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Affordability and access in focus: Metrics and tools of relative energy vulnerability

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ABSTRACT

This work will focus on the consumer's household budget to better characterize the vulnerability of low-income communities and the metrics that would be most appropriate to measure the 'affordability' of energy. The team created an Ability-to-Pay index that was used as the basis of univariate statistical correlations of 57 potential vulnerability indicators. The corresponding GIS maps offer nuanced affordability and vulnerability data for stakeholders in the power system.

1. Introduction

1.1. Background

There is no widely accepted metric for an "affordable" electricity bill in the U.S. (Staff Report, 2017a,b). Affordability for modern grid infrastructure has been defined as a system quality that "ensures system costs and needs are balanced with the ability of users to pay" (Taft and Becker-Dippmann, 2014). Therefore, this paper proposes that the threshold for "affordable" be dependent on the size of a consumer's household budget. For low-income families, more spending on energy bills translates into less spending on other expenses, such as food, health care, and education (Staff Report, 2017a,b; Norman, 2016). The work described in this paper seeks to support the national goals of ensuring affordable, universal[1] energy access by leveraging a nuanced data driven approach to develop a comprehensive framework for understanding energy affordability.

1.2. Literature review

Energy affordability has traditionally been studied from the supply side, or cost effectiveness of investments, versus the demand side, or ability of customers to pay. Established metrics of affordability have focused on cost-effectiveness of new technologies or practices and include measure such as levelized cost of energy, internal rate of return, or simple payback period (Short et al., 1995). Emerging metrics aim to measure electricity affordability from the perspective of the cost burden faced by customers. However, attempts to quantify customer affordability have been limited in a number of ways.

First, the topic of affordability, poverty, and vulnerability have been conflated. Kessides defines affordability as the "ability to purchase a necessary quantity or product or level or service without suffering undue financial hardship" (Kessides et al., 2009). The distinction between affordability and poverty is affordability varies with a customer's costs and available income whereas poverty is typically defined as income beneath a certain, absolute threshold. There are debates on which poverty threshold is most effective to use. Vulnerability is more nebulous as a method to quantify customer affordability. Andreasen and Manning define vulnerable customers as those that are "at a disadvantage in exchange relationships where the disadvantage is largely attributed to characteristics that are largely not controllable by them" (Andreasen and Manning, 1990). Lack of vulnerability metrics inhibits program design when policymakers attempt to allocate scarce resources with metrics beyond poverty. Furthermore, certain vulnerability factors may actually cause additional expense, such as disabled customers who need additional medical equipment like nebulizers or dialysis machines. Experts have found that the key challenge of quantifying affordability in the absence of defining vulnerability or relying solely on poverty thresholds is that resultant policies may target moving households above the poverty threshold rather than creating programs that could have the greatest impact on social welfare or meet the needs of those most deeply impoverished (Deller and David, 2018). For example, studies have shown that vulnerable groups, such as families with young children that received Low Income Home Energy Assistance Program

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[1] The 2017 National Security Strategy states "Attain Universal Energy Access: The United States will seek to ensure universal access to affordable, reliable energy, including highly efficient fossil fuels, nuclear, and renewables, to help reduce poverty, foster economic growth, and promote prosperity.

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(LIHEAP) to pay for energy bills had to choose between paying for food or energy bills as a coping strategy commonly referred to as "heat or eat." This situation, which the study referred to as food insecurity, poses high health risks to children from malnutrition (Frank et al., 2006).

Second, affordability measurements tend to either be linked to average expenditure or to a fixed threshold as a percentage of income. There are three ways to measure energy affordability: (1) fixed threshold of energy expenditure versus income, (2) relative measure where the threshold is set relative to the average expenditure on energy, and (3) a residual income approach measures affordability based on the idea that a household must make certain purchases beyond utilities (Kessides et al., 2009; Thalmann, 2003; Deller et al., 2015). In comparison to relative measures, fixed thresholds of energy expenditure such as energy burden, or the aggregation of a customer's net expenditure on electricity and heating over a year relative to that customer's household income, are limited because they do not take into account fuel cost fluctuations or the energy needs of the home.

Finally, Colton and other experts have argued that an energy bill (electricity and heating) is affordable if such costs do not exceed 6% of household income (Colton, 2011). This assessment is based on the assumption that utility costs should not exceed 20% of housing costs and housing costs should not exceed 30% of household income.

Colton's measure of energy affordability is based on the U.S. Department of Housing and Urban Development's (HUD) ratio of housing affordability which, for years, has assumed that a household spending more than 30% of its gross annual income on total housing costs, including principal and interest payments on the mortgage, property taxes, utilities (which consist of electricity, gas, water, and sewer), and insurance represents a housing cost burden. The HUD ratio has been criticized for a number of reasons. The ratio does not control for housing quality over time or for differences in household size and location (Bogdon and Can, 1997; Lanphear et al., 1992; Belsky et al., 2005; O'Dell et al., 2004). The ratio of housing costs may increase for a very old home that needs a roof replacement or for a large family of eight people that has higher utility bills than a family of two. In addition, it is inappropriate to use the ratio as an ability to pay because it is not based on the customer's income, assets, or debts (Hulchanski, 1995).

The reliance of the "affordability" of energy burden on housing costs is logical given that housing costs have typically been the largest household budget expense for most Americans (Stromberg and Ault, 2017). However, it is difficult to rely solely on energy burden to determine energy affordability due to trends in rising housing costs combined with stagnant wages, or lower available household budgets over time. In fact, as Fig. 1 reveals, although household expenditures have increased by nearly 14% from 2004 to 2014, median income has fallen by 13% from 2004 levels over the same time period (Pew, 2016a).

1.3. Approach

This work aimed to meet the limitation in the literature in a number of ways. First, the research team sought to locate and geospatially map vulnerable communities in the U.S. Next, the data used for the initial geospatial analysis was leveraged to address two research questions: (1) what are the most relevant metrics for energy affordability, or customer cost burden, and (2) how do these metrics differ for various socio-economic contexts?

The project meets the gaps in the literature by quantifying the importance of vulnerability metrics with the potential to improve customer affordability. This work employs a residual income approach to evaluate the validity of the commonly accepted 6% energy burden threshold. The results are flexible, because rather than choosing a single poverty threshold, such as the federal poverty level (FPL) or the area median income (AMI), this work leverages both so that the policy user can compare results for their own purpose. The results are robust because the analysis was conducted on 116.9 million U.S. households in 72,760 Census Tracts.[2]

Policymakers and other stakeholders have increasingly leveraged geospatial mapping tools in a variety of sectors over the last two decades as compututation power has increased and geographic information systems (GIS) have allowed for more widespread, complex, and comprehensive analyses than previously. Advances have made it possible to enhance strategic and organizational decisions. In healthcare, GIS has made it possible to model and map the spread of disease, to analyze and predict future disease risks, and to undertake location/allocation analysis of the distribution of services and resources (Lyseen et al., 2014). In energy, GIS has increasingly been used to develop, site, and improve the economic and social benefits of renewable energy resources, such as wind, solar, geothermal, and biomass (Domínguez and Amador, 2007; Jordão et al., 2010). In addition, states such as California are using GIS to map energy burden and other metrics of affordability.[3] This work makes illuminating GIS tools and data available to policymakers and stakeholders at the national level, with granularity at the census tract.

1.4. Scope limitations

This study developed a proxy for available budget based on income and housing costs, acknowledging that future work could include other important available budget factors. Specifically, the next largest household budget expense tends to be transportation costs, particularly in suburban or rural areas. In addition, the wealth gap, based not only on income, but on household assets minus debt, may uncover a more accurate and striking example of the financial strain on households, particularly households with children because the bottom 50% of American families with children had a net worth of -$233 in 2013 (Gibson-Davis and Percheski, 2018). In 2014, lower-income households were on average $2300 in debt so asset-based affordability measurements would need to be adjusted accordingly (Pew, 2016).

2. Ability-to-Pay index

To quantify which metrics for energy affordability or vulnerability are most relevant, the research team created a national Ability-to-Pay index. The ability to pay of a household is defined as income minus housing costs,[4] which serves as a proxy for a low-income customer's available household budget.

2.1. Definition of low and moderate income

This work relies on two common definitions of low and moderate income (LMI) communities: (1) federal poverty level (FPL) and (2) area median income (AMI). Both definitions break down U.S. households by size and name those buckets of households as extremely low, very low, etc.[5] For FPL, definitions of LMI is derived from the U.S. Department of

[2] Census Tracts are small, relatively permanent statistical subdivisions of a county or equivalent entity that are updated by local participants prior to each decennial census as part of the Census Bureau's Participant Statistical Areas Program. Census tracts generally have a population size between 1,200 and 8,000 people, with an optimum size of 4,000 people.

[3] The California Energy Commission makes a number of energy-related maps available here: http://www.energy.ca.gov/maps/; in addition, the Office of Environmental Health Hazard Assessment (OEHHA) make pollution and affordability maps available via Cal Enviroscreen: https://oehha.ca.gov/calenviroscreen.

[4] Monthly housing costs are the sum of payments for mortgages, rent, real estate taxes; fire, hazard, and flood insurance on the property; utilities (electricity, gas, and water and sewer); and fuels (oil, coal, kerosene, wood, etc.).

[5] The FPL and AMI baseline numbers (i.e. < 100% of FPL or < 30% of AMI) for each income limit are based off the 4-person family size. For households with larger or smaller sizes, percentage adjustments are made to the income

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