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Energy flexibility of office buildings:

Potential of different building types

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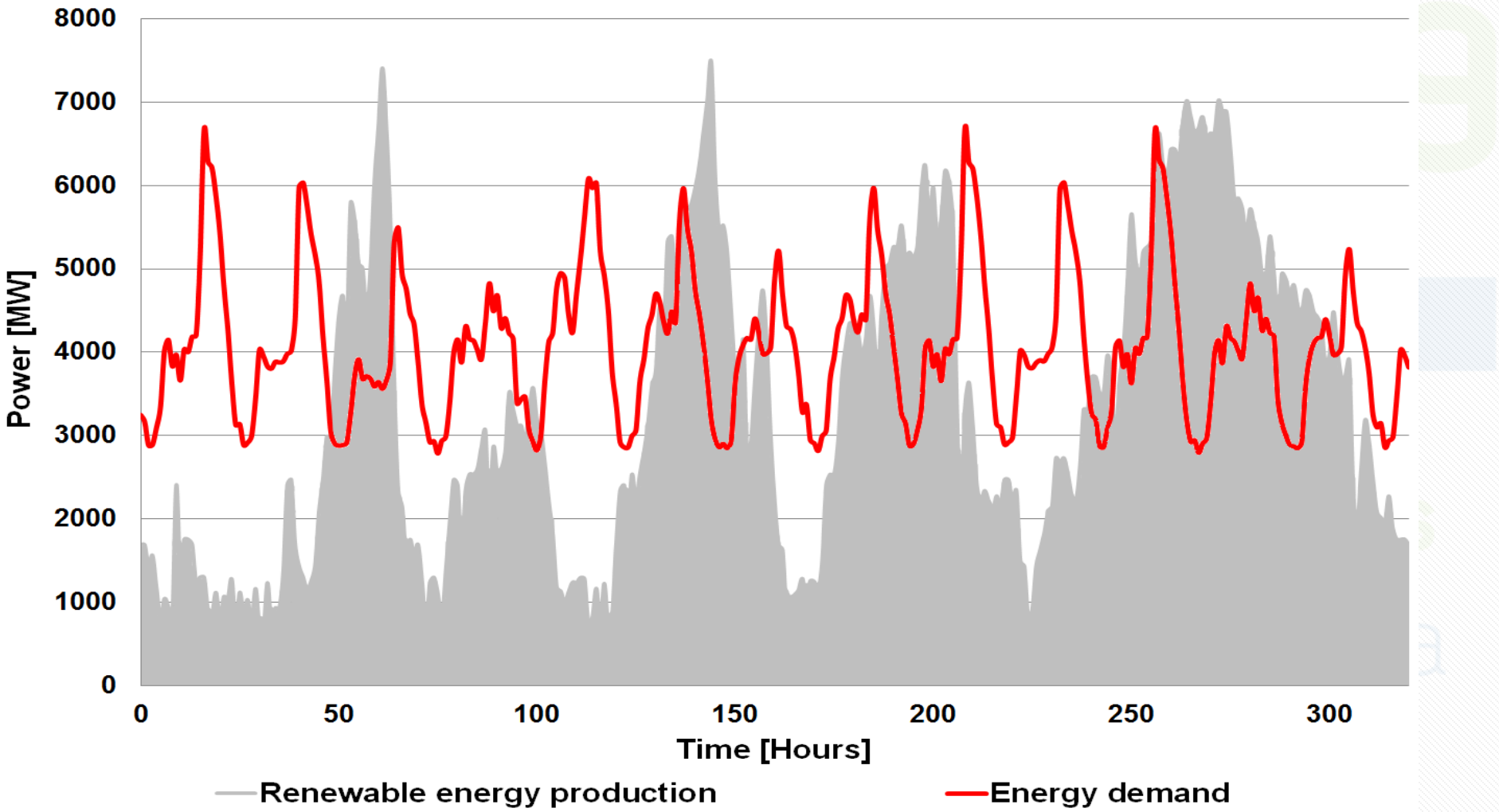
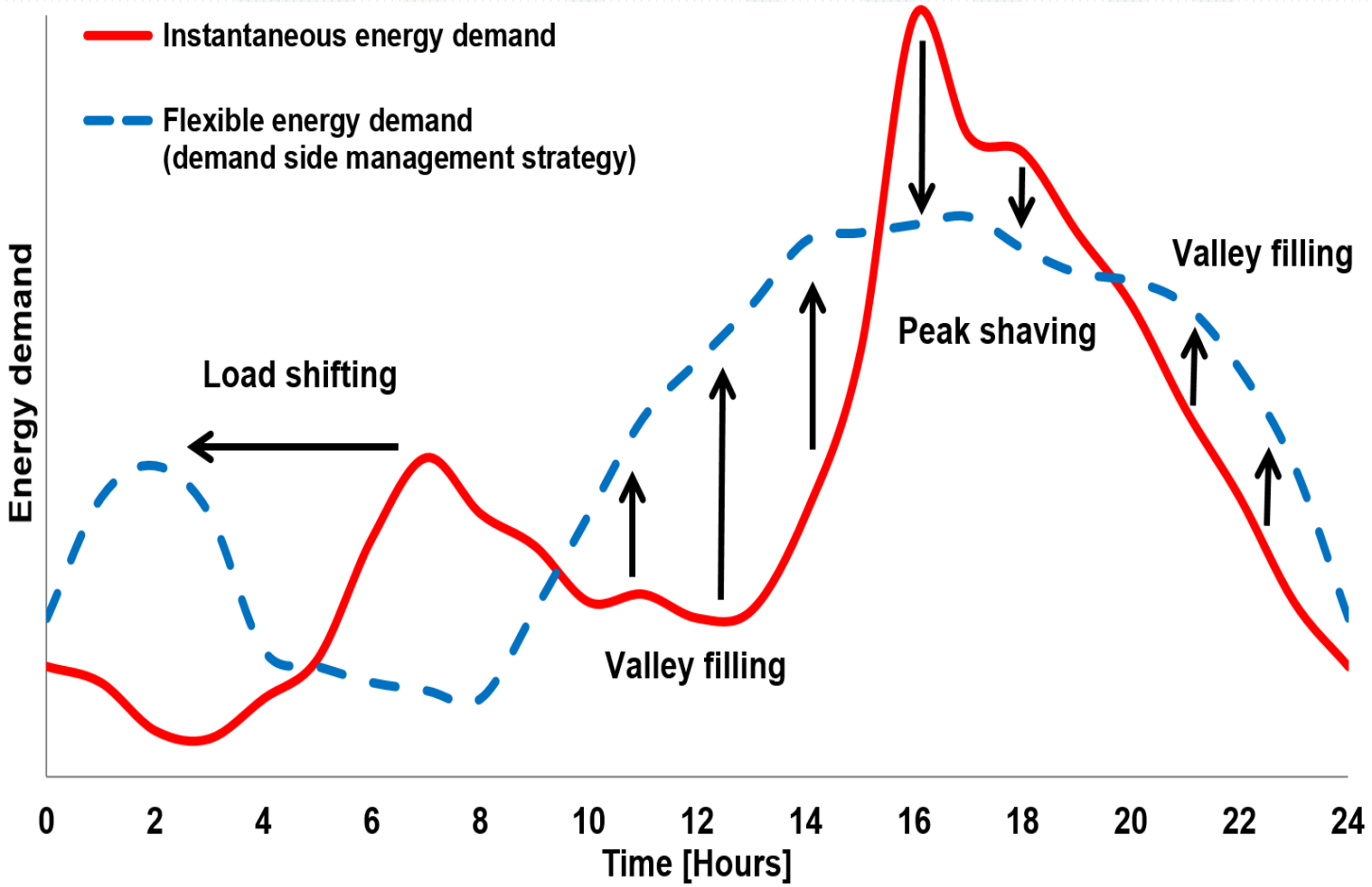
Mismatch between power demand and renewable energy production



Demand side management with building energy flexibility



- Change demand with load shifting, peak shaving and valley filling to avoid critical or costly periods
- Useful to operate a Smart Energy Grid with large share of intermittent renewable energy sources
- Possible optimization of the heating / cooling / ventilation systems operation
- Can help solving local bottle neck problems with power peak issues
- Avoid costly peak power needs

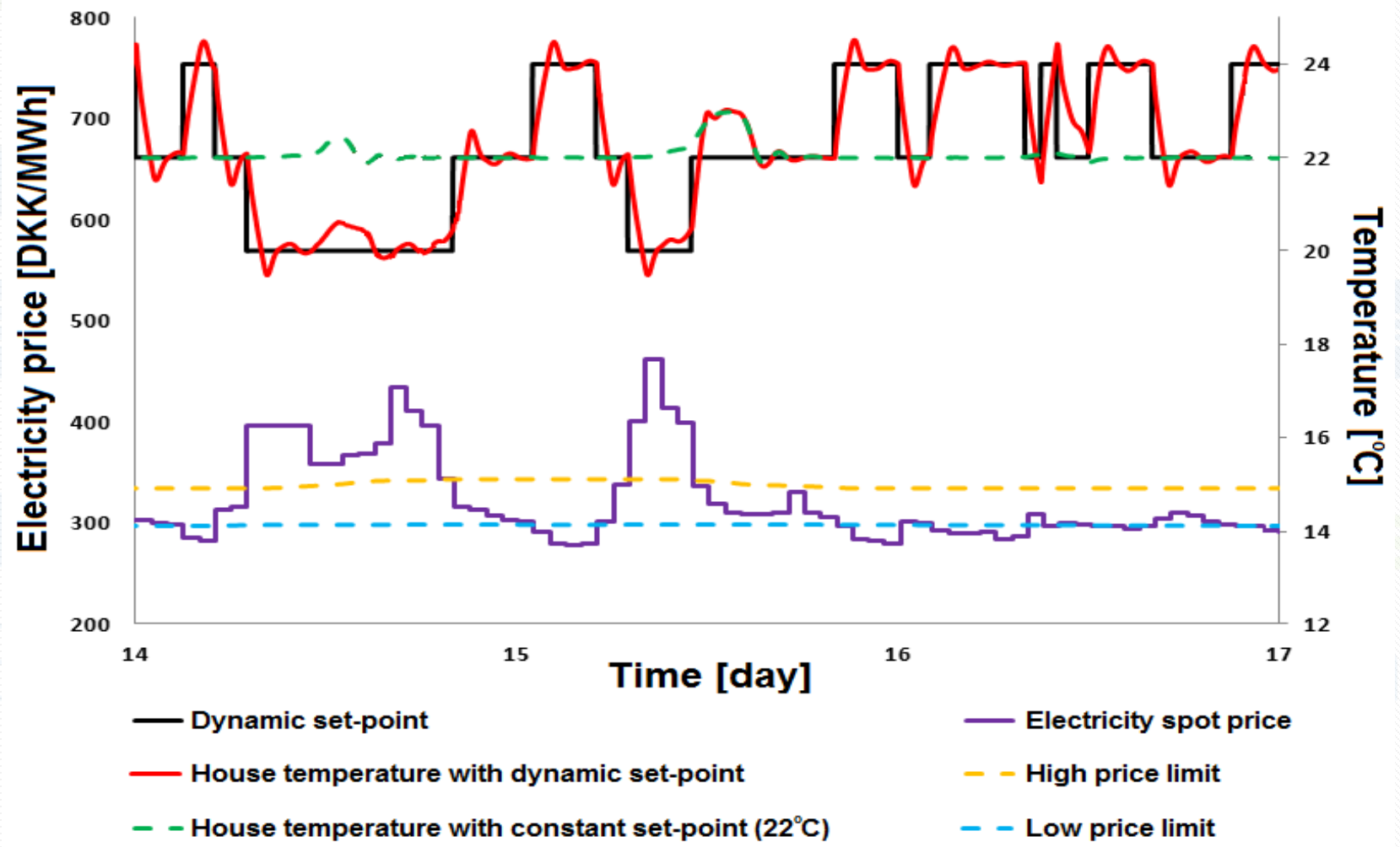
Building energy flexibility: definition

"The ability for a building to adapt its profile of energy use to the requirements of the grid (penalty signal) without jeopardizing technical and comfort constraints"

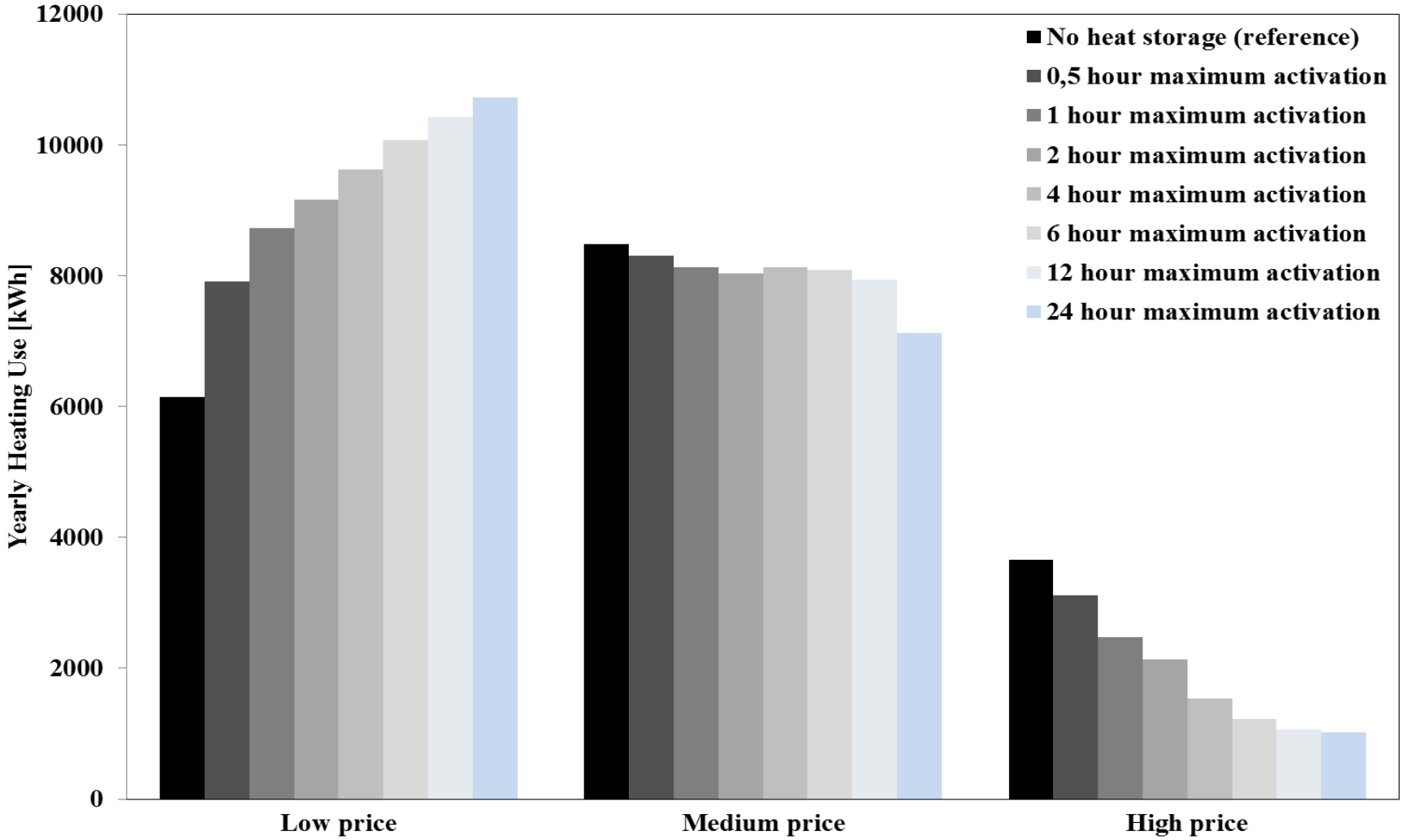
Examples of energy flexibility and demand side management

- Delay of white-good appliance services
- Scheduling charging of electrical vehicles connected to buildings
- Electrical storage in batteries of electrical vehicles connected to buildings or in batteries of building photovoltaic systems
- Thermal storage in hot water tank (domestic of water and heating system)
- Thermal storage in the indoor environment and thermal mass of buildings

Price-based indoor temperature set point modulation



Examples of energy flexibility: load shifting



Research Question

- Previous studies demonstrated the capacity of residential buildings to enable energy flexibility
- What is the energy flexibility potential in office buildings in Denmark?

Energy flexibility of office buildings – Potential of different building types

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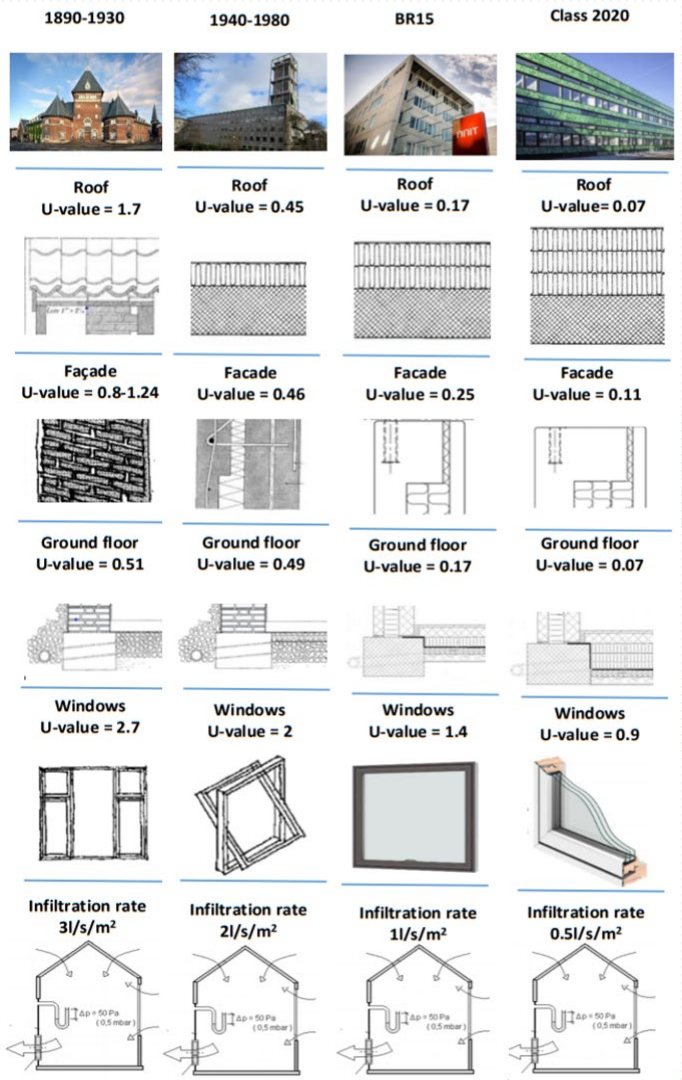

Methodology

- Identify and classify typical office building types in Denmark
- Determine properties of the 4 categories (construction period):
  - 1890 – 1930
  - 1940 – 1980
  - Buildings complying with “Building regulation 2015”
  - “Building Class 2020”
- Simulation with building energy modelling tool “Energy Plus” software
- Danish weather conditions
- “Nord Pool” electricity price for price-based demand control (rule-based controller)
- Indoor temperature set point modulation for heating and cooling systems
- Comparison of each study cases with energy flexibility index

Building energy flexibility assessment

- Ability to shift heating and cooling use from high energy price periods to low energy price periods

- Energy flexibility index:

$$F_{Flexibility} = \frac{\int_{Low} q_{heating+cooling} dt - \int_{High} q_{heating+cooling} dt}{\int_{Low} q_{heating+cooling} dt + \int_{High} q_{heating+cooling} dt}$$

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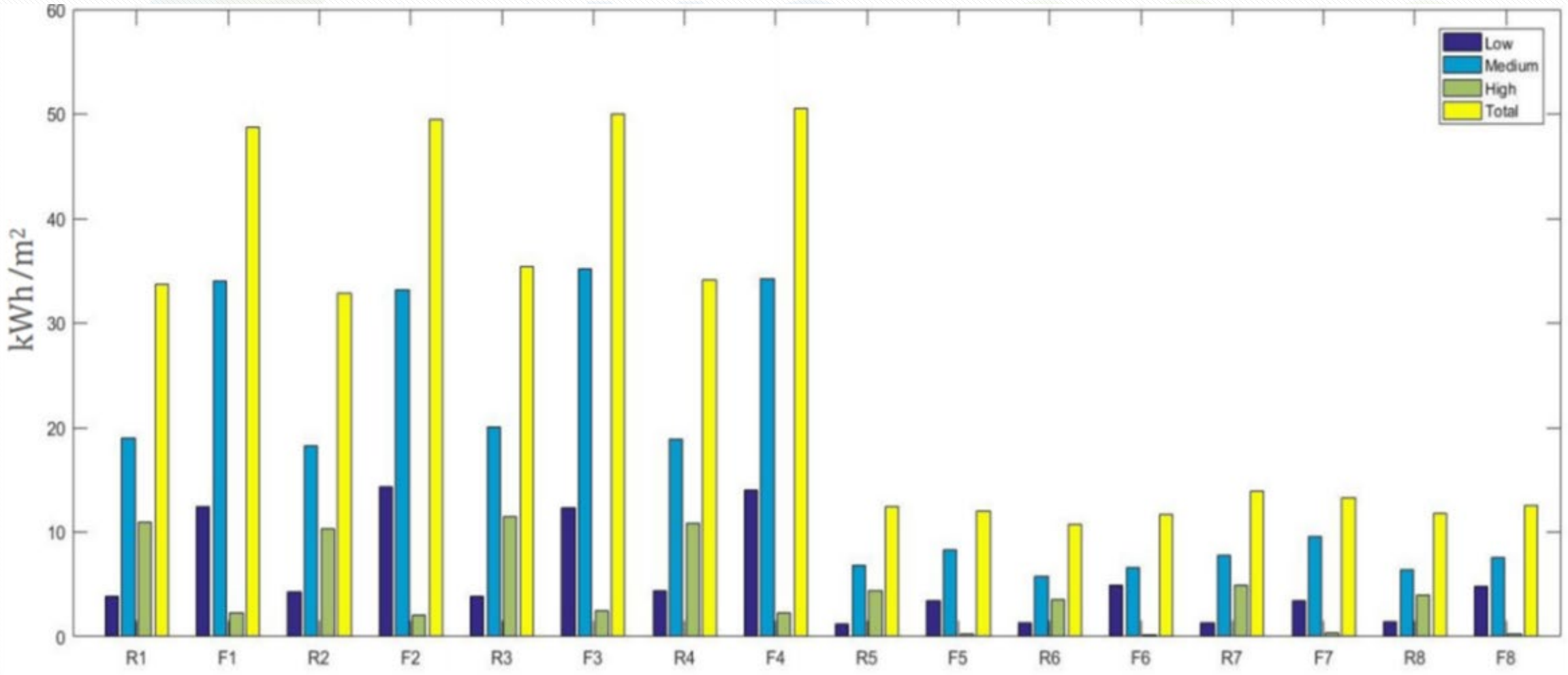
Results: comparison of energy use and distribution



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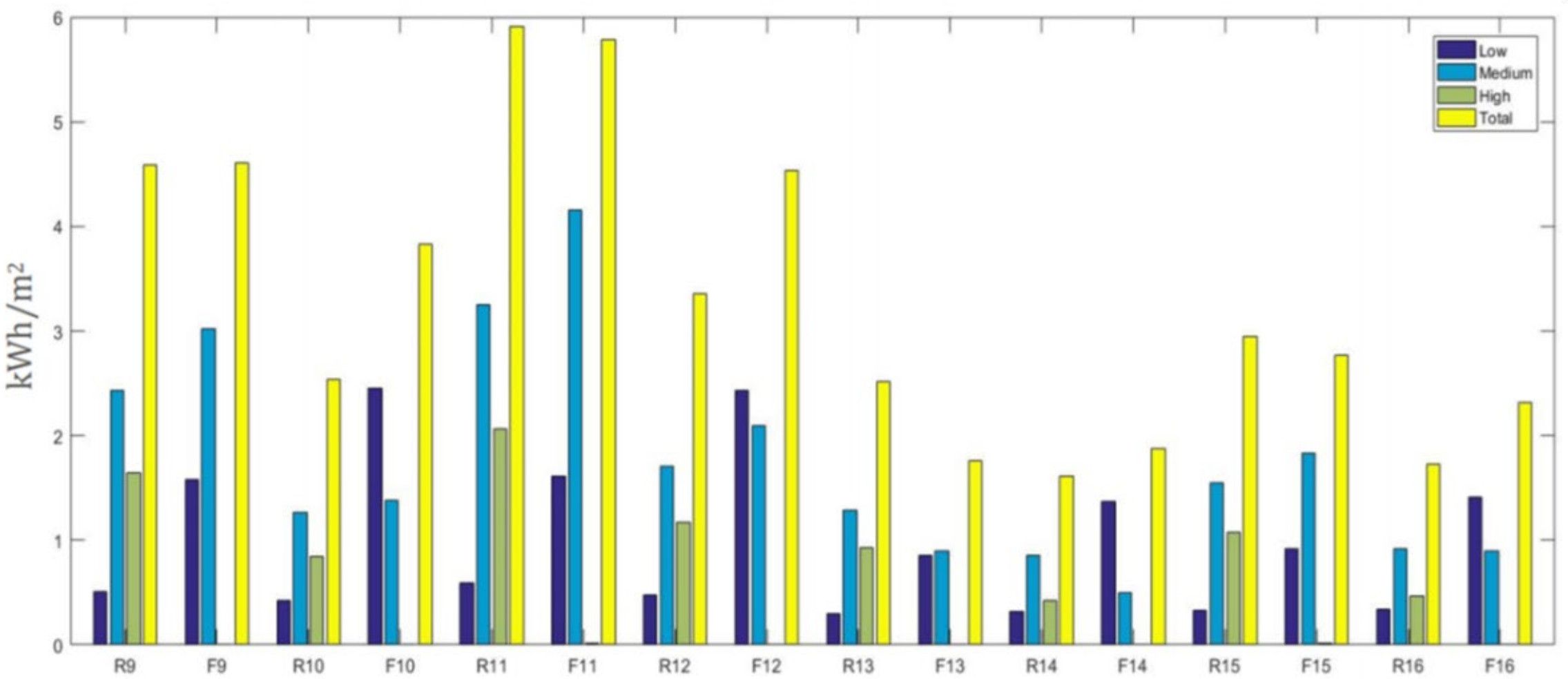

Results and discussion

Building class	Equipment option	Thermal comfort Class II [%]		Energy cost savings [%]	Energy flexibility [%]
		Ref	Flex	Flex	Flex
1890 - 1930	1	73	60	-13%	70%
	2	79	62	-16%	76%
	3	71	59	-11%	67%
	4	77	61	-15%	73%
1940 - 1980	5	72	69	26%	86%
	6	80	77	23%	94%
	7	67	64	26%	83%
	8	78	75	23%	92%
BR 2015	9	74	74	27%	99%
	10	85	84	14%	100%
	11	66	66	26%	99%
	12	83	82	16%	99%
Class 2020	13	88	88	41%	99%
	14	88	89	20%	100%
	15	83	81	32%	98%
	16	89	88	22%	100%

Conclusions

- Office buildings in Denarmk also have a significant potential for thermal storage in indoor environment and load shifting for enabling energy flexibility
- Price-based temperature set point modulation in buildings with high energy performance envelope can generate significant energy cost savings and can provide load shifting to the grid
- Price-based temperature set point modulation is not cost beneficial for buildings with low energy performance envelope
- However, poorly insulated buildings can perform load shifting
- Degradation of indoor comfort for poorly insulated buildings

Suggestions for future work

- Use of Model Predictive Control (MPC) to optimize energy flexibility control and energy cost savings
- Development of new business models are needed to motivate building owners to enable building energy flexibility
- Large scale studies of building clusters performing energy flexibility are needed

Thank you for your attention

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