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DYNAMIC ELECTRICITY TARIFFS - DESIGNING REASONABLE PRICING SCHEMES FOR PRIVATE HOUSEHOLDS IN GERMANY

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Overview

Renewable energy sources are essential for a low-carbon economy and are an integral part of virtually all climate protection strategies. However, their rapidly growing deployment poses severe challenges to the security of the German energy system, in particular the electricity grids. Due to the volatile production of electricity, the efforts and costs required to maintain grid stability increased sharply in recent years. To reduce the technical pressure on the electricity system and improve economic efficiency, many economists argue to link demand and supply via dynamic electricity tariffs (Burger et al., 2020). Following economic theory, consumers will react to these time-varying price signals to save money. Since the price signal will mirror any over- or undersupply within the electricity market, this will simultaneously relieve the electricity grids. Yet, dynamic electricity tariffs are associated with many concerns and lack popularity among private households (Ruokamo et al., 2019). Therefore, the aim of this paper is to design and develop reasonable dynamic pricing tariffs that overcome acceptance barriers of residential customers. Hence, we will utilize multiple pricing strategies to address the question how much cost savings households actually require to switch to a dynamic electricity tariff. Furthermore, we quantify CO2 emission reductions that result from households load shifting behavior. Ultimately, we will look at different types of residential customers, to identify potential target groups and formulate precise policy implications.

Methods

To evaluate the potential of dynamic residential electricity tariffs, we construct fully dynamic RTP tariffs with 15-minute time intervals for German residential customers in retrospect to the year 2018. To do so, we extent the approach developed by Freier et al. (2019) who construct dynamic EEG-surcharges. Further, we take up the five principals that a dynamic tariff should cope with proposed by Dupont et al. (2014) as theoretical basis for our tariff design. We investigate three potential underlying input variables that can act as sources of the price signal and use the average residential electricity price of 2018 as benchmark. Building upon these tariffs, we model the capability of residential case study households to shift their electricity consumption as induced response to the price signals. For this, we utilize the standard load profile for residential households (H0), which expresses a representative electricity consumption pattern for German households. Further, we quantify their potential cost savings and CO2 emission reductions for the different tariffs.
We present three case study households with different levels of annual electricity demand and varying load shifting capabilities. For each we calculate the savings potential with and without the presence of a heat pump and a thermal storage. The demand for electrical heating is not only expected to rapidly increase in the future as they are one essential feature of the energy transition, but also the compatibility with dynamic tariffs is a favorable property. Finally, by comparing the potential savings of typical residential households who use a dynamic electricity tariff with the costs associated to such tariff, e.g. investment costs, yearly metering costs and behavior adaption costs, we can determine the requirements tied to such tariffs and their overall usefulness for different consumer groups.
Overall, we develop a set of dynamic pricing schemes, were we apply different parameter variations in order to identify optimal and at the same time reasonable tariff characteristics. The evaluation of case study households allows us to draw conclusions regarding the optimal design of dynamic electricity tariffs for different types of residential customers in Germany.

Results

We are aware that our identification strategy builds upon potential uncertainties. Therefore, we do not aim to identify one unique optimal pricing design, but rather a price corridor that covers these uncertainties. Further, please note that these are only preliminary results as the paper is work in progress.

The price ratio between low- and high-price zones is essentially determining the monetary savings potential of dynamic tariffs for residential households. Compared with the residual load or the CO2 emissions caused by electricity production, the fluctuations of EEX-spot market prices are limited. Thus, they induce a smaller price range than the other two potential input factors.

We quantify the potential monetary savings for case study households for multiple dynamic tariffs, which we design based on the principals of cost causality and cost recovery proposed by Dupont et al. (2014). Depending on the size of a household, its load shifting capability, and weather they have a heat pump as additional large-scale consumption unit, households can save up to approximately 130 € per year (with constant total consumption level). Depending on the same parameters, the corresponding CO2 emission savings range from only roughly 5 kg per year to over 160 kg per year. Thus, upscaled to the over 40 mio. German households, the wide-range implementation of dynamic tariffs can yield significant CO2 reductions.

Our results not only reflect the parameter variations regarding the households, but also depend on the tariff designs. Therefore, we conduct several robustness checks. First, our results are robust to potential feedback loops, which can occur when households shifting behavior impacts input vectors that determine the price signals. Furthermore, we address changes in the underlying distribution of the input vectors and the considered period, not only as robustness checks, but also as tools for policy makers to increase savings potential.

Our next steps will be to include heterogeneous preferences in our analysis and, based on that, to finalize the quantification of net and gross savings potential.

Conclusions

After decades of theoretical discussions, the large-scale deployment of smart meter infrastructure that started in the U.S. and some European energy markets finally made a large adoption of dynamic tariffs possible for residential customers (Gambardella and Pahle, 2018). We build up on this development to quantify the savings potential of residential customers for multiple pricing strategies.

Our preliminary results underline the importance of the amplitude of the price fluctuations within the possible shifting period as decisive for the potential savings. We show that the EEX-spot market prices are not the optimal basis for the price signal in terms of monetary savings potential and CO2 emission reductions. In any case, to generate a sufficiently large incentive for load shifting behavior, all ten components of the German residential electricity tariffs must be dynamic. The incentivised shift of electricity consumption into times with high shares of renewable electricity, leads to small individual reductions of CO2 emissions, which are however significant if aggregated over all households. This can be a strong argument in favor of the implementation of dynamic electricity tariffs, especially since monetary savings are likely insufficient.

Furthermore, while manual load shifting is associated with rather high behavior adaption costs that most likely will hinder the adaption of dynamic tariffs, automatic demand response seems a promising approach. Especially heat pumps, combined with thermal storages, are typically already equiped with the necessary metering devises and thus capable to adapt their electricity consumption without any additional costs and without welfare losses.

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