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Energy consumption, energy efficiency, and consumer perceptions: A case study for the Southeast United States

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HIGHLIGHTS

- Interaction between climate, efficiency, and electricity consumption were examined.
- 2450 state residents were surveyed about clean energy and subsidy policies.
- Indirect energy efficiency costs negatively influenced electricity consumption.
- Cooling degree days were positively related to electricity consumption.
- Resident awareness influenced policy perceptions about clean energy and subsidies.

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ABSTRACT

This study examined the interaction between climatic variability and residential electricity consumption in a Southeast US state. Residential electricity consumers were surveyed to better understand how to diffuse positive attitudes and behaviors related to energy efficiency (EE) into households. The study found that 16.8% of the variability in residential electricity consumption for heating applications was explained by indirect EE costs. 36.6% of the variability in residential electricity consumption for cooling applications was explained by indirect EE costs and cooling degree days (CDD). A survey of 2450 residential electricity consumers was analyzed using the theory of planned behavior (TPB). Significant findings suggest that those residents are aware of utility EE programs are more likely to participate, view utility company motives more favorably, to support governmental subsidies for EE programs, and to support the use of clean energy by utility companies.

1. Introduction

With the understanding that the energy consumptive patterns in the United States (US) are a contributing factor to anthropogenic climate change [1], this study seeks to gain a comprehensive understanding of the relationship between energy consumption, energy efficiency (EE), climate variability, and residential electricity consumer perceptions in the Southeast United States (US). According to the US Energy Information Administration [2], the US is among the highest per capita consumers of electricity in the world, using approximately four times as much electricity as the most consumptive country in the world, China. Carbon emissions continues to rise at historic rates, with emissions more than doubling since 1986 [3]. According to Heede [3], emissions are largely driven by fossil fuel and cement producers, with only 90 such companies responsible for over 60% of global carbon emissions since the Industrial Revolution. As the largest electricity consuming sector, particularly in the Southeast US where states are more reliant on fossil fuels and per capita usage is higher than other regions in the US [4], residential consumers are a salient driver of carbon emissions related to the production of electricity. In order to ensure continued, secure energy access and lowered reliance on carbon rich fossil fuel sources, short- and long-term regulatory practices are needed to achieve production and emissions goals in the energy markets [5].

The evaluation of energy mix is of great concern. Both in the US and in other industrialized countries globally [3,6], fossil fuel reliant energy producers continue to contribute GHG emissions at higher rates than other groups. While the percentage of fossil fuels in the US and abroad in terms of percentage energy mix has decreased [7,8], issues such as increased electricity demand from non-traditional users (e.g., transportation), increased economic activity, population growth, and energy security have resulted in

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increased consumption and continued reliance on fossil fuels [8–12]. A host of technologies are available to reduce GHG emissions beyond those traditionally deployed with varying degrees of cost-effectiveness (e.g., [13–15]). However, there has been some reluctance among residents around the world to embrace clean energy sources and efficiencies in their own homes largely due to lack of awareness [16–18]. To further policy and practice, particularly around cost-effective methods to reduce consumption and emissions, the engagement of residential energy users is crucial.

Residential energy use is expected to increase carbon emissions for the sector from 17% to 21% in the US by the year 2020 [19], magnifying the implications of rising emission levels relative to energy producers. According to Shove [20], "the challenges of climate change are such that many familiar ways of life and many of the patterns of consumption associated with them are fundamentally unsustainable" (p. 1273). There are positive feedbacks in the consumptive US electricity system. Increased consumption leads to increased GHG emissions which has been shown to influence climatic variability and extreme weather events [1]. To help reduce energy consumption and related GHG emissions, Fisher and Newell [21] suggest that both policy and the diffusion of relevant knowledge through effective communication as to influence positive behavior is necessary. The current study seeks to expand beyond merely identifying energy related problems in an effort to understand the mechanisms by which EE can be diffused directly into households.

1.1. Energy efficiency programs and climate

Energy related decisions to curb consumption, ranging from federal energy policy to the type of light bulb in the home, are people-centric. To help slow energy consumption and the related GHG emissions in the US, governmental agencies as well as investor-owned, state-regulated utility companies engage in EE programs to influence adoption of technologies and pro-conservation behaviors [18]. There are billions in incentive dollars available from utilities and governmental agencies for residences to become more efficient [22], with over 30 million US dollars deployed in the focal state in 2012. The deployment of incentives to those who utilize these programs is largely based on a deemed savings model, in that efficiency upgrades are assigned a kilowatt–hour (kW h; unit of measurement of electricity) savings value approved by a state regulatory body [18]. Relying on these assigned values instead of using pre- and post-test consumption analysis make it difficult to gauge the true impact of such programs. Because of these complications, the current study will focus on *actual* peak electricity kW savings reported by utility companies in lieu of deemed kW h household savings. Also, the study will focus only on indirect EE costs that include non-incentive spending such as marketing and administration, as direct costs are incentives paid based on the deemed kW h values.

Electricity consumption and electricity savings from EE programs were reported by utility companies with the EIA. However, there is no systematic control for climatic factors in these reports. In a longitudinal residential study, Jovanovic et al. [23] demonstrated that temperature was the biggest determinant for increased electricity consumption, particularly during periods of extreme cold and hot temperatures related to electric heating and cooling equipment. Large empirical studies indeed demonstrated that both electricity ($r = .84$; [24]) and natural gas ($r \geqslant .97$; [25]) consumption are strongly linked to climatic factors such as heating degree days (HDD) and cooling degree days (CDD). HDD and CDD are measures of how much energy is needed to heat or cool a facility given local temperature conditions, where "A degree day indicates that the daily average outdoor temperature was one degree higher or lower than some comfortable baseline temperature" [26]. According to Mourshed [27], HDD and CDD are more reliable measures of climatic impact on energy consumption than temperature alone, thus they were included as the measures of climatic variability in this study.

Models predict increased temperature variability, including increased electricity demand associated with CDDs absent other factors ([1,28,29]). A salient factor not included in the models is efficiency [28]. The pricing for residential customers is traditionally volumetric, meaning that as demand increases for electricity, residential pricing stays the same [30]. With the Southeast US projected to experience more weather extremes and climatic variability associated with increasing temperature [31], the deployment of effective efficiency programs to offset the projected demand in electricity [28] in the residential sector without the option of variable pricing is crucial. Efficiency programs can range from purchasing discounted efficient lighting at major retailers to making home retrofits [18], with the entire portfolio of electricity savings measures needed to combat increased demand [32].

The current study examines the influence of EE programs (i.e., actual kW savings and costs of programs), HDD, and CDD on kW h consumption per consumer in Southeast US. More specifically, the study examined these relationships primarily relative to electric heating applications and electric cooling applications:

> *Research Question 1*. How much variability in residential kW h consumption used for heating and cooling is explained by climatic factors, EE program actual kW savings, and EE costs?

1.2. Communication and the residential electricity consumer

Communication with electricity consumers is essential to ensure that energy savings occur. For instance, Delmas et al. [33] found in a meta-analysis that incentive programs administered without feedback mechanisms resulted in increased energy consumption in the home, the opposite of the desired effect. To combat results in the wrong direction, or the rebound effect [34], states are increasingly using feedback rich deep-savings approaches that behaviorally empower residential customers to reduce electricity consumption. Asensio and Delmas [35] saw consumption reductions when this strategy was used with residential electricity customers. Darby [36] demonstrated that rich feedback can behaviorally lead to energy savings between 5% and 15%, whereas behavioral reduction in consumption outside of feedback is minimal. Craig and Allen [37] had similar results, in that households saw a year-over-year drop of over 10% in electricity consumption after a behavioral intervention that included rich feedback when controlling for climatic variability. While there are some in the US that are deploying aggressive behavioral programs (e.g., O'Power, the Shelton Group), pro-active behavioral interventions in residences remain the exception. It is not as easy as just providing incentives or presenting a message related to participating in EE and expecting people to change, however. Awareness about efficiency and related programs remains low among adults and children [18,37]. For instance, in a recent study, only 21% of residences interviewed recalled receiving information or educational materials about efficiency [19].

Dewaters and Powers [38] noted that energy literacy has an affective, or emotional, element. Mis-information and previously formed attitudes have the potential to deter the receipt of new information and further solidify potentially negative attitudes that can deter positive behaviors. In fact, Craig and Allen (2014) found individuals who did not know about utility EE programs were less supportive of the use of alternative energy, which has the potential