Diffusion of Direct Current Technology in Private Households in Germany

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Overview

With the increase in solar photovoltaic (PV) power generation and home batteries installed in private households, as well as the use of electronics and other applications that are powered by direct current (DC), e.g. heat pumps, electric vehicles (EVs), DC technologies and transmission and distribution offer lower conversion losses and thus higher efficiency compared to the entrenched alternating current (AC) technologies (Vossos et al, 2017). However, the adoption of DC infrastructure is strongly limited due to path dependency and lock-in effects of the current electric infrastructure built almost entirely upon AC. Efficiency gains in energy communities and the development of new urban districts based on DC technology, as well as efficiency gains for individual households with a PV system and a battery, will facilitate the wider scale adoption of DC technology as well as further standardization and economies of scale. In this study, we extend existing models in an investigation of private household decisions, building upon the study of Glasgo (2016) and investigating the diffusion dynamics and impacts of DC infrastructure in private homes in Germany.

Methods

We employ a two-stage approach combining the epidemic Bass Model (Bass, 1969) with Net Present Value (NPV) analysis to model financially rational household decisions, similarly to Klingler (2017) on hybrid PV/battery systems for private households.

In the first stage, we simulate household load profiles based on twelve different, representative household types and estimate the possible cost savings achievable by means of a DC circuit architecture compared to an AC architecture. The simulation considers different possible combinations of PV systems and batteries (both varying in size) for each simulated household type. The NPV of all future savings over the life-cycle of an electric household architecture are calculated for different electricity price development scenarios. In this first step, households with the highest expected cost savings are identified. In a second step, we scale the first stage results up to the national level based on German national statistics of different household types, building types, and existing forecasts for the diffusion of solar PV and batteries. This process could be performed equivalently for other countries, data availability permitting, to estimate a broader and more comprehensive picture of the worldwide diffusion of DC household architecture, which may provide even more informative insights regarding potential economies of scale effects.

We then use a variant of the Bass model and parameters of a comparable technology to estimate the potential diffusion pattern of DC homes. A major assumption of this study is that the households' decisions to adopt solar PV and batteries is independent to the adoption of DC grid infrastructure. In future studies, this assumption could be relaxed and he decisions of households could be modeled as simultaneous.

Results

Preliminary analysis shows a significant correlation between total energy consumption and potential cost savings. The cost savings are promising especially for households equipped with optimal PV and battery sizes. However, surprisingly, the amount of DC load does not seem to affect cost savings in a significant manner.

Conclusions

The results yield an improved understanding regarding the achievable cost savings of DC homes under different scenarios and the potential diffusion of DC homes in Germany, which given its widespread adoption and subsidization of PV systems, provides a meaningful insight into the future diffusion of DC household grid architectures on the international level. This is especially relevant when there is large-scale adoption of solar PV, battery and EV in the future by households, thus helping both (local) policy-makers and companies alike to better assess the potential of DC household grid architectures, especially with respect to new builds, where there is no cost of retrofitting.

References

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