TECHNISCHE UNIVERSITÄT WIEN

Investigating the demand side flexibility of the residential building stock

Philipp MASCHERBAUER, Lukas KRANZL

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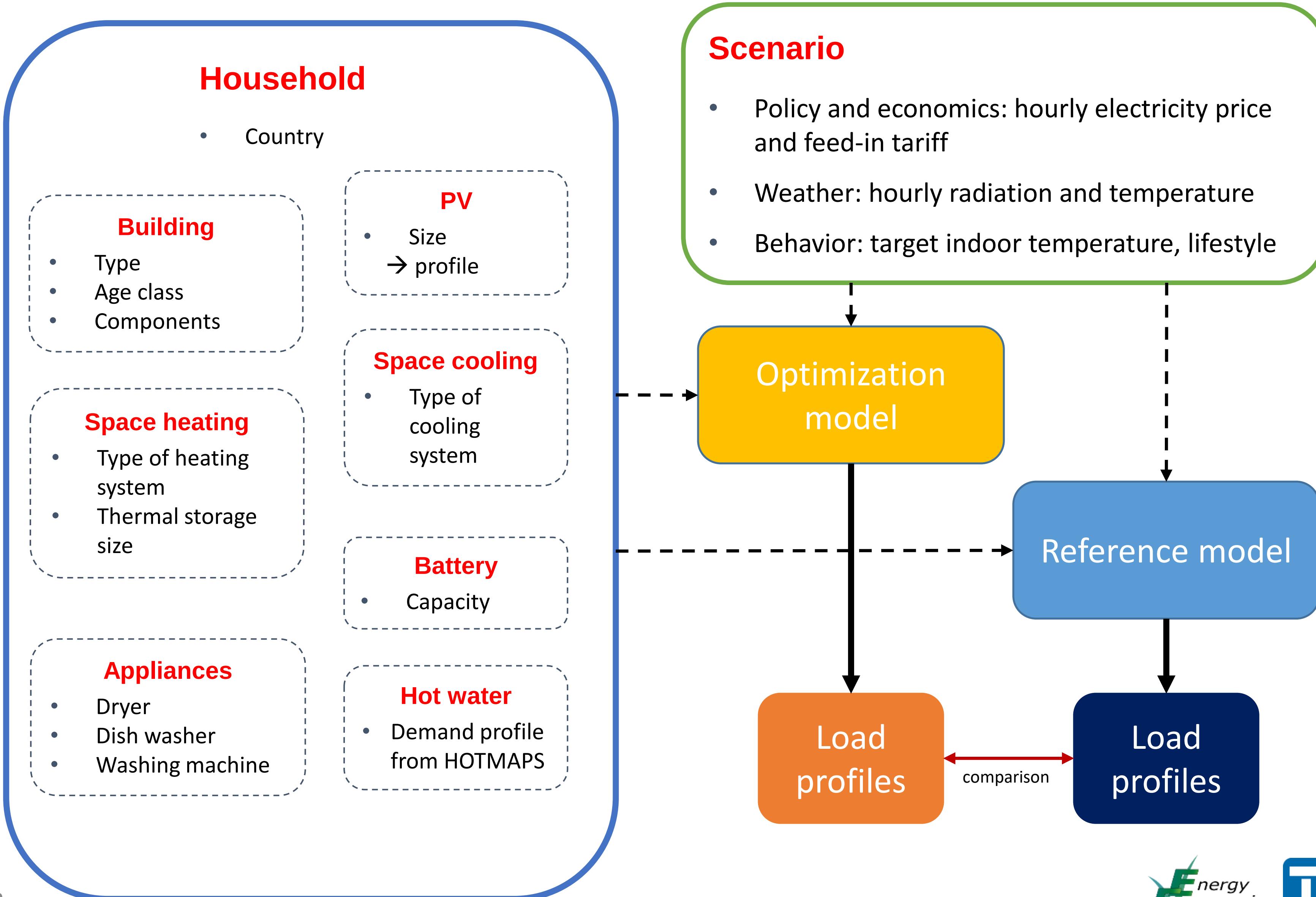
NewTrends – From Consumers to Prosumagers

- Horizon 2020 project
  - How do New Societal Trends affect energy demand?
  - Work package 5 focuses on Prosumagers and big data (new data sources) in energy demand models related to the built environment
    - Link to the project: https://cordis.europa.eu/project/id/893311

My objective:

- How can active demand response measures of buildings with heat pumps (HP) in the residential sector affect the aggregate load profile on the national level?
  - In this regard the potential storage of the thermal buildings mass is considered for every building

Method


Household
Country
Building
Type
Age class
Components
PV
Size
→ profile
Space cooling
Type of cooling system
Space heating
Type of heating system
Thermal storage size
Battery
Capacity
Appliances
Dryer
Dish washer
Washing machine
Hot water
Demand profile from HOTMAPS
Scenario
Policy and economics: hourly electricity price and feed-in tariff
Weather: hourly radiation and temperature
Behavior: target indoor temperature, lifestyle
Optimization model
Reference model
Load profiles
comparison
Load profiles

Method

Optimization model

- **Perspective:** household
- **Time resolution:** hourly
- **Objective**:
  - minimize the operation cost (s.t. hourly demand profiles of electricity / heating / cooling / hot water)
- **Decision variables:**
  - hourly operation of technologies over one year

Reference model

- **Perspective:** household
- **Time resolution:** hourly
- **Method of operation**:
  - PV generated electricity is used to cover demand
  - Surplus of electricity from PV is stored
  - If storages are full or not available, surplus is sold
  - Appliances (dishwasher, washing machine, dryer) are started randomly throughout the day between 6 am and 9 pm.
  - Thermal inertia is not utilized as storage

Buildings

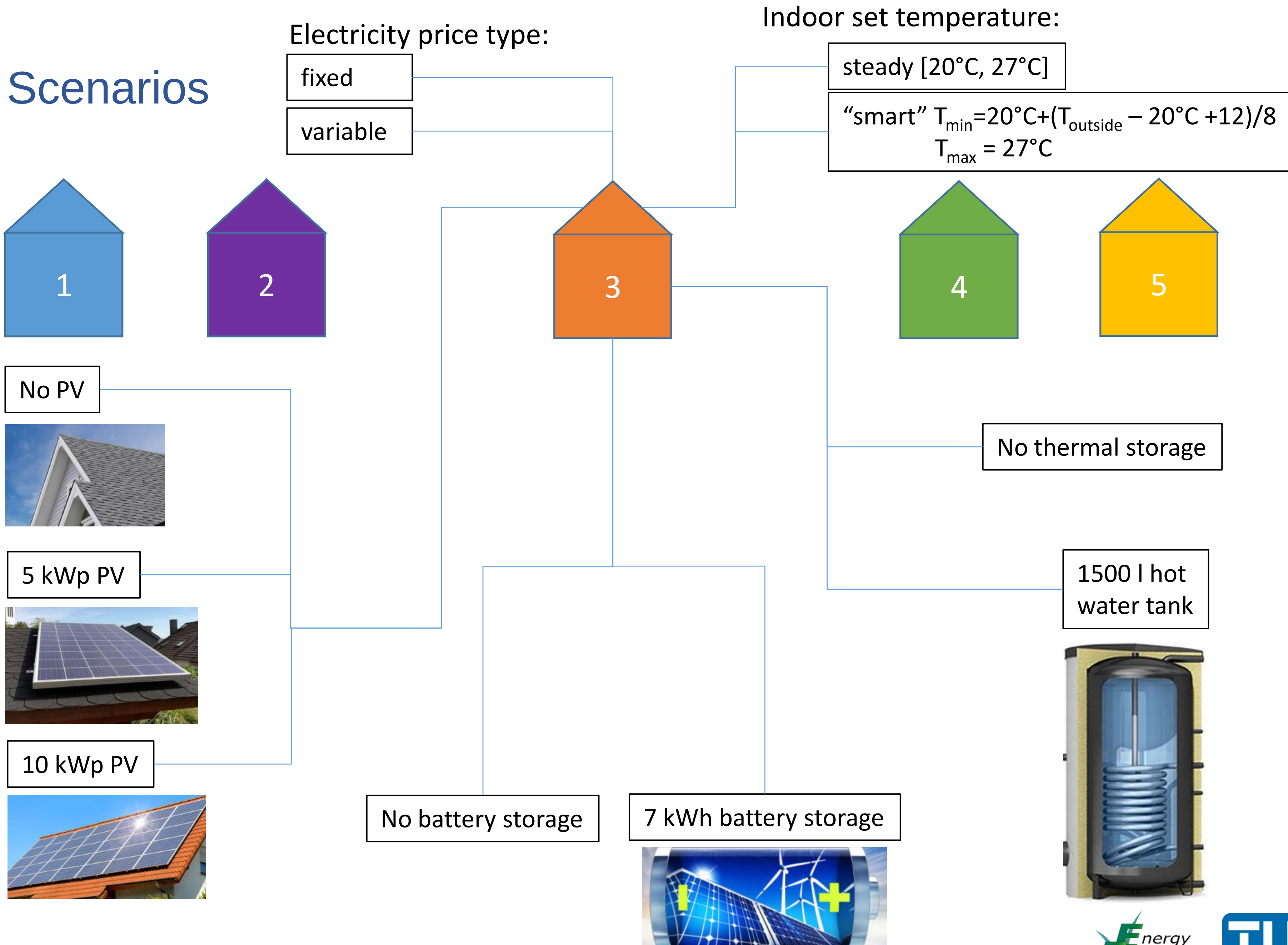
- 5 representative single family houses taken from the building stock database of the “Invert/EELab” for the case of Austria

Parameters of the representative buildings for calculation of the 5R1C model explained in DIN ISO 13790

Building ID	A_f [m²]	H_{op} [W/K]	H_{tr_w} [W/K]	H_{ve} [W/K]	C_m factor [J/K]	A_m [m²]	Construction year	Number of buildings
1	154	203	86	43.595	213 505	3	1961-1970	21 451
2	163	208	97	46.189	213 505	3	1971-1980	97 729
3	166	144	77	46.938	213 505	3	1981-1990	145 126
4	170	121	69	47.964	181 194	2.8	1991-2000	208 914
5	170	95	54	47.964	114 415	2.5	2001-2008	110 345

A_f … usable area
H_{op} … heat transmission coefficients for the opaque building components
H_{tr_w} … heat transmission coefficients for windows
H_{ve} … heat transfer coefficient for ventilation
C_m … internal heat storage capacity of the building
A_m … effective mass-related area

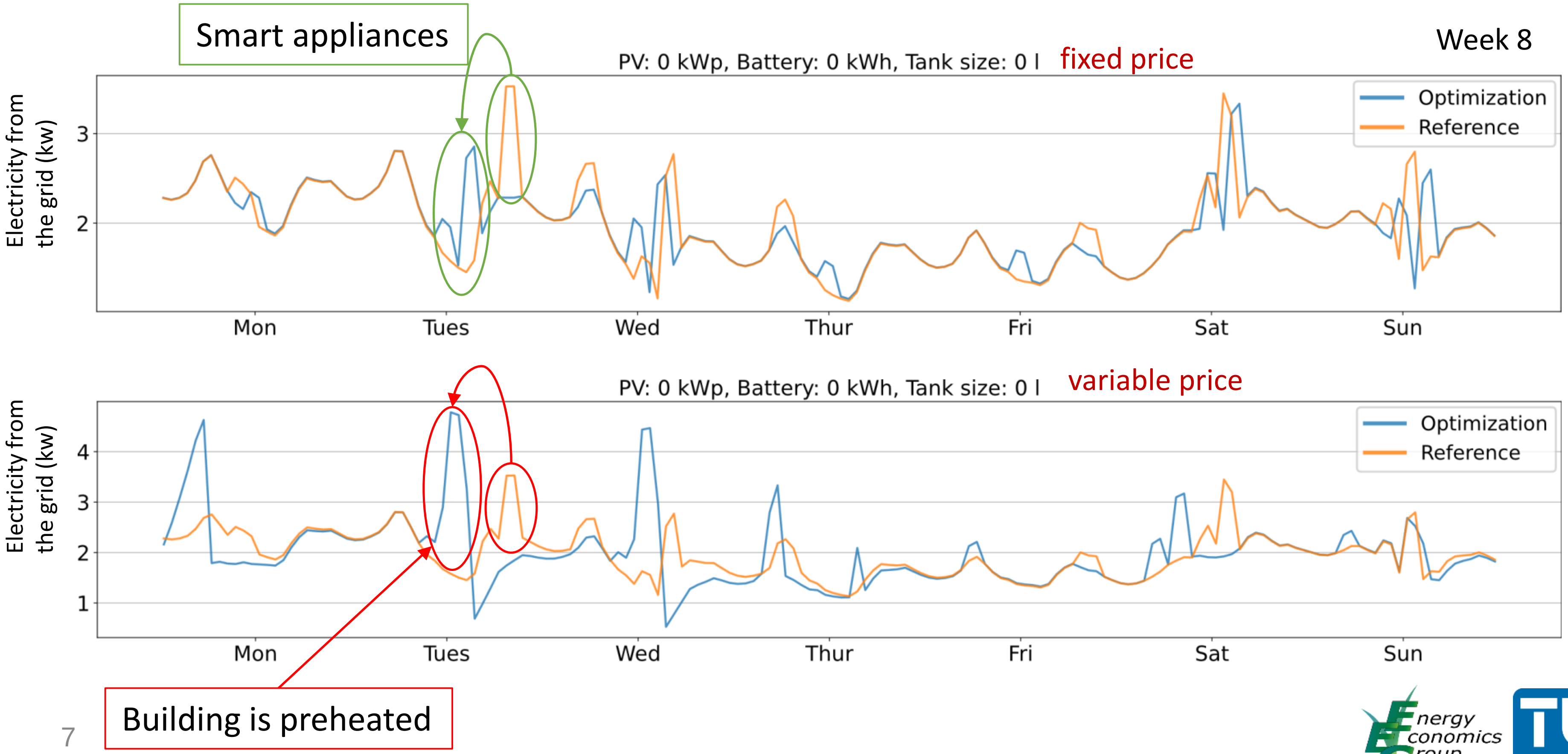
Scenarios



Electricity price type:
fixed
variable
Indoor set temperature:
steady [20°C, 27°C]
“smart” T_{min}=20°C+($T_{outside}$ – 20°C +12)/8
T_{max} = 27°C
1
2
3
4
5
No PV
5 kWp PV
10 kWp PV
No battery storage
7 kWh battery storage
No thermal storage
1500 l hot water tank

Preliminary Results

- A flat electricity price does not promote load shifting without storages
- Utilizing the thermal mass shifts peaks but also results in higher energy demand (due to losses)



Energy Economics Group

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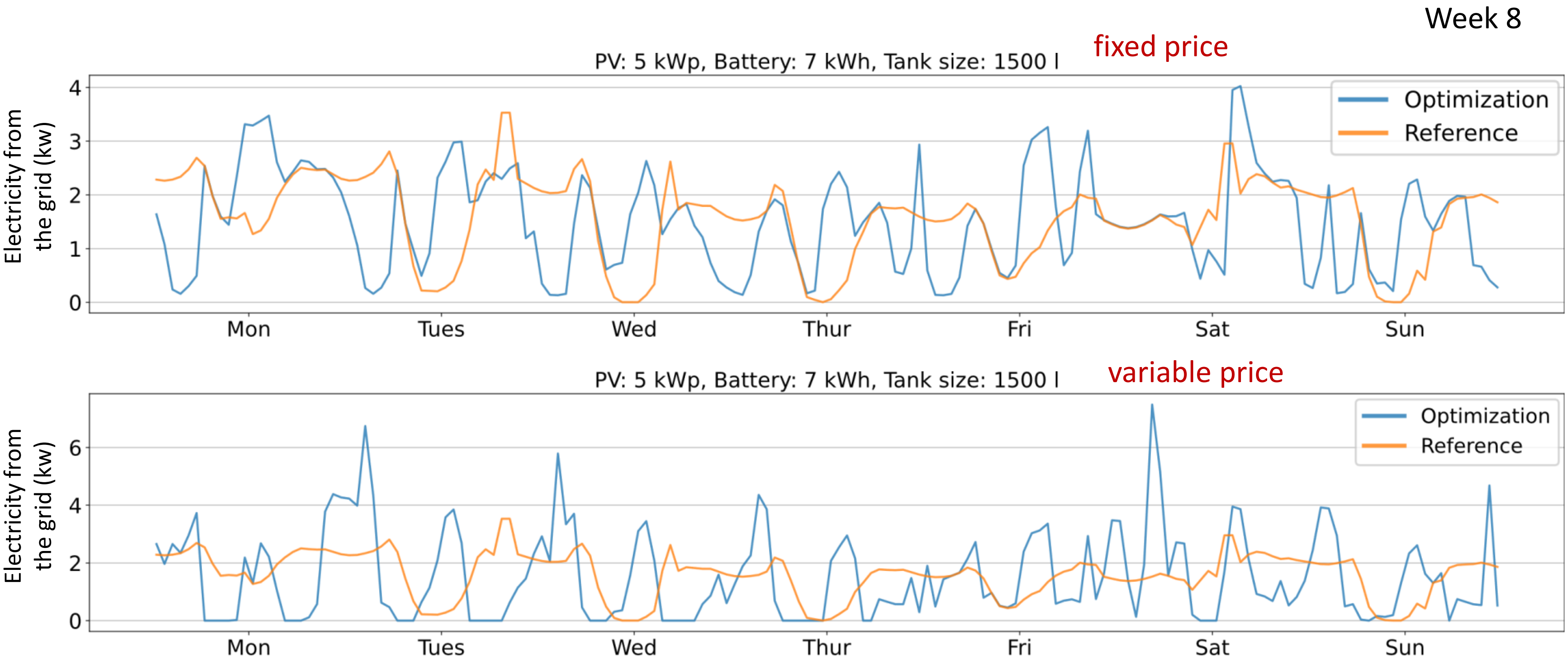
Preliminary results

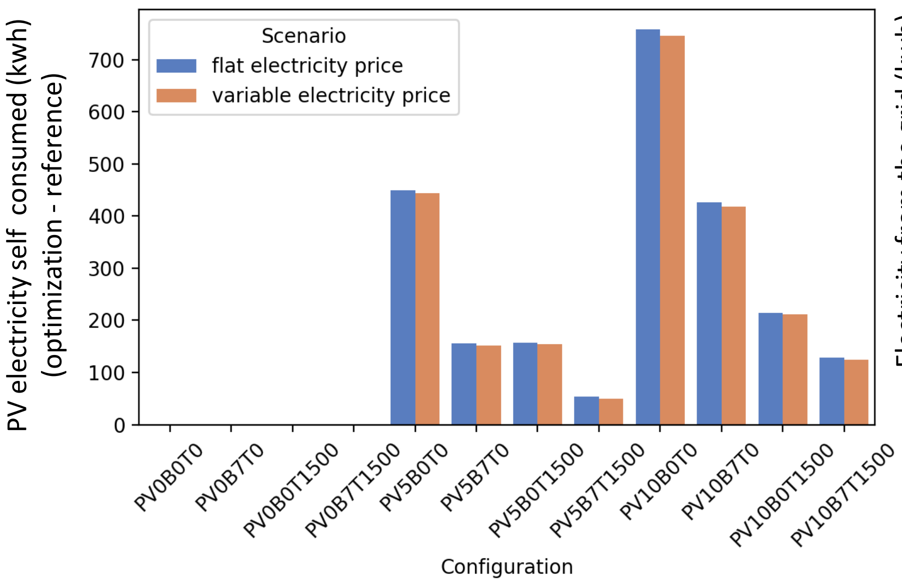
- When storages and PV are implemented the electricity demand becomes volatile especially when the price is variable



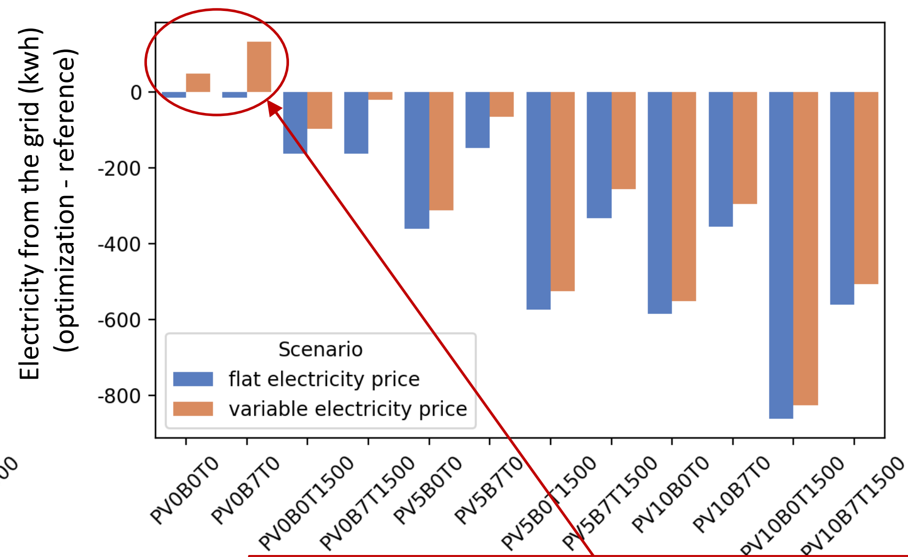
Preliminary results

- The scenario with a variable electricity price results in a higher total electricity demand (because of losses)
- PV and thermal storages reduce the total amount needed from the grid
- The scenario with a fixed electricity always results in lower electricity used from the grid
- Fixed price results in slightly higher PV self consumption compared to variable price

PV self consumption average difference between optimization and reference for different electricity prices



Grid electricity consumption average difference between optimization and reference for different electricity prices



Preheating of buildings and use of battery Storage result in higher losses

PV…Photovoltaic, B…Battery storage, T…Thermal storage

→ PV5B7T1500…**PV**: **5**kWp, **B**attery storage: **7** kWh, **T**hermal storage: **1500** l

Conclusion and Outlook

Findings

- Optimization will always result in lower Electricity demand (fixed price)
- Variable electricity price results in large amounts of energy shifted and contrary to the fixed electricity price it will increase the electricity demand when no thermal storage and PV are available.
- Even households without any kind of storage and PV can shift their demand considerably with their thermal mass

Outlook

- Quantification of overall load shifting potential
- Aggregation of load profiles to the whole building stock
- Including the actual distribution of heating systems in the buildings as well as installed PV systems
- Inclusion of investment costs
- Development of different scenarios until 2050 by coupling this model with the building stock model „Invert“
- Analyze cooling energy
- Analyze effects in other countries

Thank you for your attention!

Philipp Mascherbauer

mascherbauer@eeg.tuwien.ac.at

Orig. Photo: Patrick Stargardt