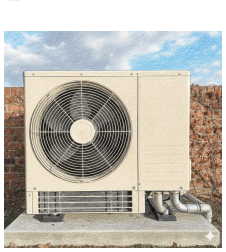
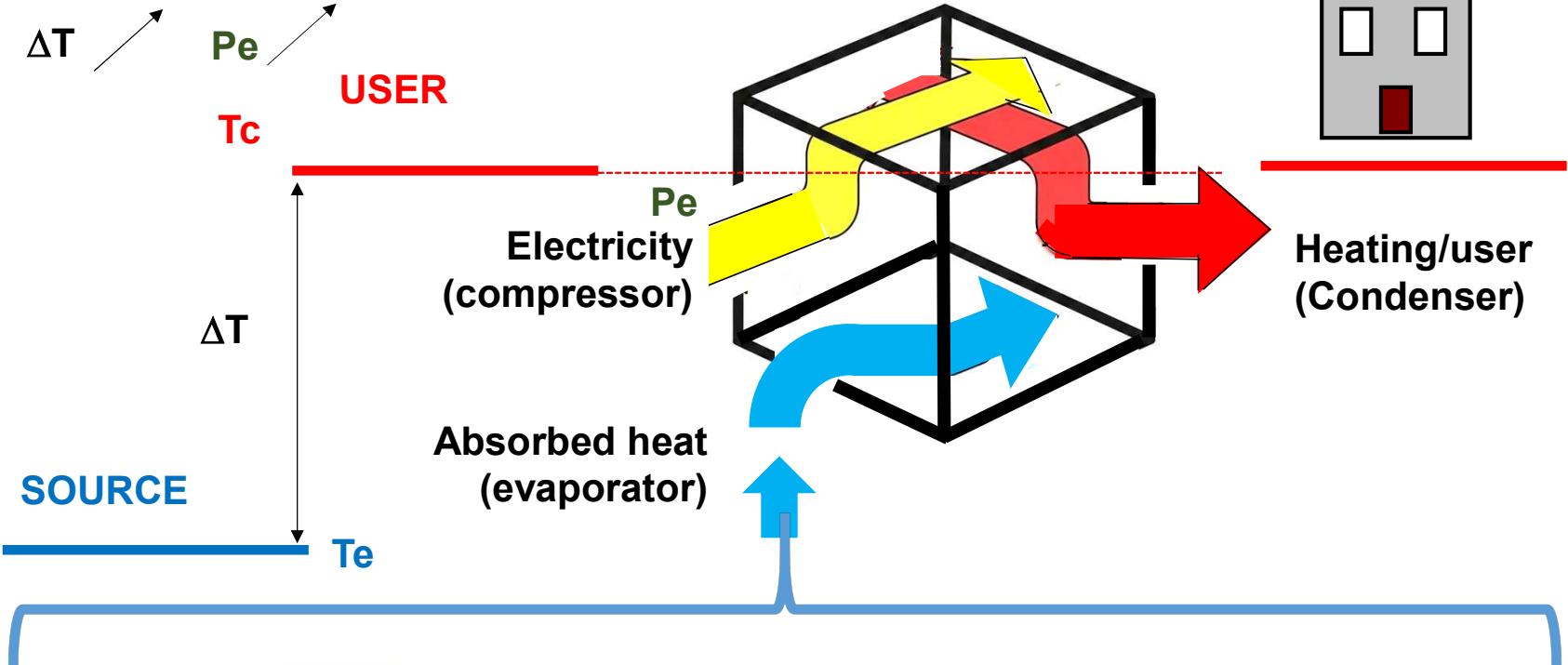
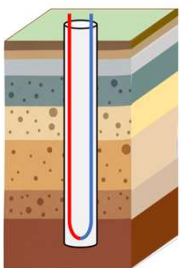


# Generation systems – heat pumps

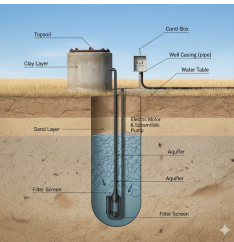
# Operation of a heat pump



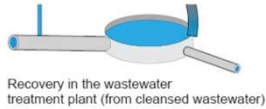
ASHP



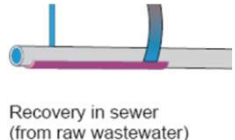
GHEs



Aquifer

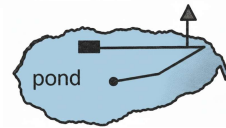
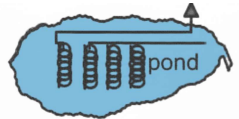


Recovery in the wastewater treatment plant (from cleansed wastewater)



Recovery in sewer (from raw wastewater)

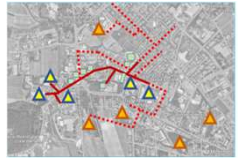
Recovery



Ponds/lakes



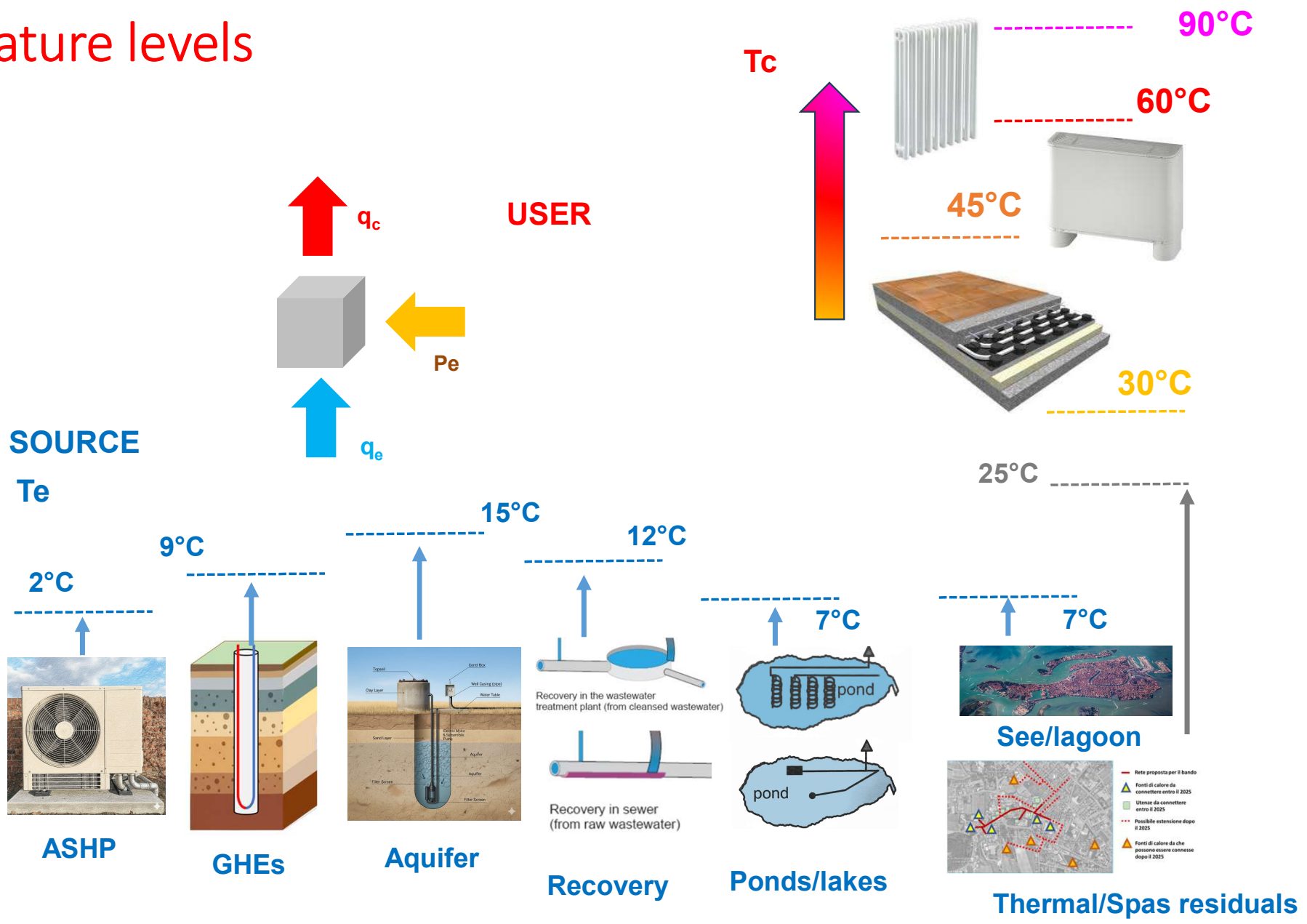
See/lagoon

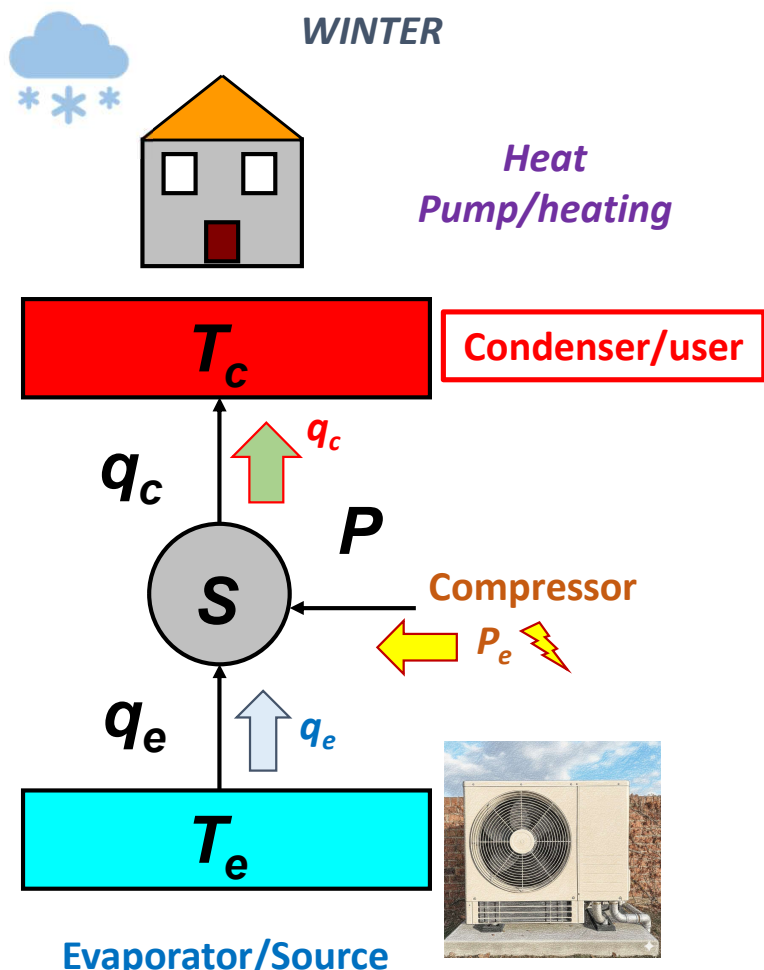


Thermal/Spas residuals

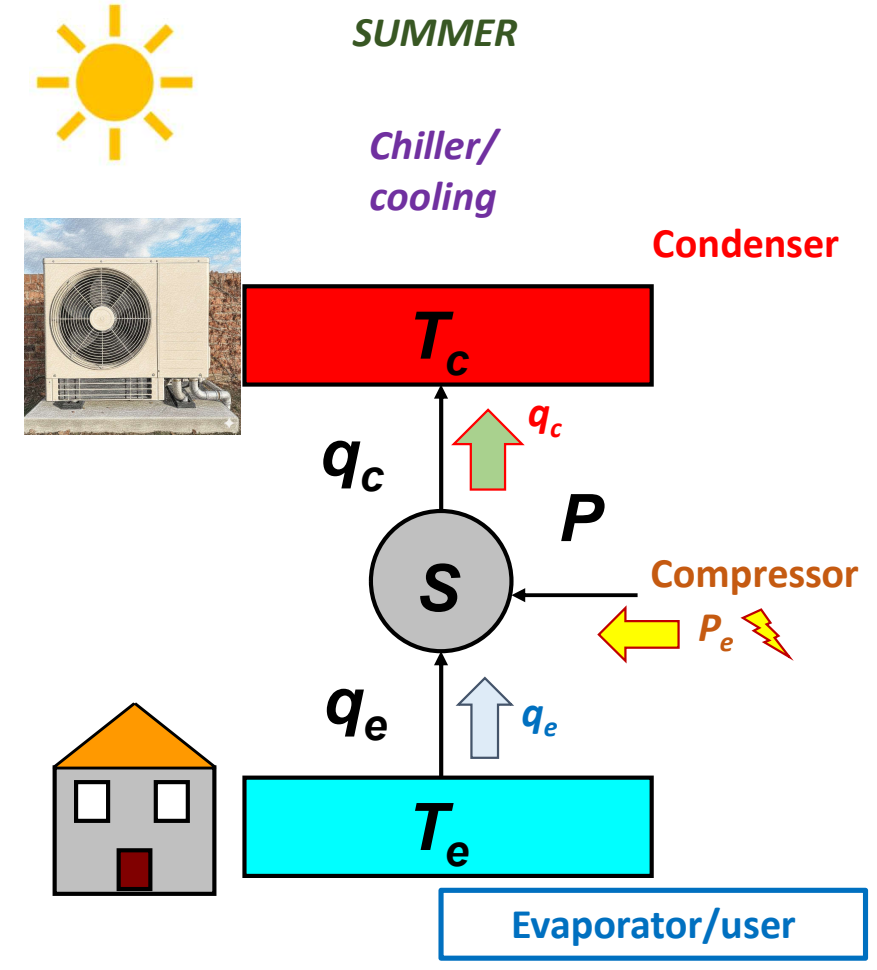
- Rete proposta per il bando  
 ▲ Fonti di calore da connettere entro il 2025  
 ■ Utenti da connettere entro il 2025  
 - - - Possibile estensione dopo il 2025  
 ▲ Fonti di calore da che possono essere connesse dopo il 2025

# Temperature levels





Coefficient of Performance  $\rightarrow$   $COP = \frac{q_c}{P_e}$

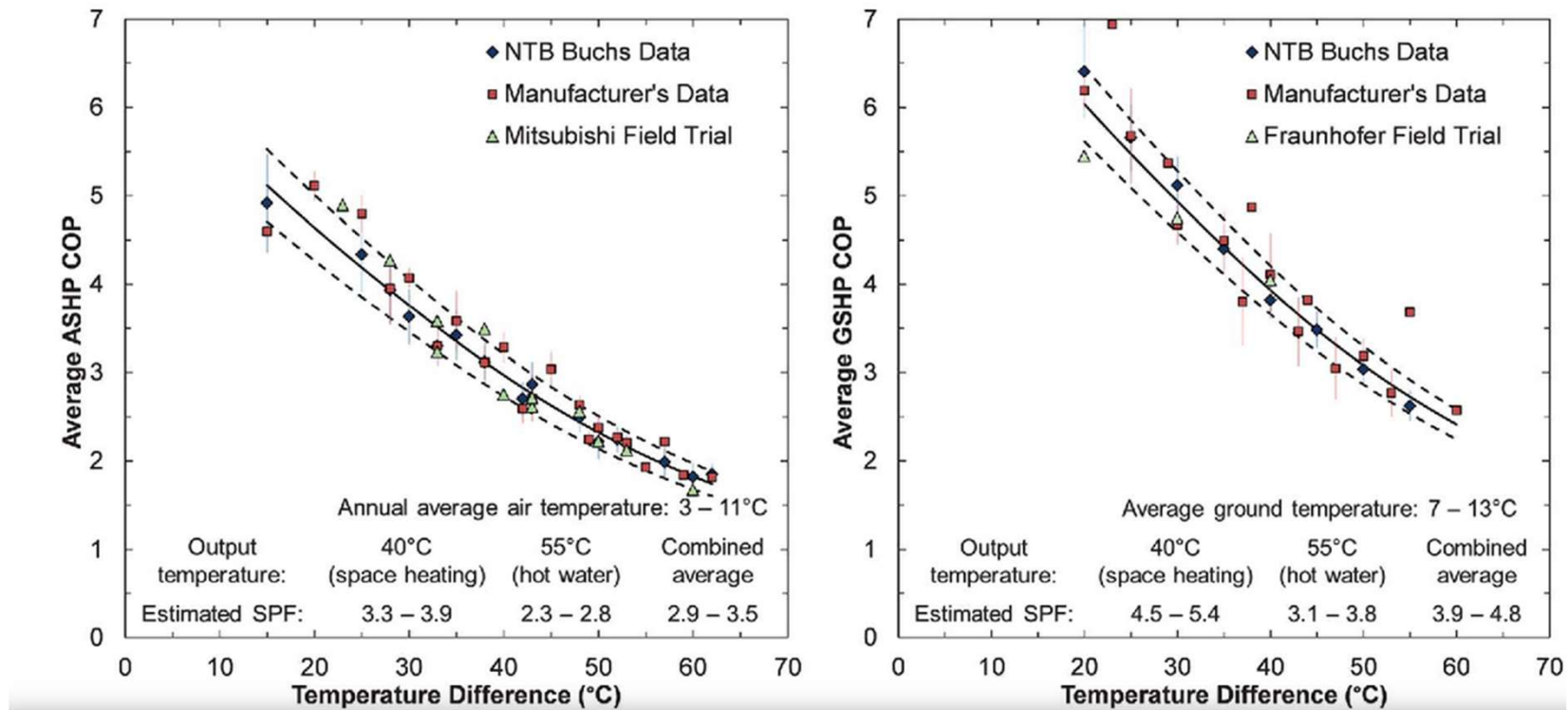


Energy Efficiency Ratio  $\rightarrow$   $EER = \frac{q_e}{P_e}$

In any case:  $q_c = q_e + P_e$

# Heat pumps

## Performance

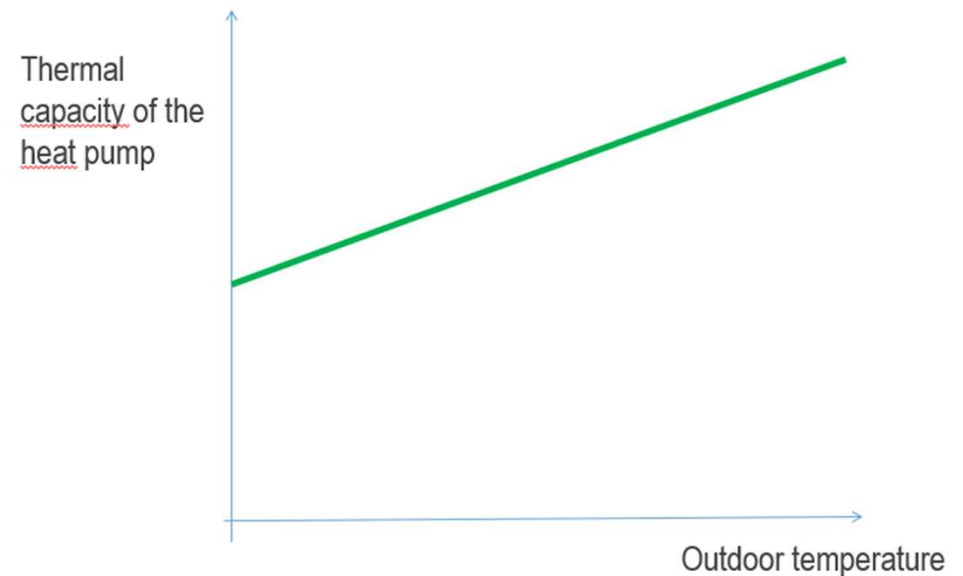


[source: Staffell et al]

# Sizing of air-to-water heat pumps

## Thermal capacity of a heat pump

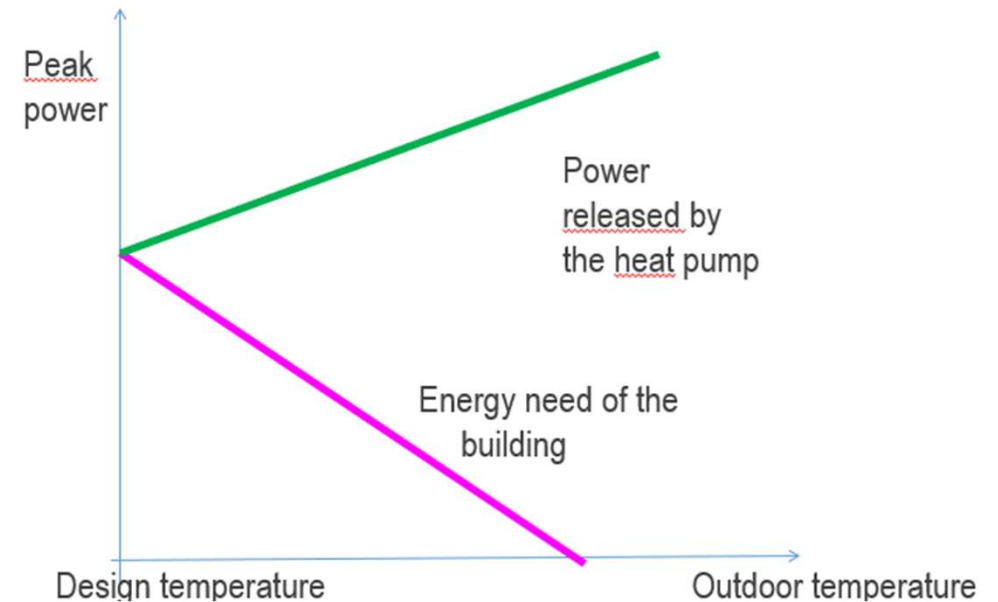
The thermal capacity of a heat pump (i.e. the thermal power supplied from the heat pump condenser to the building) decreases with decreasing external air temperature, whereas the heat load of the building (the required thermal energy to keep indoor thermal comfort) increases.

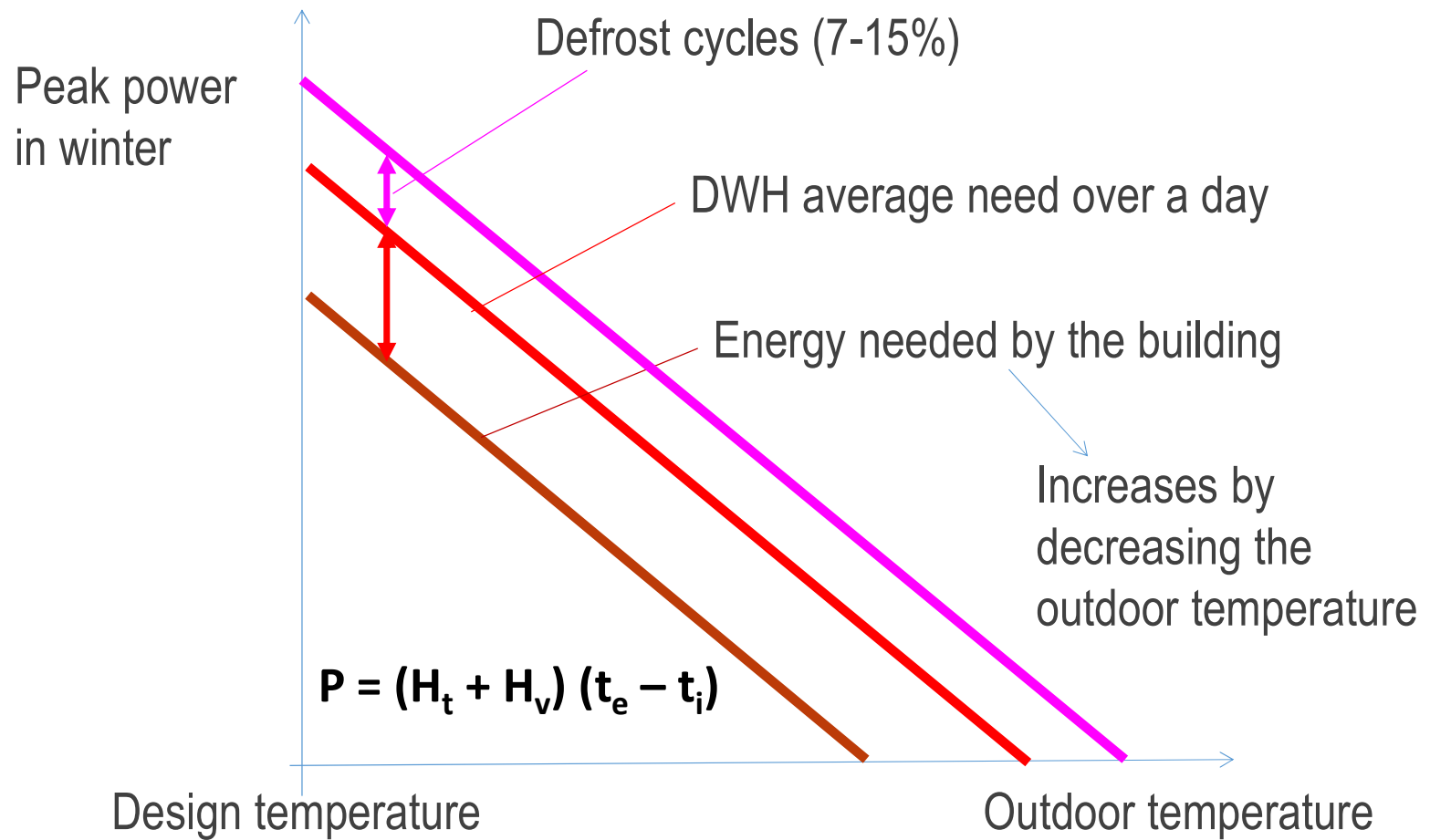


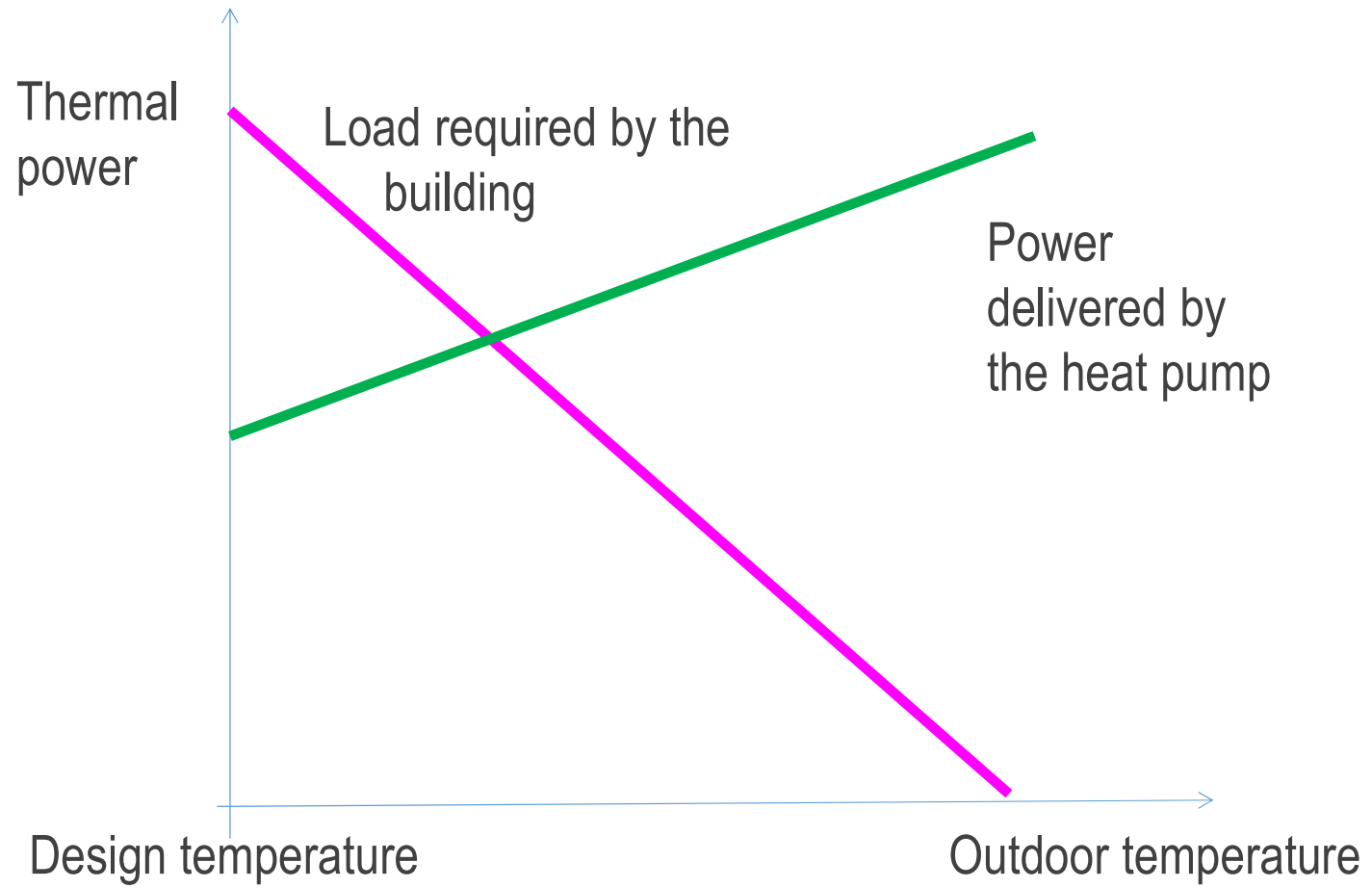
# Sizing of air-to-water heat pumps

## Heat pump only

- The heat pump is sized based on the peak load in **outdoor design conditions**.
- This is ok for new or deeply retrofitted buildings, with limited peak load and low supply temperature required by the heating system (radiant systems, fan-coils, active beams).



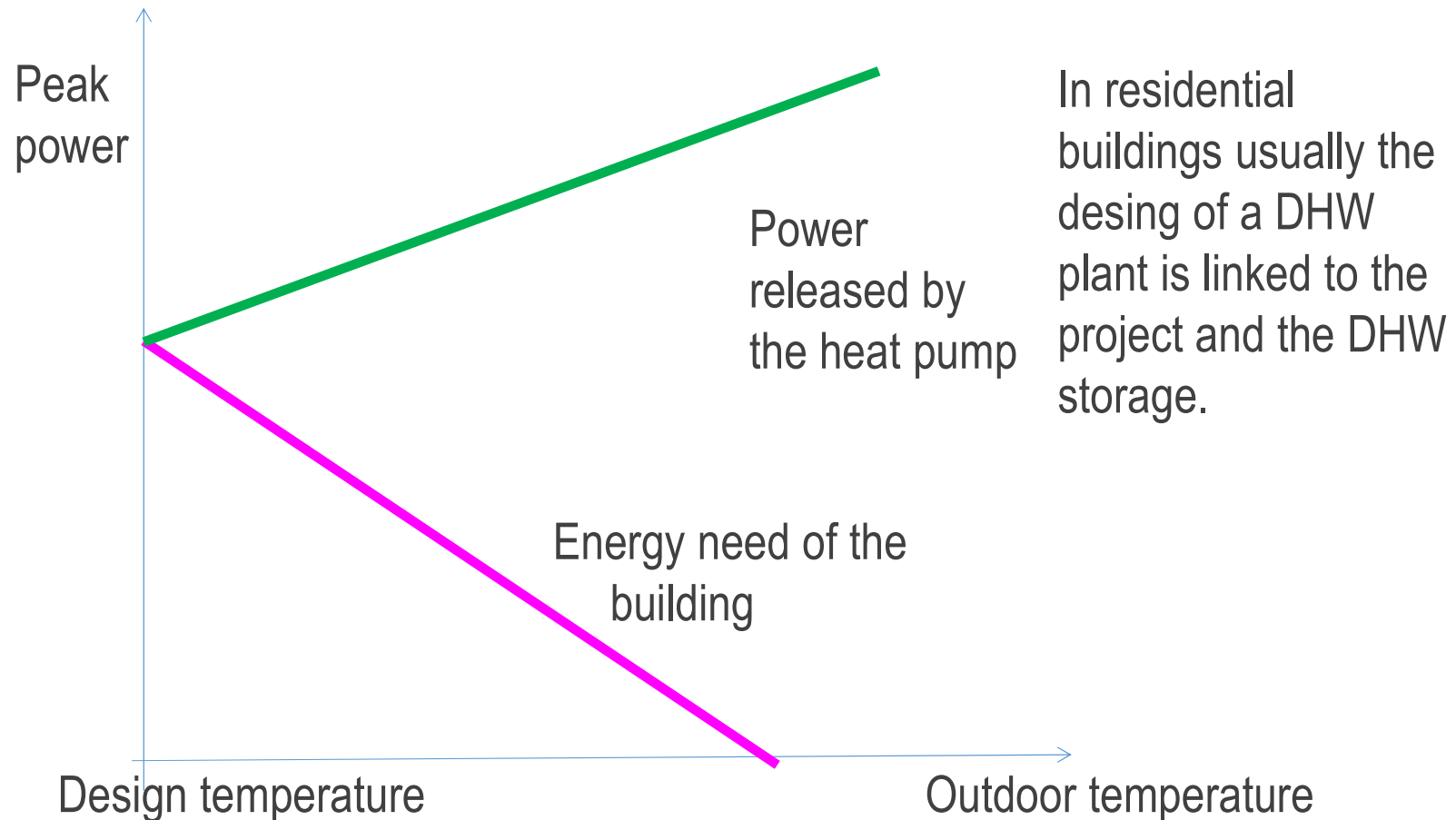




## Case 0

Base case— New or retrofitted building: limited load required thanks to the insulation level.  
Low temperature heating system (radiant system, fan-coil, active beams, fan-coil beam)

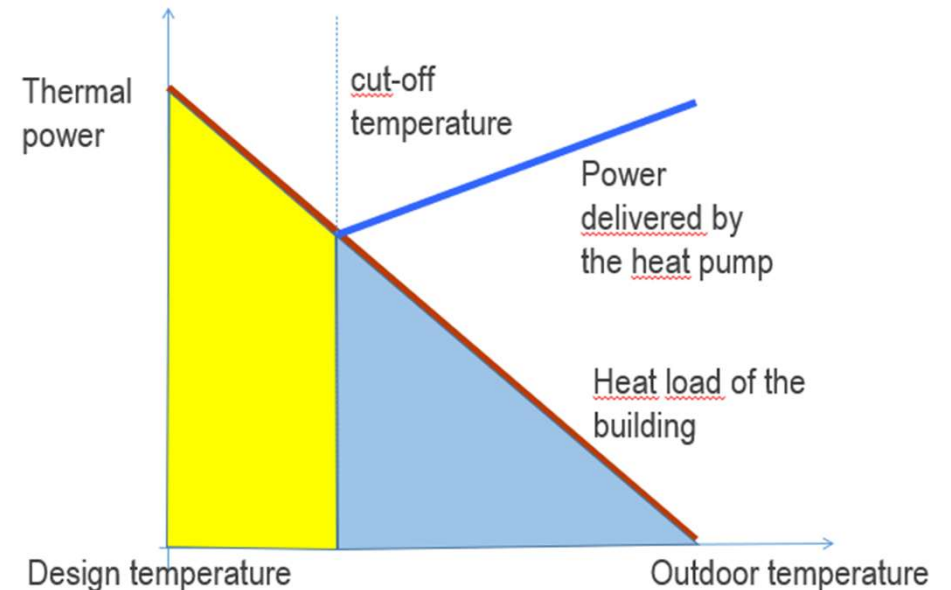
The heat pump is sized based on the peak load in outdoor design conditions



# Case 1

## Alternate operation with gas boiler

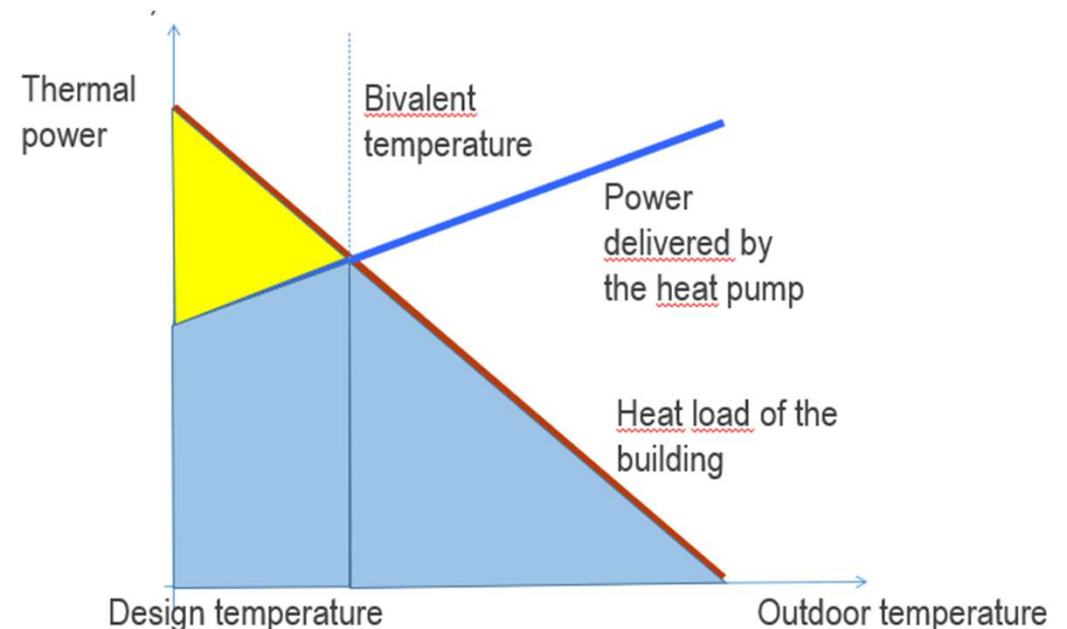
- The heat pump is sized based on the heat load corresponding to the **cut-off temperature**.
- This is ok for buildings with moderate retrofit, with significant peak load and high supply temperature required by the heating system (radiators).
- Below the cut-off temperature the heat pump switches off and the heat load is entirely supplied by the gas boiler.



## Case 2

### Parallel operation with gas boiler

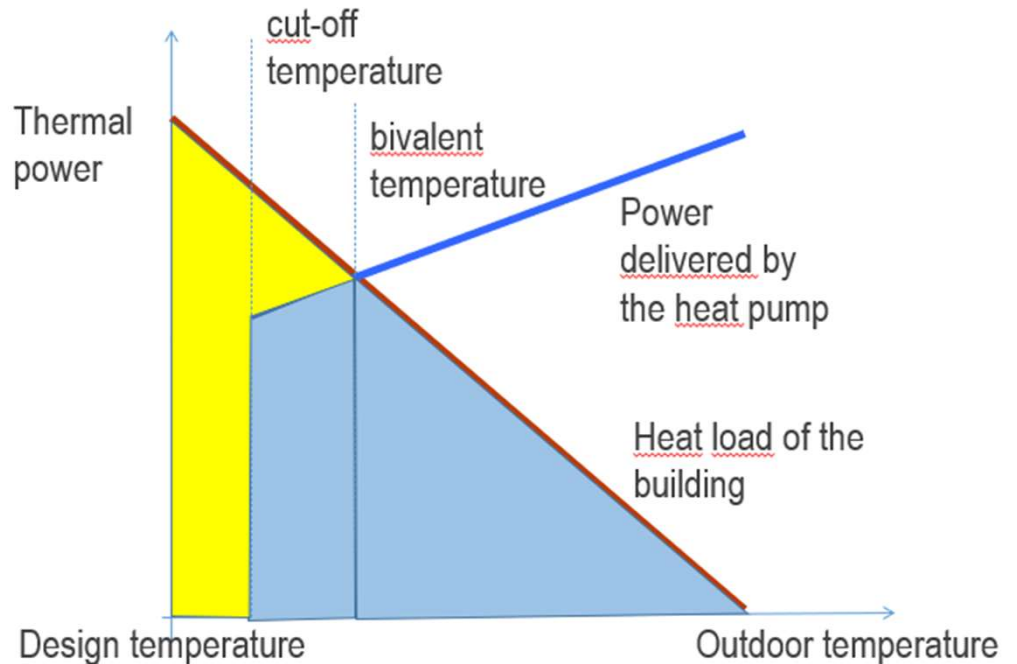
- The heat pump is sized based on the heat load corresponding to the **bivalent temperature**.
- This is ok for buildings with moderate retrofit, with significant peak load and high supply temperature required by the heating system (radiators).
- Below the bivalent temperature the heat pump and the gas boiler work in parallel.



## Case 3

### Partially parallel operation with gas boiler

- The heat pump is sized based on the heat load corresponding to the **bivalent temperature**.
- Below the bivalent temperature the heat pump and the gas boiler work together in parallel operation.
- Below the cut-off temperature the heat pump switches off and the gas boiler works.



## Resuming

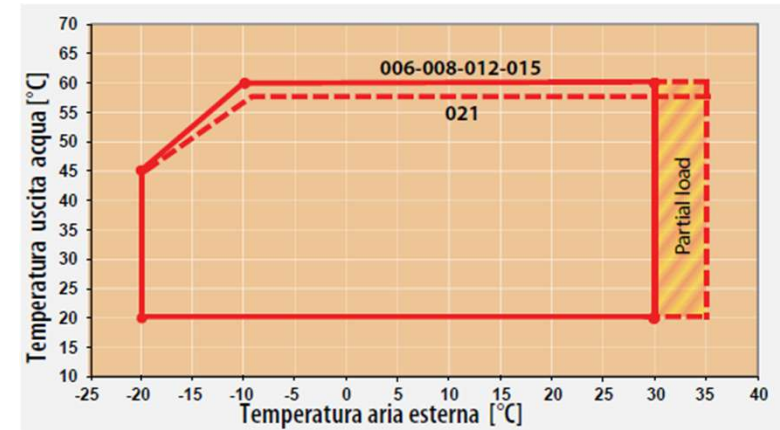
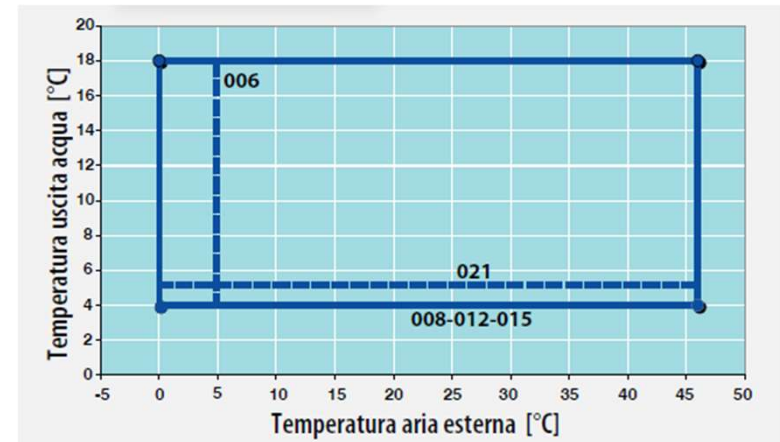
- 0) The sizing of the heat pump is done for the design temperature. The heat pump has to deliver the power needed by the building + DHW + defrost cycle.
- 1) Alternate operation: the heat pump is sized to work until the “cut-off” temperature. Below this this temperature the boiler works and the heat pump switches off.
- 2) Parallel operation: the heat pump is sized to work at the “bivalent temperature”. Below this temperature the heat pump and the boiler works simultaneously (the boiler covers the residual heat that the heat pump is not able to provide).
- 3) Partially parallel operation: the heat pump is sized to work at the “bivalent temperature”. Below this temperature the heat pump and the boiler works simultaneously (the boiler covers the residual heat that the heat pump is not able to provide) until the “cut-off” temperature is reached. Below this temperature the heat is provided just by the boiler and the heat pump switches off.

# Sizing of air-to-water heat pumps

## Operation range

The heat pump model must be suitable for the desired operating conditions, i.e. the design point must be inside the operating range provided by the heat pump manufacturer.

The operating range depends on the interaction between components (mainly the compressor) and the refrigerant.

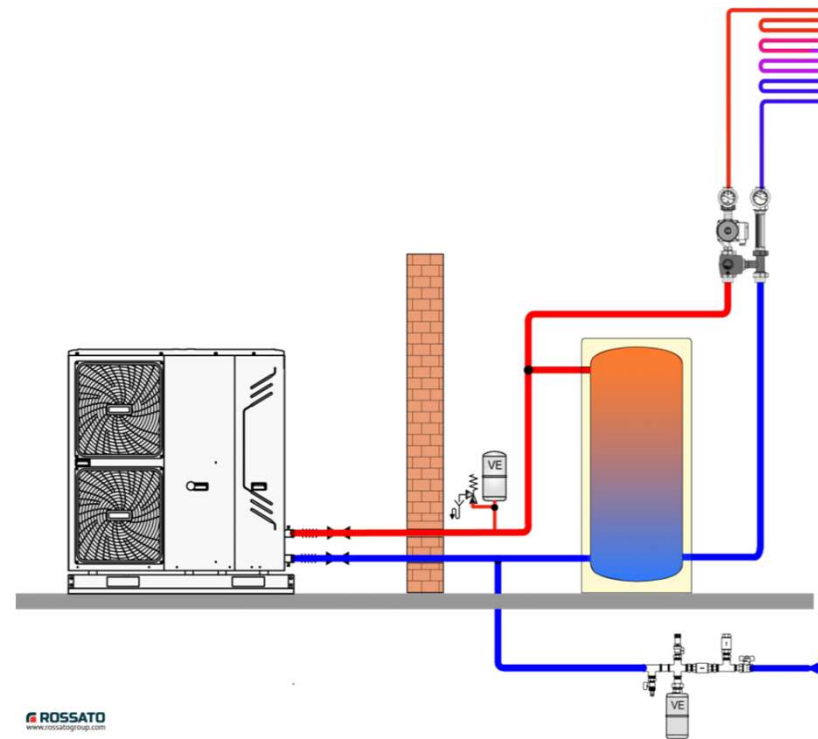


# Types of air-to-water heat pumps

## Mono-bloc heat pumps

The whole machine is outdoor.

- It is a cheap solution.
- Hydronic system (heat and cold distribution) directly connected to the outdoor machine.
- Antifreeze solution must be designed for the water of the hydronic system.



[source: Rossato]

# Types of air-to-water heat pumps

## Mono-bloc heat pumps

The whole machine is outdoor.



- 1 Evaporatore rivestito con alette ondulate per aumentare l'efficienza
- 2 Ventilatore DC ad alta efficienza
- 3 Compressore inverter doppio rotore ad alta efficienza
- 4 Inverter
- 5 Condensatore

[source: Viessmann]

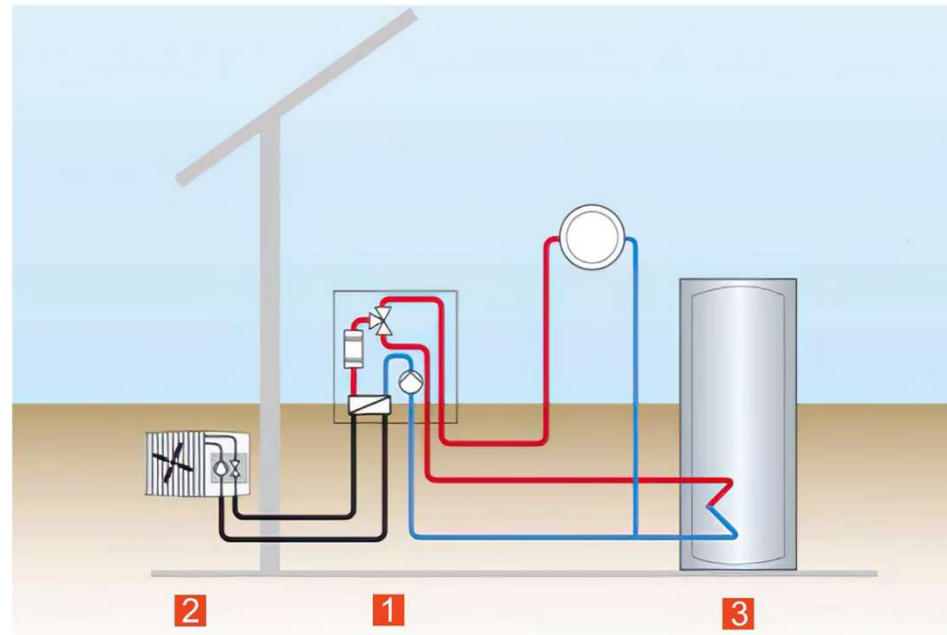
# Types of air-to-water heat pumps

## Split heat pumps

Split heat pumps are characterised by their separation into a quiet indoor unit and an air handling outdoor unit.

More efficient solution.

Possible plug&play solutions with integrated hydronic kit.



[source: Viessmann]

# Types of air-to-water heat pumps

## Split heat pumps

Split heat pumps are characterised by their separation into a quiet indoor unit and an air handling outdoor unit.

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Possible plug&play solutions with integrated hydronic kit.



[source: Enefen]

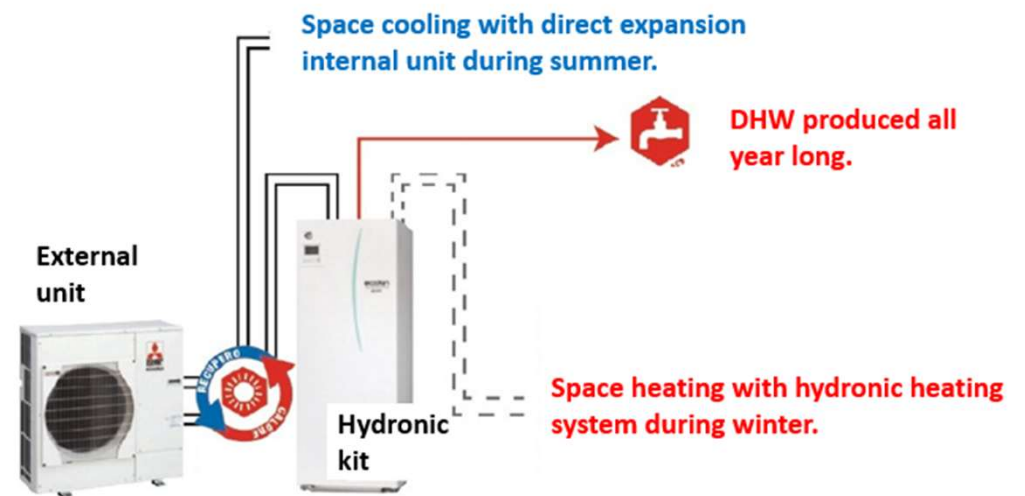
# Types of air-to-water heat pumps

## Mixed solution

The external unit can provide heating and cooling.

A hydronic kit allows to generate DHW (with a tank) all over the year and warm water for the heating system during winter.

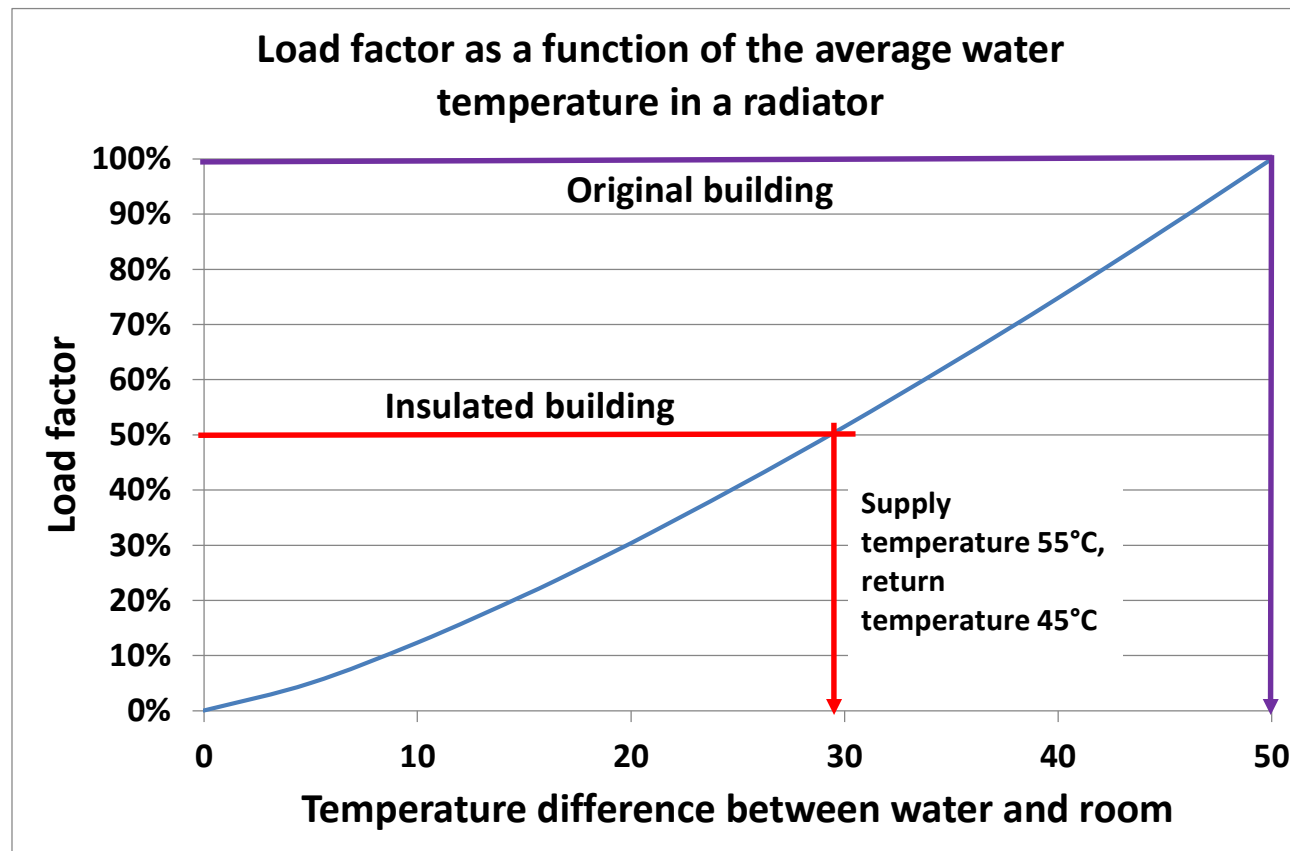
In summer the system works as a direct expansion cooling system, through indoor terminal units.



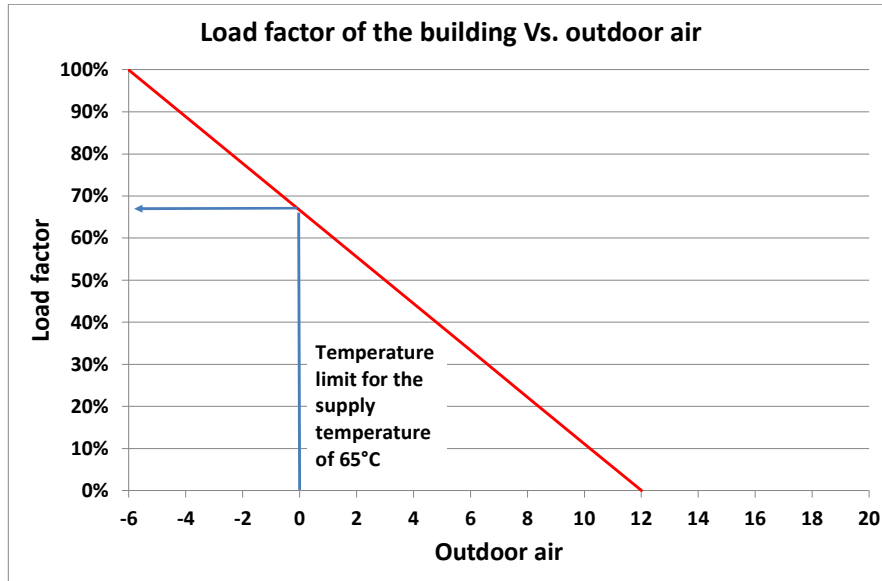
[source: Eneren]

# Possibilities and limits of heat pumps for high terminal units

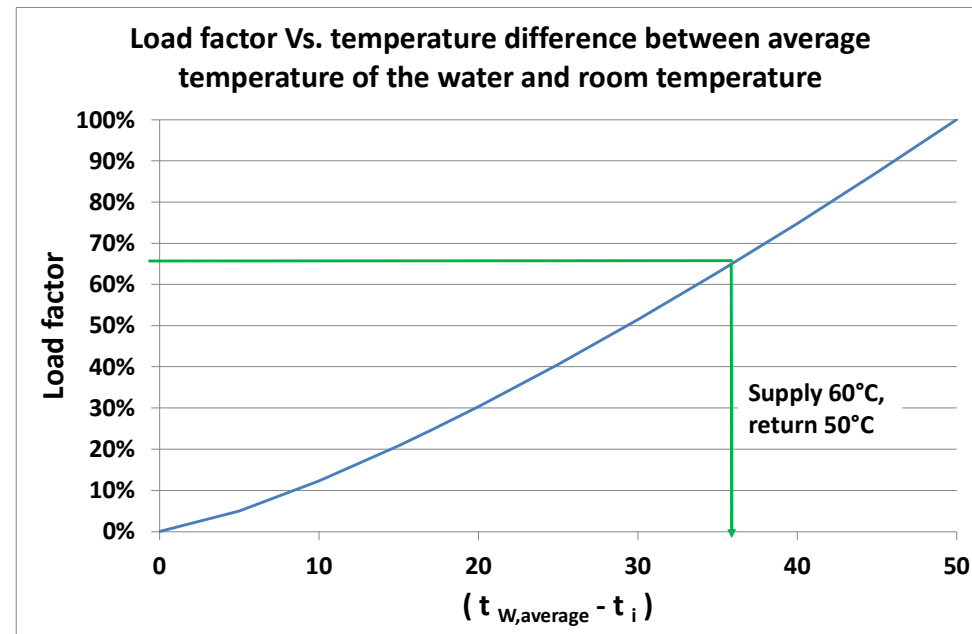
In new buildings it is possible to keep the radiators and use a heat pump



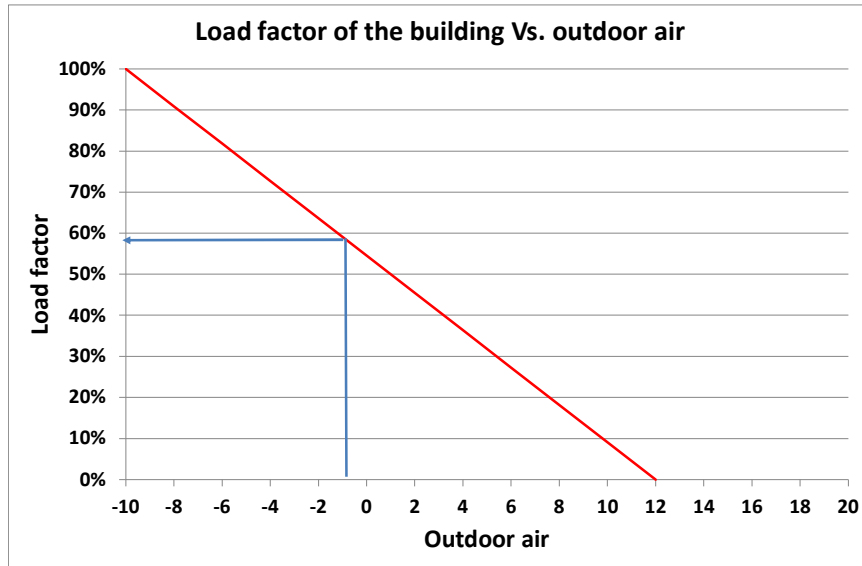
# Radiators and heat pumps in a stock building (no retrofit of the envelope)



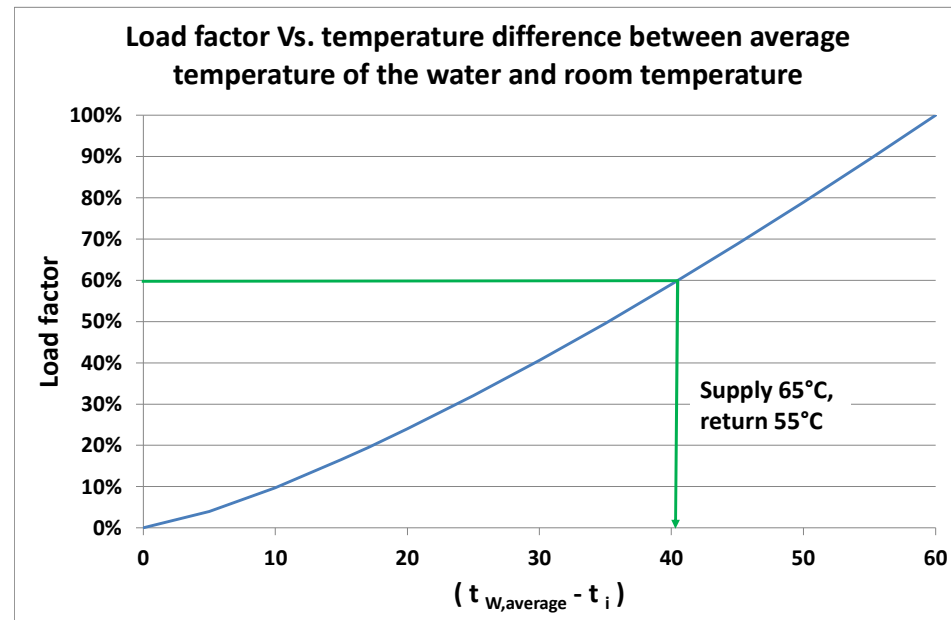
Mild climate



# Radiators and heat pumps in a stock building (no retrofit of the envelope)



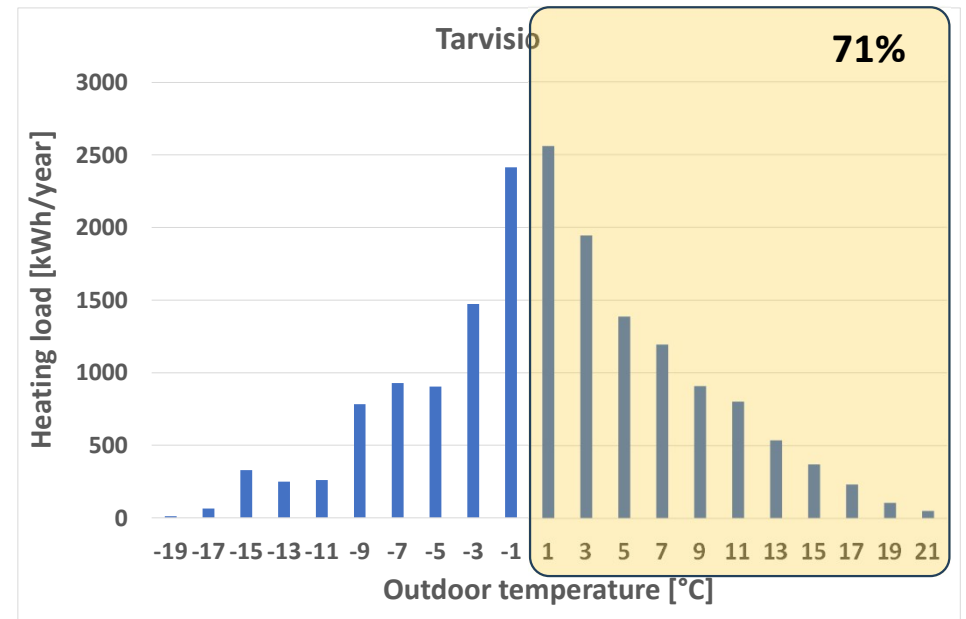
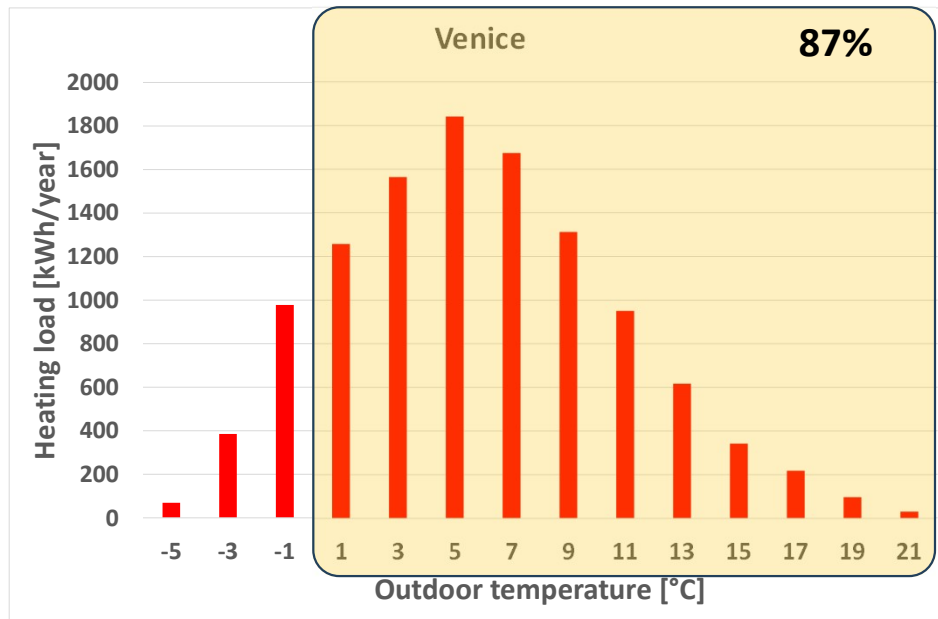
Cold climate



# Air-to-water heat pumps

## Performance

Not only the capacity but also the efficiency is severely affected by the outdoor temperature.

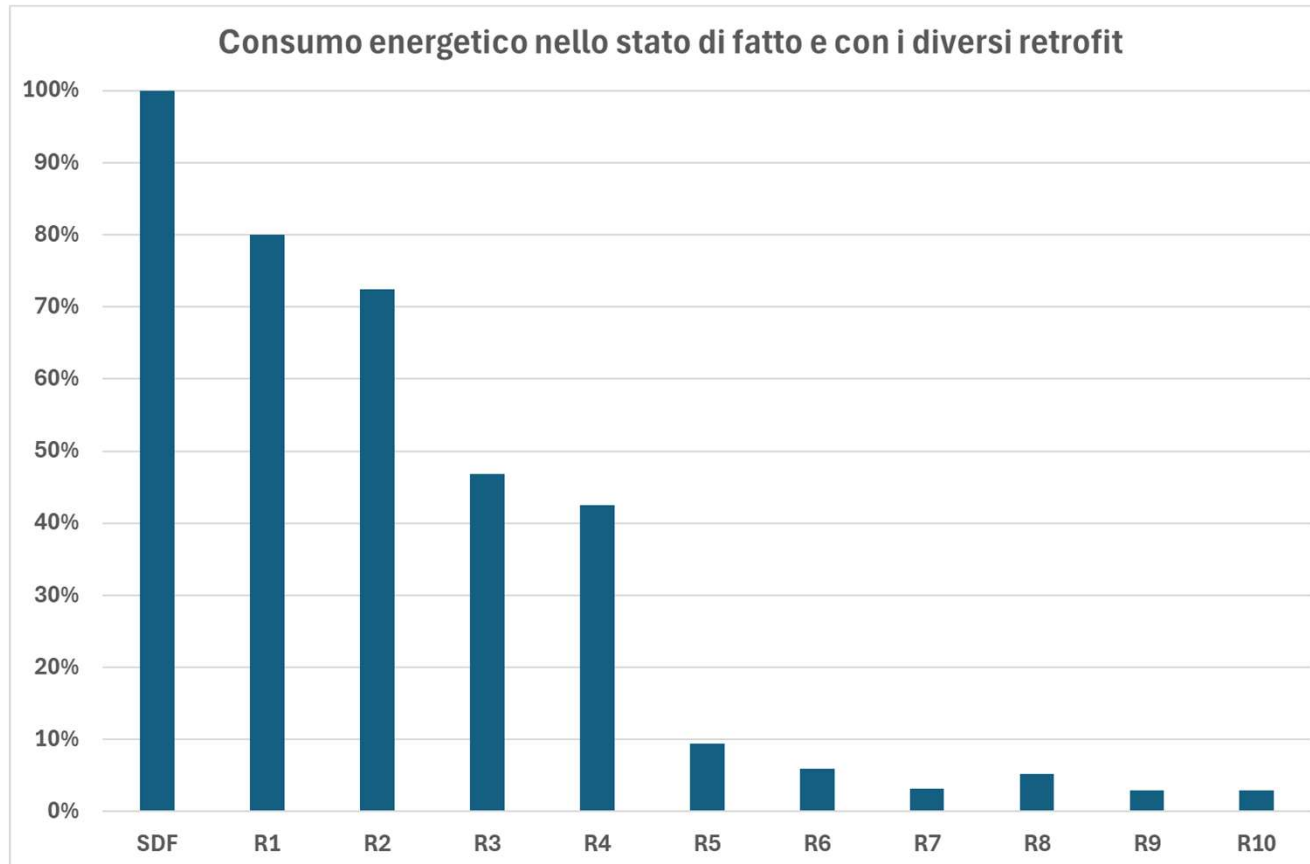


# Analysis on standard calculation

## Archetypes:

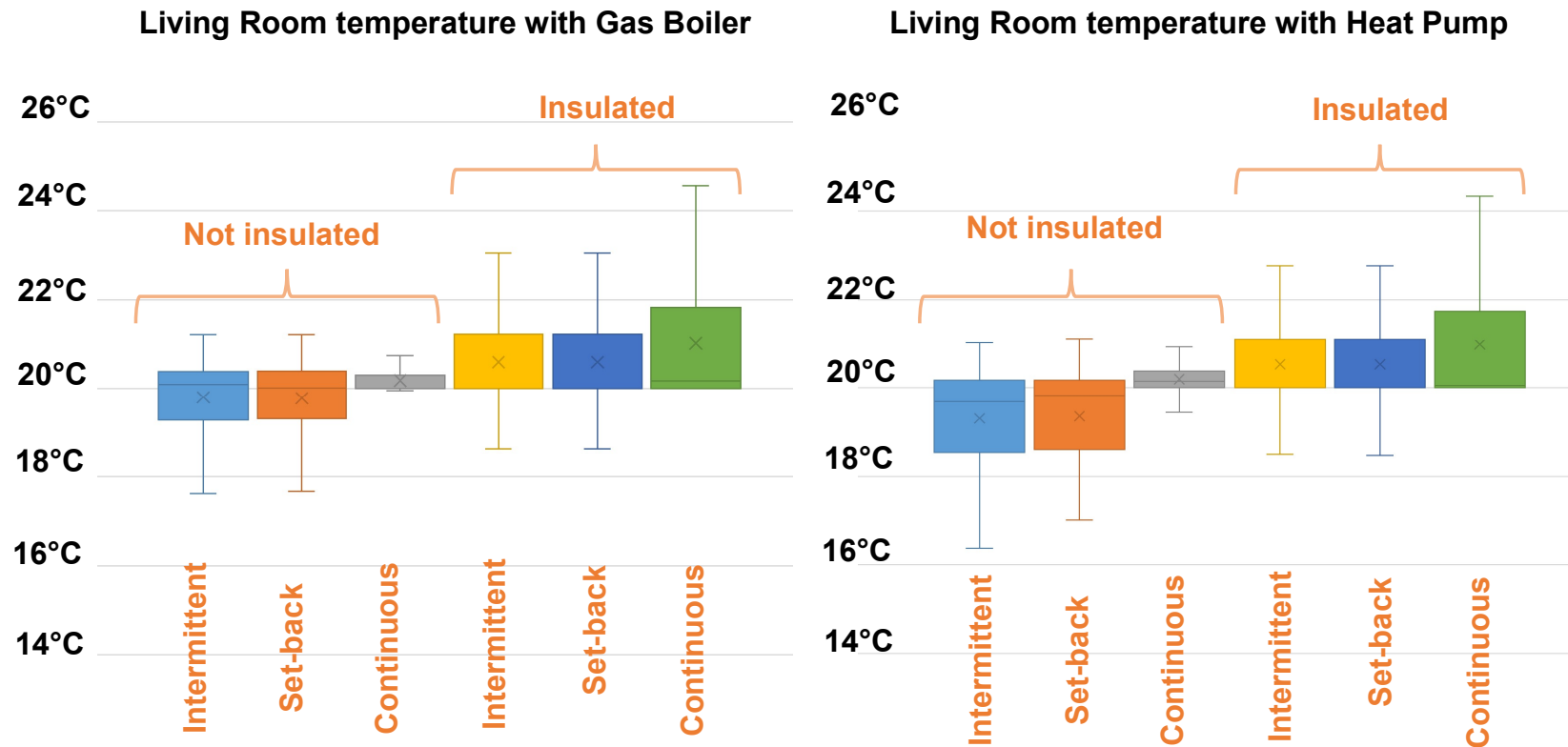
- Single Family House – SFH
- Terraced House – TH
- Multi Family House – MFH
- Apartment Block – AB

	Envelope	Windows	Hybrid	Heat Pump	PV
SDF					
R1			X		
R2		X	X		
R3	X		X		
R4	X	X	X		
R5	X	X	X		X
R6	X	X		X	X
R7	X	X		X	X
R8	X	X		X	X
R9	X	X		X	X
R10	X	X		X	X



	SDF	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
SFH	F	E	E	B	B	A4	A4	A4	A4	A4	A4
THS	G	F	F	D	D	A4	A4	A4	A4	A4	A4
THE	G	G	F	D	D	A4	A4	A4	A4	A4	A4
MFH 12	F	F	E	C	C	An(A3/A4)	A4	A4	A4	A4	A4
MFH 16	F	F	E	D	D	An(A3/A4)	A4	A4	A4	A4	A4
ABS	F	F	E	D	D	An(A3/A4)	A4	A4	A4	A4	A4
ABE	F	F	E	D	D	An(A3/A4)	A4	A4	A4	A4	A4

# Dynamic analysis on a terraced house



Joint work with *DAIKIN Europe*

# Air-to-water heat pumps

## Performance

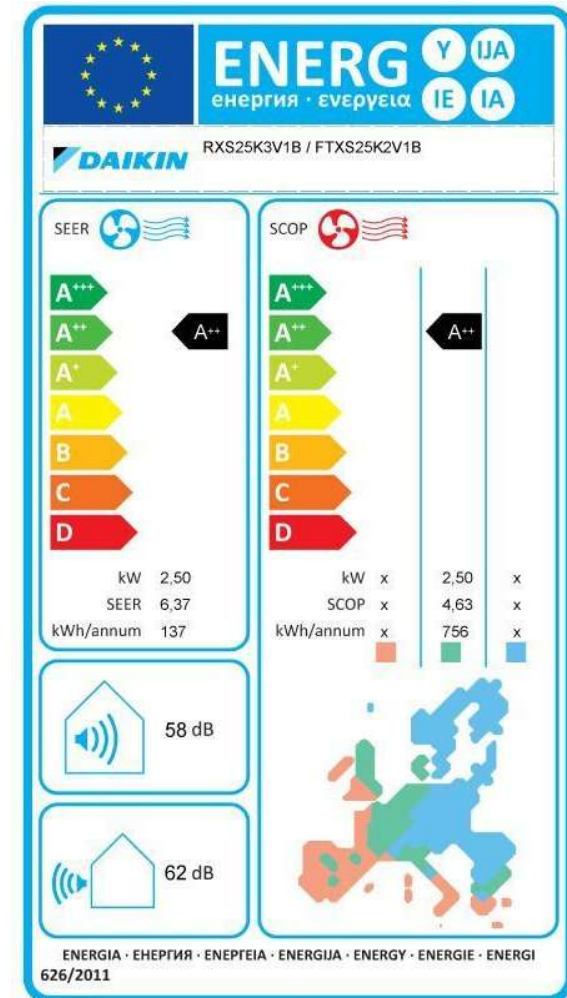
The declared performance by heat pump manufacturers follows reference standards:

- **EN 14825** (product standard): seasonal COP and EER (SCOP and SEER) are defined based on a standardized load profile in 3 different climates in Europe. It is useful to compare different heat pumps. It does not represent the efficiency for the specific building.
- Italian standard **UNI/TS 11300-4** (system standard): it is used to evaluate the seasonal performance of the heat pump of the considered building using a Seasonal Performance Factor (SPF)

# Air-to-water heat pumps

## Performance

Example of technical datasheet and energy performance label according to EN 14825.



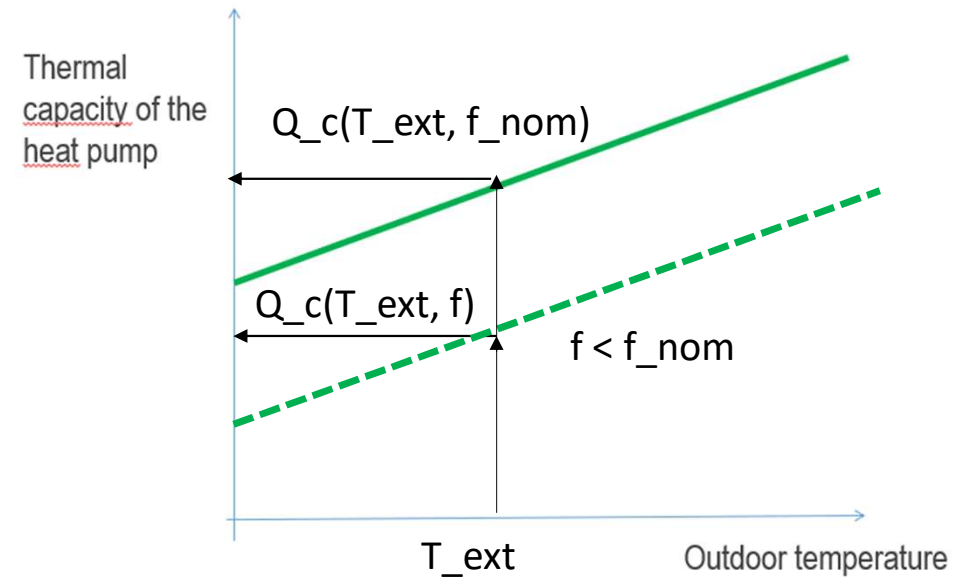
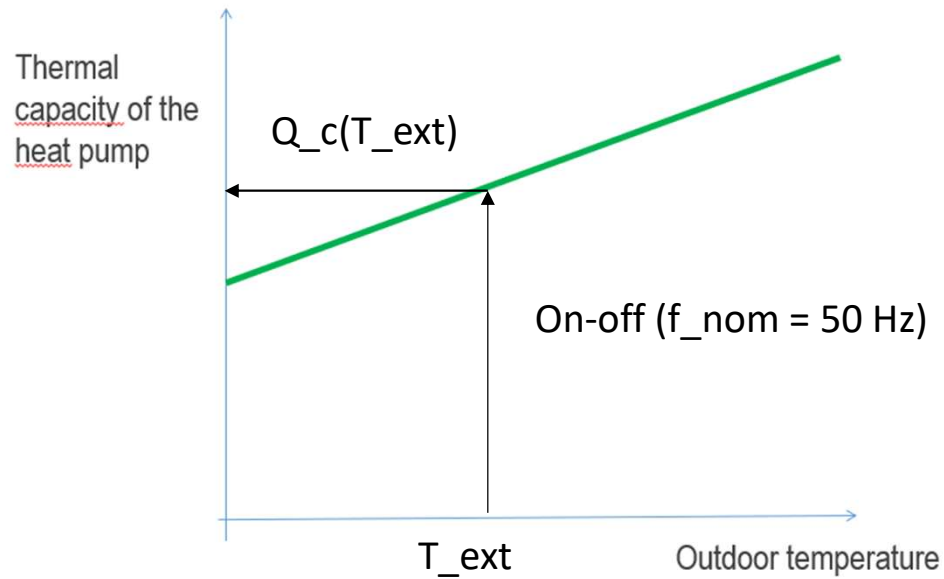
## RATED TECHNICAL DATA

MCI			006HM	008HM	012HM	015H0	015HM	021H0
Power supply		V-ph-Hz	230 - 1 - 50	230 - 1 - 50	230 - 1 - 50	400 - 3 - 50	230 - 1 - 50	400 - 3 - 50
Cooling capacity	(1)(E)	kW	4,73	5,84	10,2	13,0	13,0	18,6
Total power input	(1)(E)	kW	1,58	1,96	3,46	4,47	4,42	6,00
EER	(1)(E)		3,00	2,98	2,96	2,91	2,95	3,10
SEER	(2)(E)		4,19	3,85	3,98	4,88	4,30	4,51
Water flow	(1)	l/h	810	992	1750	2237	2237	3201
Available pressure head - LP pumps	(1)(E)	kPa	65	66	76	66	66	74
Heating capacity	(3)(E)	kW	5,76	7,36	12,9	14,5	14,0	20,0
Total power input	(3)(E)	kW	1,89	2,31	4,26	4,39	4,32	6,06
COP	(3)(E)		3,05	3,19	3,03	3,30	3,23	3,30
SCOP	(2)(E)		3,37	2,84	2,95	3,33	3,25	2,90
Heating energy efficiency class	(4)		A++	A+	A+	A++	A++	A+
Water flow	(3)	l/h	996	1281	2238	2439	2439	3470
Available pressure head - LP pumps	(3)(E)	kPa	60	55	72	58	60	74
Cooling capacity	(5)(E)	kW	7,04	7,84	13,5	16,0	16,0	25,8
Total power input	(5)(E)	kW	1,90	1,96	3,70	4,20	4,17	6,79
EER	(5)(E)		3,70	3,99	3,66	3,81	3,85	3,80
Heating capacity	(6)(E)	kW	5,76	7,16	11,9	15,0	14,5	21,1
Total power input	(6)(E)	kW	1,35	1,80	3,00	3,57	3,54	5,15
COP	(6)(E)		4,28	3,97	3,95	4,20	4,09	4,10
Maximum current absorption		A	11,0	15,0	21,0	11,0	23,0	16,0
Compressors / circuits					1 / 1			
Expansion vessel volume		dm <sup>3</sup>	2	2	3	3	3	8
Sound power level	(7)(E)	dB(A)	64	65	68	69	69	74
Transport weight - unit with pump		kg	61	69	104	116	112	199
Operating weight - unit with pump		kg	61	69	104	116	112	199

# Air-to-water heat pumps

## Performance

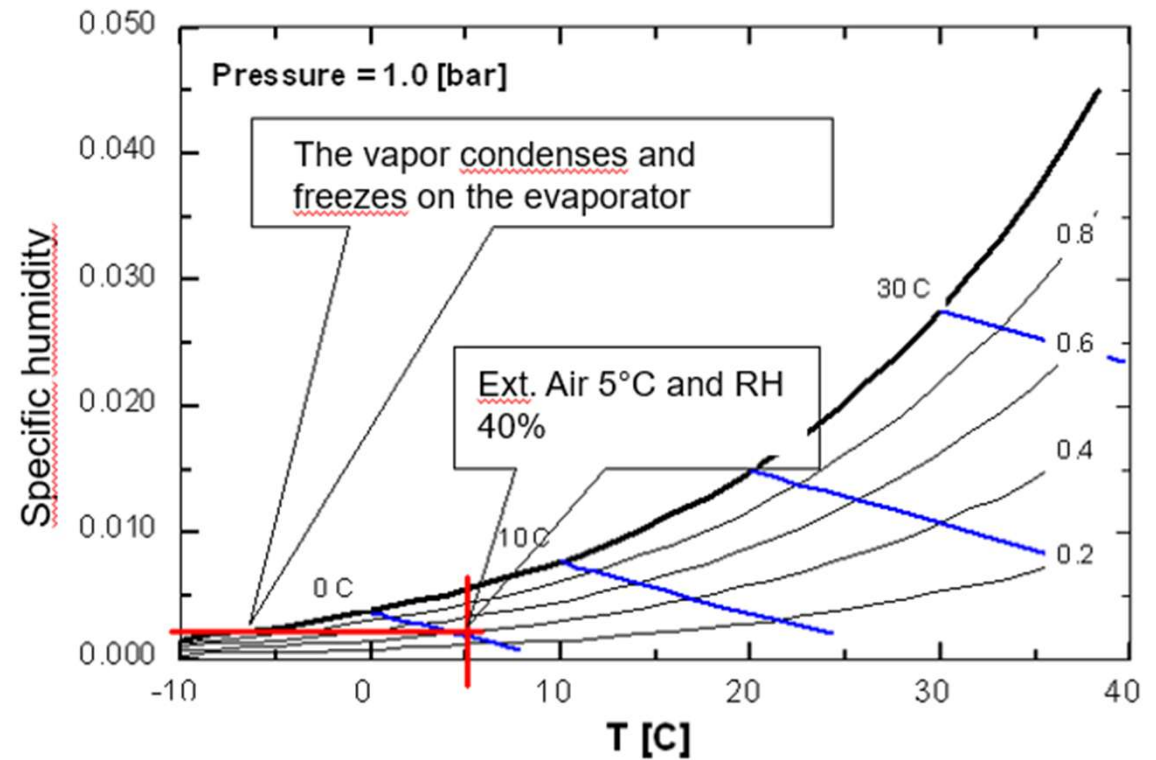
Inverter-driven vs on-off heat pumps.



# Air-to-water heat pumps

## Performance

- When outside air is cooled at the evaporator, water vapor condenses and there may be frost formation.
- If allowed to accumulate, frost inhibits heat transfer; therefore, the outdoor coil must be defrosted periodically.



# Air-to-water heat pumps

## Performance

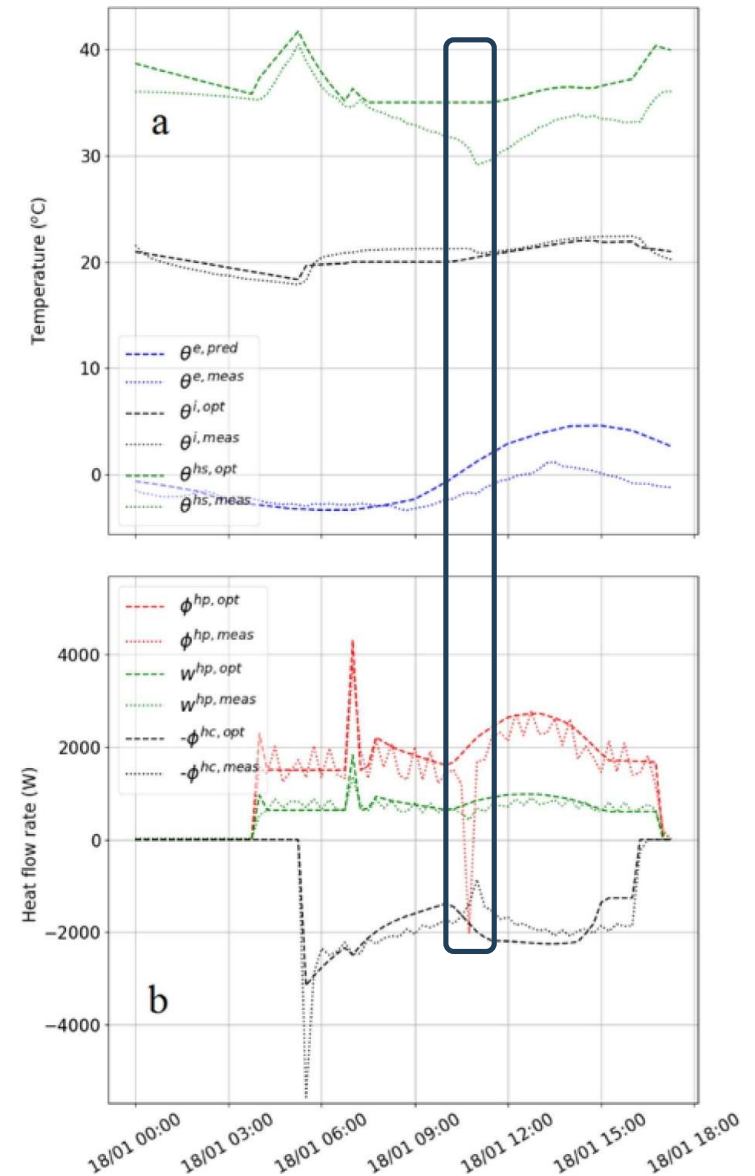
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# Air-to-water heat pumps

## Performance

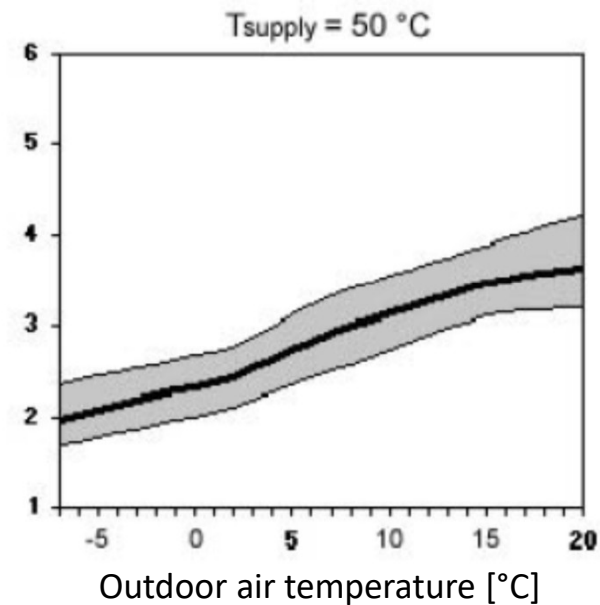
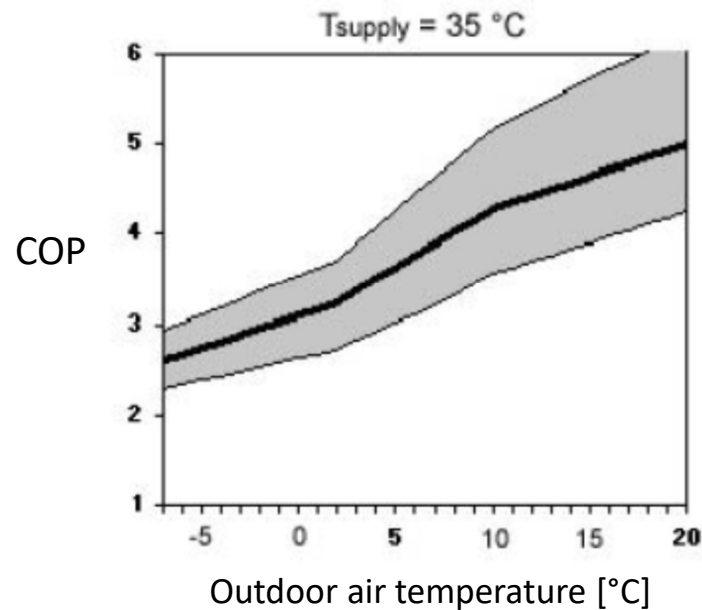
- Most systems defrost by reversing the cycle.
- Another method of defrosting is spraying heated water over an outdoor coil. The water can be heated by the refrigerant or by auxiliaries.



# Air-to-water heat pumps

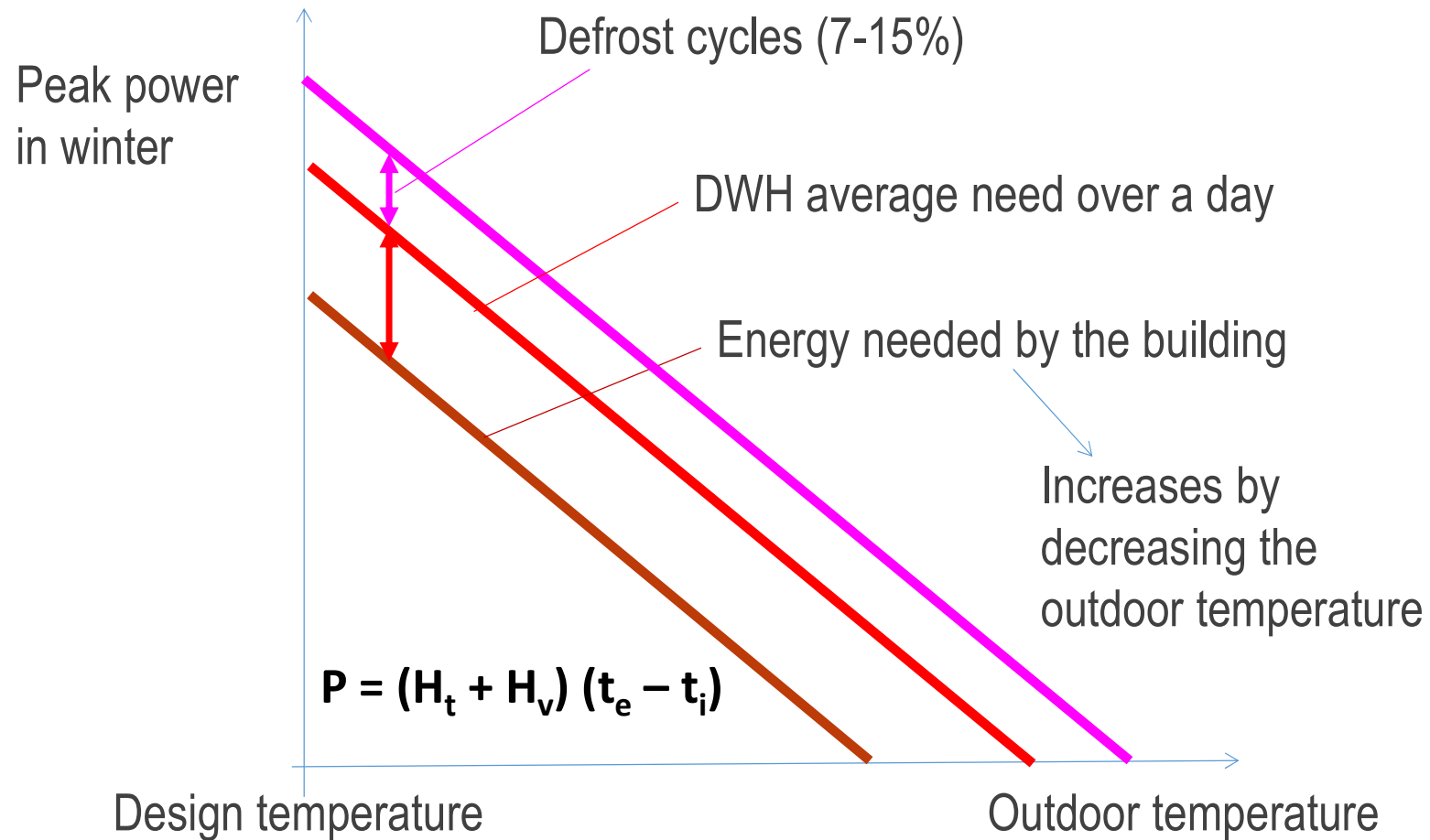
## Performance

Not only the capacity but also the efficiency is severely affected by the outdoor temperature.



[source: Winthertur Toss]

# Selection of an Air-to-water heat pumps



# References

- ASHRAE Handbook – 2020 HVAC Systems and Equipment (SI Edition)
- Staffel et al, A review of domestic heat pumps.