The Effect of Low-carbon Technology Diffusion on the Adoption of Electricity Tariffs for Demand Response

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Overview

To decarbonize the energy system, the transport and heating sectors are increasingly electrified. However, electric vehicles and heat pumps challenge distribution networks because they increase the already disproportionally high peak demand of households and might result in spatial clusters of high loads. To avoid environmental and financial costs from the installation of additional peak capacity and network reinforcement, demand-side solutions are increasingly required. Electricity consumers can contribute to solve this challenge by shifting load from peak times to hours of lower electricity demand. Therefore, the consideration of socio-technical aspects is an important factor for the energy transition and thus, an area of increasing policy interest.

While many authors emphasize the potential of load shifting, models typically overestimate households' general potential for demand response. It is unclear how different tariffs could support load shifting of different low-carbon technologies, such as electric vehicles and heat pumps. While many pilot projects tested static time-of-use tariffs, there is limited evidence for the effect of more complicated tariff designs. The literature about tariff options for demand response emphasizes that multidisciplinary studies are missing to gain further knowledge about technical, economic, and social aspects.

This study addresses these gaps by investigating and comparing the attractiveness of different electricity tariffs from both a system and a household perspective in Germany. More specifically, this study investigates how different stakeholders, mainly electricity retailers, network operators, and households, perceive different tariffs considering two main aspects. First, how the automation levels influence preferences for tariffs and second, how the diffusion of low-carbon technologies influences preferences for tariffs.

Methods

The method consists of two parts. First, we conducted 15 semi-structured stakeholder interviews and second, we developed a household survey. The insights from stakeholders in the German electricity system help to understand the potential benefits and existing barriers of different tariff designs from a system perspective. We interviewed different actors in the German electricity system, such as electricity retailers and distribution network operators, to evaluate stakeholders' perceptions of time-varying tariffs. This purposive sampling strategy, which is common for expert interviews, did not aim to achieve statistical representativeness but to cover a wide geographical area of Germany, and a wide spectrum in terms of company size.

As trials cannot provide insights into people's tariff choices, an online survey was developed to investigate households' decision-criteria for choosing tariffs and the influence of automation levels and technology diffusion on tariff preferences. Despite the likely automatic reaction of technologies to price signals, people influence the use of technologies by using override options or setting boundary conditions, such as temperature settings for heat pumps or the minimum state of charge for electric vehicles. Four levels of automation (manual, semi-automatic, automatic with exception, fully automatic) have been included and combined with five tariffs. The included tariff options in the survey were identified from the conducted expert interviews. Out of the five tariffs included in the survey, three were time-varying tariffs to represent the degree of price variations: static, dynamic and real-time pricing. The remaining two tariffs were included to compare the attractiveness of time-varying tariffs to other innovative options: an electricity saving tariff and a high-load tariff. Concerning low-carbon technologies, the survey focused

on electric vehicles, heat pumps, stationary storage and PV installations. The survey also included questions about preferred price differences between tariff time periods to assess the respondents' risk aversion.

Results

The stakeholder interviews show that although flexibility can support distribution network operations, there are large geographical differences, depending on network characteristics and distributed generation. Experts in the energy system assume that more complicated time-varying tariffs than two-phase static time-varying tariffs are neither attractive for households nor for the electricity system. In addition, social issues might arise because only households that can afford smart meters can use the benefits of more complicated time-varying tariffs. Overall, distribution network operators prefer direct load control with automated reaction, which provides higher predictability and reliability than reactions to price signals.

The household survey reveals that saving money is the most important decision criterion when choosing tariffs and automation increases the attractiveness of all tested tariff types. People with smart meters are significantly more attracted to any tariff with automation. Concerning the influence of low-carbon technologies, "Technology" is the most significant influencing factor for choosing tariffs. Electric vehicles and stationary storage are the determining technologies for choosing time-varying tariffs. Households choosing a higher price difference between time periods are three times as likely to choose a time-varying tariff, compared with households that prefer the lower price difference. This result confirms that risk-averse people are less likely to find time-varying tariffs attractive.

Conclusions

According to this study, the high-load tariff is the most attractive one combined with automation with exceptions. Therefore, households prefer to be able to override the automatic reaction of technologies to price signals in order to provide flexibility. At the same time, increased automation supports the attractiveness of all tariff types because it is more convenient. Time-varying tariffs seem particularly attractive when combined with the diffusion of electric vehicles and stationary storage. Future research should investigate whether, when and how often the override option for the automation is actually used to evaluate the reliability of flexibility provision.