How Many Appliances does it take to…?

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ABSTRACT

In this presentation we set out to establish the need to fully understand how energy is consumed in residential households by using the U.S. Energy Information Administration's (EIA) Residential Energy Consumption Survey (RECS) before using it for policy to technological decisions. We also set out to determine how many appliances need to be monitored in order for Nonintrusive Load Monitoring (NILM) to successfully enable users to reduce electricity consumption.

Keywords

NILM, RECS, energy efficiency, residential electricity, appliance

1. INTRODUCTION

In the United States, there exists an enormous variation in both the appliances and the number of appliances that comprise a household's total annual electricity use. The variation occurs due to a plethora of factors that affect appliance ownership and use including differences in geography, climate, fuel availability, and socioeconomic status. It is important to understand the makeup of a particular household's electricity consumption profile in order for electricity users to consciously reduce consumption in order to save money and to reduce environmental impacts. Understanding residential electricity consumption is also important for utilities that may wish to understand how to more efficiently preform peak shaving. Policy makers may find it beneficial to know which appliances should be targeted for efficiency improvements in various regions of the country and how electricity and other fuels are demanded for energy security purposes.

The Residential Energy Consumption Survey (RECS) data that is currently used is misleading as the RECS "End-Use of Electricity Consumption 2001" indicates that on average 42 unique types of appliances account for 92.7% of the electricity consumption, leaving 7.3% unaccounted for (termed "residual" in the survey) [1]. The idea that the "average" household's electricity load profile contains more than 42 unique appliances that account for less than 93% of the total load is unrealistic. Because there is not "average" household in existence and because each household is unique, it is important to understand how many appliances are expected to be major contributors to a given household's electric load. We have found that the typical home in the United States consumes more than 80% of its electric load in just 8 appliances. This is in stark contrast to the results shown for the average home, which consumes 80% of its electricity in 12 appliances.

Previous studies have indicated that improved knowledge of consumption leads to reductions in electricity consumption in houses of between 5% and 15% [2,3]. It is thought that disaggregation of one's electricity bill into component consumers at the appliance level may lead to reductions through behavioral change or through inefficient appliance replacement. For example, if a user were to discover that a refrigerator consumed significantly more electricity than most other appliances or the average refrigerator, he or she may choose to change the settings to a higher temperature or replace the inefficient refrigerator.

2. Methods

The Residential Energy Consumption Survey (RECS) is a survey for occupied primary housing units with a focus on energy use. The survey was started in 1978 and was in its twelfth iteration as of 2005. While a thirteenth iteration of the RECS data was in the works at the time of this presentation, it was unavailable as of October 2011. RECS provides a Microdata set that is publically available at http://www.eia.gov/emeu/recs/recspubuse05/pubuse05.html which contains all of the responses from all of the 4,832 housing units surveyed [4]. For this study, the 2005 RECS Microdata was used and supplemented with the 2001 RECS End-Use Survey (reference) when the Microdata was insufficient. While the 2001 Microdata is over ten years old, it is the best supplemental data available for the purposes of this study.

Looking at the RECS Residential End Use Survey shows us that there are 42 unique appliances that contribute to the average household's electric load. Of these 42 appliances, 23 appliances contribute at least 0.1% of the average electricity load in one or more of the U.S. Census regions. Anything that contributes less than 0.1% of the electricity load is ignored for simplicity of this study. It should be noted that rare appliances with large electric demands may contribute less than 0.1% to the average home's electric load but may contribute much more than 0.1% to the electric load of a household if it is present. A good example of this (though it is slightly higher than the 0.1% cutoff) can be seen in pool, hot tub, and spa heaters which at the maximum contribute to 0.15% in the South Atlantic Census Region but in reality consumed 2,300 kWh annually in 2001 in homes that had this appliance compared to the average household electricity consumption of 10,656 kWh annually.

3. Results

The RECS data ("Average") is misleading if used for policy and technology decisions such as NILM. 80% of the average household electricity consumption is spread amongst twelve appliances when accounted for in decreasing order. In contrast, realistic scenarios indicate that the 80% threshold may be reached by counting only the top 8 appliances.

There are significant differences beween the average scenario that is presented by RECS and the more realistic scenarios developed by our team. While this is the case, there is little regional variation, at least at the U.S. Census Region level. The higher electricity consumption and lower number of appliances needed in the southern census regions run hand-in-hand. In the south, there is a greater dependence on air conditioning, which increases both the electric load as well as the contribution of one of the largest

appliances in the home. This same phenomenon is also observed in the more realistic scenarios.

Table 1. The number of appliances needed to reach a given threshold for each of the four scenarios.

Threshold	Average	Likely	Gas	Electric
50%	4	4	3	3
80%	12	8	7	8
90%	18	11	9	11

4. Discussion and Conclusions

Understanding the difference between average residential electricity consumption and actual residential consumption is very important when looking at common data like the RECS microdata and the RECS End Use Table. One should not make household level policy or decisions based on the RECS average data, which would overestimate the number of contributing appliances to a household electric load. Likewise, one should be careful when using household or appliance level data when crafting policy at a level that is higher than the household.

Estimating the number of appliances that contribute to a home's electricity consumption is a difficult, complex problem that many parties are interested in and should be interested in, in order to reduce residential electricity loads. Concerned parties include national, state, and local policy makers as well as utilities that wish to perform peak shaving and consumers of electricity who may wish to reduce consumption for economical and environmental concerns.

The RECS relies on relatively few data points and contains errors. Hopefully the RECS will continue to grow in sample size and improve in data quality as it moves from the 2005 survey to the 2009 survey. Regardless of improvements that may be made to the RECS dataset, it is vital that policy makers, utilities, and homeowners are able to distinguish between the average home and what an actual home may consume in terms of electricity in order to better facilitate reductions in electricity consumption.

5. ACKNOWLEDGMENTS

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