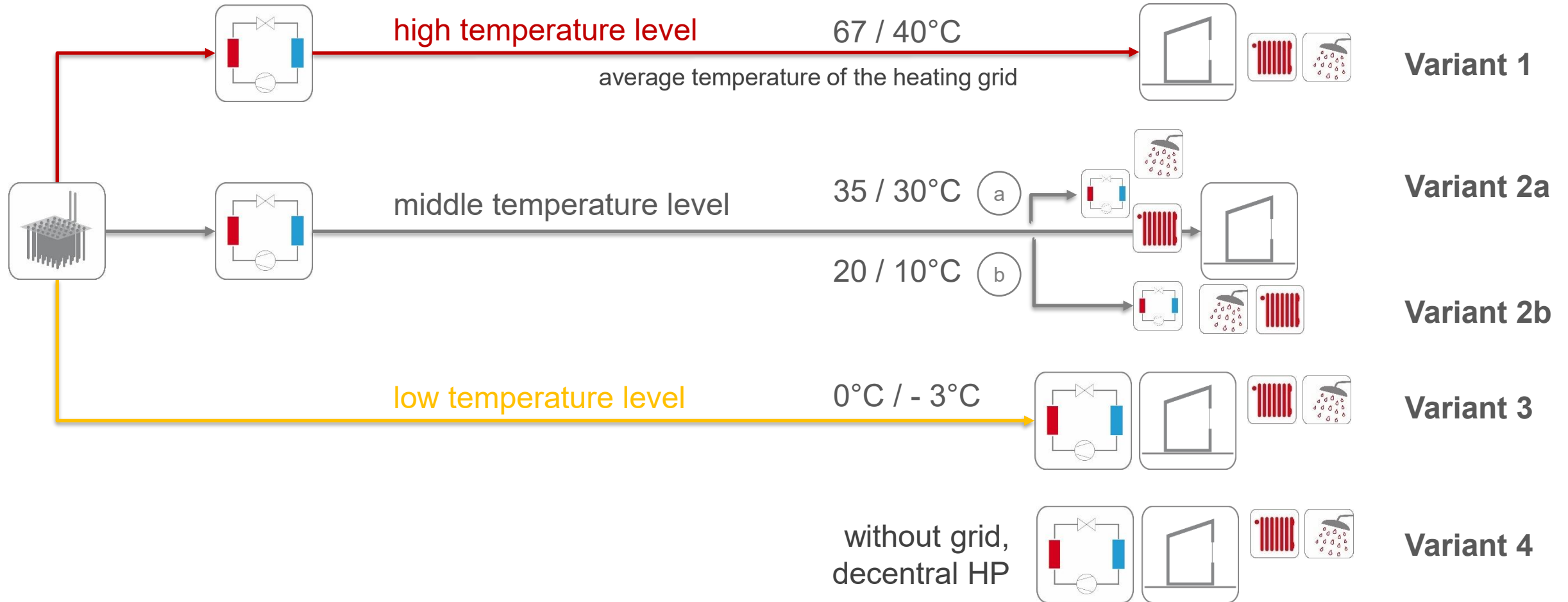


# Techno-/economic analysis on HP system concepts in districts

Franziska Bockelmann, Fabian Ochs und Carsten Wemhöner

# Heat Pump System Topology – Definition Annex 61



$T_{source}$   
(borehole heat exchanger (ground)  $0^{\circ}\text{C}$ )

$T_{sink}$  space heating, DHW (circulation)  
(no space cooling)

# Cases for the study

No. of buildings  
4 to 134 buildings

Gross floor area  
4,800 to 168,400 m<sup>2</sup>

Specific heat demand  
6 to 105 kWh/(m<sup>2</sup>a)



No. of example districts  
12 districts (concepts)

Heat grid length  
110 to 4,725 m

Heat line density  
142 to 9,984 kWh/m

# Methode: calculation and analyses

Kapitalkosten (alle Angaben netto)						
Betrachtungszeitraum	20 a	Annuitätenfaktor	0,0704	0,0704	0,0704	
Kapitalzins	3,5%	Preisdynam. Barwertfaktor	16,861			
Preisänderungsfaktor	2,0%					

Konzept	HT central HP		MT + DHW-HP /IT + [DRHW+SH]-H		LT decentral HP		dec. w/o grid		Erdsonden	
	A1	A2a	A2b	A3	A4	A4	A4	B3	B3	
Investitionsbetrag	*****	*****	*****	*****	*****	*****	*****	*****	*****	
Finanzierungsbedarf nach Förderung [I]	*****	*****	*****	*****	*****	*****	*****	*****	*****	
Fördersumme gesamt [I]	-	-	-	-	-	-	-	-	-	
Kapitalgebundene Annuität [I/a]	337.873	362.764	375.040	320.048	231.575	311.779				
Betriebsgebundene Annuität [I/a]	42.094	50.225	55.801	45.953	29.505	32.602				

Kapitalkosten Brutto	
Konzept	HT central HP
Variante	A1
Investitionsbetrag	*****
Finanzierungsbedarf	*****
Fördersumme gesamt	-
Kapitalgebundene Annuität	402.069
Betriebsgebundene Annuität	50.092

HT central   A1   0												
Nr.	Name	Relativer Preis [I/a]	Dimensionierung	Investitionsbetrag A0	Förderquote	Förderung I	Investitionsbeitrag A0 nach	Nutzungsdauer T_N	Aufwand Instandsetzung I_Inst	Aufwand Wartung & Inspektion I_Op	Aufwand Betrieb I_Op [I/a]	
0	Langzeitwärmespeicher, Erdbecken, komplett		m <sup>3</sup>	0	0%	-	0	40 a	1,0%	0,3%	0	
1	Wärmenetz, Fernwärme, Trasse	1.200	m	309	1.030.800	0%	-	1.030.800	40 a	0,5%	0,5%	0
2	Wärmenetz, Fernwärme, Hausanschlussleitung	400	m	480	192.000	0%	-	192.000	40 a	0,5%	0,5%	0
3	Wärmenetz, Fernwärme, Hausübergabestation	115	kW <sub>th</sub>	94	172.267	0%	-	172.267	20 a	0,5%	0,5%	0
4	Elektrisches Heizelement, Elektrodenkessel		kW <sub>th</sub>	0	0	0%	-	0	20 a	1,0%	2,0%	0
5	Wärmepumpe Luft-Wasser	165	kW <sub>th</sub>	1.428	236.308	0%	-	236.308	18 a	1,0%	1,5%	5
6	Wärmepumpe Sole-Wasser	165	kW <sub>th</sub>	0	0	0%	-	0	18 a	1,0%	1,5%	5
7	Erdwärmesonden		m	0	0	0%	-	0	40 a	0,5%	0,5%	0
8	Außenluftkühler für WP		kW <sub>th</sub>	0	0	0%	-	0	18 a	1,0%	2,0%	0
9	Solarthermiekollektoren		m <sup>2</sup>	0	0	0%	-	0	25 a	0,5%	1,0%	0
10	Photovoltaik	500	kW <sub>p</sub>	2.407	1.203.604	0%	-	1.203.604	25 a	0,5%	0,2%	0
11	Wärmespeicher, Behälter (zentral)	0,45	m <sup>3</sup>	94	42.507	0%	-	42.507	40 a	0,5%	0,2%	0
12	Elektro- & Anlagentechnik	16%	%	1	458.110	0%	-	458.110	15 a	0,0%	1,0%	0
13	Energiezentrale Gebäude		BGF	1.000	0	0%	-	0	50 a	0,0%	1,0%	0
14	Baustelleneinrichtung, Doku, Engineering, Inb	4,5%	%	1	152.802	0%	-	152.802	50 a	0,0%	1,0%	0
15	Monitoring		Stk	0	0	0%	-	0	20 a	0,0%	1,0%	0
16	Ableitung Mittelspannungsebene inkl. Verlegung		m	0	0	0%	-	0	15 a	0,0%	1,0%	0
17	dez. Wärmepumpe (TW und I oder RH)		kWh	0	0	0%	-	0	18 a	1,0%	1,5%	5
18	dez. Pufferspeicher		m <sup>3</sup>	0	0	0%	-	0	20 a	1,0%	1,0%	0
19	Anschlussleistung Endkunden			0	0	0%	-	0				
20	Anzahl Gebäude	1	Stk	16	0	0%	-	0				
21	Heizstab / Durchlauferhitzer (TW)		Stk	0	0	0%	-	0				
22				0	0	0%	-	0				
23				0	0	0%	-	0				
24				0	0	0%	-	0				
25				0	0	0%	-	0				
26				0	0	0%	-	0				
27				0	0	0%	-	0				
28				0	0	0%	-	0				
29				0	0	0%	-	0				
30	Unvorhergesehenes	20%	%	3.548.398	709.880	0%	-	709.880	20 a	0,0%	0,0%	0
31	Planung	20%	%	4.258.078	851.616	0%	-	851.616	20 a	0,0%	0,0%	0
32	Personalkosten			0			-				1000	

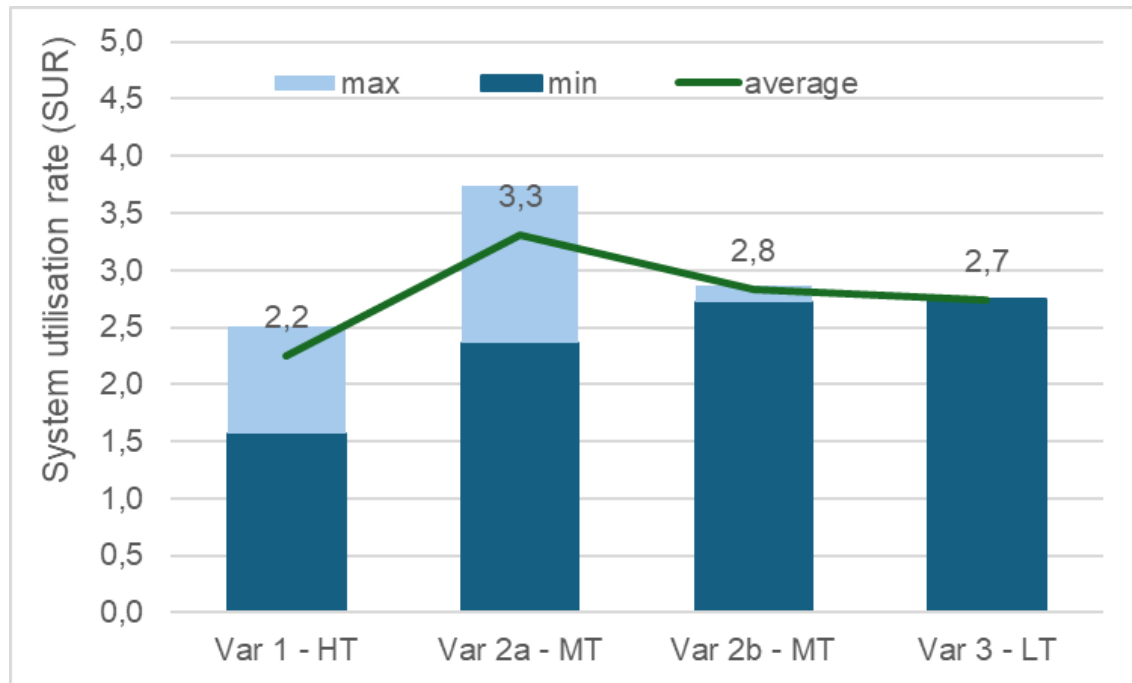
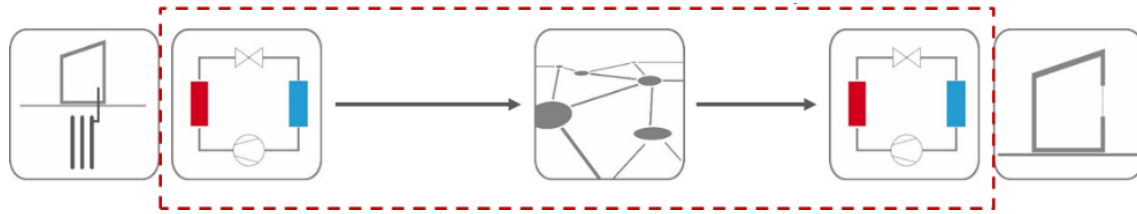
## ➤ Annual energy balance

### Inputdata:

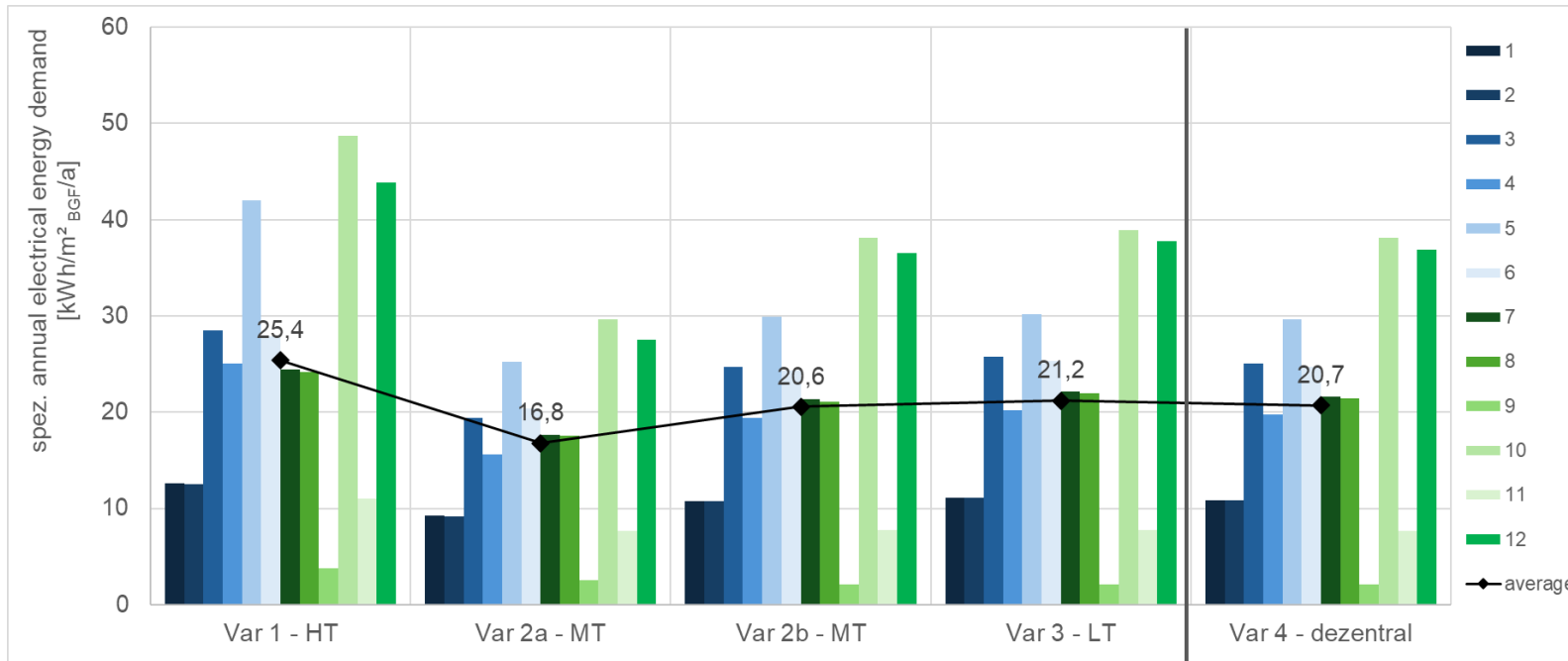
- No. of buildings
  - Gross floor area
  - Heating demand for space heating and domestic hot water
  - Thermal peak load (total and DHW)
  - Grid length
- 
- Economic efficiency calculation according to the annuity method in accordance with VDI 2067

# System utilisation rate (SUR)

## System boundary for performance factor calculation



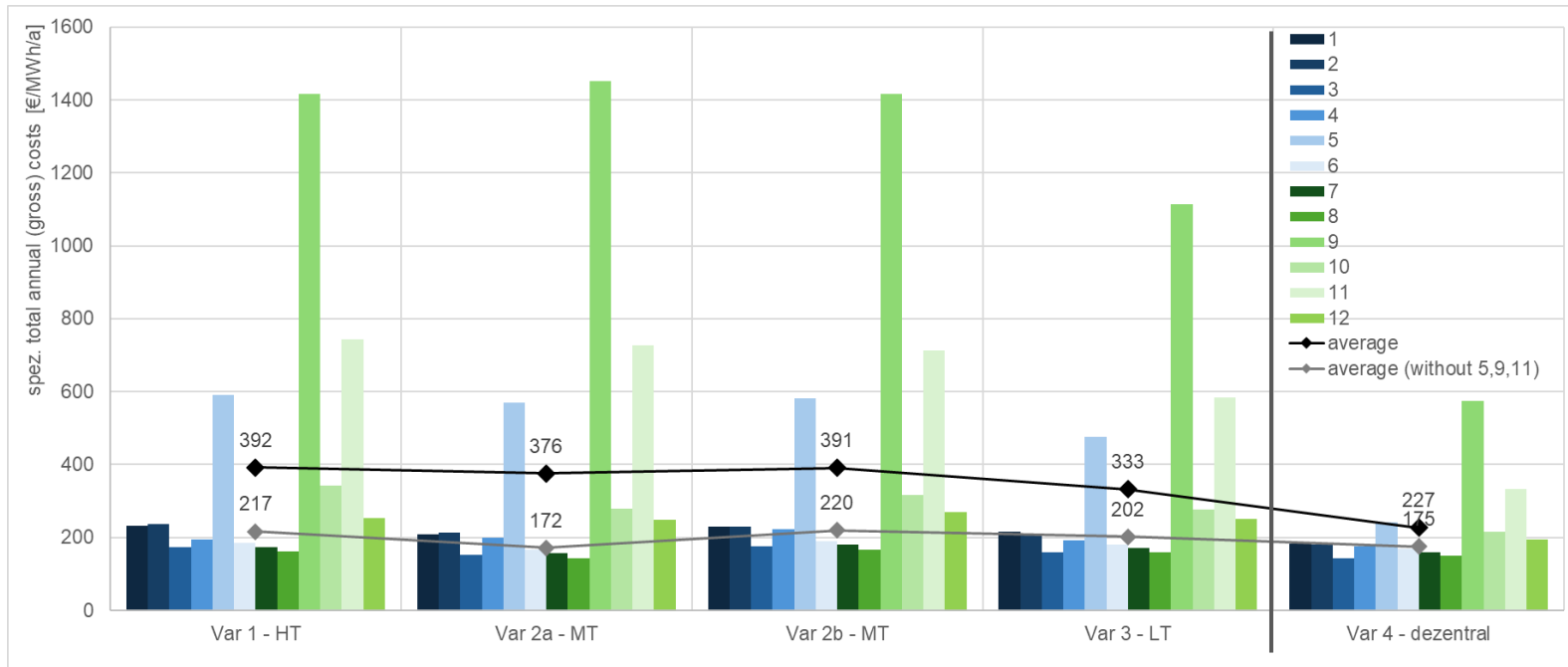
- Power requirements for auxiliary energy (peripherals in the technical centre and in the network) not taken into account
- Highest SUR: central heat pump and booster heat pump (var. 2a) on average 3,3
- Lowest SUR: hightemperatur grid (var. 1) on average 2,2
- Low-temperatur grid (var. 3) 2,7



Note:  
 Districts 5, 10 and 12: high thermal energy demand  
 District 9: very low thermal energy demand

- Average electricity demand of 16.8 to 25.4 kWh/(m²a)
- Little variation between variants: based on different energy requirements and network losses (network lengths)
- Significant differences between the districts
- Lowest energy requirement: central heat pump + booster heat pump (variant 2a) → high system efficiency
- Highest energy requirement: high-temperature grid (variant 1) → low system efficiency and influence of high temperatures

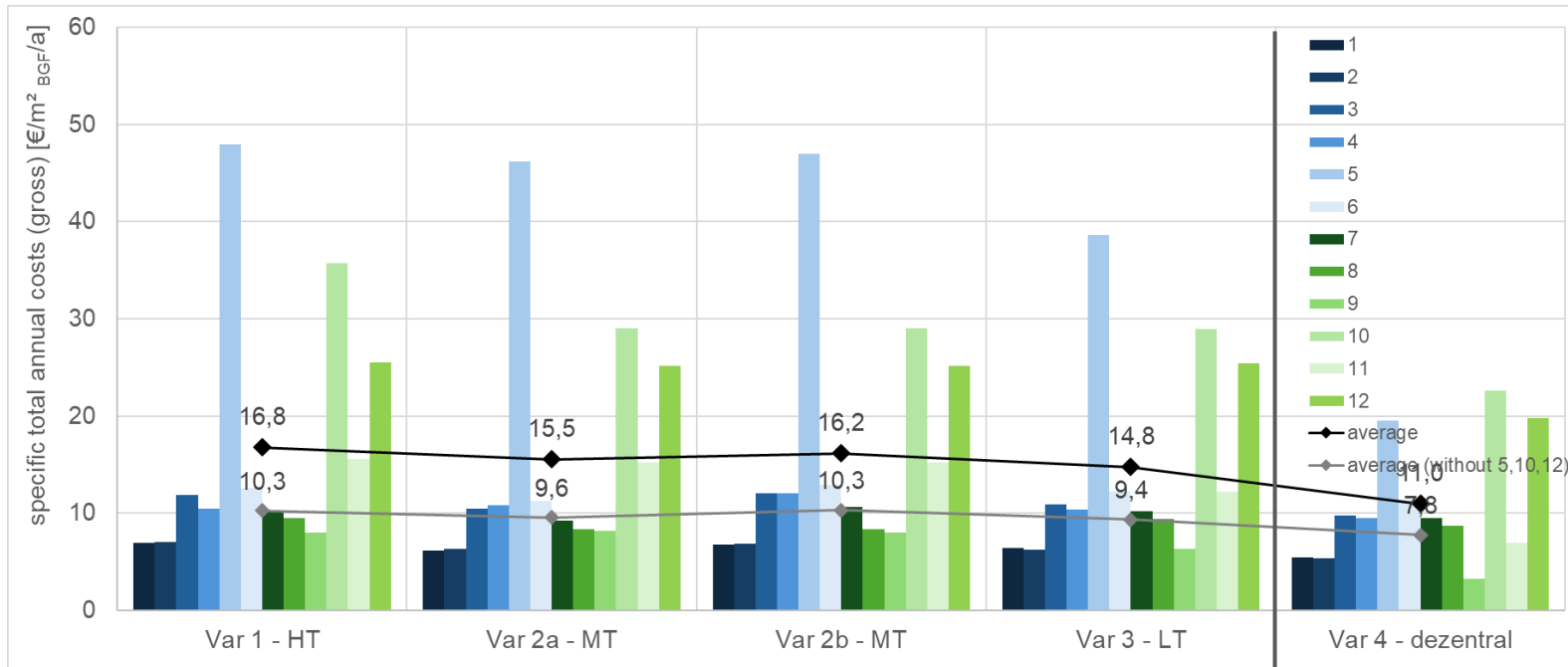
# Specific total annual costs (gross) – heat production cost (LCOH)



- Reduction in heat production costs by reducing the network temperature and moving the heat pump from a centralised to a decentralised location
- On average 333 to 391 €/MWh (172 to 220 €/MWh)
- Lowest heat production costs: semi-supply with central heat pump + booster heat pump (var 2a) and low-temperature network (var 3)
- Decentralized supply without heating grid is most cost-effective

Note:  
 Districts 5,10 and 12: high thermal energy demand, high net length } heat line density < 500 kWh/m  
 District 9 and 11: very low thermal energy demand

# Specific total annual costs (gross)



Note:  
 Districts 5, 10 and 12: high thermal energy demand, high net length } heat line density < 500 kWh/m  
 District 9 and 11: very low thermal energy demand

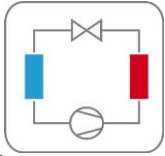
- Similar trend to heat production costs
- On average 14,8 to 16,8 €/m<sup>2</sup>a (9,4 to 10,3 €/m<sup>2</sup>a)
- Highest cost/m<sup>2</sup>: central heat pump with high-temperature grid (var. 1)
- Lowest cost/m<sup>2</sup>: low-temperature grid (var. 3) and semi-supply with central heat pump + booster heat pump (var. 2a)
- Decentralised supply without a heating grid is the most cost-effective option



Preliminary study with very rough assumptions (annual balance sheet)

Various options are available for the design and integration of HP

- Central heat pump with high temperature level
- Semi-central supply – central heat pump + decentralized booster for DHW / DHW+SH
- Decentralized heat pump with low-temperature grid



BUT: System topology and integration options depend on the neighbourhood and local conditions.

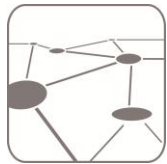


- Decentralised heat pump integration outperforms centralised solutions: decentralised heat pumps can generally achieve better efficiency (lowest heat losses, best heat pump performance) than centralised heat pumps.
- Semi-centralised (with booster heat pump) achieves good energy efficiency, but is challenging from an economic perspective (investment costs).
- Not economically viable if the neighbourhood
  - requires a too large grid (network length)
  - has too low heat demand
  - heat line density is below 500 - 1,000 kWh/m

## Workflow to support decision-making for cost-optimal design - future integral planning approach



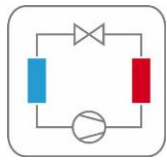
- ✓ Starting point - basis of the design:  
**specification of boundary conditions** (total heat demand (kWh/a), network length and layout, heat line density (kWh/m), source availability, climate, renewable potential)



- ✓ **Optimization of buildings:**  
high efficiency standards with low-temperature distribution systems and maximum PV yield



- ✓ Limitation of **network size and complexity:** compact neighborhoods with corresponding grid are more economical and energy-efficient than widely scattered buildings and large neighborhoods.

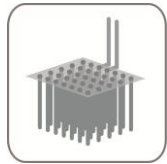


- Preference for **decentralized or semi-centralized heat pump concepts:**  
decentralized heat pumps with minimal distribution losses and maximum performance.



- **Topology of the heat pump** system determines its efficiency!

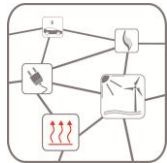
- Minimization of **grid temperatures:**  
design of grid for the lowest possible temperatures that are still compatible with the requirements of the buildings - cold district or medium temperature semi-central systems.



- Placement of the **source**: restrictions on the choice of heat source for the heat pump in decentralized solutions without a grid. More options and easier connections of sources with network topologies.



- Cold local heating grids enable buildings to be **cooled in summer** within the framework of a network/system.



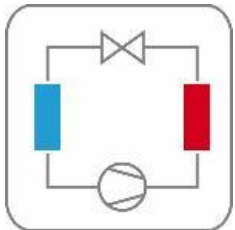
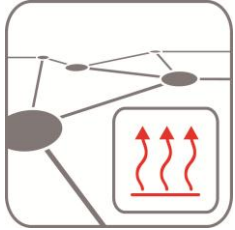
- Simultaneous operation of heat pumps for various building requirements enables **waste heat recovery** for other functions.



- High energy efficiency of heat pumps and systems makes it possible to achieve **ambitious energy/emission targets**.



- Annuity method for calculating total annual costs.
- Safety aspects** to be considered with natural refrigerants are becoming more relevant from a centralized to a decentralized perspective.



# Thank you for your interest!