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A Behavioral Science Perspective on Consumers' Engagement With Demand Response Programs

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Residential electricity demand response programs can play a substantial role in facilitating a sustainable energy transition, but it is important to examine the consumer behaviors necessary to harness this potential. We outline three behavioral dimensions relevant for effective demand response, namely investment, participation, and actual response. We discuss the factors that underpin them as well as possible behavioral interventions to promote demand response behaviors.

I. Introduction

To mitigate the effects of climate change, countries worldwide are pursuing a transition towards sustainable energy systems (IPCC, 2018). As renewables, such as decentralized photovoltaic generation, gradually replace conventional power plants, this leads to increasing fluctuations in electricity supply and misalignments with local demand due to (local) weather conditions. In consequence, large investments in backup capacity, storage, and grid improvements are necessary to balance supply and demand (Klaassen et al., 2017). However, a large portion of the overall capacity is only used during very limited times, suggesting that economic efficiency can be greatly improved if electricity demand is better matched to the available supply (Strbac, 2008). Demand response (DR) programs aim to change consumption patterns, for example, by shifting electricity usage to match supply (see Kim & Shcherbakova, 2011). This allows a more efficient grid and can increase the share of renewable energy generation in the system. Modeling studies show a great potential of DR across sectors, including the residential sector (Gils, 2014).

Yet, to harness its potential, consumers[1] need to actively engage in DR programs (Parrish et al., 2019). For example, modeling studies often assume a certain level of participation in DR programs or examine the load shifting capability of certain household appliances, but it is uncertain whether residential consumers would take the behavioral steps to harness this potential (Schuitema et al., 2017). Recent studies have aimed to close this gap by examining certain behavioral aspects underlying DR, such as people's participation in dynamic tariffs (e.g., Nicolson et al., 2018; Parrish et al., 2020; Scharnhorst et al., 2021). However, effective DR requires consumers to engage consistently in a set of different behaviors beyond mere participation.

In this paper, we adopt the framework on sustainable behavior and the energy transition proposed by Steg et al. (2015) to examine the role of consumers in DR. Following the framework's proposed steps, we first examine the behaviors and decisions necessary for DR to be impactful. Building on earlier research, we identify three distinct behavioral dimensions that are particularly relevant in this context, namely investments in enhancing technologies, participation in DR programs, and actual response in terms of reducing or shifting electric loads. Second, we review the barriers and drivers of these three behavioral dimensions by drawing from the wider literature on sustainable energy behavior and connecting it to the context of DR. Third, based on a review of studies on consumer engagement in DR, we discuss how behavioral interventions can target relevant underlying factors to effectively promote DR behaviors.

II. Demand response and dimensions of consumer behavior

DR programs aim to increase flexibility on the demand side of electricity, typically by providing information or financial incentives to consumers, sometimes with aided automation (Parrish et al., 2019). They can be based on non-monetary incentives, such as environmental messaging (Gyamfi & Krumdieck, 2011), but typically rely on financial incentives.

Specifically, price-based programs use dynamic tariffs (e.g., time-of-use pricing) to incentivize flexibility by in-

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1 We use the term *consumers* throughout this manuscript, but acknowledge that consumers increasingly become *prosumers* who both produce and consume electricity.

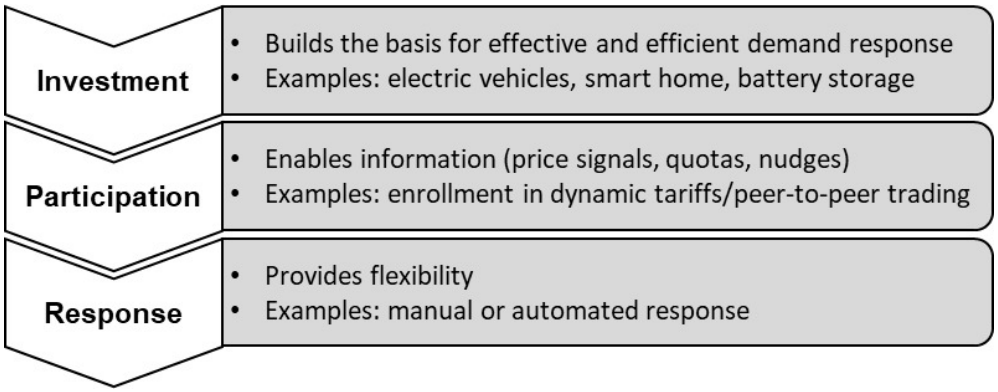

Figure 1. Behavioral dimensions relevant to the realization of demand response potential

creasing/decreasing the cost of electricity at certain times (Nilsson et al., 2018). Incentive-based programs provide rewards or discounts to consumers in exchange for load reductions. While consumers can react to DR programs' signals by manually shifting their electricity usage, studies suggest the level of response is greater if response is automated, for example through smart appliances or direct load control by utilities (Faruqui & Sergici, 2010). From a behavioral science perspective, this implies that consumers need to engage in a set of different types of behavior in order to unfold the potential of DR. Building on earlier work (e.g., EPRI, 2012; Schuitema et al., 2017), we propose three distinct behavioral dimensions relevant for effective DR, namely investments, participation, and actual response (Figure 1).

First, consumers need to have the technical capability to shift loads effectively and efficiently. This requires the adoption of relevant technologies, which entails that consumers decide to invest in them (cf. Schuitema et al., 2017). While households can theoretically provide flexibility in their electricity consumption without any technology investments, this potential is often limited. For example, investing in a heat pump or an electric vehicle allows greater demand response than common household appliances, such as dishwashers (Wang et al., 2014), particularly if complemented by automated technologies (e.g., smart home). DR capabilities can also be enhanced by investments in battery storages (Mackey et al., 2013). Notably, investments in these technologies nowadays are mostly unrelated to consumers' intention to shift loads, although they can play an important role in facilitating both a more effective (i.e., higher loads) and efficient (e.g., automated) response. Nevertheless, the adoption of DR technologies on its own does not necessarily lead to an effective response, but enables it, given that consumers appropriately engage with these technologies (Peters et al., 2018).

Second, consumers need to participate in DR programs, such as enrolling in a dynamic tariff. This enables consumers to receive signals (e.g., financial incentives) necessary for an actual response (see Lehmann et al., 2019). For example, consumers enrolled in a time-of-use tariff with surcharges at certain times of the day are expected to reduce or shift their consumption due to the price signal (Kim & Shcherbakova, 2011). However, enrolling in a program or tariff is a one-time decision that subsequently requires a response to the signals provided by the program.

Thus, third, consumers need to actually reduce or shift their electricity consumption manually or via automation. Manual shifting requires a continuous active response, which is likely effortful and therefore limited (Schuitema et al., 2017). Automation can mitigate these limitations and thus facilitate a greater and more predictable demand response. However, automation, too, needs to be accepted and implemented by consumers (e.g., setting of initial preferences).

Notably, the three behavioral dimensions of DR differ in their characteristics. Investment decisions reflect a one-time behavior with a long-term focus and high financial stakes, whereas a manual response reflects a consistent change of habitual behaviors (cf. Karlin et al., 2014). This point is important because a body of psychological research suggests that different behavioral dimensions may be determined by different underlying barriers and motivations (e.g., Sloot, Kutlaca, et al., 2018; Stern, 2000) and thus require different behavioral interventions (Schultz, 2014).

III. Drivers and barriers of demand response

Interventions to promote DR are most effective when they target relevant barriers and motivations underlying these behaviors. A large body of literature has studied the factors related to different energy behaviors (see e.g., Steg et al., 2015, for an overview). It follows from our discussion of the three behavioral dimensions underlying DR that different drivers and barriers are focal in explaining these dimensions (see Table 1 for an overview of selected factors).

Financial incentives and costs play a major role in most DR programs. Costs are often a barrier to the adoption of expensive technologies (e.g., Steg et al., 2018), such as investments in electric heating technologies (Su et al., 2019), and household income is positively related to technology adoption (Kastner & Stern, 2015). Dynamic tariffs rely on financial costs or savings as the main incentive, assuming that consumers rationally shift their energy consumption accordingly (cf. Nilsson et al., 2018). Yet, consumers often do not act rationally and the subjective perception of risks, costs, and benefits can influence behaviors, such as technology investment decisions (Kastner & Stern, 2015). Addi-

Table 1. Overview of behaviors, drivers, barriers, and possible interventions

Behavior dimension	Drivers and barriers	Possible interventions
Investment	Financial costs (initial purchasing expenses)	Reducing financial barriers (providing incentives)
	Perceived benefits and risks	Providing information (e.g., about benefits) via trusted sources
	Visibility of technologies	Social influence strategies
	Trusted information from relevant and influential stakeholders	Community initiatives/block leaders
Participation	Environmental motivations	Emphasizing environmental benefits
	Innovativeness	
	Low consumer awareness	Reducing complexity of programs or tariffs
	Insufficient information	Defaults
		Opt-out nudges
Response	Environmental motivations	Tailored and timely feedback (e.g., real-time feedback on consumption)
	Effort	Commitments
	Comfort	Use of automation with defaults
	Habits	Implementation intentions

Note. We group drivers and barriers together in the table since many of these factors can act in both ways (e.g., visibility of technology can be a barrier to investment decisions when perceived as low, but as a driver when perceived as high)

tionally, changes to everyday energy behaviors may be inhibited because they are perceived as effortful and having negative effects on one's comfort (Steg et al., 2018). In contrast to one-time investment decisions, actual demand response often requires changes to set routines and habits that happen mostly unconsciously (Verplanken & Whitmarsh, 2021). Similarly, many consumers have a low awareness of the electricity tariff in which they are enrolled (Layer et al., 2017). Nevertheless, certain general motivations can act as drivers of DR behaviors. Specifically, many people are motivated to protect the environment and strive to behave consistently with their pro-environmental motivation (e.g., Van der Werff et al., 2013). Such intrinsic motivations are important because they can promote behavior change despite certain efforts or costs (Dietz, 2015). Moreover, individuals engaging in DR behavior based on their intrinsic pro-environmental motivation are more likely to consistently engage in a set of related behaviors, such as using new DR technologies in appropriate ways (Peters et al., 2018).

Other personal motivations may play a role too. For example, consumers who see themselves as more innovative may adopt new technologies or participate in novel DR programs more readily (Wolske et al., 2017). Finally, consumers are influenced by others around them, especially by people or groups who are important to them (Jans et al., 2018). Research has shown that consumers are more likely to adopt new technologies (e.g., photovoltaic systems) in areas with a visible adoption rate (Bollinger & Gillingham, 2012). They are also more susceptible to information (e.g., about benefits of a technology) from trusted sources, such as people in their own social network, neighborhood, or groups they belong to (e.g., Scheller et al., 2020).

IV. Behavioral interventions to promote demand response among consumers

Behavioral interventions can be defined as initiatives to influence a behavior, for example by providing relevant information or changing the environment in which a decision is made (Nielsen et al., 2020). As intervention types are diverse, we propose several possible interventions to target each of the three behavioral dimensions outlined in Figure 1. First, technology investments are inhibited by high cost barriers. Financial incentive interventions can reduce these barriers and thus promote the adoption of technologies such as electric vehicles (Sierzchula et al., 2014) or photovoltaic systems (Sarzynski et al., 2012). Yet, people in a late stage of the decision process (i.e., close to investing) may be less sensitive to financial incentives and costs and may need to be additionally motivated by other factors (Langbroek et al., 2016). As many people are not familiar with DR technologies, providing specific and tailored information about their benefits can be valuable, particularly if this information comes from trusted sources (Kastner & Matthies, 2016). Social influence strategies and community approaches may be particularly effective, as they can signal that others value and endorse certain behaviors (Abrahamse & Steg, 2013). For example, studies indicate that volunteers in one's network (so-called block leaders) or membership in a community energy initiative can motivate behaviors, such as adopting photovoltaic systems (Sloot, Jans, et al., 2018).

Second, in contrast to investments, participation in a DR program has low costs but often requires a change in set routines (e.g., actively changing existing electricity tariffs). Compared to investments and actual response, less re-

search has studied the factors and interventions related to consumers' initial enrolment in a program. Some research suggests that DR programs (e.g., dynamic tariffs) are often perceived as complex, suggesting that reducing their complexity may promote participation (Layer et al., 2017; Srivastava et al., 2020). Yet, a main difficulty pertains to encouraging consumers' switching to a new type of program or tariff from their current one, as active voluntary participation in dynamic tariffs is generally low (Parrish et al., 2019). Nudges, such as default tariffs in online portals or opt-out enrolments, may provide effective solutions to this problem, as they can take the need for an active decision away from the consumer (Ebeling & Lotz, 2015; Nicolson et al., 2018). While automatic opt-out enrolment still gives consumers the ability to not participate, enrolment rates typically remain high (Parrish et al., 2019), indicating that consumers often accept participation in DR programs. Interestingly, some research found that people were more willing to enroll in a DR program when environmental benefits were emphasized than when financial benefits, or both, were emphasized (Schwartz et al., 2015). In other studies, financial reasons did not play a key role for participation in peer-to-peer electricity trading networks (Hackbarth & Löbbe, 2020) or in community energy initiatives (Sloot et al., 2019). Thus, emphasizing financial benefits of participation should be viewed with caution.

Third, an effective demand response often requires changes to habitual everyday behaviors. Most DR programs rely on financial costs, rewards, or savings. However, findings on the effectiveness of such financial incentives are mixed, with some evidence suggesting a relationship between financial incentives and the degree of response and other evidence not finding this relationship (e.g., Faruqui & Sergici, 2011; Gyamfi et al., 2013; Srivastava et al., 2018). Another problem is that consumers typically do not immediately experience the consequences of their response, as today's billing is temporally separated from the shifting of loads. Providing tailored and immediate (e.g., real-time) feedback (e.g., via in-home displays or apps) can overcome this barrier and facilitate demand response (Sintov & Schultz, 2015). A large body of research has shown that feedback can be effective in reducing overall electricity consumption (Delmas et al., 2013; Karlin et al., 2015). Research also suggests that feedback is more effective in combination with other interventions, such as goal setting (Karlin et al., 2015). To overcome the effort of changing habitual energy behaviors, strategies, such as commitment making and forming implementation intentions (if-then plans), can also be effective (Kurz et al., 2015; Van der Werff et al., 2019). Yet, given the limitations of these approaches in consistently changing everyday behaviors, DR can likely be enhanced by using automation instead of relying on a manual response (Sintov & Schultz, 2015). However, automation via programmable smart appliances or direct load control requires that consumers accept to give up some control over their energy use. Override options may alleviate these concerns (Schuitema et al., 2017). Nevertheless, it is important that consumers are aided in setting (initial) preferences for an automated response to be effective. For example, Gyamfi et al. (2013) discuss a study on programmable thermostats in which not even half of the 35,000 monitored households had switched the thermostats into the appropriate program mode that allowed for automated temperature control. Given the benefits of automation technologies, future research into consumer adoption and interaction with these technologies is important.

V. Conclusion

To conclude, DR programs require consumers to consistently engage in a set of different behaviors to unfold their potential. Consistency is vital to avoid potential rebound effects with negative environmental or energy system effects (cf. Khan et al., 2016). Different drivers and barriers underpin these behaviors, and interventions to promote DR programs should thus be carefully designed to target these specific factors. While considerations of financial barriers and incentives are important, they need to be carefully designed and tested (see e.g., Frederiks et al., 2015), and other non-financial interventions can be implemented to promote demand response behaviors. Automation technologies should receive special attention, as they seem to have great potential for effective and efficient demand response, despite some behavioral challenges. Moreover, synergies exist between the different behavioral dimensions, since program participation generally yields higher benefits in combination with relevant technology investments, and vice versa. Ideally, practitioners should aim to link different strategies in order to consistently promote technology investments, program participation, and actual response and thus maximize DR programs' impact.

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