on the appropriate outcome such as rewards or discounts within the preferences of the consumer such as money, environment, sense of responsibility, and so on.

Planned Action Theory: In addition to Reasoned Action Theory, there should be an understanding of "perceived behavioral control". Sometimes it is not easy to convert an intention into actual behavior, and perceived behavioral control explains the difference between people's beliefs and behaviors. This has been seen in many behavioral change studies about environmental issues; consumers have a certain level of knowledge, they tend to act environment consciously, but their behaviors are not appropriate to their intentions [27]. The main conflict in consumer behavior is not converting the intention always to an actual behavior. Providing feedback is thought helpful to convince people to change their behaviors towards their intention, being more careful about energy efficiency.

Value Belief Norm Theory: Values are defined as the level of worthiness of a person's principle. For example, it cannot be expected from someone, who does not have worries about environmental issues, to behave pro-environmentally [25]. According to this theory, behavioral change is possible if people value an issue. Therefore, the target group of people should be determined first. With this theory we asked households what are they mostly driven by. If they value the money, their reactions to monetary rewards or disincentives will be higher. Or, if they were environmentally conscious, they would like to see their impact of energy saving on the environment.

Attitude Behavior Context Model: This model tries to explain behavior as a combination of attitudinal and contextual factors. While beliefs, norms, and values are considered in attitudinal frame, incentives, social norms, and other external factors such as institutions and regulations are counted in contextual group factors [27]. One drawback of this theory is the lack of evaluation of habits in factor groups.

Triandis' Theory of Interpersonal Behavior: Triandis' Theory evaluates all the factors mentioned so far, and this makes it more complicated than other behavior theories. In addition to beliefs, values, norms, and external factors, habits are also included in the theory. Although the theory is more comprehensive, it has not been applied in any behavioral change studies [27].

Persuasion Theory: This theory is an explanation for internal factors affecting behaviors. In Persuasion Theory, credibility and the response rate are extremely important [27]. Once people are persuaded to take some measures, results of the applied measures and people's benefits from these measures should also be provided. For this reason, explanations about current electricity consumption patterns and possible methods to reduce peak load consumption should be trustworthy. As credibility is important, we supported our survey data with the existing work of the Ministry. Regarding trustworthiness, households were also asked about the people they would like to see in policy campaigns. Moreover, the feedback measures and also rewards are designed as a quick response to change in residential consumption.

Elaboration Likelihood Model: Elaboration Likelihood Theory is also based on persuasion. In this theory, a mere message can persuade some consumers, but some people are not able to get message directly, and they follow others' behaviors [27]. Elaboration Likelihood Theory involves both Persuasion Theory and Social Learning Theory.

Social Learning Theory: Social learning theory discusses people learn from their own experiences and watching other's behaviors. The interaction between people helps to change behaviors. This theory has been very useful in several pro-environmental studies [27]. This theory helped to create some scenarios used in the network analysis. TV messages reminding people of using energy efficiently or social influences in schools are thought to be effective in behavioral change studies.

Cognitive Dissonance Theory: People can have some behaviors conflicting with their attitudes as it has been explained in Planned Action Theory. This theory claims these kinds of behaviors are more likely to change [25]. Once the distinction between actual behaviors and their attitudes is shown, it becomes easier to attain behavioral change. Providing feedback is completely based on this theory, and it succeeded in high rate of efficiency in applied policy interventions.

Social Identity Theory: Social Identity Theory says people consider the group they are in as an image for themselves, and in this group people tend to adapt sustainable behaviors more easily [28]. This theory is supportive for social influences, which will be listed in following chapters as one of the behavioral measures.

Social Comparison Theory: This theory is another tool to be used in social influence; in a competitive atmosphere people are more likely to achieve their targets [28]. In the questionnaire participants were asked whether they would like to know the comparison of their consumption with others, and unsurprisingly they mostly answered "no". However, there are many examples in the literature showing the impact of knowing others' consumption. Social influences are mostly supported by this theory, and they led to higher reduction rates in energy demand.

Prospect Theory: According to the Prospect Theory developed by Kahneman and Tversky, people would like to avoid a loss rather than gain an advantage [29]. This statement emphasizes people would reduce the electricity consumption, or opt for changing their behavior on this target, if only there is a cost of not having this measure. If the cost were not high for consumers, they would not value it and never try to change their behavior. Since the benefits and the cost of a policy will have different impact on consumer behaviors, in the survey rewards and disincentives were listed respectively.

Comments

The common conclusion from these behavioral theories is that behavior cannot merely be explained by actions of people. The intention, the attitudes, and the values of people should be involved in theories for comprehensive understanding consumer behaviors. Each theory can be accepted as an improved type of the previous one. This argument led us to consider the inner factors effecting behaviors for both survey and scenario design. Secondly, as proven in these scenarios, the gap between the intention and the actual behavior of consumers, and the impact of others on a person's behavior have also supported our study.

2.3. Behavioral Change Measures

Energy saving behaviors are examined in two groups. One shot behaviors needing relatively higher investments are named as efficiency behavior. Next group consists of repetitive behaviors and known as curtailment behaviors [30].

Insulation investments, buying energy efficient appliances are in the first group. Turning lights off, caring about stand by consumption, using electrical appliances in an efficient way are examples of curtailment behaviors.

This section includes the policies applied in several countries and achieved reductions in energy consumptions. Increasing the knowledge, providing feedback, giving rewards, disincentives, and social influences are the basic policies, we have also chosen for our survey and network analysis. Each policy intervention will be discussed in detail in the following sections. Increasing the knowledge of Turkish residential users are particularly important since their awareness about energy efficiency is relatively low. Therefore, information has been chosen as the first measure to be offered in our survey. Feedback and rewards have also considerable impacts on achieving efficient use of energy via behavioral change. Lastly, social influences has been thought as a good combination of each measure. Through social influences, it is estimated to reach higher number of people and higher reduction rates in energy demand.

2.3.1 Information

Information is the basic strategy used to develop energy conservation behaviors. Informational interventions increase the awareness and the knowledge of energy issues in people. There are several ways to spread information among people.

- Workshops
- Information leaflets and posters
- Mass media campaigns
- Tailored information: Home audits
- modeling
- Energy labeling

2.3.1.1 Workshops

Workshops can be considered brief, intensive courses in which information about energy efficiency and possible ways to reduce residential electricity consumption are provided. However, these do not always result in behavioral changes. Geller [31] investigated how effective a workshop is, and he revealed that although workshops were effective to increase the awareness and knowledge about related subjects, they did not lead to real changes in behaviors [32].

2.3.1.2 Information leaflets and posters

Information leaflets and posters are quick messages to people containing clear information and attractive pictures and figures explaining efficiency measures. In 2000, there was a campaign in Germany to attract people to standby consumption of electrical products making up a significant share of household electricity consumption. The campaign used posters with fun and entertaining pictures and slogans. After three months, the slogan was known to 33% of the population, one year later 35% remembered the slogan [33]. This proves the effectiveness of posters on increasing awareness. However, there is an argument about the longevity of this measure. Hayes and Cone [34] found a poster reduces electricity consumption temporarily. When the poster was displayed in a dormitory, it led to a 30% savings in the use, but later on this reduction fell to 9% [35].

2.3.1.3 Mass media campaigns

There is no doubt mass media is a powerful tool to reach a large number of people. Media is used to provide information on energy issues and then to reinforce success of ongoing campaigns or projects.

On television, messages can be given directly and people are asked for their participation. The success of this method is arguable. Luyben [36] evaluated the effectiveness of the US President Jimmy Carter's message about reducing residential energy consumption. Just after the President was on TV, people were surveyed randomly, and it was concluded his message did not lead to an increase in the knowledge level of citizens [32]. However, in another study a group of scientists reported a 20-minute TV program about energy saving caused 10% reduction in energy consumption [35].

Over the period 2004 and 2005, there was a campaign to change the attitudes of Manchester citizens towards a more sustainable life. In addition to national and local politicians, television personalities, and sporting celebrities also supported the campaign. This reassured citizens it was not a mere political campaign. The campaign reached approximately five million people with a variety of TV slots, radio features, and print media articles, and definitely increased the awareness of issue [37].

2.3.1.4 Tailored information

Specific information and individual advice for households are considered in this category. One benefit of this method of giving tailored information is participants get only relevant information and do not get confused. Home audits are considered tailored information.

Winett *et al.* [38] studied households receiving energy audits, and showed that they reduced electricity use by 21% [32]. McDougal *et al.* [39] worked on the Canadian ENERSAVE program. Participants were surveyed about their energy use habits, and then given tailored information. Two years later, they were asked if they reported any savings or not. This time no differences were found between people who had tailored information and who did not have [32]. This can be explained by a short retention.

In 1999 two US military housing unit were observed. The units were similar in nearly every respect. They had no billing, no economic motivation for saving. Awareness was raised by education and campaigns. While the unit in Washington reduced their gas and electricity consumption by 10%, in Arizona there was 2% increase in the consumption [28]. This effect happens sometimes when applying interventions. Some households may increase their usage after a project started or a measure is learned and implemented.

To be effective the source of the information has significant importance. When information comes from a credible source such a family member, local authority, or independent organizations, it is taken into consideration by households [25]. In a study in Finland, ordinary people are trained to act as energy experts in their residences. There are some advantages and disadvantages of having such experts. Households found these experts close by, since they live in the same residences. They did not hesitate asking or learning from them. However, as experts worked voluntarily the monitoring of them was not possible, and no standards were described for the study. In the end significant conservation was reported, electricity consumption decreased by 10%, and water use decreased by 20% [40].

2.3.1.5 modeling

A family or an office can be used as a model to encourage energy conservation in homes or companies. Once the methods they apply and savings they achieve are presented to other people, it becomes easy for others to take similar measures.

Winett *et al.* [41] used cable TV as a tool for modeling. A TV program was shown as an example of a middle class family's energy conservation. In another study, 10% reduction in energy use was achieved, and a significant increase in knowledge was reached [32].

2.3.1.6 Energy labeling

Energy labeling is a common tool to build and increase awareness about energy consumption of goods. A labeling program helps to get more information on the product, affects consumers' preferences, and indirectly increases consumer satisfaction. The most common problem with energy labeling is average consumers do not relate the label information to their actual savings [24].

In Germany, a case study was conducted on labeling. There were already some labels to inform German consumers about the environmental performance of different product groups. EcoTopTen Initiative (ETT) was aiming to be useful, reliable, and common brand for customers. The goods were evaluated related to environment, quality, and cost in several product categories. Results showed that ETT is a good project succeeded getting attention and spreading knowledge, but this knowledge should be applied in daily life, when families invest or purchase a new product [42].

2.3.2 Feedback

Technically, feedback is defined as the process in which part of the output of a system is returned to its input in order to regulate its further output [43]. There is an idea of Katzev and Johnson [44], if people are given information indicating their energy saving, they are more likely to develop a positive attitude toward doing so and eventually they attain energy conscious behaviors [25].

Electricity bills are the simplest feedback mechanism, but today most of the people even do not look at their bills. They do not know whether their consumption has changed or not, or if electricity cost has increased or not. In order to make people aware of their consumption, feedback can be given continuously, daily, weekly, or monthly, and its frequency will change the efficiency (or effectiveness) of the measure. This will be seen in following sections.

Feedback should also be noted previous energy consumption of a household can lead to different reactions for this household's current consumption. Brandon and Lewis [45] concluded users with high and medium energy use easily reduce their consumption, while users with low electricity consumption are likely to increase their use [25]. This is proved by many studies, which will be examined later on.

- Direct Displays
- Dynamic Pricing
- Indirect feedback

2.3.2.1 Direct displays

Direct displaying of consumption gives a chance to consumers to know the amount of electricity they use in terms of kWh, money, or emissions to the atmosphere. There are several methods of providing this kind of information. In 1998, there was a study in Japan observing 319 households energy consumption with IHD. In this program the effect of the frequency of monitor use was tested. It was concluded the higher number of access to the monitor, the higher level of energy conservation people could achieve [46].

In 2007, San Diego Gas & Electric ran a pilot program in California with 300 participants. These 300 households were consuming greater than 700 kWh of electricity in a month, especially had swimming pool at home. In addition to In-home-display devices (IHD), consumers were warned with phone calls and emails. People with high electricity consumption were targeted. During peak hours, they were warned by phone calls and emails, and were expected to reduce their consumption. At the end of the study there were approximately 13% reduction in their consumption [46].

- Continuous feedback

  Continuous feedback is provided with a monitor, which displays electricity use continuously either in monetary terms, kilowatt-hours, or environmental effect (emission rates). Ammons [47] and Van Raaij and Verhallen [48] stated an immediate feedback just after the action as the most effective. Stern [49] also emphasized this statement, and considered the immediate feedback more likely to save energy [35].

  McClelland and Cook [50] gave households continuous feedback during one year, and on average 12% reduction in electricity use was achieved [32]. Another study to compare the effects of gas consumption feedback at different frequency was conducted by Van Houwelingen and Van Raaij [51]. It appeared households who received continuous feedback achieved the highest gas saving (12.3%), households with monthly feedback reduced their gas use by 7.7%, followed by 5.1% reduction in households where people were taught to read their own gas meter, finally information alone resulted in 4.3% saving [32]. As it is seen from this study, only information will not bring much saving, and continuous feedback will result in much more reduction on the consumption.

- Daily feedback

  Daily feedback is given by a monitor displaying daily consumption of users. It is expected to see feedback helps to reduce consumption and increase savings, but there is another question about the longevity of its effect. In Bittle *et al.* [52]'s study households were examined in two groups: ones having daily feedback and a control group. The feedback group saved an average of 4% on their electricity use. Then, the treatment was reversed, and people in the control group previously received feedback, and others not. Initial feedback group continued saving more energy than the other group [32].

  This group of scientists, Bittle *et al.* [52], furthered their study and explored the differences of feedback contents. One group was given daily feedback with previous day's consumption and the other group was given cumulative feedback since the beginning of the month. Whereas the cumulative feedback was more successful than daily feedback, households with lower consumption of electricity had increased their consumption as a result of the given feedback [32].

- Weekly or monthly feedback

  Seligman and Darley [53] studied the impacts of a weekly feedback mechanism on use. Half of the participants received weekly feedback about electricity savings while the rest did not receive any feedback. Households in the feedback group consumed 10.5% less electricity compared to the control group [32].

  Hayes and Cone [54] examined the effect of monthly feedback on electricity use, both in monetary and in terms of kilowatt-hours. Households who had received feedback reduced electricity use by 4.7%, while households in the control group increased electricity use by 2.3%. After the feedback was removed, households were continued monitoring for two more months, and during this period, the pattern was reversed. It was recorded households in the experimental group used 11.3% more, while households in the control group saved 0.3% [32].

- Comparative feedback

  Feedback about individual performance relative to performance of others is thought to be helpful in reducing household energy use. Comparative feedback will evoke the feeling of competition, social comparison, or social pressure, which is thought to be useful in adopting energy saving methods [32].

  Midden *et al.* [55] tested the effectiveness of comparative feedback, individual feedback, monetary rewards, and information. The comparative feedback consisted of a comparison with consumption levels of households in similar respects. Once households who had either received comparative feedback, individual feedback, or rewards tended to save more than the control group. There was no conclusion comparative feedback was much more effective than individual feedback, they had both influenced the consumption. Providing households with information alone was not successful at all [32].

  Other study by Brandon and Lewis [45] compared the impact of several feedback mechanisms such as comparative feedback, individual feedback, feedback about financial costs, and feedback about environmental costs. Also, one group of households was given feedback via a leaflet, and other group received computerized feedback. Computerized feedback was relatively successful. High and medium consumers saved energy 3.7% and 2.5%, respectively whereas low consumers increased their use by 10.7%, which reminds us of the finding by Bittle *et al.* [32].

2.3.2.2 Dynamic pricing

This section consists of three dynamic pricing methods, which offers different prices to customer at different time of the day.

- Real Time Pricing (RTP)

  Real time pricing informs consumers about the actual cost of electricity at any given time, and this method lets consumers adjust their electricity usage accordingly; for example, scheduling usage during periods of low demand to pay cheaper rates [56].

  In 2004, a study by Hydro One Networks of Ontario, Canada examined the effect of real time pricing on over 400 participants. Consumers were only provided with in home displays (IHD) and no incentives were given. 6.5% reduction in electricity consumption was achieved on average. A similar study to this was conducted in British Columbia (BC) and Newfoundland and Labrador between 2005 and 2007. Approximately 200 customers from Newfoundland and BC markets participated in the study, and they decreased the electricity consumption by 18% and 2.7% respectively [46].

- Critical Peak Pricing (CPP)

  The price for electricity during higher demand periods will rise, in this measure consumers are warned about these periods and they are expected to reduce their consumption. Country Energy of Australia ran a pilot program in 2004 with 200 households to test IHD giving critical peak pricing. The IHD was equipped to show real-time electricity consumption information in both monetary and environmental terms and to indicate different colors for different prices during peak, off-peak, and critical peak hours. Over 12-month period 8% savings and 16% reduction in bills were achieved. There was 30% reduction in demand response as well [46].

- Time-of-Use Pricing (TOU)

  Time-of-Use (TOU) pricing means the price you pay for electricity changes depending on the time of day and feedback is given regarding this information [57]. In 2007, Hydro One Networks conducted a study with 486 customers and observed their electricity consumption in four different groups. The first group was subject to TOU rates and given IHDs, the second group was subject to TOU and had incentives, the third group had only IHDs, and lastly group four did not have TOU rates, IHD devices, or any incentives. Results showed IHD is the most powerful tool to reduce consumption. When TOU rates were given with IHDs, the impact was stronger (7.60% conservation). Both techniques are useful to decrease electricity demand as well. Whereas TOU reduced the demand by 3.7%, with the existing of IHD reduction was 5.5 % in demand [46].

2.3.2.3 Indirect feedback

Instead observing their consumption, utility companies solely record consumption data and give feedback to customers. Electricity bills are considered an indirect feedback method. In addition to billing, using smart meters helps households to control their consumption. Consumers, who have smart meters at home, are charged at different price for different period of a day. With the existence of a smart meter, they could plan their usage in a more sustainable way.

- Self-meter reading

  This method means to read households' meters individually without any explanation, consumers observe only the changes on their meters. A survey carried out by Meyel [58] indicated the knowledge level and understanding of people about their energy meters are really low. More than half of the participants did not know where their gas or electricity meters were and 45% even could not read them [35]. Winett *et al.* [59] studied the effects of self-monitoring and daily feedback. They concluded households who had received daily feedback used 13% less electricity, and households who read their outdoor meters reduced their electricity consumption by 7% [32].

- Prepayment method

  In this method, consumers pay for electricity in advance. As long as people have credits on their cards, they use the electricity. Cards also provide information on their consumption.

  In 1993 a "pay-as-you-go" project was conducted with 100 participants in Arizona and on average 12.8% energy saving achieved [60]. Previously Woodstock Hydro in Canada had conducted similar study and concluded 15% reduction in electricity consumption [46].

- New format of billing

  Bills are the most common feedback to electricity customers. There are several ways to make bills more informative with adding some charts. These charts may help to increase the understanding and the awareness by visualizing households' energy use trends, comparisons of energy use to the previous month or the same month in the previous year, and comparisons to other users such as neighbors [25].

  There are some arguments on the format of bills. Norwegian households find the use of charts or figures simple and childish. Comparisons on the region or even on the street are not always possible, utility companies may differ. However, billing with direct feedback mechanism would be more helpful to costumers to show them what they use and what it costs in terms of money, kWh, or emissions [25].

2.3.3 Rewards and Incentives

Monetary rewards may motivate people to conserve energy. Rewards can be given as a result of a reduction in the consumption [32]. Dwyer *et al.* [61] stated incentives or rewards work best when used in conjunction with feedback, otherwise households cannot monitor their performance. Furthermore, rewards or incentives can, in effect, be seen as one way of giving feedback to households whether or not they are saving energy. Rewards can be effective if designed well, however, research has shown the effects of rewards and incentives are not always maintained for the long-term, but in most cases only for as long as the intervention is being implemented [25].

Winett *et al.* [62] examined the differences between high and low monetary rewards in combination with feedback and information. During the first month of the intervention, intervention was successful, and households in both groups saved more energy than the other groups. In the second part of the intervention, households who initially only received information were now given a high reward, and it resulted in savings of 7.6%. Two months later, households who had received a high reward, feedback and information achieved 12% reduction in their electricity [32].

Hayes and Cone [54] did an experiment on student residents in West Virginia, USA. The experiment was trying to find out the most effective method of reducing energy use. Whether monetary payments related to households' saving ratio, energy information, or daily feedback on consumption would lead to higher reduction in the consumption. Payments resulted in immediate and long-lasting reductions in consumption; on average reduction was 33%. Feedback also reduced consumption by 18%. However, when subjects were given information alone, impact was effective for a short term. Initially 30% reduction was achieved, but two weeks later this fell to a 9% [35]. It can be concluded information alone does not have long-term effect; monetary incentives lead to the highest saving rates.

Pitts and Wittenbach [63] examined tax credits' effects on consumers' decisions to insulate their homes. Households installing insulation were given a tax reduction. Two years after, they were surveyed and unfortunately tax credit seemed not to have an impact on their insulation decision [32]. Tax credits are relatively ineffective measures to change behaviors.

2.3.4 Goal Setting

Goal setting is another method of encouraging households to save energy. This measure is often applied on a self-selective basis, i.e. households themselves will define and commit to a certain energy saving goal, or the researcher can set a goal for them. McCalley and Midden [64] found households who had a self-set goal were the most successful in reducing their energy use, by a total of 21% [25].

McCalley and Midden [64] applied goal setting in combination with feedback to laundry habits. A goal was set, and participants were given immediate feedback about their energy use. Results showed that people had a goal in trials saved more energy than other group that was given only feedback. Study did not reveal any difference between people who had set their own goals and people who had been assigned a goal [32].

2.3.5 Commitment

A commitment is an oral or written pledge or promise to change, and it may be linked to a specific goal. This promise can be a pledge to oneself, in which case it may activate a personal norm such a moral obligation to conserve energy. The promise can also be made public, for instance, by means of an announcement in the local newspaper. Then, social norms such as expectations of others may play a role as determinants of conservation behavior [32].

De Young [65] claimed commitment can be even more effective than incentives or rewards in terms of rapid behavior change, and it can also result in long-term behavior change. Katzev and Johnson [44] ran a study on 66 respondents' electricity use behavior, and found those in the commitment intervention groups conserved more energy and produced more energy conservers than the control group [25].

Pallak and Cummings [66] used commitment to increase residential gas and electricity conservation. Households in private commitment or control group increased both electricity and gas consumption, whereas households who made a public commitment showed a lower rate of. This effect was maintained over a period of six months following removing of the intervention [32]. Public commitment is seen as more successful to achieve targets.

2.3.6 Social influences

Behavioral change measures up to now, are relatively on small scale. When the measure is taken in a larger group, its effects are expected to be more significant. Such groups or organizations make people achieve a common goal or even sometimes compete with each other to get the highest reduction in their consumption will be evaluated in the following section.

- **Eco-teams**

  A good example of social influences is the Dutch EcoTeam Programme (ETP). EcoTeams works voluntarily as a group of six to ten people. These people already know each other as neighbors or friends. Teams meet once a month and share their own experiences, ideas, and achievements related to a wide range of subjects, from energy consumption to transport issues, from environmental issues to purchase decisions [67]. A three-year study of 150 EcoTeam participants found after the ETP program, participants reduced their gas, electricity, and water use considerably compared to a group representative of the Dutch population. A two-year follow up study showed a majority of the initial behavioral changes were maintained. Electricity consumption reduced by 4.6% and two years later reduction was 7.6% compared to control group [25]. It may be concluded that the impact of a social influence last longer than an individual behavioral change measure.

  It is likely the people who took part in the EcoTeam program were generally more motivated to behave in a pro-environmental way, however the results suggest the program achieved considerable, and more importantly, long-term behavioral changes. People had the chance to observe each other, and they are also provided with opportunities and responsibility to "do the right thing" as well as being directly involved [25].

- **Energy Experts**

  Energy expert is as program coordinated by the Centre for Energy Efficiency (Motiva) in Finland. The aim of the program was to achieve energy efficiency in households via ordinary people after energy training. Motiva is a government owned limited company formed for energy efficiency promotion. It operated the program at the national level and facilitates energy expert action by maintaining energy educators' network, providing information and information services for the expert program [40].

  Energy experts were volunteer people who have been trained to be active in energy issues in their building and around. Experts could monitor changes in the consumption, and they also provided advice and assistance to others about more efficient energy and water use practices. They also acted as bridge between the organization and households [40].

This program was considered successful. On average in the building where energy experts worked, 5% saving in heating energy, 10% reduction in electricity use, and 20% reduction in water use were reported [40].

- **Energy Trophy Program**

  Energy Trophy (ET) was a EU-wide program supported by the European Commission's Intelligent Energy Europe (IEE) Program, the German Federal Environmental Agency, and Ecoperl. The program was like a competition for energy savings, specifically in offices by changing of the behaviors of employees. No high investments were required, behavior change was used as main measure to reduce consumption.

  The first round of ET started in 2004-2005 with 38 companies and institutions from six countries. The results from the first round were promising with an average energy savings of 7% and the winning company recording a 30% savings. Overall, the program achieved a total reduction of 3700 MWh or 1885 tones of CO_2 which mean a cost savings of 205,000 EURO [68].

- **Manchester is my Planet**

  Program had the goal of making Manchester leading city on pro-environmental issues. Communications played an important role to achieve this goal. 10,000 citizens signed a pledge by November 2008. The pledge was about increasing understanding of the subject, tackling with climate change concerns, and changing behaviors at homes and offices [37]. This project definitely brought large awareness on energy issues and increased the awareness of citizens.

2.4. Related Work

There is a huge resource about residential energy efficiency in the literature. After a long literature review, we will summarize some related works in this section. As well as the methodology is used, the articles also have been useful to design the survey used in this study. While some studies focus on variable prices on electricity demand, some observe the impact of factors affecting residential energy demand. In some studies new methods are developed to estimate residential load profiles and findings are compared with existing consumption data. Furthermore, some of the papers investigate how consumer responds to policy change among household groups.

Capasso *et al.* [69] proposed a bottom-up approach for establishing residential load profiles. Demographic and individual factors were taken into account and a Monte Carlo simulation was used to get average consumer behaviors and characteristics. Although the bottom-up approach had some limitations, the result of the model was encouraging.

Tsuji *et al.* [70] also used a bottom-up approach model to estimate residential energy demand in Japan. First, households were categorized according to the number of people in houses and the presence of households at home during a day. Then time scheduling for appliances was determined. Required probabilities for model were obtained from monitoring 66 households for one or two-year periods. This paper concluded the bottom up approach is a simple and successful method to estimate residential electricity demand. A bottom-up approach is the most common method to estimate residential energy demand in such studies.

Achao and Schaeffer [71] applied the logarithmic mean Divisia index decomposition technique to residential electricity consumption of Brazil. Consumption was investigated in three aspects: activity, intensity, and the structure. The activity effect in the model referred to the number of households, whereas the intensity effect meant the variation in consumer use. Geography and income were taken as structural factors of the model. The model explained variations in electricity consumption over the period from 1980 to 2007 and the technique was concluded as a valuable tool for further research, especially for policy makers.

Paatero and Lund [72] developed a model generating residential electricity load profiles. A bottom-up approach method was used, data was collected from public reports and statistics. Consumption cycles of each appliance were determined, seasonal and hourly factors were taken into account. Three different Demand Side Management measures were applied, including shifting the use or turning off the appliances. The most severe measure, which includes blackouts, resulted in the highest reduction in electricity demand.

Rasanen *et al.* [73] studied a more comprehensive cluster of consumers. A Self-organizing Map was used to evaluate 6,000 households. These households were divided into 12 categories according to building characteristics and annual electricity consumption. The method provided more detailed information of consumers and then more specific tips were given to each category of households.

Widen *et al.* [74] developed a model through time-use data of several households in Sweden. Time-use data was collected from households' notes, the household wrote down their daily activity sequences. The model considered activities only involving the use of electricity and hot water. A data set of daily activities was compared to the measured consumption data, there was reasonable accuracy in the method. The model was found efficient to depict residential load for the use of electricity and hot water and useful for further research.

Michalik *et al.* [75] developed a structural model for households' electricity consumption. 100 customers were surveyed, 17 appliances were considered. The consumption patterns were obtained in 15-minute time intervals through a life-style matrix. The results helped in the explanation of consumption differences among household groups and the model was applied for simulation of demand side management programs. In their next study, Michalik *et al.* [76] used fuzzy filters and this allowed the consideration of uncertainty of consumer behaviors.

The study of Pombeiro *et al.* [77] is about analyzing residential electricity according to income, education, number of rooms, family size, and type of tariff. Twenty-two households were monitored in Lisbon, but consumption per appliance was out of the scope of interest. It is concluded consumption differs a great deal regarding inner values, more so than habitation characteristics. Consumption data was recorded and evaluated in segments. In fact, type of tariff had a strong relation with electricity consumption.

Yohanis *et al.* [78] considered more than 200 homes, which represented Northern Ireland households' consumption patterns, and finally twenty-seven homes were chosen to investigate. These households were examined according to the floor area, time of the day and season, house type, number of residents, income, age, location, and the ownership of the house. The paper found out as the floor area increases the electricity demand rose as well. The winter consumption is much higher than the summer consumption. Moreover, as the number of occupants increases in the house, the electricity demand per person decreases.

Ghami and Brauner [79] examined 51 houses in Austria regarding their electricity consumption. The obtained consumption patterns were based on the floor area, house type, number of electrical appliances, day of the week, number of occupants, age of children, and the location of the house. The correlation between these parameters and the electricity consumption was shown clearly. Dwelling area and presence of children had significant impact on the electricity consumption. Peak demand mostly occurred through entertainment devices. Standby consumption in residential areas should be prevented by better efficiency policies or smart metering technologies.

A very comprehensive study conducted in the UK reviewed the previous studies about residential energy consumption [80]. In addition to this comprehensive summary of other studies, a survey was done in six categories during 6 months in the south-east of England in 1994. The attitudes and beliefs of respondents, ownership level of appliances, usage patterns, purchasing habits, information, and labeling schemes were investigated respectively. Responses were considered in the frame of physical and behavioral determinants of electricity consumption. It was concluded people were willing to get information about household energy use and interested in modifying their behavior in order to reduce their consumption and its environmental effects.

Gottwalt *et al.* [81] investigated the impact of having smart appliances and variable prices on the residential electricity consumption. According to their use dependency on a person, electrical appliances were grouped into three. A shifting interval was determined for each appliance and different scenarios were created for the probability of smart start use. Finally dynamic prices were added to the model. Load profiles were generated via a bottom-up approach. Results concluded that equipping households with smart meters is reasonable, and although variable prices would create new peak periods, the shifting potential for residential consumption is high.

Khan [82] studied the responses of customers to dynamic pricing. According to the sensitivity to dynamic price, consumers were divided into three groups: not sensitive, moderate, and sensitive. The information level of consumers was also evaluated, perfect information was provided with smart devices such as advanced metering in households. The Winters Method for Seasonality was used to forecast the demand. Data was taken every half an hour. Simulation was completed via a programming language C-Sharp. Research showed both consumers and suppliers would benefit from dynamic pricing, especially with real time information of the electricity price.

A similar study in China was conducted to measure consumer responses to price increases [83]. Households were divided into four categories regarding their total electricity consumption. They were asked about preferences and responses to variable price increases. A Monte Carlo Simulation was used to estimate demand. The more increase in peak time price, the higher responsiveness was obtained in shifting of electricity use. In order to change peak demand, the price increase would be above a certain value.

Gyamfi and Krumdieck [84] researched the impact of information about supply security, price, and the emission rate on the response of demand side management projects. A case study was conducted in Christchurch, New Zealand. Consumers were questioned through a mail-back survey. Results showed supply security and price are equally effective for people to respond, but the emission sensitivity of household is very low. In their next study, Gyamfi and Krumdieck [85] used bottom-up diversified demand model to generate load profiles in the same region, Christchurch. This model required a demand for each appliance, and a saturation ratio for each appliance. Hourly variation factor was obtained after a survey. People were asked to give the likelihood of appliance use during peak hours. Frequency of the use was defined with linguistic variables. Three scenarios were examined: reducing the consumption in peak hours, shifting the demand to off-peak hours, and both of them simultaneously. Scenario three led to the highest reduction in load profile.

Zhang *et al.* [86] developed a three-dimensional model for UK households, which pointed out three parameters and each parameter's two level (low or high): energy efficiency level of the property, greenness of behavior, and daytime occupancy period. According to this model, eight categories for UK residential consumers were obtained, and appropriate policies were offered to each household group. For example "pioneer greens" are the ones whose house is energy efficient and whose behaviors are appropriate to sustainability, and spend less time in homes. They were considered very differently from "disengaged wasters" which are the opposite of this first group of households: low energy efficiency in the house, low awareness for energy efficiency, and high occupancy in home. While low tax rates were offered to "pioneer greens", higher tax rates should be set for "disengaged wasters" to improve their energy efficiency. "Pioneer greens" consume most energy in the evenings, so it could be useful for them to find best energy supply tariff. However, "disengaged waters" consume the most energy, this group of people should be mandated to get efficiency measures and their awareness and knowledge should be enhanced primarily.

Another study in the UK focused on generation of domestic electricity load profile at a local community level, in Bradford [87]. Eight scenarios were developed. In these eight scenarios, the number of occupants at any age group and the occupancy period were different. This helped to see the contribution of each category of households to the overall peak and to offer appropriate measure to specific household group. Residential consumption mostly changed with the occupancy. It was also concluded that for the higher accuracy of the data, the higher number of input data should be used.

Vassileva *et al.* [88] studied the understanding of consumer preferences when they were provided with web-based feedback. The paper searched for an answer whether consumers are more responsive to personalized measures or one tool is sufficient to reach efficiency targets in general. Study emphasized the differences in income groups and house types. Several questions were asked to draw the general picture of Swedish households in the questionnaire. 660 households participated in the study. Paper proved consumer preferences for several policy implementations have high dependency on households' characteristics.

A survey was conducted to see consumers' preferences about the smart grid [89]. People were asked whether they would like to attain sustainable behaviors, tendency to pay more for green energy, to work in teams, and to get comparative data about their consumption along with recommendations. The paper concludes as the electric power grid changes, the interaction of suppliers with end-users should also change. New technologies should be developed and new services should be created to lead consumers to use electricity efficiently.

Williams [90] studied consumer purchasing and behaviors, but the focus was electronics. Consumers were defined in three categories regarding their possession of electronics and the number of computers they had. Survey data was used to fill in parameters in the model. People were asked several questions about the time they used their computers plugged in, time period computers are charged, estimated time for stand-by use etc. Paper aimed to see differences between consumer groups, and figured out the electricity demand of a household was highly dependent on the number of electrical devices in the house.

Yao and Steemers [91] developed a computer interface to see domestic load profiles in the UK, which was thought to be helpful for designing renewable energy systems at the early stages. A simple method of prediction of daily load profile was introduced in the paper and cluster analysis was applied to five different occupancy scenarios. Then the electric appliance load, domestic hot water load, and the heating load were calculated separately. The result of the study was compared to the real consumption data and it was concluded the estimation was very close. The method was considered applicable for further research on the design of renewable energy systems.

Lampropoulos *et al.* [92] developed a simulation considering the impact of electricity vehicles on the electricity load. A hybrid approach was used to estimate demand. Mobility information of household was taken from existing statistics and applied to the model. This study is helpful to see the integration of the future technology with consumer behaviors. The model should be examined thoroughly.

Chapter 3

Understanding Consumption Behaviors of Turkish Consumers

A general summary of research problem will be presented in the first section, then we will explain how the survey was designed and what the general results of the survey are. We will continue by clustering households. Finally, the discussion part is given, in which we make some conclusions and present our recommendations.

3.1. Introduction to Research Analysis

Residential electricity consumption accounts for 23% of total electricity consumption in Turkey. Moreover, the number of residential electricity users is more than 80% of total electricity consumers and residential consumers contribute to the largest peak demand. In addition to Turkey's increasing residential energy demand, the share of standby consumption is also worth considering, 3% of total electricity goes for unused consumption. As mentioned in Chapter 2, the use rate of electrical appliances is high, especially the rate of electric teapots and electric heaters are as much as essential products, such as a fridge and washing machine. All these facts indicate the requirement for sustainability in Turkish residential sector.

Sustaining supply security, reducing risks due to energy importation, and regulations regarding the use of electrical appliances are already listed in the Ministry's targets. As demonstrated by these facts and targets, electricity consumption should be taken seriously, and not only government but also both producers and consumers should play their role to reach sustainable energy efficiency.

Developing technology has increased the efficiency of electrical appliances. However, residential electricity use keeps increasing. This is mainly because the number of the appliances and their use have also increased remarkably. The increase can be explained by having the variety of appliances and the comfort seeking behavior of people and so on. This emphasizes the importance of studies on understanding the residential energy use and customer behaviors towards energy efficiency measures and policies. Understanding electricity consumers and knowing their need more closely is quite common in studies. Most are aiming to reduce consumption, and to help consumers' budget, these studies, on a national level, also help to make people conscious of energy issues and to better the country's economy. Although there are some studies for Turkish users, this study will be the first one to discover the general tendency of Turkish consumer groups' energy use and reactions of these groups to certain efficiency policies.

Studies towards understanding the customers have three elements: one for the consumers and one for electricity providers, and one for countries. As we all know, energy is not as visible as water. Therefore, consumers do not know the amount of energy they consume when they use energy. Some users may think that they use energy efficiently and they do not consume much energy. However, in general, there is a gap between consumer intention and active behaviors. This gap may be a tool for behavioral change. Once they are convinced of their consumption as inefficient and not compatible with their intention, it is easy for them to adopt efficient use manners. Using energy efficiently will reduce the consumption and decrease the electricity bill of households. More importantly, in the long term, society will certainly gain from this. Secondly, meeting demand is a primary target of electricity providers. Companies that have more accurate customer profiles in their hands will estimate true demand. In addition, today consumer free choice is not common in Turkey, however their numbers will increase in the near future and providers will compete to attract or keep their customers. In such a rivalry, companies who know their consumers, understand their concerns, and even guide them regarding their electricity consumption will succeed. Last but not least, countries will also gain from understanding consumers. In order to reach a sustainable environment, reducing energy consumption and gas emissions are crucial. For countries whom energy demand is dependent on imports, managing energy demand is much more essential. Moreover, making appropriate policies for consumer groups will avoid wasting time and budget for the country. These are all possible through a better understanding of consumers, and it requires a precise study on the subject.

This study is trying to understand current practices of households and their intention to different policies. Possible policy interventions within the scope of the research are determined as information, feedback, rewards and disincentives, and also social influences. Consumer behaviors are questioned and attitudes of consumers towards energy consumption and the energy savings have been depicted.

In the literature consumer behaviors are investigated both by monitoring and surveying. Due to the limited budget and time, surveying has been chosen as a method to collect the residential consumption information of a sample of Turkish people. While designing our survey, we used data obtained by Ministry. Since we do not predict the electricity demand, instead of asking electrical appliances and their use times in detail, we tried to find out what consumers' preferences are and what they think about the efficiency policies offered. Once the questionnaire was completed, possible changes on the electricity demand and its effects on the network are analyzed. In the analysis, the data provided by the ministry is used too. Following sections explain how the survey was designed and summarizes the general finding of the survey.

3.2. Survey Design

It is possible to reach a general picture of residential electricity consumption for Turkey. However, there is a need for research into current practices of households and their intention towards different policies about energy efficiency. In this thesis, our objective is to achieve an understanding on: (1) a general overview of consumers; their consumption habits and their attitudes towards energy usage, (2) reactions to possible policies and characteristics of the household, (3) clustering households according to their current energy consumption behaviors and attitudes, and (4) analyzing the changes in demand by using the general findings of our study. For this reason, a survey was designed and details of the survey are explained in following sections. Aside from questions such as income, education, the number of people in the house, and the floor area, the questions were designed to allow easier clustering of how residential users respond to the issues such as pricing, willingness to change their behavior, the kind of additional information they thought it would be effective to reduce their consumption, and the types of energy policies they would be willing to engage with.

Since we wanted to make the survey short, we used some of the existing data for our analysis, and did not ask them in our questionnaire. 2010 Energy Efficiency Report of Turkish Households survey data collected by the Renewable Energy Head Office of the Ministry of Energy and Natural Resources provided comprehensive data on energy use behaviors of 2,530 households, where only one member of each household answered the questions [7].

Another authorized project by the Ministry started nearly at the end of 2012 was called 'Mrs. Energy", targeting to develop information about the type of electrical appliances, the ownership rate of these appliances, the conscious level of energy efficiency, and the use of electricity in residential areas. The survey was conducted in 20 provinces, and 79.2% of participants were housewives [93].

Both Mrs. Energy and 2010 Energy Efficiency Report Surveys revealed that Turkish consumers are not aware of energy labels. The ownership rate of appliances keeps rising, peak period usage of electrical products is quite common, which emphasizes the potential in residential areas to reduce electricity consumption and save the energy. These statements from existing projects are considered supportive to the research questions: residential electricity consumption is increasing steadily and this consumption depends on several factors. Possible reduction of the consumption and the increase in the efficient use of electricity could be achieved through appropriate policies targeted to the right household groups.

Firstly a trial was designed. The pilot run consisted of 14 pages and 56 main questions and too many sub-questions, which made more than a hundred in total. One extra page was added to obtain respondents' comments and suggestions to enhance the questionnaire draft. 41 questionnaires were sent out to people in and around İstanbul Şehir University. Not only academic and administrative members participated in the survey, but also students, security workers, and service staff. This study wanted to see how questions could be shortened and if some could be eliminated.

There were five parts in the pilot run. The first part was about electrical appliances in the households and their use. The next part focused on the electricity consumption behaviors and attitudes of consumers. In the third part of the pilot, some useful information was provided about efficient use of electricity and energy savings in residential areas. Just after this quick information part, consumers' willingness to change some certain behaviors was questioned. The next part was about applicable policies and consumer preferences. The last part was to determine households' characteristics. In two weeks pilot surveys were collected from respondents. EXCEL was used to collect answers. After analyzing and discussing of the results, eventually three months later, the pilot could be converted into the final survey.

The pilot run had many questions that could be tiring and distractive for consumers. For example, many products were listed and these products' age, energy label, frequency of use and so on were asked in the trial. Since our target was not estimating demand, we decided to eliminate such questions, and use the existing data as a reference. Also in the final draft of the survey, there was no extra page to give information. Questions also included short definitions of some terms, or efficiency hints were provided briefly before the consumer preferences were asked. In the fourth part of pilot run, where response to several polices were asked, a Likert Scale was used. The Likert Scale is a scale which allows respondents to rate their preferences. However, analyzing these responses was difficult. The Likert Scale did not provide a distinguishing measurement between households. Therefore, in the final run of the survey, people are asked to opt for the option they would like to attain most.

The final survey comprised of 50 questions, which took a maximum of fifteen minutes to complete. The survey was accessible to the public through the website in Turkish between July 2013 to August 2014. The questions were targeted at end users.

Questionnaire was accessible to respondents on a website for almost a year. 526 people answered all the questions in the survey, and 140 people left some part of the survey incomplete. Completion rate of the survey is quite high (79%). Questionnaire is comprised of three parts and it is thought to take ten to fifteen minutes to complete. The first part is about consumer behaviors and their attitudes, including awareness of energy issues, peak hour usage, and standby consumption. Part II starts with a list of behavioral change measures. It seeks for an answer which policy will be most effective on changing behaviors. Each policy is asked in detail for the best design and implementation preferred by households. Demographic questions such as income, household size, occupation of the house, and so on are given in the last part.

First part of the survey is used to develop a general picture of household sample. Current consumption attitudes and behaviors obtained from this part will be summarized in following section. Questions in part II with demographic questions from part III are essential for clustering households. The entire survey makes it possible to estimate some impacts of reduction of electricity consumption via behavioral change policies on the electricity network. The whole survey can be found in Appendix A.

3.3. Factor Analysis of The Survey

Factor analysis investigates relationship between variables, and it helps to present variables in a condensed way [94]. This analysis is important to see how a survey is designed. We did not claim our study to be a perfect research on understanding consumer behaviors. Since we would like to collect a diversity of information regarding residential electricity use, we abandoned some requirements of factor analysis. Only the first part of the survey, where we are looking for an answer to current consumption behaviors and attitudes, is examined with factor analysis.

Consumer behavior towards energy efficiency was measured with twelve items. All twelve items were assessed on a 5-point scale (0 = always or completely yes, 5 = never or completely no). Items were in reference to several subjects such as energy labeling, standby consumption, and greener consumption habits. These items are listed below. Exploratory factor analysis with the principles component analysis extraction, and the Varimax method rotation were conducted for examining whether the items were grouped correctly or not. To verify the data set as suitable for factor analysis, the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) value and the Bartlett's test of Sphericity value were checked [94]. In this analysis KMO value was 0.646 and Bartlett's test was significant (p=.000), therefore the factor analysis was appropriate.

The investigated items are:

1. I have energy efficient products in my house (Class A or above)
2. I consider energy labels when purchasing a new product
3. I use efficient light bulbs in my house
4. I unplug the TV, DVD etc. when they are not in use
5. I unplug the PC, notebook etc. when they are not in use
6. Some dishwasher and washing machines have alarms after the program, in this case I turn off the alarm
7. I run the dishwasher and the washing machine at full capacity
8. I turn off unnecessary lights
9. I prefer to boil water on a gas furnace instead of a kettle
10. I prefer to heat the meal on the gas furnace instead of a microwave
11. I prefer to iron in the early times of day instead of at peak hours
12. I prefer not to use kettle/tea-coffee machines during peak hours

There was a five-factor structure that explained 61.24% of the variance. The first three items above, loaded on the first factor, and the next three items (item 4, 5, and 6) loaded on the second factor, item 9 and item 10 loaded on the third factor, item 11 and 12 loaded on the fourth factor, and item 7 and item 8 loaded on the fifth factor. As expected, the components regarding energy labeling are in one group under the first factor. Components regarding stand by consumption belong to the second factor. Customer's greener cooking practices are collected under the third factor. Shifting electricity use from peak hours to reduce demand is related to the items 11 and 12, these items loaded factor 4 together. Lastly, basic consumption habits are explained in factor 5. Detail of the analysis is given in Appendix B .

Comments

- There is not a Cronbach alpha coefficient recorded to indicate how efficient consumers' behaviors are in the literature. In the current study, the internal consistency of the scales was quite low (Alpha = 0.571). In order to be considered acceptable, this value should be above 0.7 [94]. However, the questionnaire did not claim to be a perfect scale of efficient behaviors. For a better research, some items with low item-total correlation should be removed. As stated before, in this research it was not appropriate to remove some items according to the reliability test, since we will need these items to interpret the survey later in the analysis.
- In order to shorten the questionnaire, similar questions, which are under the same factor in this analysis, could be asked as one question. For example; "please indicate your awareness of energy labeling/stand by consumption/willing to shift the use of electricity" etc. There was limited information about Turkish consumers' habits, therefore we asked all these questions separately to allow for further analysis.

3.4. General Findings of the Survey

In this section, the results of the survey are presented. The questionnaire obtained consumer behavior and attitudes towards energy efficiency. Results regarding the peak demand behavior, willingness to shift this time use to less peak hours, and standby consumption are given. The motivation level of consumers for behavioral change is also presented. Households' response to policies is summarized in detail. In order to explore the relationship between variables and to make comments on survey results *Crosstabulation* tables are used in the SPSS program. Crosstabulation is a method to compare the observed and expected frequencies or proportions of independent cases [94]. Outputs of crosstabulation are given as graphs to better visualize the results.

Demographic information

Out of 666 surveys, a total of 526, representing 79% were completed. Most respondents (58%) were from İstanbul. The majority of the houses (51%) had a size of 101-150 m^2 and 30% of the houses were occupied by 4 people. Most households (73%) reported their education level of graduate or post-graduate and 36% of people stated an income of 1,001-3,000 TL. The monthly electricity bills have no difference in winter and summer, and 35% consumers said that they pay 60-90 TL for the electricity bill. 44% of respondents expect 10-25% reduction in their residential consumption through efficient use of electricity. 58% of people stated that household members have similar consumer behaviors in general.

Survey questions regarding their subjects are analyzed below in the order of in the questionnaire.

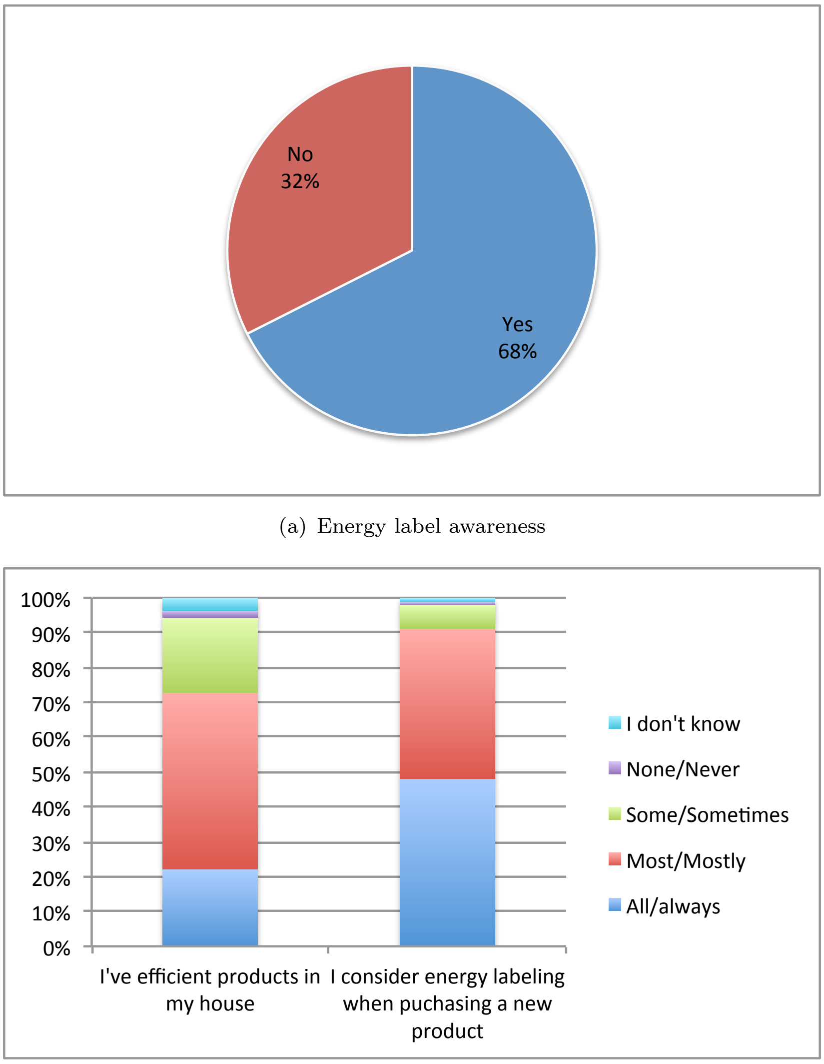
Energy labeling

In a survey completed by 526 people, 68% of consumers said they are aware of energy labeling (Figure 3.1(a)). Although the awareness level of consumers are quite high among respondents of survey, it is not consistent with the existing data obtained from the Ministry's report. According to the results, nearly all of these consumers are aware of the energy class of appliances in their house and they take into account the energy class when purchasing a new product (Figure 3.1(b)).

Although they are familiar with energy class, consumers do not favor of buying energy efficient products due to their expensiveness. It is followed by the option "I do not believe that efficient products could reduce the consumption", and finding labels untrustworthy comes next (Figure 3.2(a)). Giving incentives to replace old products with more efficient ones could be more attractive for people. Even though, people, who find efficient product more expensive, stated they would change their old products on their own with a higher percentage (Figure 3.2(b)). It is also interesting, people seem to be persuaded about the importance of having efficient products and albeit they have higher prices people seem ready to renew their old appliances with an adequate incentive. Both the government and product manufacturers should consider this issue and play a role.

When we look at some current practices of consumers, we see knowing energy class and having more efficient products in their houses do not mean consuming energy efficiently. Figure 3.3(a) and Figure 3.3(b) show there are no differences on the percentage of efficient consumption behaviors among consumers who consider energy labels when buying a new product and who do not. Here again, we come to the reality, having energy efficient products does not mean the efficient use of energy. Understanding consumer behavior becomes more significant when we want to establish energy saving behaviors.

Replacing old and energy-consuming products with efficient ones definitely will help reducing energy consumption and carbon dioxide emissions. Whereas half of the participants state they would change products if there were an incentive, 42% of them say they would change product without any incentive. Most of the consumers are of the opinion there should be a discount of at least 20% off the original price for replacing old

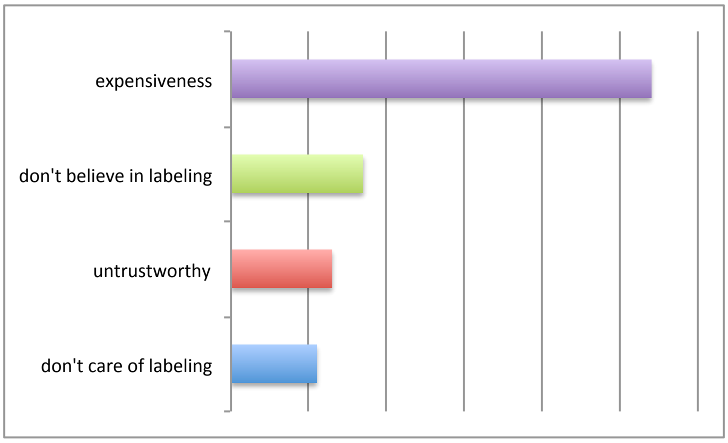


(a) Energy label awareness

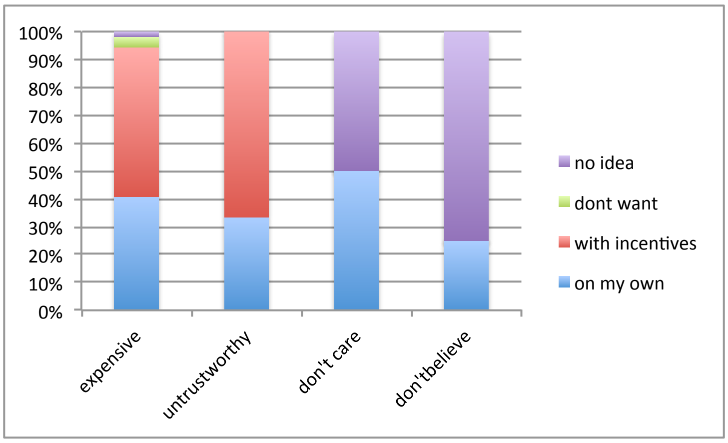
(b) Considering consumers' awareness of energy labeling

Figure 3.1: Energy labeling-I

appliances with energy efficient ones. In a research, replacing old and low-energy-class fridges (approximately 4 million products among Turkish households) with A-class products was found to save 1.6 billion kWh electricity and 293 million TL for the country. It would not be necessary to install new power plants with these savings. Moreover the cost of incentives (250 TL for each product) was expected to amortize in three years [95]. Consumers already seemed convinced about the necessity of having efficient products. Therefore there should be more studies examining the impact of incentives on energy savings.



(a) Reasons not to consider energy labels



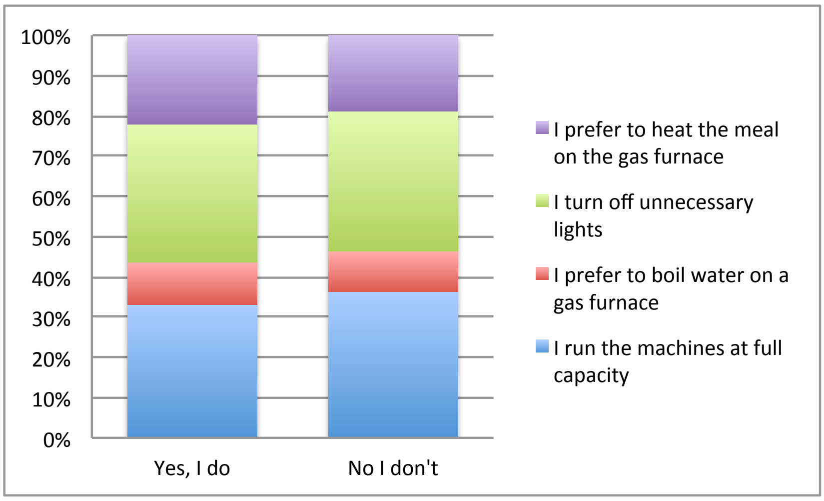
(b) Motivators for having more efficient products for each reason

FIGURE 3.2: Energy labeling-II

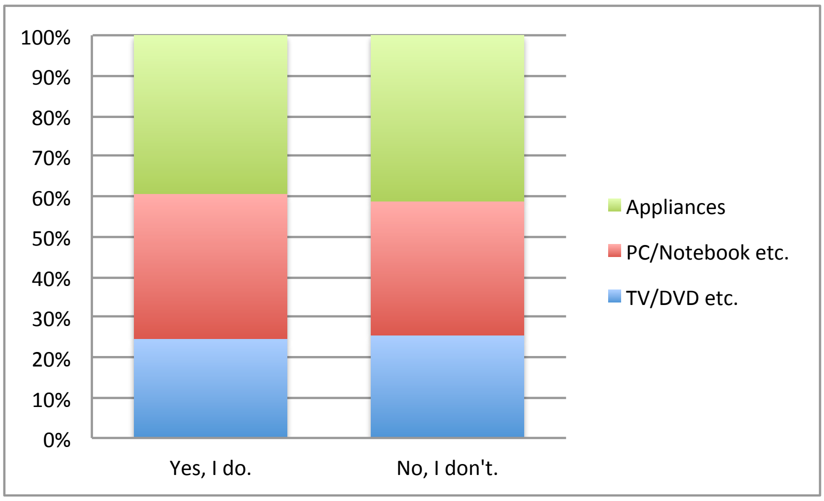
Peak hour usage

Electrical teapot or coffee machine emerged as the appliance which had the highest number of respondents indicating they always use it between five to ten o'clock in the evening, followed by dishwasher. Figure 3.5 shows the usage level of some household appliances during high electricity demand period.

Other question regarding peak time usage in the questionnaire was whether consumers would shift their use to low peak hour period or not. It was the dishwasher that was indicated by most participants as they could shift its use to another time, followed by the washing machine (Figure 3.6). Despite their attitudes towards shifting washing machine and dishwasher use participants are not in favor of changing the use of kettle/tea or coffee machines. This can be explained by the traditional habit of Turkish households. Generally, they would like to have their coffee or tea after dinner, this time coincides with the high demand period. We cannot expect consumers to shift this habit to another time period. However, they should be informed about a more efficient way to use cooking



(a) Comparison of considering energy labels and some current practices



(b) Comparison of considering energy labels and standby consumption

FIGURE 3.3: Considering energy label awareness in contrast to current consumption habits

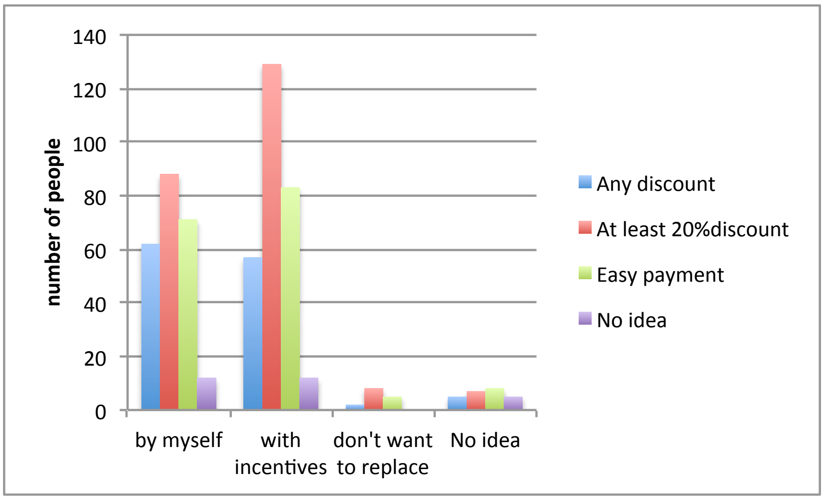


FIGURE 3.4: How would you replace your old products with more efficient ones?

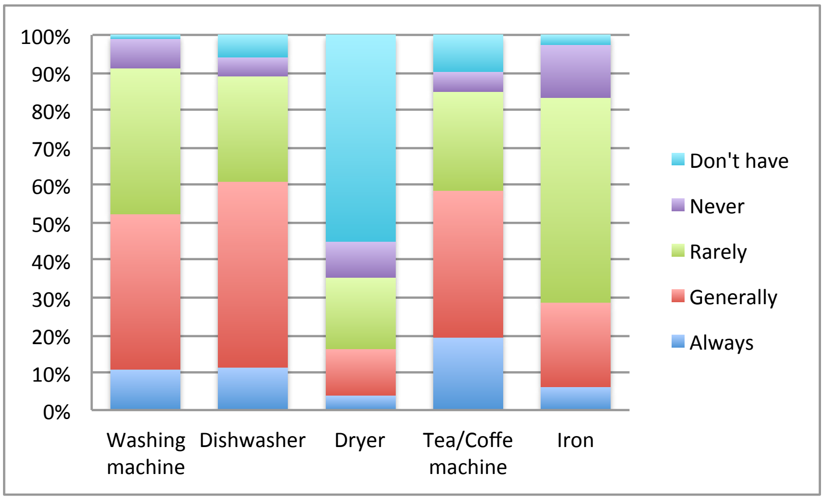


FIGURE 3.5: Consumers' response to question of peak time usage

appliances. Instead of electricity, using a gas furnace should be emphasized. Meanwhile, product manufacturers should increase the efficiency of current appliances in the market.

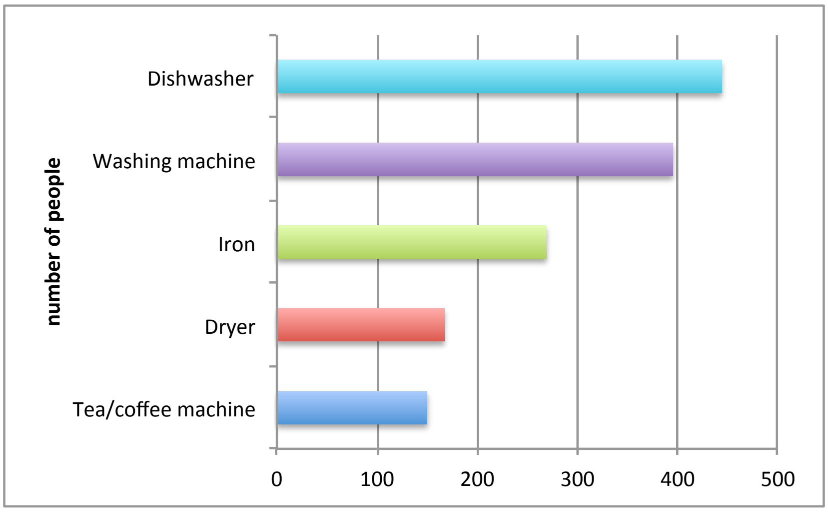


FIGURE 3.6: Willingness to shift the use of some appliances

Participants were also asked what motivator would be most effective to change their behavior regarding electricity consumption during peak hours. "More expensive electricity at that time", "idea of protecting environment" and 'willingness to reduce our country's dependency on energy" were listed as most preferred motivators in Figure 3.7. Monetary drivers are expected to be more effective for behavioral change. Therefore, these results are not surprising.

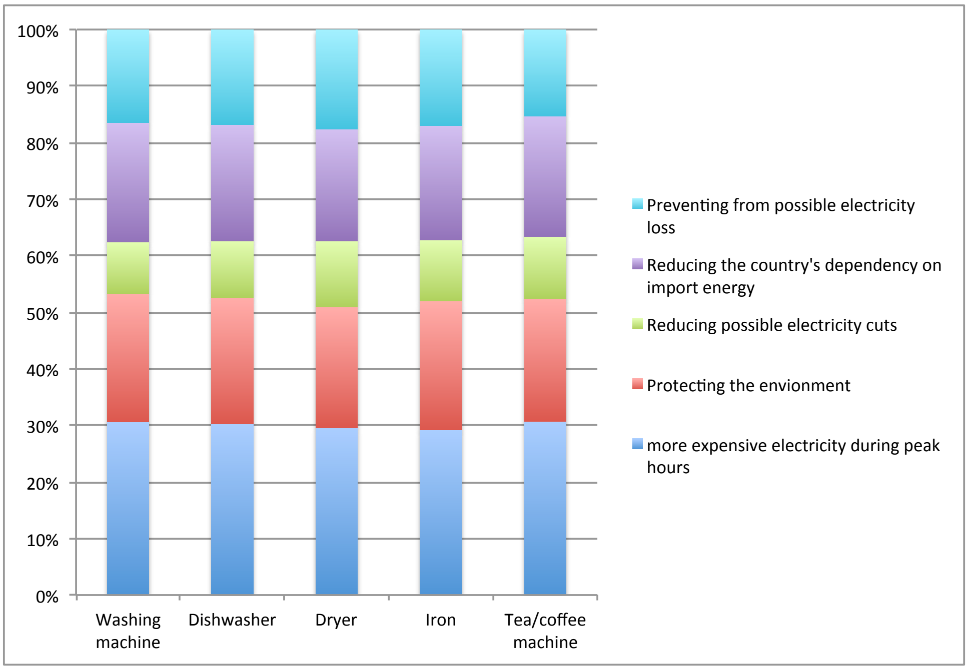
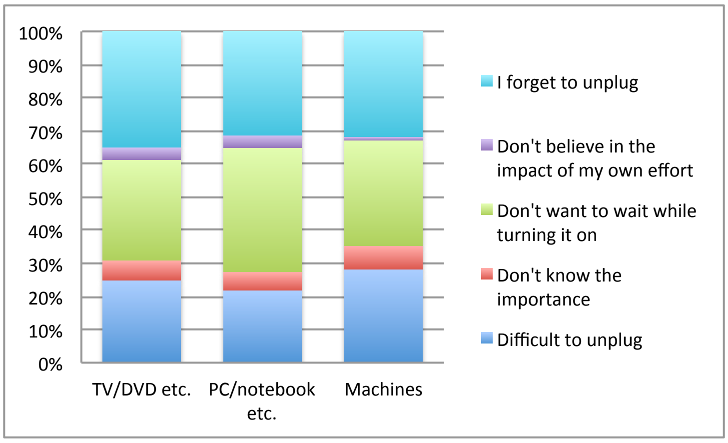


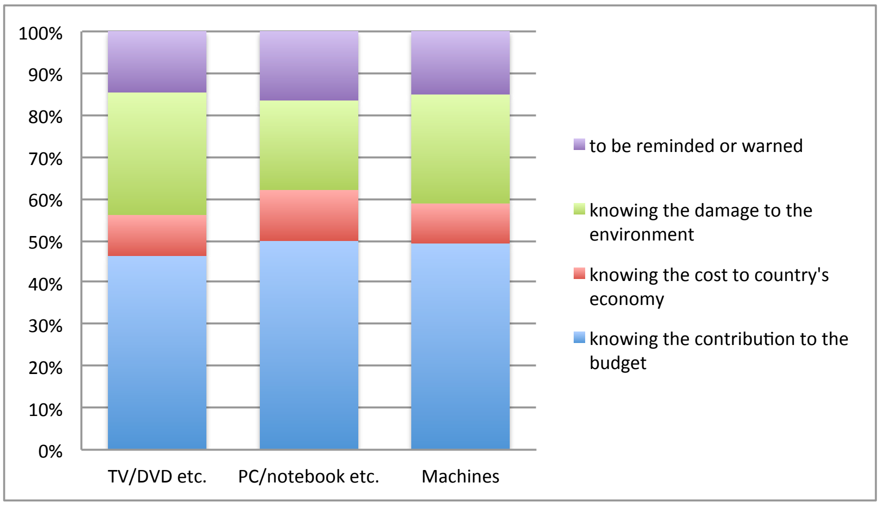
Figure 3.7: Which motivators are more helpful to reduce your electricity use at peak hours?

Standby consumption

There were three basic questions examining residential standby consumption. First of all, consumers were asked whether they leave computers, televisions, or other appliances standby. Then the reasons why they leave these products standby were questioned. Lastly, consumers opted for the most appropriate answer as their motivation to avoid standby consumption. Surprisingly, consumers defined themselves as conscious about standby consumption. As is mentioned earlier, Turkey's standby consumption is high and keeps increasing [18]. Figure 3.8(a) shows the answers for the reason leaving products standby. People stated that for television "forgetting to unplug" is the most common answer. Whereas, the time passes until returning on computers e.g. has the highest rate for leaving computers standby. For washing machine or dishwasher, difficulty to unplug is also stated as a reason. As it can be seen from Figure 3.8(b), households' biggest motivator to prevent standby consumption is to know the contribution of this consumption to the household budget. Since forgetting to unplug products and knowing the impact of unused electricity to the bill are common answers, policy makers should consider this. There should be new interventions showing the impact of standby consumption and reminding households to avoid it.



(a) Reasons why consumers leave products standby

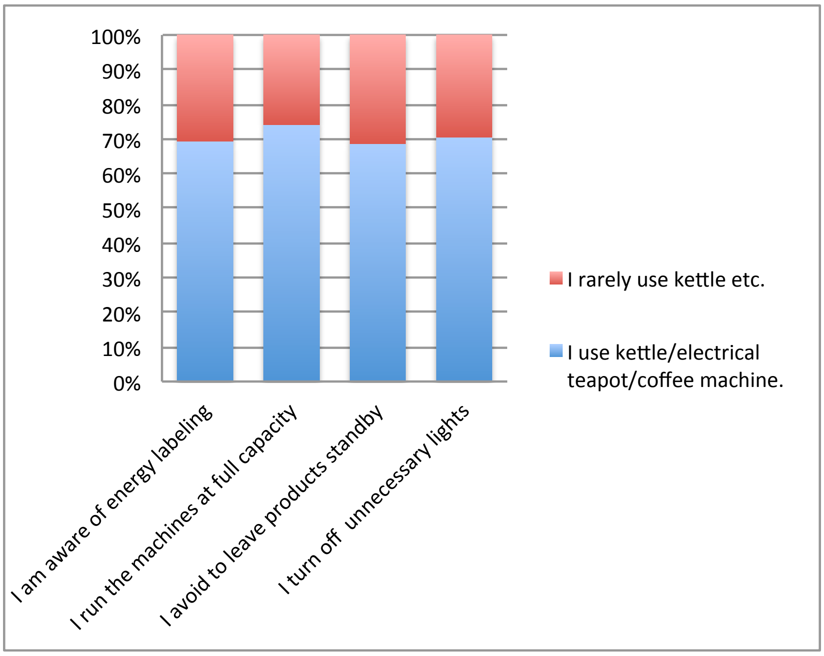


(b) Motivators to stop standby consumption

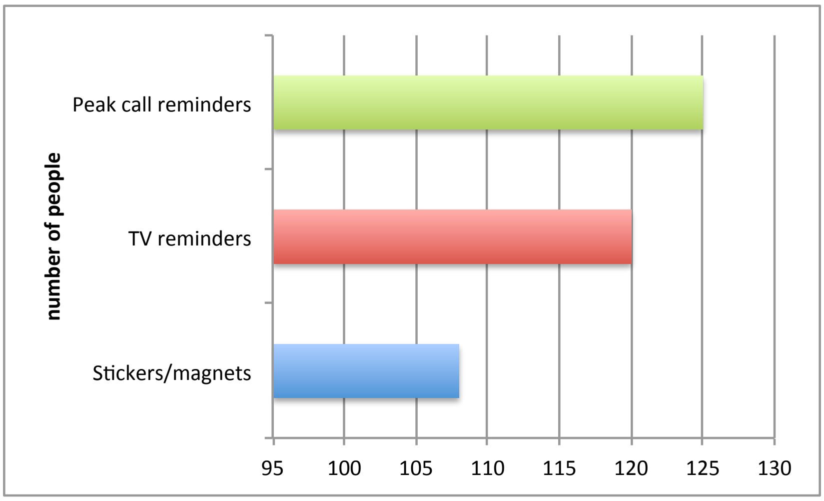
Figure 3.8: Standby consumption

Kettle use

Although consumers defined themselves as conscious regarding some behaviors or attitudes towards energy efficiency, their kettle use is on the opposite of this scheme. Figure 3.9(a) indicates the ratio of households who use kettle often and who use rarely in contrast with their other behaviors. As seen, even consumers have more efficient consumption habits in their home are not conscious of the impact of using an electric teapot, coffee machine, or kettles. End-users can be thought as more resistant to change their kettle use habits. And when they were asked how would be more effective to prevent them from using kettle or electrical teapot/coffee machine during peak hours of electricity, most households believe in the impact of policies reminding them of halting or shifting the consumption (Figure 3.9(b)).



(a) Kettle use vs. some other consumer behavior and attitudes



(b) Motivators to shift kettle use

FIGURE 3.9: Kettle use

Electrical heater

The use of electrical heater had a small ratio among households (7.3%). Providing quicker warming for people was indicated as most common reason for its use. However, insufficient warming of the house has a high rating too. Figure 3.10 shows the reasons for the use of electrical heaters. According to the Mrs. Energy Survey Report, the possession of an electric heater and its use is high among Turkish households. However, in our survey participants hardly have electrical heaters. The most common reasons of their use are for a very short time and for a certain place. As it is with kettle use, people should be informed using electricity for heating is not reasonable and more expensive. Furthermore, Figure 3.10 indicates inadequate warming of houses is another problem among households. It is significant to emphasize the issues such as insulation and energy savings will be achieved through insulation, leading to more sustainable development.

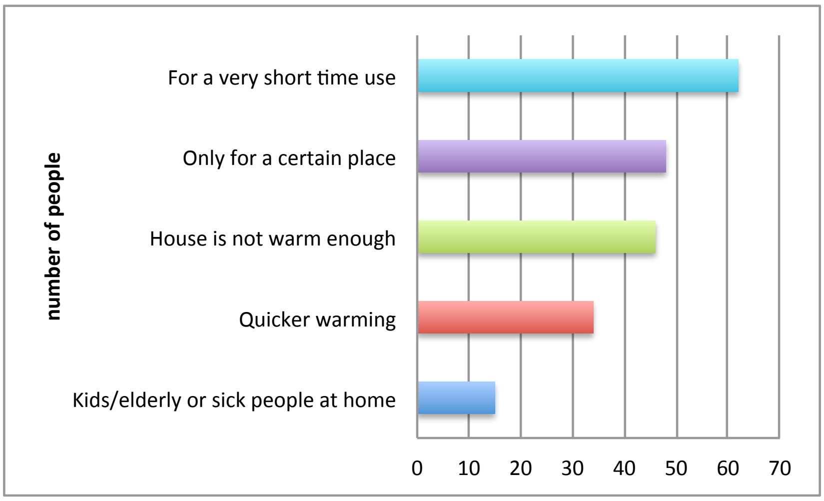
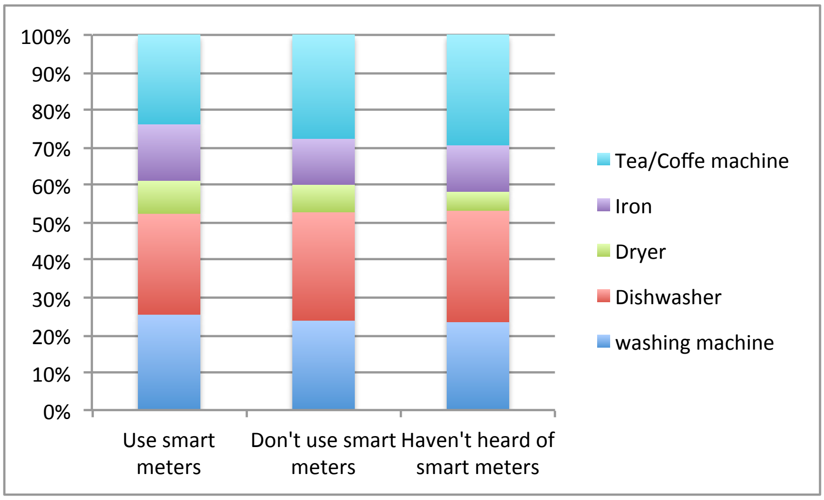


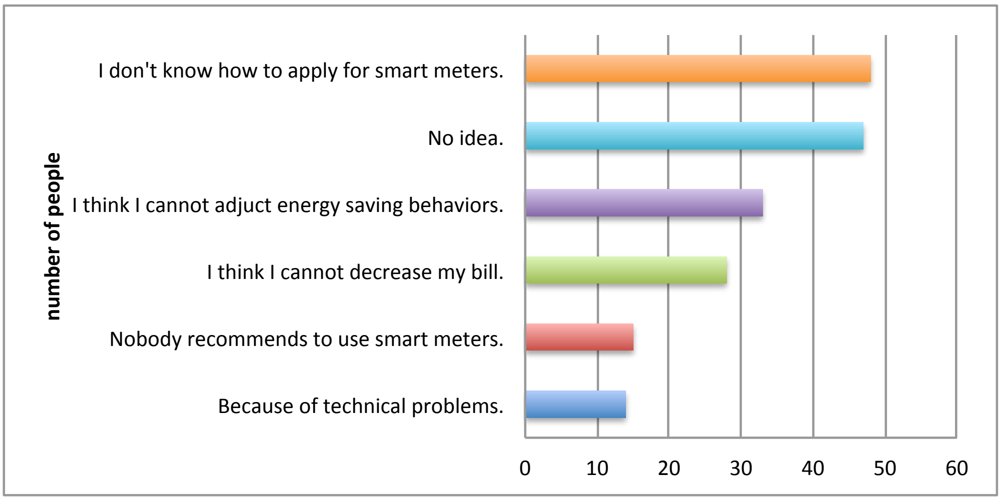
FIGURE 3.10: Reasons of electrical heater use

Smart meters

In the first part of questionnaire, people's knowledge about smart meters was researched. Smart meters are used to allow consumers to use electricity at different prices in various periods. Nearly 70% of participants stated they were aware of smart meters, but only half of them used in their homes. When consumers are examined about their electricity use during peak hours and possession of smart meters, the results are confusing. The percentage of using appliances from five to ten o'clock is nearly the same among users who have smart meters and who do not (Figure 3.11(a)). This means consumers are not well informed about the practice and purpose of smart meters. Moreover, the most common reason why consumers do not use smart meters is they do not know how to apply for one (Figure 3.11(b)). Smart meters can be thought as a monetary driver for consumers. However, consumption behaviors of households are opposite to their preferences, they said they were more responsive to monetary tools. Here again we face the lack of information. Also, policy makers seem not to properly work on this subject. Smart meters could bring about energy saving when they are used in the correct way. Certainly, there should be detailed work on the implementation of smart meters.



(a) Comparison of peak time use with possession of smart meters



(b) Reasons why consumers do not prefer to use smart meters in their homes

FIGURE 3.11: Smart meters

Familiarity of efficiency projects

In the end of the first part of the survey, participants were asked about the efficiency projects conducted by the Ministry of Energy and Natural Resources, and 79% of them said that they have never heard of these projects (Figure 3.12). Familiarity with the projects was very low and limited. As a researcher on the subject, we have seen public ads, posters, and also social media campaigns about the projects. However, even people around us have never heard of these projects. This might be explained by announcing the project in the wrong places or at wrong times. It is very sad to realize such a project with a high budget and great effort of all the involved organizations is not responded to by society.

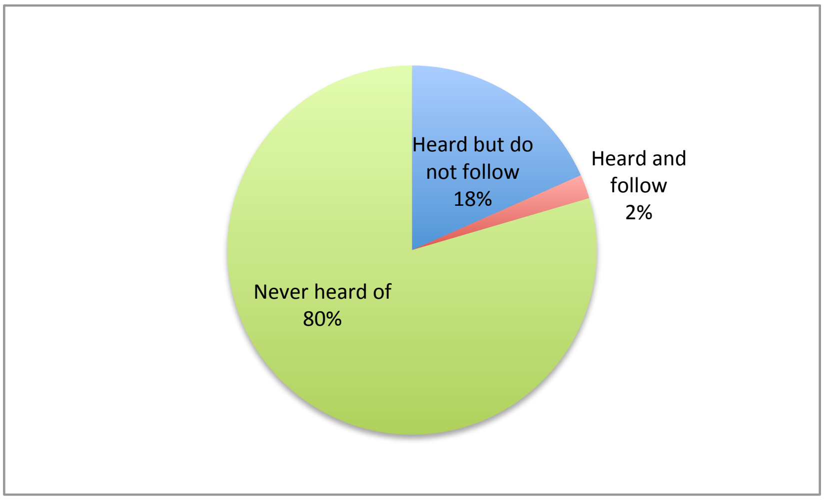


Figure 3.12: Awareness level of efficiency projects run by Ministry

Measures

Second part of the survey includes some efficiency policies and households' response to these policies. After a detailed review, some measures successful in changing behavior were chosen to appear on a list within our survey. Of these listed measures and the most common replies to them are summarized in Figure 3.13.

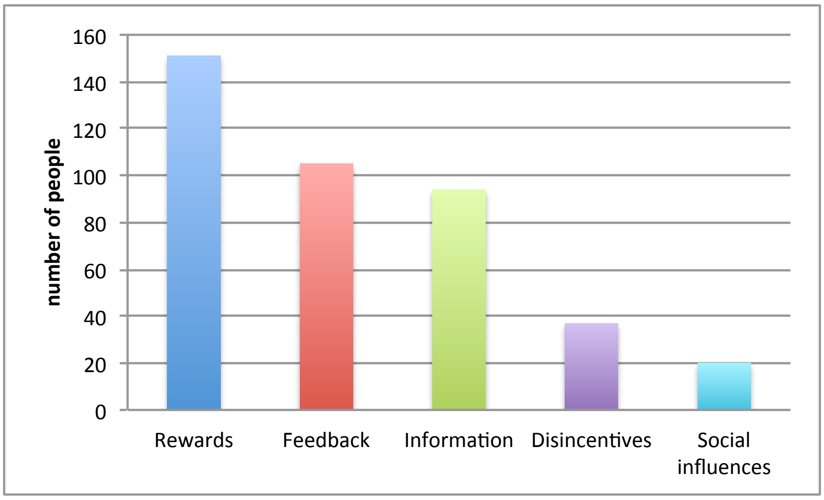


Figure 3.13: Which measure would be more effective to change your behavior?

First of all, 23% of participants chose informative measures as more effective for behavioral change. Figure 3.14 gives a very brief analysis of questions regarding the method or route of the information. People are interested in learning methods of efficient use of electricity mostly via television and the Internet. Public service advertisements and then documentaries are the kinds of formats they would like to see on TV. Academics are the most popular answer to the question, "Who would you like to see most in energy efficiency studies?". As is explained in the Persuasion Theory, credibility is important for behavioral change. Consumers trust in scientists more than popular culture icons.

As seen in Figure 3.14(b) participants mostly chose TV and the Internet as sources of information. When they were asked about the format of TV programs, public service ads were the most common answer (40%) (Figure 3.14(d)). On the other hand, current energy efficiency projects of the Ministry have already being announced on TV as public service ads for a long time, but 80% of respondents stated they have never heard of these projects (Figure 3.15). This is another sign that current policy is not working and should be improved urgently.

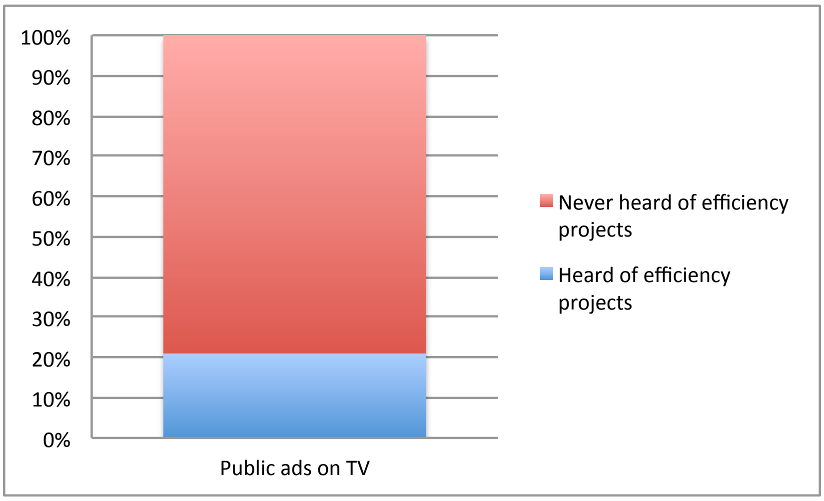
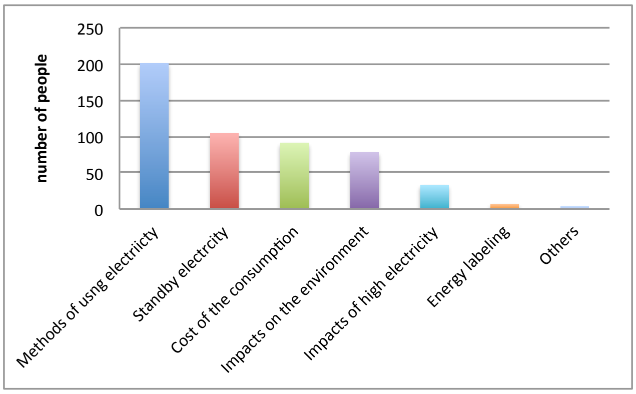
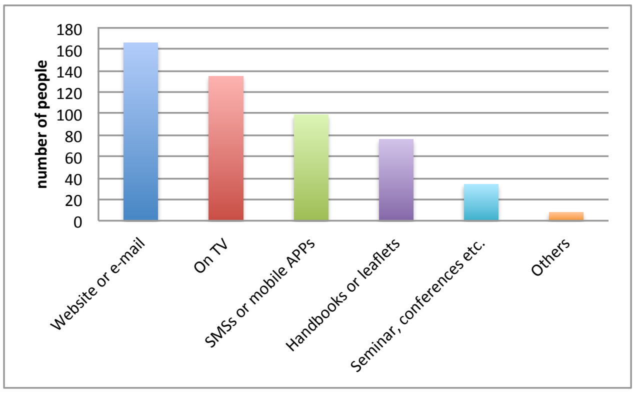


Figure 3.15: Comparison of awareness level of efficiency projects with consumers preferred public ads

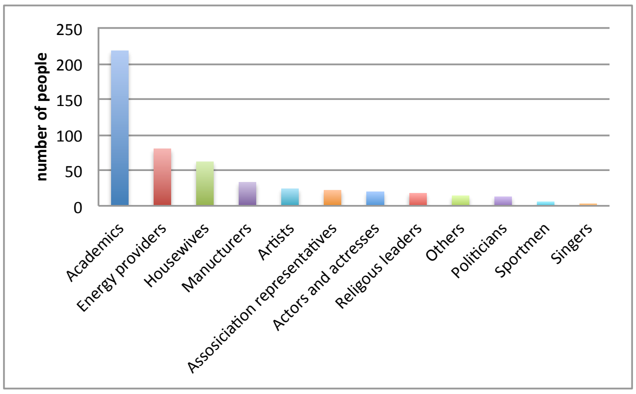
One fourth of participants have chosen feedback as their preferred behavioral change measure. Figure 3.16(a) indicates consumers are open to a new format of billing. They are willing to see more informative data on their bill including the environmental impact of their consumption, the comparison with last month's consumption and so on. Although consumers seem open to new formats of feedback such as e-mail, they are pleased with having their electricity bills on a monthly basis. Providing access to their consumption at any time also impacts consumption and should be an alternative to keep consumers more often informed of their energy consumption. Although existing work proves that more frequent feedback is more effective, participants think differently. There may be a misunderstanding in the survey about having feedback more often versus payments.



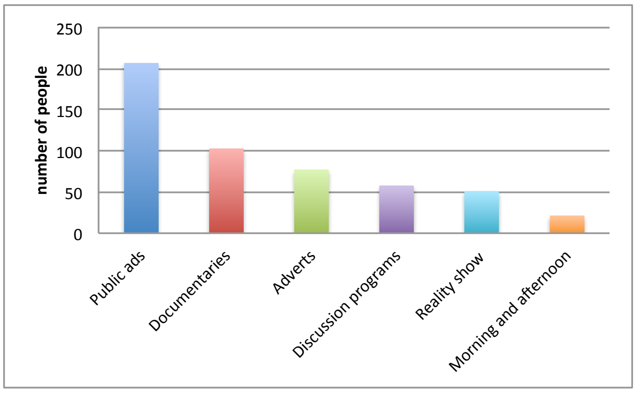
(a) What should informative policies be about?



(b) How do you prefer to be informed most?

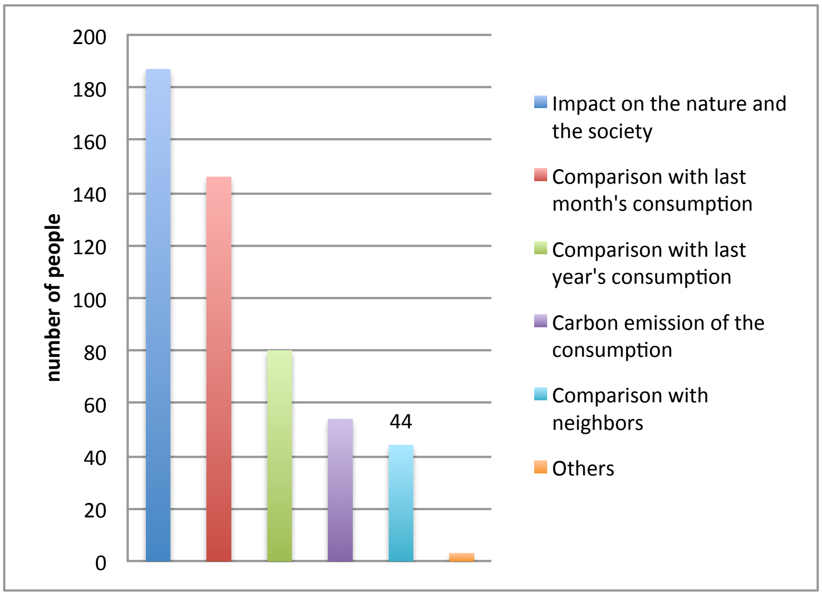


(c) Who would you like see most in information campaigns?

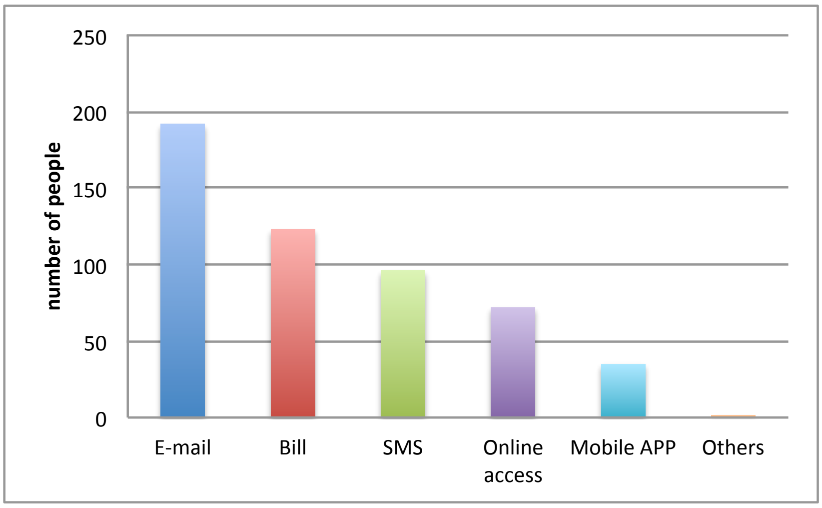


(d) Which TV format do you think is best?

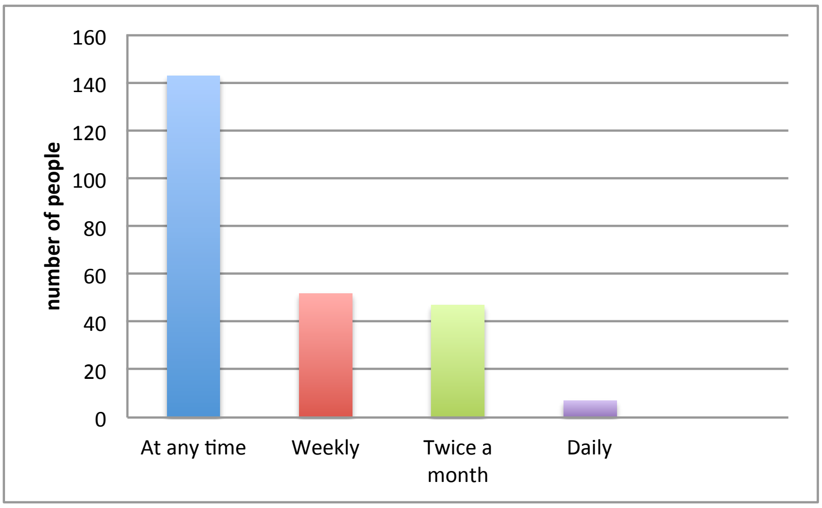
FIGURE 3.14: Details of "information" as a behavioral change measure



(a) What should feedback include?



(b) How would you like to get your feedback?



(c) What would be the most effective frequency of feedback?

FIGURE 3.16: Details of “feedback” as a behavioral change measure

At a rate of 37.1%, reward is the most common method to incentivize for behavioral change. Unsurprisingly, people have opted for monetary rewards in return for using energy efficiently (Figure 3.17). In addition to a reward, disincentives had also been listed in the survey and disincentives were chosen by 9.1% of participants. It would not be wrong to consider disincentives as the opposite of rewards. For this reason, monetary disincentives could be a tool to attain energy efficient behaviors. According to Prospect Theory people will react to a loss rather than a gain. Therefore we would expect to see disincentives at a higher percentage among participants. However, it is not also surprising for households to opt for rewards. The Rational Choice Theory says people are always in favor of gaining benefits.

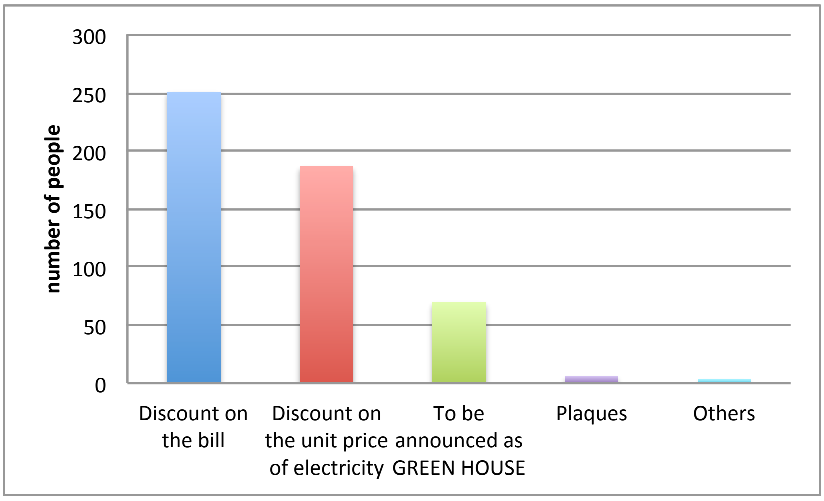
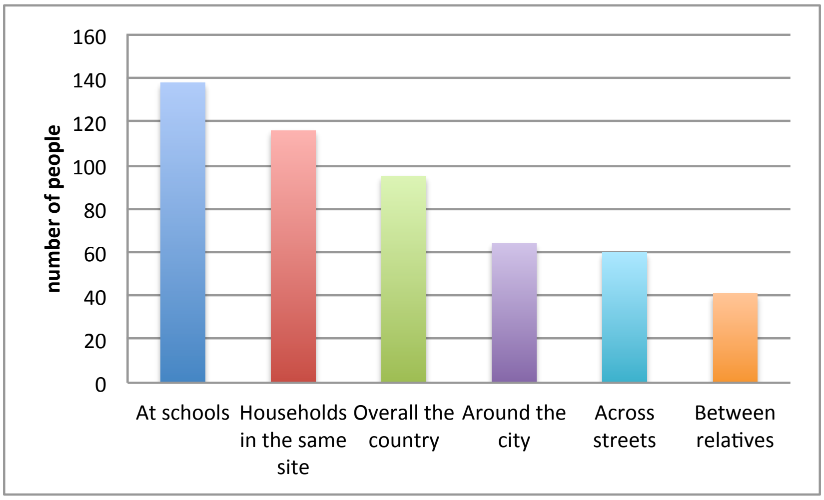


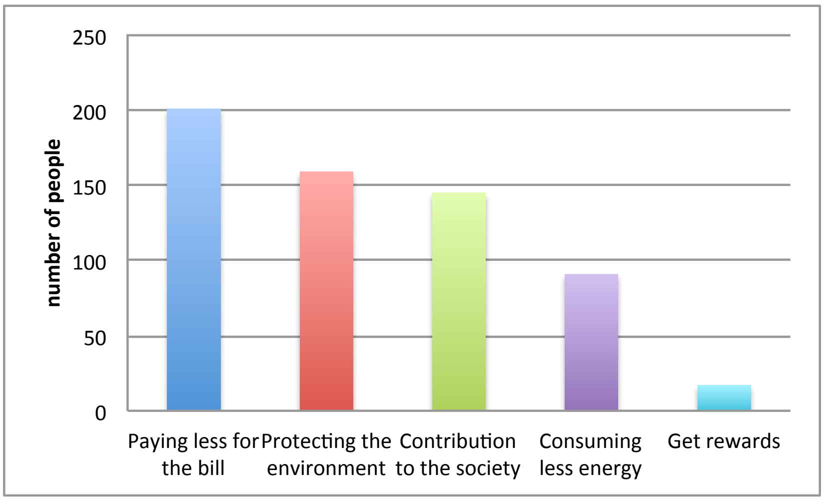
FIGURE 3.17: How should rewards be?

Last, only 5% of respondents choose social activities as a behavioral change measure. People think activities taking place at schools would be more enjoyable and more informative as it is shown in Figure 3.18(a). Participants, who are interested in social activities regarding energy efficiency, have indicated their biggest motivator is "making contribution to awareness level of society" (Figure 3.18(b)). Probably, households with children are willing to participate in such activities for the purpose of being a good model for their children and leaving them a better society. In this case, monetary drivers come in second place, and in contrast with the general attitude, rewards become the least significant motivator for social influence. Social influence is a measure that is a combination of information, feedback, and rewards. Social Identity Theory and Social Comparison Theory claim higher energy savings, as consumers are more likely to change their behaviors in a group. Especially schools are good places to start. For example, another authorized project named ENVER by the Ministry promoting energy efficiency in lightening had been conducted in schools. Students were provided efficient light bulbs in

2008 and as is seen today both from the Ministry's reports and our survey, the knowledge level of efficiency in lightening is quite high among Turkish households.



(a) In what scale should social influences be?



(b) Drivers for being involved in a social influence

FIGURE 3.18: Details of "social influences" as a behavioral change measure

Other questions regarding behavioral change measures

In very last part of the policy section in the survey, new policy examples are discussed and their feasibility is asked to the participants. Nowadays, the Turkish audience is familiar with some colorful messages on TV played after 21:00 o'clock reminding kids of going to bed. In our survey, people were asked whether they found similar quick messages on TV effective or not for changing their behavior. These messages have been thought of as "don't leave your TV standby", "Please turn off unnecessary lights". 74.3% of participants found these kinds of messages helpful to get sustainable behaviors into their homes. People were also asked whether they thought stickers or magnets on the appliances reminding them of using energy efficiently could be helpful. Giving advice such as "run me after 22:00", "run me at full capacity", "choose eco program" etc. were found effective with 62.6%. It is also seen in the survey 74.1% of households would reduce or shift their electricity consumption when they were warned about high demand periods. This shows consumers are willing to change their behavior to reduce demand. Once they are informed about impacts of high electricity demand and perhaps with the help of warning calls or messages, a large reduction in energy consumption could be achieved. Figure 3.19 indicates the frequency of these three policies among participants. Quick messages on TV is mostly preferred and might be more useful than public ads announcing residential energy efficiency by Mrs. Energy Project. Calls or SMSs might also be an alternative to remind consumers of the high demand period and help avoiding this time or shifting use to another time.

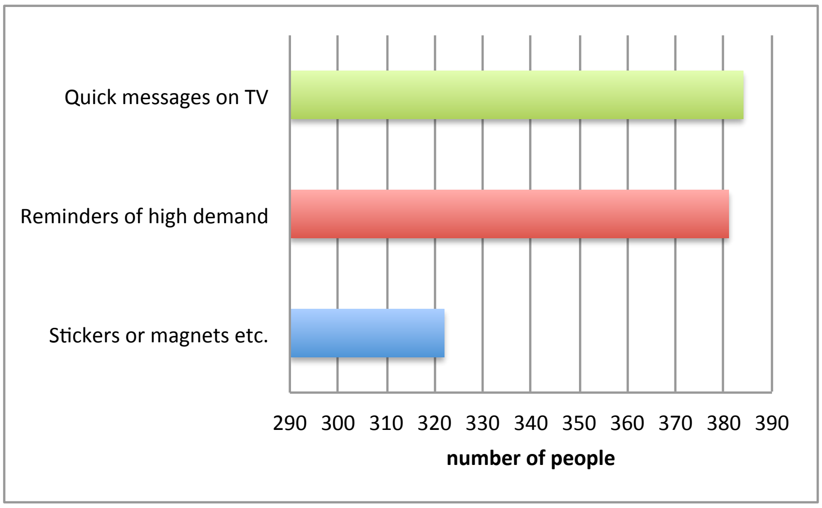


FIGURE 3.19: Frequency of some policies promotes efficient use of energy

3.5. Cluster Analysis

Cluster analysis is a segmentation method largely used in similar academic studies for the purpose of grouping households into clusters according to their current actions and willingness to change habits towards energy efficiency [96].

There are several clustering methods with different specifications. To analyze mixed variables on different scales, the two-step cluster analysis was developed, and in this study we will use this method. Mooi and Sarstedt [97] in 2011 explained two-step clustering procedure as:

In the first stage, the algorithm undertakes a procedure that is very similar to the k-means algorithm. Based on these results, the two-step procedure conducts a modified *hierarchical agglomerative clustering procedure that combines the objects sequentially to form homogeneous clusters. This is done by building a so-called cluster feature tree whose "leaves" represent distinct objects in the dataset.*

For clustering analysis, a set of variables was determined. These variables should be discriminating and well representative of the sample. Four variables have been selected to create the most reasonable cluster analysis. These are:

- Peak hour usage
- Willingness to shift the usage of electricity during peak hours
- Intention to replace products with more efficient ones
- Size of the house (as a demographic factor)

In order to ensure there is no correlation between these variables above, correlation analysis was done using SPSS software. Whereas values above 0.90 indicate high correlations, the closer value to zero means low collinearity between the variables. Table 3.1 proves none of them are correlated with each other.

TABLE 3.1: The correlation matrix

Pearson correlation	**Variable 1**	**Variable 2**	**Variable 3**	**Variable 4**
(1) Intention to replace products	1	.045	.009	-.043
(2) Peak hour usage	.045	1	-.006	-.041
(3) Willingness to shift	.009	-.006	1	.060
(4) Size of the house	-.043	-.041	.060	1

The outputs from the analysis process will be summarized step by step. For better understanding of the summary, the relevant SPSS window is given in Figure 3.20. First, the determined variables are moved to a continuous variable box. Since we have both continuous and categorical variables in our dataset, Log-likelihood is selected as a distance measure. We could choose a number of clusters by giving a fixed number, but we let the algorithm automatically decide on the appropriate cluster number. There are two clustering criteria: Schwarz Bayesian Criterion (BIC) and Akaike's Information Criterion. These two criteria were applied to the analysis and results were the same for both. After many trials, the best result was accepted and examined.

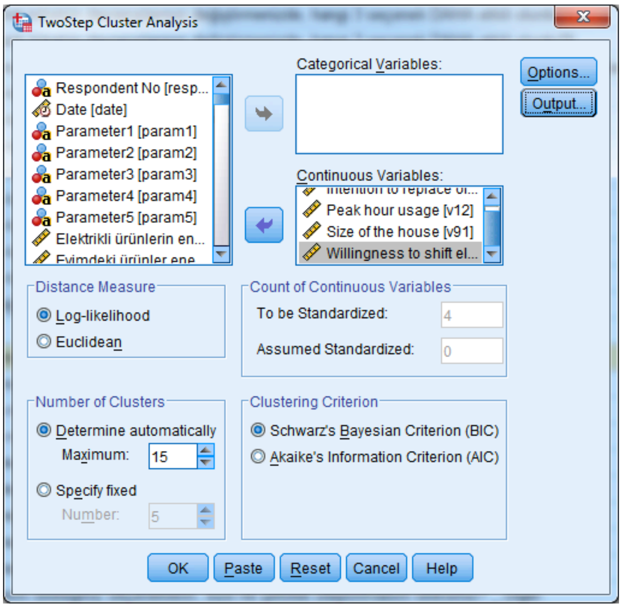
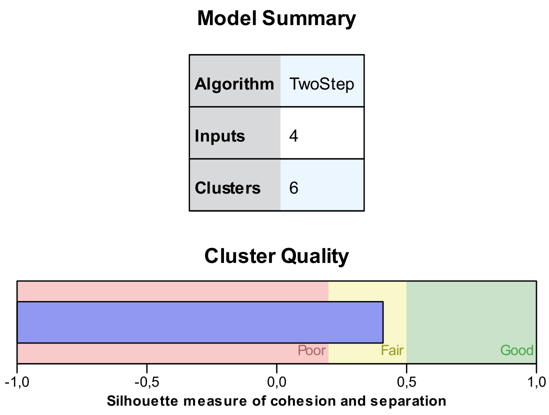
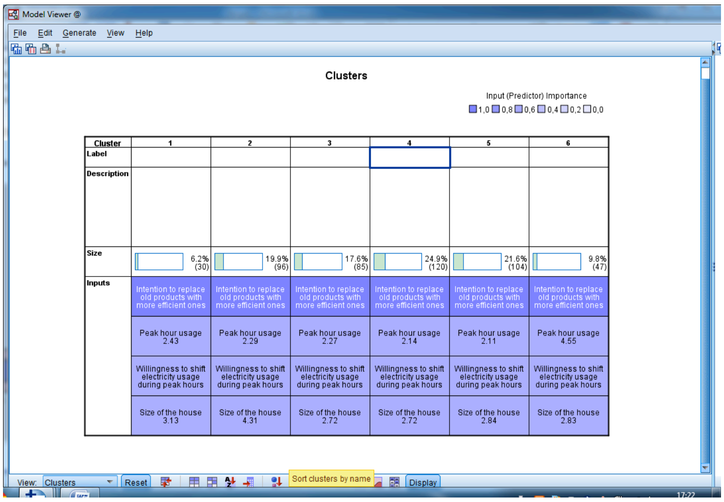


Figure 3.20: Two-step cluster analysis box

After this window, SPSS produces a basic result of the analysis seen in Figure 3.21(a). This result summarizes that a two-step clustering method was applied, four variables input, and a resultant six clusters were obtained. Lower part of the figure indicates cluster quality, which is fair. By double-clicking on this window, we receive detailed information about the clusters as it is seen in Figure 3.21(b). The findings of the output are summarized in Table 3.2. The mean values of each variable in each cluster are given in the table. The cluster profiles will be identified according to its characteristics. Clustering was completed with 482 households not with 528. Some households were eliminated. As some responses from these households were missing, and were not included in the final clustering analysis.



(a) Two-step clustering model output



(b) Model viewer box

FIGURE 3.21: View of SPSS outputs

TABLE 3.2: The mean values of variables for each of the clusters

		Cluster 1	Cluster 2	Cluster3	Cluster 4	Cluster 5	Cluster 6
	Cluster size	6.2% (30)	19.9% (96)	17.6 % (85)	24.9% (120)	21.6% (104)	9.9 % (47)
Variables	Intention to replace products	3.73	1.54	1.61	2	1	1.55
	Peak hour usage	2.43	2.29	2.27	2.14	2.11	4.55
	Willingness to shift	1.90	2.25	3.20	1.60	1.60	1.79
	Size of the house	3.13	4.31	2.72	2.72	2.84	2.83
Evaluation fields	Motivator	2.40	2.25	1.96	2.01	2.16	1.85
	Income	2.97	3.68	2.82	2.63	2.93	2.45
	Measure	2.32	2.34	2.61	2.60	2.28	2.68

3.5.1 Overview of Clusters

Six clusters have been produced, and in this section an overview of the attributes of each cluster will be examined. In addition to the four previously mentioned variables, there were three additional variables used. These three variables were given under the name of evaluation fields. They were not used to cluster the households, but only helped to describe the obtained household clusters.

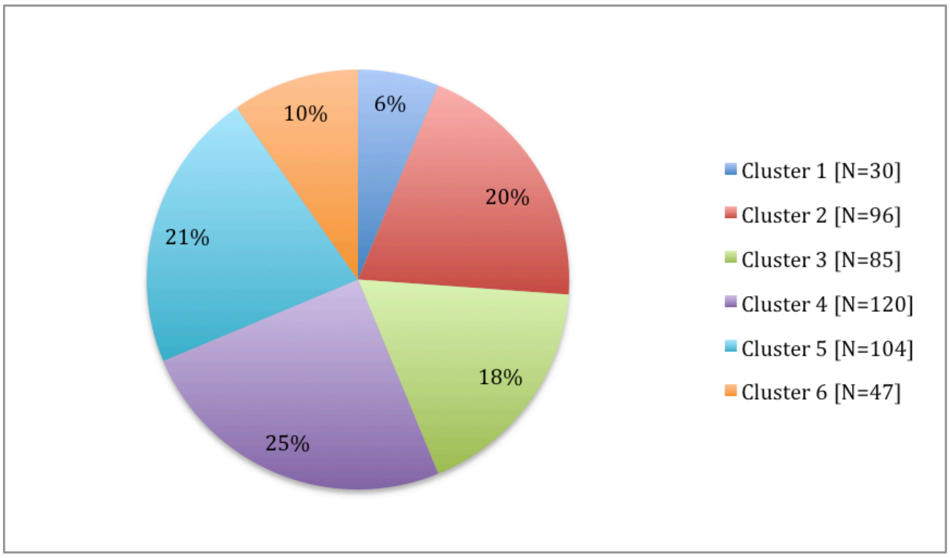


FIGURE 3.22: The overview of six clusters produced for the household sample

3.5.2 Profiling the Clusters

- Cluster 1 *(Outdated users)*

  The first cluster encompasses households with the worst energy usage practices, meaning they use energy inefficiently. These households are more resistant to own more efficient products and also to change their habits to save energy. Although they have a high income, even with an incentive, they are not in favor of replacing old appliances. Moreover, their awareness level of energy labeling and projects pursued by the Ministry is the lowest among the clusters.

  It should be noted this cluster with high income and larger living area has high potential for energy savings. In addition to their inefficient use of electricity, being unwilling for behavioral change makes this group of households a challenging task for policy makers. In order to reduce their energy consumption, they believe they have to be reminded or to be warned. It can be seen they are not motivated towards energy efficiency. Rewards are the most common intervention measure among all the households, but these households are also interested in information.

Workshops held by academics and reality shows on TV, which describe household's energy consumption and show how to use energy more efficiently in practice, are preferred as information sources.

- Cluster 2 *(Untroubled users)*

  Households in this cluster can be described as the least concerned with the highest income and the highest occupation in the largest houses. The education level average is the lowest. However, energy efficiency projects by Ministry are highly acknowledged in this cluster.

  The highest energy consumption is seen in this cluster. Even if they adopt more efficient behaviors, these households do not see any visible fall in their consumption. Although their peak time use of electricity is quite high, their willingness to reduce this consumption is relatively low. Despite their current habits, they express their biggest drivers for energy reduction as the environment. In addition to rewards, they are also interested in feedback. Instead of billing, they prefer online access or mobile applications to see their energy consumption. Similar to Cluster 1, these households are also not conscious about energy issues. But the difference is these consumers in the second cluster are driven only by environmental motivators. Feedback is a secondary measure opted by this group.

- Cluster 3 *(Average users)*

  This cluster consists of households with an average level of intention to have efficient products, average use of electricity during peak hours, and also with moderate income and middle-sized houses. Their biggest motivator is monetary value.

  As for information methods: SMSs or mobile application are chosen. The feedback should involve last year's consumption in the same period and should be available at any time. These households do not believe messages on TV and magnets or stickers on appliances reminding efficient use of energy will help to change their behavior. These average users of electricity are driven by monetary tools. New alternatives of information and feedback might be effective for these households. Particularly interactive tools such as the Internet and mobile phone messaging can be used in policies offered to Cluster 3.

- Cluster 4 *(Peak-time users)*

  These households exhibit the highest electricity usage during peak time. However, their willingness to change this consumption behavior is also high. These households' income is relatively low and they are driven by monetary value. A reduction in their electricity bill could be the best reward for adopting energy efficiency. They would like to see in their feedback carbon emission data and the long-term impact of the consumption on nature and society. Furthermore, despite the views of the third cluster, these households believe the impact of the messages on TV and the reminders on appliances for changing behavior. As Cognitive Dissonance Theory claims, once people are convinced of the gap between their intention and active behaviors, it becomes easier to adopt efficient behaviors. Monetary tools are expected to be more effective among these relatively-low income households.

- Cluster 5 *(Attentive users)*

  This group consists of highly educated and the most concerned households about energy efficiency. They have the best energy use practices and efficiently consume energy in their homes. These households also expect the highest drop in their bill as a result of changing their behavior.

  Their peak time usage is high, but they are very willing to reduce this consumption. Their intention to replace current appliances is also high. The impact of high electricity use on their own budget and the country's economy would be effective to change their actions in favor of efficient use of energy. Information is their most preferred measure. They would like to learn strategies for efficient use of electricity, and for this purpose public ads are attractive. Although they are driven by monetary value, these households opt for being rewarded with plaques in return for their efficient use of energy.

- Cluster 6 *(Off-peak users)*

  This cluster involves low occupied households with the lowest energy consumption and highly educated users. Similar to the second cluster, cluster six is also familiar with the projects promulgated by the Ministry. Peak hour consumption is low. They are most interested in the impact of the consumption on their electricity bill, and also satisfied with the current bill format. Their intention to acquire more efficient products is at a medium level. Smaller living area and fewer number of consumers in the household result in low consumption at peak hours. Therefore, the potential for energy savings is also low. Relatively high-income level and highly-educated consumers are another characteristics of the sixth cluster.

Distribution of some other variables among certain groups of households

The importance of our study is that investigating consumers' responds to some successful behavioral change interventions. In order to make additional conclusions we tried to investigate the distribution of some distinctive variables among certain groups of households. When this section is examined, it should be noted that questions were designed on a 5-point scale (0= always or completely yes, 5= never or completely no). The lower rate of mean values in tables below, indicate the higher efficiency in behaviors of households.

First, preferred measure was taken as a variable. Within these groups, some daily habits are examined. For example, cleaning practices mean using washing machine and dishwasher, and household routine regarding entertainment includes using TV, PC and so on. It is found those consumers who have more energy efficient practices such as running washing machine at full capacity, turning off unnecessary lights, preferring more efficient ways to cook or clean the house, are in one group: Group 1 and people in this group prefer being informed. Whereas the best consumer practices are seen in the first group, Group 2 has the least concerned people about their electricity use. These people believe in disincentives and to be involved with social influences are better ways to adopt more sustainable behaviors.

Table 3.3: Mean values of certain variables regarding households' routine

	Group (# of people)	**Gr. 1 (94)**	**Gr. 2 (57)**	**Gr. 3 (151)**	**Gr. 4 (105)**
		Information	Disincentives and Social influence	Rewards	Feedback
current practices	cleaning	1.51	1.75	1.62	1.69
	lightening	1.44	1.61	1.38	1.46
	entertainment	2.88	3.05	2.97	2.97
	cooking	2.44	2.50	2.54	2.35

The most concerned consumers about standby consumption are clustered in the first group. For behavioral change and efficient use of energy, this group prefers to get information. End-users who are mostly driven by monetary tools are in Group 3, and they opted for rewards as a behavioral change measure. Feedback has been chosen consumers, by last group, who are less concerned about their standby consumption (Table 3.4).

Table 3.4: Mean values of certain variables regarding standby consumption

	Group (# of people)	**Gr. 1 (94)**	**Gr. 2 (57)**	**Gr. 3 (151)**	**Gr. 4 (105)**
		Information	Disincentives and Social influence	Rewards	Feedback
avoiding standby	TV etc.	2.40	2.61	2.31	2.48
	PC etc.	1.88	2.05	1.91	1.95
	Machines	1.71	1.73	1.83	1.78

As it is already said, consumers are willing to shift their electricity use from a peak period to less peak hours. However, consumers who opted for rewards and social influences are not in favor of changing their consumption habits (Table 3.5).

Kettles and tea or coffee machines are mostly used during peak hours and according to the responses, this trend does not seem to be changeable with a single policy implementation. Providing information and feedback about the energy consumed by these machines will be a more effective way to alter consumer behavior.

When the households are arranged by income, there are five groups (Table 3.6). Consumers with the lowest income are clustered in the second group (0-1,000 TL). Low-medium-income households (1,000-3,000 TL) belong to the first group. Medium-income consumers (3,000-5,000 TL) are in Group 4. Group 3 consists of high-medium income

TABLE 3.5: Mean values of certain attitudes towards shifting

	Group (# of people)	**Gr. 1 (94)**	**Gr. 2 (57)**	**Gr. 3 (151)**	**Gr. 4 (105)**
		Information	Disincentives and Social influence	Rewards	Feedback
Willing to shift	Washing machine.	1.69	1.61	1.84	1.85
	Dishwasher	1.48	1.88	1.58	1.54
	Iron	2.64	2.58	2.56	2.48
	Kettle etc.	2.90	3.04	3.01	2.97

households (5,000-10,000 TL), and lastly households with the highest income are in Group 5.

TABLE 3.6: Household groups by income level

	Groups				
	Group 1	Group 2	Group 3	Group 4	Group 5
Income level	low-medium	the lowest	high-medium	medium	the highest
TL	1000 − 3000	0 −1000	5000−10000	3000− 5000	>10000
Aware of projects	2.70	2.63	2.57	2.52	2.70
Smart meter awareness	1.91	2.03	1.98	1.99	1.96

Income level of consumers does not matter for the awareness of work done by Ministry. Income level of Group 1 and Group 5 are very different, and both households in these groups stated they have never heard of the Ministry's projects (Table 3.6).

When consumers are asked whether they are familiar with smart meters or not, it is seen the lowest-income households are not aware of such implementation and never heard of smart meters. Table 3.6 shows which group has the highest mean. It means the ratio of people who replied they were not familiar with smart-meter is highest in this group.

When households are examined across their income and standby consumption, it is noted consumers with the lowest income are more concerned about standby consumption and try to avoid this. However, Group 5 with the highest level of income has the least concerned people about standby consumption. In addition to this, Group 2 is driven by mostly monetary tools to avoid this consumption, whereas Group 5 is more responsive to the environment and society (Table 3.7).

TABLE 3.7: Mean values of the attitude towards standby consumption regarding income level

	Group					
		Group 1	Group 2	Group 3	Group 4	Group 5
Avoiding standby	TV etc.	2.37	2.23	2.53	2.53	2.68
	PC etc.	1.96	2.03	1.97	1.92	2.14
	Machines	1.68	1.61	1.82	1.87	1.96

Surprisingly income level does not have a clear impact on consumers' willingness to shift or current practices at home. Mean values do not give an explainable result.

Similarly clustering by the province and the electricity bill have been implied. However, obtained clusters have very close means to each other and did not provide an explainable result. As it will be discussed in the following section, there are some limitations of our survey study. Since we started to conduct the survey from our friends at İstanbul Şehir University, the sample unfortunately has become biased in some aspects such as education and the province.

3.6. Discussion

The 526 household included in this survey were used to depict a general view of residential electricity consumption of Turkish consumers. Although sample size is relatively larger than similar studies in the literature, unfortunately, some variables such as education could not provide a discriminating data on Turkish households. This is because the survey was spread through our university environment first, and it kept the education level of participants high. This study would be enhanced with a more representative sample and would be extended further by adding monitoring household to the research.

First of all, the term of energy class is widely known among Turkish consumers. The knowledge level of energy labeling seems high. However, consumers' responded to several questions indicate that their active behaviors and attitudes towards using high-efficiency products. Once consumers are convinced about the gap between their action and intention, it is easier to attain sustainable behaviors (explained in Section 2.2 by Cognitive Dissonance Theory).

Secondly, Turkey's electricity consumption during high demand period is definitely worth considering. Especially dishwashers are used quite often between the hours of 17:00 and 22:00. Behavioral change could bring about energy saving in the aspect of shifting this consumption. People are already willing to change their habits, thus the potential impact of shifting this use on the economy, environment, and society should be clearly investigated. Today in the market, there are also some products allowing consumers to decide at what time to run the machine. These are the latest and mostly most-efficient products, once again the importance of replacing old appliances with the new and efficient ones should be emphasized.

There is a huge potential to save at home, but certainly education is required first to further familiarize the public with the concepts of energy saving. Demand side management is a powerful tool to control demand increase. Numerous studies proved that demand side programmes succeeded in managing electricity demand, decreasing costs and also emission.

The possession of a clothes dryer is the lowest ratio among other appliances, such as washing machines and dishwashers. In our survey, nearly half of participants do not have dryers in their home. However, the number of dryers is expected to increase in the proximate future. Therefore, product developers and policy makers should allow only energy efficient dryers on the market.

Although [18] claims Turkey's standby consumption is high and worth to considering, participants expressed an opposing view. They said they were very careful to unplug any products when they are not in use. As Cognitive Dissonance Theory says, these conflicting behaviors can be prevented by explanation of the distinction between actual behavior and attitudes of people.

Forgetting is the most common reason why people leave products on standby. However, instead of warnings or reminders participants believe if they knew the impact of standby consumption on their monthly bill, they would avoid leaving products on standby. The Persuasion Theory explains this sense with the importance of the credibility and the response rate. After people are informed about avoiding standby consumption, they would like to see the results of their new-adopted behavior and the benefits of it. This can be achieved by a more detailed format of feedback.

Among all other electrical appliances, kettle use deserves much attention. Even more conscious households about energy efficiency (according to their responds, households with more frequent sustainable habits) are not in favor of stopping or shifting the use of kettle or tea/coffee machines. On this subject, besides informing consumers about the energy consumption of these machines, product developers should also play a role. There should be more available efficient electrics on the market to further reduce energy consumption. Moreover, our survey shows that new policy implementations could be more effective. For example, reminding calls during peak hour of electricity demand or quicker messages on TV screens telling people to avoid this consumption are popular responds for decreasing or avoiding the use of kettle or tea/coffee machines at peak period.

When consumers are examined about their electricity use during peak hours (17:00-22:00) and possession of smart meters, the results are confusing. Half of the use of washing machines, dishwashers, and tea/coffee machines or kettles occurs during peak hours, when the price is higher with the smart meters. This means consumers are not well informed about the practice and the purpose of smart meter use. The survey results support the hypothesis that consumers would change behaviors most in order to achieve monetary benefits. Turkish consumers are required to be well-informed about a measure or the method they follow to use energy more efficiently. More informative measures should be the primary target.

Regarding the questions about measures, the survey points out rewards would be the most effective way to change behaviors, especially in schools. In the literature, there are many examples of social events organized at schools or work offices and achieved reduction in electricity consumption in the end. As it is prescribed in Section 2.2 by Social Learning Theory and Social Identity Theory, social influences will be effective for behavioral change. Although respondents put social influences in last order in the list, when they are supported with rewards, their impacts would be higher. Actually, there is no need to think these measures separate from each other. Their effectiveness would be higher with the support of any other. There should be more projects on Demand Side Management in Turkey. As the knowledge level of households and their willingness are considered, an alteration in billing format can be efficient as well. People are also open to more informative feedback. Consumers do not examine the bill, most even do not see the bill and pay it automatically. Therefore, an e-mail or online access might be an alternative to reach people. The results of our survey give an idea about the familiarity of current projects, and indicate the current form of these projects is not adequate to get people's attention. For example, when households were asked about the format of TV programs, public service ads were the most common answer (40%). On the other hand, current energy efficiency projects of the Ministry have already being announced on TV as public service ads for a long time, but 79% of respondents stated they have never heard of these projects. In order to reach consumers there should be some improvements in public service advertisements. Timing could be altered or format and people who are involved should resign. Public service ads are not sufficient in their current form. One other reason not to be known in a larger group of people is that projects run by Ministry and supported by authorized organisations are kept limited within a group of in a political view. I quote this from my own experience, Mrs. Energy Meetings were very informative and enjoyable too. It clearly incentivized housewives to use energy efficiently by gifting more efficient household electrics to participants. However, the group of people belonged to only one single political view, and gathered with the opportunity of this single political party. Of course these meetings are a policy, but policy makers should not let it be converted into politics.

Lastly, surveyed households included in this thesis were found to group into six clusters based on their energy use habits and household characteristics. This was our first clustering trial, and it was proved the number of people residing in a home has a major influence on energy consumption. Cluster 2 with the highest number of people at home had the highest energy consumption. Whereas, in Cluster 6, with the least number of users at home, consumed the lowest amount of energy among all clusters. Although Cluster 2 and Cluster 6 differ in their education level, the awareness of projects held by the Ministry is similar. Second trial was comprised of evaluating some extra variables among clusters. It is found that households in a lower income group are more attentive to standby consumption. These households are mostly driven by cost or monetary benefits. Whereas, the highest income level of people state the environment as their biggest motivator for energy savings.

As it is seen in each cluster with two trials, preferences of each group are different. Therefore unique and more cluster-specific interventions are likely to have greater impact on energy saving among certain households.

Chapter 4

Application On Turkish Electricity Network

A mathematical model has been proposed to find the impact of behavioral change on electricity network. First, problem is defined and the detailed explanation of the mathematical formulation is given in Section 4.1. Then, several scenarios are generated by considering survey results. Impacts of these scenarios on Turkish network are examined. Section 4.2 ends with the comparison of scenarios and possible savings from each scenario.

4.1. Problem Definition

A mathematical model has been developed to find the impacts of behavioral change on the electricity network. In this very basic model, transmission lines and energy losses are neglected; only satisfying the electricity demand is considered. A single-objective optimization model is proposed to address the reduction in the cost with respect to some efficiency scenarios and to investigate the environmental effects of such policies emission rates are recorded for each scenario.

The mathematical formulation of the model is presented in this section. As stated before, this model is a very simple model disregarding transmission lines, energy losses, and location of the generation. The target here is to represent the effects of behavioral change studies on electricity demand.

The definition of the sets, the decision variable, and the parameters used in the mathematical model is given in following paragraphs.

Sets:

I: Available electricity generation sources.

G: Total number of days chosen.

N: Total number of hours in each day.

H_{dn}: set of hours where demand is high and the policy applied might switch the demand from these hours.

L_{dn}: set of hours where demand is low and the policy applied might switch the demand to these hours.

O_{dn}: set of hours where switching scenarios have no impacts

D: set of dispatchable units which can provide a continuous output on demand, i.e. fossil fuels, nuclear plants.

ND: set of non-dispatchable units such as solar and wind turbines. These units are periodic and uncontrollable.

Decision variables:

x_{idn}: the amount of electricity generation from unit i on day d and hour n.

Parameters:

c_i: generation cost of unit i (\$/MWh).

K_i: installed capacity of unit i (MW).

f_i: capacity factor of unit i.

w_{dn}: adjustment factor of day d and hour n. This means the number of days represented by each selected day and hour. For example, if the problem is solved with a single day chosen, the adjustment factor of this day will be 365.

D_{dn}: electricity demand on day d and hour n (MWh).

e_{dn}: possible demand reduction due to efficient use of electricity on day d and hour n. It is calculated by multiplying the demand and the efficiency rate EF_{dn}. EF_{dn} is defined as efficiency rate of a scenario that leads to decrease in demand.

$$e_{dn} = D_{dn}.EF_{dn} \qquad \forall d, n \tag{4.1}$$

s_{dn}: reduction in demand due to the shifted amount of electricity on day d, hour n. It is calculated by multiplying the demand and SF_{dn}, which is the ratio of electricity switched from time high hours of day d.

$$s_{dn} = D_{dn}.SF_{dn} \qquad \forall d, n \in H_{dn} \tag{4.2}$$

t_{dn}: increase in demand due to the shifted amount of electricity on day d, hour n. It is calculated by multiplying the sum of switching ratio from times H_{dn} and ST_{dn}, which is the ratio of electricity switched to time low hours of day d.

$$t_{dn} = (\sum_{n} SF_{dn})ST_{dn} \qquad \forall d, n \in L_{dn} \tag{4.3}$$

The problem is solved given a single-objective function problem. The objective function and the model are as follows.

min $z = \sum_{i}^{I} \sum_{d}^{G} \sum_{n}^{N} x_{idn}.c_i.w_{dn}$

s.t.

$$\sum_{i}^{I} x_{idn} \geq D_{dn} - e_{dn} \qquad \forall d, n \in O_{dn} \tag{4.4}$$

$$\sum_{i}^{I} x_{idn} \geq D_{dn} - e_{dn} - s_{dn} \qquad \forall d, n \in S_{dn} \tag{4.5}$$

$$\sum_{i}^{I} x_{idn} \geq D_{dn} - e_{dn} + t_{dn} \qquad \forall d, n \in T_{dn} \tag{4.6}$$

$$\sum_{i}^{I} x_{idn} \leq K_i.f_i \qquad \forall i, d, n \in D \tag{4.7}$$

$$\sum_{i}^{I} x_{idn} = K_i.f_i \qquad \forall i, d, n \in ND \tag{4.8}$$

$$x_{idn} \geq 0 \tag{4.9}$$

Equations 4.4 to 4.6 pertain to demand constraints. These constraints reflects the changes with respect to the impact of policies on the electricity use. If the policy includes efficient use of electricity, which will lead reduction in demand, demand is reduced by e_{dn} (Equation 4.4). If the policy includes shifting for some hours, then demand in the corresponding hours will be decreased as in Equation 4.5. This shift will increase the demand in the hours where policy is organized to shift the demand to as in Equation 4.6.

Equation 4.7 and 4.8 are related to capacity constraints. If the demand is met by dispactchable units, the amount of electricity produced will be less than or equal to the capacity (Equation 4.7). However, if the electricity comes from nondispatchable units such as wind or solar energy, generated amount of electricity will be equal to the multiplication of the capacity of the nondispatchable unit (K_i) and its capacity factor f_i.

4.2. Numerical Example

In this section, a variety of problems are solved for different scenarios. Turkey's electricity consumption and production data in 2013 is used to demonstrate the impact of selected policies on the electricity network. First of all, the one-year consumption of Turkey has been investigated in detail. The most representative and appropriate days to the total consumption data are selected for the model. Since peak hours occur at different periods of the day, examined days are divided into three: weekday, Saturday, and Sunday. There are two periods having peak hour demand on weekdays. The first peak in demand is seen around noon, and the latter occurs around 4 o'clock in the afternoon. Whereas the highest demand on Saturdays are observed generally at 14:00, electricity demand reaches the highest value after 6 o'clock on Sunday evenings. 6 hours for high demand (H_{dn}) and 6 hours for low demand (L_{dn}) occurs has been noted for the model. The rest 12 hours in each day are listed in the set of O_{dn}.

The highest consumption for weekday, Saturday and Sunday of the month has been noted. However, the access of daily demand data is restricted, and it is available only from June 2013 to today. In order to represent the first five months of 2013 a further investigation has been done. In accordance with the consumption data and peak hour period, October has been chosen to represent February, March, April, and May. January consumption on weekdays and on Sunday is very close to December consumption data, and only for Saturday, June consumption is used. In total, there are 21 days in the mathematical model. Table 4.1 shows selected dates with maximum demand and the number of days (w_{dn}) they represent.

TABLE 4.1: Adjustment factor and demand data of the examined days in the model

Month	**Weekday**	w_{dn}	**Demand(MWh)**	**Saturday**	w_{dn}	**Demand(MWh)**	**Sunday**	w_{dn}	**Demand(MWh)**
June	27.06.2013	20	753181	29.06.2013	9	716231	30.06.2013	5	634760
July	11.07.2013	23	768880	13.07.2013	4	738304	14.07.2013	4	667179
August	29.08.2013	22	772150	03.08.2013	5	729777	04.08.2013	4	673163
September	03.09.2013	21	738240	14.09.2013	4	692108	01.09.2013	5	627527
October	08.10.2013	109	686383	05.10.2013	21	659473	27.10.2013	21	608318
November	29.11.2013	21	715829	30.11.2013	5	689871	17.11.2013	4	603641
December	19.12.2013	45	762976	21.12.2013	4	727342	22.12.2013	9	661298

The network has 8 types of generation units. These units are listed in Table 4.2 with the corresponding capacity, cost, and emission data. The source of the various data elements is given with a footnote. The capacity data has been taken from yearly reports of the Turkish Electricity Transmission Company (TEIAS) for each unit [98]. Units cost are compiled from the report released by the Energy Information Administration (EIA) [99]. Levelized cost of electricity has been chosen as a unit cost. Levelized cost of electricity includes capital cost of the plant, fuel cost, operational and maintenance cost. These types of costs are thought as a better option to avoid some drawbacks of our mathematical model. In our model, electricity generation units are accepted as wholly available for each region. However, in reality, some units are installed only in certain regions, such as wind turbines and hydraulic plants. If the fuel prices were considered only, there would not be any cost for these two units. Emission rates are adopted from several resources [100–103].

The created scenarios are applied to the model and results are obtained. First of all, the scenarios are listed below and explained in detail. Then, solutions for the mathematical model are given in Table 4.3. The model also considers the case of having no policy applied in order to see change in the cost, the demand, and the emissions.

TABLE 4.2: Generation units by source and their related characteristics

Units (i)	**Capacity** (K_i)[a]	**Factor** (f)[b]	**Unit Cost** (c_i)[c]	CO_2	SO_2	NO_x
(source)	(MW)		($/MWh)	(lbs/MWh)	(lbs/MWh)	(lbs/MWh)
Liquid Fuels	694	0.77	223.6	543.04	2.55	0.88
Hard coal/lignite	8515	0.85	115.9	734.51	5.51	1.47
Imported coal	3912	0.85	95.6	779.53	5.85	1.56
Natural gas	20255	0.85	128.4	398.97	0.31	0.25
Waste energy	224	0.85	102.6	726.33	0	0.47
Geothermal	311	0.75	47.9	154.4	0	0
Hydraulic	22289	0.50	84.5	0	0	0
Wind	2760	0.30	80.3	0	0	0

[a] TEIAS [98]
[b] Özcan [104]
[c] EIA [99]

The created scenarios are applied to the model and results are obtained. First of all, the scenarios are listed below and explained in detail. Then, solutions for the mathematical model is given in Table 4.3. The model also considers the case of having no policy applied in order to see change in the cost, the demand, and the emissions.

1. Feedback given via displays at high demand hours leads to switching 7% of residential electricity demand to low demand hours
2. Feedback given via displays at high demand hours leads to switching 13% of residential electricity demand to low demand hours

3. Feedback given via displays between 17:00 and 22:00 leads to switching 7% of residential electricity demand from peak period to low demand hours

4. Feedback given via displays between 17:00 and 22:00 leads to switching 13% of residential electricity demand from peak period to low demand hours

   When the scenarios are created the lowest and the highest reduction rates in the literature are taken in the account. Results of our survey are also used to decide on the policy. For example, participants of the survey showed a high willingness to change their consumption behaviors when they are warned via calls, messages, or devices. The first 4 scenarios examined this case for 2 different time periods. One is for very high demand hours, which occurred in 2013, and the other one is for the period between 17:00 and 22:00. 7% and 13% are the minimum and the maximum efficiency rate in the literature achieved by feedback interventions. In the model, residential electricity consumption is taken as one fourth of the total demand [4]. Therefore, while the optimization problem is solved, these ratios 7% and 13% are multiplied with 0.25, and converted into 0.0175 and 0.0325. These rates are replaced into the value of SF_{dn} *in the model. For these scenarios, shifting is accepted as equally distributed to low demand hours, and* ST_{dn} *becomes 0.1666. There are six hours considered at low demand hours, therefore* ST_{dn} *is taken as* 1/6.

5. Efficient use messages on TV, magnets, and stickers leads to 10% reduction in residential electricity demand

6. Efficient use messages on TV leads to 10% reduction in residential demand with 74.3% willingness of households

7. Magnets or stickers reminding of efficient use of electricity leads to 10% reduction in residential demand with 62.6% willingness of households

   Scenario 5, 6 and 7 are created from responses of our survey participants who find quick messages on TV and magnets useful to remind themselves of efficiently consuming energy. Such studies in the literature have resulted in a 10% reduction in household energy use. Therefore, this rate was applied to the model considering the fact that residential use accounts for 25% of Turkey's total electricity demand. EF_{dn} *is taken 0.025, and we accepted equal reduction rates for each hour. When the willingness of consumers is considered* EF_{dn} *has become 0.018575 and 0.01565 respectively for Scenarios 6 and 7.*

8. One-month information campaign started in September leads to 10% reduction in residential electricity demand

9. Long-lasting campaign with decreasing efficiency rate

10. One-month information campaign started in June leads to 10% reduction in residential electricity demand

11. Long-lasting campaign with decreasing efficiency rate in summer

    Scenario 8 to 11 examine the impact of information campaigns started at different times for short and long duration. Three-month period is considered for these cases. Whereas for short duration campaigns, EF_{dn} is taken 0.025, in long-lasting campaigns this ratio is accepted decreasing after one month. For example, if EF_{dn} is 10% in September, in the following month it is taken as 7%, and 3% for November. Of course, these rates are multiplied with 0.25, which is the rate of residential use in total demand.

12. Focusing standby consumption during sleeping hours with 3% efficiency rate

13. Focusing standby consumption during sleeping hours with 1.5% efficiency rate

    Scenario 12 and 13 examine the standby consumption. In these cases, it is assumed consumers avoid standby consumption when they go to bed. The sleeping hour is taken as 8, from 01:00 to 09:00 for summer and from 00:00 to 08:00 for the rest of the year. For these cases, EF_{dn} is taken as 0.0075 and 0.00375, as standby consumption is defined 3% of total electricity use in Turkey [18]. In the second case, we assumed less amount of standby use avoided.

14. Replacing 4 million old fridges with efficient ones leads to 0.78% reduction in total demand

    Scenario 14 evaluates the impact of replacing old fridges with more efficient products as presumed in [95]. Total electricity consumption of old fridges at homes is assumed as 600 MWh. The electricity consumption ratio of these fridges in maximum demand is found as 1.58%, and at least 50% efficiency assumed with a more efficient product. Therefore, EF_{dn} is taken as 0.008. As a fridge consumes electricity for 24 hours, the same reduction rate is taken for each hour.

15. Giving rewards in June leads to 7% reduction in residential electricity demand

16. Giving rewards in June leads to 13% reduction in residential electricity demand

17. Giving rewards in August leads to 7% reduction in residential electricity demand

18. Giving rewards in August leads to 13% reduction in residential electricity demand

19. Giving rewards in December leads to 7% reduction in residential electricity demand

20. Giving rewards in December leads to 13% reduction in residential electricity demand

Scenario 15 to 20 are created to see possible effects of giving rewards at different times with different efficiency rate in the literature. The same EF_{dn} value is taken for each hour, 0.0175 and 0.0325 are for respectively 7% and 13% reduction rates.

21. During school term (from October to May), 10% reduction on average in residential electricity demand

22. During summer holiday (from June to September, 10% reduction on average in residential electricity demand

23. During summer holiday (from June to September, 5% reduction on average in residential electricity demand

    Scenario 21 to 23 are for the impact of social influences for school period and summer holiday when the occupancy of the house is higher. 10% reduction is converted 0.025 for the value of EF_{dn}. When we assume less decrease, it has become 0.0125 for Scenario 23.

24. Avoiding all of kettle use between 17:00 and 22:00 with 2% efficiency rate

25. Avoiding kettle use between 17:00 and 22:00 with 29% willingness of households leads to 0.74% reduction in demand

26. Replacing kettles with 35% more efficient ones leads to 0.88% reduction

27. Replacing kettles with 50% more efficient ones leads to 1.27% reduction

28. Replacing tea/coffee machines with 35% more efficient ones leads to 8.95% reduction

29. Replacing tea/coffee machines with 50% more efficient ones leads to 12.79% reduction

    Scenario 24 to 29 are created by using responses of our survey participants and examining the use of kettles or electrical teapots between 17:00 and 22:00. In the first case, the scenario of not using any kettles at a given time is examined. According to our survey, 59% of households use kettles between 17:00 and 22:00, and it is presumed that the policy will lead to 2% reduction in total, and this rate included the use of oven instead of kettles. Since there are six hours between 17:00 and 22:00, EF_{dn} is taken as 0.02/6. Scenario 25 takes the willingness of consumers consideration. In this case EF_{dn} is multiplied with 29% willingness of consumers to avoid kettle use, and it is taken as 0.74/6 %. Next four scenarios evaluate replacing kettles or electrical teapots with more efficient ones. The rates given in scenario description are values for EF_{dn} calculation, and are divided by 6 in the model. Please note that, in these six scenarios the usage time for kettle is taken as

2 minutes, and 1 hour for teapots. Average electricity consumption data of these devices in the market is taken, and the ownership rate of electrical teapots is assumed as one third of kettles in use. EF_{dn} *becomes 0.00147, 0.0021, 0.01492, and 0.02132 respectively for scenarios 26, 27, 28, and 29.*

30. Shifting all of washing machine use between 17:00 and 22:00 to late hours leads to 5.2% reduction

31. Shifting all of dishwasher use between 17:00 and 22:00 to late hours leads to 5.6% reduction

32. Shifting all of the iron use between 17:00 and 22:00 to the early hours in the morning leads to 4.4% reduction

33. Shifting washing machine use of consumers only willing to change their habits leads to 3.9% reduction

34. Shifting dishwasher use of consumers only willing to change their habits leads to 4.7% reduction

35. Shifting iron use of consumers only willing to change their habits leads to 2.39% reduction

    Last six scenarios focus on shifting of electricity consumption by using our survey data on the willingness to shift consumption of some certain products and electricity consumption data of these products in the literature. The first three examines the case all households follow the policy and shift their usage. Calculations considered the number of electrical products in use, and the power use of these products. The frequency of use in peak period is taken from our survey data as 52.3%, 60.9%, and 28.9% respectively for washing machine, dishwasher, and iron. And then, the willingness rate of shifting electricity use from our survey data is embodied in the problem (76%, 86%, and 51.8% respectively for washing machine, dishwasher, and iron. In shifting scenarios of washing machines and dishwasher, the same ST_{dn} *value is taken, demand is accepted equally distributed among* L_{dn}*. And,* SF_{dn} *values are used as given in each scenario description. However, for the use of irons, early hours in the morning has been chosen (8 o'clock and later). Therefore,* ST_{dn} *has changed for each day. For example, on the first day of the model low demand hours are given as 3:00, 4:00, 5:00, 6:00, 7:00, and 8:00. Since, we considered 8 o'clock and later hours,* ST_{dn} *has become 1. On day 6, low demand hours occurred at 5:00, 6:00, 7:00, 8:00, 9:00, and 10:00.* ST_{dn} *is calculated by division of 1 to 3, and has become 0.333.*

Table 4.3: Cost, non-fossil source use, and emission rates for each scenario

Cases	**Cost**	**non-fossil use**	CO_2	SO_2	NO_x
	(billions of $)	%	(lbs)	(lbs)	(lbs)
0	26.516	41.47	$9.335.10^{10}$	$5.36.10^{8}$	$1.53.10^{8}$
1	26.515	41.47	$9.338.10^{10}$	$5.37.10^{8}$	$1.53.10^{8}$
2	26.514	41.47	$9.340.10^{10}$	$5.37.10^{8}$	$1.54.10^{8}$
3	26.515	41.47	$9.338.10^{10}$	$5.37.10^{8}$	$1.53.10^{8}$
4	26.514	41.47	$9.339.10^{10}$	$5.37.10^{8}$	$1.53.10^{8}$
5	25.691	42.54	$9.070.10^{10}$	$5.33.10^{8}$	$1.51.10^{8}$
6	25.903	42.26	$9.139.10^{10}$	$5.34.10^{8}$	$1.52.10^{8}$
7	26.000	42.13	$9.170.10^{10}$	$5.34.10^{8}$	$1.52.10^{8}$
8	26.448	41.56	$9.313.10^{10}$	$5.36.10^{8}$	$1.53.10^{8}$
9	26.428	41.58	$9.307.10^{10}$	$5.36.10^{8}$	$1.53.10^{8}$
10	26.437	41.57	$9.310.10^{10}$	$5.36.10^{8}$	$1.53.10^{8}$
11	26.362	41.67	$9.287.10^{10}$	$5.36.10^{8}$	$1.53.10^{8}$
12	26.446	41.56	$9.311.10^{10}$	$5.36.10^{8}$	$1.53.10^{8}$
13	26.481	41.52	$9.323.10^{10}$	$5.36.10^{8}$	$1.53.10^{8}$
14	26.256	41.80	$9.252.10^{10}$	$5.35.10^{8}$	$1.53.10^{8}$
15	26.461	41.54	$9.317.10^{10}$	$5.36.10^{8}$	$1.53.10^{8}$
16	26.413	41.60	$9.302.10^{10}$	$5.36.10^{8}$	$1.53.10^{8}$
17	26.464	41.54	$9.318.10^{10}$	$5.36.10^{8}$	$1.53.10^{8}$
18	26.419	41.59	$9.304.10^{10}$	$5.36.10^{8}$	$1.53.10^{8}$
19	26.419	41.59	$9.305.10^{10}$	$5.36.10^{8}$	$1.53.10^{8}$
20	26.336	41.70	$9.279.10^{10}$	$5.36.10^{8}$	$1.53.10^{8}$
21	25.989	42.15	$9.163.10^{10}$	$5.34.10^{8}$	$1.52.10^{8}$
22	26.219	41.85	$9.241.10^{10}$	$5.35.10^{8}$	$1.53.10^{8}$
23	26.368	41.66	$9.288.10^{10}$	$5.36.10^{8}$	$1.53.10^{8}$
24	26.487	41.51	$9.326.10^{10}$	$5.36.10^{8}$	$1.53.10^{8}$
25	26.506	41.49	$9.332.10^{10}$	$5.36.10^{8}$	$1.53.10^{8}$
26	26.503	41.49	$9.331.10^{10}$	$5.36.10^{8}$	$1.53.10^{8}$
27	26.498	41.50	$9.329.10^{10}$	$5.36.10^{8}$	$1.53.10^{8}$
28	26.383	41.64	$9.294.10^{10}$	$5.36.10^{8}$	$1.53.10^{8}$
29	26.330	41.71	$9.277.10^{10}$	$5.36.10^{8}$	$1.53.10^{8}$
30	26.514	41.47	$9.341.10^{10}$	$5.37.10^{8}$	$1.54.10^{8}$
31	26.514	41.47	$9.342.10^{10}$	$5.37.10^{8}$	$1.54.10^{8}$
32	26.437	41.57	$9.312.10^{10}$	$5.36.10^{8}$	$1.53.10^{8}$
33	26.514	41.47	$9.340.10^{10}$	$5.37.10^{8}$	$1.54.10^{8}$
34	26.514	41.47	$9.341.10^{10}$	$5.37.10^{8}$	$1.54.10^{8}$
35	26.473	41.53	$9.323.10^{10}$	$5.36.10^{8}$	$1.53.10^{8}$

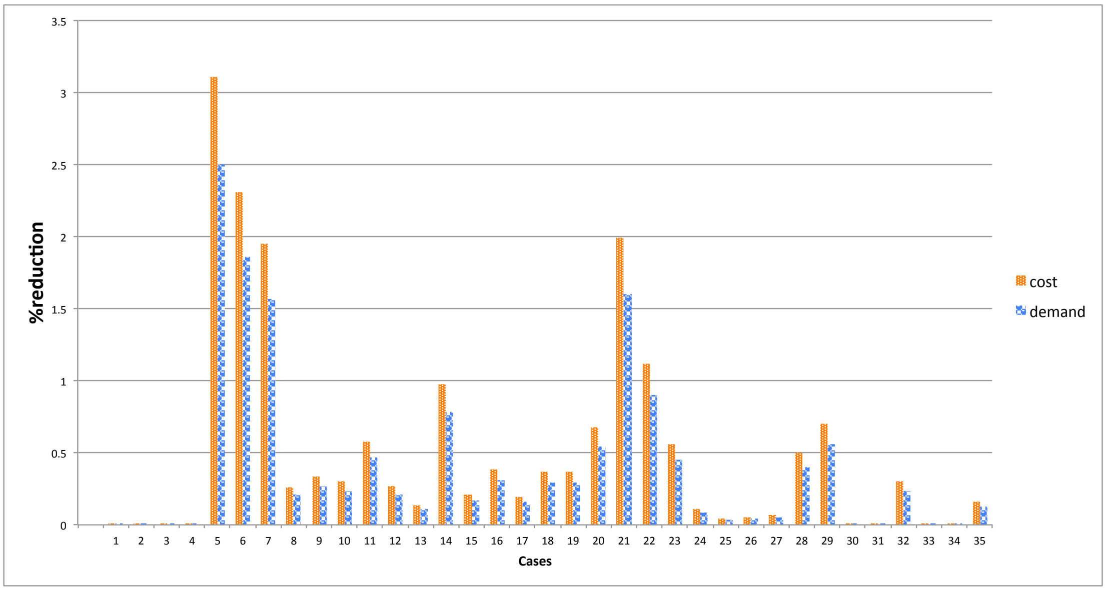


Figure 4.1: Reduction in cost and demand from each scenario (%)

When there is no policy adopted the cost becomes \$26.5 billion and the demand equals to $2.58X10^8$ MWh. 41% of electricity is generated from non-fossil fuels in this case. Although it is very little, all of the created scenarios lead to a decrease in demand and cost. This should emphasize the importance of encouraging using behavioral change policies in a large scale to meet sustainability targets.

Figure 4.1 shows the reduction rate of scenarios both in the cost and the demand. As seen, Cases 5, 6, 7, 21, and 22 lead to the higher reductions rates. Since higher percentage of renewables (43%) is used in the generation process, the emission rates of these scenarios are also lower than the other cases.

Although there is always a reduction in the cost and the demand, emission rates increase in some scenarios. Scenarios 1 to 4 and scenarios 30, 31, 33, and 34 end up with higher emission rates. This increase can be explained by using higher amount of coal in the generation process. Considering environmental impact of different scenarios is noteworthy to reach sustainability in the framework of global regulations.

As a summary of case results, these can be concluded:

- Results show that policy makers should be careful when they design their policy. In some cases, gas emission is increased. This is because the new policy might increase demand in a way that dirtier generation units has to be used.
- Messages on TV or magnets and stickers seem to an efficient way of promoting behavioral change. These types of new policies should be considered.
- Information campaigns will lead higher reductions, especially when they are implemented in summer for a long-time period.
- Avoiding standby consumption and giving incentives to replace old fridges with more efficient ones will bring a noticeable change to the network.
- As seen in similar studies higher reduction goals lead higher efficiency on the demand, and rewards can be used as an efficient behavioral change measure. Moreover, this kind of policy will be more effective at times when the energy demand is higher. Scenario 20 leads higher reduction in the demand and the cost, when the highest peak occurred in December.
- Social influences can also be suggested to promote efficient use of electricity among Turkish households. Scenario 21, which proposes to follow efficiency measures during school term, has the higher reduction ratio among similar cases.
- Although avoiding kettle use or replacing kettle with more efficient ones has impact on the electricity network, the importance should be given to electrical teapot

to reach higher reduction rates. Having tea after dinner is a traditional habit of Turkish households and it cannot be avoided. Survey results show that the ownership and the use rate of these products are high, and households were unwilling to avoid their use at peak hours. Therefore, policy makers should examine the problem carefully. Making manufacturers to develop higher efficiency tea machines can be one option, or severe policies can be developed to prevent using electricity to boil water or making tea.

- Shifting scenarios except from case 32 and 35 do not have a visible impact on the network. Furthermore, Scenario 30, 31, 33, and 34 causes rise in the emission rate. Shifting iron use from late hours to early morning will be effective to deal with the peak demand.

4.3. Conclusion

The result of this modeling showed behavioral change measures influence domestic energy consumption. Selecting the right type of intervention to initiate efficient use of energy in residential area is not easy. As discussed, behavior is a combination of several internal and external factors. The most appropriate policy for behavioral change should be chosen as a result of good understanding of consumer behaviors. For better understanding of consumers, monitoring households would be more effective. However, surveying is also a good method to collect household energy consumption behaviors and attitudes data. The biggest drawback of our survey is being long, and this caused distraction of the respondents.

Both cluster analysis and the mathematical model proved the importance of evaluating all types of households and policies for the best result of a behavioral change measure. Our model was very basic, and the focus was to show the impact of different policies on the electricity network. Long-lasting interventions lead to higher reductions in the cost and the demand. This studies suggestion is first understand the consumers; their behaviors and preferences thoroughly, and then apply a combination of several measures. Whereas a single measure such as information or feedback alone has a limited impact on consumers, social influences enhanced with rewards and information campaigns will bring more efficiency.

For further research, not only allocation but also a generation expansion planning problem can be solved via a more detailed model. This model comprised of only consumption data, and disregarded transmission lines and distribution losses. Examination of Turkey's energy planning in the future and the impact of behavioral change policies could guide policy makers to invest in better option: finding the most efficient behavioral change measure or establishing new generation plants.

Appendix A

Household Survey

HANELERDE ELEKTRİK TÜKETİMİ

(* İşareti ile başlayan sorular zorunludur.)

I. İlk bölümdeki sorular elektrik tüketim davranışlarınızı anlamak ve enerji verimliliğine ilişkin tutumlarınızı görmek üzere sorulmuştur.

Elektrikli ürünlerin enerji tüketimine ilişkin bilgi veren ve onların hangi enerji sınıfına ait olduklarını belirten etiketlere 'enerji etiketleri' denir. Enerji etiketlerinden haberdarım.

(Sadece bir seçeneği işaretleyiniz.)

- Evet, haberdarım. ☐
- Hayır, değilim. ☐

Evimdeki ürünler enerji verimliliğine uygundur (A sınıfı ve üzeri).

(Sadece bir seçeneği işaretleyiniz.)

- Hepsi ☐
- Çoğu ☐
- Bir kısmı ☐
- Hiçbiri ☐
- Bilmiyorum ☐

Yeni ürün alırken enerji etiketlerini göz önünde bulundururum.

(Sadece bir seçeneği işaretleyiniz.)

- Her zaman ☐
- Çoğu zaman ☐
- Nadiren ☐
- Hiçbir zaman ☐
- Bilmiyorum ☐

Haberdarsanız ve yeni ürün alırken enerji etiketlerine dikkat etmiyorsanız, sebebi:

(Bir ya da birden çok seçim yapabilirsiniz.)

- Verimli ürünleri daha pahalı buluyorum ☐
- Etiketlerin doğruluğuna güvenmiyorum ☐
- Enerji etiketlerini önemsemiyorum ☐
- Verimli ürünlerin tüketimimi azaltacağına inanmıyorum ☐
- Diğer ☐ _______________

Ürünlerin enerjiyi verimli kullanım oranı A,B,C,D,E,G harfleriyle gösterilir. A sınıfı ürünler yüksek verimlilik oranına sahipken, G sınıfına doğru verim düşmektedir. A sınıfı bir ürünün hem enerji tüketimi hem atmosfere karbondioksit salınımı, en düşük enerji sınıfına ait aynı ürüne kıyasla yaklaşık %50 daha azdır.

Düşük enerji sınıfına ait elektrikli ürünlerinizi DAHA verimli olanlar ile değiştirmek konusunda:

(Sadece bir seçeneği işaretleyiniz.)

- Enerjiyi verimli kullanmak adına kendi imkanlarımla değiştirebilirim. ☐
- Enerjiyi verimli kullanmak isterim, ancak teşvik verilirse değiştirebilirim. ☐
- Değiştirmek istemiyorum. ☐
- Fikrim yok. ☐

Birçok kullanıcının aynı anda elektrik tüketimini arttırması neticesinde, günün en yüksek talebi `PUANT TALEP' meydana gelir. 17.00-22.00 arası ülkemiz için elektrik talebinin en yüksek olduğu saatlerdir.

Aşağıdaki ürünleri saat 17.00 ile 22.00 arası kullanıyorsanız belirtiniz.
(Her satırda sadece bir seçeneği işaretleyiniz.)

	Her zaman	Çoğu zaman	Nadiren	Hiçbir zaman	Yok
Çamaşır makinesi	☐	☐	☐	☐	☐
Bulaşık makinesi	☐	☐	☐	☐	☐
Kurutucu	☐	☐	☐	☐	☐
Çay/ kahve makinesi/ su ısıtıcı	☐	☐	☐	☐	☐
Ütü	☐	☐	☐	☐	☐

Evi aydınlatmada kullandığım ampuller tasarruflu ampullerdir.

(Sadece bir seçeneği işaretleyiniz.)

- Hepsi ☐
- Çoğu ☐
- Bir kısmı ☐
- Hiçbiri ☐
- Bilmiyorum ☐

Televizyon, uydu alıcı, DVD oynatıcı, müzik seti vb. elektrikli araçları kullanmadığım zaman fişten çeker veya düğmesinden kapar, elektrik tüketmediğinden emin olurum.

(Sadece bir seçeneği işaretleyiniz.)

- Her zaman ☐
- Çoğu zaman ☐
- Nadiren ☐
- Hiçbir zaman ☐
- Bilmiyorum / Yok ☐

Sahip olduğum bilgisayarları (masaüstü, dizüstü, tablet) kullanmadığım zaman (örneğin geceleri) enerji tüketmeyecek şekilde kapatırım.

(Sadece bir seçeneği işaretleyiniz.)

- Her zaman ☐
- Çoğu zaman ☐
- Nadiren ☐
- Hiçbir zaman ☐
- Bilmiyorum / Yok ☐

Bazı çamaşır ve bulaşık makineleri işlem bittikten sonra ikaz ışığı ile uyarı verirler. Bu ve benzeri durumlarda ikaz ışığını söndürürüm.

(Sadece bir seçeneği işaretleyiniz.)

- Her zaman ☐
- Çoğu zaman ☐
- Nadiren ☐
- Hiçbir zaman ☐
- İkaz ışığı yok. ☐

Eğer elektrikli ürünleri, kullanmadığınız halde enerji tüketecek şekilde bırakıyorsanız, sebebi:

(Bir ya da birden çok seçim yapabilirsiniz.)

- Fişten çekmek /Kapatmak zor geliyor ☐
- Fişten çekilmesi / Kapatılması gerektiğini bilmiyordum ☐
- Kullanmak üzere tekrar açtığımda beklemek istemiyorum ☐
- Tek başıma dikkat ediyor olmamın bir etkisi olacağına inanmıyorum ☐
- Dikkat etmek istiyorum ama alışık değilim, unutuyorum ☐
- Diğer ☐ _______________

Aşağıdakilerden hangisi kullanılmadığı halde tüketilen elektriğin önüne geçmenizde DAHA etkilidir?

(Sadece bir seçeneği işaretleyiniz.)

- Elektrik faturamıza / Hane bütçesine etkisini bilmek ☐
- Ülke ekonomisine maliyetini bilmek ☐
- Çevreye verilen zararı bilmek ☐
- Hatırlatılmak veya uyarılmak ☐

Çamaşır ve bulaşık makinesini çalıştırmadan tam dolmasını beklerim.

(Sadece bir seçeneği işaretleyiniz.)

- Her zaman ☐
- Çoğu zaman ☐
- Nadiren ☐
- Hiçbir zaman ☐
- Bilmiyorum ☐

Gereksiz yanan ışıkları söndürürüm.

(Sadece bir seçeneği işaretleyiniz.)

- Her zaman ☐
- Çoğu zaman ☐
- Nadiren ☐
- Hiçbir zaman ☐
- Bilmiyorum ☐

Suyu, ısıtıcı(kettle) yerine gazlı ocakta ısıtmayı tercih ederim.

(Sadece bir seçeneği işaretleyiniz.)

- Her zaman ☐
- Çoğu zaman ☐
- Nadiren ☐
- Hiçbir zaman ☐
- Su ısıtıcım yok ☐

Yemek ısıtırken mikrodalgayı kullanmak yerine gazlı ocağı tercih ederim.

(Sadece bir seçeneği işaretleyiniz.)

- Her zaman ☐
- Çoğu zaman ☐
- Nadiren ☐
- Hiçbir zaman ☐
- Yok ☐

Isınmak için elektrikli ısıtıcı kullanırım.

(Sadece bir seçeneği işaretleyiniz.)

- Her zaman ☐
- Çoğu zaman ☐
- Nadiren ☐
- Hiçbir zaman ☐
- Yok. ☐

Elektrikli ısıtıcı kullanıyorsanız, sebebi:

(Bir ya da birden çok seçim yapabilirsiniz.)

- Evde çocuk, yaşlı veya hasta bulunduğundan. ☐
- Ev yeteri kadar ısınmadığından. ☐
- Kısa süreliğine ısınmak için. ☐
- Çabuk ısınma sağladığından. ☐
- Belli bir alanı ısıtmak için. ☐
- Diğer ☐ _______________

<u>Saat 17.00-22.00 arası artan elektrik talebi şebekede aşırı yüklenmeye neden olduğundan elektrik kayıplarını ve elektrik kesintisi ihtimalini arttırır. Bu zaman dilimindeki tüketimin azaltılması veya başka saatlere kaydırılması elektrik talep yönetimi açısından önemlidir.</u>

Aşağıdaki ürünleri kullanımımı gece saat 22.00'dan sonraya kaydırabilirim.
(Her satırda sadece bir seçeneği işaretleyiniz.)

	Evet	Belki	Hayır	Bilmiyorum	Yok
Çamaşır makinesi	☐	☐	☐	☐	☐
Bulaşık makinesi	☐	☐	☐	☐	☐
Kurutucu	☐	☐	☐	☐	☐

Hem gün ışığından faydalanmak hem de şebekede meydana gelecek yüksek talebi önlemek adına ütüyü günün erken saatlerinde yapmayı tercih edebilirim.

(Sadece bir seçeneği işaretleyiniz.)

- Kesinlikle evet ☐
- Evet ☐
- Bazen ☐
- Hayır ☐
- Bilmiyorum ☐

Bu zaman diliminde, çay/ kahve makinesi/ su ısıtıcı kullanmaktan kaçınabilirim.

(Sadece bir seçeneği işaretleyiniz.)

- Kesinlikle evet ☐
- Evet ☐
- Belki ☐
- Hayır ☐
- Bilmiyorum / Yok ☐

Belirtilen zaman dilimindeki elektrik tüketim davranışlarınızı değiştirmenizde, hangi 3 seçenek DAHA etkili olurdu?

(Bir ya da birden çok seçim yapabilirsiniz.)

- Saat 17.00-22.00 arası elektriğin daha pahalı olması ☐
- Çevreye verilen zararı azaltmak fikri ☐
- Olası elektrik kesintilerinin önüne geçmek düşüncesi ☐
- Ülkemizin enerjide dışa bağımlılığını azaltmak isteği ☐
- Meydana gelebilecek enerji kayıplarını önlemek düşüncesi ☐

Günün farklı zaman dilimlerinde kullanılan elektriğin farklı fiyatlandırıldığı sayaçlar 'Akıllı Sayaçlar' olarak bilinir. Bu uygulamaya ilişkin:

(Sadece bir seçeneği işaretleyiniz.)

- Haberim var, kullanıyorum. ☐
- Haberim var, kullanmıyorum. ☐
- Haberim yok. ☐

Akıllı sayaçlardan haberdar ama kullanmıyorsanız sebebi:

(Bir ya da birden çok seçim yapabilirsiniz.)

- Faturamı azaltabileceğimi düşünmüyorum. ☐
- Tasarruf sağlayacak şekilde davranışlarımı değiştirebileceğime inanmıyorum. ☐
- Nasıl başvuracağımı bilmiyorum. ☐
- Kullananlar tavsiye etmiyor. ☐
- Teknik sorunlar nedeniyle. ☐
- Bilmiyorum / Fikrim yok. ☐
- Diğer: ☐ _______________

Enerji ve Tabii Kaynaklar Bakanlığı'nca yürütülen ENVER, ENERJİ HANIM projeleri hakkında:

(Sadece bir seçeneği işaretleyiniz.)

- Duymuştum, ama takip etmiyorum. ☐
- Haberim var ve faydalanıyorum. ☐
- İlk defa duyuyorum. ☐

II. Bu bölümdeki sorular, enerjiyi daha verimli kullanmak ve elektrik tüketiminizi azaltmak üzere uygulanabilir politikalara yaklaşımınızı ölçmek üzere sorulmuştur.

Hanelerde enerjinin verimli kullanılmasına yönelik uygulanabilir yöntemler aşağıda verilmiştir.

A. Bilgilendirme: Enerjiyi verimliliği ve tasarrufla ilgi bilgi verilmesi

B. Geribildirim: Tüketicilere enerji tüketimlerine ilişkin bilgi verilmesi (tüketimin maliyeti, çevreye etkisi vb.)

C. Ödül: Enerjinin verimli kullanılması, faturanın düşürülmesi karşılığında tüketicinin ödüllendirilmesi

D. Ceza: Enerji tüketiminin artması, belli bir değerden fazla olması durumunda cezai uygulamalar

E. Sosyal etkinlikler: Enerji tüketimini azaltmak üzere çevre haneleri de kapsayan etkinlikler

Sizce bu yöntemlerden hangisi, davranışlarınızı değiştirmenizde DAHA etkili olur?

(Sadece bir seçeneği işaretleyiniz.)

- Bilgilendirme ☐
- Geribildirim ☐
- Ödül ☐
- Ceza ☐
- Sosyal etkinlikler ☐

Aşağıdaki sorularda (27-34) EN ÇOK tercih ettiğiniz seçeneği belirtiniz.

Hangi konularda bilgi almak istersiniz?

(Sadece bir seçeneği işaretleyiniz.)

- Elektriği verimli kullanma yöntemleri ☐
- Tüketilen enerjinin çevreye etkisi ☐
- Tüketilen enerjinin maddi karşılığı ☐
- Enerji etiketlerinin içeriği ☐
- Fişte bırakılan ürünlerin enerji tüketimi ☐
- Elektrik talebinin yüksek olmasının sistem üzerindeki etkisi ☐
- Diğer: ☐ _______________

Tercih ettiğiniz konular hakkında nasıl bilgilendirilmek istersiniz?

(Sadece bir seçeneği işaretleyiniz.)

- Seminer, konferans vb. eğitim programları ☐
- Broşür veya el kitapçıkları ile ☐
- TV yayınları ile ☐
- İnternet üzerinden (web sitesi, e-posta ile) ☐
- Cep telefonu ile (SMS veya mobil uygulamalar) ☐
- Diğer: ☐ _______________

Bilgilendirme çalışmalarında kimleri görmek istersiniz?

(Sadece bir seçeneği işaretleyiniz.)

- Akademisyenler ☐
- Ev hanımları ☐
- Siyasi liderler ☐
- Beyaz eşya üreticileri ☐
- Enerji tedarikçileri ☐
- Sporcular ☐
- Dini önderler ☐
- Ulusal veya yerel dernek temsilcileri ☐
- Şarkıcılar ☐
- Sinema veya TV oyuncuları ☐
- Sanatçılar ☐
- Diğer: ☐ _______________

Enerji verimliliğine yönelik çalışmaların televizyonda hangi formatta olmasını istersiniz?

(Sadece bir seçeneği işaretleyiniz.)

- Kamu spotu şeklinde yayınlar ☐
- Gündüz kuşağı, kadın programları ☐
- Belgesel şeklinde detaylı programlar ☐
- Reklamlar, sanal reklam uygulamaları ☐
- Sorularımızı ve fikirlerimizi paylaşabileceğimiz tartışma programları ☐
- Reality şov tarzında, seçilen hanelerde enerjinin verimli kullanımını işleyen programlar ☐

Geribildirimin tüketiminizle ilgili hangilerini kapsamasını istersiniz?

(Sadece bir seçeneği işaretleyiniz.)

- Geçen seneye göre kıyas ☐
- Çevre hanelere veya mahalle ortalamasına göre kıyas ☐
- Geçen aya göre kıyas ☐
- Ne kadar karbon salınımına neden olduğunuz bilgisi ☐
- Tüketiminizin uzun vadede doğaya ve topluma etkisi ☐
- Diğer: ☐ _______________

Yukarıda geribildirime dahil olmasını istediğiniz seçeneklerin, size ne şekilde ulaştırılmasını istersiniz?

(Sadece bir seçeneği işaretleyiniz.)

- Fatura ☐
- Kısa mesaj ☐
- Elektronik posta ☐
- Online erişim ☐
- Mobil uygulamalar ☐
- Diğer: ☐ _______________

Geribildirimin ne sıklıkla yapılmasını istersiniz?

(Sadece bir seçeneği işaretleyiniz.)

- Ayda bir defa ☐
- Ayda iki defa ☐
- Haftalık ☐
- Günlük ☐
- İstediğim her an erişilebilir olmalı ☐

Enerjiyi verimli kullanan, elektrik tüketimine dikkat eden tüketiciler nasıl ödüllendirilirse, sizin de davranışlarınızı değiştirmenizde etkili olurdu?

(Sadece bir seçeneği işaretleyiniz.)

- Fatura indirimi yapılmalı ☐
- Elektriğin birim fiyatında indirim uygulanmalı ☐
- Yeşil ev ilan edilerek duyurulmalı ☐
- Plaket verilmeli ☐
- Diğer: ☐ _______________

Televizyon izlerken, çocuklara uyku vaktini hatırlatan mesajlara rastlamışsınızdır. Benzer şekilde, elektrik tüketim davranışlarınızı değiştirmeye yönelik mesajlar almak davranışlarınızı değiştirmenizde etkili olur mu?

(Örneğin; televizyonunuzu kapatırken fişten çekmeniz vb. gibi hatırlatmalar)

(Sadece bir seçeneği işaretleyiniz.)

- Kesinlikle evet ☐
- Evet ☐
- Belki ☐
- Hayır ☐
- Bilmiyorum ☐

Kullandığınız elektrikli gereçlerin üzerine veya yakınına, enerji verimliliğine yönelik hatırlatıcı etiketler veya mıknatıslı nesneler yerleştirmek davranışlarınızı değiştirmenize yardımcı olur mu?

(Örneğin; bulaşık makinenizin üzerinde, cihazı tam dolu veya gece geç saatlerde çalıştırmanızı tavsiye eden notlar vb.)

(Sadece bir seçeneği işaretleyiniz.)

- Kesinlikle evet ☐
- Evet ☐
- Belki ☐
- Hayır ☐
- Bilmiyorum ☐

Toplam elektrik talebinin yüksek olduğunu bildiren bir uyarı alsanız ve bir süreliğine kullandığınız enerjiyi azaltmanız veya başka saatlere kaydırmanız beklense, davranışlarınızı değiştirir misiniz?

(Sadece bir seçeneği işaretleyiniz.)

- Kesinlikle evet ☐
- Evet ☐
- Belki ☐
- Hayır ☐
- Bilmiyorum ☐

Sahip olduğunuz elektrikli eşyaları daha verimli olanlar ile değiştirmek konusunda verilecek teşvikle ilgili ne düşünürsünüz?

(Bir ya da birden çok seçim yapabilirsiniz.)

- Ürün fiyatı üzerinden herhangi bir indirim yeterlidir. ☐
- Ürün fiyatı üzerinden en az %20 indirim uygulanmalı. ☐
- Ödeme kolaylığı olmalı. ☐
- Düşündüğünüz belli bir indirim oranı varsa (%): ☐ ______________
- Fikrim yok. ☐

<u>Yapılan çalışmalar tüketicilerin, diğer tüketiciler ile etkileşim içinde olduklarında enerji tüketimlerini azaltmakta daha başarılı olduklarını göstermektedir.</u>

Evlerde enerjiyi daha verimli kullanmak adına düzenlenen etkinliklere katılmanız istenseydi, hangisi EN ÇOK ilginizi çekerdi?

(Sadece bir seçeneği işaretleyiniz.)

- Okullarda, öğrenciler ve velilerin katılımıyla ☐
- Akrabalar / Yakınlar arasında ☐
- Apartman/ site sakinleri arasında ☐
- Mahalle genelinde ☐
- İl genelinde ☐
- Yurt genelinde ☐

Enerjinin verimli kullanılmasının yaygınlaştırıldığı bu tip etkinliklere katılmanızda, sizi EN ÇOK motive eden ne olurdu?

(Bir ya da birden çok seçim yapabilirsiniz.)

- Daha az enerji tüketmek ☐
- Daha az fatura ödemek ☐
- Çevreyi korumuş olmak ☐
- Bilinçli topluma katkı ☐
- Ödül kazanmak ☐

III. Son bölümdeki sorular hane özelliklerini belirlemek amacıyla sorulmuştur.

Yaşadığınız il

(Sadece bir seçeneği işaretleyiniz.)

- ADANA ☐
- ADIYAMAN ☐
- AFYONKARAHİSAR ☐
- AĞRI ☐
- AKSARAY ☐
- AMASYA ☐
- ANKARA ☐
- ANTALYA ☐
- ARDAHAN ☐
- ARTVİN ☐
- AYDIN ☐
- BALIKESİR ☐
- BARTIN ☐
- BATMAN ☐
- Metin ☐ _______________

Konutunuzun büyüklüğünü (metrekare) belirtiniz.

(Sadece bir seçeneği işaretleyiniz.)

- 0-50 ☐
- 51-100 ☐
- 101-150 ☐
- 151-250 ☐
- 251'den büyük ☐

Konutta yaşayan kişi sayısını belirtiniz.

(Sadece bir seçeneği işaretleyiniz.)

- 1 ☐
- 2 ☐
- 3 ☐
- 4 ☐
- 5 ☐
- 6 ☐
- 7 ve üzeri ☐

Bütün gününü evde geçiren kişi sayısını beirtiniz.

(Örneğin; çalışmayan veya okula gitmeyen hane sakinleri)

____

Yaşınız?

____

Mezuniyet durumunuz nedir?

(Sadece bir seçeneği işaretleyiniz.)

- İlköğretim ☐
- Ortaöğretim ☐
- Yükseköğretim ☐

Hane gelirini belirtiniz. (TL)

(Sadece bir seçeneği işaretleyiniz.)

- 0-1000 ☐
- 1001 - 3000 ☐
- 3001 - 5000 ☐
- 5001 - 10000 ☐
- 10000 ve üzeri ☐

Aylık elektrik faturanız ne kadardır?

(Her satırda sadece bir seçeneği işaretleyiniz.)

	<30 TL	30-60 TL	60-90 TL	90-150 TL	>150 TL
Yaz	☐	☐	☐	☐	☐
Kış	☐	☐	☐	☐	☐

Evinizde enerjiyi verimli kullandığınız takdirde, elektrik faturanızı ne kadar düşürebileceğinizi tahmin ediyorsunuz?

(Sadece bir seçeneği işaretleyiniz.)

- En fazla faturamın %10' u ☐
- %10 ile %25 arası ☐
- %25' den fazla ☐
- Fark edilir bir düşüş olacağını sanmıyorum ☐
- Bilmiyorum ☐

Lütfen size en uygun seçeneği işaretleyiniz.

(Sadece bir seçeneği işaretleyiniz.)

- Evin diğer üyeleri de çoğunlukla benzer tüketim davranışları içerisindedir. ☐
- Evin diğer üyelerine göre ben, enerjiyi daha bilinçli tüketirim. ☐
- Evin diğer üyeleri benden daha bilinçli enerji tüketim davranışlarına sahiptir. ☐

Appendix B

Tables for Factor Analysis

Table 1. KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		,646
Bartlett's Test of Sphericity	Approx. Chi-Square	434,450
	df	66
	Sig.	,000

Table 2. Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2,326	19,380	19,380	2,326	19,380	19,380	1,744	14,534	14,534
2	1,570	13,087	32,467	1,570	13,087	32,467	1,677	13,973	28,507
3	1,340	11,169	43,636	1,340	11,169	43,636	1,343	11,192	39,699
4	1,085	9,038	52,674	1,085	9,038	52,674	1,317	10,978	50,677
5	1,028	8,569	61,243	1,028	8,569	61,243	1,268	10,565	61,243
6	,841	7,012	68,255						
7	,828	6,898	75,153						
8	,765	6,378	81,530						
9	,643	5,357	86,887						
10	,581	4,844	91,731						
11	,534	4,447	96,178						
12	,459	3,822	100,000						

Extraction Method: Principal Component Analysis.

Table 3. Rotated Component Matrix[a]

	Component				
	1	2	3	4	5
I consider energy labels when purchasing a new product	,839				
I have energy efficient products in my house (Class A or above)	,825				
I use efficient light bulbs in my house	,553				
I unplug the PC, notebook etc. when they are not in use		,783			
I unplug the TV, DVD etc. when they are not in use		,750			
Some dishwasher and washing machines have alarms after the program, in this case I turn off the alarm		,562			
I prefer to heat the meal on the gas furnace instead of a microwave			,828		
I prefer to boil water on a gas furnace instead of a kettle			,722		
I prefer to iron in the early times of day instead of at peak hours				,765	
I prefer not to use kettle/tea–coffee machines during peak hours				,718	
I run the dishwasher and the washing machine at full capacity					,816
I turn off unnecessary lights					,678

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 7 iterations.

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