Impact of occupant behaviour on energy – and power demand

HOUSEHOLD ELECTRICITY AND DOMESTIC HOT WATER

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Background: Designing a building

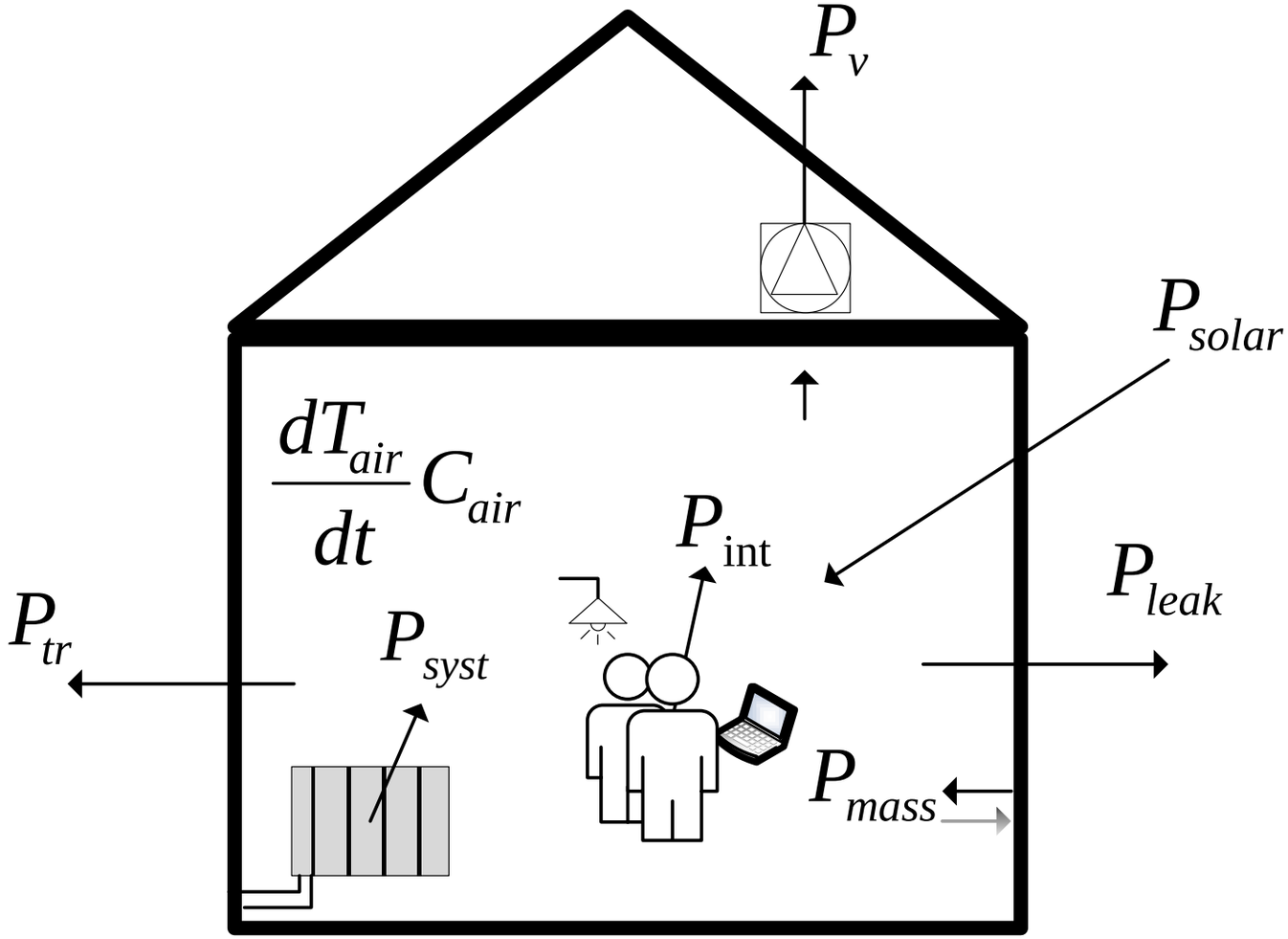
Define goals
- Functionality
- Efficiency

Designing the building	Simulating the building
Building Parameters • Geometry /room layout • Envelope properties • Orientation • Window-to-wall ratio	**Occupant variables** • Presence/Absence • Use of appliances • Use of DHW • Interactions that causes energy use
Location Parameters • Longitude and Latitude • Altitude • Surroundings	**Outdoor climate variables** • Outdoor temperature • Sunlight • Wind

Evaluate design performance
- Functionality
- Efficiency

Background: The heat balance of a building

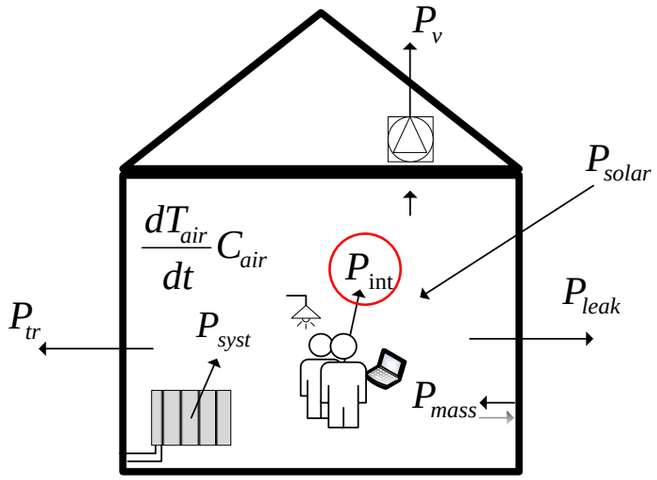
- Losses
  -Ventilation, $P_{vent}(t)$
  -Transmission, $P_{tr}(t)$
  -Air leakage, $P_{leak}(t)$
- Gains
  -Occupants, $P_{int}(t)$
  -Sun, $P_{solar}(t)$
- Inertia
  -Thermal mass, $P_{mass}(t)$
- Balance
  -Heating system, $P_{syst}(t)$
- Outcome
  -Indoor temperature, $\frac{dT_{air}}{dt}C_{air}$

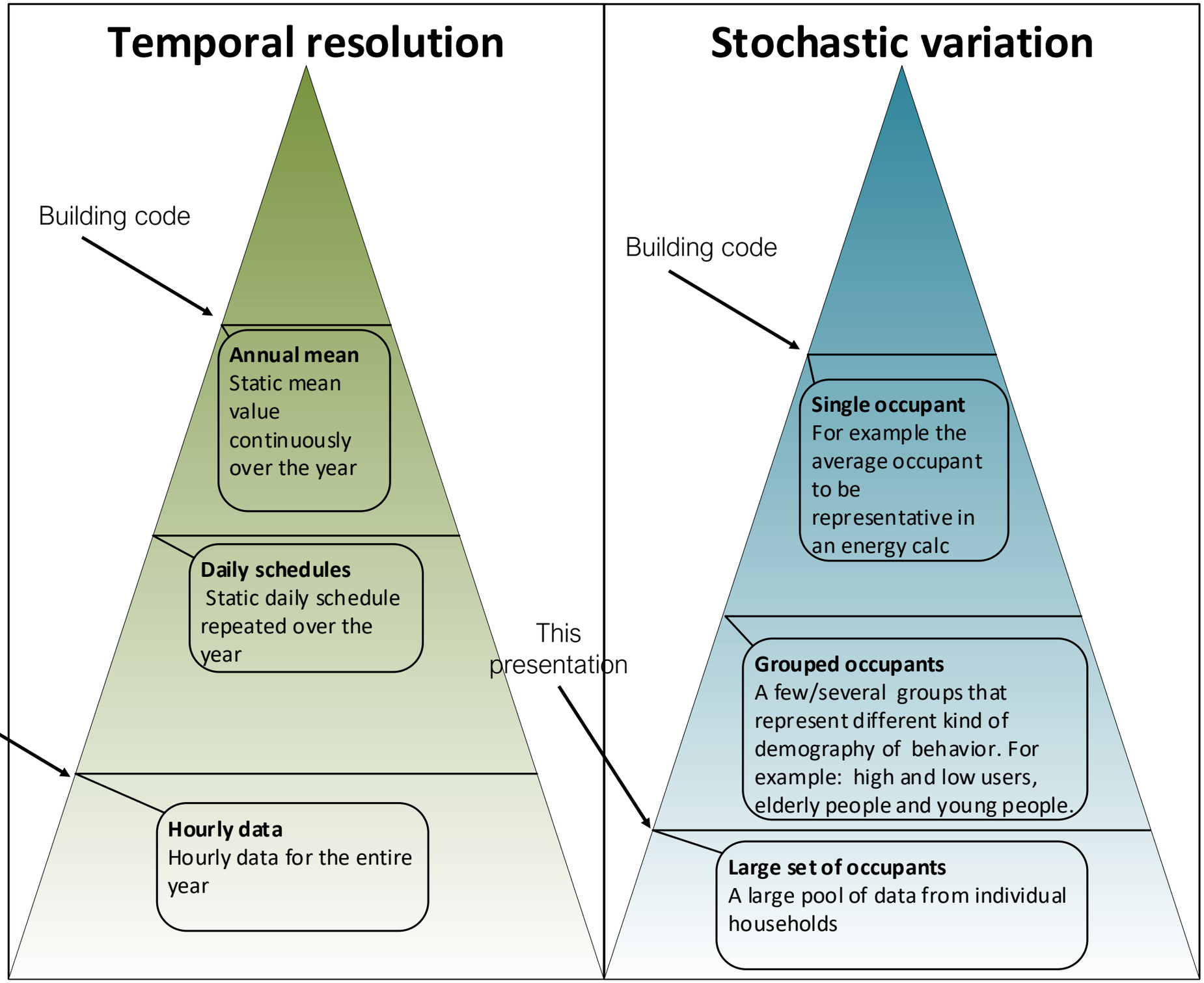


$$E_{syst} = \sum_{i=1}^{N} P_{syst,i} \cdot dt_i \qquad (kW\ h/a)$$

$$\frac{dT_{air}}{dt}C_{air} = P_{int}(t) + P_{solar}(t) + P_{mass}(t) + P_{syst}(t) - P_{tr}(t) - P_{leak}(t) - P_v(t) \qquad (W)$$

Background: Varying internal loads

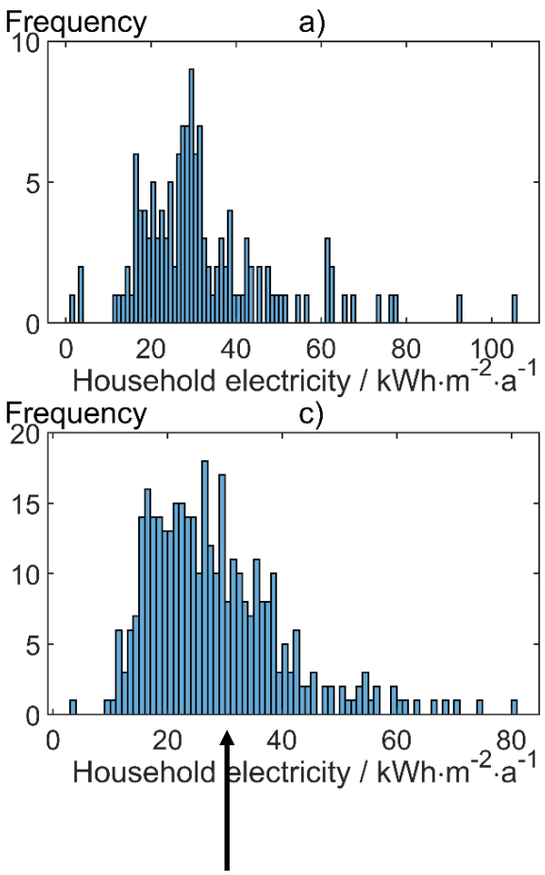


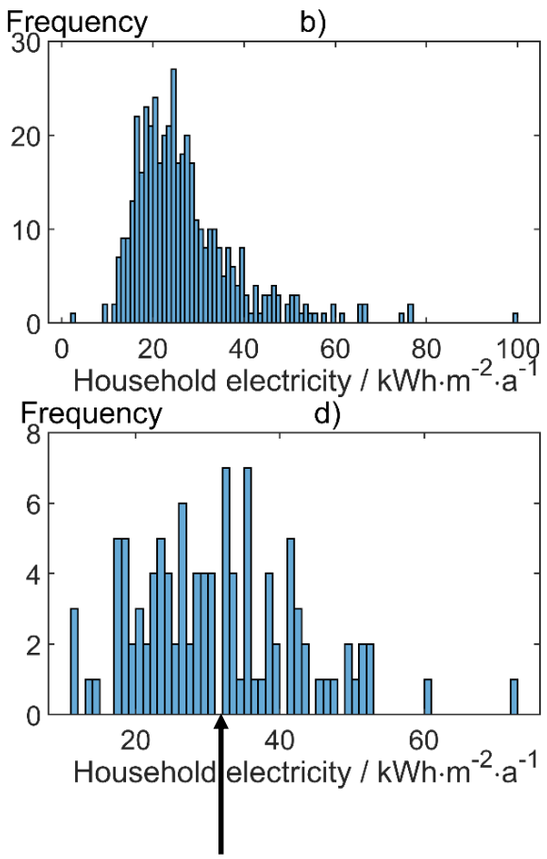


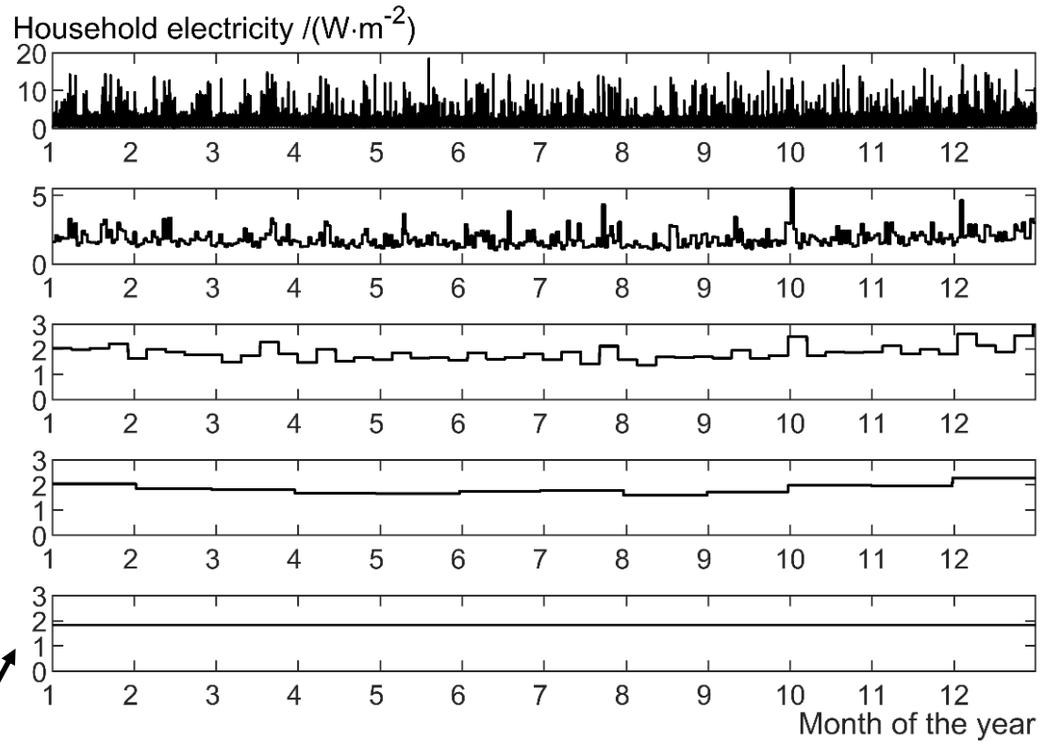
Method - Data

- Temporal resolution
- Stochastic variation

- 1000 apartments – 1 year
- DHW – Household electricity

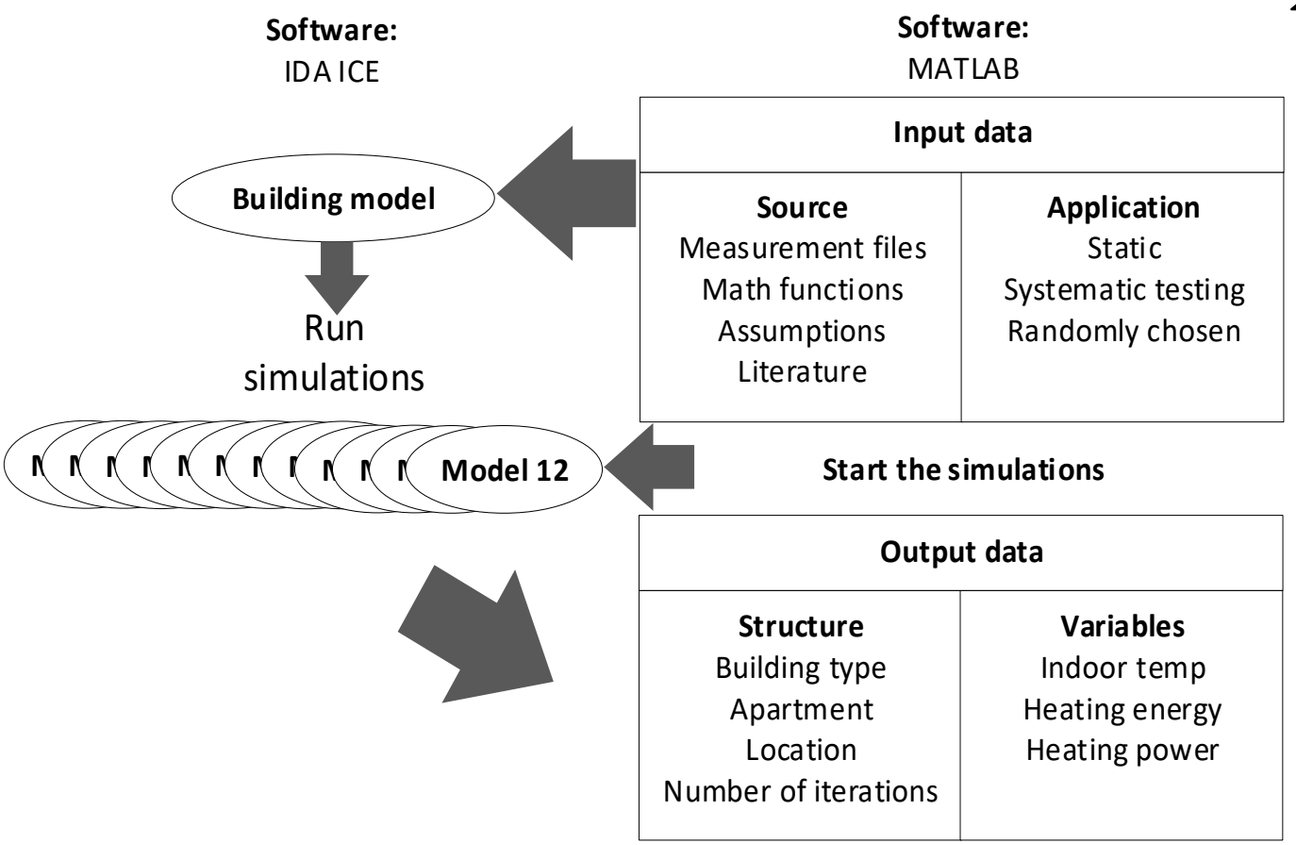


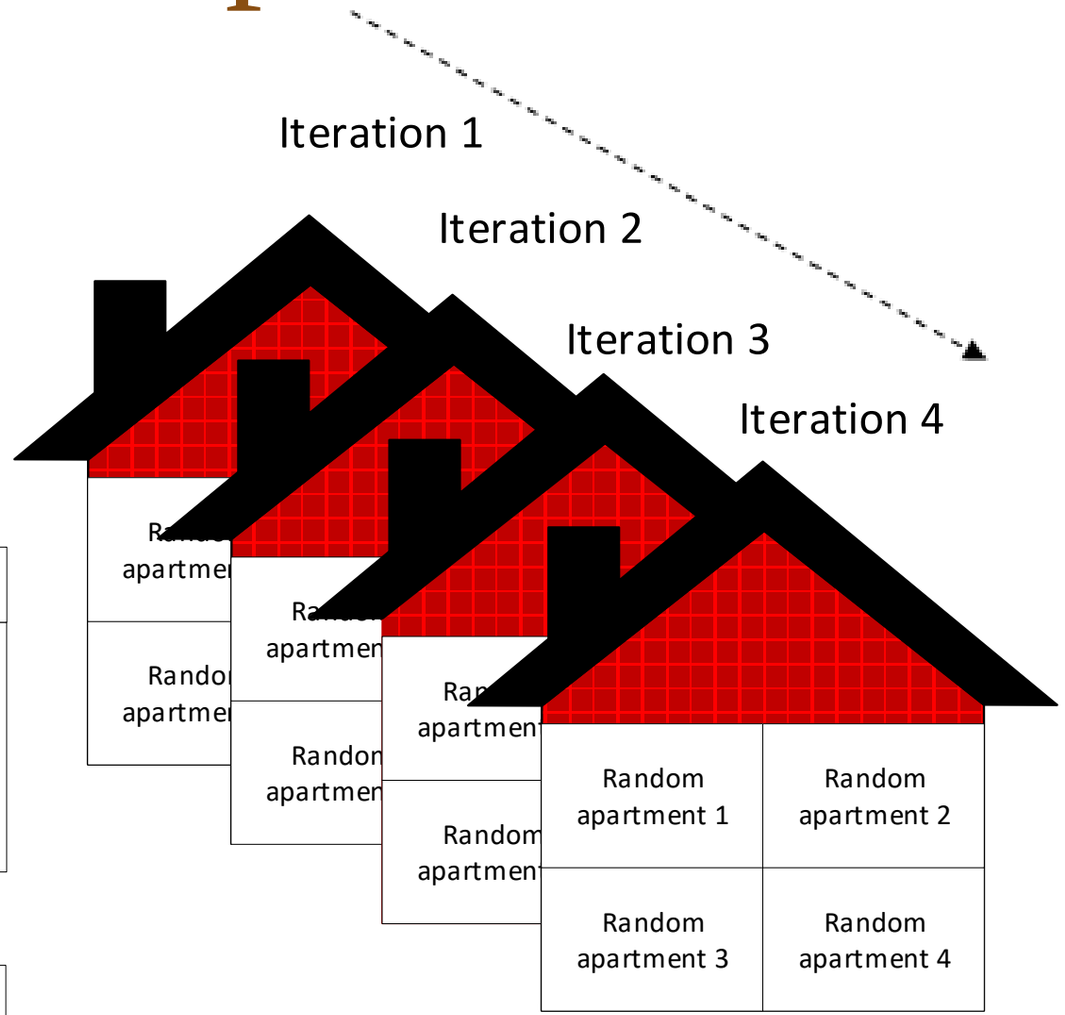


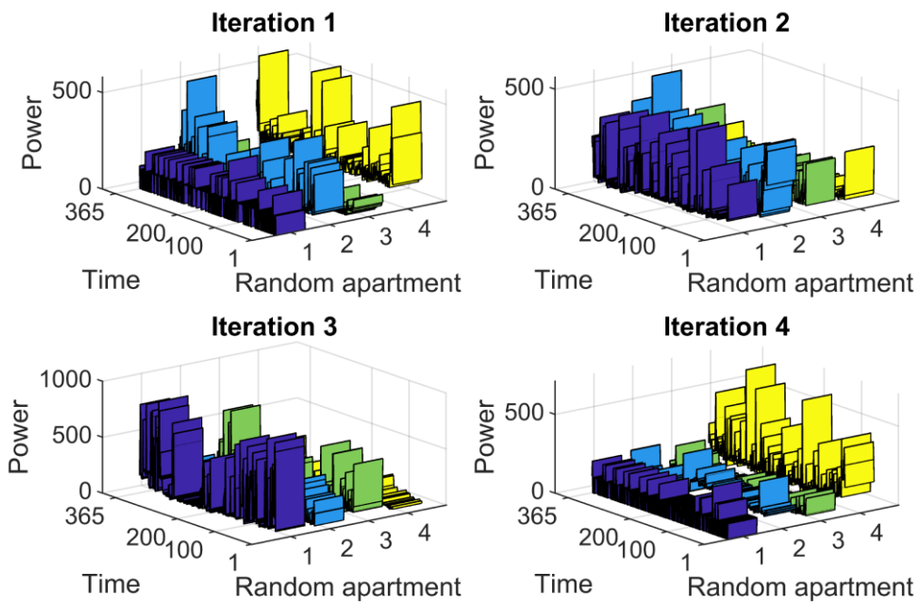


Method – simulation procedure

- Simulating variations
- IDA-ICE & MATLAB

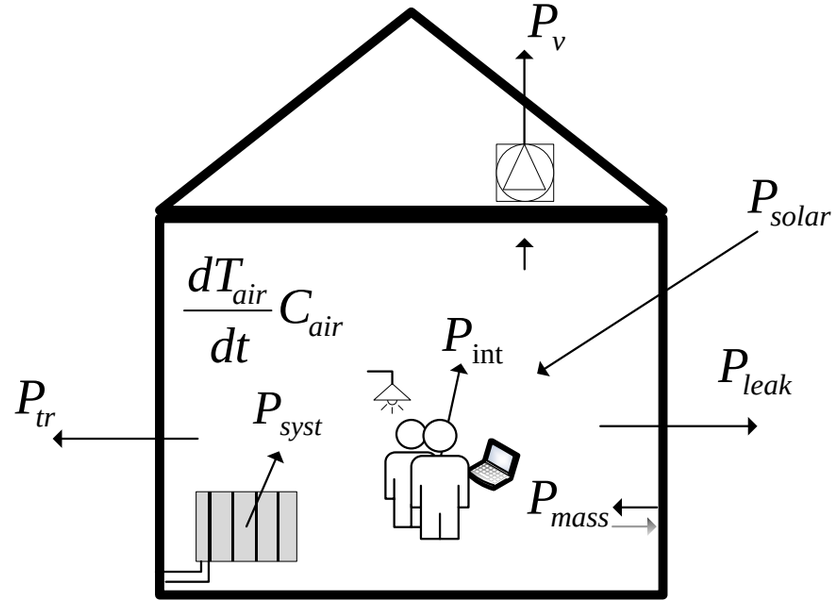


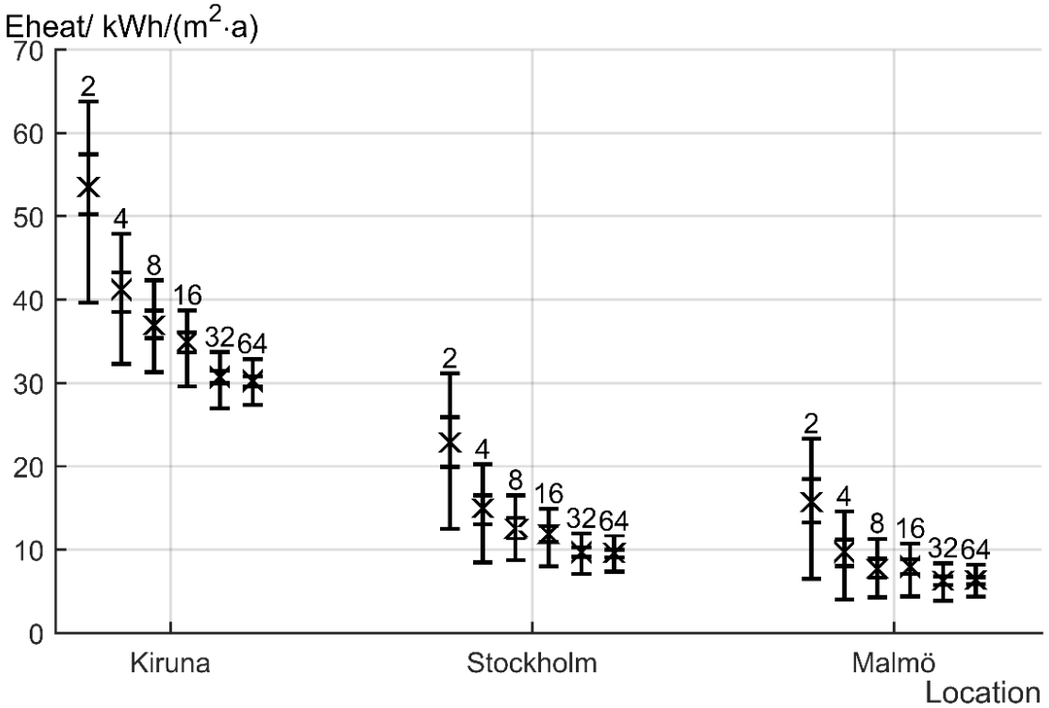


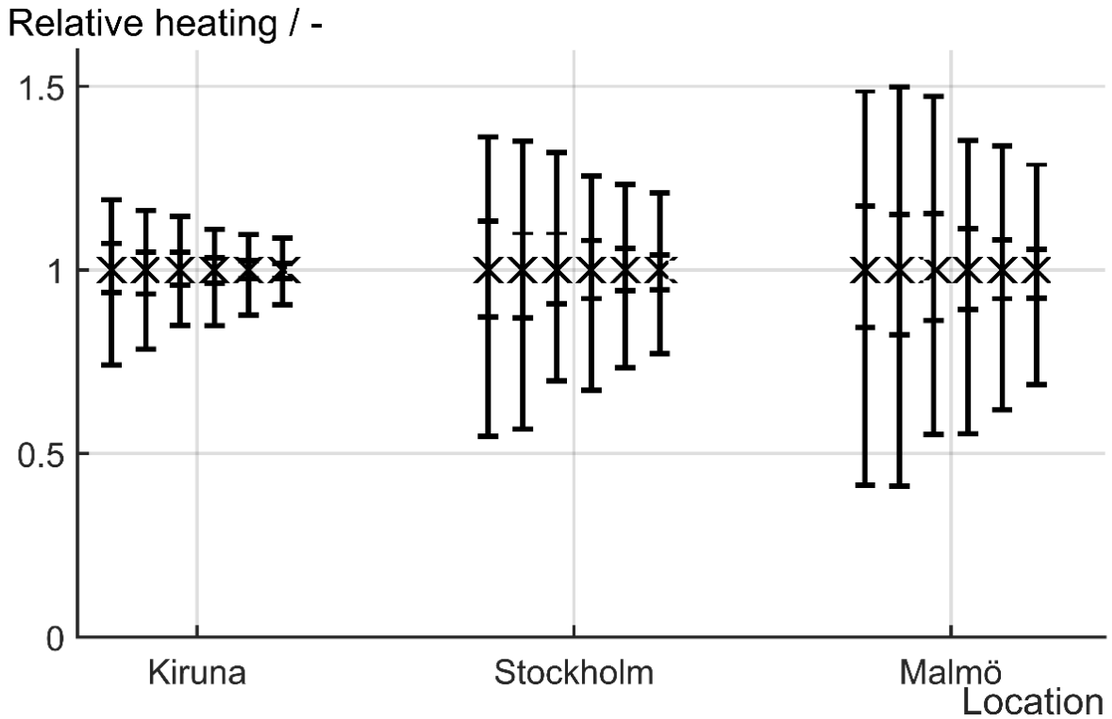


Results - Energy

- Impact of stochastic variation on energy demand for space heating

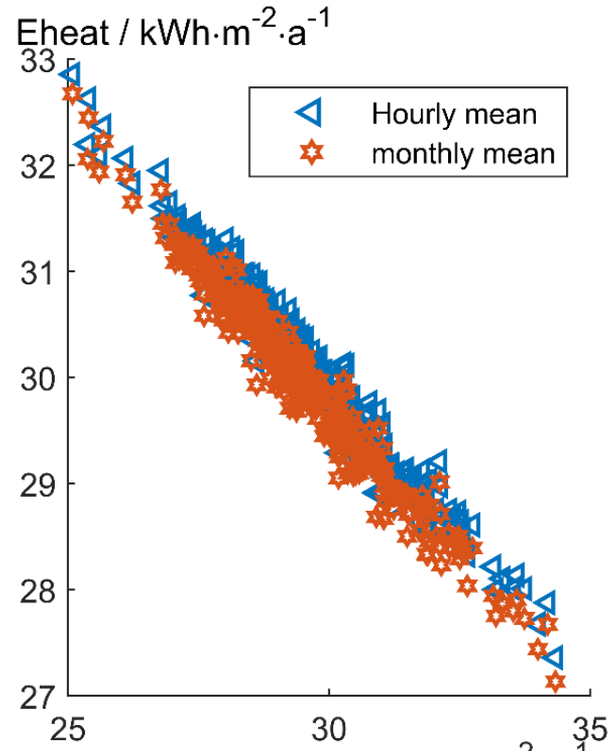


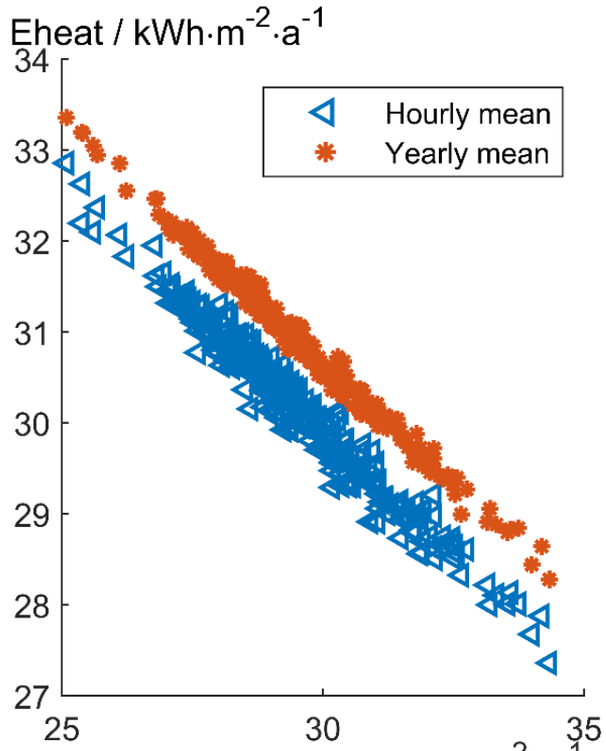


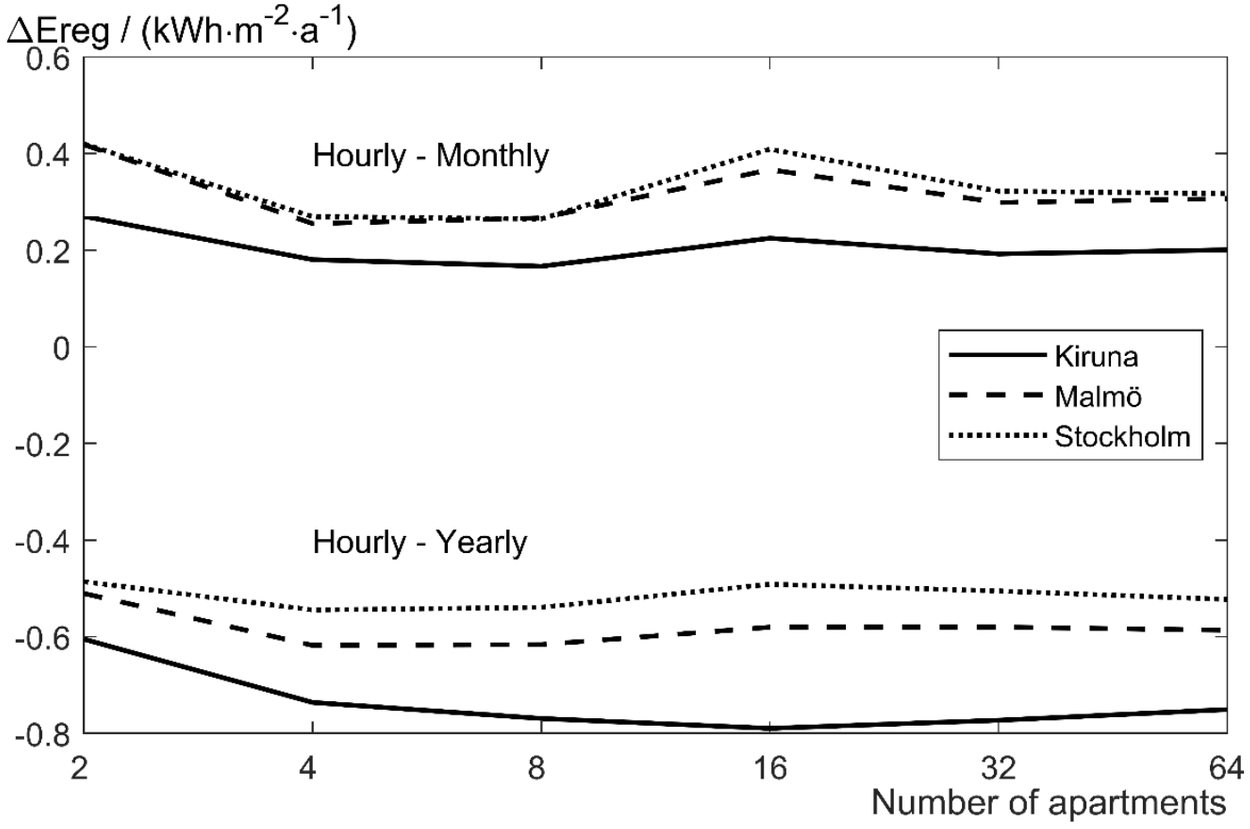


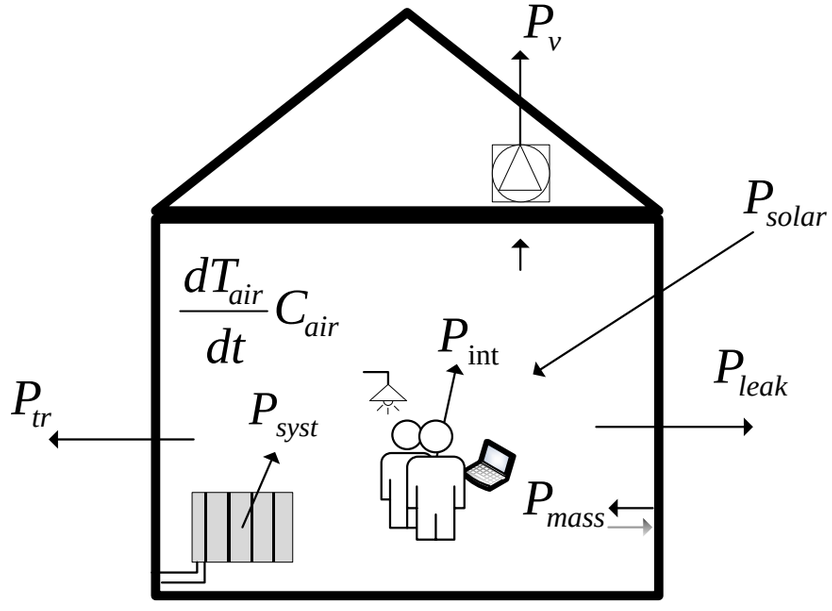
Results - Energy

- Impact of temporal resolution on energy demand for space heating



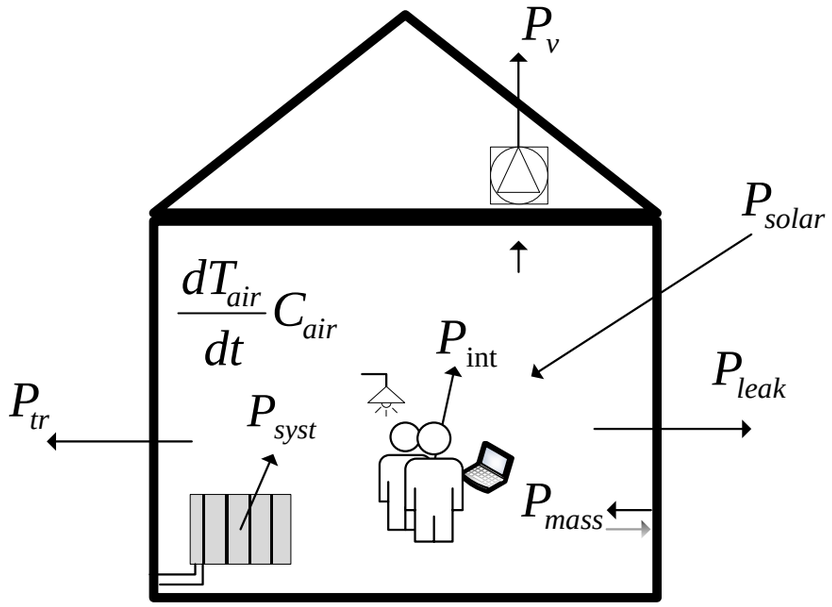


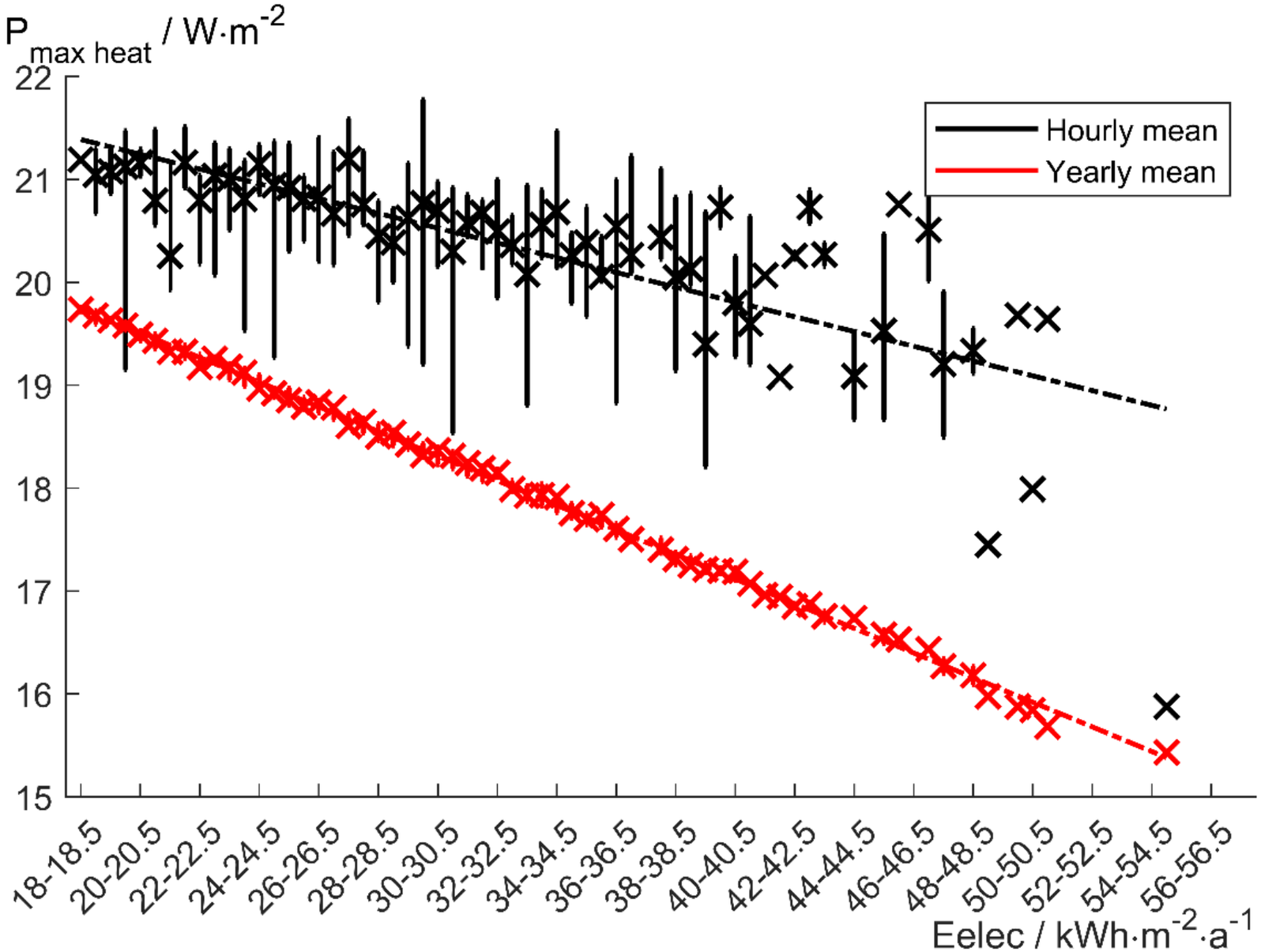




Results - Power

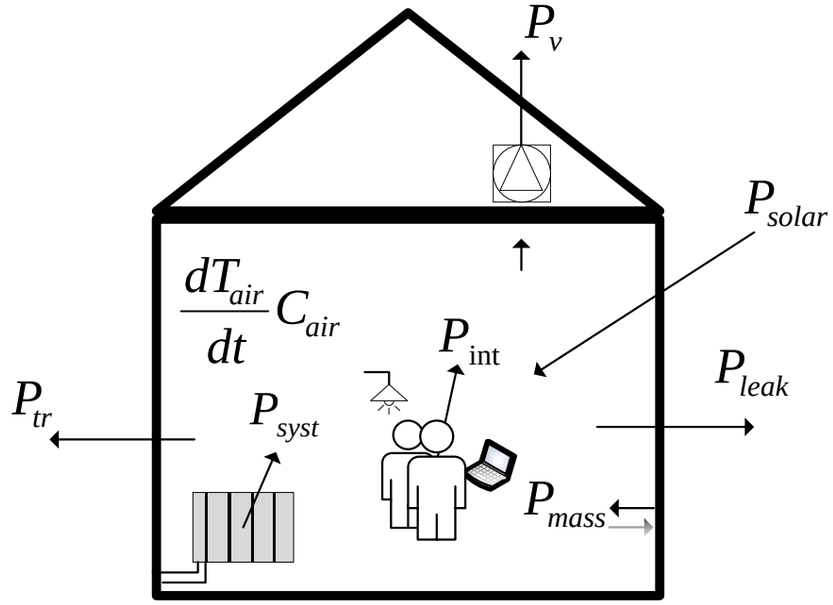
- Impact of temporal resolution and stochastic variation on power demand for space heating

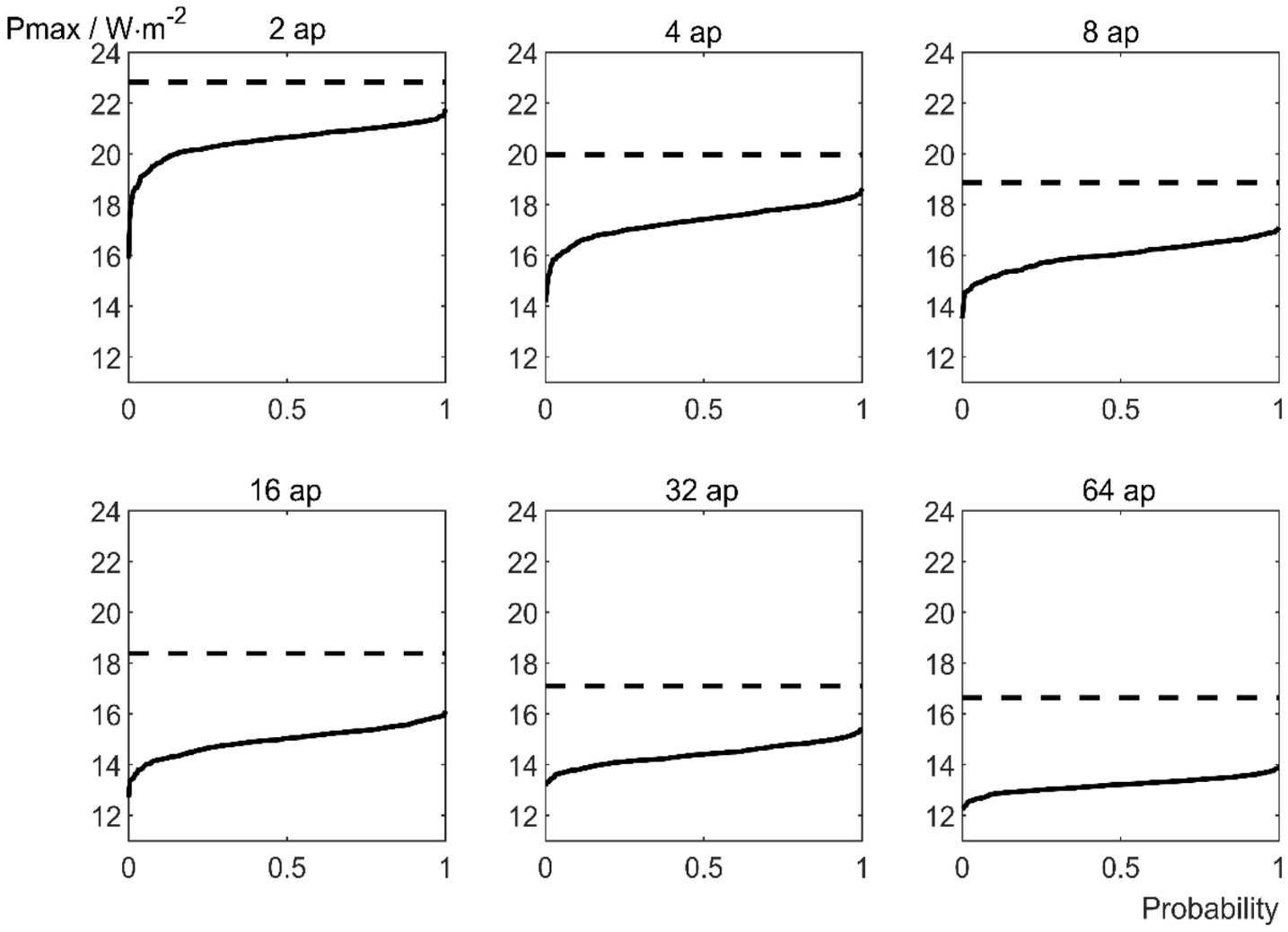




Results - Power

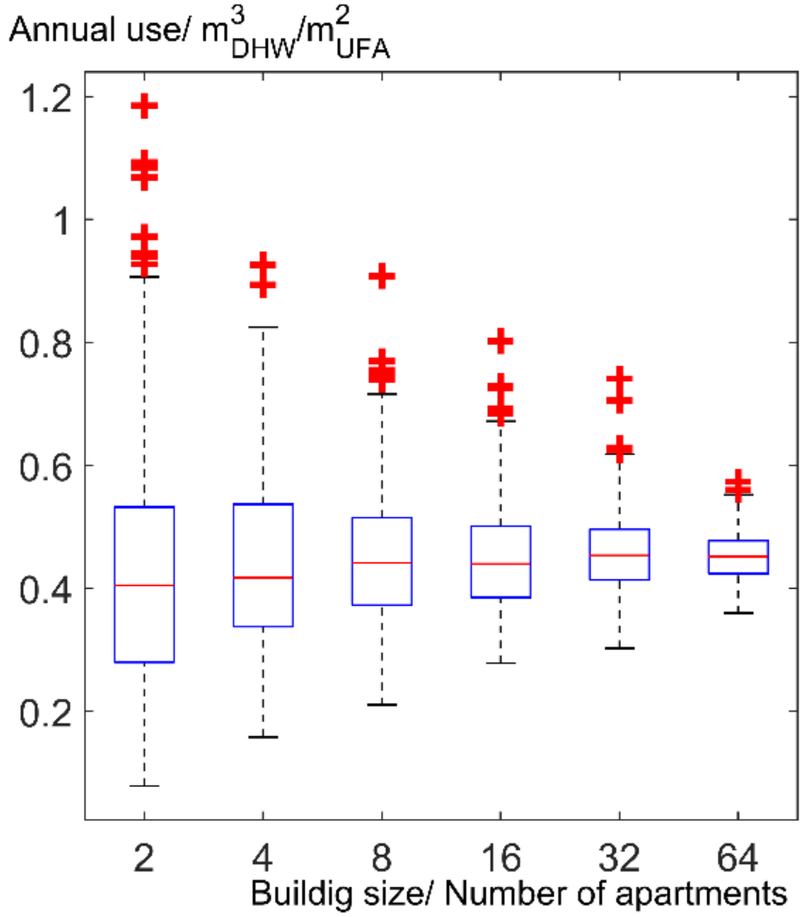
- Comparing heating demand – unoccupied – dashed line and 300 different occupant combinations (hourly values)





RQ1: Results & Discussion

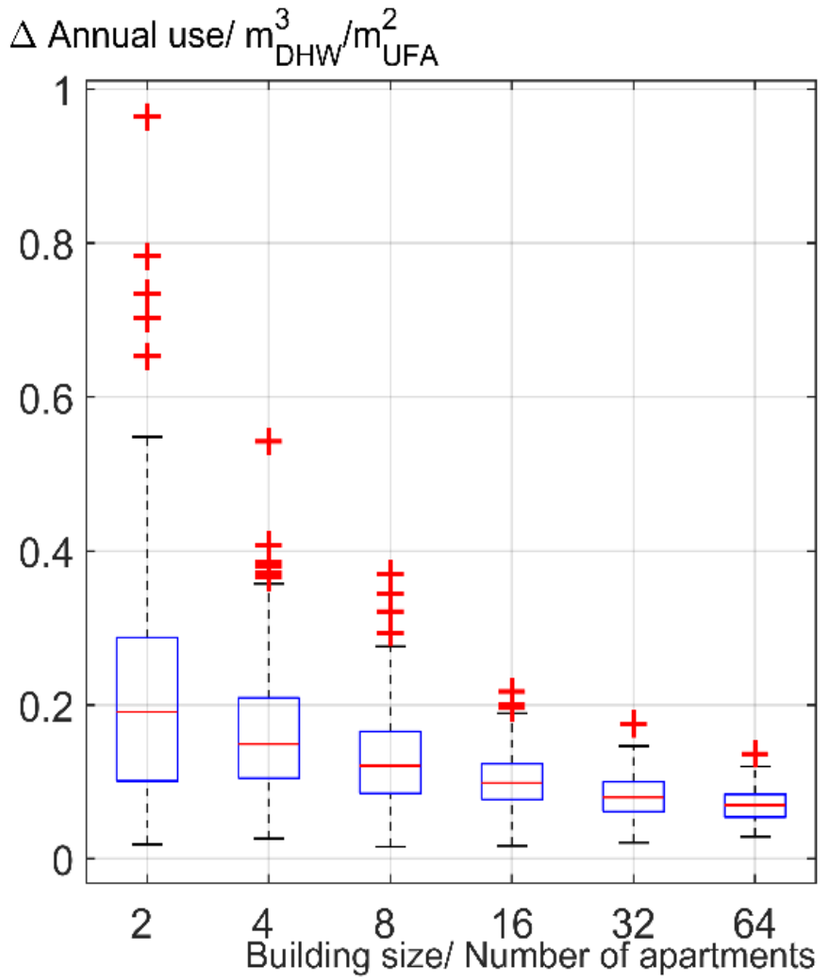
- Spread decrease with increasing number of apartments
- Translate to energy
- 55kWh/m³ approximately for heating the water
- Interquartile range 14.3 kWh/(a·m²) to 3.3 kWh/(a·m²)



Number of apartments	25-perc/ (m^3_{DHW}/m^2_{UFA})	Median/ (m^3_{DHW}/m^2_{UFA})	75-perc/ (m^3_{DHW}/m^2_{UFA})	Interquartile range/ (m^3_{DHW}/m^2_{UFA})	Mean/ (m^3_{DHW}/m^2_{UFA})
2	0.29	0.42	0.55	0.26	0.45
4	0.34	0.43	0.54	0.20	0.45
8	0.38	0.45	0.53	0.15	0.46
16	0.40	0.45	0.51	0.11	0.46
32	0.41	0.45	0.49	0.09	0.45
64	0.42	0.45	0.48	0.06	0.45

Results & Discussion : Occupant behaviour

- Variation in use in between years in buildings with the same apartments
- Median energy varies from
  11 kWh/(a·m²)
  to
  3.9 kWh/(a·m²)



Number of apartments	25-perc/ (m^3_{DHW}/m^2_{UFA})	Median/ (m^3_{DHW}/m^2_{UFA})	75-perc/ (m^3_{DHW}/m^2_{UFA})	Interquartile range/ (m^3_{DHW}/m^2_{UFA})	Mean/ (m^3_{DHW}/m^2_{UFA})
2	0.10	0.19	0.29	0.19	0.21
4	0.10	0.15	0.21	0.10	0.16
8	0.08	0.12	0.17	0.08	0.13
16	0.08	0.10	0.12	0.05	0.10
32	0.06	0.08	0.10	0.04	0.08
64	0.05	0.07	0.08	0.03	0.07

Conclusions

- **How does heating power and energy demand vary due to different occupant behaviour?**
  -Energy demand for space heating can vary ±40 to 60 % for occupants with uncommonly high or low use of household electricity and by ±5 to 20 % for the most common 50 % of the combinations.

  -The varying annual use of domestic hot water varied by almost factor of two, from 0.25 m^3_{DHW}/m^2_{UFA} for the 25 percentile to over 0.5 m^3_{DHW}/m^2_{UFA} for the 75 percentile.

  -Impact of time resolution on energy demand less prominent

  -Impact of time resolution on power demand have a similar impact as the stochastic variation

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