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Standby electricity consumption and saving potentials of Turkish households

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HIGHLIGHTS

- This is the first study examining standby electricity consumption of Turkish homes.
- Surveys and standby power measurements are conducted at 260 homes in Ankara, Turkey.
- Average household standby power and consumption are estimated as 22 W and 95 kW h/yr.
- Two scenarios are applied to determine potentials in reducing standby consumption.
- Effects of socioeconomic and demographic factors on standby consumption are studied.

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ABSTRACT

The share of the residential sector currently accounts for about 25% of the national electricity consumption in Turkey. Due to increase in household income levels and decrease in the costs of appliances; significant increases in appliance ownerships and residential electricity consumption levels have been observed in recent years. Most domestic appliances continue consuming electricity when they are not performing their primary functions, i.e. at standby mode, which can constitute up 15% of the total household electricity consumption in some countries. Although the demand in Turkish residential electricity consumption is increasing, there are limited studies on the components of the residential electricity consumption and no studies specifically examining the extent and effects of standby electricity consumption using a surveying/measurement methodology. Thus, determining the share of standby electricity consumption in total home electricity use and the ways of reducing it are important issues in residential energy conservation strategies. In this study, surveys and standby power measurements are conducted at 260 households in Ankara, Turkey, to determine the amount, share, and saving potentials of the standby electricity consumption of Turkish homes. The survey is designed to gather information on the appliance properties, lights, electricity consumption behavior, economic and demographics of the occupants, and electricity bills. A total of 1746 appliances with standby power are measured in the surveyed homes. Using the survey and standby power measurements data, the standby, active, and lighting end-use electricity consumptions of the surveyed homes are determined. The average Turkish household standby power and standby electricity consumption are estimated as 22 W and 95 kW h/yr, respectively. It was also found that the standby electricity consumption constitutes 4% of the total electricity consumption in Turkish homes. Two scenarios are then applied to the surveyed homes to determine the potentials in reducing standby electricity consumption of the households.

1. Introduction

The amount of electricity consumed by the household appliances that are connected to power and not actively performing their main functions has been studied by many researchers since early 1990s [1–3]. Standby electricity consumption (SEC) is the best known and widely used term for this type of residential electricity end-use. Many more studies are later conducted to determine SEC of various new and stock household appliances [4–11], amount of household and national SEC and/or standby power [12–24], and associated CO_2 emissions [22,25]. Due to the increasing trend in standby electricity consumption, many countries and non-governmental bodies have taken steps to reduce standby power of new appliances in the market, such as implementing appliance energy efficiency standards and labels [26–33]. The effects of these steps in reducing the household and national electricity consumption, electricity expenditures, and associated CO_2

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emissions are also studied by many researchers [9,10,13,15,21,34–36].

The share of residential sector in total electricity consumption has been increasing and currently accounts for about one fourth of the total electricity consumption in Turkey [37]. The residential electricity consumption was 1,056,600 MW h and 14.5% of the total consumption in 1970. The electricity consumption of the residential sector increased by about 39 times and reached to 41,410,700 MW h in 2010 constituting 24.1% of the national electricity consumption, which increased by about 24 times in this period.

Due to the significant increase in GDP per capita in terms of current US$ levels from $2791 in 1990 to $10,135 in 2010 [38] and decrease in the costs of household appliances; new appliance purchase rates have increased from 2.8 million in 2002 to 6.18 million in 2010 in Turkey [39]. As the number of appliances increases, the amount of electricity consumed by appliances at standby mode also increases. In a study that estimated the SEC of Turkish households using the bottom-up approach, Lebot et al. [25] assumed an average standby power of 10 W per household for Turkey for 1997. Also assuming that this standby electricity consumption is for 24 h, the authors estimated that residential SEC accounts for 1.5% of the national electricity consumption in 1997. In another study conducted by International Energy Agency in 2001 which was also based on bottom-up approach, the standby power estimate for Turkey is taken as 20 W and SEC share is estimated as 3% for 1997 [40]. Other than these studies, no other study has yet been conducted using either whole-house measurement or bottom-up approach to determine the amount and percentage of SEC for Turkish households. Therefore, the main objective of this study is to determine the standby power and standby electricity consumption of Turkish households accurately using an extensive surveying and measurements methodology.

In this respect, the average standby power and electricity consumption of Turkish households are determined using whole-house measurements approach. Surveys and measurements are conducted at 260 homes in Ankara, the capital city of Turkey. The SEC fraction in the total household electricity consumption is also determined and compared with results of other whole-house measurements studies. Using survey and standby power measurements data, scenarios such as decreasing standby power of the appliances to 1 W and replacing some of the existing appliances with newer ones available in the market are applied to determine the amount of reduction that could be obtained in total household electricity consumption and associated CO_2 emissions. These results are also extrapolated to the national urban housing stock to determine the reductions in national residential electricity consumption and total CO_2 emissions.

In Section 2 of this paper, the methodology used to determine household standby power and electricity consumption, fraction of SEC to the total household electricity consumption, potentials in reducing SEC and associated CO_2 emissions are explained in detail. The appliance and household standby power and consumption statistics and results of the scenarios to reduce standby power are given in Section 3. The conclusions are presented in Section 4 of the paper.

2. Methodology

Currently two approaches are used in determining the standby electricity consumption of the households, namely whole-house measurements approach or bottom-up estimates approach. The whole-house measurements approach mostly involves visiting a number of sample houses, conducting a detailed survey about appliances characteristics and occupant electricity consumption behavior, and measuring standby power of the appliances in the homes. The total household electricity consumption is calculated by using the data gathered while conducting the survey and billing data of the households. The standby power of the appliances determined from measurements is multiplied by the number of hours the appliances are left at standby mode, which was obtained from the surveys, to determine the SEC of the household. By using these information, the share of SEC to the total household electricity consumption is then determined.

Bottom-up estimates approach is used when detailed appliance saturation and appliance standby power data is available. In this approach, the appliance saturation data is multiplied by the average estimated appliance standby power and standby hours. This approach is mostly accurate for major appliances for which detailed saturation and power data are available; but not very accurate for minor appliances due to lack of saturation and power data, which actually constitute most of the SEC of the households [41].

The primary objective of this study is to determine average standby power and electricity consumption, and fraction of SEC to the total household electricity consumption for Turkish households using whole-house measurements approach. Thus, during house visits data on lighting and appliances of the household is documented, and all appliances with standby power are measured, where available (i.e. if the appliance is hard wired into the electrical system it is not measured, such as door bells, security alarms, intercoms and furnace/boilers fans). The standby power measurements are conducted with a true RMS power Extech 380803 power analyzer [42]. This is a dual range meter (0–200 and 200–2000 W) with 0.1 W resolution for the low range and 1 W resolution for the high range. The accuracy of the measurements is ± 0.9% of reading +0.4 W for the low range and ±0.9% of reading +4 W. for the high range. The meter also has a built-in data logger, which can store up to 1012 readings during continuous data logging.

The standby power measurements of the appliances are conducted when the appliances are plugged to the power, not performing their main function but can be activated or switched on by a remote control, can be performing some secondary function (e.g. could have a display or clock which is active in this mode), and in their lowest power consuming mode. This type of mode of the appliances is also called as "passive standby power" [43,44].

The volunteer households for the whole-house measurements are identified mainly based on their household income levels, since it is desired that the sample of this study would be a representative of the Turkish urban household stock. The other criterion is that these households do not use electricity for space heating. A survey with 45 questions and a section to tabulate the standby power measurements is prepared. The survey questions are prepared to get detailed information of the dwelling, occupants, appliances and lighting, consumption behavior, and billing data. In addition to the surveys, the standby power measurements are also conducted at three electronics retail stores to determine the standby power of various new household electronic appliances currently available in the market.

In order to determine the total household electricity consumption, average electricity consumption of major household appliances are gathered from open literature based on their size, model, brand, age, etc. For example, the refrigerators are categorized based on their type (top or bottom freezer, single or two doors, etc.), volume, and age; and average annual electricity consumption for each category is determined from the web sites of local and international retailers and government agencies such as *Natural Resources of Canada* and *US Federal Trade Commission*. The active appliance electricity consumption is calculated by summing the electricity consumption of all appliances in the household when they are performing their primary functions as given below.