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POWER SECTOR EFFECTS OF DIFFERENT ROLL-OUTS OF FLEXIBLE VERSUS INFLEXIBLE HEAT PUMPS

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Overview

The electrification of heating is seen as a crucial measure to reduce the fossil fuel use in the heating sector. Heat pumps are an efficient technology in this regard, using environmental heat in order to reduce the electricity needs for heating. In Germany, policy makers are counting on heat pumps to decarbonize the heating sector, with a declared target of six million installed heat pumps by the year 2030. Given the current stock of around 1.6 million heat pumps, such a transition implies an increase in the electricity system load. In addition, it is also expected that the electricity needs for mobility and other energy services will increase substantially at the same time. In this context, it is not yet well understood how an increased heat pump stock affects the electricity sector. Earlier studies have shown that flexible heat pumps can help to integrate more renewable energy into the power system (Hedegaard & Münster, 2013) and reduce investment needs into electricity storage (Hilpert, 2020). In this study, we explore the effects of different heat pumps roll-outs in Germany on the electricity sector in the year 2030. In particular, we focus on different degrees of flexibility in the heat pump operation by varying the maximum heat storage capacities, with fully inflexible heat pumps as a "worst-case" scenario.

Method

We use the open-source energy system model DIETER (Dispatch and Investment Evaluation Tool with Endogenous Renewables) to investigate the effects of different heat pump roll-outs on the electricity system. DIETER is a capacity-expansion planning model which minimizes system costs and determines power system investments and operation in an hourly resolution. The model can depict a wide array of sector coupling options, including mobility and heating. We model Germany in the year 2030 in interconnection with its electric neighbor countries (and Italy), but hold the power plant portfolio in those countries constant. We consider a slow, medium and fast heat pump roll-out with varying degrees of flexibility, along with a fleet of 15 million electric cars in Germany and an electricity demand of 39 TWH_{el} for domestic hydrogen production. For heating and electrolysis, we assume 100 percent renewable energy supply, while the renewable energy target for all other electric loads is 80 percent in the yearly balance.

Results

Results show that additional heat pumps induce an increase in solar PV capacity in Germany. Equipping heat pumps with heat storage reduces the need for additional power generation capacity and for short-term storage capacity in particular. Batteries and heat storage serve as complements here, especially when it comes to taking up renewable surplus generation of daily PV peaks. Even with only two hours of heat storage capacity, heat pumps can align a substantial part of their electricity consumption with PV peak generation periods, which shows that even small heat storage improves the integration of heat pumps into the system. While 73 GWh of battery storage is installed when considering inflexible heat pumps, this additional need is almost diminished when heat storage of up to six hours is assumed. Increasing the heat storage further, up to 168 hours, has only minor additional benefits. With respect to electricity sector costs, we inspect a rest-reducing effect of additional heat storage. Additional costs decrease with larger heat storage, with the largest drop in cost between inflexible heat pumps and heat pumps with a two-hour storage. Between a heat storage capacity of 24 hours and 168 hours, the decrease in costs is neglectable. This hints at the fact that heat storage of heat pumps is primarily used to balance daily fluctuations.

Conclusions

An increased deployment of heat pumps requires additional investments in renewable energy sources if heating is supposed to be provided using only green energy. Our results show that the even small heat storage capacities of two or six hours can reduce the power generation and storage capacities by balancing diurnal fluctuations in renewable energy supply. Though a fast roll-out of fully inflexible heat pumps induces an additional need for short-term electricity storage, additional investment needs in power generation capacity are negligible. We find only minor power sector effects of increasing the heat storage capacity beyond six hours.

References

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