Energy performance evaluation of a nearly Zero Energy Building

The reasons for the performance gap between expected and actual building operation

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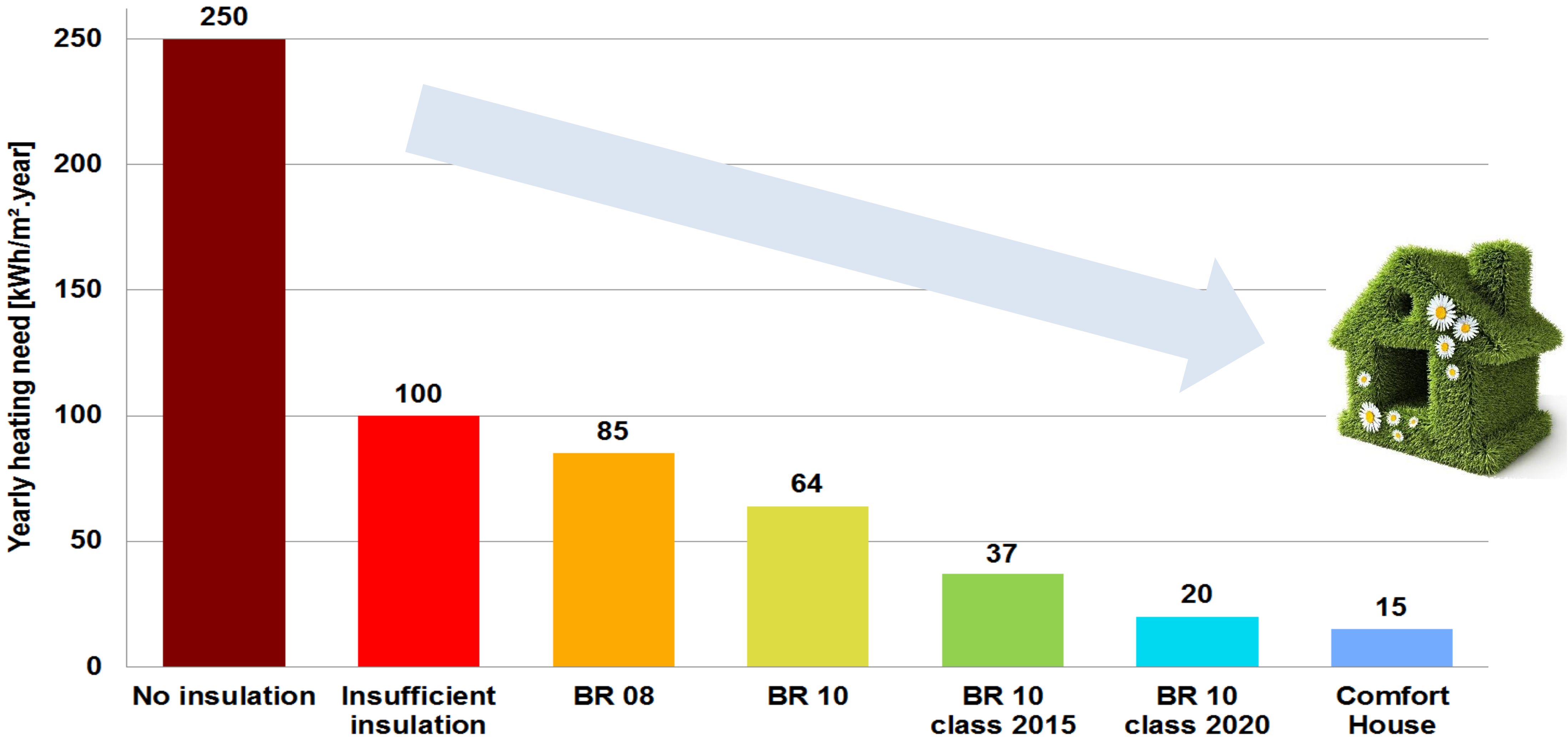
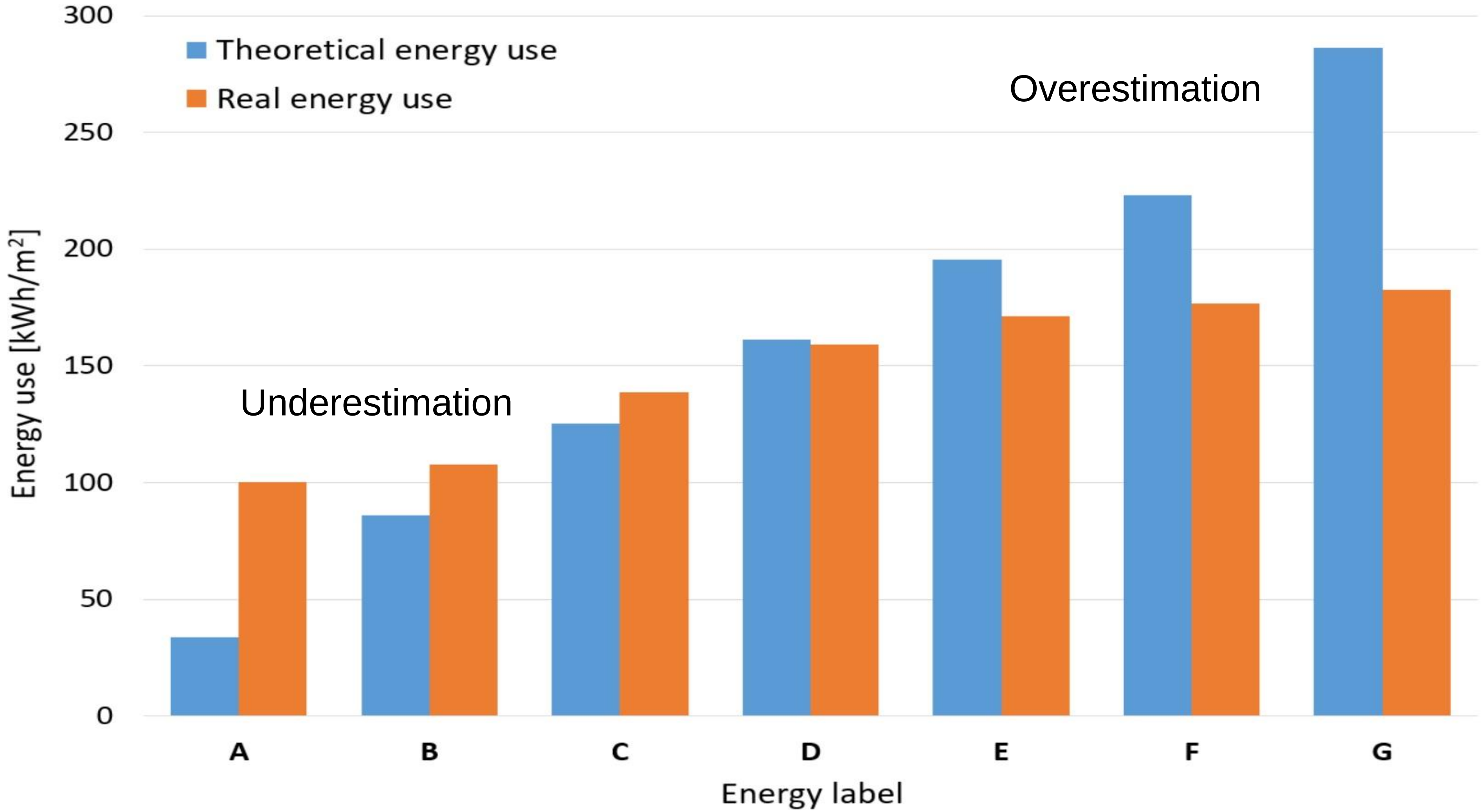
Tightening of the building energy regulations



Yearly heating needs according to building energy regulations in Denmark

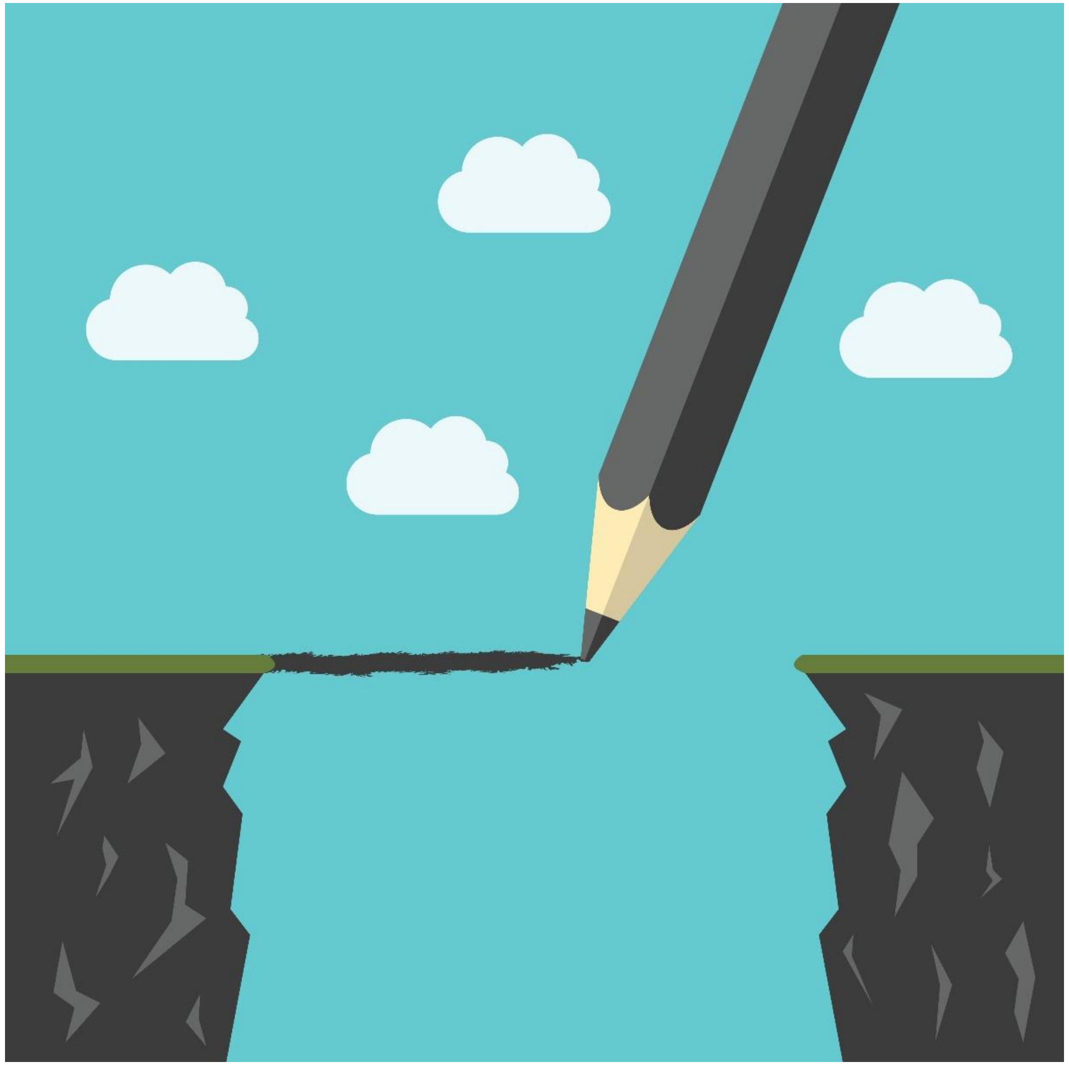
Gap between theoretical and real energy use in buildings



Comparison theoretical and real energy use of 230 000 houses in Denmark [Gram-Hanssen and Hansen, 2016]

Bridge the gap

Need better understanding of occupants and users' practices that have large impacts on performance of low-energy buildings.

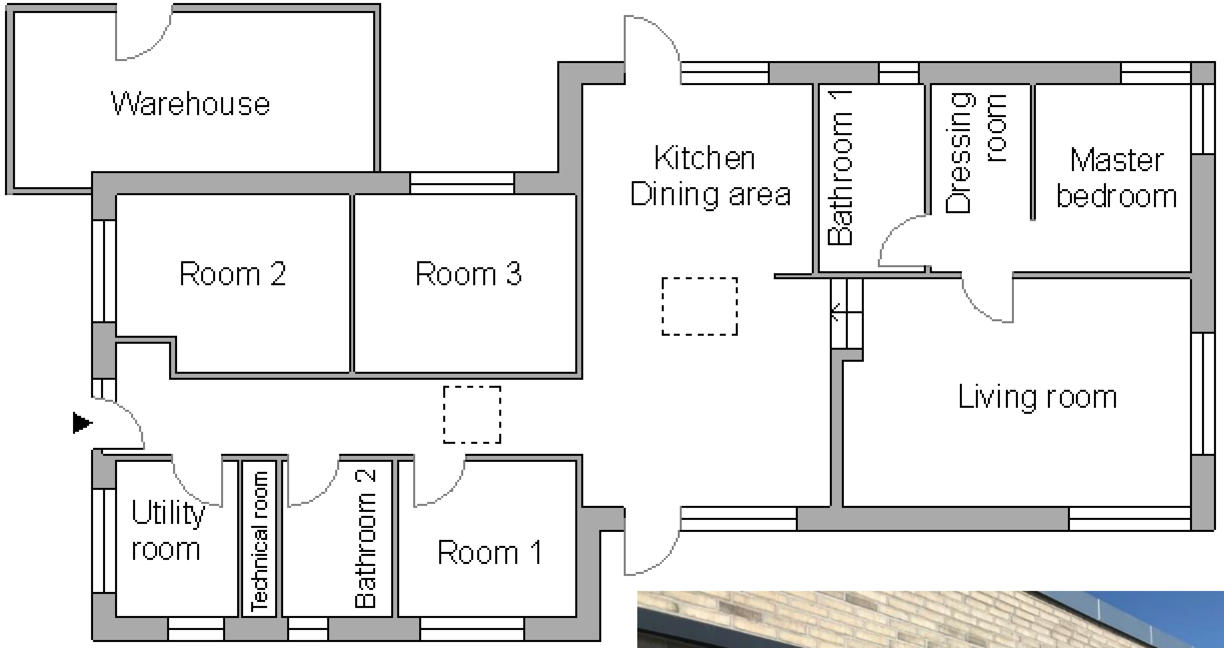


Case study of a nZEB in Denmark

One-year monitoring and assessment of energy performance and indoor environment quality.

Case study of a nZEB in Denmark

- One-story single-family house in Denmark
- 160 m^2
- 4 bedrooms, 2 bathrooms
- Nearly Zero Energy Building
- Built in 2017
- Design yearly primary energy use: 30 kWh/m^2
- Occupants: a young couple



Case study of a nZEB in Denmark

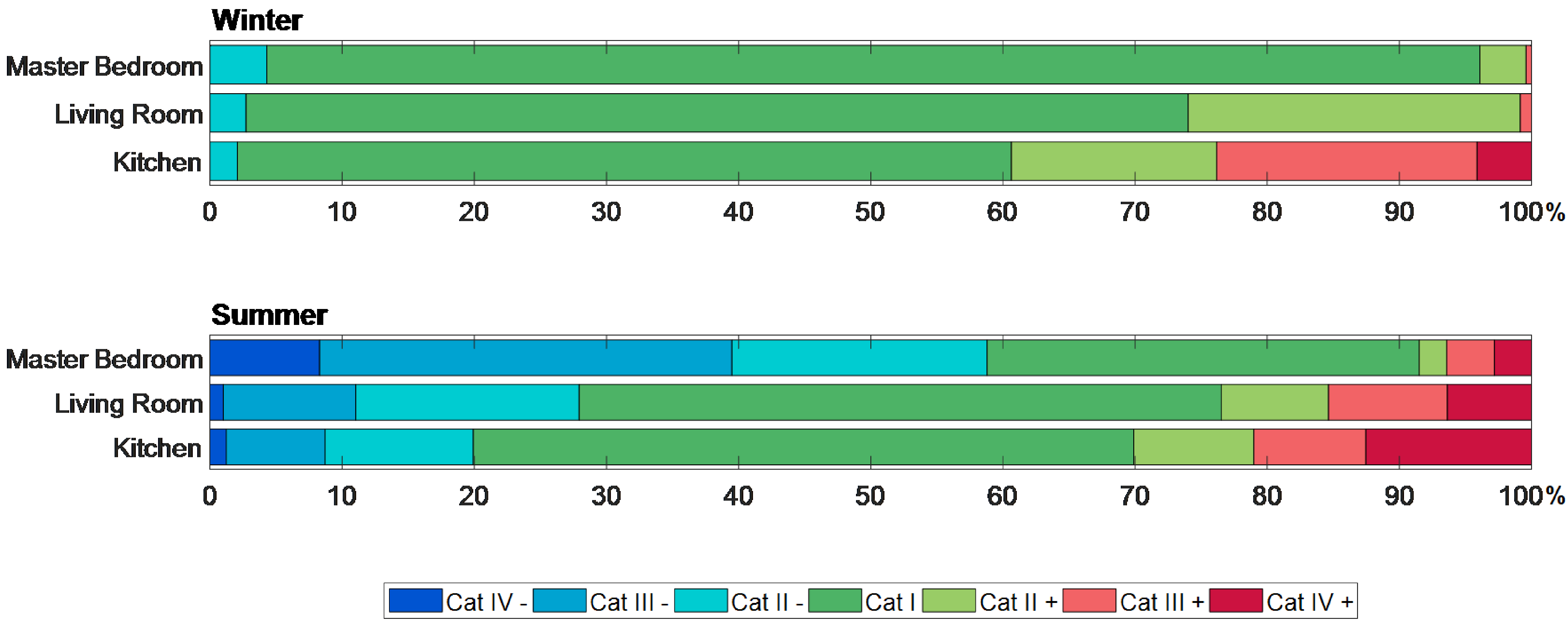
- Floor heating system: district heating
- Ventilation unit: Air-to-water heat pump for heat recovery and DHW production
- Ventilation control:
  - CO_2
  - Humidity
  - Temperature
  - Occupancy schedule
- Automated natural ventilation through windows with louvers and skylights
- Automated external solar shading to avoid overheating
- Rain and burglar protection

Energy and indoor environment monitoring

- Space heating
- Domestic hot water production
- Ventilation unit
- Lighting
- Electricity for white good appliances
- Electricity for other appliances

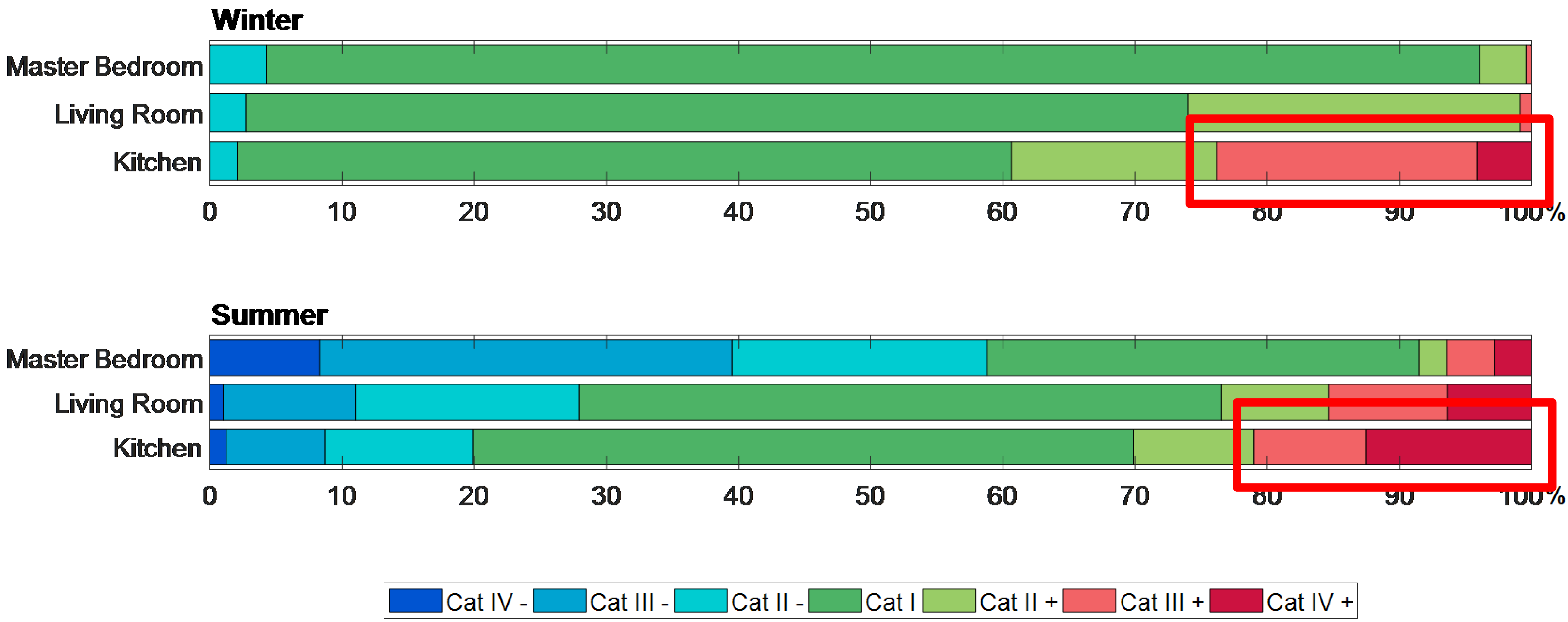
- Indoor temperature
- Indoor CO_2 concentration
- Indoor relative humidity

Indoor environment monitoring



Indoor thermal comfort time distribution (occupied hours)

Indoor environment monitoring



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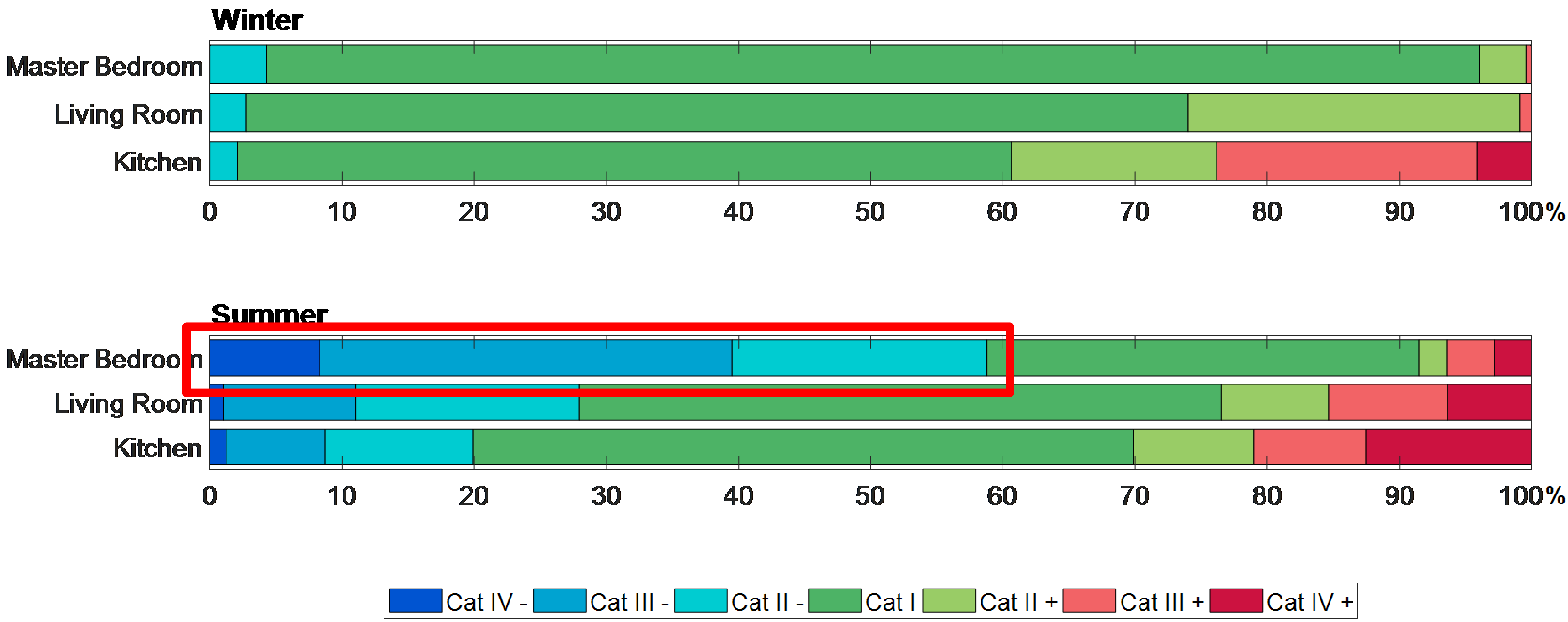


Indoor thermal comfort time distribution (occupied hours)

Indoor environment monitoring

Room	Cat I	Cat II	Cat III	Cat IV
Living room	94.4%	3.9%	1.6%	0.1%
Kitchen - dinning room	95.7%	3.0%	1.2%	0.1%
Master bedroom	21.9%	16.3%	39.3%	15.4%

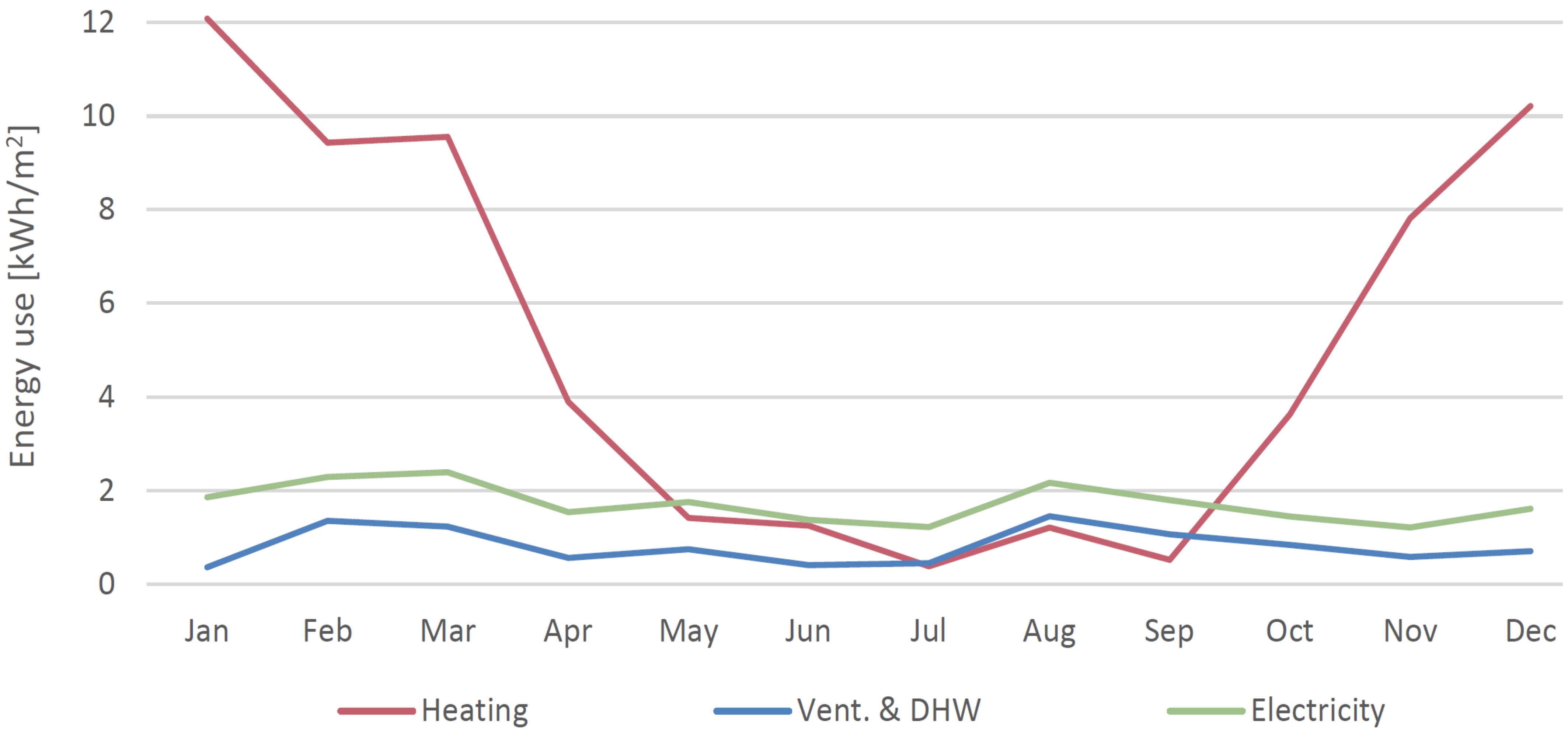
Indoor air quality: CO2 concentration comfort category time distribution (occupied hours)

Indoor environment monitoring

Room	Cat IV-	Cat III-	Cat II-	Cat I	Cat II+	Cat III+	Cat IV+
Living room	0.0%	0.5%	11.3%	78.5%	9.8%	0.0%	0.0%
Kitchen - dinning room	0.0%	3.5%	12.5%	77.0%	7.1%	0.0%	0.0%
Master bedroom	0.0%	0.9%	4.0%	90.9%	4.0%	0.2%	0.0%

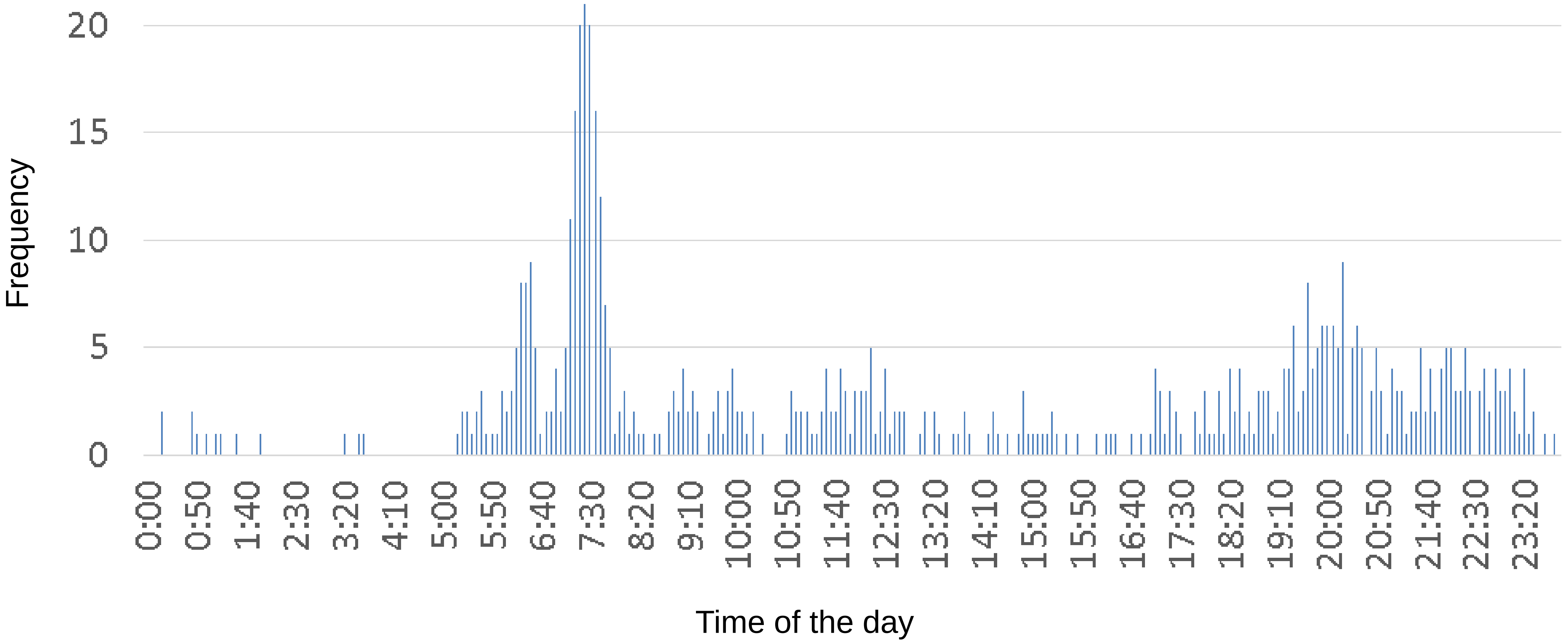
Indoor air quality: Relative humidity comfort category time distribution (occupied hours)

Detailed energy monitoring



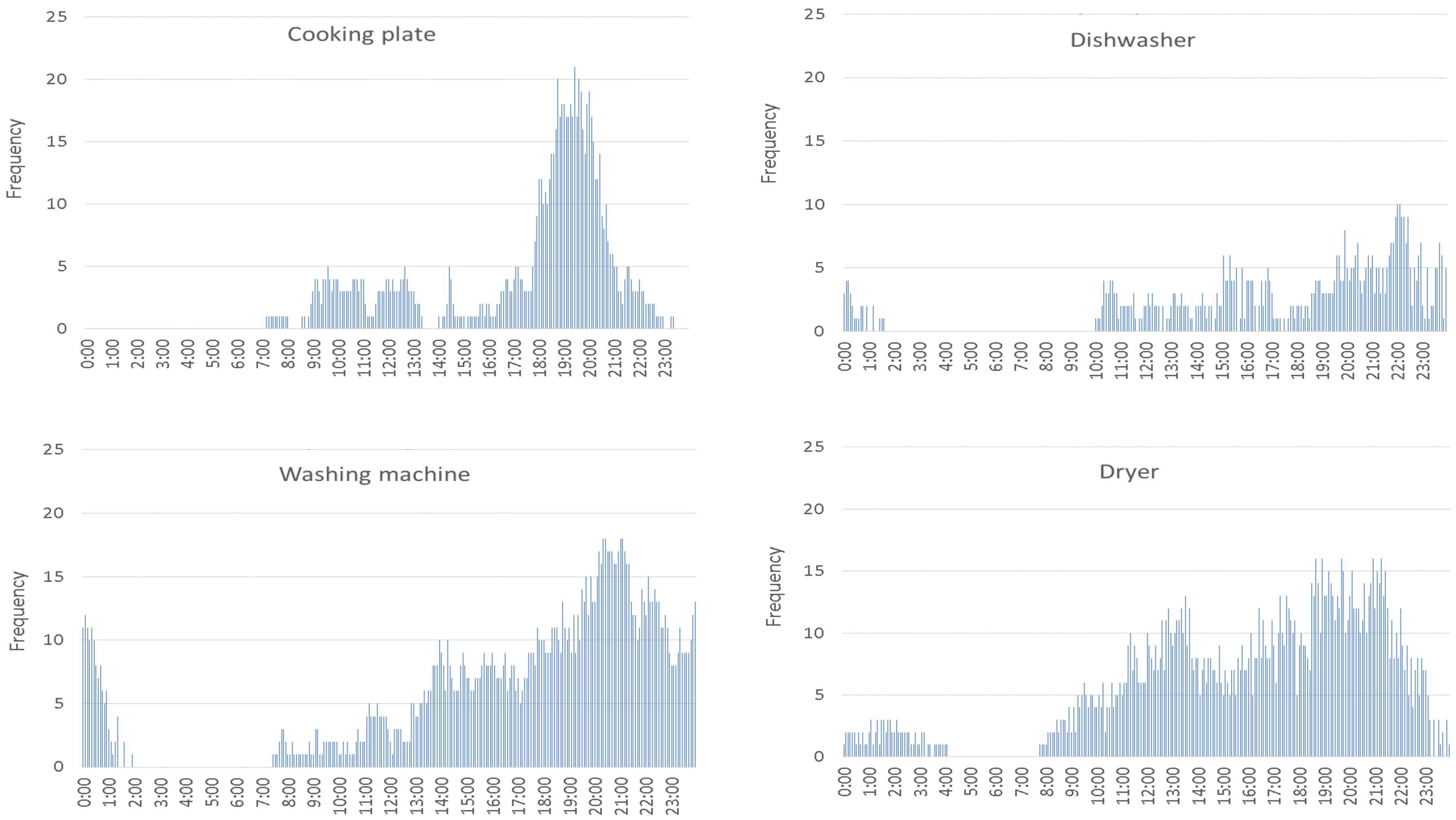
Monthly energy use

Detailed energy monitoring



Daily distribution of the domestic hot water usage

Detailed energy monitoring



Daily distribution of appliances use

Comparison with energy frame calculation tool

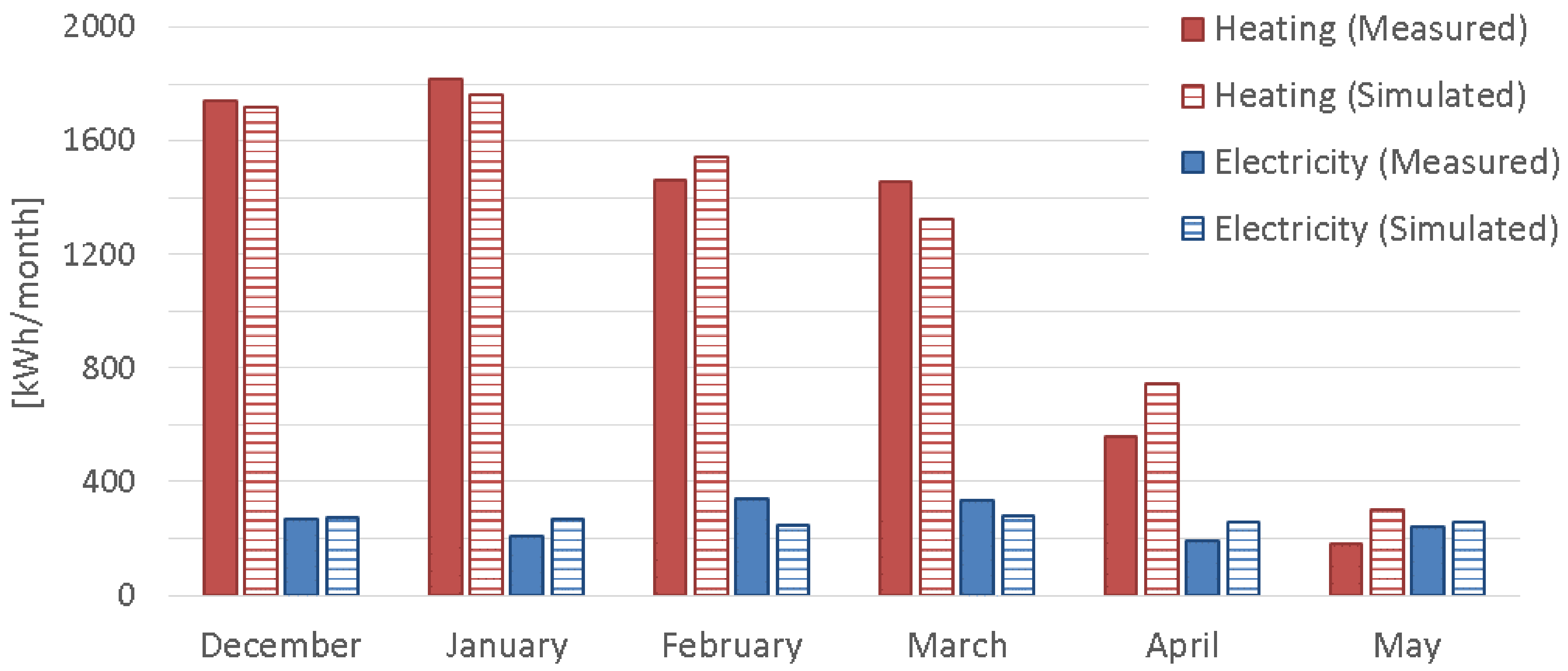
	Measured energy use [kWh/m^2]	Be18 energy frame calculation [kWh/m^2]	Difference [%]
HVAC	58.2	30.8	89%
Appliances	15.8	54.8	-71%
Total	74	85.6	-14%

Comparison between design and actual energy use

Comparison of occupancy profiles

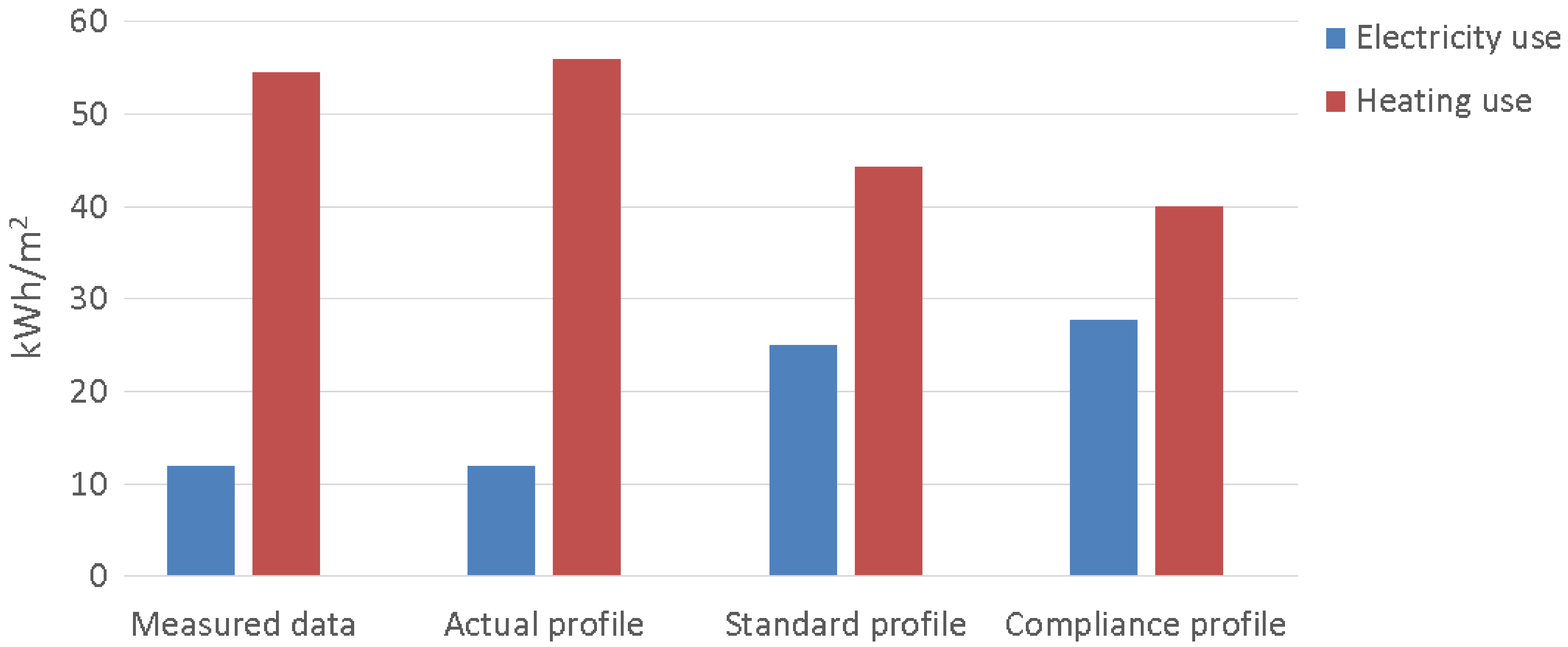
- Limited prediction of the energy frame tool
- Inadequate people and equipment load profiles
- Comparison (on Energy+) of 3 occupancy profiles:
  - Compliance profile: from national regulation
  - Standard profile: average from surveys and measurements in similar houses
  - Actual profile: based on current monitoring and interviews of occupants to understand interaction with building systems

Comparison of occupancy profiles



Comparison measured and simulated energy use with the ***actual*** *occupancy profile*

Comparison of occupancy profiles



Comparison measured and simulated energy use with the 3 different occupancy profiles

Conclusions

- This nZEB house has a good indoor environment and a good summer comfort
- Significant difference between energy frame calculation and real energy performance
- In this case, the difference can be almost completely explained by occupants' profile
  - Heating use of the compliance profile is 40% lower than reality
  - DHW use of the compliance profile is 100% higher than reality
  - Electricity use of the compliance profile is 130% higher than reality
  - Standard profile also overestimates electricity use and underestimates heating needs

Conclusions

- If we know the occupants, we can accurately calculate nZEB energy performance with building simulation tools

- Other uncertainties in building model or weather data have very small impact in this case

- Energy frame calculation tools assess the level of performance of the house but should not be expected to predict the real energy use.

- Indoor CO_2 sensors used for system control were found to be unreliable in this case

Thank you for your attention !
Any questions ?

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For more information:

Carpino C, Loukou E, Heiselberg P K, Arcuri N 2019 Energy performance gap of a nearly zero energy building: influence of occupancy modelling and effectiveness of simulation. **Under Revision.**