MODELLING THE ADOPTION AND DIFFUSION OF HEAT AND ELECTRICITY SELF-SUPPLY FOR VARIOUS REPRESENTATIVE CONSUMERS AND ITS EFFECTS ON THE ELECTRICITY MARKET

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Overview

In the scientific as well as in the political context, the field of "self-supply" is becoming increasingly important in Germany. Over the recent decades, new technologies like PV-, battery storage and CHP-systems have emerged, allowing consumers to generate electricity and heat independently for themselves. By becoming more and more affordable during the last few years, these technologies now represent reasonable alternatives to the prevailing supply from public grids. While at first the main motivation for consumers to supply electricity and heat independently was of ideological nature, the introduction of EEG funding in Germany in 2000 increasingly brought economic reasons of self-supply to the fore and lead to a widespread adoption of PV systems.
Since investments were mostly only economically feasible due to these funding, the coming reduction (or even expiry) of this subsidies now reveals self-supply in a new light. In addition, the decline of the cost of these new technologies, for PV and storage systems in particular, which is sure to continue for the next years, leads to further dynamics.
A number of publications suggest that with low public support via feed-in tariffs or other instruments, the profitability of self-supply technologies requires a high share of self-consumption (e.g. (Chiaroni u. a. 2014)). As regular electricity usage enables only a relatively low degree of flexibility, many publications suggest the use of self-produced energy for heating (e.g. applying heat pumps or electric heaters) or for charging electric vehicles (Weniger, Quaschning, und Tjaden 2014). Yet, only few publications elaborate on this and quantify it by including further technologies in their models (for example (Bardt u. a. 2014)).
To determine the full economic potential of self-supply technologies in a post-FIT scenario, it is important to identify further possibilities to increase the share of self-consumption. This can be done by taking into account all relevant technologies like heat pumps, CHP, and the like. Hence, this implies a self-supply model that couples the consumer's electricity and heating sector.
Besides the issues on the consumer side, a widespread adoption of self-supply technologies is likely to have an impact on the energy system. Still it is unclear whether these dynamics will solely lead to marginal effects, and whether they will only slightly affect the expansion targets set within the scope of the German Energiewende, or whether they will lead to an explosive expansion of PV, storage and other technologies. Especially the latter case could lead to considerable regulatory problems, and political instruments to steer these developments are yet to evaluate (as of before this project). Those effects include the development of grid fees and other quantities, which also have an impact on welfare distribution (see e.g. (Bost, Hirschl, und Aretz 2011), as well as on grid stability (see (Moshövel u. a. 2015) for a comprehensive study).
However, the impact and intensity of these effects depend especially on the actual adoption of self-supply technologies and not merely their economic potential. In order to quantify these impacts, it is necessary to model the diffusion and adoption of self-supply technologies. While a number of publications deal with drivers and barriers of the adoption of self-supply technologies (mostly PV), none of them quantifies the effects (e.g. (Rode 2014)).

Methods

In order to fully understand and investigate the interplay of these dynamics, we need a model that covers all technical and legal aspects of self-supply. Such a model is required to distinguish between individual types of consumers; In addition, due to the close interactions that are possible between electricity and heat generation technologies, only a combined examination of these sectors will yield meaningful conclusions. A model that fulfills all these specifications at the required level of detail is not available up to now.
Furthermore, even if self-supply is an increasingly favorable alternative to grid supply, it is also unclear how quickly consumers will adapt the new technologies. Several factors, such as cost-effectiveness versus conventional supply methods, or the grade of market penetration, could affect the market in opposing ways. To this date, there is no comprehensive concept for the market diffusion of self-supply technologies.
To address these questions, we developed a multi-stage model for self-supply. Consisting of three parts, it primarily combines a private-sector decentralized optimization of the energy-supply of a set of representative consumers with a model for market diffusion.

In its first stage, the model optimizes the electricity and heat supply for each representative consumer individually for one model year. This takes into account various highly detailed technology options as well as grid supply, and results in a technology portfolio that is economically optimal for each type of consumer.
The second model stage consists of a market diffusion model, which estimates how many consumers from the first stage will invest in the optimized technology portfolio for the considered model year. This model stage yields the total expansion figures for each particular self-supply technology.
In addition, a third stage will examine the effects of this newly added capacities on the overall energy system, in particular their impact on network charges and on the EEG levy. The resulting changes are fed back into the optimization of the next model year. Through this feedback, the three stages of the model are interlinked and so repeated over and again for consecutive model years, starting 2016 up to 2030.

Results

First results suggest that an explosive expansion of self-supply systems is unlikely to occur. In a business-as-usual scenario, PV expansion did not exceed the Energiewende targets, and network charges rose only marginally.
In both a minimum and a maximum scenario, upper and lower boundaries of PV expansion and network charges were determined. Additionally, we calculated several sensitivities to determine the leading influencing factors for the expansion of self-supply technologies. In a "measures scenario" we altered a number of these influencing factors to steer the expansion.

Conclusions

The different stages of the model allow to both draw conclusions for technology diffusion as well as for the technology adaption by single representative consumers. Regarding single consumers, we focused on the "single-family household" representative consumer, which is by far the most common type of consumer in Germany. For them, some of the findings are:

- PV systems are economical for almost all consumers, even without funding.
- With their nowadays costs, battery systems are almost never part of an optimized technology portfolio, unless their costs drop dramatically (which doesn't mean they're not economical, since second- or third-best solutions are ignored due to the optimization nature of the model).
- Heat pumps are suitable to increase the self-supply quota.

Regarding technology diffusion and its impact on the system, we conclude the following aspects (with others):

- Under the assumed circumstances, a quick diffusion and market adaption of self-supply technologies will not occur in the next decades.
- The influences of self-supply on network charges are rather small.
- The EEG funding is a very effective control mechanism, since PV diffusion and adoption react extremly sensitive to changes of even an expiration of this subsidy. It's current implementation will act as a driver of self-supply until it expires.

These lists are not complete due to the course of this abstract.

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