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An incandescent truth: Disparities in energy-efficient lighting availability and prices in an urban U.S. county

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HIGHLIGHTS

- Bulb availability and price were explored across poverty strata and store types.
- 130 in-store surveys were conducted in Wayne County, Michigan.
- Energy-efficient bulbs were less available in high-poverty areas and smaller stores.
- Energy-efficient bulbs were more expensive in high-poverty areas and smaller stores.
- Cost to upgrade from incandescent to LED was 2 times higher in high-poverty areas.

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ABSTRACT

In the U.S. lighting represents about 9% of the average household's primary energy consumption and 20% of the average household's energy bill. Lighting in U.S. homes is in a state of transition with steady growth in the adoption of more energy-efficient lighting technology, such as, compact florescent lamps (CFL) and light-emitting diodes (LEDs). However, the adoption of energy-efficient lighting is not equitably distributed across socioeconomic groups, with poorer households less likely to adopt than higher-income households. This case study in Wayne County, Michigan explores the lack of parity in energy-efficient lighting adoption from an energy justice perspective by evaluating distributional disparities in light bulb availability and price in 130 stores across four poverty strata and five store types for a more holistic understanding of potential barriers for poorer households. We found that (1) energy-efficient bulbs were less available in high-poverty areas and smaller stores; (2) energy-efficient bulbs were more expensive in high-poverty areas and smaller stores; (3) upgrade costs from incandescent and halogen lamps (IHLs) to CFLs or LEDs were higher in high poverty areas; and (4) both poverty and store type were significant predictors of LED availability, while store type was the most significant predictor of LED price variability. We suggest several ways that the development and implementation of energy efficiency policies and programs may consider these disparities that affect access and affordability, in order to achieve a more just energy-efficient transition.

1. Introduction

Individual participation in the transition to a low-carbon, cleaner energy future, requires household adoption of energy-efficient technologies. For prolific adoption trends to materialize, new technology must be recognized as being both cost effective and socially accepted [1,2]. It is therefore critical to understand energy transitions from a socio-technological perspective, exploring the interaction between humans and technology [3]. Moreover, if transitions are to be equitable, or just, the implementation of new energy technologies, policies, and programs, must consider the impact on and participation of poor and other disadvantaged populations [4].

Residential lighting is one technology undergoing a rapid transition centered on enhanced energy efficiency. Indoor lighting has experienced major technological shifts over time, from the 125-year-old incandescent to the highly-efficient lighting technology we know today [5–7]. In the U.S., lighting accounts for 10% of residential electricity consumption, 9% of the average household's primary energy consumption, and 20% of the average household's energy bill [8]. The U.S. Energy Information Administration (EIA) estimates that by 2040 the average household will use less than half the electricity for lighting as it did is 2016, as households upgrade from less energy-efficient

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incandescent and halogen lamps (IHLs) to more energy-efficient compact fluorescent lamps (CFLs) and light-emitting diodes (LEDs) [8]. Additionally, government policies have required advancements in lighting energy efficiency and incentivized decreased energy waste as critical means for achieving national security, economic, health and environmental goals. For instance, the federal Energy Independence and Security Act (EISA) of 2007 legislated requirements for increased lighting energy efficiency. Subsequently, manufacturing of lighting technology has evolved and adapted to meet these and other standards [5].

Lighting upgrades are often the first residential energy efficiency measure pursued, offering one of the easiest ways to cut household energy bills due to ease of replacement, relatively low upfront costs, and short paybacks periods. Thus, many energy efficiency programs substantially focus on lighting upgrades as a cost-effective, entry-level measure when compared to more capital-intensive efficiency measures [2,9,10]. In addition to an economic case for lighting upgrades, an environmental case also exists that supports widespread replacement of older, less efficient lighting [11]. According to some, the ultimate goal is to replace all IHLs, and even CFLs, with LEDs; despite increased efficiency of IHLs required by EISA, because LEDs last 25 times longer and consume 75% less electricity [5,12,13]. In one estimate, converting all conventional lighting to LEDs could reduce energy consumption by 1000 TW h yr^{-1}, the equivalent of about 230 500-MW coal plants and reduce greenhouse gas emissions by roughly 200 million tonnes [14].

Although policy and market forces are driving growth in LED adoption, only 29% of U.S. households use at least one LED bulb in their home [15]. Moreover, industry reports indicate patterns of energy-efficient lighting adoption are not equitable across socioeconomic groups. Lower income households (those earning less than $50,000 per year) are less likely than higher income households to purchase LEDs [16]. Instead, growth in market demand for LED lighting is being driven by young and higher income consumers [16].

The lack of parity in energy efficient lighting technology across socioeconomic groups has real implications for the imbalance in residential energy dynamics that exist between these groups. First, although low-income households consume 16% less energy, annually, when compared to non-low-income households, low-income households have an energy use intensity (EUI), or the amount of energy consumed per square area, that is 27% greater than non-low-income households [17]. Since EUI is a proxy for energy efficiency, it is clear that while low-income households consume less energy, they are consuming that energy less efficiently. Secondly, this variance in residential energy efficiency comes with a social price, which can have both direct and indirect impacts on energy affordability [18]. The average low-income household has an annual energy burden, or the percentage of household income spent on energy bills, ten times that of non-low-income households, 10.4% compared to a 1.2% [17]. Energy burdens exceeding 6% are considered unaffordable [19]. The relationship between energy consumption, efficiency, and burdens cannot be understood by a simple economic explanation. Disparities in energy consumption, efficiency and burdens have clear spatial distributions in urban areas that are closely related to the demographic and socioeconomic characteristics of place, and to pervasive racial and income segregation that are commonplace in many U.S. urban areas [20–22].

Therefore, it is crucial to employ an energy justice perspective that aims to establish a more holistic understanding of the factors that perpetuate energy efficiency disparities across socioeconomic groups by exploring the hidden justice implications for rapidly transitioning technologies. Thus, this study explores the retail dynamics and distributional inequities of residential lighting technology availability and price across socioeconomic groups and store types.

1.1. Background

Socioeconomic disparities in access to energy efficient technology is a fundamental aspect of energy *in*justice. Thus, it is important to frame the relationship between energy efficient technology access and price with socioeconomic disparities in energy efficiency and energy burdens from an energy justice perspective, particularly the issue of distributional injustices. Walker and Day [18] introduce three interacting distributional issues that lead to inequalities in access to adequate levels of energy services: (1) inequalities in income; (2) inequalities in energy prices; and (3) inequalities in technology energy efficiency. Additionally, Sovacool and Dworkin [23], posit that the "simplest and most accepted" principles of their energy justice framework are availability and affordability (p. 367).

Exploring the availability and price of energy-efficient lighting, as a widely understood and basic form of residential energy consumption, may reveal broader barriers facing poorer consumers in the adoption of technology that could reduce their energy consumption and improve energy affordability. Studies have identified a number of barriers that seek to explain socioeconomic disparities in the adoption of energy-efficient technologies and subsequent disparities in energy efficiency and burdens, particularly those barriers that impede poor households from participating in beneficial programs [1,6,7,21,24–28]. Barriers may fall into a number of categories, including, market, institutional, social/cultural, behavioral, and political/regulatory [1,6,7,21,24–27]. Two of the most cited barriers to energy-efficient technology adoption are higher initial costs and information deficits [1,6,7,24,25,27,29]. Although the adoption of more efficient lighting is recognized as "low-hanging fruit," for many households, particularly the poor, the upfront cost to upgrade from an incandescent to a more energy-efficient bulb is a significant barrier [30,11]. Additionally, a lack of sufficient information, or information deficit, can impede adoption of technology and even participation in beneficial programs [1,9,21,26]. This is especially true in urban, poor neighborhoods which often lack access to technical information and knowledge about new technology [30,31]. Such barriers have been cited as reasons why CFL bulbs never successfully penetrated residential households as the accepted better lighting technology, despite their greater efficiency over incandescents; however, LEDs have had a better fate and have surpassed CFLs as the preferred energy-efficient lighting upgrade [1,5,16].

In the 1980s, consumers treated lighting as a commodity and often purchased replacement bulbs at grocery stores instead of large retail chains like Wal-Mart and Home Depot, yet grocery stores were less likely to stock energy-efficient bulbs, like CFLs, which was a barrier to early adoption [5]. However, today, little is known about the distribution of light bulb retail dynamics and the potential barriers that may prevent parity in energy-efficient lighting adoption across socioeconomic groups and store types. The type of store in which merchandise is sold can be an important predictor of its availability and price [32,33]. Furthermore, retail patterns and store types vary by neighborhood income; high-poverty neighborhoods lack large retail stores and chains which often sell products as lower prices, and are instead associated with smaller retail stores which often sell products at higher prices [37]. Additionally, a well-established body of literature on disparities in availability and price of healthy food across socioeconomic groups and story types, often referred to as food justice studies, provides a model for understanding availability and price disparities in energy-efficient lighting. Food justice studies find that retail patterns, including spatial distribution, store type, and access to personal vehicles, result in either limited availability of and access to healthier food options or paying higher prices for healthier foods at stores located in high-poverty neighborhoods [33–38].

1.2. Study objectives

Despite much interest in residential lighting upgrades, there has been little systematic empirical research documenting variations in the availability and price of light bulbs across socioeconomic groups and store types. To the authors' knowledge this is the first local-level study