Modelling heat pumps as flexibility option in Austria's electricity system in 2030

Franziska Schöniger, Philipp Mascherbauer, Gustav Resch, Lukas Kranzl & Reinhard Haas
TU Wien, Institute of Energy Systems and Electrical Drives, Energy Economics Group, Vienna, Austria

INTRODUCTION

Decarbonizing of the energy system is a major transformation:

- Electricity sector: Increase of **fluctuating renewable electricity** generation (i.e., wind and solar power)
  increased flexibility need
- Heating sector: **Increase of heat pump capacity** or electric heating
  increased flexibility potential
- **Sector coupling** offers opportunities: Heat pumps can provide flexibility to the future electricity system by **shifting their electricity demand** to times of high renewable electricity generation by **using the thermal mass of the buildings**. In this way, they can **foster the integration of variable renewable technologies** like wind and solar photovoltaics (PV).

RESEARCH QUESTION

What's the load shifting potential of residential heat pumps providing flexibility to the Austrian electricity system in 2030?

STATE OF THE ART

- Heat pumps and electric heating have significant flexibility potential in the electrical system, which is dependent on the structure of the country's power and (district) heating sectors, as well as building stocks (Schill & Zerrahn, 2020) (Kirkerud, Bolkesjø, & Trømborg, 2017) (Gea-Bermúdez et al., 2021).
- **Two main approaches** of modelling power-to-heat flexibility in the literature:
  1. Limitation of **shifting time** (h)
  2. Limitation of **thermal storage capacity** (MWh) representing the thermal mass of the buildings

METHOD

Soft linking a detailed building model and a bottom-up energy system model

1. **Detailed building model Invert/EE-Lab**
   (Invert, 2022)
   - Simulation of all relevant building parameters like insulation state, indoor/outdoor temperature, and comfort needs.
   - The central parameters defining the buildings' ability to store heat and shift electricity demand (see Fig. 1) are derived: e.g. electric load that may be employed as a flexibility option or temporal limits for changing this load due to seasonal cycles and building features.
2. **Energy system model Balmorel**
   (The Balmorel Open Source Project, 2019)(Wiese et al., 2018)
   - The information derived from this first step is then integrated with the bottom-up, open-source energy system model.
   - The investment and dispatch optimization of the electricity and district heat sector as well as decentral heat pumps in Austria 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 (Table 1).

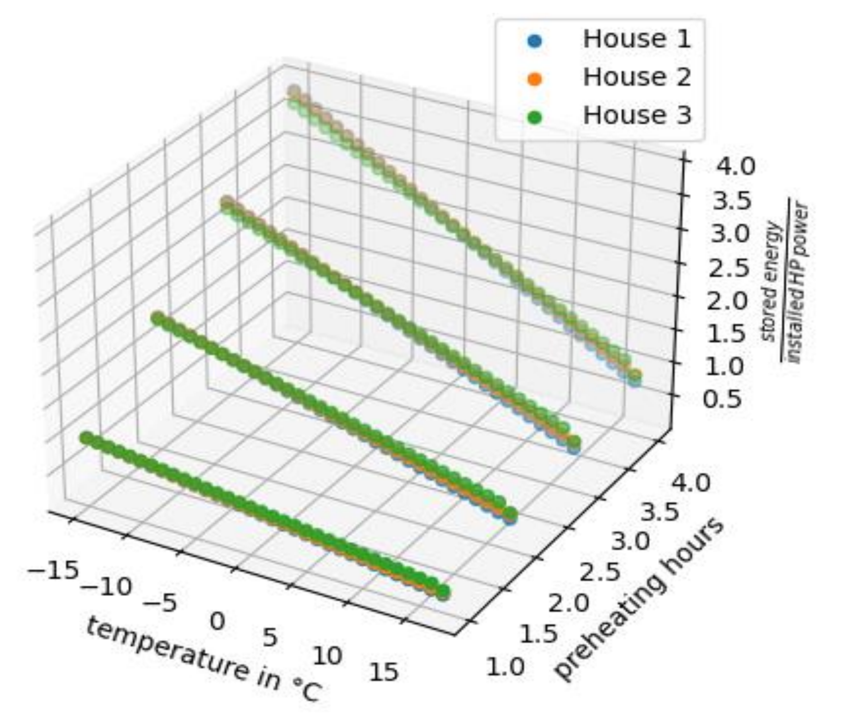

Figure 1: Ability to store energy in the building mass in dependence of building type, outdoor temperature and preheating hours (accepted time of interference to increase the room temperature from 20°C to 22°C).

Table 1: Scenario assumptions. Sensitivity analyses (+/-50%) of all parameters were performed.

Annual el. demand by flexible heat pumps [TWh]	Installed el. capacity flexible heat pumps [MW_el]	Thermal storage capacity [MWh /MW_installed heat pump capacity]	Thermal loss per hour
2	1818	3	5%

RESULTS & CONCLUSIONS

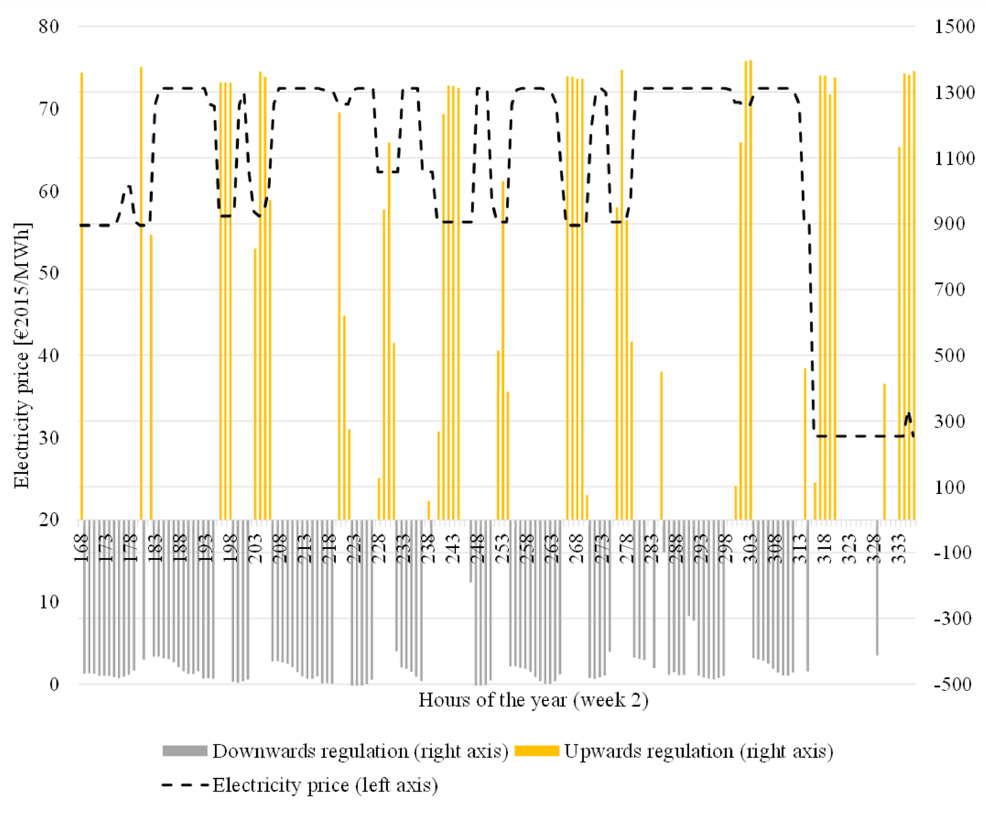

Figure 2: Heat pumps regulate their electricity demand upwards in times of (relative) low and downwards in times of high electricity prices. Load shifting displayed for week 2.

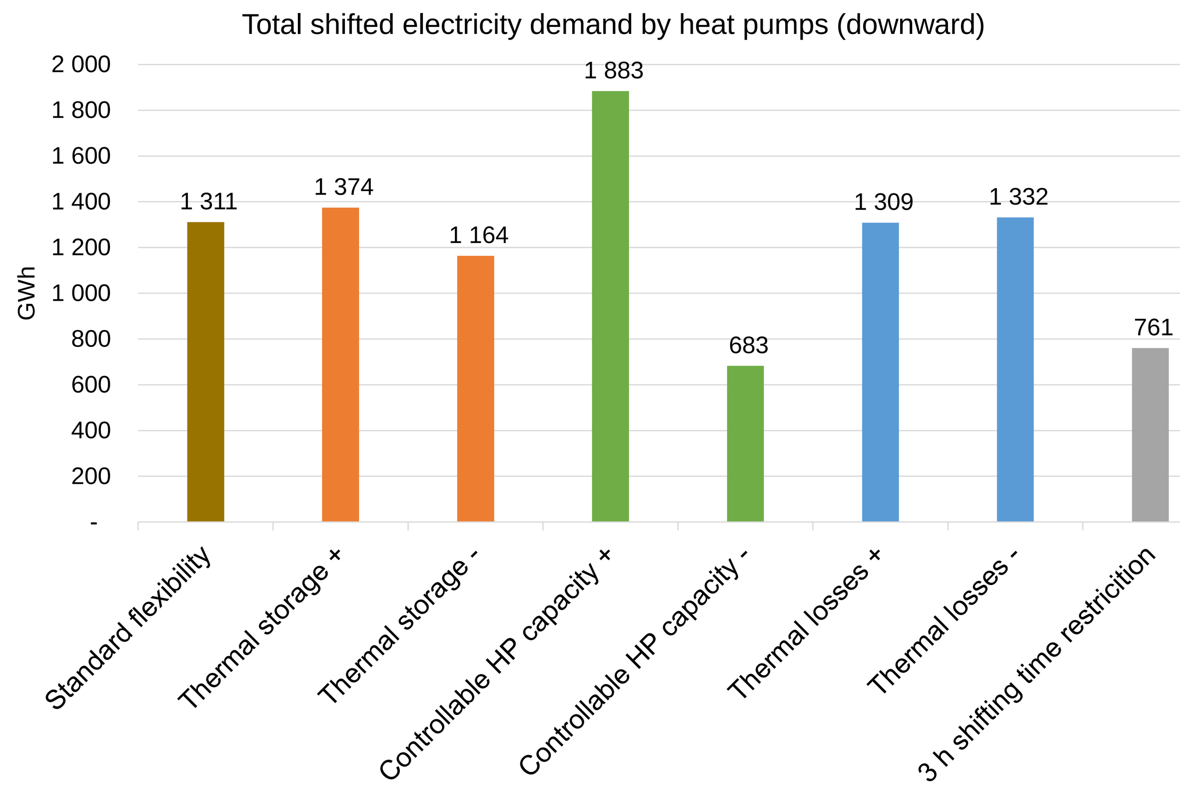

Figure 3: Shifted electricity load, i.e. provided flexibility to the electricity system, compared for all scenarios. **Shifted electricity between 683 and 1883 GWh, i.e. 1-2.5% of annual Austrian electricity load in 2030.**

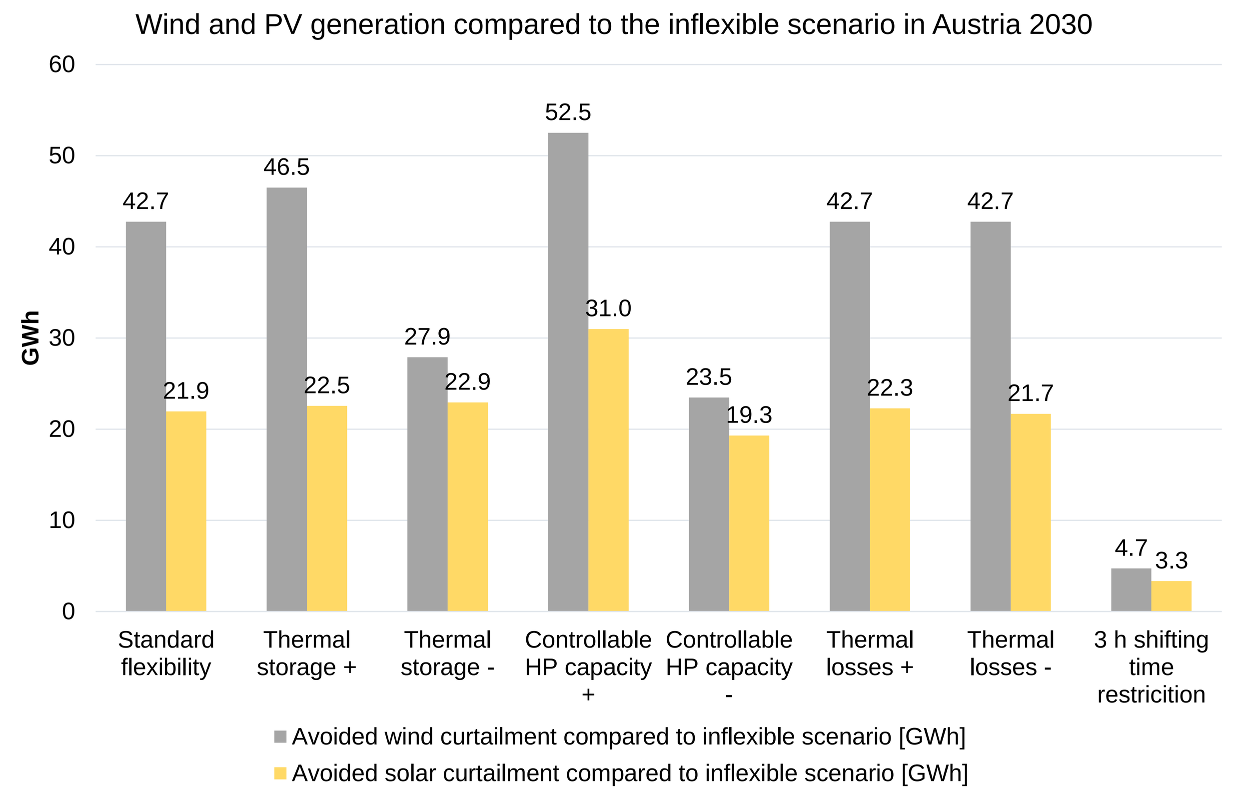

Figure 4: Flexible heat pumps reduce wind and solar curtailment in all scenarios compared to the inflexible scenario. Avoided curtailment is in the range of <1% of total wind and solar generation. **Wind is reacting more sensitive to increased thermal capacity because of timewise correlation of wind generation and heat pump flexibility (both high in winter).**

- Flexible heat pumps in the model react to electricity spot price signals and shift their electricity demand to times of relatively low prices (cf. Figure 2).
- Apart from the standard flexibility scenario (cf. Table 1), **sensitivity analyses** on +/- 50% of thermal storage capacity, installed controllable heat pump capacity, and thermal losses were conducted. Additionally, the effect of a 3 hours shifting time restriction was evaluated (cf. Figure 3).
- Wind and solar curtailment is reduced by heat pump flexibility, wind production is profiting more from heat pump flexibility since both is peaking during winter (cf. Figure 4).

FINDINGS

- Flexible heat pumps are able to **reduce electricity system costs, renewable electricity curtailment** and natural gas generation in Austria 2030.
- Results are **most sensitive to assumed installed and flexible heat pump capacity** (controllable).
- **Wind production is more sensitive** to heat pump flexibility than solar production.

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Contact: schoeniger@eeg.tuwien.ac.at | +43 1 58801 370378 | https://eeg.tuwien.ac.at/