TECHNISCHE UNIVERSITÄT WIEN

Power to heat flexibility in Austria’s electricity system in 2030

Franziska SCHÖNIGER[1], Philipp MASCHERBAUER, Gustav RESCH, Lukas KRANZL, Julian LINKE, Reinhard HAAS

TU Wien, Institute of Energy Systems and Electrical Drives, Energy Economics Group, Gusshausstrasse 25-29/370-3, AT-1040 Vienna, +43 1 58801 370378

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Flexibility as enabler for the integration of renewables

- **Increasing capacities of heat pumps** or electric heating (fueled by RENEWABLE electricity) in the heating sector

- Sector coupling offers potential flexibility to the system by using the **heat storage potential of the building stock** (thermal mass) to shift electricity demand to hours of higher renewable energy production in the electricity grid

Motivation & objectives

Different **approaches** in literature and **energy system modeling practice** of how to model power-to-heat flexibility:

- Scheduled heat load profile can be shifted according to certain limitations
- Flexibility potential is limited by **shifting time** → size of storage is time-dependent
- Storage size is defined by the thermal mass that is present in the building stock
- Thermal **losses**

- **Studies** e.g. by Kirkerud et al. (2021), Olkkonen et al. (2018), Moser et al., (2015), Weiß, (2019), and Spreitzhofer (2018): Literature about a) quite detailed building models and b) energy system models

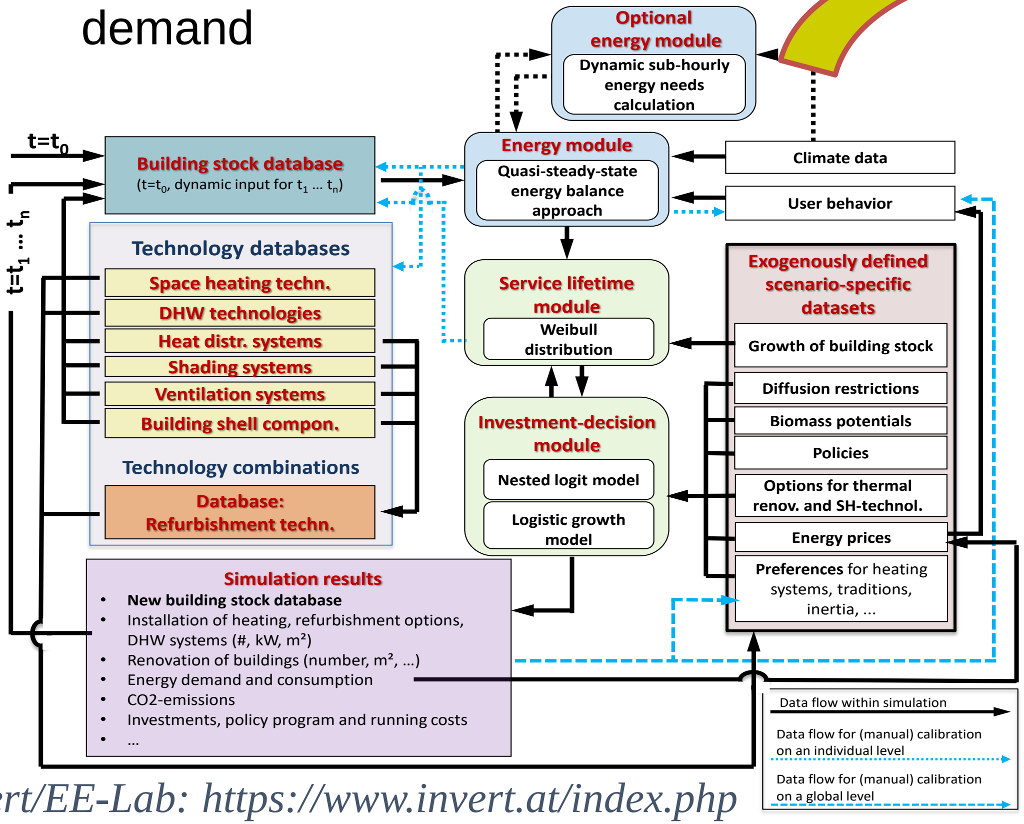
1. Identify **soft links between** a **detailed building model** and an **energy system model**
    - ➢ **Appropriate** representation of **heat pump flexibility**
    - ➢ What information of the detailed building model is **needed**?

2. Case study: What is the **flexibility potential residential heat pumps** (space heating) can provide to the electricity system in **Austria** for **2030?**

Different models need different information

Data from the detailed building model…

- Contains more than 1000 building types and their characteristics
- Detailed representation of heating demand

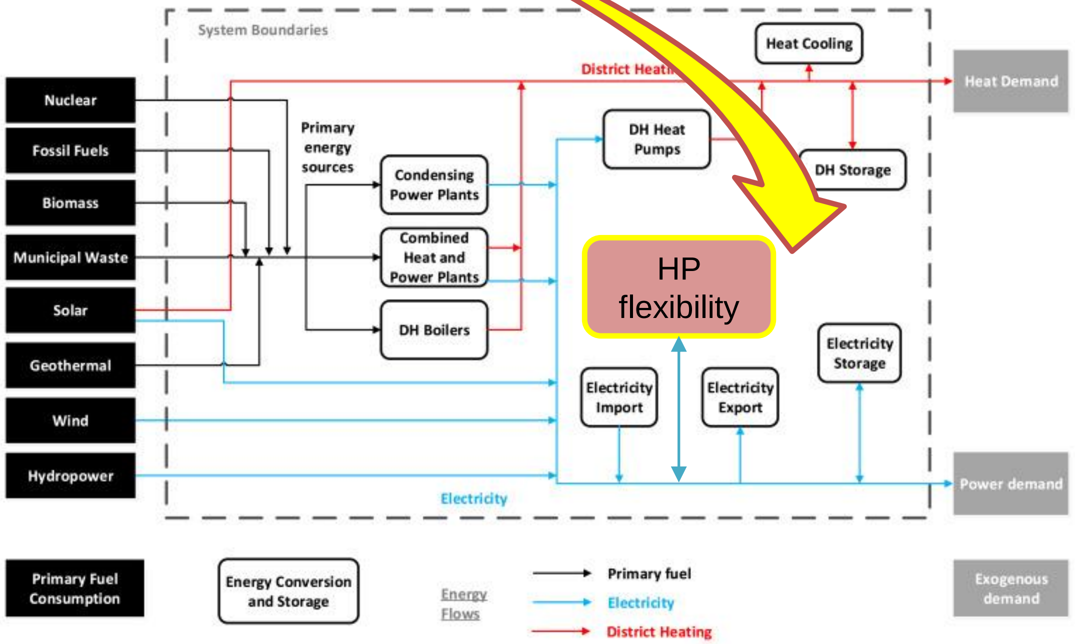


Invert/EE-Lab: https://www.invert.at/index.php

… feeding the energy system model

- Covers the electricity and district heat sector
- Includes generation patterns of variable renewable energies

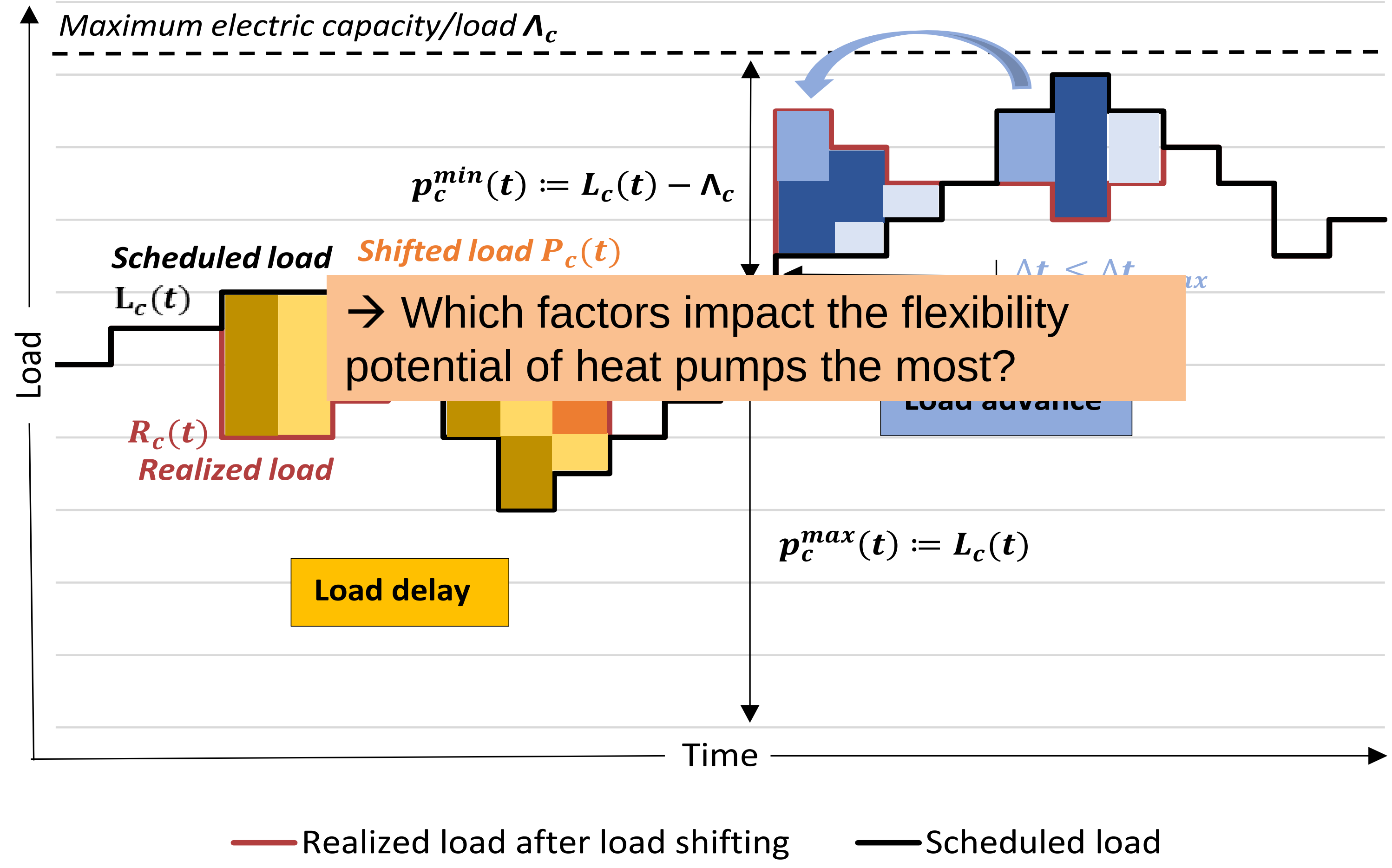
simplification



Balmorel: https://github.com/balmorelcommunity/Balmorel

Theoretical concept of load shifting in Balmorel

based on Kirkerud et al. (2021) and Gils (2016)

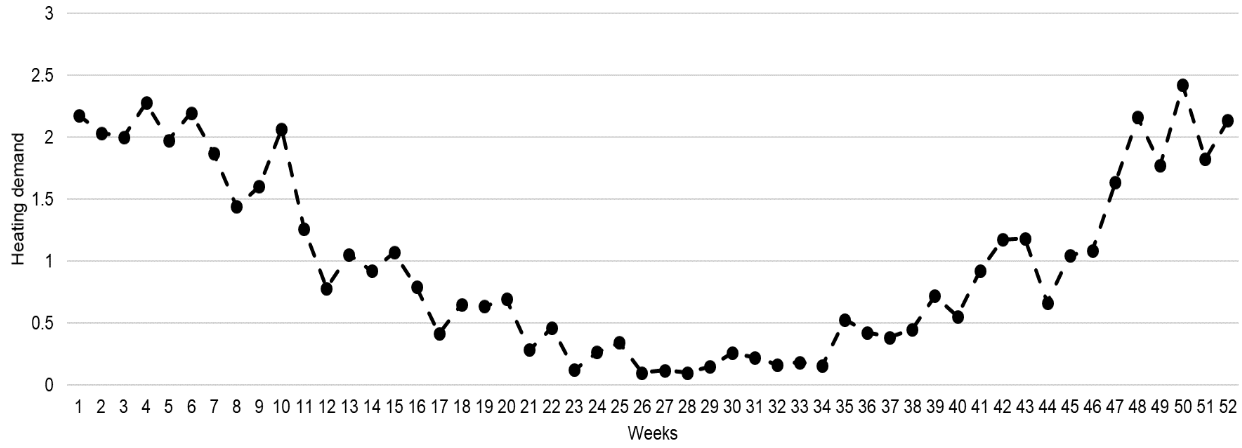


→ Which factors impact the flexibility potential of heat pumps the most?

$$p_c^{min}(t) \leq P_c(t) \leq p_c^{max}(t) \;\; \forall\, t, c$$

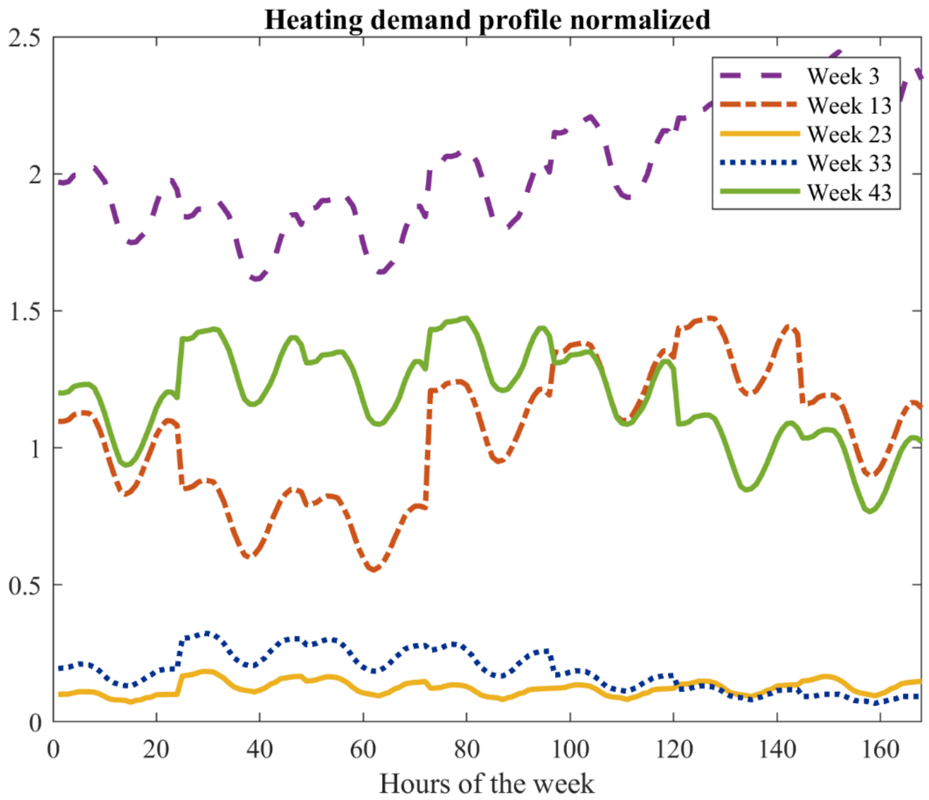
c	Load shifting technology
$\Delta t_{c,max}$	Maximal shifting time for technology c [hours]
$L_c(t)$	Scheduled load of technology c [MW]
$R_c(t)$	Realized load after load shifting of technology c [MW]
$P_c(t)$	Shifted load of technology c [MW]
$E_c(t)$	Energy content of “virtual storage” of technology c [MWh]
tt	One timestep within the timeframe of load shifting
Λ_c	Maximum electric capacity/load of technology c

1) Heating demand profile determines seasonal and hourly availability



Seasonal…

… x **weekly** patterns.

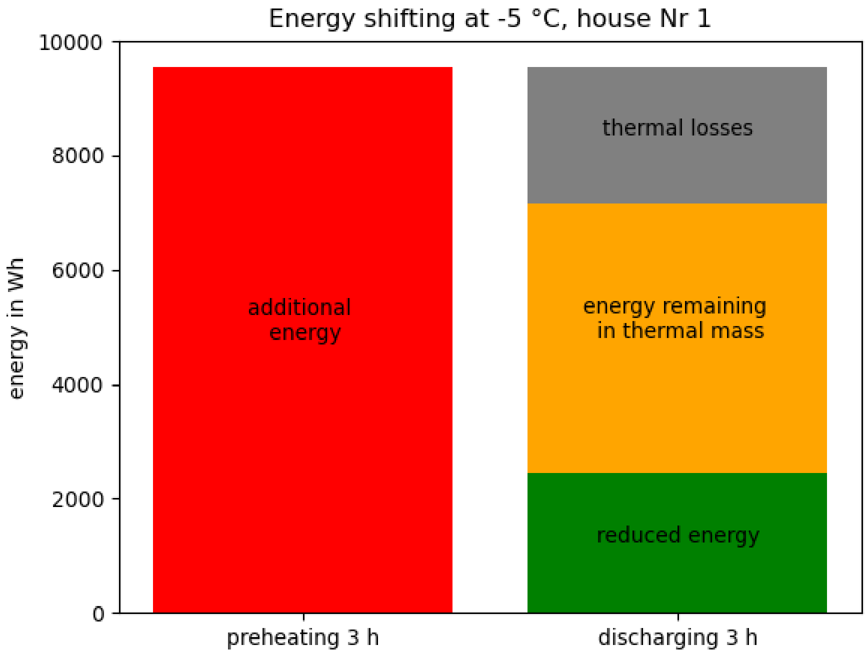


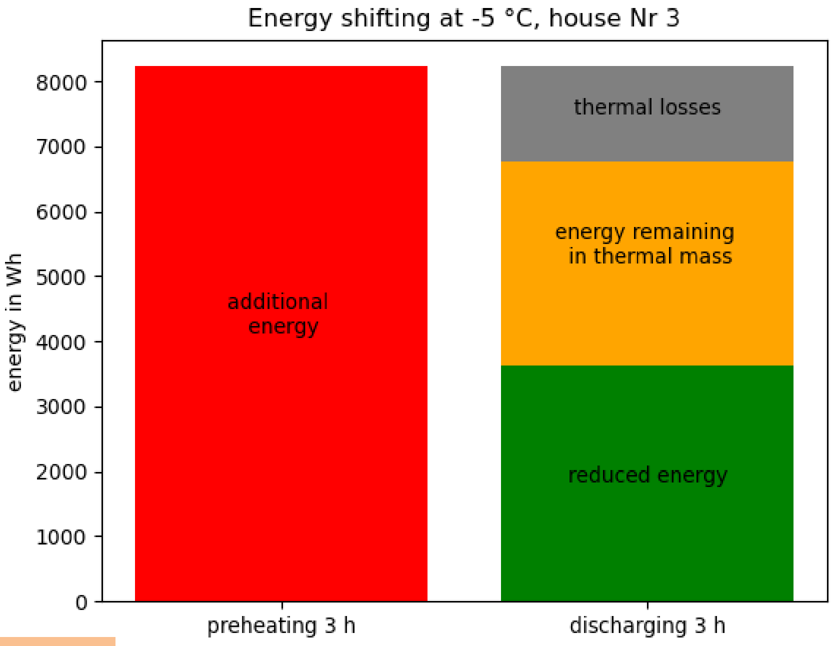
- Original data on NUTS2 level, aggregated for Austria
- Year 2010, residential space heating
- Source: Hotmaps project: Pezzutto et al. (2018)

→ Variation of weekly profile

2) Impact of building type (thermal mass + heat demand)

- Calculations based on DIN ISO 13790: Energy performance of buildings - Calculation of energy use for space heating and cooling
  - Representative building types: Nr 3 better insulated than Nr 1
  - Room temperature increased from 20°C to 22°C for three hours





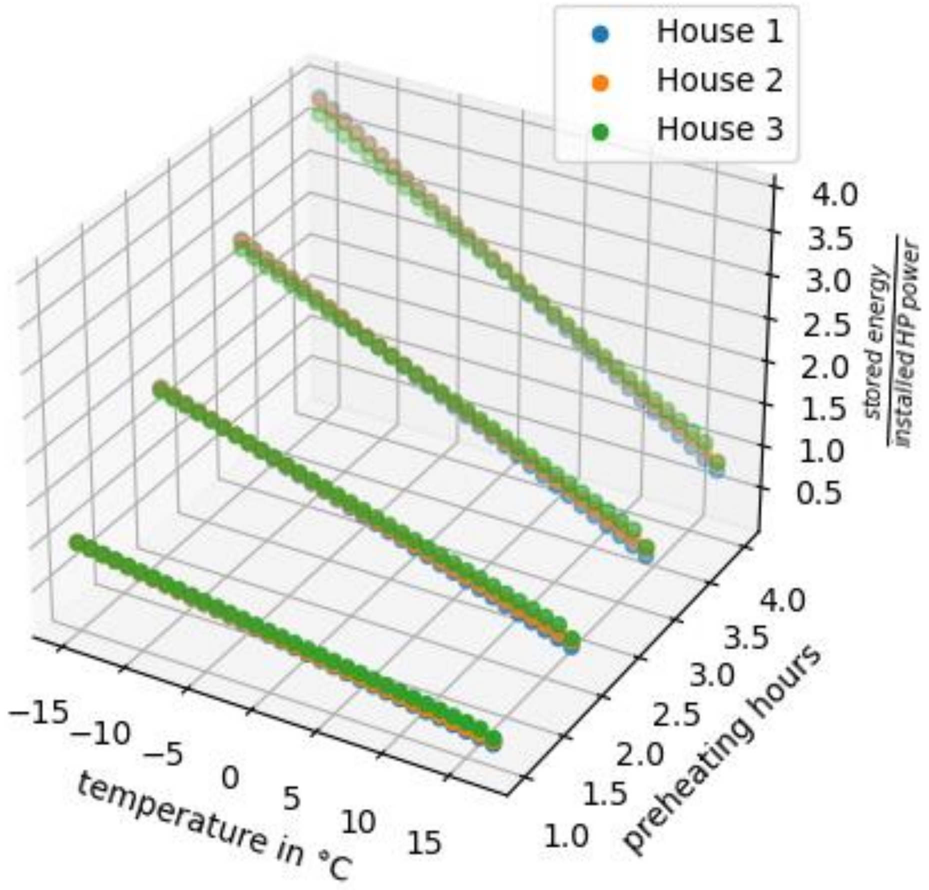
→ Variation of thermal losses in the storage process

What factors do influence the ability to shift?

Energy shifting potential is depending on

- Acceptable **time of interference** (here preheating phase) → comfort
- **building type**
- outside **temperature**/heating demand

→ Variation of time restrictions/storage volume (default 2)



Modelling assumptions

Austria 2030, hourly resolution, perfect foresight

- Installed, controllable residential heat pumps: 1818 MW_{el} and 2 TWh_{el} demand
- Electricity and district heating system of the neighbouring countries is modelled as well (without flexibility options)
- Default: storage 2.0 (3636 MWh_{el}), 5% thermal loss per hour, winter profile, no ramping
- Investment options for the electricity sector: large-scale batteries and natural gas CC

			Winter profile (week 43)						
	Inflexible scenario (reference)	Summer profile (week 33)	4 hours shifting time	Storage volume 2.0	Storage volume 4.0	10% loss	More HP (+50% inst. cap.)	Ramping (50%)	0% loss
Thermal loss per hour	-	5	5	5	5	**10**	5	5	**0**
Installed HP capacity flexible [MW]	0	1818	1818	1818	1818	1818	**2727**	1818	1818
Ramping constraints (% of installed HP capacity per hour)	-	-	-	-	-	-	-	50	-
Storage capacity [MWh/MW installed]		2.0	time-dependent	2.0	**4.0**	2.0	2.0	2.0	2.0

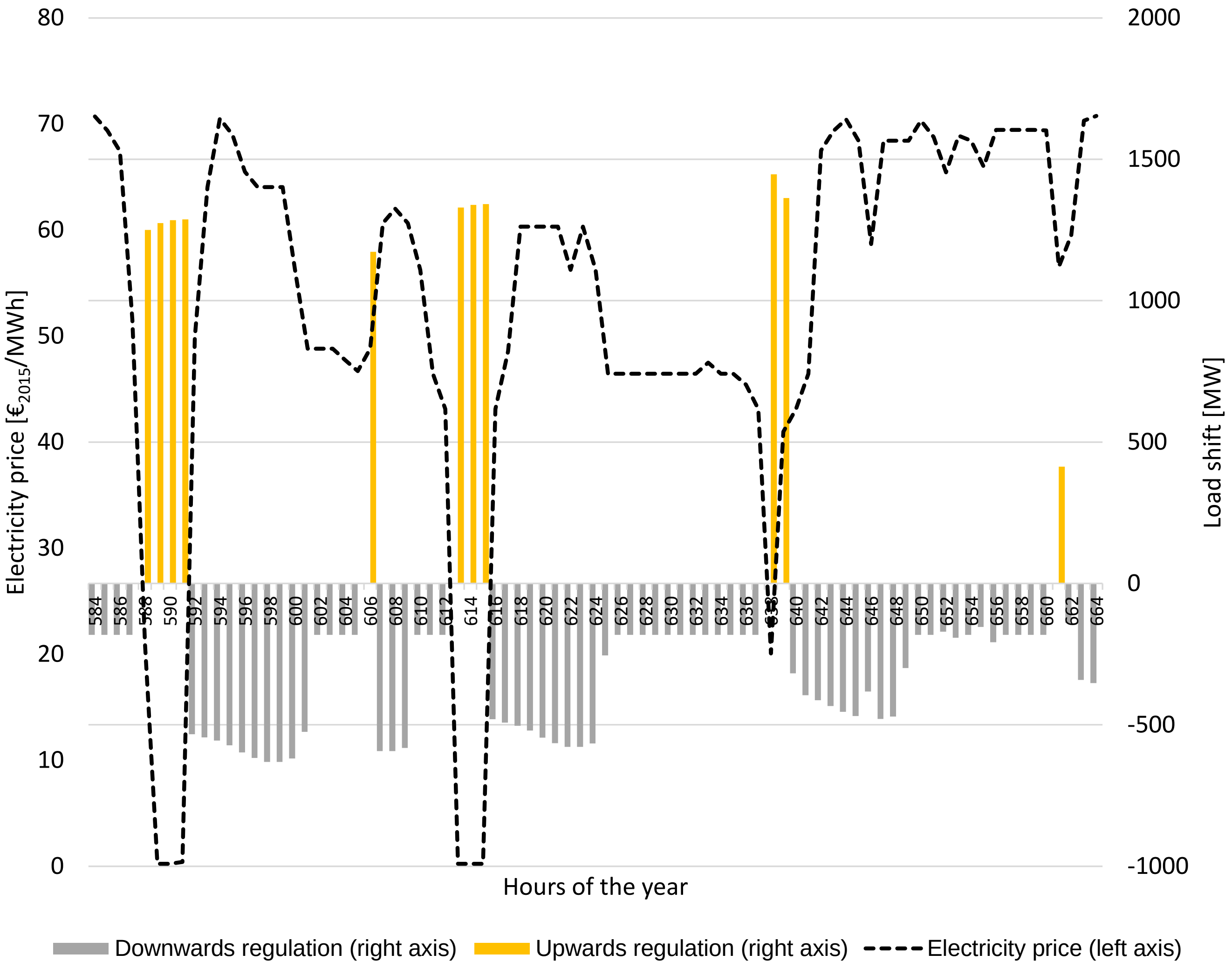
Installed el. capacities

MW	Austria
Coal	
Geothermal	1
Lignite	
Natural gas	4176
Oil	6
Waste	150
Nuclear	
PV central	776
PV decentral	11 529
Hydro reservoirs	
Hydro pump storage	
Hydro run-of-river	6 940
Biogas	109
Biomass	686
Wind offshore	
Wind onshore	5 316
Sum	29 687

Preliminary results & conclusions

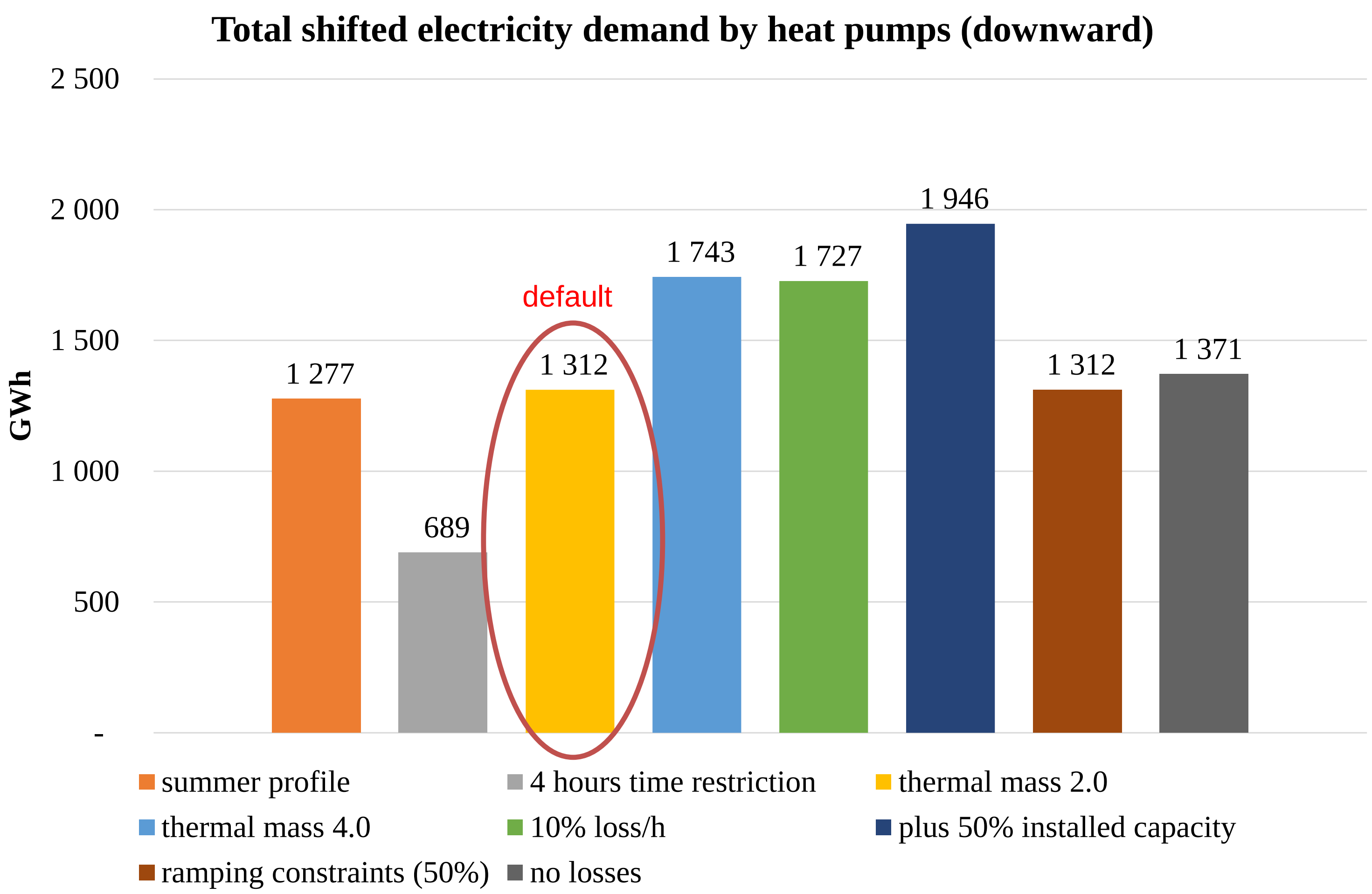
Flexible heat pumps react to market price signals

- 80 consecutive hours (randomly chosen)
- In hours of low prices, we see upwards regulation of the heat pumps and in hours of high prices downwards regulation



Total shifted electricity → flexibility provided

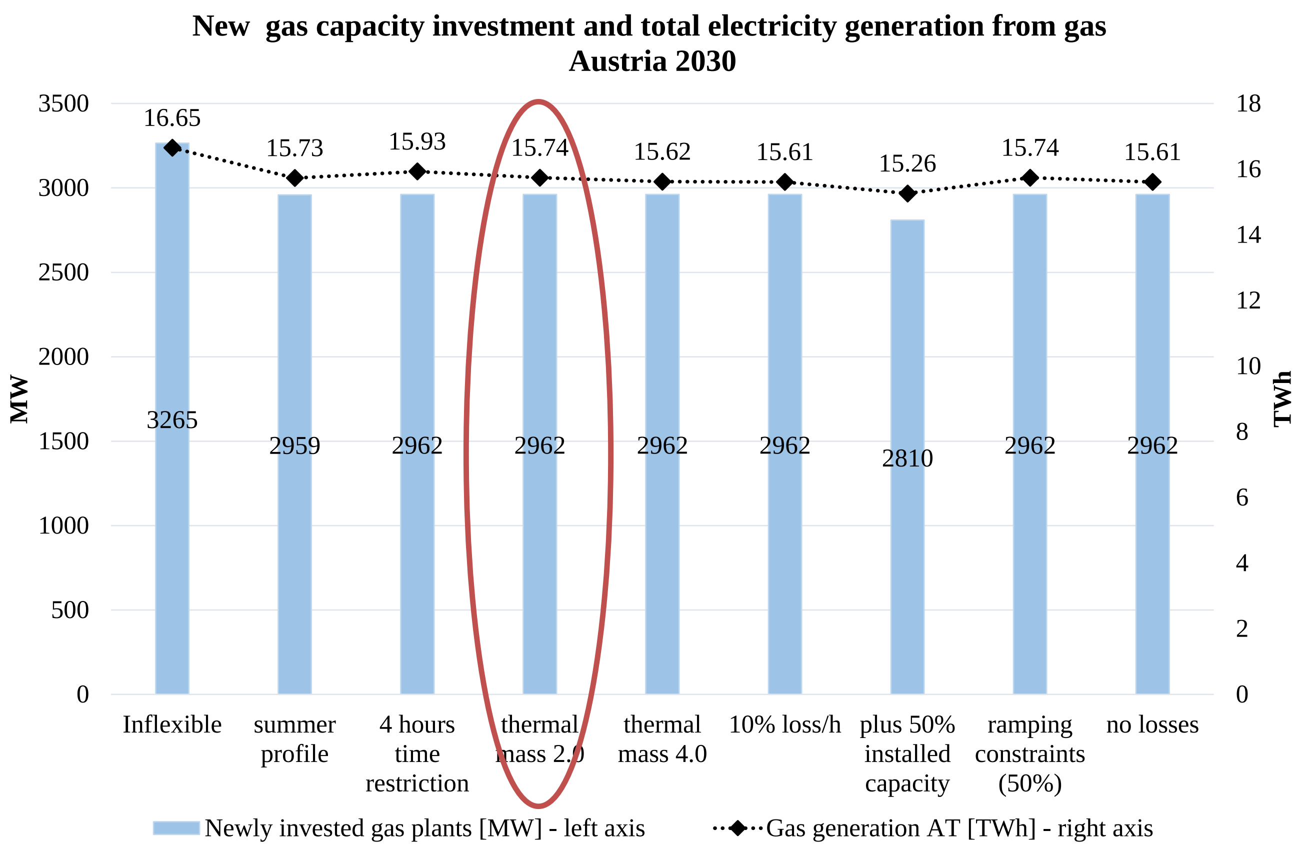
- **Summer profile** (slightly less variation) results in slightly less shifted energy → **no big impact**
- Results are quite **sensitive** to **limitation of shifting time** (in line with literature)
- **Ramping constraints** (50% of installed capacity) have **no impact**



Reduced natural gas capacities and generation by flexible heat pumps

- **Installed natural gas capacity** is **decreased** in all flexible scenarios almost to the same extent (exception: more flexible HP capacity reduces need for flexible power plant capacity significantly)

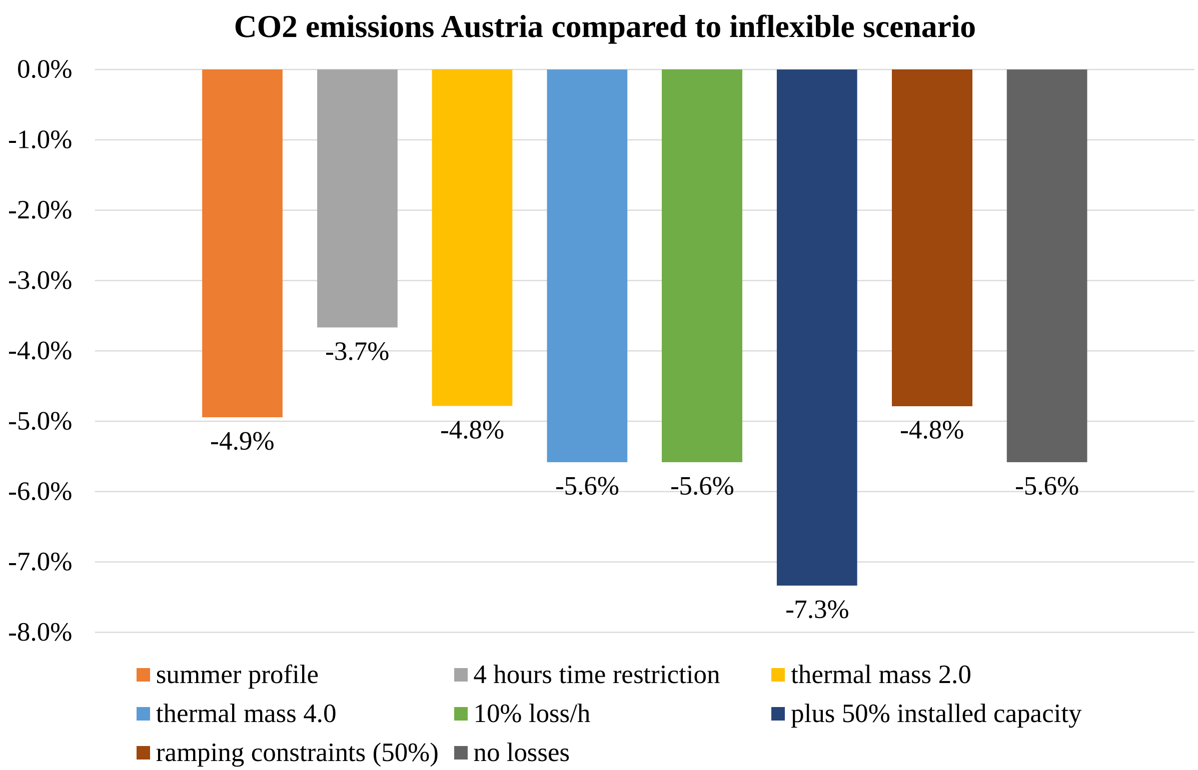
- Bigger **differences in the generated electricity from natural gas**: in the case of time restricition, it is higher → **correlation with shifted energy**



Reduced CO_2 emissions by flexible heat pumps

- Increased power-to-heat sector coupling decreases need for electricity from natural gas in Austria

→ reduced CO_2 emissions in the electricity and district heat sector



Conclusions & Outlook

Findings

- Flexibility provided by heat pumps can **reduce electricity system costs**, **required investments in other flexibility options** as well as **reduce CO_2 emissions** in the Austrian electricity system of 2030
- **Impact of weekly heating demand profile** (summer vs. winter) is rather **limited**
- Flexibility potential is very sensitive to **assumptions on installed heat pump capacity** and the **flexible share** of them as well as **shifting time** limitations (comfort)

Outlook

- **Refine** and discuss **shifting time limitations** (social vs. technical limitations) → high impact!
- Include **other sectors** than residential (**industrial, tertiary**)
- Split potentials in seasonal parts witch varying parameters (e.g. losses higher in winter)

Literature

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Franziska Schöniger

TU Wien

Energy Economic Group, EEG

Gußhausstraße 25-29 / E370-3

1040 Vienna, Austria

Tel: +43 1 58801 370378

Email: schoeniger@eeg.tuwien.ac.at

Web: http://www.eeg.tuwien.ac.at