THE EFFECT OF HEAT PUMP FLEXIBILITY ON AUSTRIA'S ELECTRICITY SYSTEM IN 2030

Franziska SCHÖNIGER [1*], Philipp MASCHERBAUER[2], Gustav RESCH[2], Lukas KRANZL[2], Reinhard HAAS[2]

Summary

Heat pumps can provide flexibility to the electricity sector by using the thermal mass of the buildings and adapting their electricity consumption according to renewable electricity generation levels in the grid. In this way, they are able to enhance the integration of variable renewable technologies such as wind and photovoltaics (PV). We analyze the potential of residential heat pump flexibility provided to the Austrian electricity system in 2030. We use a detailed building model to calculate the necessary technological parameters that determine the demand shifting potential of heat pumps, as well as an open-source bottom-up energy system model to assess the implications on the overall power system. Our findings show that residential heat pumps could reduce overall electricity system costs, wind and PV curtailment (up to -1.4 %), investments in new dispatchable power plant capacities (up to -455 MW), and CO_2 emissions (up to -7.3%) by shifting their electricity demand to times of high renewable electricity generation.

Introduction

Decarbonizing our energy system is a major transformation that will necessitate increasing the share of renewable power generation and integrating it into the entire system, as well as the electrification of formerly fossil-fueled activities. Increasing the capacity of heat pumps or electric heating to decarbonize the heating industry is required. Increased sector coupling, such as electricity to heat, provides potential flexibility to the system while increasing the amount of variable renewable output increases the requirement for flexibility solutions. These technologies can be employed in future energy systems to give flexibility to the electrical grid by utilizing the heat storage capabilities of the thermal mass of the buildings or integrated buffer tanks to shift power demand to hours when renewable energy production is greater in the grid. The purpose of this paper is to determine how much flexibility residential heat pumps can provide to the Austrian power grid in 2030. Heat pumps and electric heating have significant flexibility potential in the electrical system, which is reliant on the structure of the country's power and (district) heating sectors, as well as building stocks [1] [2]. We highlight Austria's role, focusing in particular on the influence of several techno-economic characteristics on the flexibility potential for 2030.

Method

The method of approach is divided into two parts. To analyze the central aspects of the flexibility potential of the building stock heated by heat pumps, a detailed building model is used to simulate all relevant building parameters like insulation state, indoor and outdoor temperature, as well as comfort needs of the habitants. From this analysis, the central parameters defining the buildings' ability to store heat and shift electricity demand are derived and fed into the bottom-up energy system model. These are e.g. the electric load that may be employed as a flexibility option, as well as the temporal limits for changing this load due to seasonal cycles and building features.

In Austria and its neighboring countries, we model the electricity and district heat sectors, as well as decentral heat pumps and electric heating for the year 2030. The investment and dispatch optimization of the electricity system is done using the open-source energy system modelling framework Balmorel [3][4] minimizing overall system cost in hourly resolution. As output, we derive required investments in generation and storage technologies, overall system cost, electricity spot prices, renewable curtailment, and emission levels in different scenario settings.

[1*] Nachwuchsautorin; TU Wien, Institute of Energy Systems and Electrical Drives, Energy Economics Group, Gusshausstrasse 25-29/370-3, 1040 Wien, +43 1 58801 370378, schoeniger@eeg.tuwien.ac.at, https://eeg.tuwien.ac.at/
[2] TU Wien, Institute of Energy Systems and Electrical Drives, Energy Economics Group Gusshausstrasse 25-29/370-3, 1040 Wien,

Results and conclusions

The model informs on the flexibility potential provided by heat pumps and utilized by the energy system in Austria in 2030. The electricity demand shifted downwards in times of high renewable generation ranges between 689 and 1946 GWh in the considered scenarios and enhances the integration of variable renewable electricity generation [5][6] by reducing curtailment (see Figure 1).

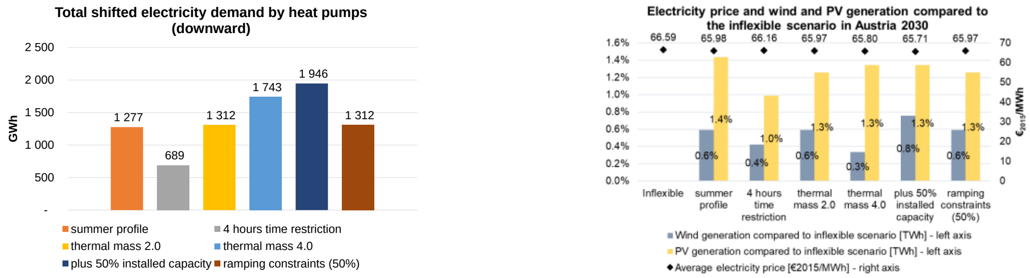

Figure 1: Total shifted electricity demand by flexible heat pumps, electricity prices, and avoided curtailment of PV and wind in the modelled scenarios.

The benefits of flexible heat pumps and electric heating in Austria in 2030 can be determined in terms of reduced system cost, needed investments in new dispatchable generation technologies, i.e. in natural gas power plants (up to -455 MW, see **Fehler! Verweisquelle konnte nicht gefunden werden.**), CO_2 emissions (up to -7.3%), and wind and PV curtailment (up to -1.4 %, see again Figure 1) by shifting their demand compared to a system with inflexible heat pumps and electric heating.

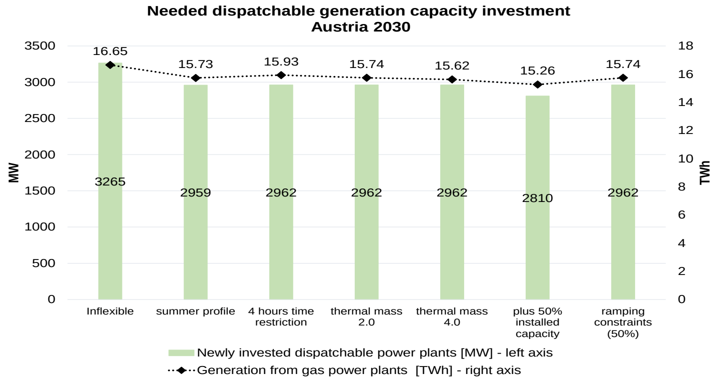

Figure 2: Newly invested dispatchable generation capacity and total electricity generation from natural gas in the modelled scenarios.

This allows us to derive policy recommendations on how heat pump and electric heating flexibility can be implemented and used best for the electricity system in Austria in 2030. We also find that the results are highly sensitive to the limitation of shifting time and installed capacities of flexible heat pumps.

Funding

This work was supported by the Climate and Energy Fund (Klima- und Energiefonds) in the framework of the project SECURES of the 12th Austrian Climate Research Programme (ACRP) (KR19AC0K17532).

References

[1] W. P. Schill and A. Zerrahn, “Flexible electricity use for heating in markets with renewable energy,” *Appl. Energy*, vol. 266, no. March, p. 114571, 2020.
[2] J. G. Kirkerud, T. F. Bolkesjø, and E. Trømborg, “Power-to-heat as a flexibility measure for integration of renewable energy,” *Energy*, vol. 128, pp. 776–784, 2017.
[3] The Balmorel Open Source Project, “Balmorel,” *Energy System Model*, 2019. [Online]. Available: http://www.balmorel.com/. [Accessed: 09-Apr-2019].
[4] F. Wiese *et al.*, “Balmorel open source energy system model,” *Energy Strateg. Rev.*, vol. 20, pp. 26–34, 2018.
[5] J. Gea-Bermúdez *et al.*, “The role of sector coupling in the green transition: A least-cost energy system development in Northern-central Europe towards 2050,” *Appl. Energy*, vol. 289, no. September 2020, 2021.
[6] D. Katsman, “The potential of demand flexibility provided by heat pumps to the Austrian electricity system,” Technische Universität Wien, 2020.