THE EQUITY OF RESIDENTIAL ENERGY PRICING WITH HEAT PUMPS AND ELECTRIC VEHICLES

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Overview

Massive investment in the coming decades are aimed towards meeting sustainability targets around the world. In Europe, these investments will transform the electricity grid and result in increasing the grid bill paid by consumers through the tariff.

These tariffs recover network costs from network users based on a set of principles, and weighing some principles against each other (Reneses & Ortega, 2014). An especially important principle in this sector is pricing fairness, or equity, whereby equal customers are priced equally for the same product. Equity has been a particularly influential matter in the context of network tariffs, and has been studied in a wide range of contexts (Lamb et al., 2020). A well-studied example of new technologies mass-adoption on network costs is solar photovoltaic panels (Ansarin et al., 2020). However, the strategy of electrification of transport and heat for decarbonisation poses a growing risk of seeing vulnerable consumers more severely impacted by the additional cost on the network. In particular, the impacts of electric vehicles (EVs) and heat pumps (HPs) on the allocation of grid costs among users under different tariff designs were overlooked by previous research.

In this paper, we focus on the impact of adopting these two technologies on network pricing equity. We quantify how different network tariff designs associated with social policy measures will reallocate grid payment across categories of consumers, focusing on low and high financial status households, further zooming in on ownership of HPs and an EVs. We use a uniquely large dataset of 1,4 million households in Denmark providing (fully anonymized) socio-economic information on an individual household basis. This allows us to inform which consumer categories will pay the largest share of future grid investment in each tariff design, and to provide insightful recommendations for policymakers aiming to design electricity tariffs that reach measures of social progressiveness.

Methods

Our study uses a set of tariffs that are compared to the base (default) tariff used in Denmark which recovers 55% of grid costs via a volumetric (fixed per-kWh) rate, and 45% via a fixed subscription charge. Our method consists in comparing the reallocation of the relative payment made to the grid operator per household category under the different tested tariffs, focusing on weak and strong financial status households and further considering how the ownership of a HP or EV affects their network bill. We consider the following changes and extensions to the tariff, and a redistributive policy for the tariff:

1. Varying the relative percentage of grid costs recovered from volumetric rate and subscription payment (from 100% volumetric-based to 100% subscription-based).
2. When a volumetric part applies, the volumetric payment is set in two block rates (Time-of-Use scheme), with a base period and a peak period. We assume that the peak block applies during the 5% highest yearly domestic demand hours and that 20% of the volumetric payment is covered during these 5% of hours, while the remaining 80% are recovered through the base block.
3. A redistribution policy redirects costs from households with low financial status to other households and reflects the state's redistributional goals for residential pricing (Lamb et al., 2020).

All tariffs are designed such that the total recovered revenue for network costs remains the same, i.e. the tariffs are revenue-neutral for the grid operator. Sensitivity analyses are made on the hours considered as peak, on the payment distribution between peak and base period and on the redistribution policy. We define vulnerable households as those that have smaller living spaces and lower income.

Data

2017 data from the Danish Energihub was provided by Denmark's transmissions system operator, Energinet. This data contains per-hour electricity meter readings for Danish households. Incomplete or faulty meter readings with more than 1000 faulty hours were removed, and lower levels of faulty hours were replaced by category averages. In total, approximately 1.4 million meter readings were used for this study, representing about half of the country's population.

This energy data was combined with individual household data from public Statistics Denmark (Danmarks Statistik). We used information about socio-economic factors for each household to provide insights regarding potential disproportionate impacts on households with weaker financial status. For this dataset, we defined such a household as one that has a house living area of under 110 m^2 (or apartment living area under 66 m^2) *and* gross annual income under 240k DKK. This is a more composite representation of both wealth and income for a household's financial status. This corresponds to 18% of all households in the dataset.

Preliminary Results

In this abstract, we present the preliminary results for the tariff defined in the method section. We aim to present results for the full range of parameters and sensitivity analyses in the conference.

We first investigate the yearly average grid bill per household category under the tested tariffs and compare it with the base case. We see dissimilar increases in costs for households with weak and high financial status (Figure 1), with the latter finding worse outcomes as the volumetric share of the network tariff increases. The increase in grid costs is far more dramatic for vulnerable households with ownership of HPs. Likewise, variations in household payments increase as more volumetric rates are used for network cost recovery.

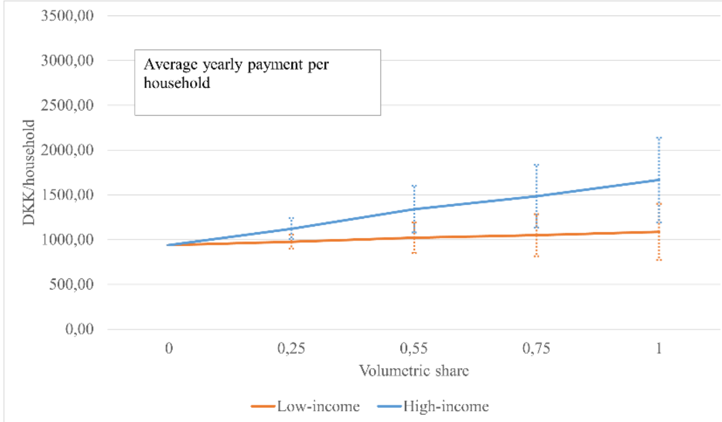

Figure 1 - Average annual grid payment per household per volumetric share of network tariff. Colors indicate low financial status (orange) and high financial status (blue) households. Brackets show standard deviation.

Ownership of EVs/HPs also impacts grid tariff payments (Figure 2). In the base case, households pay about 75% more just for using the electricity network when HPs/EVs are used. The costs of grid tariff (y axis) increase significantly for households with HPs/EVs as network tariff is switched from fully fixed to fully volumetric. On average, households that have not adopted EVs or HPs pay about 1000 DKK/year (151 USD/year) for network costs, which increases slightly as more of network costs is recovered from the volumetric part.

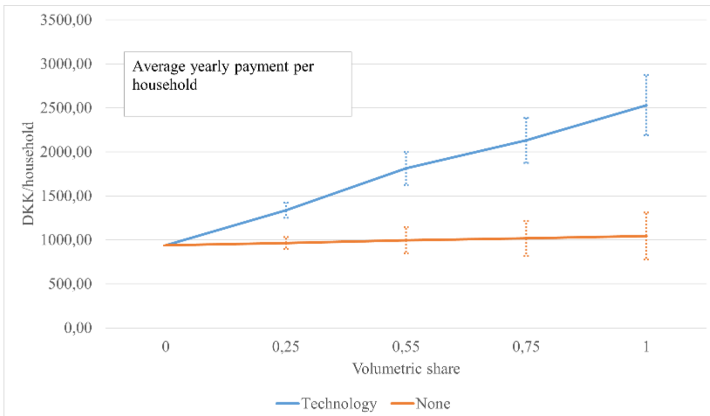

Figure 2 - Average annual grid payment per household based on volumetric share of network tariff and percentage of peak hours. Colors indicate ownership (blue) and non-ownership (orange) of EV/HPs. Brackets show standard deviation.

We next focus on the impact of tariff changes on the electricity bills of consumers, especially on the comparison between households with low and average financial status. To compare these households, Figure 3 shows relative payments compared to the amount paid in the base case (with no peak pricing and 55% volumetric cost recovery). We see that a fixed charge scenario provides a cheaper relative payment (on average) for poorer households, while increasing the volumetric part of the network tariff makes it more expensive for both household groups.

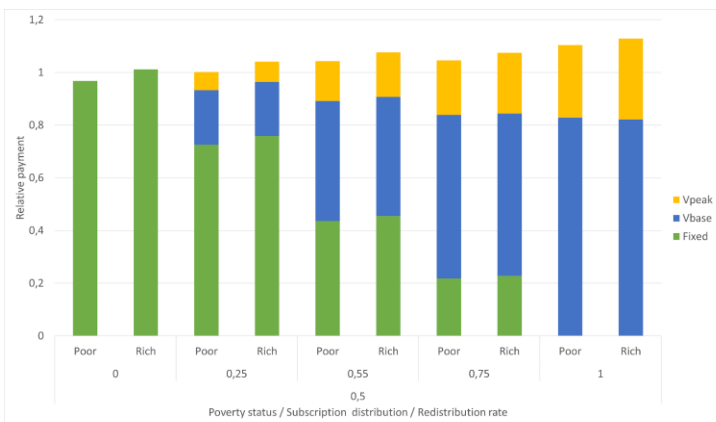

Figure 3 - Relative annual grid payment of households with low and average financial status for different share of volumetric network tariff. Colors indicate tariff component.

Conclusions

These results inform policymakers who aim to increase electrification of heating and transportation systems, while ensuring socially desirable targets are met. In particular, for Denmark's case, we see that EV/HP ownership can dramatically increase the electricity bill of households. This is especially concerning for households with a worse financial status, as the higher electricity burden will further discourage potential investment in cleaner and sustainable energy technologies. For similar reasons, fixed charges were disfavored for recovery network costs. However, this research adds to the body of evidence suggesting that these charges may be overall better for the future electricity grid.

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