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14th IEA HEAT PUMP CONFERENCE

Comparison of seasonal energy efficiency of different compressor types

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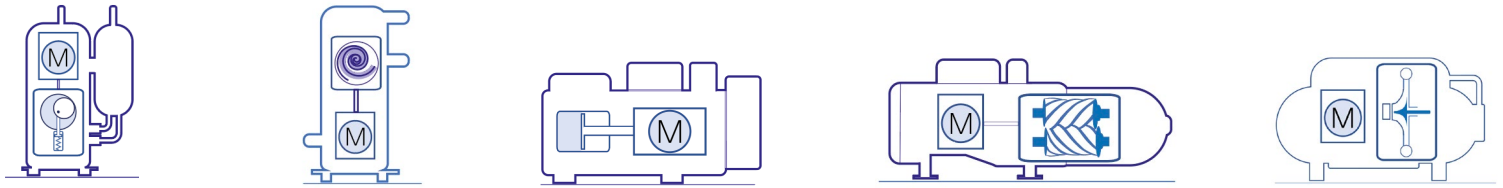


Agenda

1. Database – compressor characteristic maps
2. Seasonal evaluation method - aCOP
3. Results

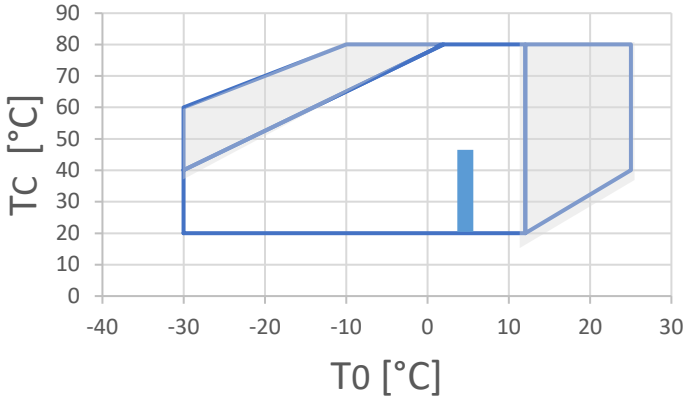
Compressor database

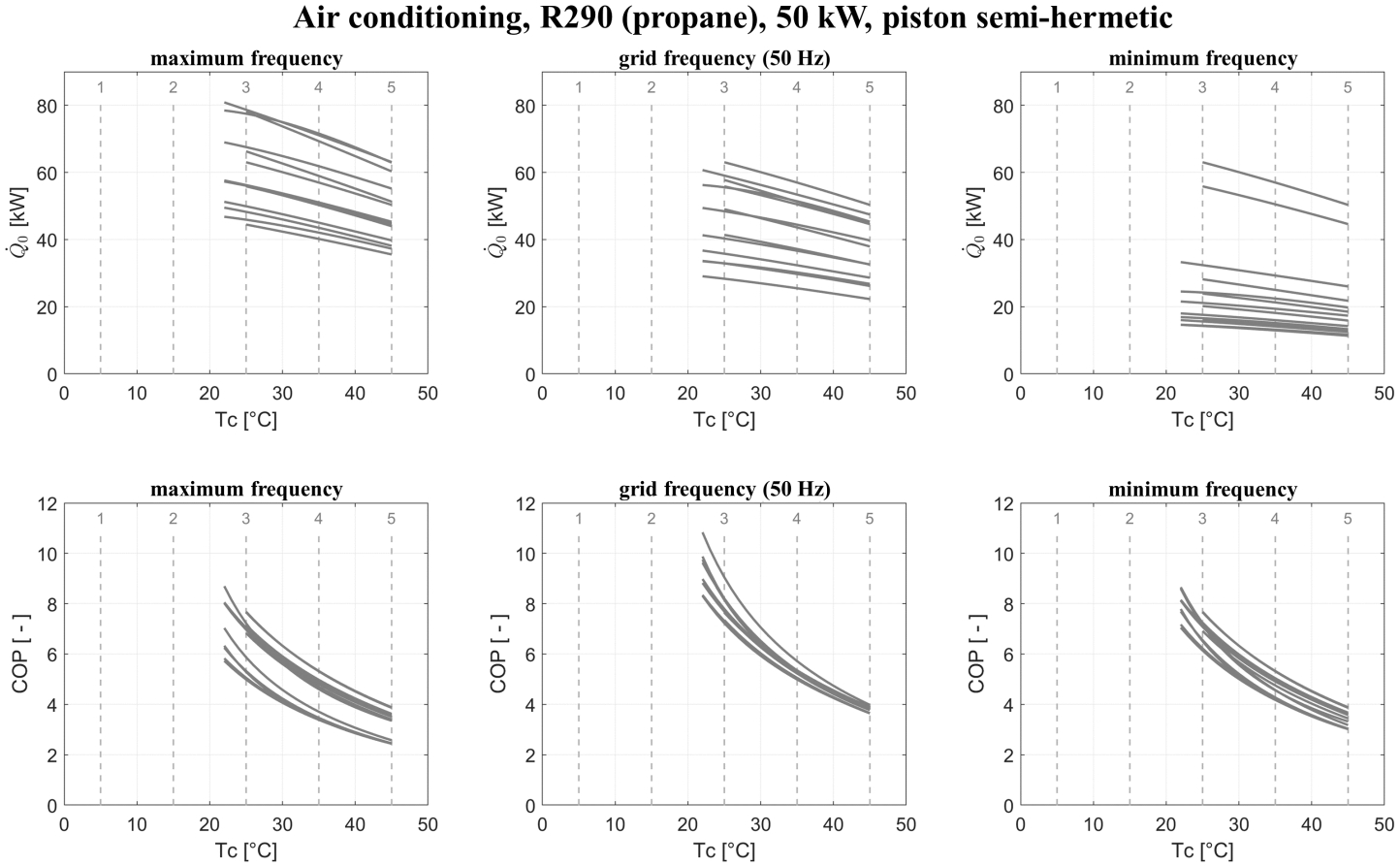
- 1400 compressors / 6 manufacturers
- Compressor performance according to polynomials (EN 12900)
- Capacity control with variable frequencies

Application	Design point (T_0 / T_c)	Design capacity ($\dot{Q}_{0\_design}$)	Refrigerant
Air conditioning	5 / 45 ° C	20 / 50 / 100 / 300 kW	R1234ze / R290 / R454B / R513A / R717 / R744
Medium temperature	-10 / 45 ° C	2 / 10 / 50 / 100 kW	R449A / R513A / R744
Low temperature	-30 / 40 ° C	1 / 5 / 25 / 50 kW	R449A / R744

Compessor neutralization

- Selection based on:
  Application / Refrigerant / Capacity ±30% / Type
- Summary of compressors from several manufacturers for each selection
- Every manufacturer equally weighted

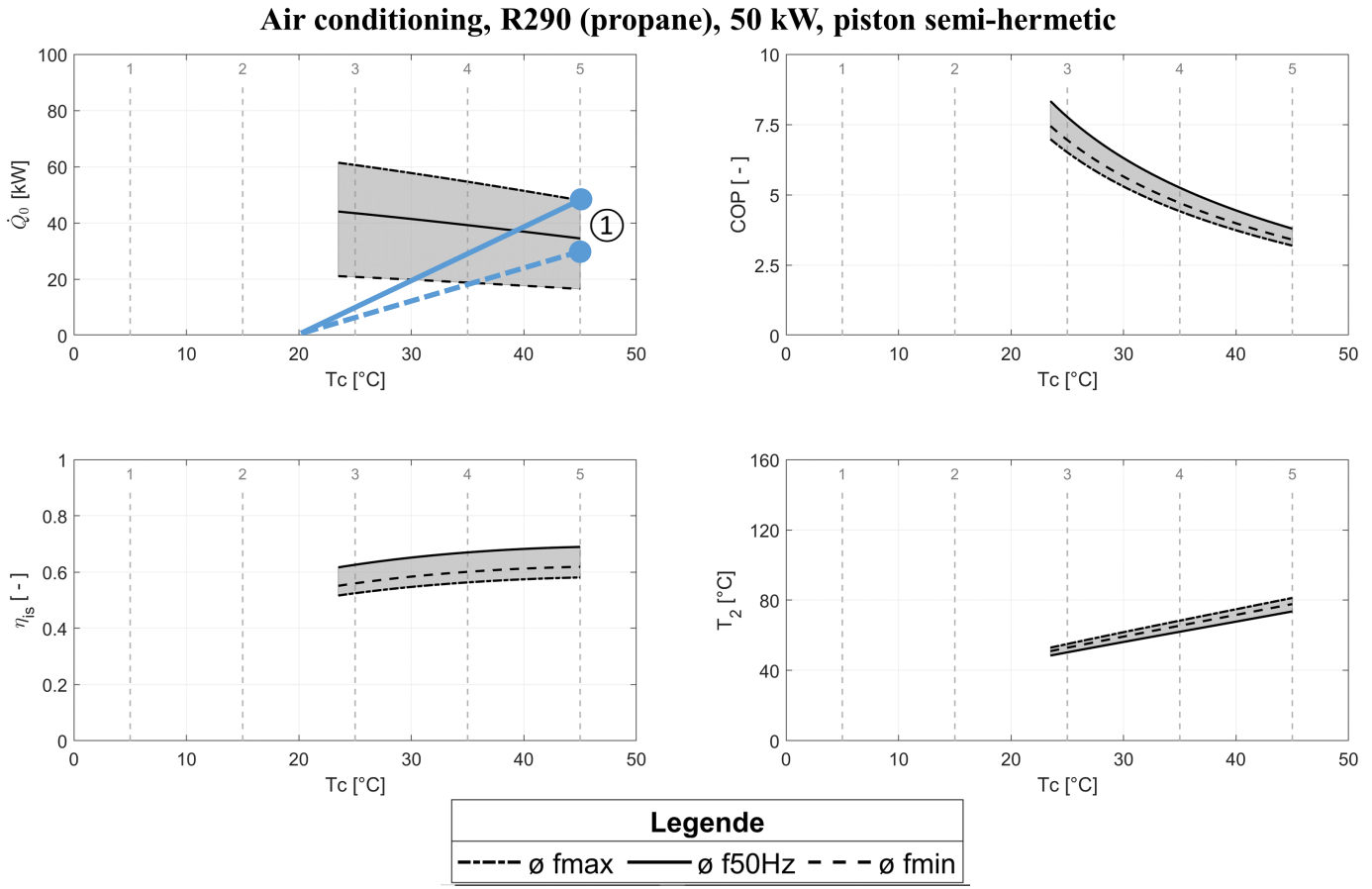




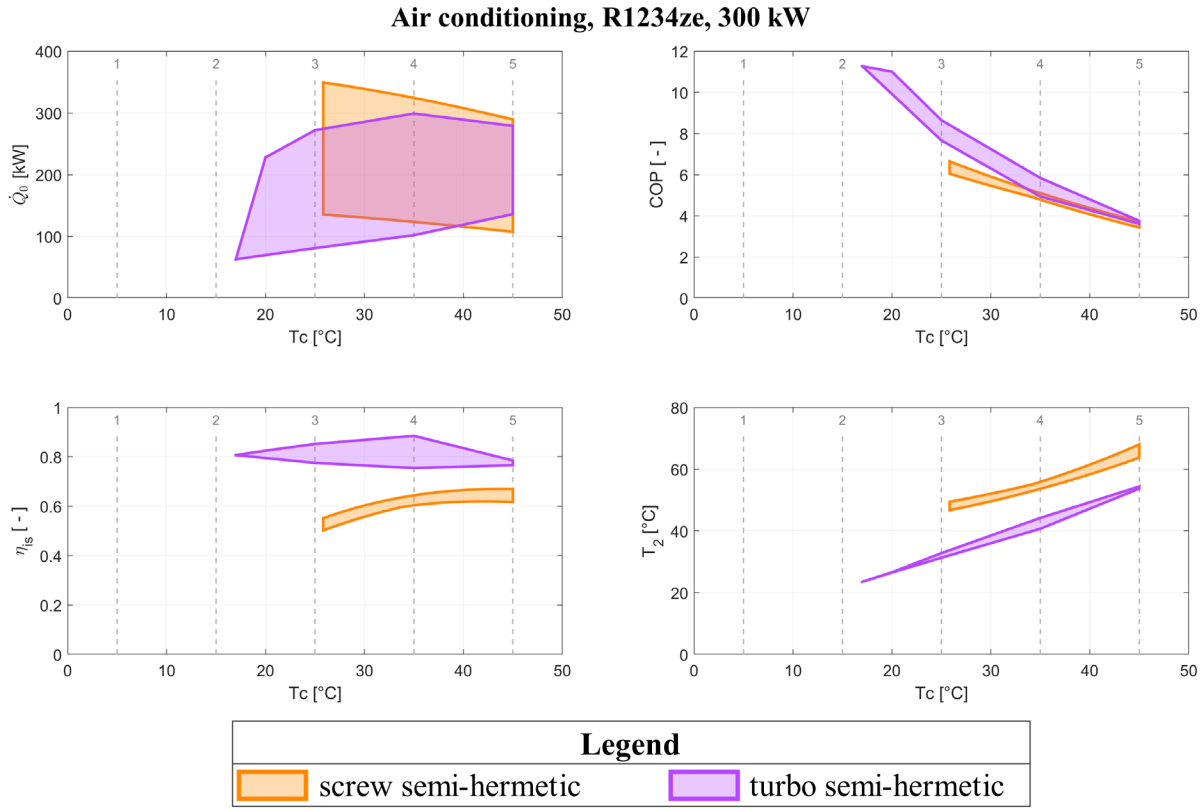
Compressor characteristic map

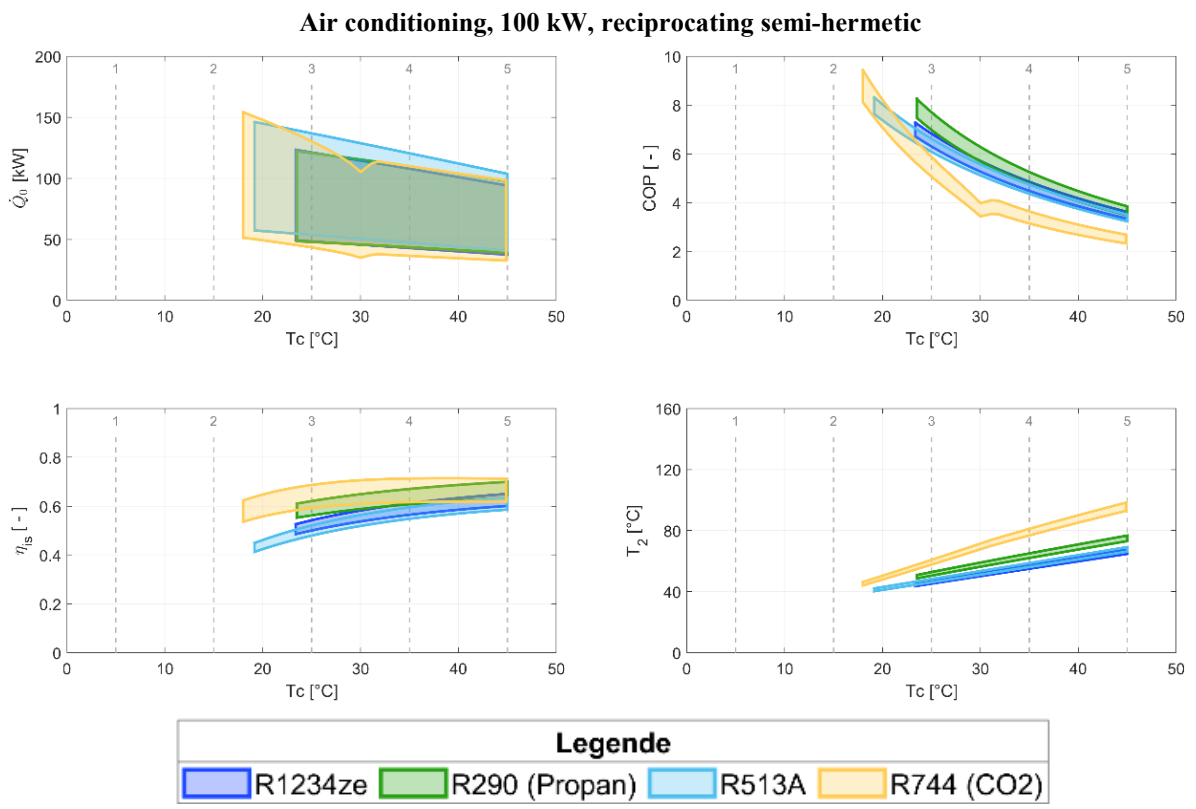
- Average behavior of the compressor type
  - Performance
  - Operating limit
  - Capacity control range
- 70 compressor characteristic maps created
- Data for seasonal efficiency evaluation
- Useful for conceptual considerations

① Influence of oversizing on the operation of the compressor



Comparison characteristic map





aCOP - definition

$$aCOP = \sum_{i=1}^{5} w_i \cdot c_i \cdot COP_i$$

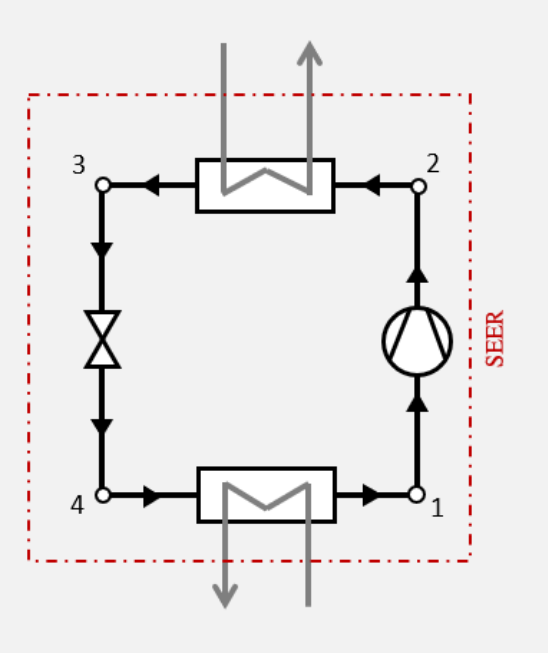
$aCOP = annual$ Coefficient of Performance

$COP =$ Coefficient of Performance

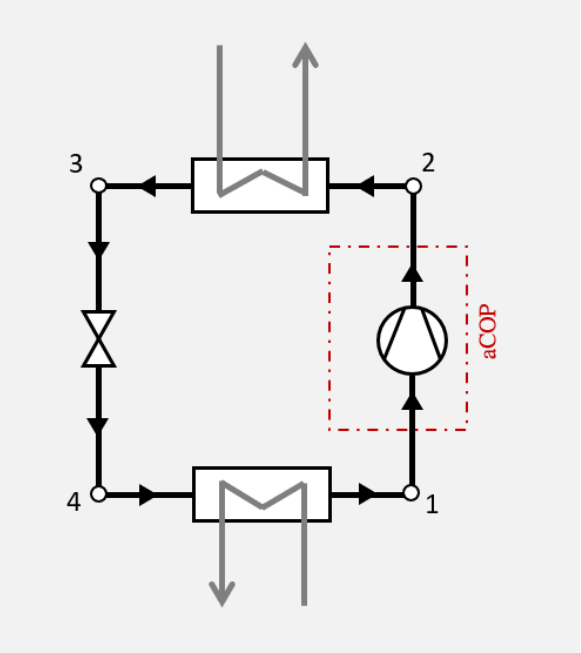
$w_i = weighting\ factor$ (energetic $share$)

$c_i =$ cycle factor

SEER (EN 14825)
- 4 operating points
- 1 load profile (AC)



aCOP
- 5 operating points → T0 / Tc
- 5 load profiles



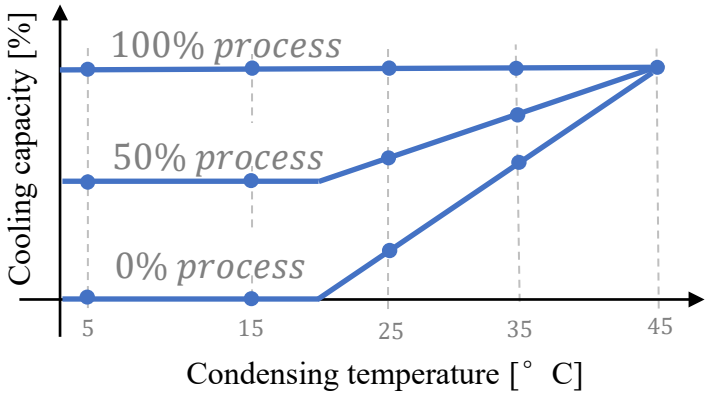
aCOP - conditions

Operating points

- Condensing temperature T_c
  - Corrected by limits of compressor*
- Evaporating temperature T_0
  - depending on application

Load profiles

- 5 Load profiles
- Capacity depending on Tamb



Operating point	T_c [°C]	T_0 [°C]
1	5*	-30 / -10 / 5
2	15*	-30 / -10 / 5
3	25*	-30 / -10 / 5
4	35	-30 / -10 / 5
5	45	-30 / -10 / 5

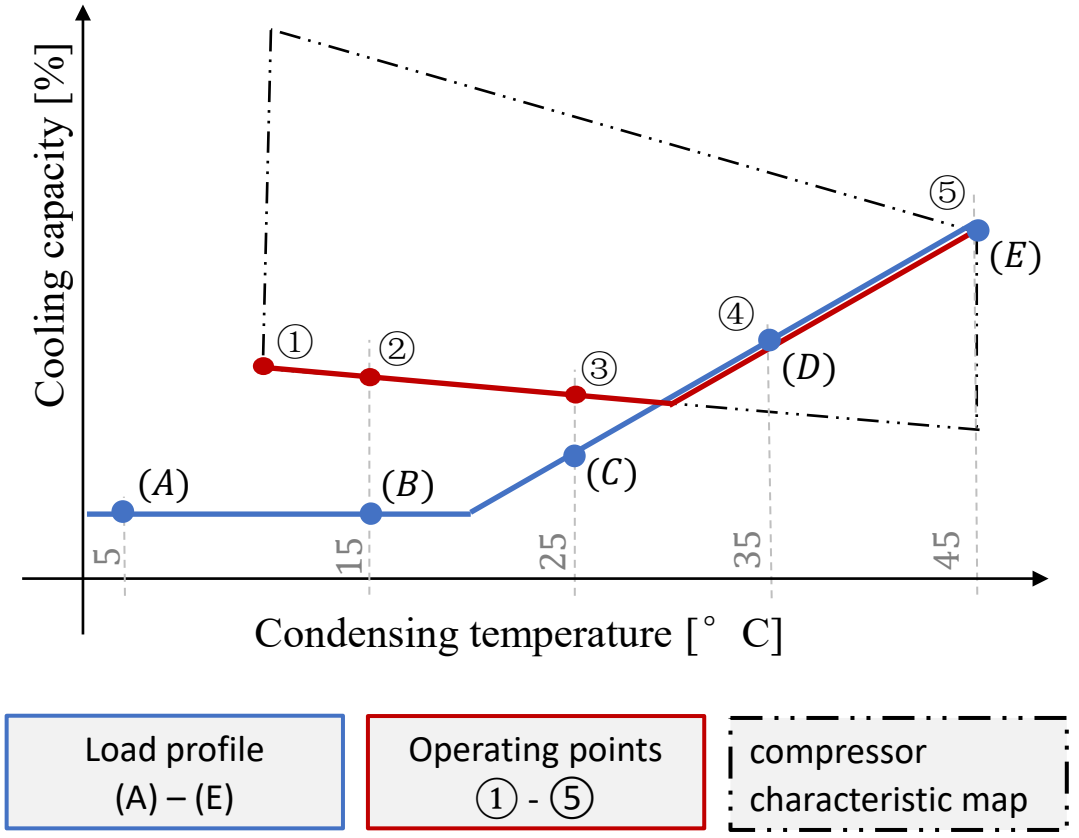
Load profile	Operating point				
	1	2	3	4	5
100% variable / 0% process	0 %	0 %	15.8 %	57.9 %	100 %
80% variable / 20% process	20 %	20 %	32.6 %	66.3 %	100 %
50% variable / 50% process	50 %	50 %	57.9 %	78.9 %	100 %
25% variable / 75% process	75 %	75 %	78.9 %	89.5 %	100 %
0% variable / 100% process	100 %	100 %	100 %	100 %	100 %

aCOP – COP (compressor)

$$aCOP = \sum_{i=1}^{5} w_i \cdot c_i \cdot \boldsymbol{COP_i}$$

COP based on compressor-specific operating points

- Load profile (A) – (E)
- Operating points ① - ⑤ (based on specific limitations)
- COP (based on compressor characteristic map)



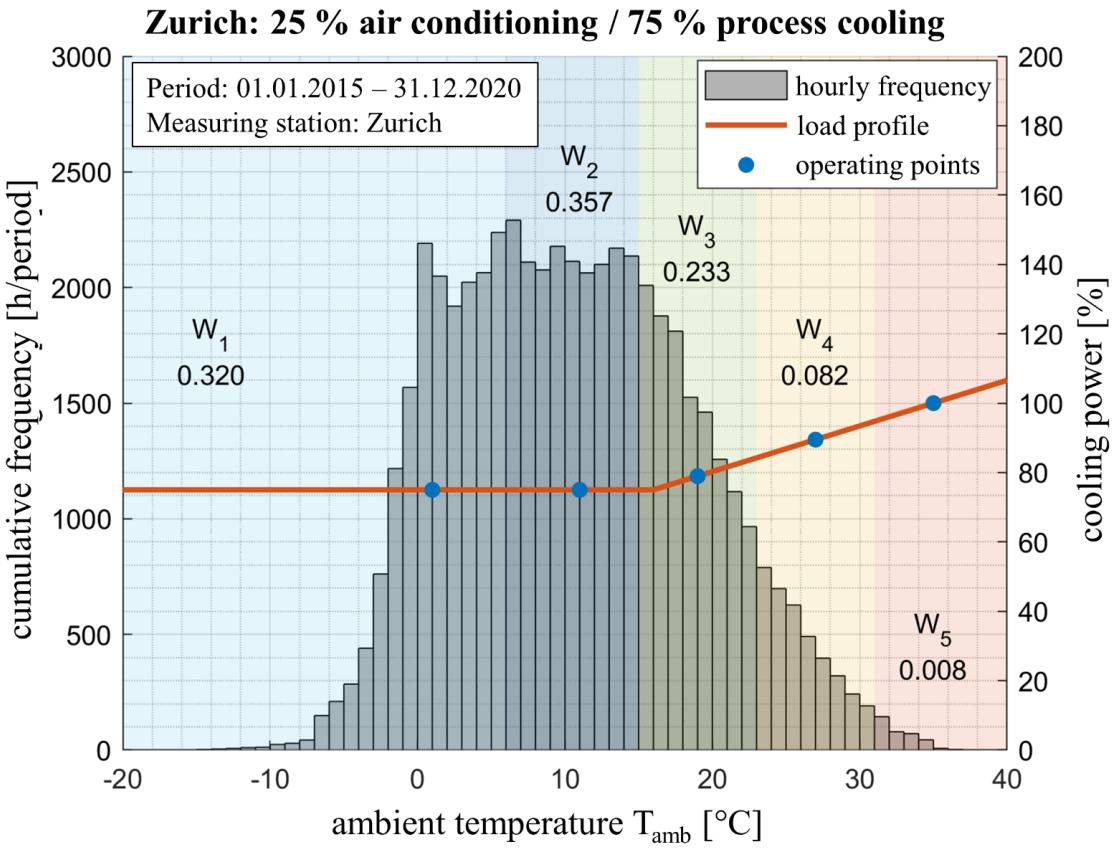
aCOP – weighting factor

$$aCOP = \sum_{i=1}^{5} w_i \cdot c_i \cdot COP_i$$

Energetic share of the annual consumption:
(based on load profile an location)

Weighting factor	Temperature range (x)	
	Min.	Max.
w_1	-20 ° C	6 ° C
W_2	6 ° C	15 ° C
W_3	15 ° C	23 ° C
W_4	23 ° C	31 ° C
W_5	31 ° C	40 ° C

$$w_i = \frac{\sum_{x_{min}}^{x_{max}} (h_x * \dot{Q}_{demand_x})}{\sum_{-20}^{40} (h_x * \dot{Q}_{demand_x})}$$



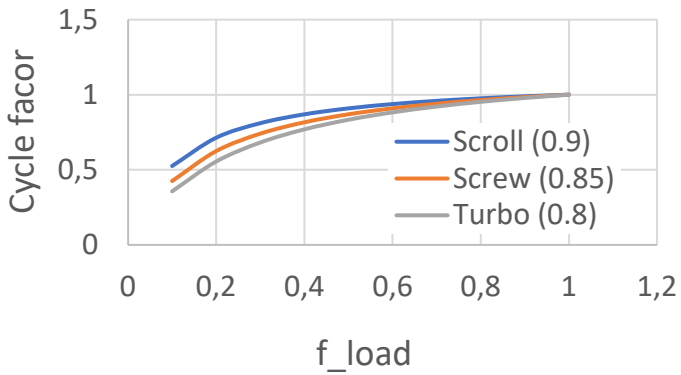
aCOP – cycle factor

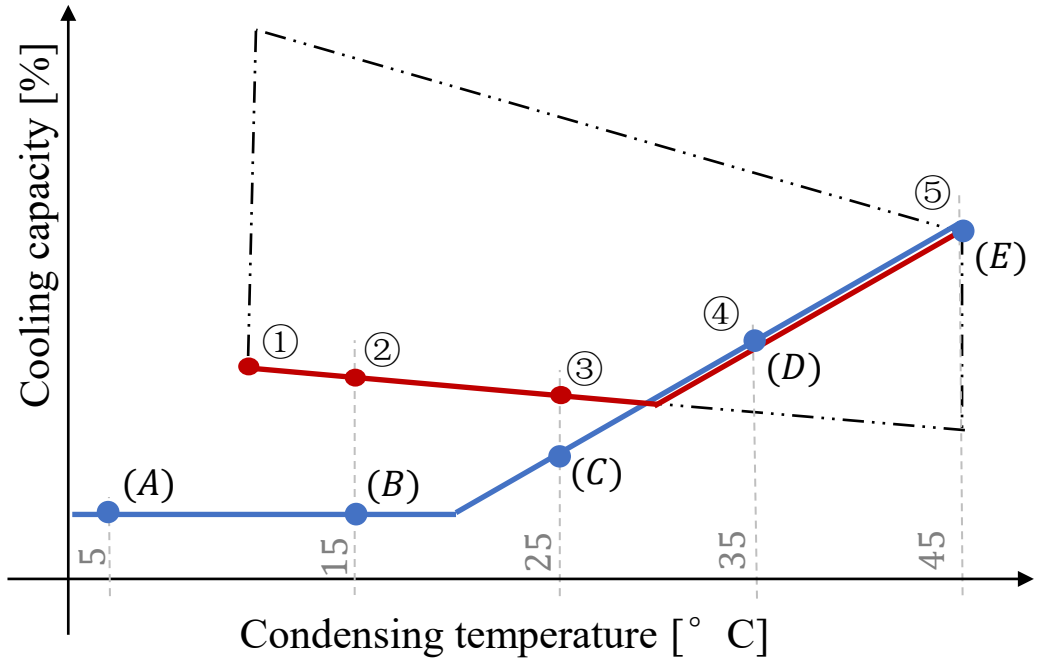
$$aCOP = \sum_{i=1}^{5} w_i \cdot c_i \cdot COP_i$$

Cycle factor: $f_{load} = \frac{\dot{Q}_{dem}}{\dot{Q}_{comp}}$

$$c_i = \frac{f_{load}}{f_V * f_{load} + (1 - f_V)}$$

Compressor Type	f_v
Rolling piston	0.9
Scroll	0.9
Reciprocating	0.9
Screw	0.85
Turbo	0.8





Load profile ($\dot{Q}_{dem}$)

Operating points ($\dot{Q}_{comp}$)

Results

Input compressor tool

Application (T0)
Design capacity
Refrigerant

Load profile

Location

Output compressor tool (air conditioning, 20 kW, R513A)

$$aCOP = \sum_{i=1}^{5} w_i \cdot c_i \cdot COP_i$$

Ranking	Compressor-Type	Anual Coefficient of Performance		t_amb	t_c	COP Average	COP Low - Best	Load Profile
1	Reciprocating semi hermetic	**aCOP (Average)**	**6.4**	1 °C	19 °C	8.3	(5.9 - 10.0)	4 kW
				11 °C	19 °C	8.3	(5.9 - 10.0)	4 kW
				19 °C	25 °C	6.4	(4.8 - 7.6)	6.5 kW
		aCOP (Low - Best)	(4.7 - 7.6)	27 °C	35 °C	4.7	(3.9 - 5.1)	13 kW
				35 °C	45 °C	3.1	1.9 - 3.4)	20 kW
2	Scroll hermetic	**aCOP (Average)**	**5**	1 °C	21 °C	7.5	(6.8 - 8.5)	4 kW
				11 °C	21 °C	7.5	(6.8 - 8.5)	4 kW
				19 °C	25 °C	6.6	(6.1 - 7.1)	6.5 kW
		aCOP (Low - Best)	(4.4 - 5.6)	27 °C	35 °C	5	(4.7 - 5.3)	13 kW
				35 °C	45 °C	3.7	(3.4 - 3.9)	20 kW
3	Reciprocating hermetic	**aCOP (Average)**	**4.1**	1 °C	16 °C	7.1	(6.3 - 7.9)	4 kW
				11 °C	16 °C	7.1	(6.3 - 7.9)	4 kW
				19 °C	25 °C	5.6	(5.2 - 5.9)	6.5 kW
		aCOP (Low - Best)	(3.7 - 4.5)	27 °C	35 °C	4.3	(4.1 - 4.4)	13 kW
				35 °C	45 °C	3.2	(3.1 - 3.3)	20 kW

Contact

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