Demand Site Flexibility in Buildings

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Outline

- Demand for energy flexibility
- Flexibility indicators and control strategies
- Three use cases of energy flexibility in buildings

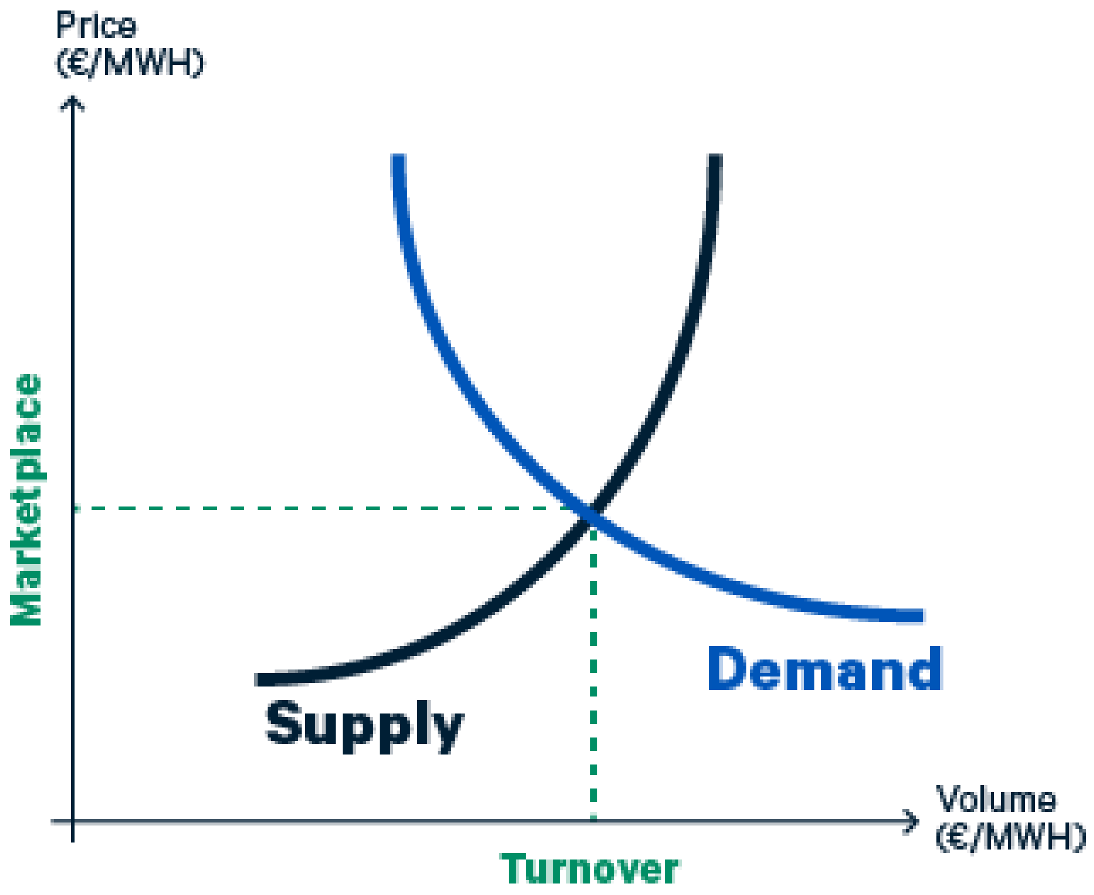
An indicator to measure smart readiness of building

"Smartness of a building refers to the ability of a building or its systems to sense, interpret, communicate and actively respond in an efficient manner to changing conditions in relation to the operation of technical building systems or the energy system and to demands from building occupants."

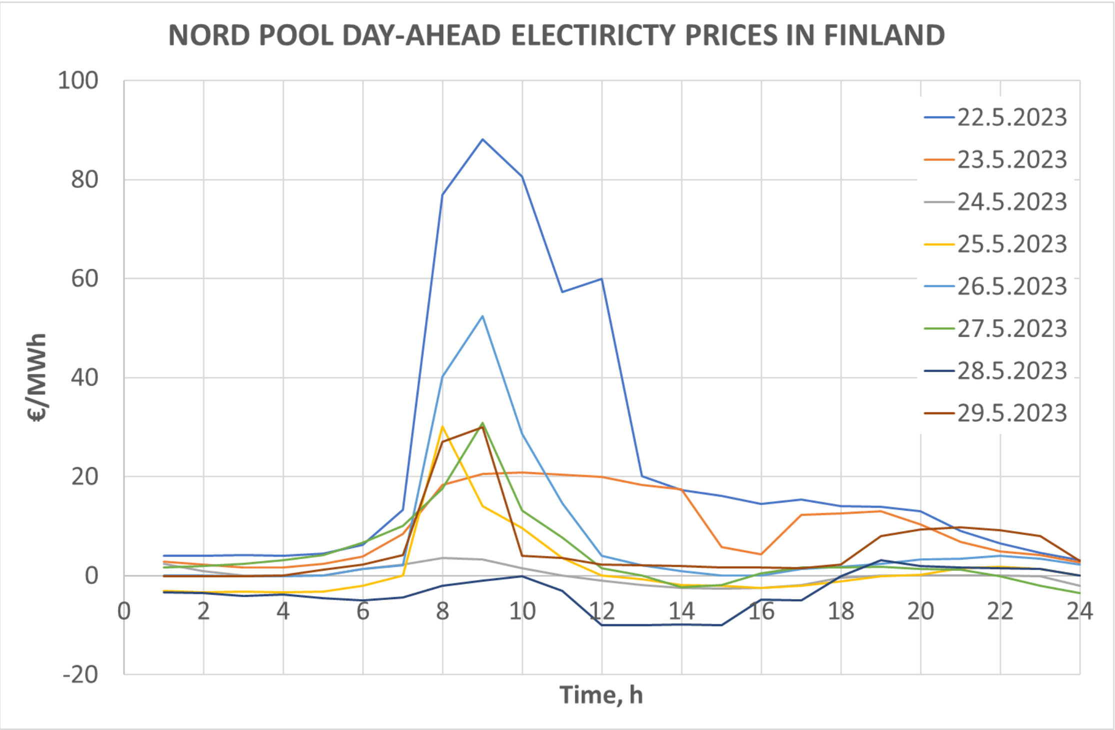
Market price of electricity

The market price of electricity varies greatly depending on the production situation and the amount of consumption.

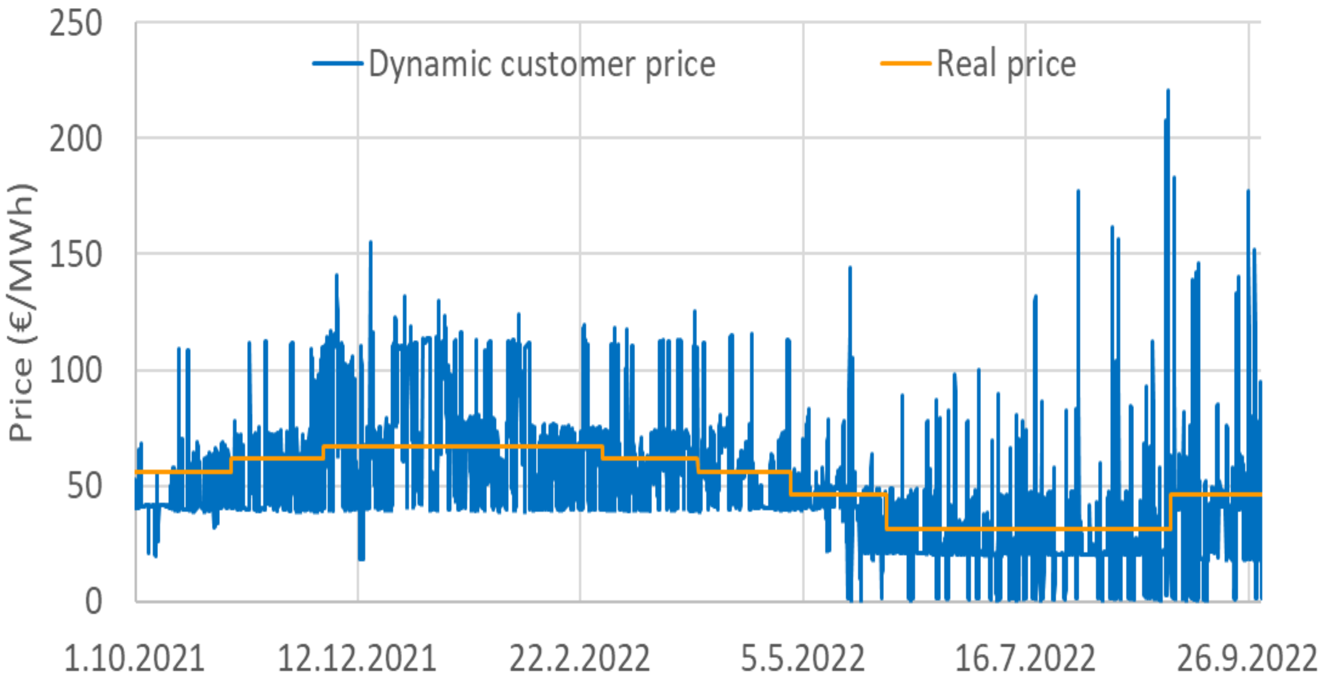
In the Nordic electricity market, the next day's price is determined based on the buy and sell offers made at 12 noon the previous day.



Dynamic energy price is an incentive for demand response

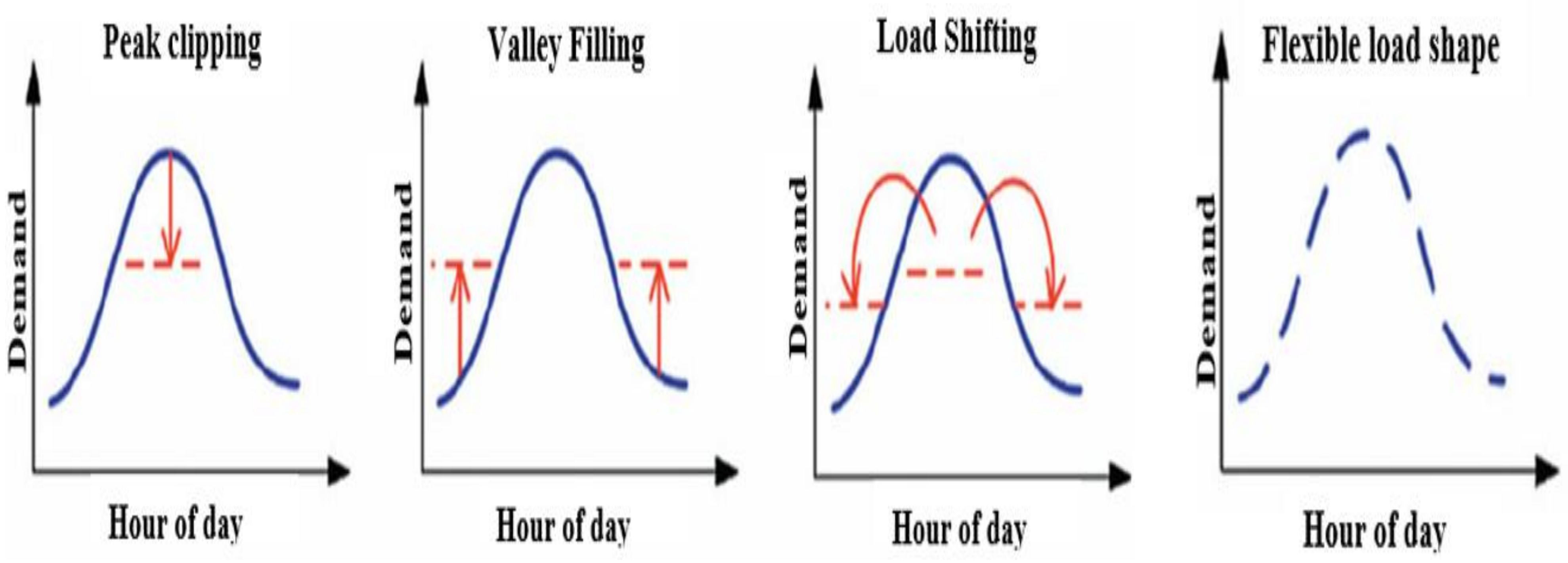


Dynamic energy price of electricity



Dynamic energy price of district heating (new business model)

Methods for demand response



Flexibility factors could be mainly divided into three main categories

Temporal Flexibility (time)

To quantify flexibility including the time forced or delayed operation needed to fill or deplete a storage capacity.

The Amplitude of Energy/Power Modulation

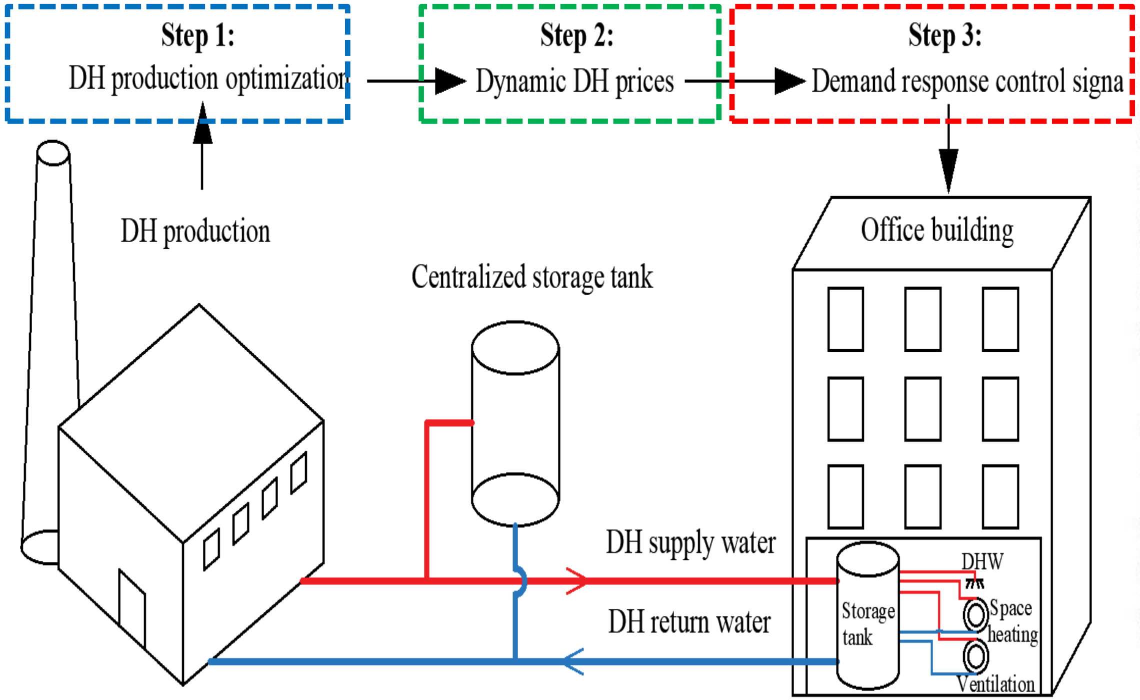
To quantify the amount or percentage of energy/power can be shifted by thermal mass or thermal storage.

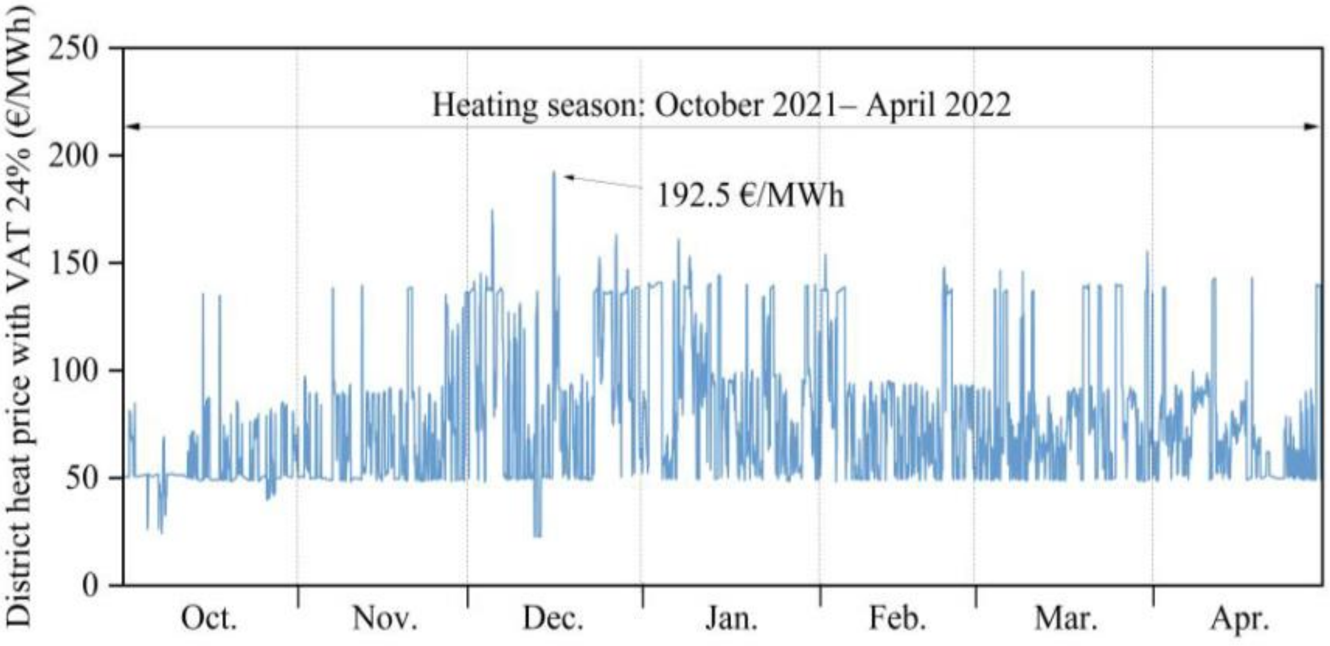
Cost

To quantify the costs of activating flexibility, such as based on dynamic energy price to optimize power profile in order to reduce costs.

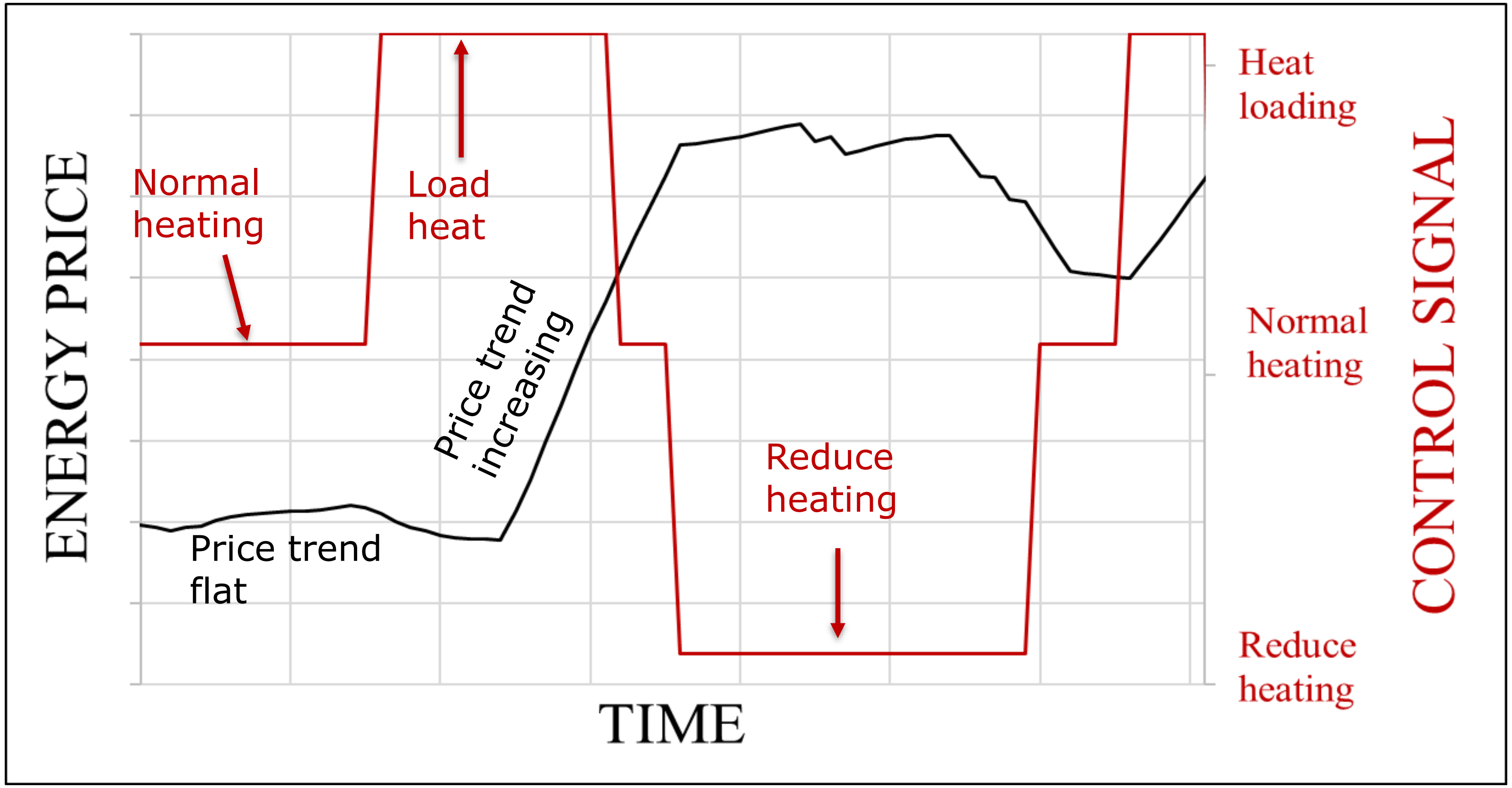
Energy flexibility use case of a district heated office

Use case of utilization of demand response in district heated office building



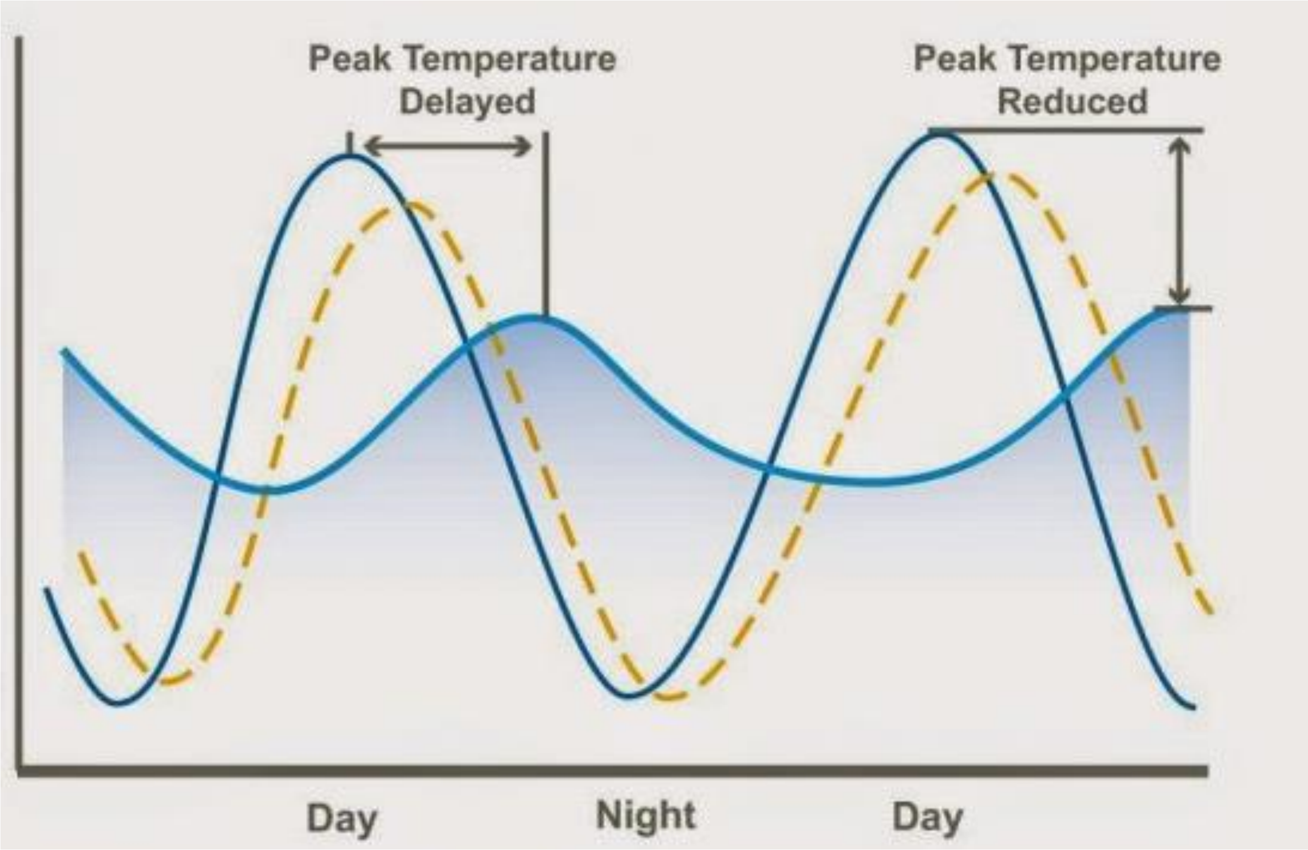


Principle of rule-based demand response control strategy



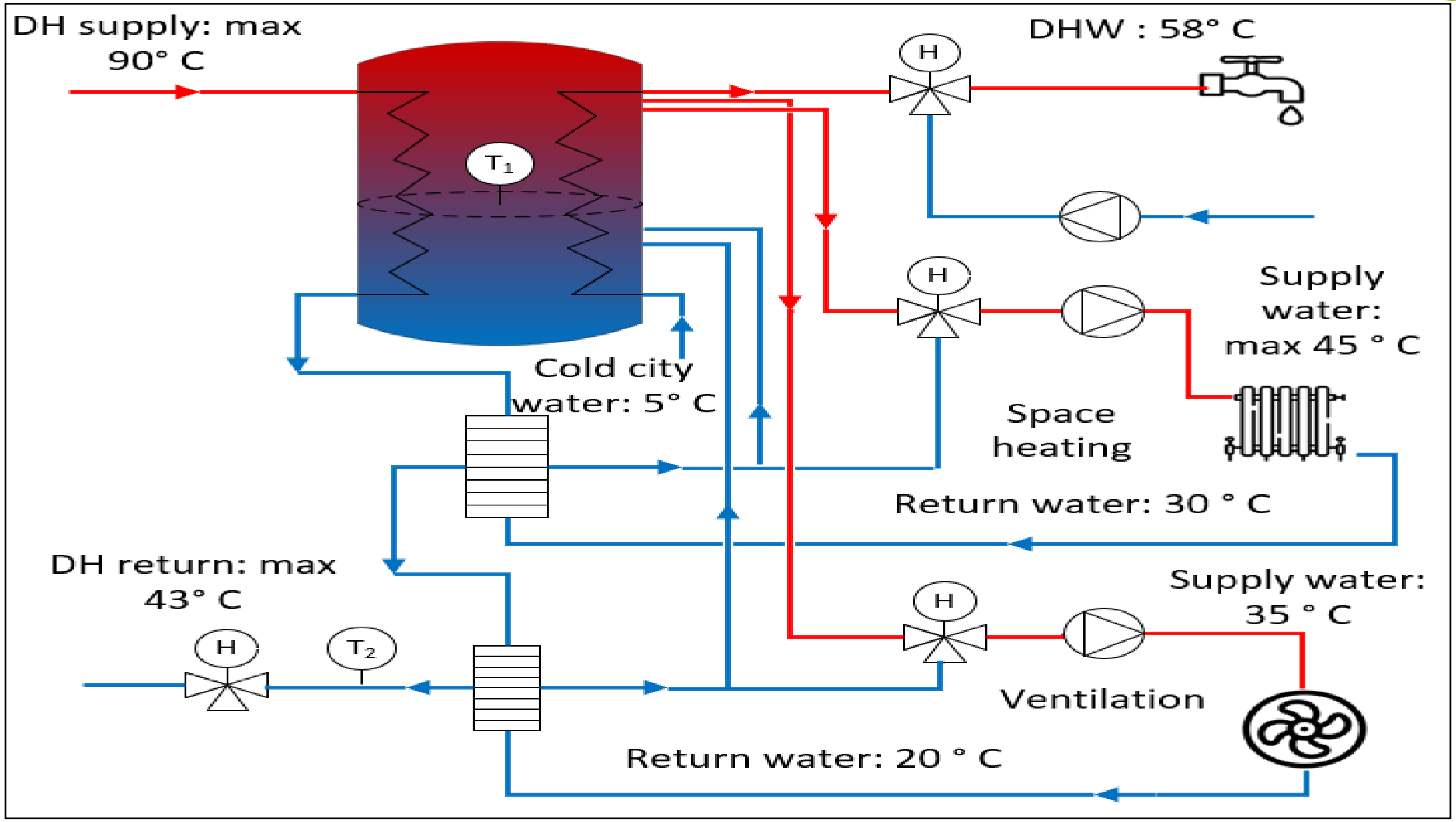
Control signal is set on the basis of a rising or falling price

Utilization of thermal mass of building for short term energy storage



Electronic thermostats in water radiator

Utilization of water tank for short-term energy storage and peak power cutting in a district heated office building



Water tank (5 m³) is integrated in a district heating sub-station

Benefits of demand response for building owner

Cases	Max heating power (kW)	Heat Energy consumption		District heat energy cost		Power fee		Total cost	
		kWh/m²	Diff.	€/m²	Diff.	€/m²	Diff.	€/m²	Diff.
Ref. 21	113.2	61.5		5.00		3.47		8.47	
Ref. 20	111.8	57.6	-6.2%	4.70	-6.0%	3.43	-1.2%	8.13	-4.0%
DR-SH	112.8	60.6	-1.4%	4.52	-9.6%	3.45	-0.6%	7.97	-5.9%
DR-ST	112.4	62.6	1.9%	4.83	-3.4%	3.44	-0.9%	8.27	-2.4%
DR-ST-PL	64.2	62.4	1.5%	4.85	-3.0%	2.04	-41.2%	6.89	-18.7%
DR-SH-ST	112.4	61.7	0.4%	4.36	-12.8%	3.44	-0.9%	7.80	-7.9%
DR-SH-ST-PL	64.2	61.2	-0.4%	4.53	-9.4%	2.04	-41.2%	6.57	-22.4%

Space heating – 5.9 %

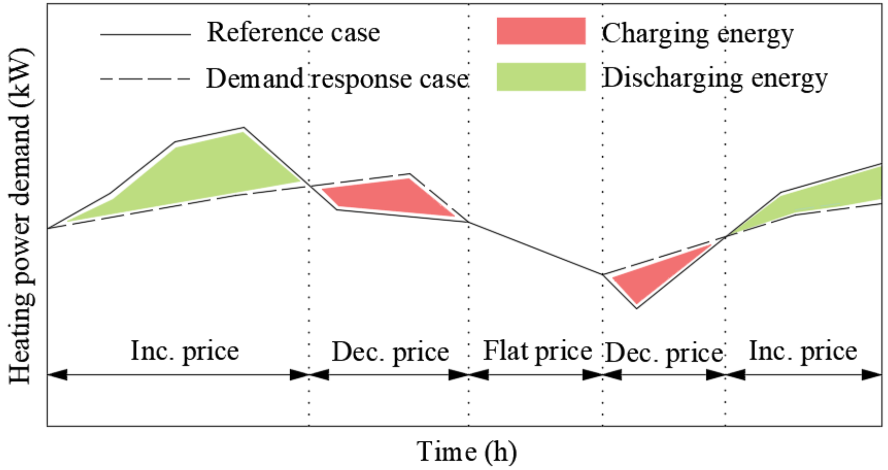
Space heating+ energy storage – 7.9 %

Space heating+ energy storage+ power cutting (-44 %) – 22.4 %

How energy efficiency increased ?

Energy flexibility indices

$$FF^{+} = \frac{\int_0^{\tau} \left(P_{charging} - P_{ref} \right) \cdot dt}{\int_0^{\tau} P_{ref} \cdot dt} \qquad FF^{-} = \frac{\int_0^{\tau} \left(P_{ref} - P_{discharging} \right) \cdot dt}{\int_0^{\tau} P_{ref} \cdot dt}$$



The ratio of charged and discharged energies compared with standard strategy

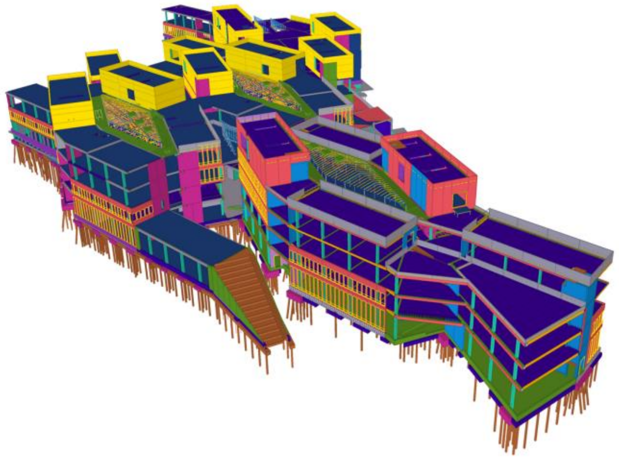
Cases	DR-SH	DR-ST	DR-ST-PL	DR-SH-ST	DR-SH-ST-PL
FF^{+}	10.3%	8.4%	7.5%	19.0%	12.5%
FF^{-}	-14.2%	-4.6%	-4.3%	-19.3%	-15.9%

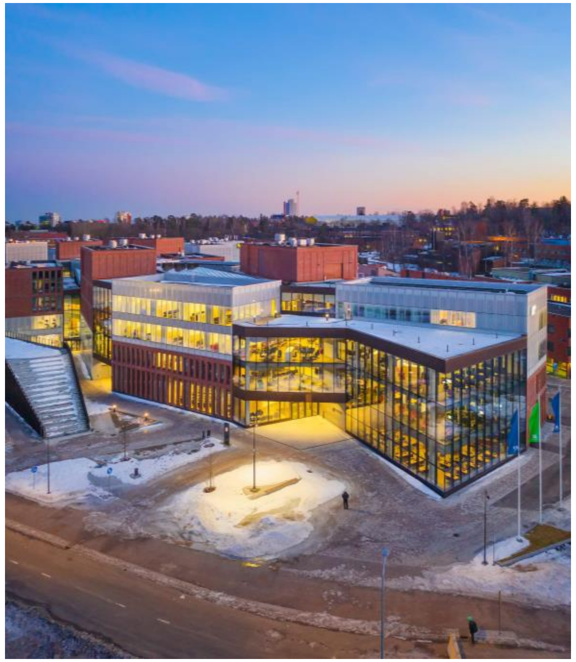
→ Energy flexibility with thermal mass slightly higher than with water tank

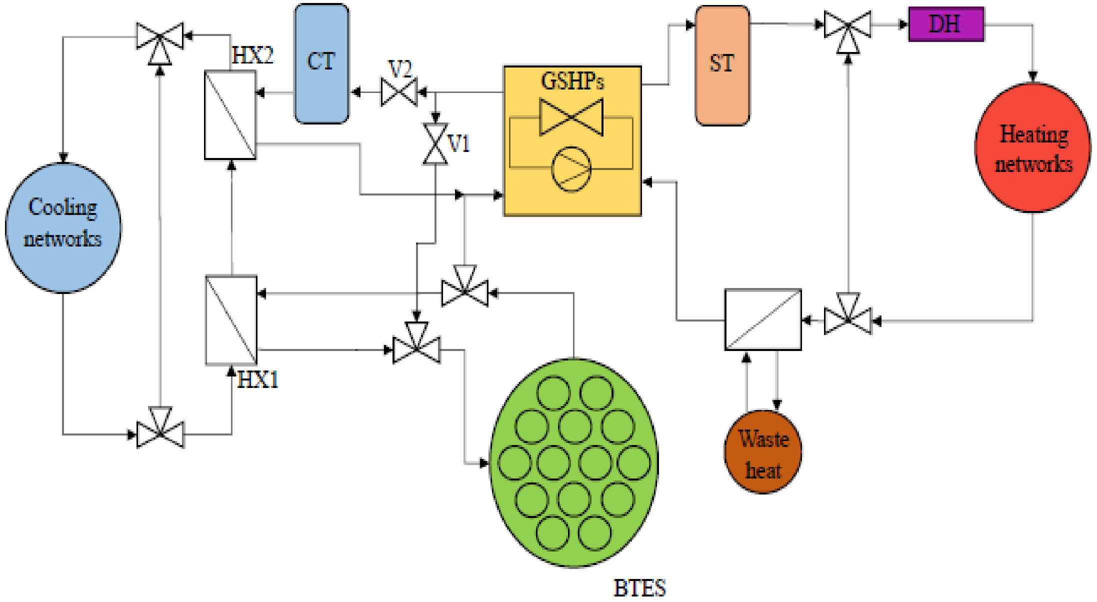
→ Power cutting reduces energy flexibility

Energy flexibility use case of a hybrid heated large building complex

General scheme of the energy system of a large building complex



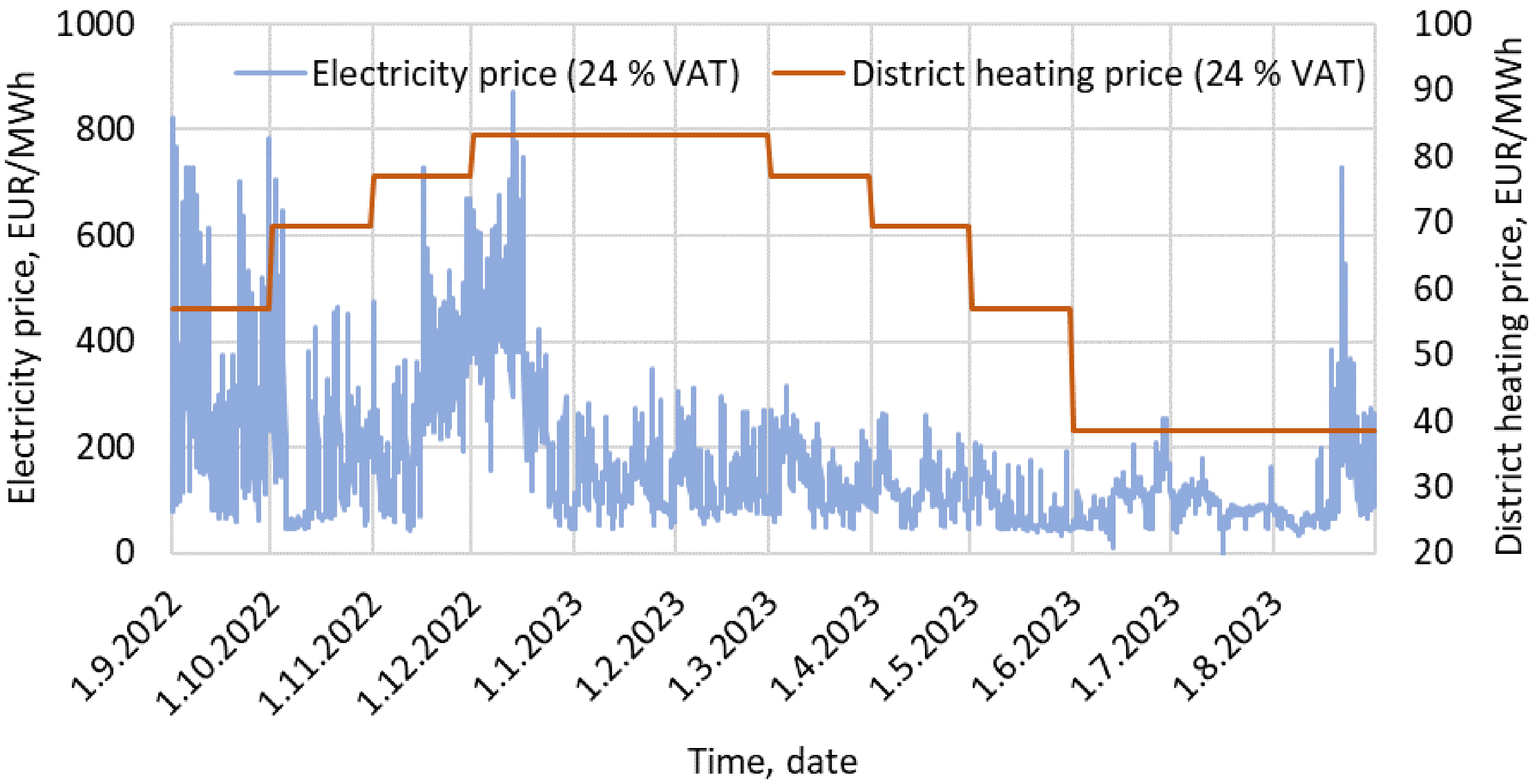




The total floor area is 40120 m^2.
74 bore holes (depth of 320 m)

Heat pump power 790 kW
District heating power 1680 kW

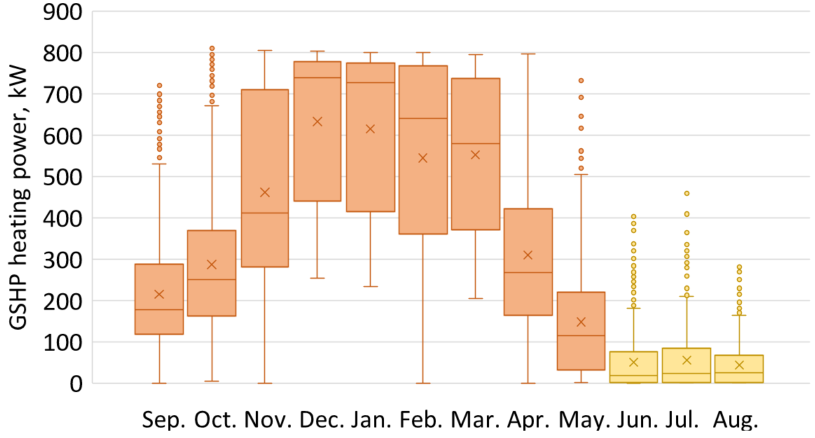
Energy costs and control strategy



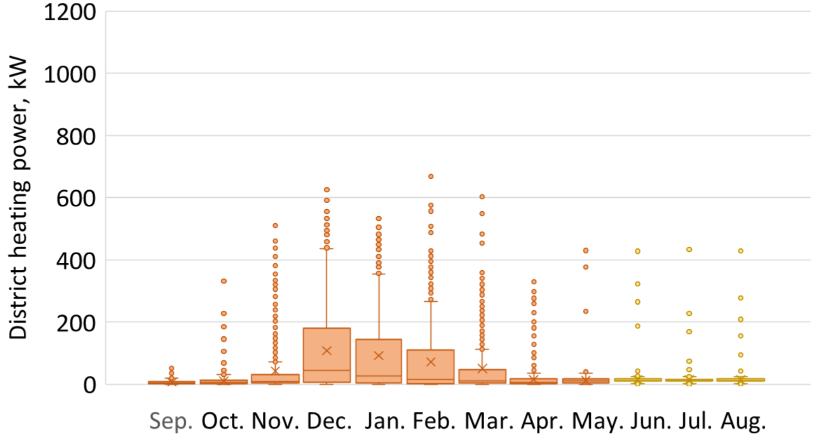
The heating source is selected according to the comparison of **Energy price and efficiency (COP) of heat pump** in the control time horizon (3 h).

Ground source heat pump (GSHP) and district heating (DH) power distribution

89.7 %

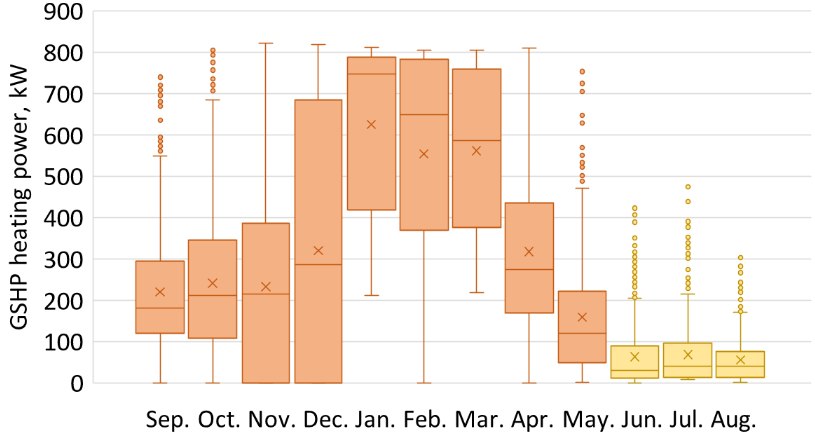


10.3 %

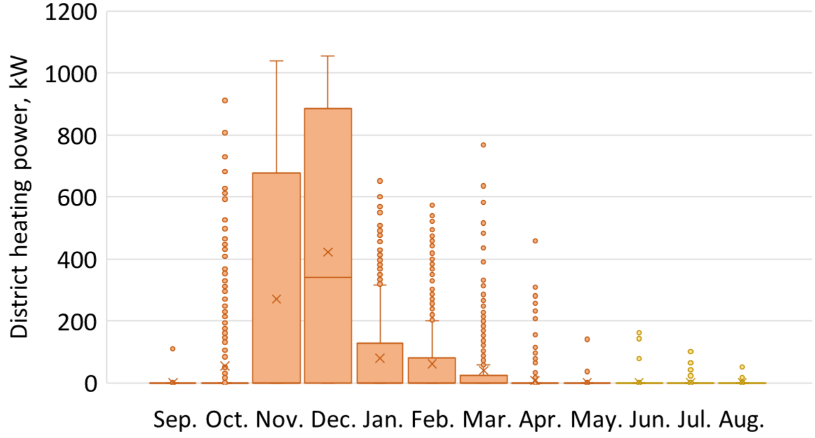


GSHP base heating

78.5 %



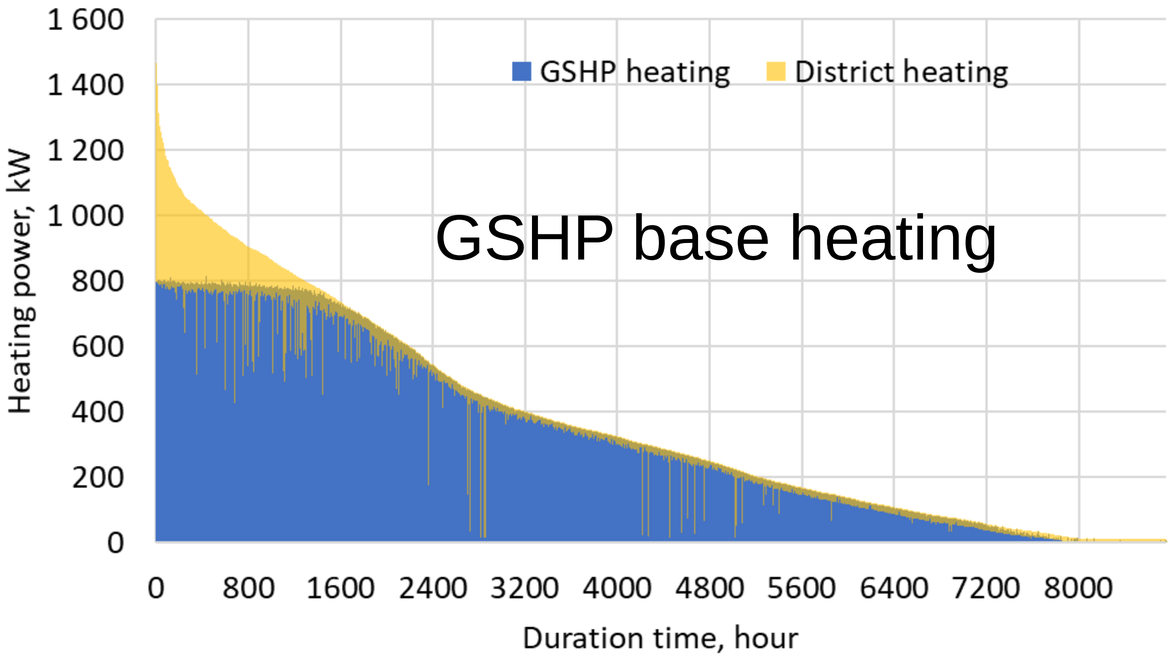
21.5 %

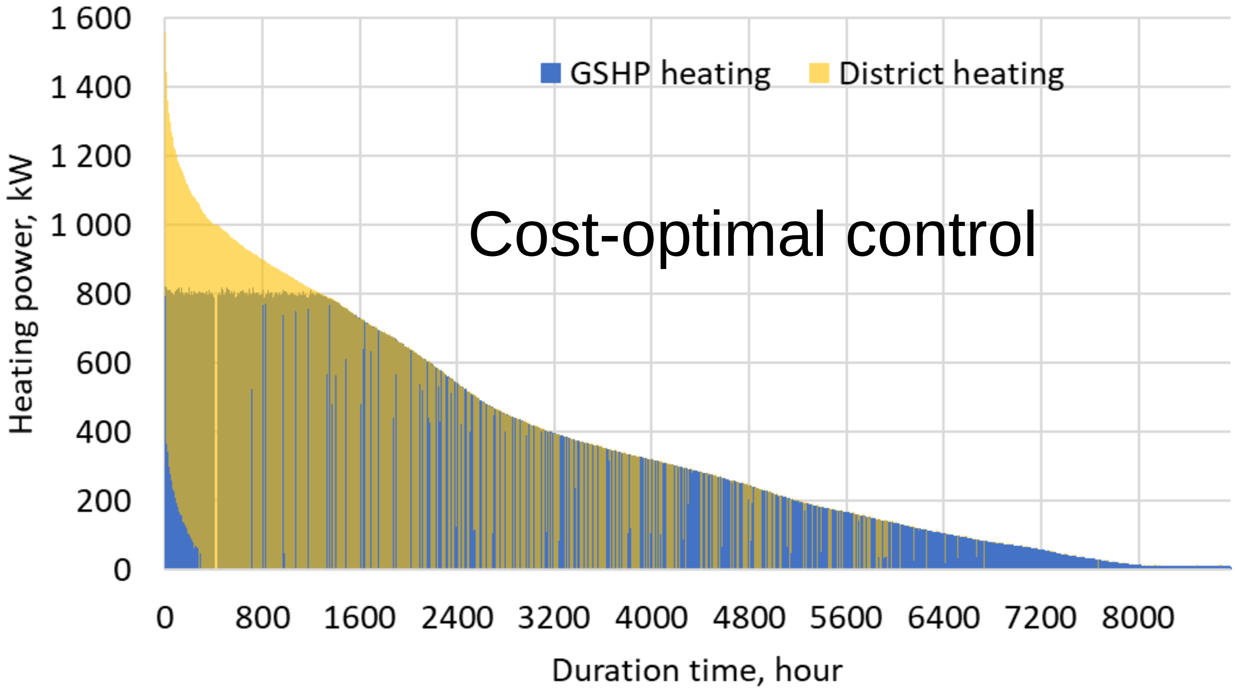


Cost-optimal control

Duration curves of the total heating powers

Heat pump 790 kW,
District heating 1680 kW

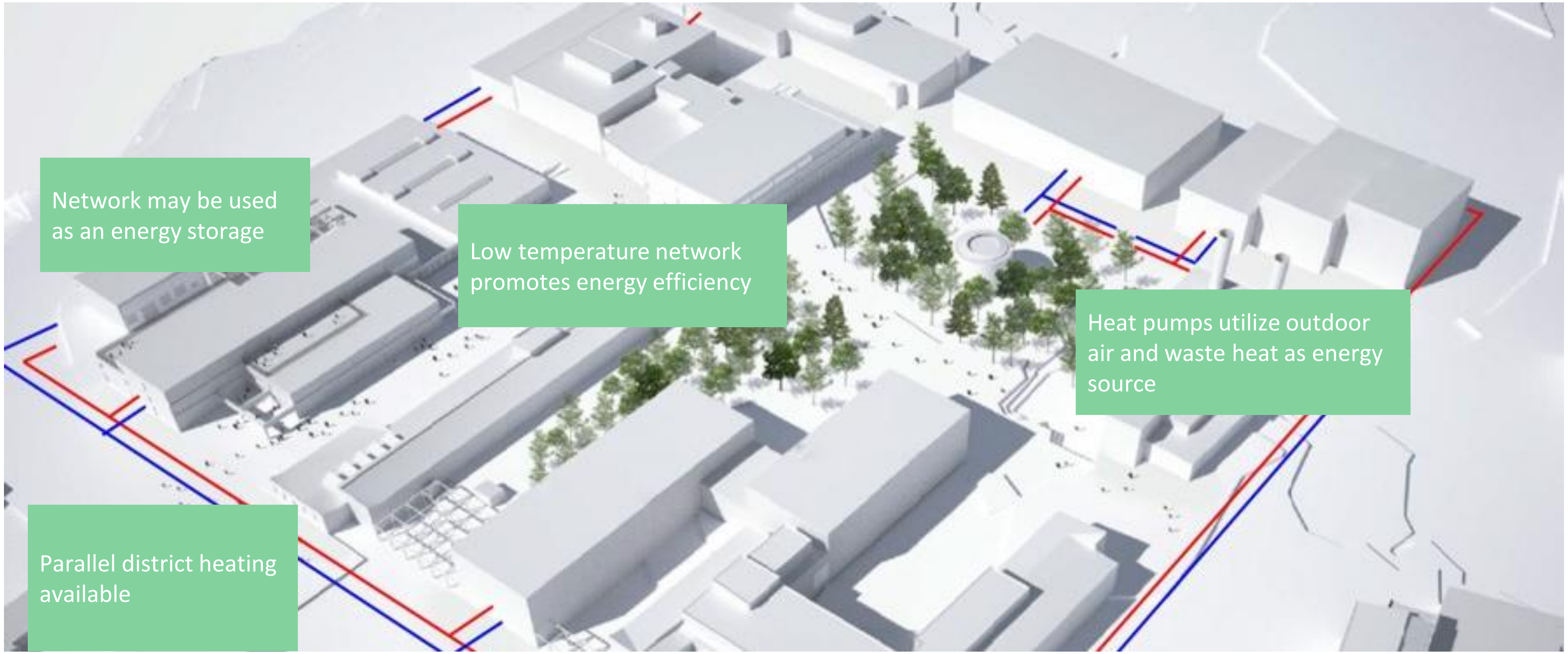




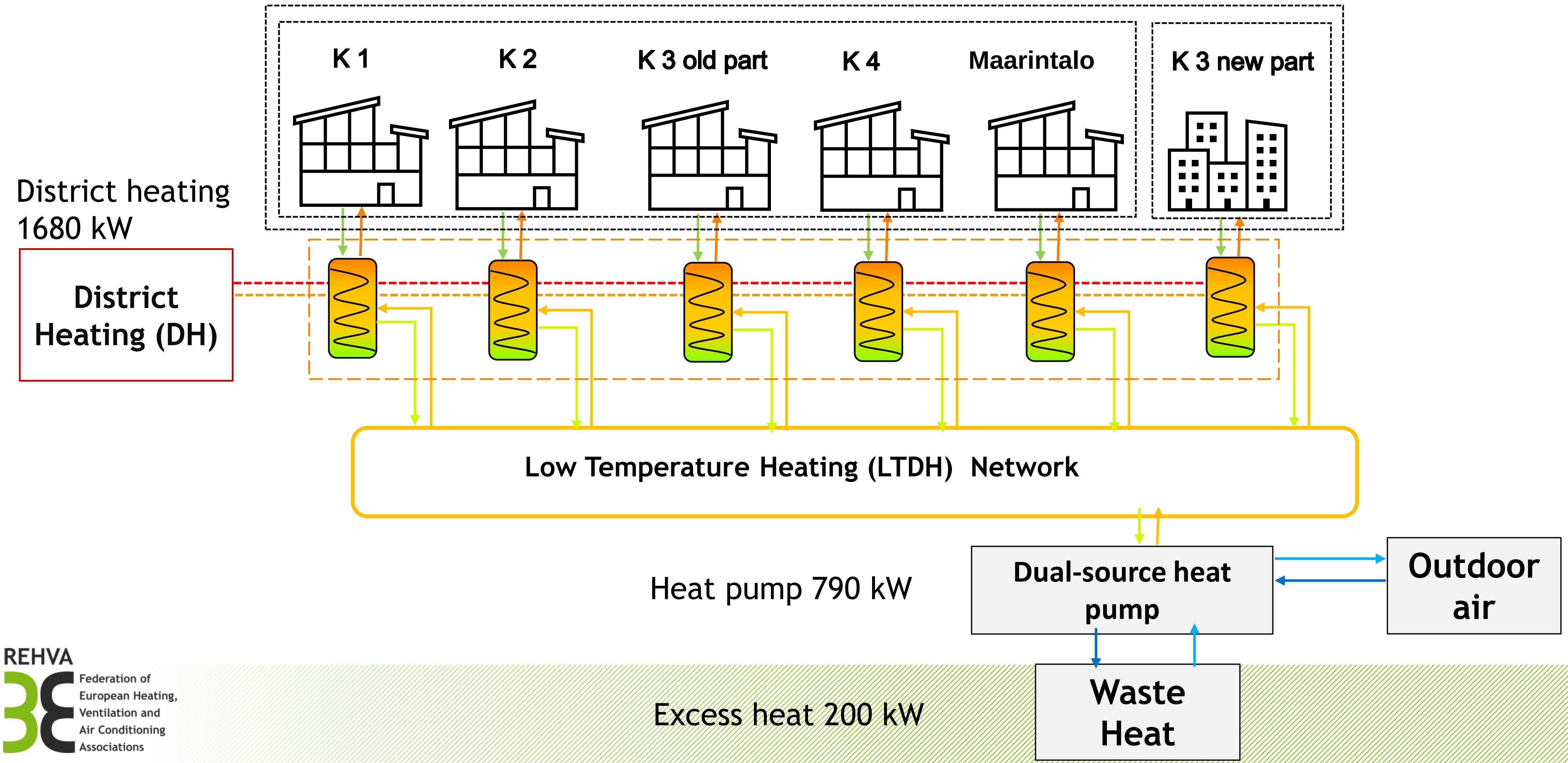
Energy costs saving 13 %

Energy flexibility use case of a small energy community

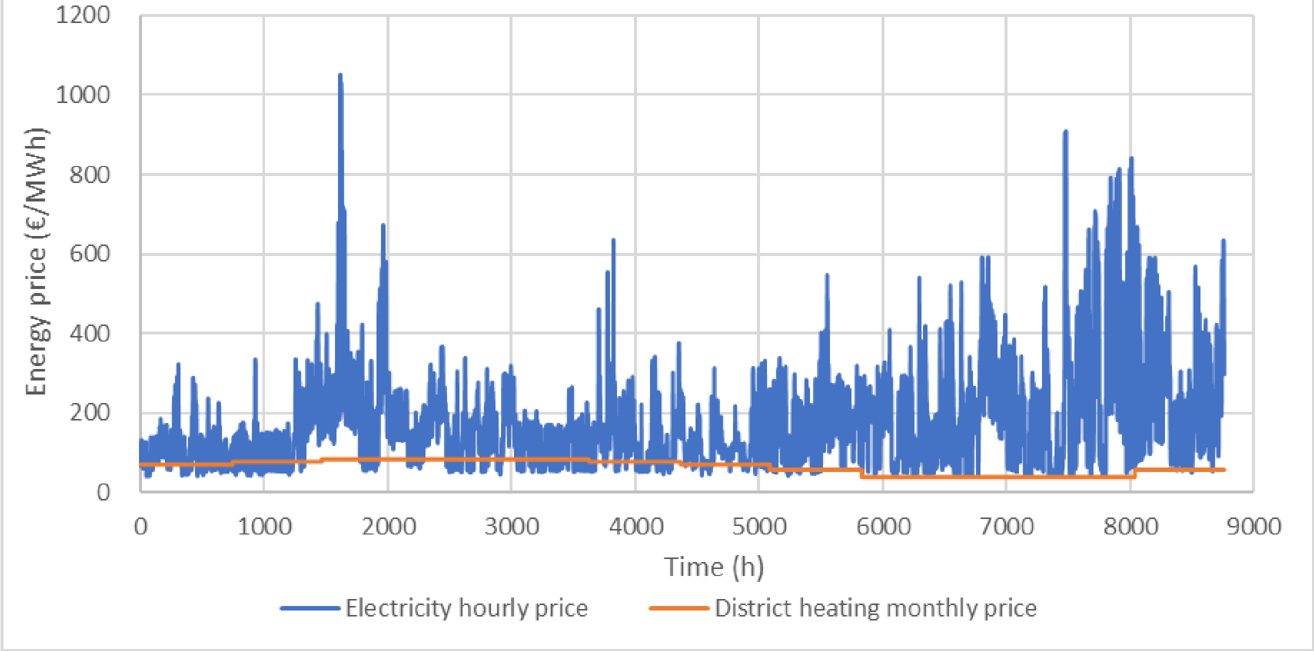
General scheme of a small energy community



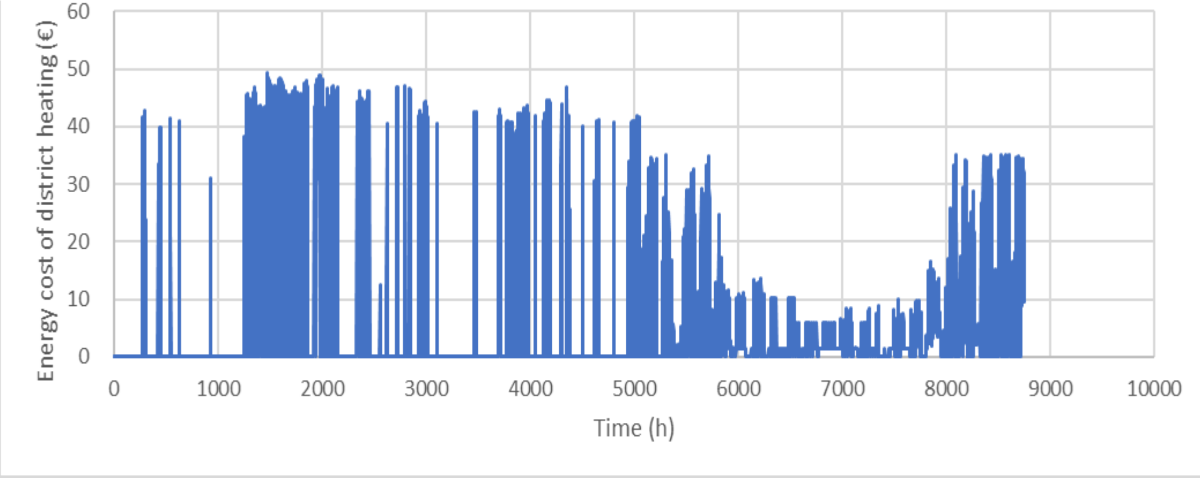
Energy system of a small energy community



Energy prices and optimal usage of district heating



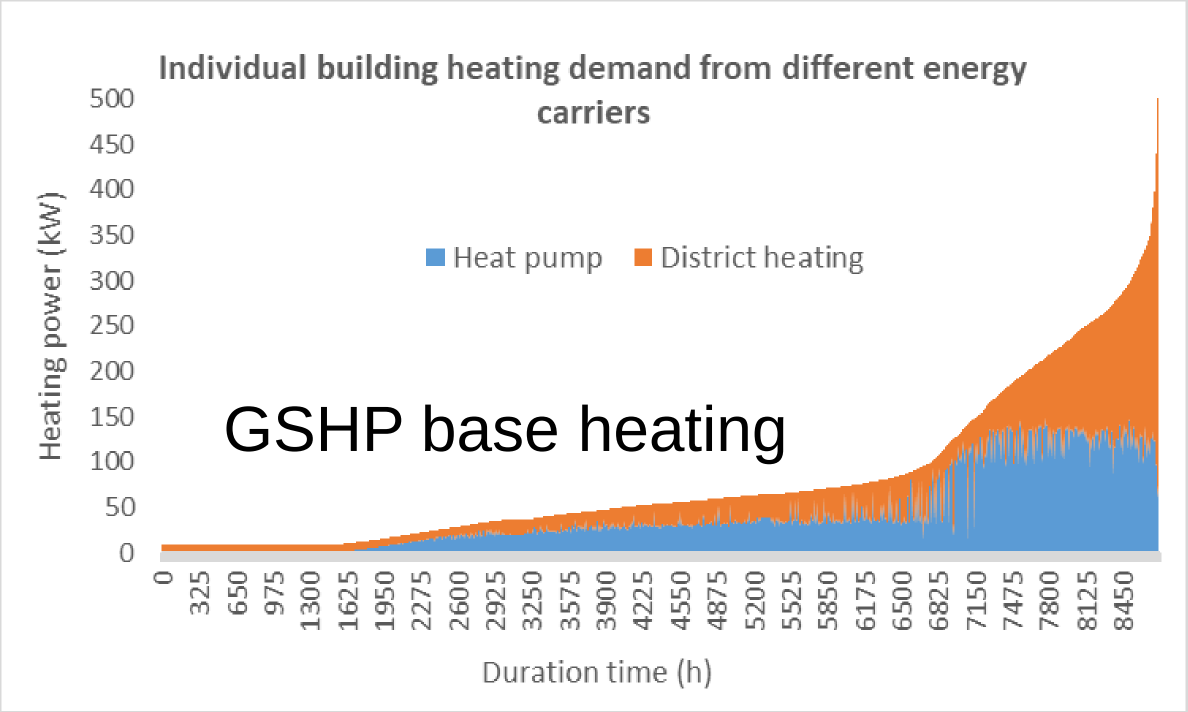
Hours when is more profitable to use district heating than heat pump



Dual energy source heat pump

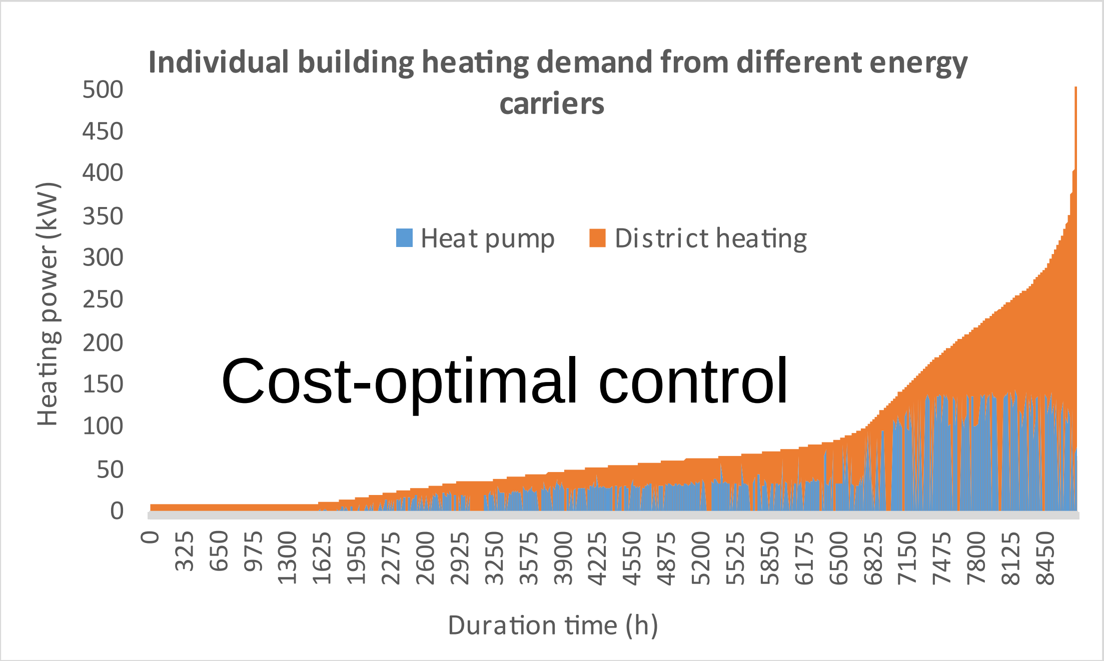
Toutdoor	COP
-10	2,5
0	2,55
10	3
20	3,3

Duration curves of the total heating powers



Energy ratio 43 % of district heating

Energy ratio 57 % of heat pump



Energy ratio 54 % of district heating

Energy ratio 46 % of heat pump

Energy costs saving 18 %

Conclusion

- Demand response and power cutting reduce cost about 6-23 % in an office building
- Cost-optimal control in hybrid systems reduces energy costs 13 % in a large building complex
- Cost-optimal control reduces energy costs 18 % in a small energy community

Buildings are built for people to live and work comfortably, effectively and safely