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Effective and persistent changes in household energy-saving behaviors: Evidence from post-tsunami Japan

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HIGHLIGHTS

- Some households' adaptations to electricity shortage can be new efficient habits.
- The electricity shortage in Japan was used as a natural experiment.
- Some behaviors contributed to 2–4% electricity savings and persisted for two years.
- Behaviors requiring frequency and discomfort cannot be effective or persistent.
- Lowering the electricity-usage level of appliances might be a promising behavior.

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ABSTRACT

This paper focuses on households' development of new energy-efficient habits as demonstrated in the context of a major electricity shortfall event. Energy conservation policies should encourage households to take measures that are actually effective in reducing energy consumption and that can be sustained over long periods of time. Few studies, however, have empirically examined what types of energy-saving measures are actually effective and persistent. The electricity shortages following the 2011 Great East Japan earthquake, tsunami, and nuclear disaster provided an opportunity to examine this question. A web survey of households in Japan was implemented to obtain data on metered electricity use in the summers of 2010–2013, household behaviors for electricity savings, and household socioeconomic attributes. Regression analysis was conducted to explain the effectiveness and persistence of energy saving behaviors. Results indicate that most households took several electricity-saving measures after the disaster to adapt to the electricity shortage. Certain types of measures led to 2–4% savings in electricity consumption (per measure) and persisted for two years. The effective and persistent electricity-saving measures tended to be those that did not require either frequent efforts or considerable discomfort. Findings suggest that electricity-saving behaviors requiring infrequent effort and little discomfort can become engrained as new habits or lifestyles. In particular, one promising measure may be to lower the electricity-usage settings of appliances.

1. Introduction

Energy conservation is an important issue for the sustainability of our societies. Global energy demand has steadily increased by approximately threefold in the last 50 years [1], contributing to concerns regarding climate change and energy security. Among the various types of energy, electricity requires special attention because electricity consumption is projected to increase by 80% from 2008 to 2035 and its share of total energy consumption is estimated to grow from 17% to 25% during the same period [2]. The residential sector represents an important part of electricity consumption in the world. U.S. Energy Information Administration [3] estimated that the residential sector's share of world electricity use increases from 28% in 2010 to 31% in 2040. Thus, household electricity consumption can be an important target for energy conservation policies.

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Focusing on household energy consumption behavior, this paper investigates the opportunities and lessons that can be gained from sudden energy supply shocks, specifically, electricity shortfalls in natural disasters. Most energy conservation programs and policies focus on energy consumption during normal circumstances. Routine behaviors are difficult to change, however, and some policies effect reductions in energy consumption by targeting opportunities for change, such as providing incentives for energy-efficient options when consumers purchase new household appliances. This study is based on the premise that electricity shortfalls in events such as natural disasters also prompt behavioral changes and may reveal new lessons and opportunities for energy conservation policies.

Studies have found that when forced by sudden electricity shortages, consumers are capable of substantially reducing energy consumption through emergency measures. IEA [4,5] reported on several events where adapting to electricity shortages led to sizable short-term electricity savings, including up to 20% in Brazil 2001, 25% in USA (Alaska), 20% in South Africa, and 14% in USA (California). Generally, such reductions may be temporary and energy consumption may be back at the original levels after the shortfall is resolved. However, there is the possibility that some part of the conservation effect can be maintained even after the crisis. For example, households can learn about the merits of electricity-saving behaviors through the experience of engaging in them, which might change households' habits or lifestyles to become more electricity-efficient. Or, the electricity shortfall might motivate households to replace old appliances with more electricity-efficient ones. In fact, Lutzenhiser et al. [6] and Leighty and Meier [7] found that a majority of households adopted conservation measures during electricity crises in California and Alaska, respectively, and that many of these measures persisted for a year afterwards. They did not, however, examine the effectiveness or longer-term persistence of the conservation measures.

Understanding the effectiveness and persistence of energy conservation behaviors is central to developing effective energy conservation policies. In broad terms, policy makers' actions can reduce a household's energy use through the following sequence of actions and effects: (1) They implement a policy intervention; (2) the intervention increases the household's motivation to conserve energy; (3) the increased motivation makes the household adopt some energy-saving behaviors; (4) each type of energy-saving behavior contributes to reducing energy consumption; and (5) the household's metered energy use is reduced. Numerous studies have investigated the direct relationship between steps (1) and (5). They have focused on the effectiveness of such interventions as home audits, labeling, mass media campaigns, commitments, goal setting, rewards, and feedback (see [8–11] for recent reviews). With advances in information and communication technologies, issues related to smart meters or eco-feedback systems [12–17], peer network effects [18–21], network synergy effect [22–24], and human-based energy retrofit [25] have been attracting greater attention. These studies reveal to what extent and how such interventions contribute to households' energy reduction. Numerous other studies investigate the psychological or socio-economic mechanisms linking steps (1), (2), and (3). They aim to identify the underlying factors influencing household energy conservation (see [26–28] for recent reviews). Determinants of energy conservation may be associated with psychological factors [29–33] or socio-economic attributes such as income and household size [13,15,34–36]. In contrast, previous studies have paid little attention to step (4)—the effectiveness of energy-saving behaviors—which limits our understanding of the whole process from policy intervention to a household reducing its energy use.

Energy-saving behaviors are often recommended from a technological perspective. However, some energy-saving behaviors may have little or negligible effects on electricity savings in reality even if they are expected to achieve a large reduction in energy use from technological perspectives [37]. This is because technological and behavioral factors are closely interwoven, and both must be considered in regards to energy conservation [38]. The intensity and frequency of energy-saving measures might be too low to significantly reduce consumption. For example, if households unplug an electrical appliance once a week or increase the thermostat setting of their air conditioners by just 0.5 °C, they may achieve little in energy savings. Even if households take such behaviors more often and with more intensity to have a significant saving effect immediately after the intervention, this effect might diminish over time if the households cannot maintain their initial measures in terms of frequency or intensity in the long run. As another example, replacing electrical appliances with more efficient models may cause a "rebound effect," whereby people pay less attention to electricity costs and increase the frequency of using the new appliances because they are energy efficient [39,40]. Therefore, to identify effective behaviors, it is necessary to empirically examine the relationship between energy-saving behaviors and actual energy use reduction by using field data, especially metered data.

Only a few studies have empirically examined the extent to which energy-saving behaviors contribute to energy use reduction. Lopes et al. [11] reviewed papers published in scientific journals during the 21st century and found just four studies related to this topic [12,41–43]. In particular, Ueno et al. [12] installed an online information system for nine households and monitored their energy-saving behavior and its effects. Abrahamse et al. [41] evaluated the effect of energy-saving behavior by using a tool developed by environmental scientists. de Almeida et al. [42] estimated the energy-saving potential of substituting technology best practices for current practices. Ouyang and Hokao [43] examined the relationship between energy use and an index of energy-saving behaviors. None of these studies statistically demonstrated which energy-saving behaviors are effective by using metered electricity use data. Thus, they cannot specify with statistical significance what kinds of electricity-saving behaviors are actually effective in reducing electricity use.

To address this gap, the current study aims to empirically examine the extent to which specific energy-saving behaviors actually contributed towards reducing energy consumption. In Japan, the electricity shortages following the tragic earthquake, tsunami, and nuclear disaster on March 11, 2011 (the 3/11 disaster) provided an opportunity to estimate the effects of electricity-saving behaviors because many households nationwide implemented such behaviors to avoid blackouts. Taking advantage of this opportunity, we implemented a questionnaire survey in which households were asked about their metered electricity consumption and energy-saving behaviors. Specifically, the study addressed the following three research questions:

1. What electricity-saving behaviors were undertaken by households to adapt to the electricity shortages caused by the 3/11 disaster?
2. How much did electricity-saving behaviors contribute to electricity savings?
3. Did households' behaviors and their effects on electricity savings persist?

A few studies have investigated household adaptations to temporary shortfalls in electricity supply. Lutzenhiser et al. [6], Leighty and Meier [7], Nishio and Ofuji [44,45], and Kimura and Nishio [46] investigated how households responded to the electricity supply crises in California, Alaska, and Japan, respectively. They found that