



Promoting acceptance of direct load control programs in the United States: Financial incentive versus control option



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ABSTRACT

Residential direct load control (DLC) is an important type of demand response designed to reduce electricity consumption during peak hours through utility companies' control over the operation of certain household appliances. Despite many benefits of DLC, customers' concern for losing control has been hindering its adoption. This study aims to investigate U.S. residents' willingness to accept two popular A/C-related DLC programs in summertime with or without financial incentives or an override option, and to identify the socio-demographic characteristics associated with the decisions. Results of an online survey among 1482 U.S. residents indicate half of the participants are willing to accept DLC without any conditions; however, both an incentive of \$30 and an override option boost acceptance rates. Importantly, the override option is more effective than the financial incentive. Residents who are younger, Democrats, non-Whites, have higher education levels, live in larger dwellings, and live with more people are more likely to adopt DLC than their counterparts. Residents who are older, Republicans, Whites, homeowners, and live in a house preferred an override option to financial incentives more often. The implications were discussed in terms of improving power system stability through better DLC program design and implementation.

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1. Introduction

To increase the efficiency of energy utilization and the penetration of renewable energies, the need for power system flexibility is rising. Demand response (DR), one of the most important and beneficial flexibility options [1], has been widely implemented by utility companies and other agencies globally. DR is defined as changes in electric usage from normal consumption patterns in response to changes in electricity prices or incentive payments designed to limit electricity use when the wholesale market price is high, or when power system reliability is jeopardized (mostly, during peak hours) [2]. In the United States (U.S.), DR provided over 30 gigawatts (GW) of peak reduction capability in 2015 [3]. This study aims to investigate public acceptance of a specific type of DR program among U.S. residents: direct load control (DLC). Unlike programs that rely on price signals, DLC programs usually involve

utilities requesting operational control over customers' specific household appliances (such as air conditioners or electric hot water system) for a limited time period, with some financial incentives provided. See Ref. [4] for an overview of different types of DR programs. This study chooses to solely focus on DLC programs because they allow for a more accurate estimate of and more flexible control over reducible loads during peak hours. Additionally, DLC programs are gaining greater potential in reducing peak hour loads with the recently increased use of automatic control devices or smart appliances at home [5,6].

Despite the clear benefits of DLC and other DR programs, participation rates have not been satisfactory. As a result, the industry and researchers are striving to find out what factors, especially customer characteristics, affect public acceptance of DR, including the DLC programs. Researchers found that, although the public consider DLC programs as acceptable in principle, there is at

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least one major barrier – the sense of losing control [7], because every DLC program entails giving up some control over a household appliance from residents' perspective. We believe this may particularly be a problem in the U.S., where customers' freedom to make decisions is highly valued [8,9].

The goal of our study is threefold: (1) to investigate customers' willingness to accept certain popular DLC programs during peak hours in the U.S.; (2) to compare the effectiveness of a financial incentive versus that of simply providing an override option, which is a way to restore some control within customers, in boosting the acceptance rate; (3) to explore a set of socio-demographic and dwelling features (e.g., age, income, education, ethnicity, political orientation, household size, homeownership, dwelling size, and dwelling type) as the potential factors influencing a resident's decision to accept or reject the DLC programs, as well as one's preference for a financial incentive or override. This study takes an important step towards an effective estimation of controllable loads during peak hours based on customers' acceptance in relation to socio-demographics, household and dwelling features, and specific incentive design. The findings are expected to contribute to designing better DLC programs across different customer subgroups.

1.1. DLC programs and financial incentives

DLC programs have been, in fact, one of the most popular type of DR programs in the U.S. since their inception nearly 50 years ago [10]. As of 2011, DLC programs had more than 5.5 million U.S. customers contributing more than 4500 MW in peak demand reduction, and the numbers are still growing [3]. As of 2012, more than 200 utilities across the U.S. were offering some type of DLC program for residential customers [2].

After reviewing the majority of popular DLC programs across the U.S. market, we built our research scenarios based on the two most popular types. Specifically, one type involves the installation of an automatic switch on a customer's A/C unit, which automatically turns the unit off during times of peak demand – typically for 5–30 minutes. The other type involves the installation of a smart thermostat, which automatically adjusts temperatures during peak hours, thereby lessening the demand in the power system.

Despite the popularity of these programs, the determination of the incentive amount is often arbitrary. Utility companies across the U.S. are offering anywhere from \$25 to \$100 per year, \$5 to \$20 per month, or 3 cents to \$1 per kWh saved, to encourage participation in DLC programs. Additionally, a few programs offer gift cards or thank-you checks instead of credits or discounts on electricity bills (e.g., 'Control Your A/C Remotely with a Smart Thermostat' and 'CoolNYC' programs from the investor-owned energy company, Con Edison). Interestingly, however, financial incentives may not be the sole determinant because no relationship was found between incentive amount and participation rate in DLC programs [11,12]. This study investigates the effectiveness of financial incentives by examining whether an incentive of \$30 per summer (3 months in total) would increase the acceptance rates of automatic switch and smart thermostat programs. Based on the financial incentives currently offered by the majority of U.S. utility companies, \$30 per summer seemed to be a reasonable amount.

1.2. Issue of losing control

The concept of control has been widely studied in the areas of building design and adoption of home energy management technologies [13–15]. Control includes objective (actual) control and subjective (perceived) control [16]. Perceived control is defined as a person's belief that he or she is capable of obtaining desired

outcomes, avoiding undesired outcomes, and achieving goals [17]. It is related to Bandura's (1991) conceptualization of self-efficacy, i.e., "people's beliefs about their capabilities to exercise control over their own level of functioning and over events that affect their lives" ([18], p. 257). One study [19] found significant correlations between perceived control and building occupants' comfort and health, and another study [20] echoes this research, stating that perceived control can be extremely important in increasing occupant satisfaction. Another recent study [21] defined thermo-specific self-efficacy as occupant's "expectations towards their competences to execute desired operations improving their perception of the thermal environment successfully" (p. 194) and demonstrated its impact on thermal comfort.

As mentioned earlier, the study of control is especially relevant to understanding public acceptance of DLC programs. A recent study using both interview and survey methodologies showed that almost all respondents in Great Britain associated DLC with losing some level of control, and the sense of losing control contributed to unwillingness to accept DLC programs [22]. Despite few empirical studies relating control to DR acceptance, the importance of customer control has been widely demonstrated in the study of smart meter acceptance – a technology that directly enables many DR programs, including DLC programs [23,24]. Meanwhile, perceived control was found to be related to energy conservation intention [25], the intention to purchase green electricity [26], and engagement in pro-environmental behaviors [27,28], which may be driven by the same motivations as those influencing DLC acceptance.

Based on the literature, it is important to grant customers some level of control or restore some sense of control to keep them satisfied and accepting of DR programs. However, in a review of about 80 DLC programs currently running in the U.S., we found that many programs focus on financial incentives as opposed to offering control options. For example, many DLC programs, such as the Summer Saver Program from San Diego Gas & Electric, only allowed customers to change the amount of time their AC unit was cycled off. In some programs, if customers are unhappy with the temperatures, they must opt out of the DR program completely, as required by the TXU Energy iThermostat program in Texas. On the other hand, some programs did allude to providing customers some level of control, stating that customers can manually opt out at any time by adjusting their thermostat (e.g., Austin Energy Power Partner Thermostats program or the Reliant Energy Degrees of Difference with Nest program). However, only two programs of the nearly 80 in our review stated explicitly that customers were 'in control' over the decision to override the DLC thermostat settings at any time (e.g., Pacific Gas & Electric's SmartAC program and the Consolidated Edison Company of New York's Smart Thermostat program).

To determine whether financial incentive or control option is more effective in influencing DLC acceptance, we analyze how typical U.S. residents would respond to a \$30 incentive per summer versus the option to override the automatic settings at any time. More importantly, we investigate how socio-demographic and dwelling characteristics related to residents' responses to the financial incentive and the control option.

1.3. DLC acceptance and socio-demographics

Socio-demographics refer to a combination of demographic and sociological factors that describe a population, typically including age, gender, ethnicity, education level, income level, occupation, marital status, household size (number of people in a household), homeownership, residence, etc. [29]. In studies of residential energy consumption, researchers often expand this variable set to

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