# A Review on Heat Pump Technology

ASEH

TEJARAT ASIA

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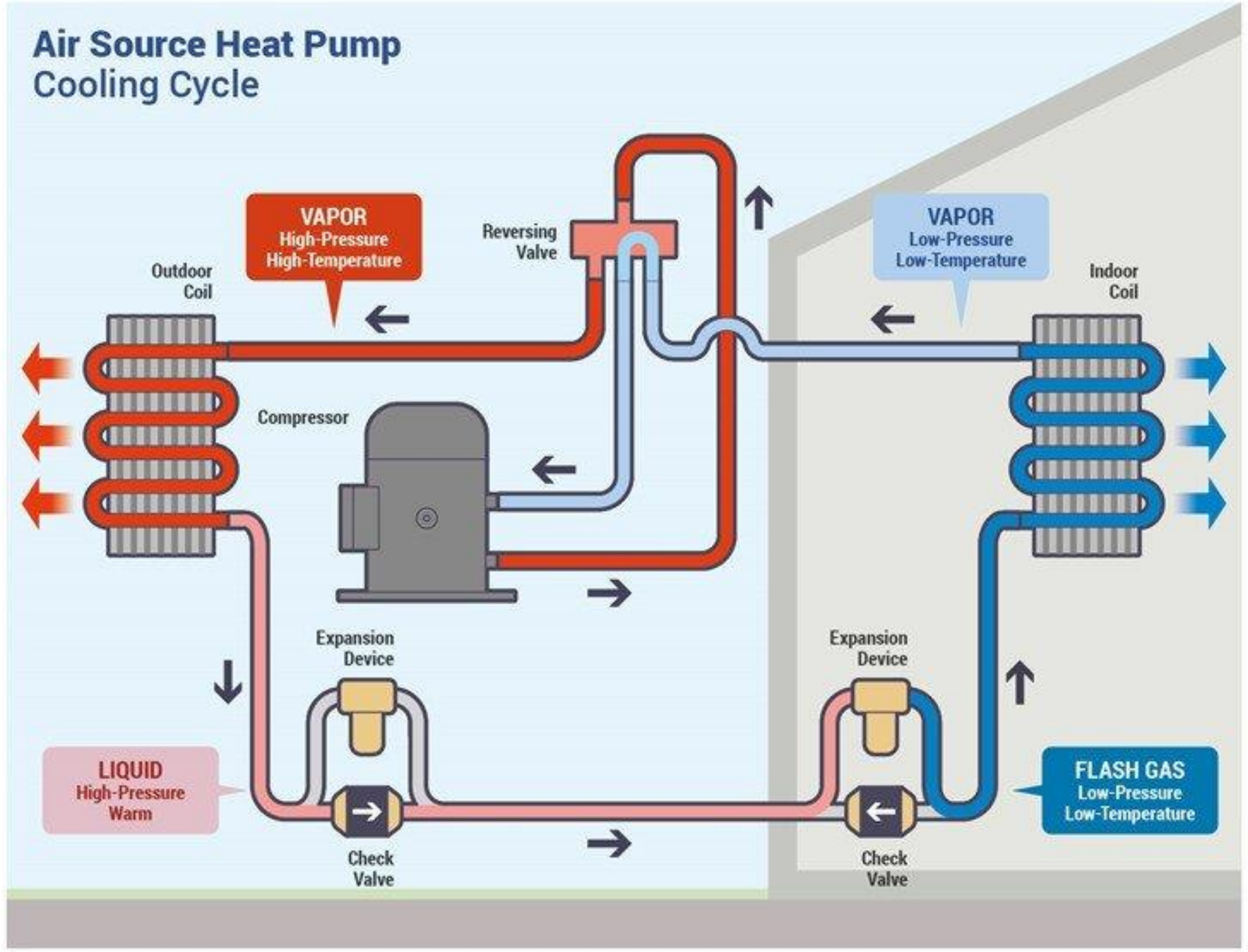
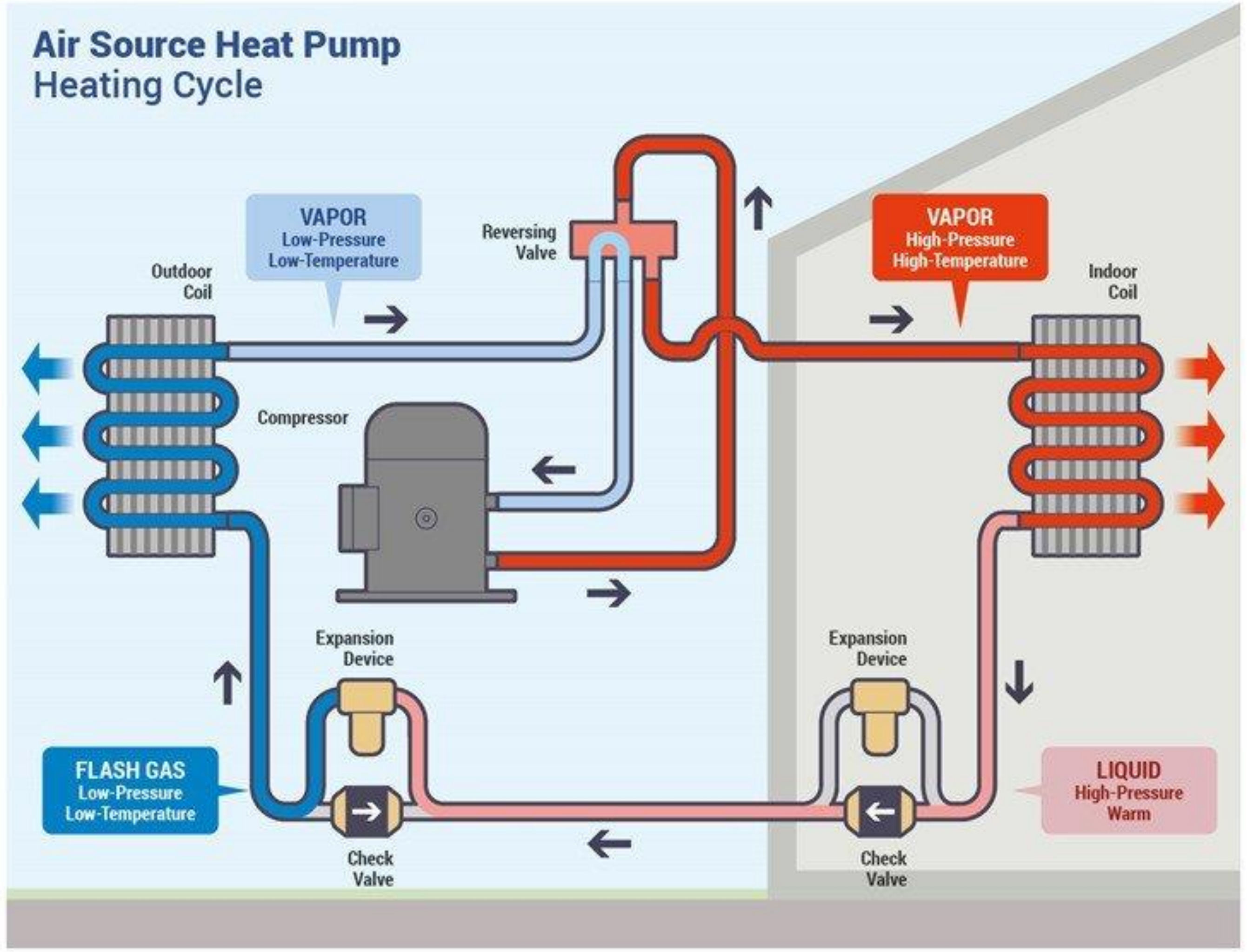
# What is a Heat Pump?

# What is a heat pump?

" It has become common practice now to call a heat pump any device that extracts heat from a source at low temperature and gives off this heat at a higher temperature, which can be useful" [1]

[1] I. Dincer, M. Kanoglu, (2010), *"Refrigeration systems and applications and applications"*, Wiley and Sons, Chapter 6.



# Heat pump classifications

- Based on Backup System:

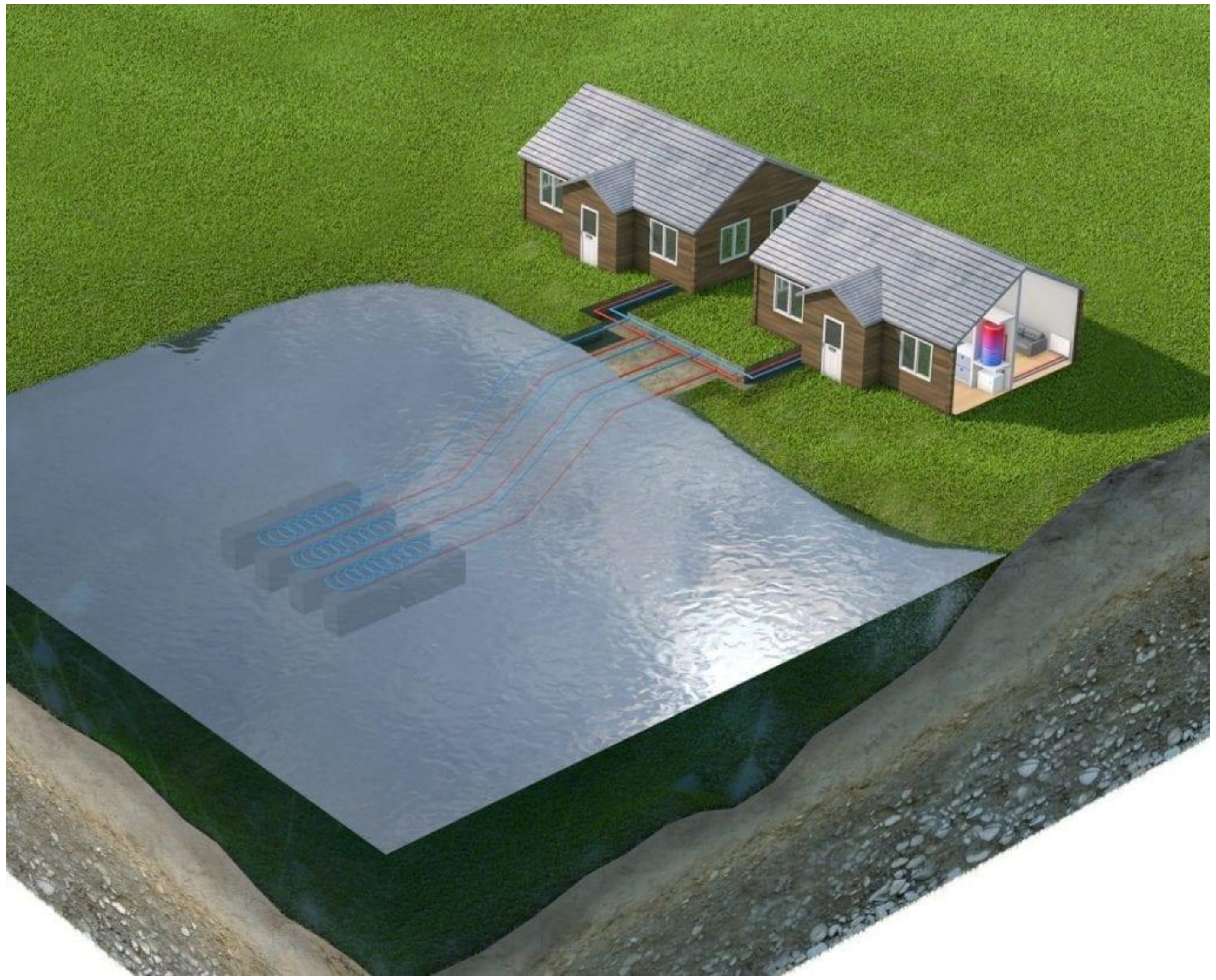
Bivalent: Heat pumps operating with supplementary heat are often said to be operating in a bivalent mode.

Monovalent: A heat pump operating without electric resistance heating or without other backup is said to be operating in a monovalent mode.

- Based on Heat Source:

The technical and economical performance of a heat pump is closely related to the characteristics of the heat source. (IEA-HPC 2001)

| Heat source | Temperature Range |
|---|---|
| Ambient air | -10-15 |
| Exhaust air | 15-25 |
| Groundwater | 4-10 |
| Lake water | 0-10 |
| River water | 0-10 |
| Sea water | 3-8 |
| Rock | 0-5 |
| Ground | 0-10 |
| Waste water and effluent | >10 |

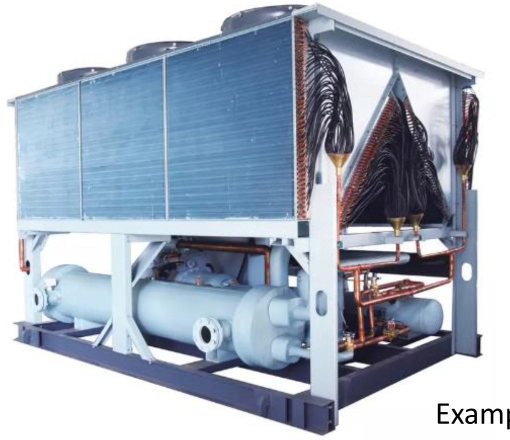


# Heat pump classifications

- Based on Source and Sink:

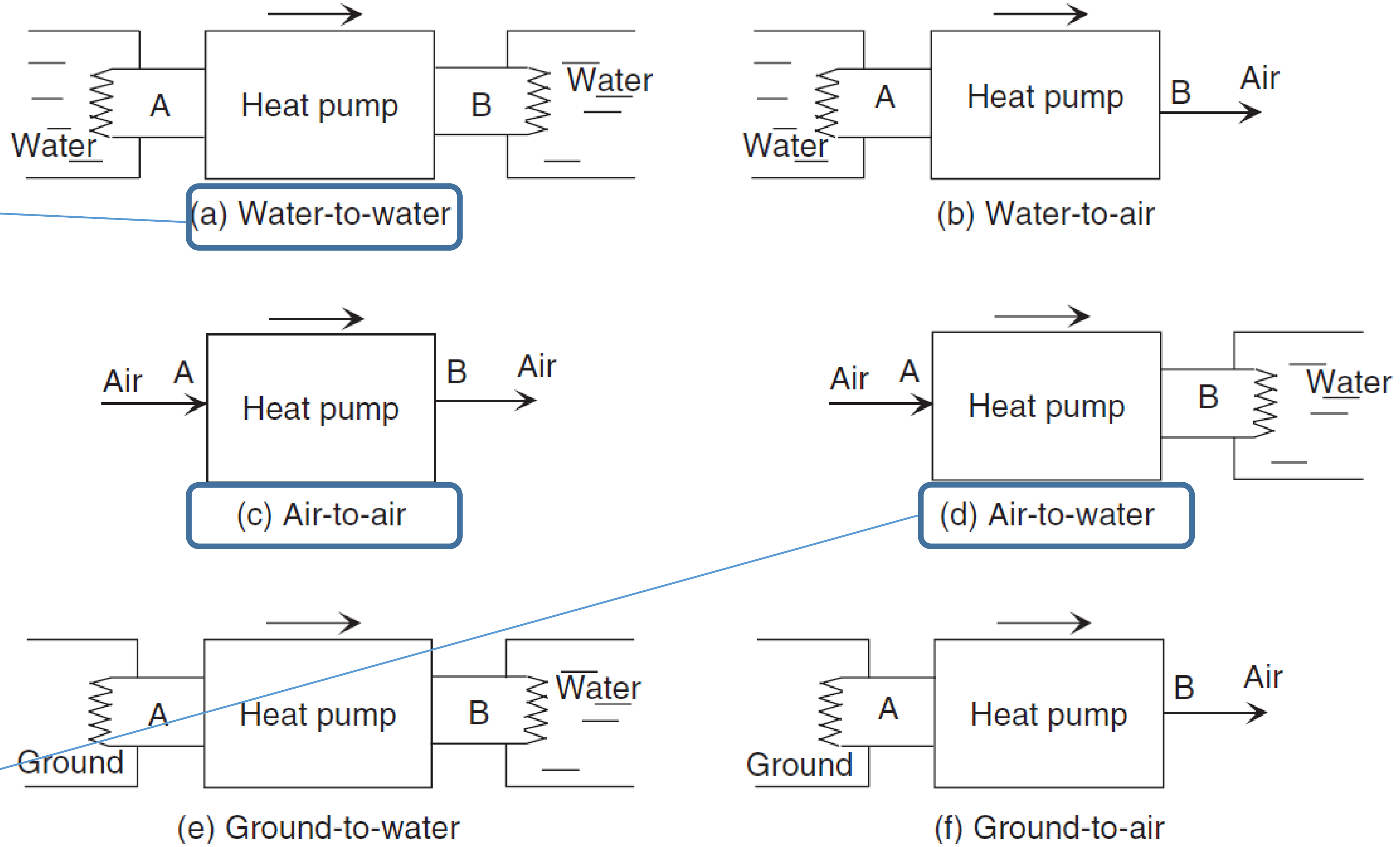
Example

R134a, R513A (Optional)
Screw compressor
Cooling: 470.1kW- 2331 kW
Heating: 523kW- 2568 kW



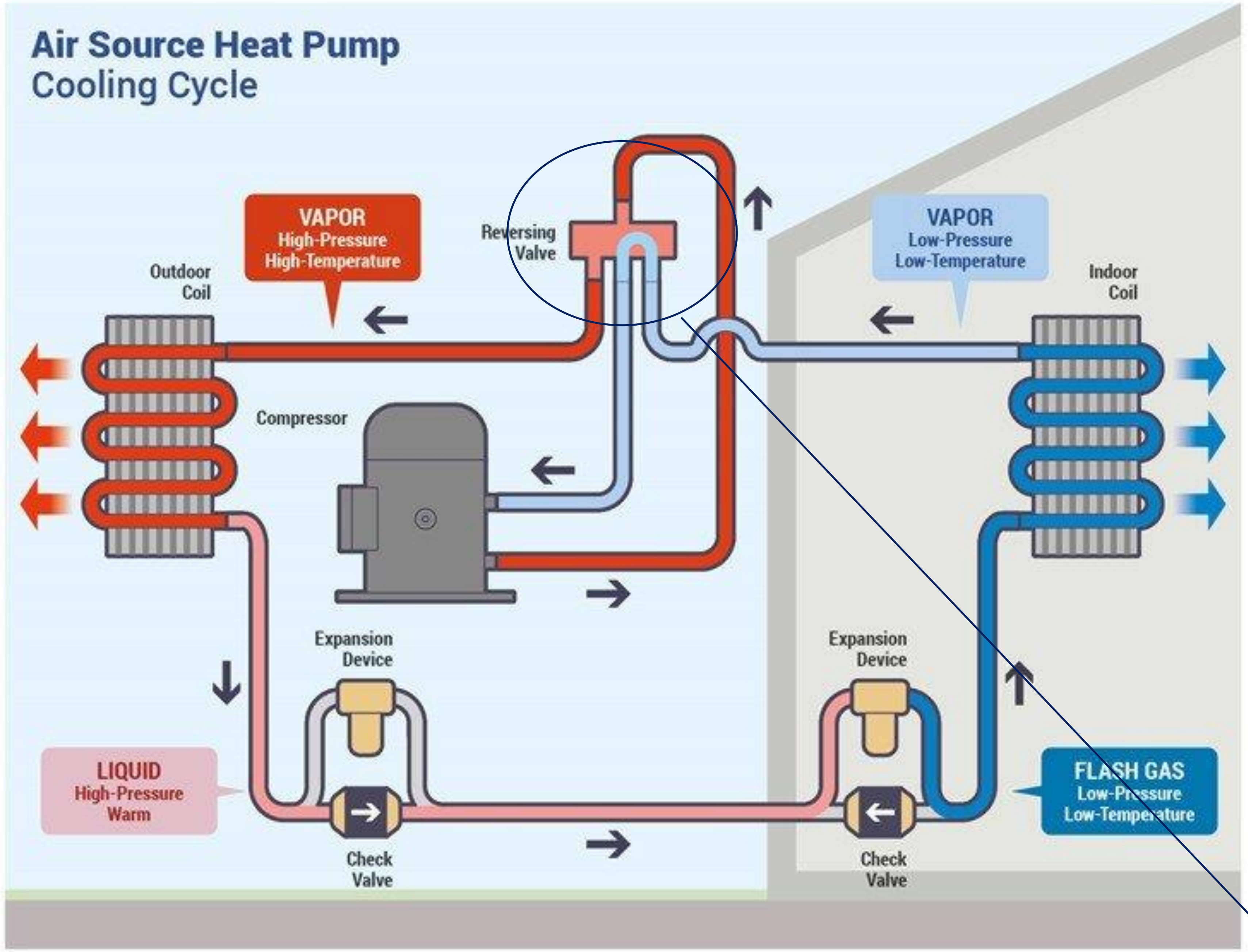
Example

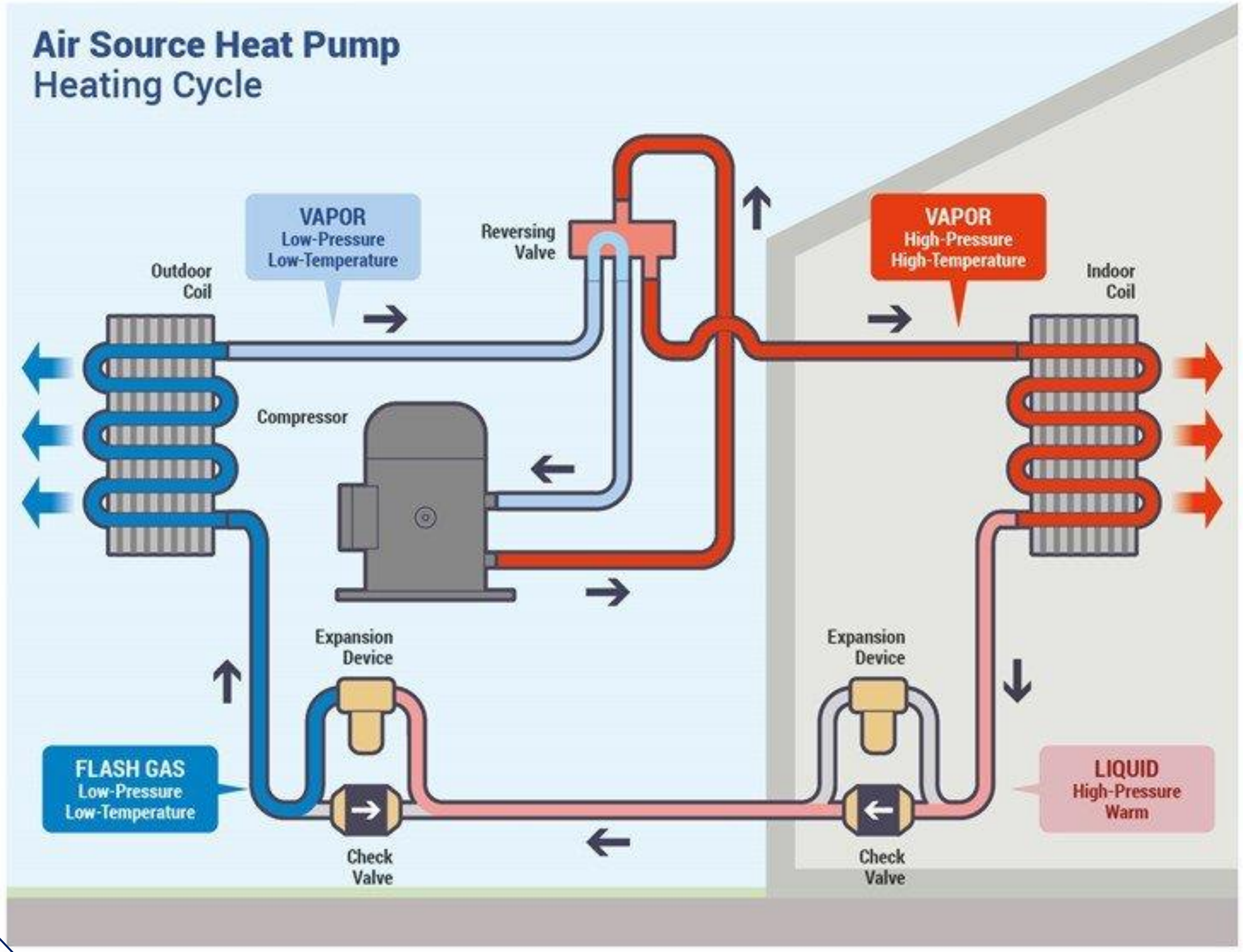
R134a, R407C
Screw compressor
Cooling: 200kW- 1510 kW
Heating: 220kW- 1684 kW



# Heat Pump Cycle

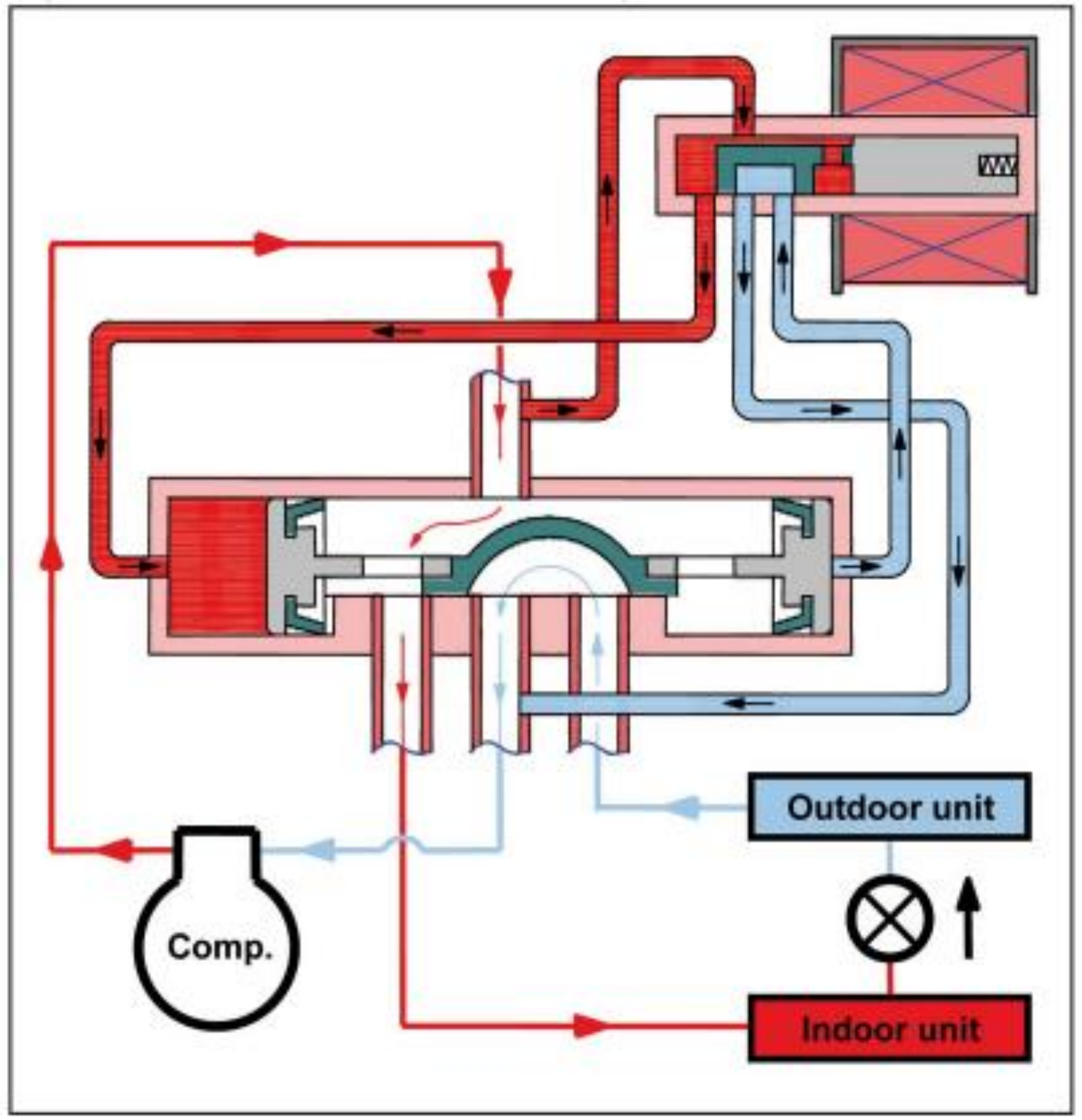
# Heat pump cycle



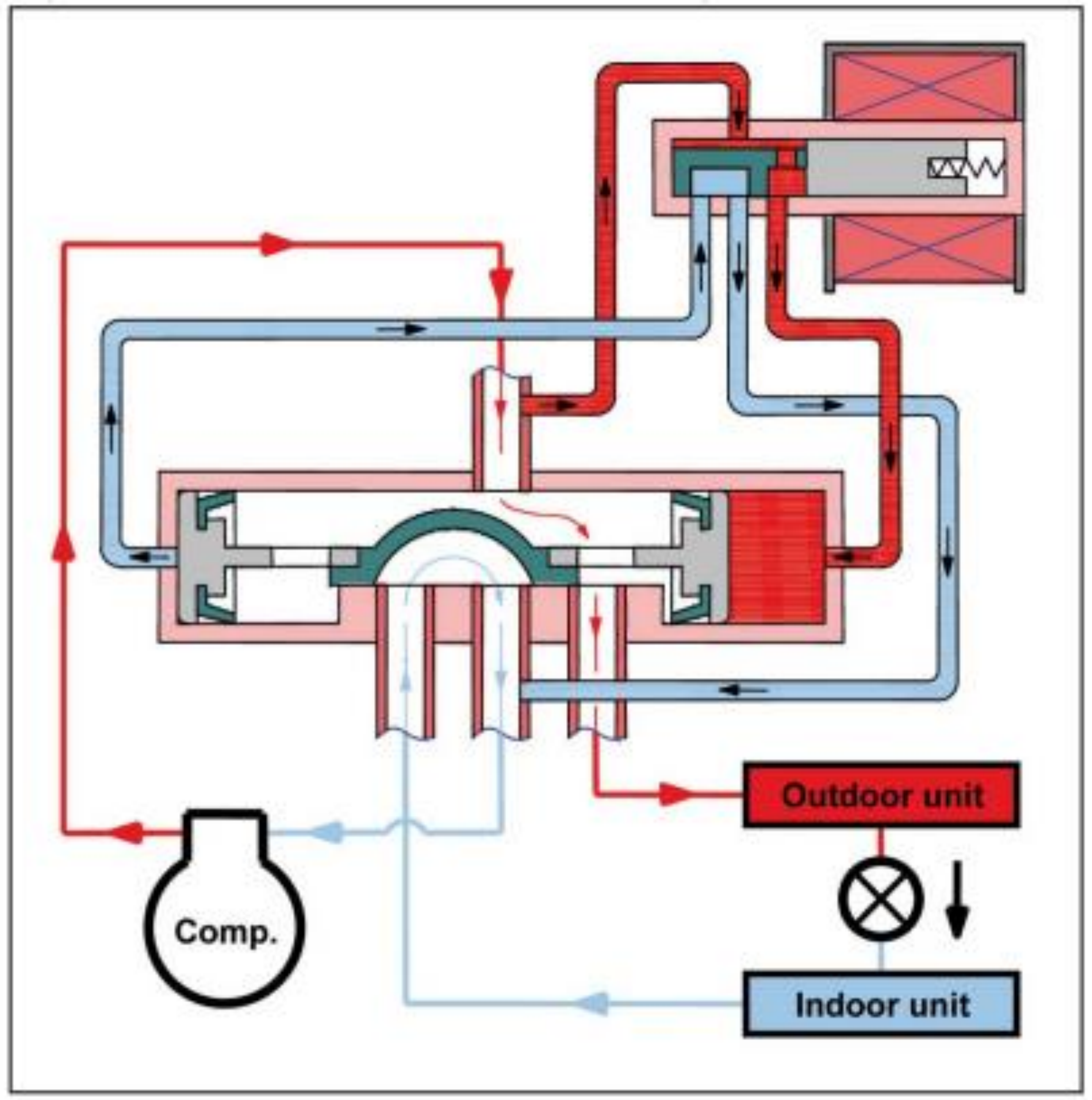




!!!! Don’t forget the suction line accumulator

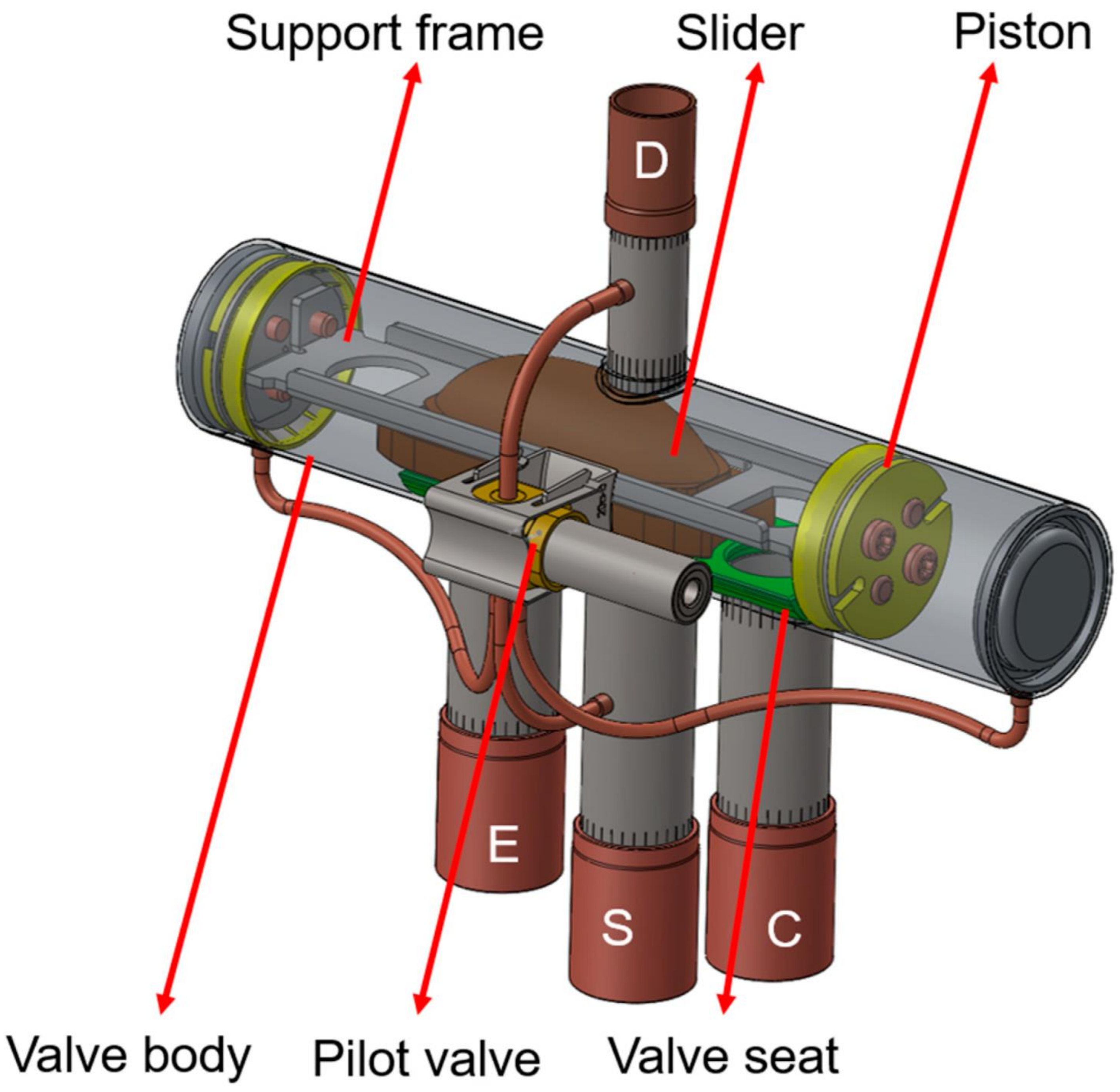
# Four way reversing valve




Heating Mode



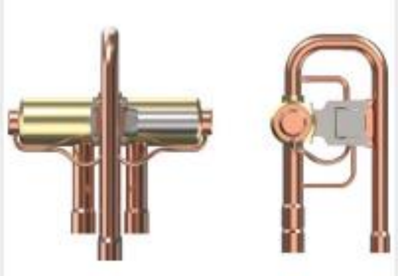
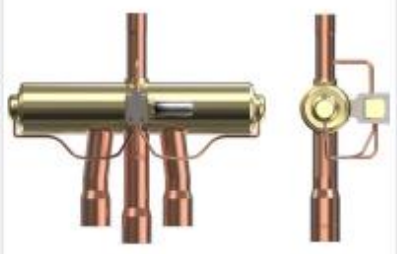
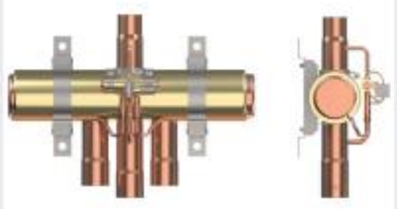

Cooling Mode

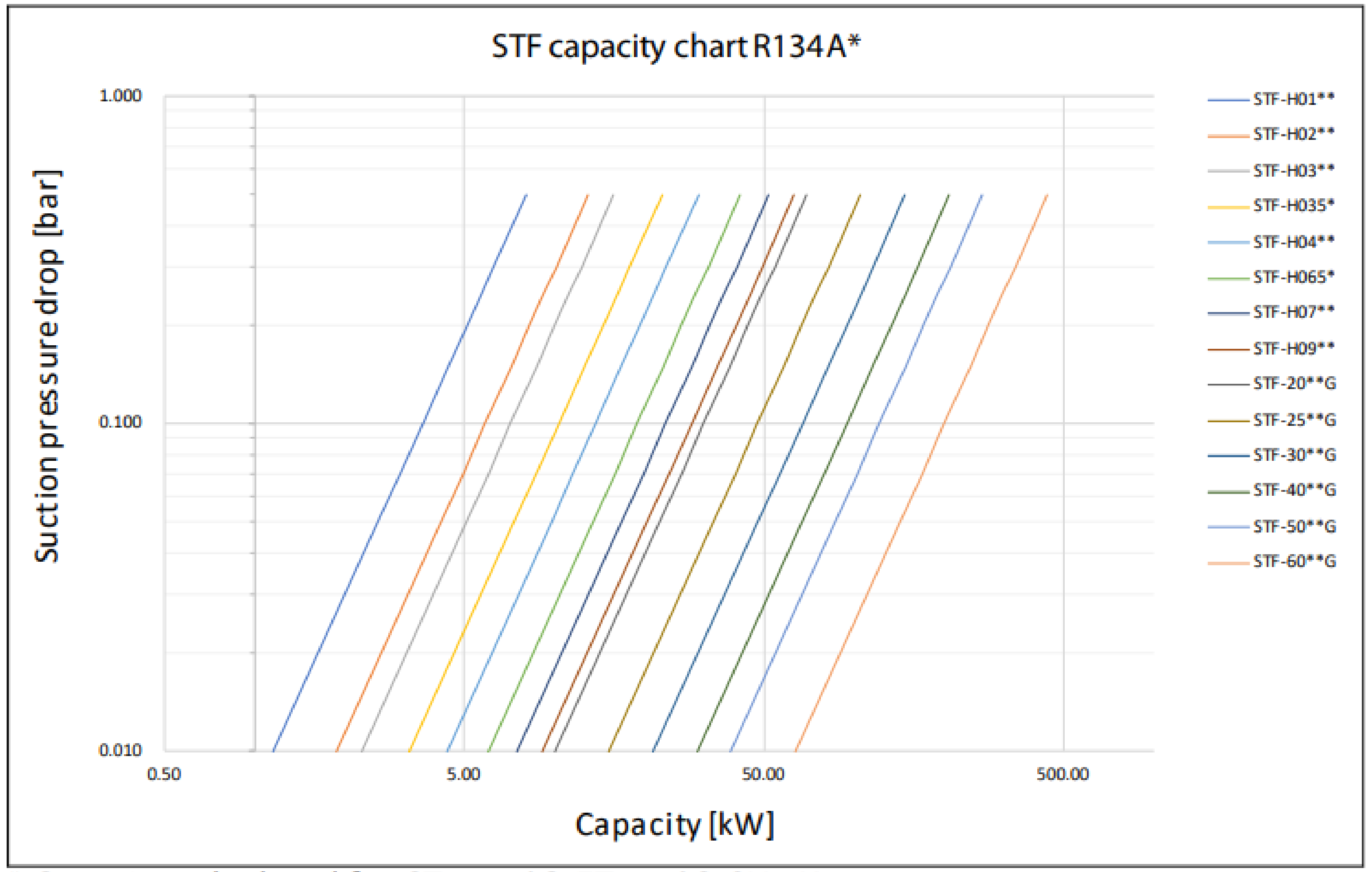


# Four way reversing valve

| Model | Packing format | Danfoss code | Capacity [kW] (1) | Style | Discharge | Suction | Media temperature | MWP | Approval |
|---|---|---|---|---|---|---|---|---|---|
| | | | R290/R410A | | [in] | [in] | [°C] | [bar] | |
| STF-H0167 | 45 | 061L1348 | 4.8 | A | 5/16 | 3/8 | 130 | 45 | CE |
| STF-H0267 | 32 | 061L1349 | 9.5 | A | 3/8 | 1/2 | 130 | 45 | CE |
| STF-H0321 | 32 | 061L1350 | 9.5 | E | 1/2 | 5/8 | 130 | 45 | CE |
| STF-H0351 | 32 | 061L1351 | 13.7 | B | 1/2 | 5/8 | 130 | 45 | CE |
| STF-H0429 | 24 | 061L1352 | 18.2 | F | 1/2 | 3/4 | 130 | 45 | CE |
| STF-H0651 | 24 | 061L1353 | 25.1 | B | 1/2 | 3/4 | 130 | 45 | CE |
| STF-H0731 | 6 | 061L1354 | 31.2 | F | 3/4 | 7/8 | 130 | 45 | CE |
| STF-H0951 | 6 | 061L1355 | 38.12 | B | 3/4 | 7/8 | 160 | 49 | CE |
| STF-H0954 | 6 | 061L1356 | 38.12 | F | 7/8 | 11/8 | 160 | 49 | CE |
| STF-2028G | 1 | 061L1357 | 41.8 | F | 11/8 | 13/8 | 160 | 49 | CE |
| STF-2525G | 1 | 061L1358 | 63.2 | G | 11/8 | 13/8 | 160 | 49 | CE |
| STF-3015G | 1 | 061L1345 | 89.4 | G | 11/8 | 15/8 | 160 | 49 | CE |
| STF-4016G | 1 | 061L1346 | 125.5 | G | 15/8 | 15/8 | 160 | 49 | CE |
| STF-5017G | 1 | 061L1360 | 161.3 | G | 15/8 | 2 1/2 | 160 | 49 | CE |
| STF-6009G | 1 | 061L1361 | 265.8 | G | 15/8 | 2 3/8 | 160 | 49 | CE |
| STF-25U25G | 1 | 061L1365 | 63.2 | G | 11/8 | 13/8 | 160 | 49 | UL |
| STF-30U15G | 1 | 061L1366 | 89.4 | G | 11/8 | 15/8 | 160 | 49 | UL |
| STF-40U16G | 1 | 061L1367 | 125.5 | G | 15/8 | 15/8 | 160 | 49 | UL |
| STF-50U16G | 1 | 061L1368 | 161.3 | G | 15/8 | 2 1/2 | 160 | 49 | UL |
| STF-60U9G | 1 | 061L1369 | 265.8 | G | 15/8 | 2 3/8 | 160 | 49 | UL |

(1) Capacity is indicated for 0.1bar suction pressure drop and condition 54.5 CCT, 7.2 CET and 5K SH

| Style A | Style B | Style E | Style F | Style G |
|---|---|---|---|---|
|  |  |  |  |  |

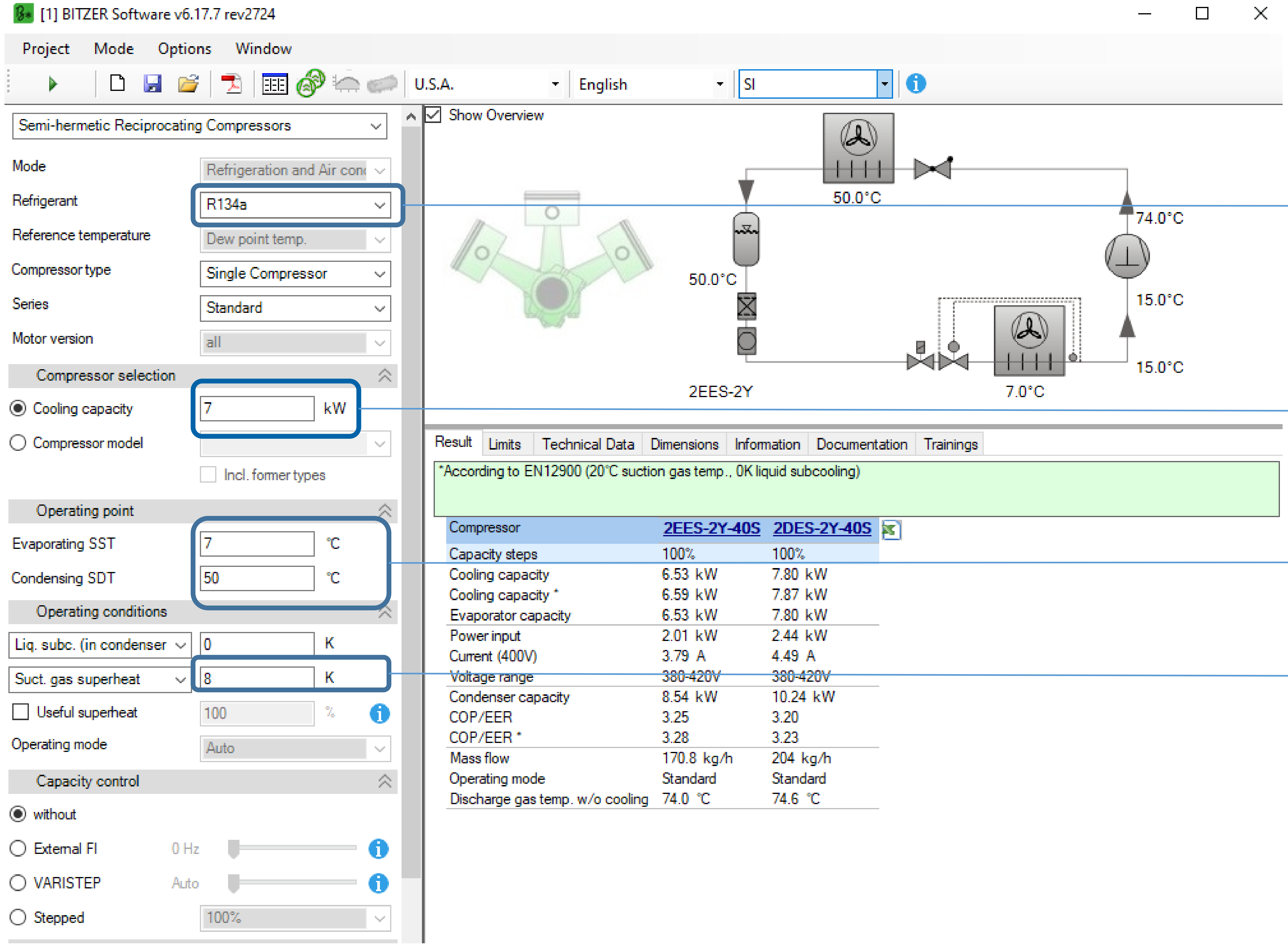



* Capacity calculated for CT 54.4 °C, ET 7.2 °C, SH 5K

# / Balance Point

# Balance Point

Cooling Load=7 kW , Heating Load= 9 kW




Refrigerants

Cooling Load

Evaporating and Condensing Temperatures

Super heat

# Balance Point

## Cooling Mode

- Selected Evaporator: 3 Fans (30cm Diameter)
- Selected Condenser: 1 Fan (50 cm Diameter)

$$\dot{Q}_H = C \times Eff \times (T_c - T_{out})$$

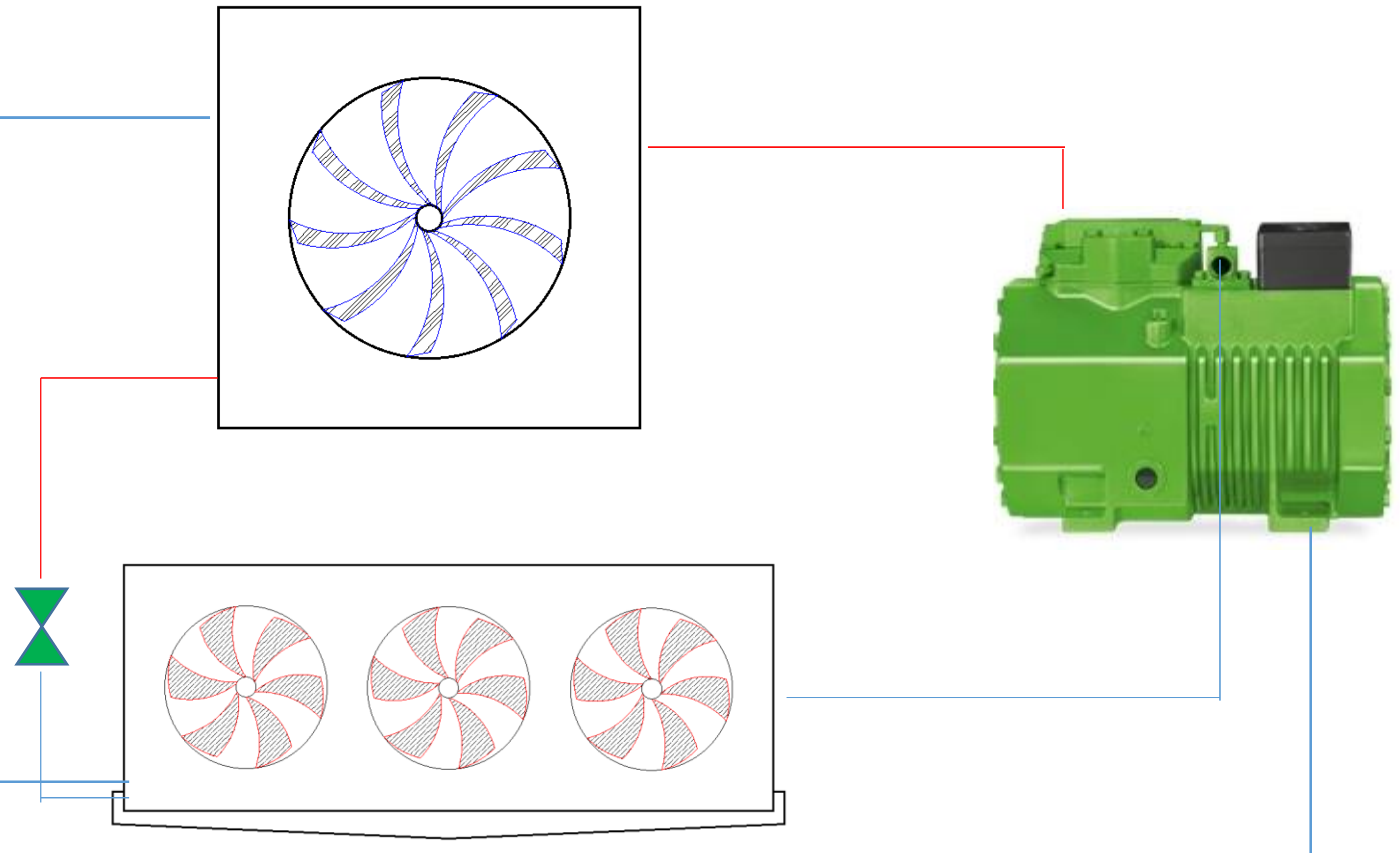
**Results:**

If Tr=18°C and Tout=40°C

Balance Point:

Te=8.3 °C and Tc=49.2 °C

Qc=8.35 kW, W=2.45 kW, Qh=10.8 kW



$$\dot{Q}_C = C \times Eff \times (T_r - T_e)$$

$$\dot{Q}_C = c_1 + c_2T_e + c_3T_c + c_4T_e^2 + c_5T_eT_c + c_6T_c^2 + c_7T_e^3 + c_8T_cT_e^2 + c_9T_eT_c^2 + c_{10}T_c^3$$

# Balance Point

## Heating Mode

- Selected Condenser: 3 Fans (30cm Diameter)
- Selected Evaporator: 1 Fan (50 cm Diameter)

$$\dot{Q}_C = C \times Eff \times (T_r - T_{e)}$$

**Results:**

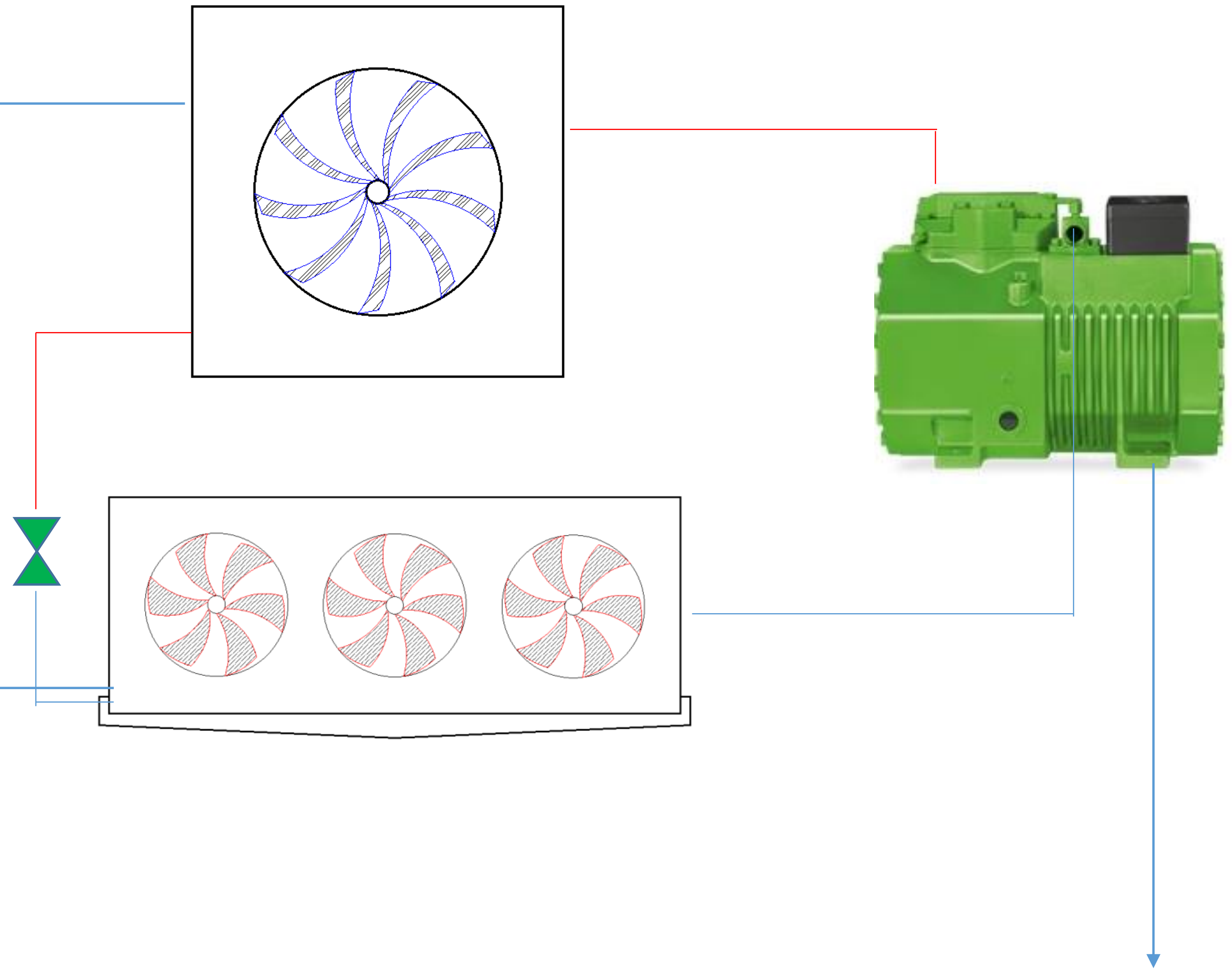
If Tr=25°C and Tout=5.3°C

Balance Point:

Te=0.1 °C and Tc=35.4 °C

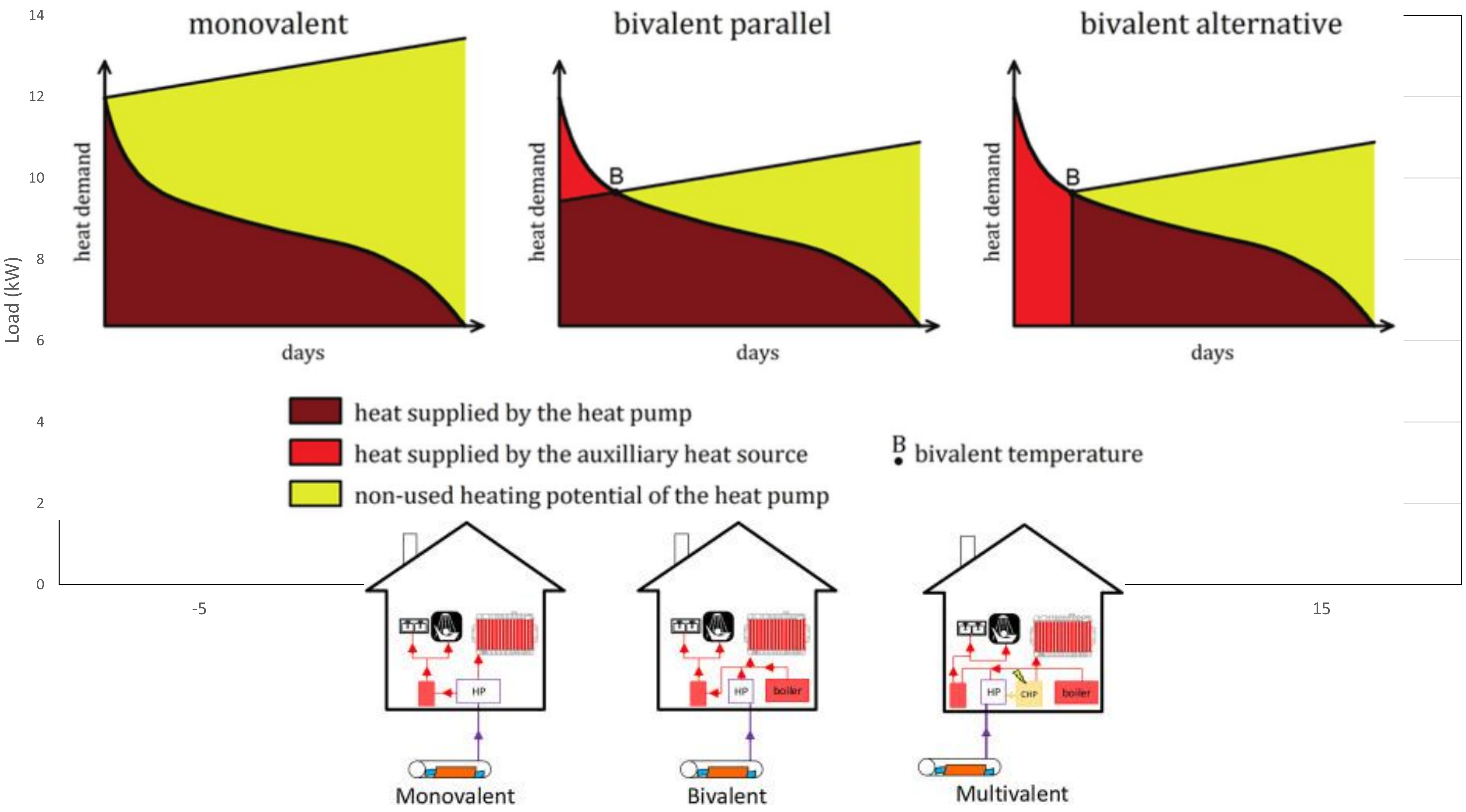
Qc=7.2 kW, W=1.8 kW, Qh=9 kW

$$\dot{Q}_H = C \times Eff \times (T_C - T_{out)}$$



$$\dot{Q}_C = c_1 + c_2T_e + c_3T_c + c_4T_e^2 + c_5T_eT_c + c_6T_c^2 + c_7T_e^3 + c_8T_cT_e^2 + c_9T_eT_c^2 + c_{10}T_c^3$$

# Balance Point



# Suitable Refrigerants

# What are the most suitable refrigerants?


- "..HCFC-22, HFC 134-a and HFC-407C are the most widely used refrigerants in new heat pumps…"

S.K. Wang, (2001), *"Hand book of Air Conditioning and Refrigeration"*, McGraw-Hill, Chapter 12.

- "…R 134a, R407c, R410a, R717 respectively for medium and large sized, small sized and industrial scale heat pumps…"

Aspirationenergy.com, "Refrigerants used in Heat Pumps and How to choose it wisely"

- **R134a,R513A, R407c, R410A, R32, R1234yf, R1234ze** → **Most mentioned**



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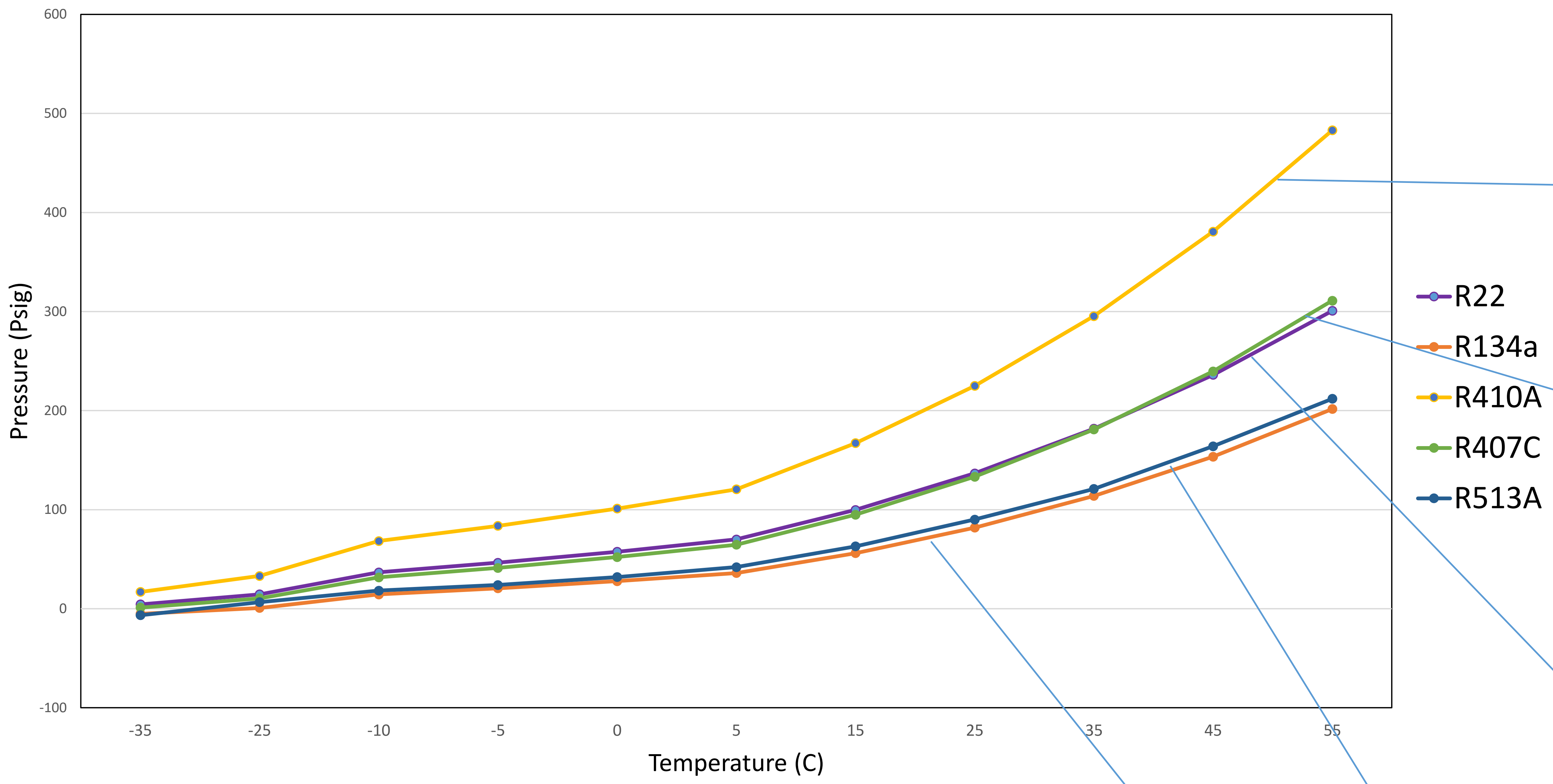
# What are the most suitable refrigerants?

- **Pressure and Compressor Envelope** → **Needs More Attention**



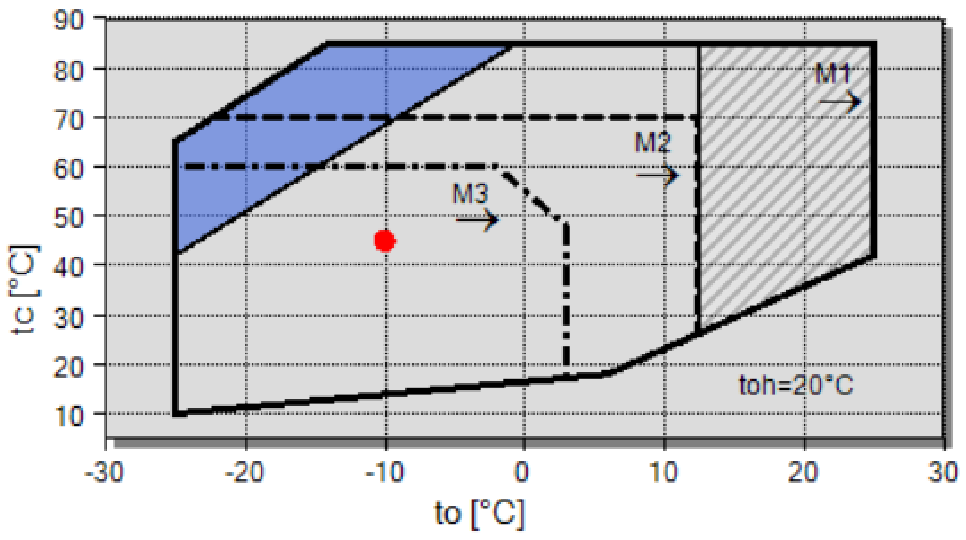




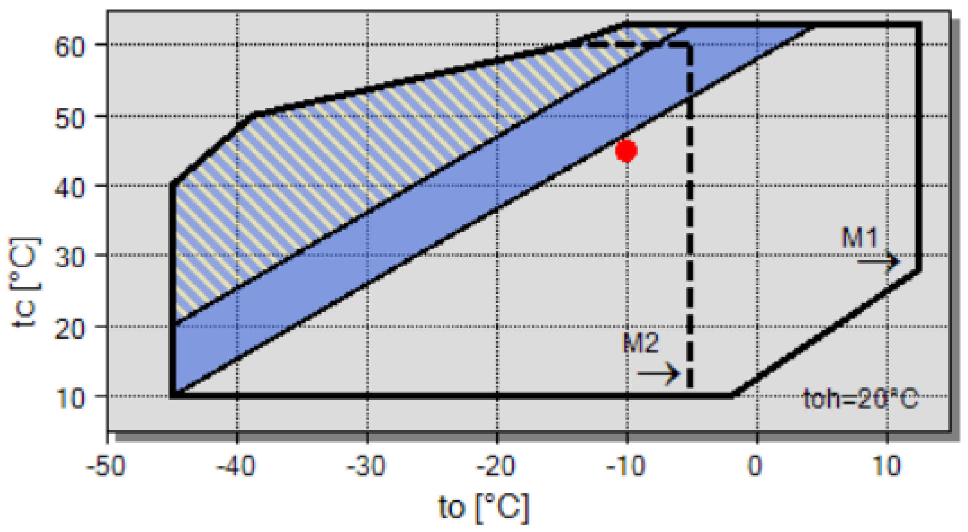

# What are the most suitable refrigerants?

- **Pressure and Compressor Envelope** → **Needs More Attention**

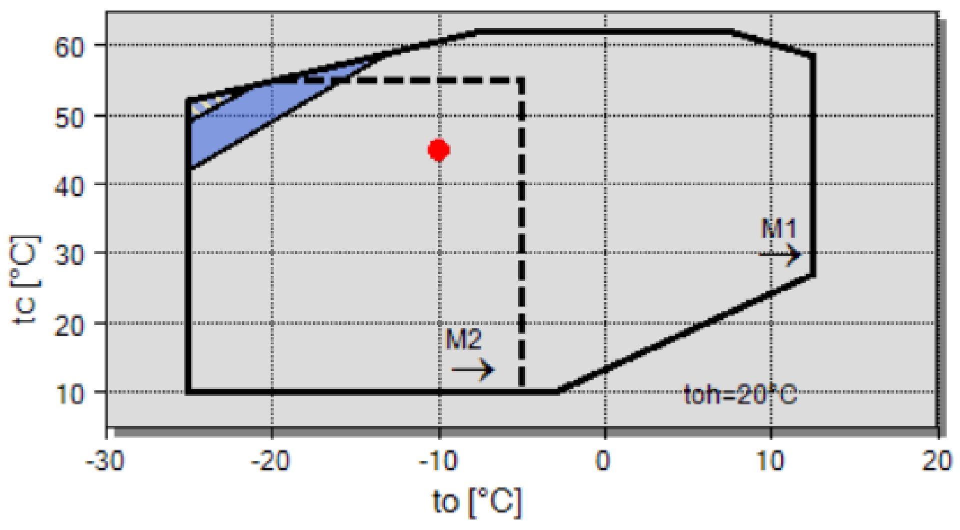
2DES-3Y



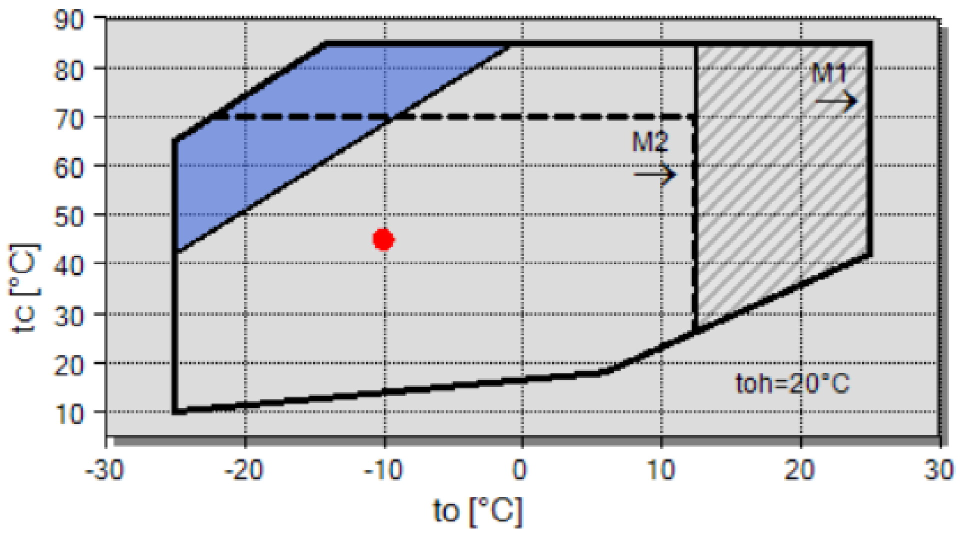

R134a




R22




R407C




R513A

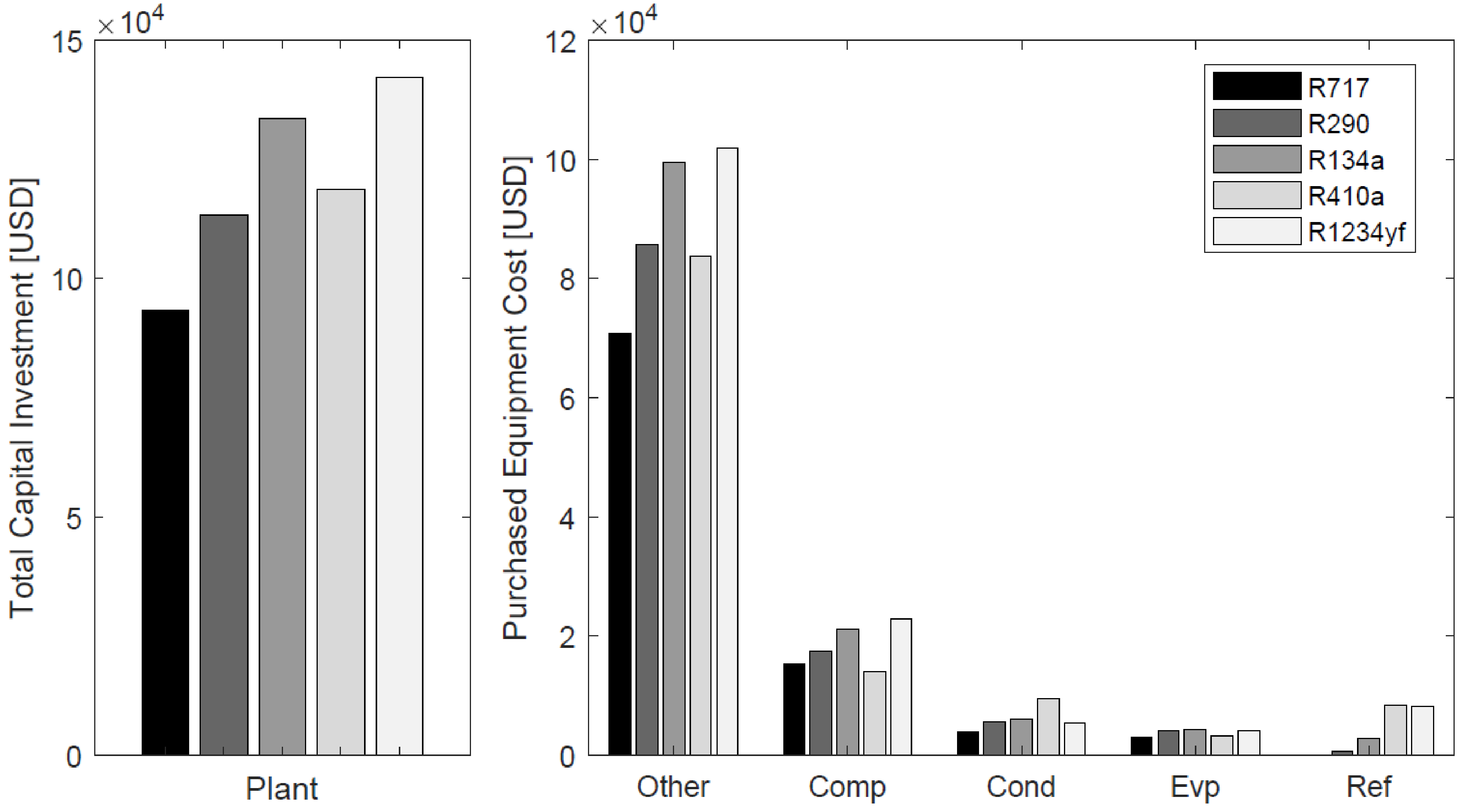
# What are the most suitable refrigerants?

- **Pressure and Compressor Envelope** → **Needs More Attention**

  - N. Stefan, C.S. Wuust, S. Thorsen, E. Brian, (2018), *"Comparison of Heat Pump Design and Performance for Modern Refrigerants"* , In Proceedings of 13th IIR- Gustav Lorentzen Conference on Natural Refrigerants.

| *Refrigerant* | *Group* | *GWP 100 [years]* | *ASHRAE Safety Group* | *ASHRAE Flammability* | *ASHRAE Toxicity* |
|---|---|---|---|---|---|
| *R717 (Ammonia)* | *Natural* | *0* | *B2L* | *Yes (Low)* | *Yes* |
| *R290 (Porpane)* | *Natural* | *3* | *A3* | *Yes (Highly flammable)* | *No* |
| *R1234yf* | *HFO* | *4* | *A2L* | *Yes (Low)* | *No* |
| *R134a* | *HFC* | *1430* | *A1* | *No* | *No* |
| *R410A* | *HFC* | *2088* | *A1* | *No* | *No* |

| *Parameter* | *Unit* | *R717* | *R290* | *R134a* | *R410A* | *R1234yf* |
|---|---|---|---|---|---|---|
| *Exergy destruction* | $[kW_{ex}]$ | *22.3* | *27.6* | *26.9* | *25.2* | *31.7* |
| *Exergy efficiency* | *[-]* | *0.67* | *0.64* | *0.64* | *0.65* | *0.62* |
| *COP* | *[-]* | *3.1* | *2.6* | *2.6* | *2.8* | *2.3* |
| *Total Charge* | *[kg]* | *3.5* | *7.1* | *15.9* | *27.1* | *20.3* |
| *Specific Heat Charge* | $[g \cdot kW^{-1}]$ | *23* | *47* | *106* | *181* | *135* |
| *Cost of heat* | $[USD \cdot MWh^{-1}]$ | *44* | *51* | *55* | *50* | *60* |



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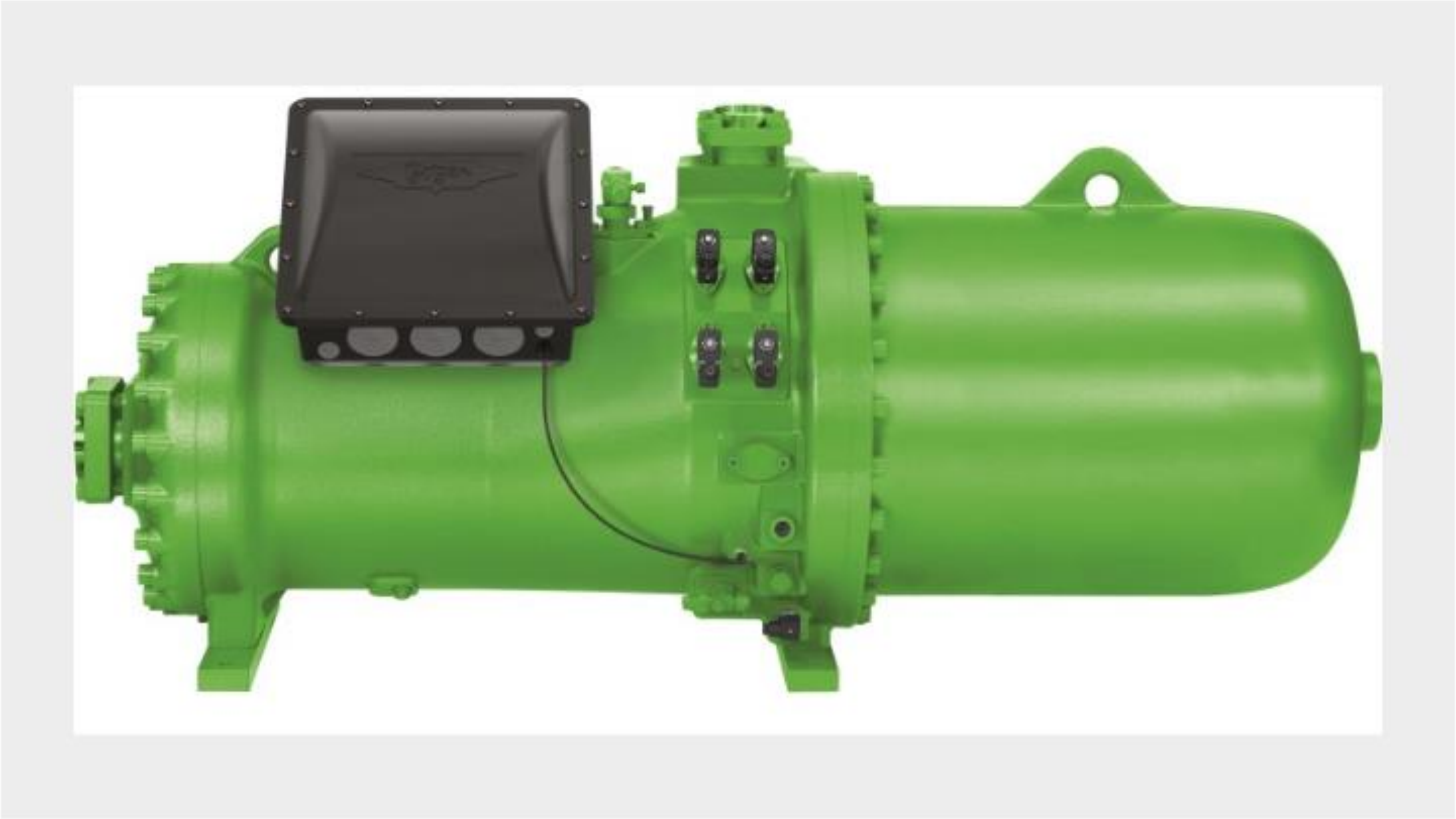
# / Bitzer Screw Compressors For Heat Pump

# Bitzer Screw Compressor For Heat Pump

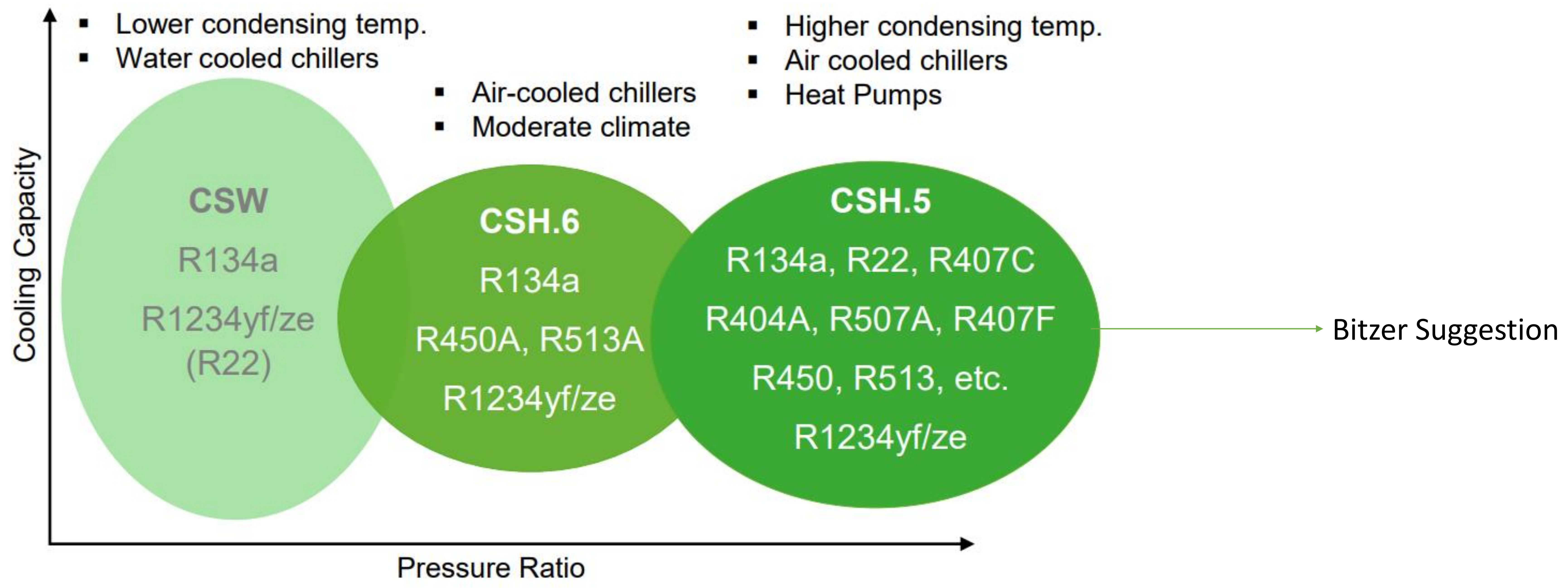
## BITZER APPROVES CSH SCREW COMPRESSORS FOR USE IN LARGE HEAT PUMPS

16.03.2021



*BITZER has approved selected CSH screw compressors for use in large heat pumps*

# Bitzer Screw Compressor For Heat Pump



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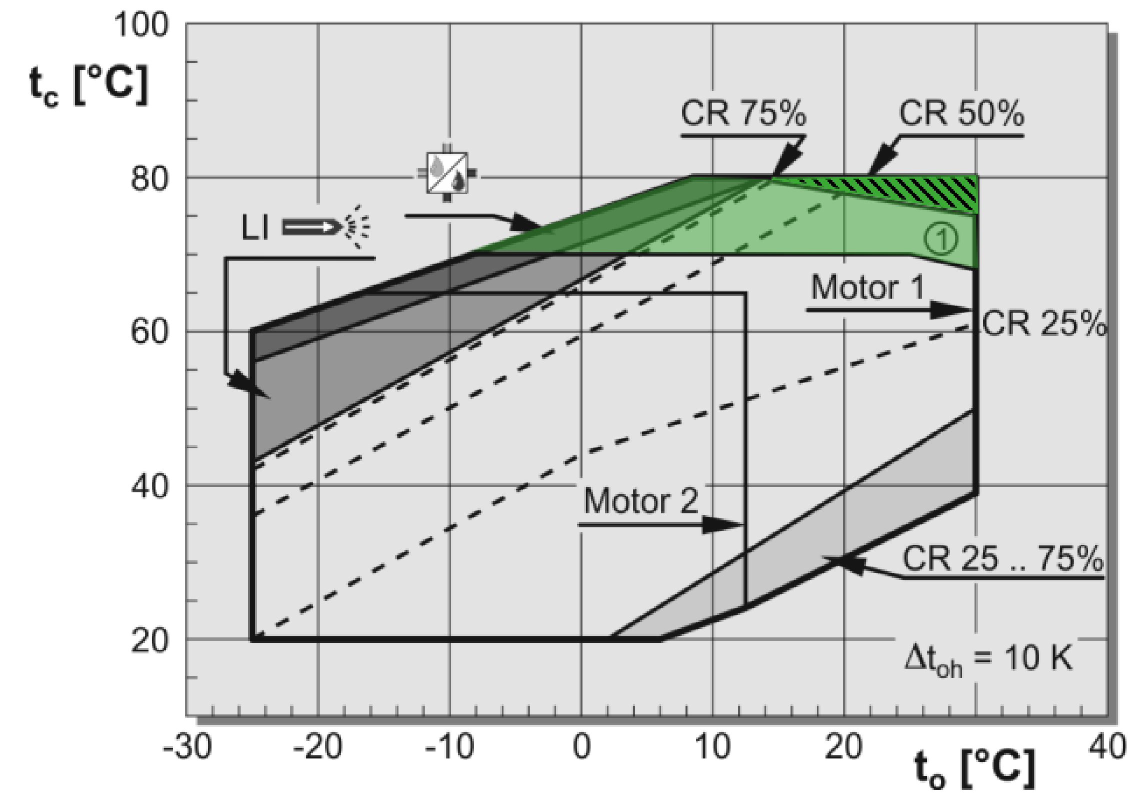
# Bitzer Screw Compressor For Heat Pump

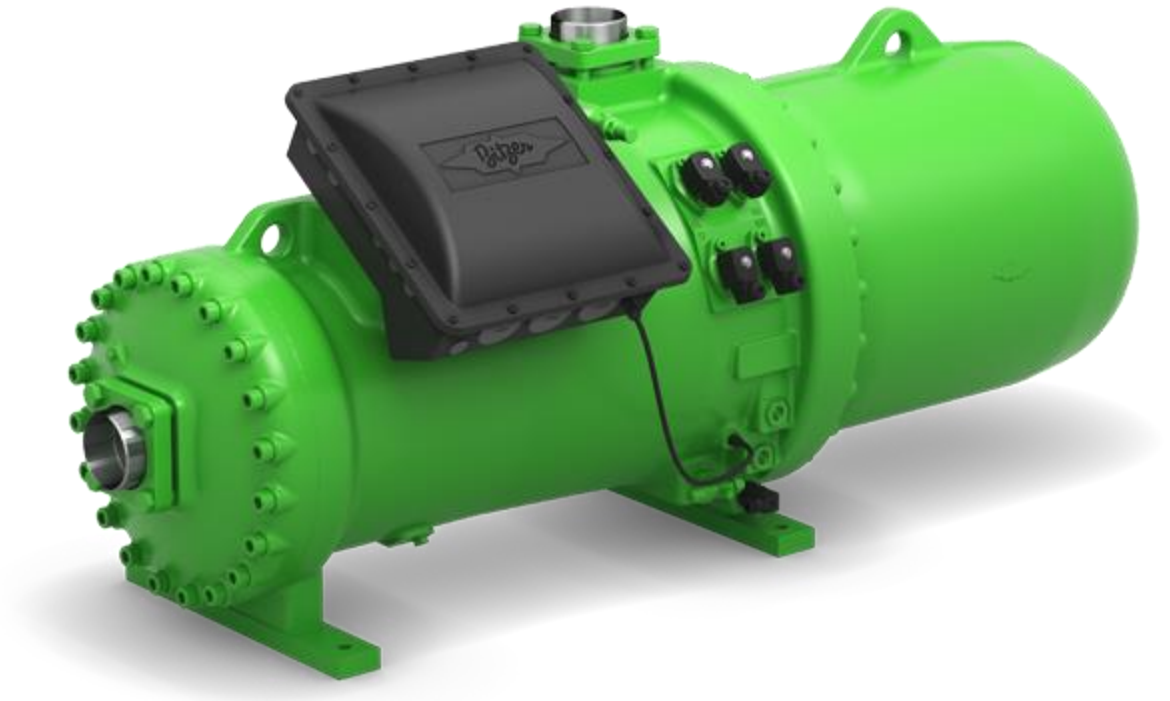
## For R134a, R1234yf, R450A and R513A




Only for listed compressors

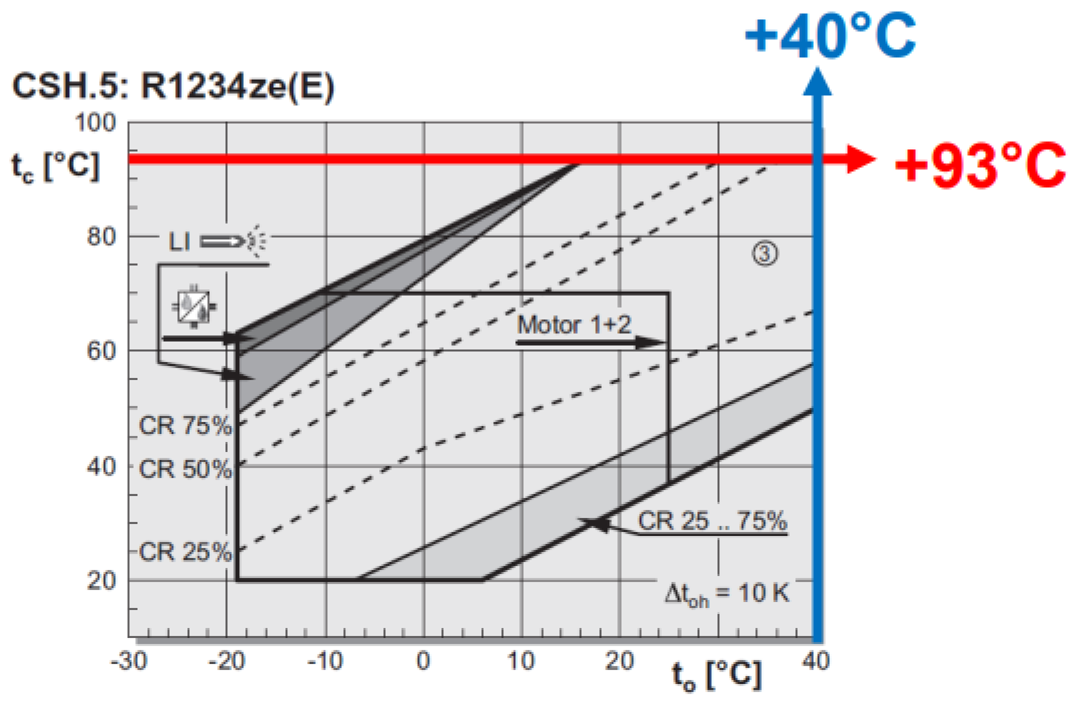
Only for listed compressors and R450A

CSH6553-50(Y)
CSH6563-60(Y)
CSH7553-70(Y)
CSH7563-80(Y)
CSH7573-90(Y)
CSH7583-100(Y)
CSH8553-110(Y)
CSH8563-125(Y)
CSH8573-140(Y)
CSH8593-180(Y)
CSH9553-180(Y)
CSH9563-210(Y)
CSH9573-240(Y)
CSH9583-280(Y)

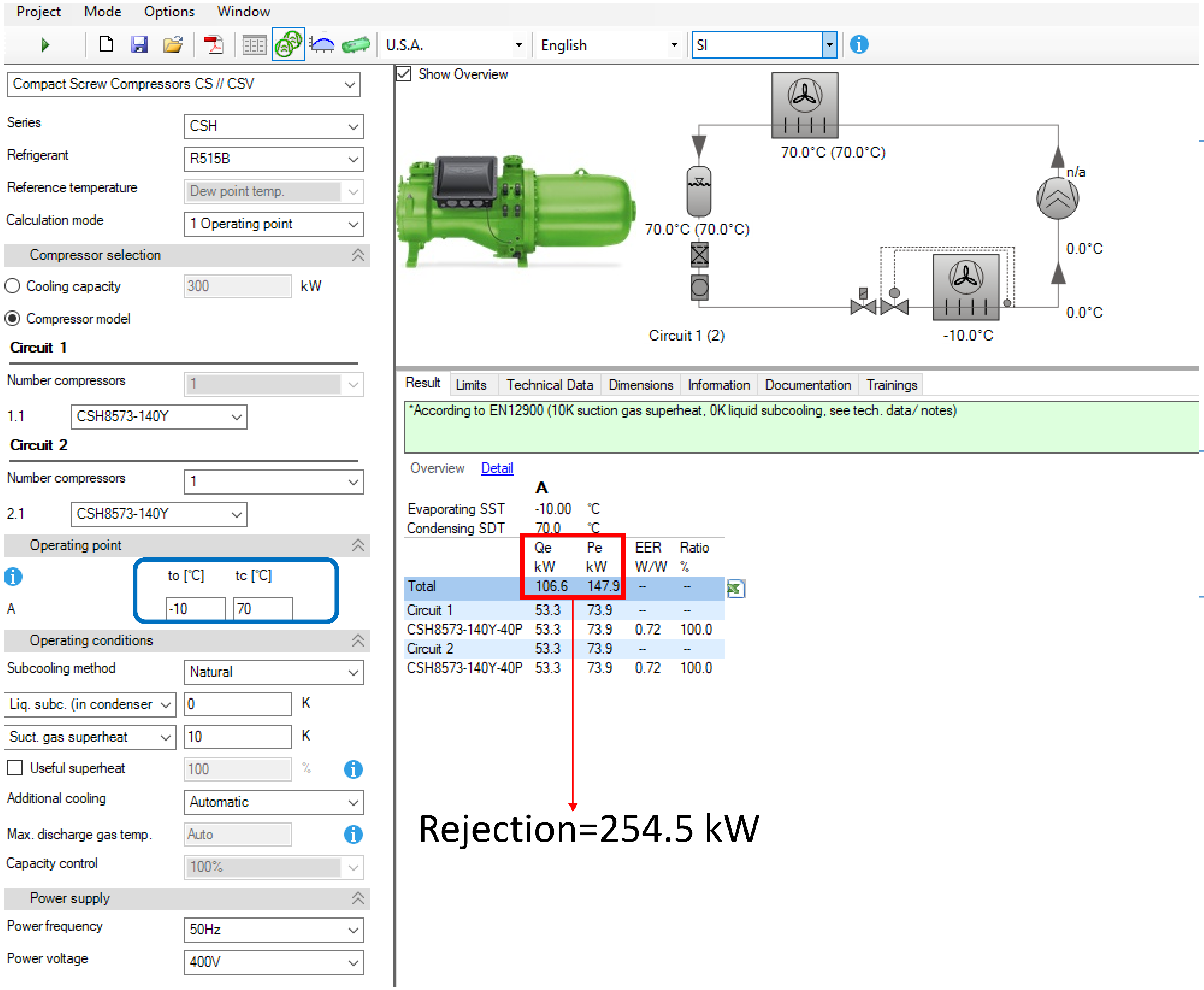


Heat-Pump for high-temperature applications

- **CSH.5** with R1234ze(E) and R515B
  - New maxi SDT = **+93°C** (hot sanitary water +90°C)
  - New maxi SST = **+40°C**
- Safe and stable thanks on-board monitoring with SE-i1
- Available in BITZER Software **6.15.2** (05.10.2020)



# Bitzer Screw Compressor For Heat Pump




Refrigerant

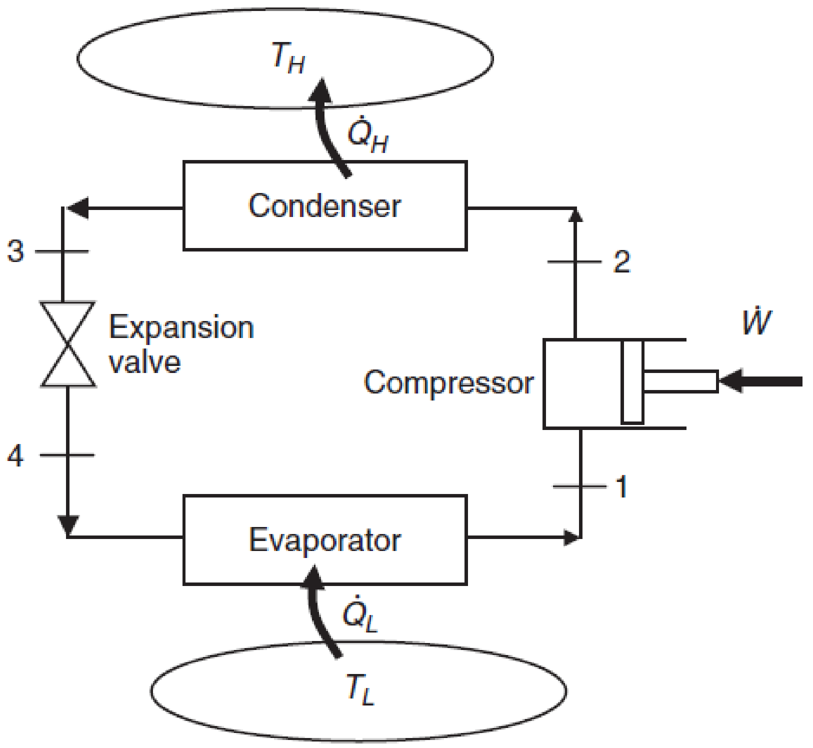
Selected Compressors

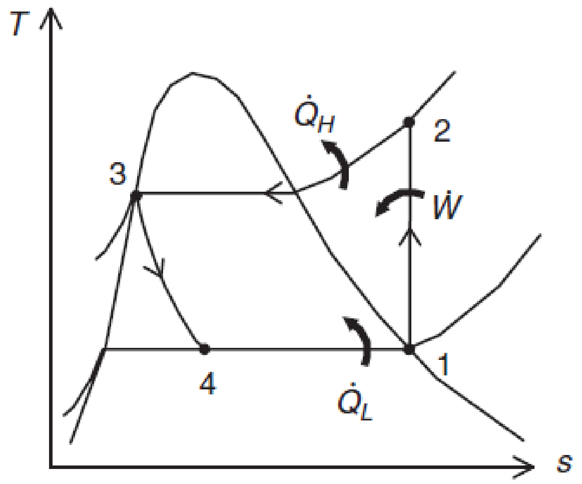
Evaporator and Condenser Temperatures

Rejection=254.5 kW

# / Heat Pump Performance

# Heat Pump performance evaluation





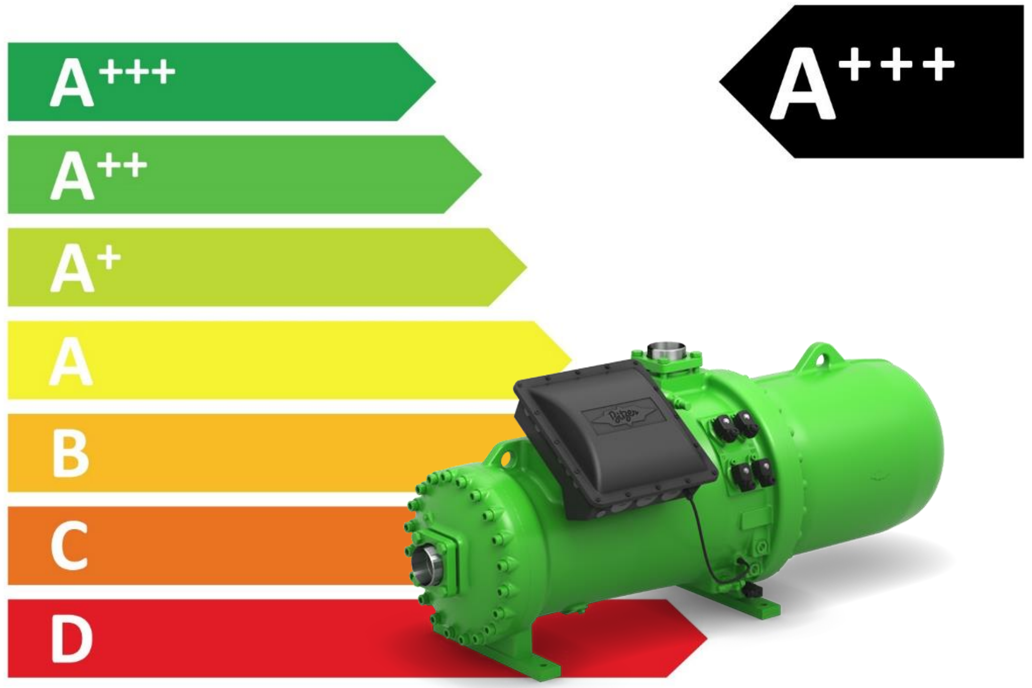
Compressor: $\dot{W} = \dot{m} \times (h_2 - h_1)$
Condenser: $\dot{Q}_H = \dot{m} \times (h_2 - h_3)$
Evaporator: $\dot{Q}_L = \dot{m} \times (h_1 - h_4)$
Expansion Valve: $h_3 = h_4$

$$COP = \frac{\dot{Q}_H}{\dot{W}}$$

The most common measurement used to rate heat pump efficiency

Air source heat pumps: COPs= 2 to 4
Water source heat pumps: COPs= 3 to 5

$COP$ @ $8.3°C$ $(47°F)$
$COP$ @ $-9.4°C$ $(17°F)$




✖ While COPs is helpful, it does not provide the whole picture



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# Heat Pump performance evaluation


- Primary Energy Ratio (PER)

$$PER = \eta \times COP$$

- Energy Efficiency Ratio (EER)

$$EER = cooling\ capacity \left(\frac{Btu}{h}\right) / electrical\ energy\ input\ (W)$$

In practice, EER ratings higher than 10 are the most desirable.

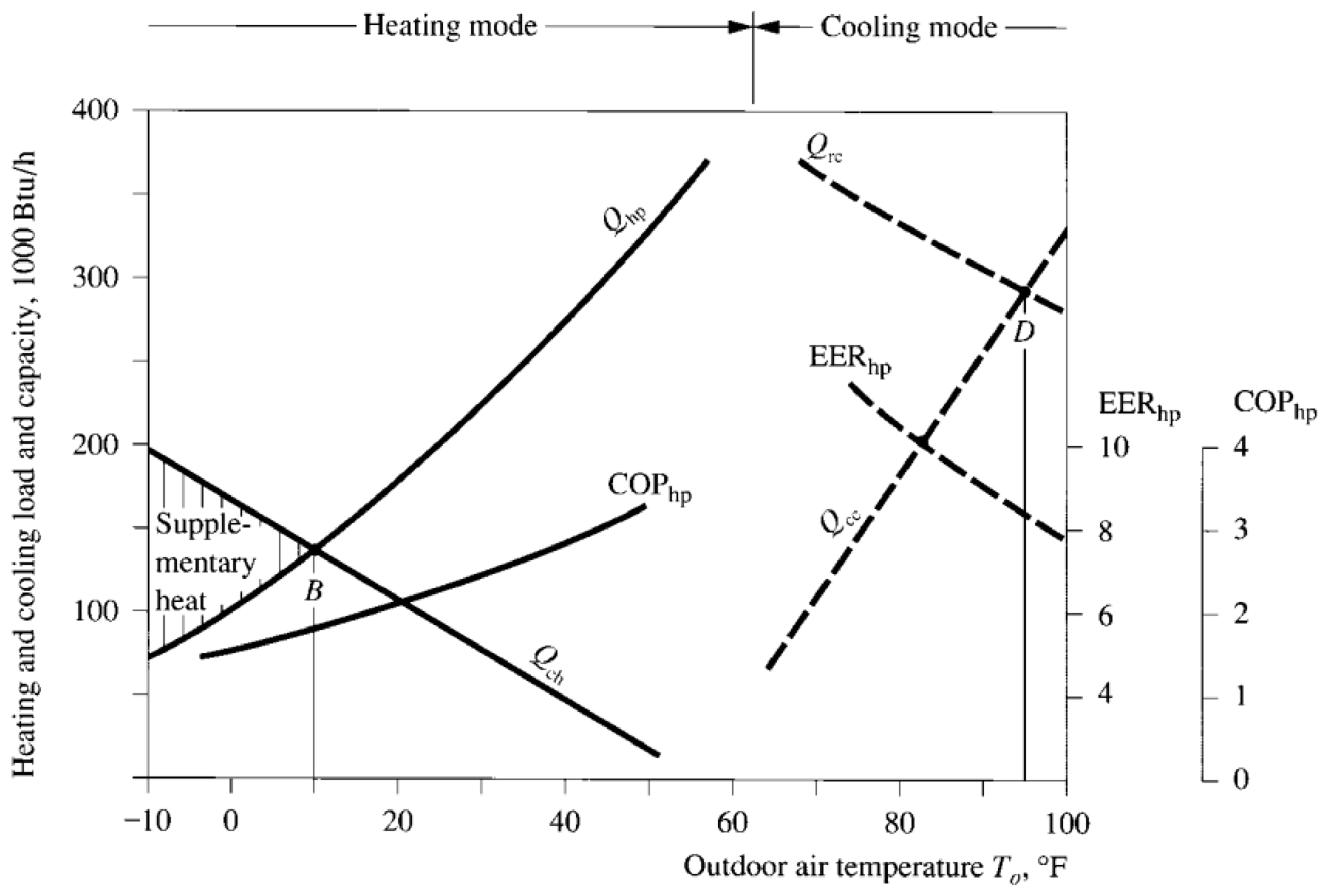
- Heating Season Performance Factor (HSPF)

$$HSPF = total\ seasonal\ heating\ output (Btu) / total\ electrical\ energy\ input\ (Wh)$$

An HSPF of 6.8 corresponds to an average COP of 2. HSPFs of 5-7 are considered good.

- Seasonal Energy Efficiency Ratio (SEER)

$$SEER = total\ seasonal\ cooling\ output (Btu) / total\ electrical\ energy\ input\ (Wh)$$



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# Heat Pump performance evaluation

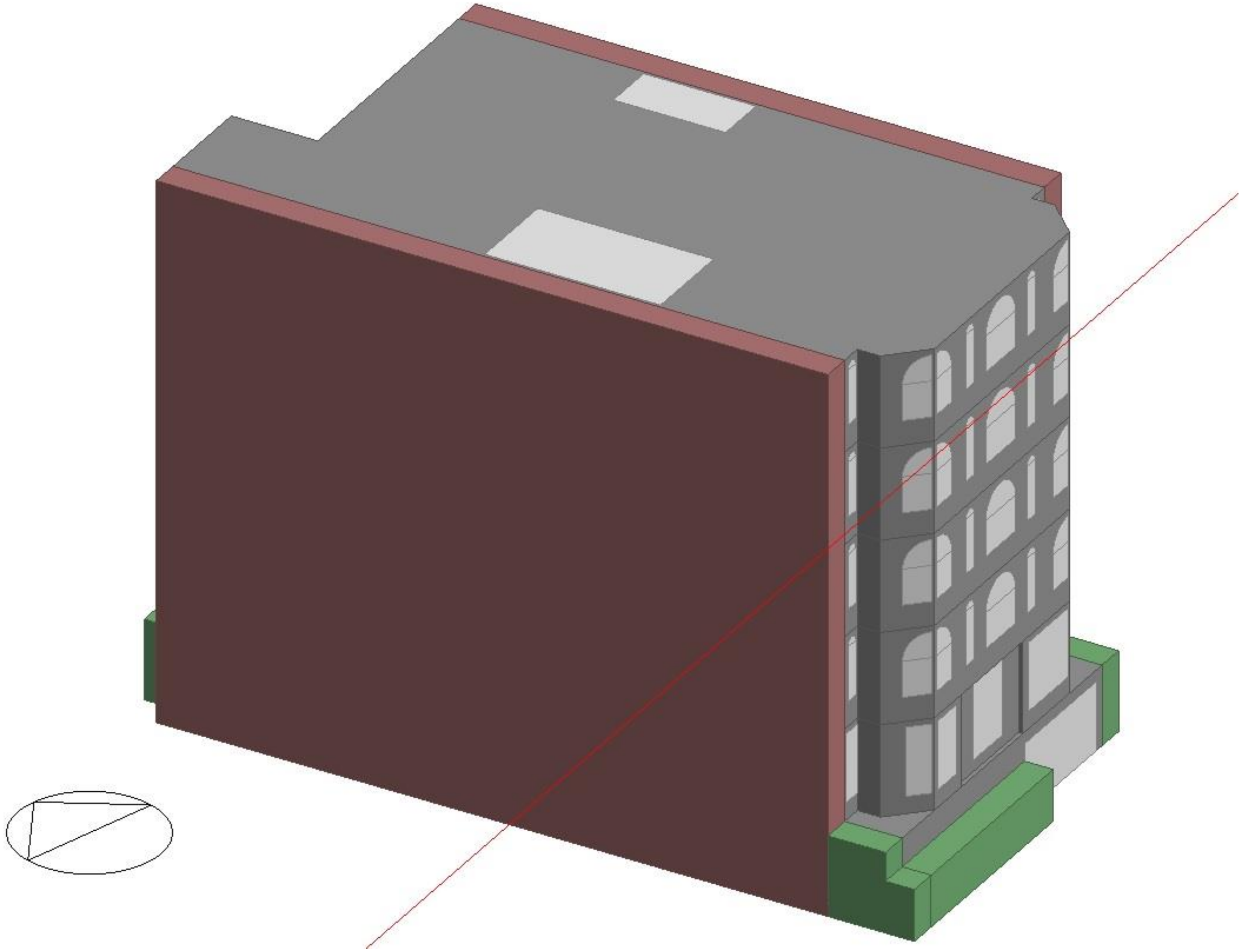
- Minimum Performance Based on ASHREA 90.1-1999

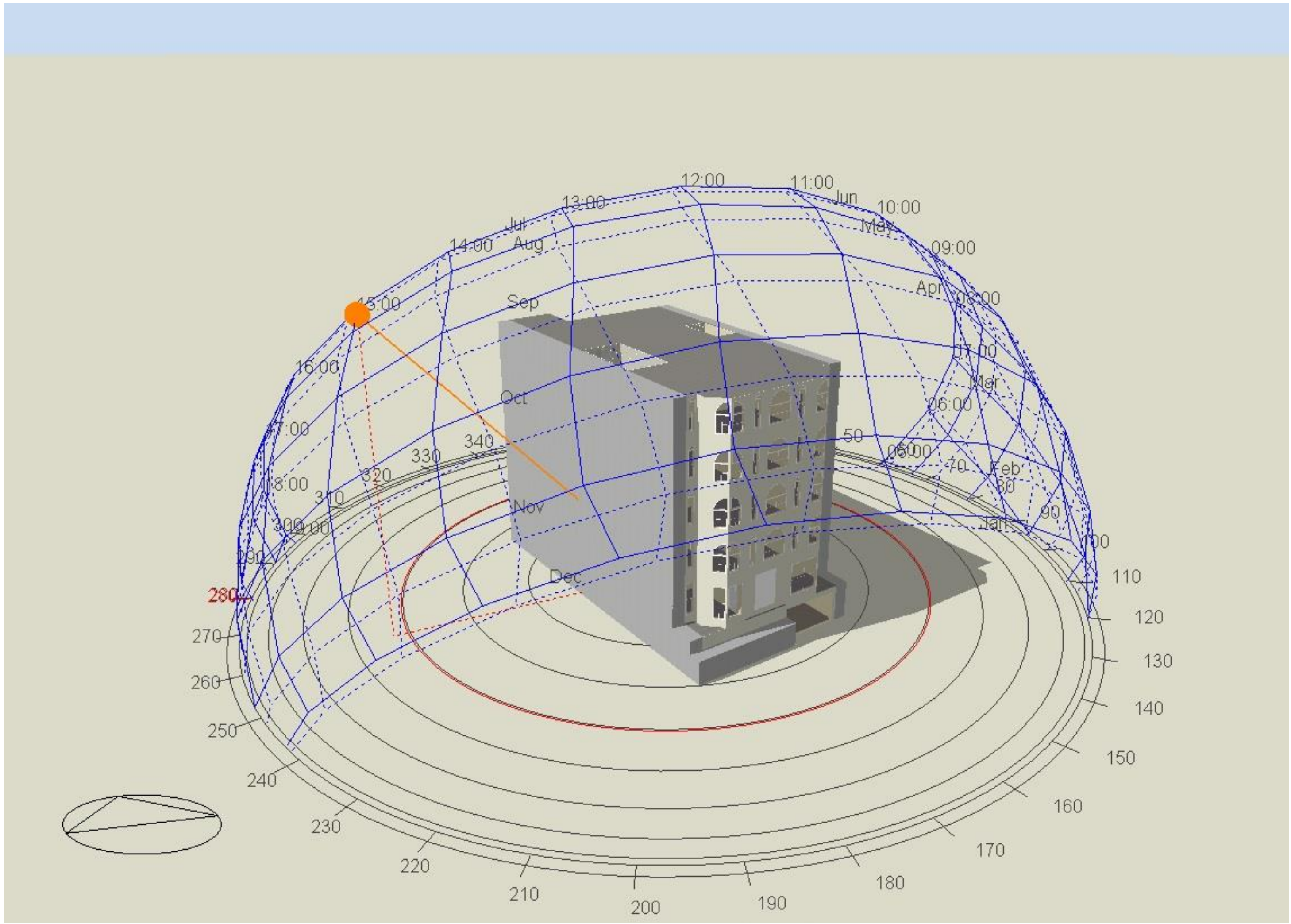
| Size | Cooling description | Minimum efficiency | Efficency as of 10/29/2001 | Heating rating condition | Minimum efficiency | 10/29/2001 |
|---|---|---|---|---|---|---|
| < 65,000 Btu/h | Split system<br>Single package | 10.0 SEER<br>9.7 SEER | 10.0 SEER<br>9.7 SEER | Split system<br>Single package | 6.8 HSPF<br>6.6 HSPF | 6.8 HSPF<br>6.6 HSPF |
| ≥ 65,000 Btu/h and < 135,000 Btu/h | Split system and single package | 8.9 EER | 10.1 EER | 47°Fdb/43°Fwb outdoor air | 3.0 COP | 3.2 COP |
| ≥ 135,000 Btu/h and < 240,000 Btu/h | Split system and single package | 8.5 EER | 9.3 EER | 47°Fdb/43°Fwb outdoor air (≥ 135,000 Btu/h) | 2.9 COP | 3.1 COP |
| ≥ 240,000 Btu/h | Split system and single package | 8.5 EER<br>7.52 IPLV | 9.0 EER<br>9.22 IPLV | | | |

Test Standards:
-AHRI Standard 210/240, *“Performance Rating of Unitary Air-Conditioning and Air-source Heat Pump Equipment”*
-ISO 13256-1:2021,*”Water-source heat pumps-Testing and rating for performance-Part1:Water-to-air and brine-to-air heat pumps”*
-ISO 13256-2:2021, *“Water-source heat pumps-Testing and rating for performance-Part2:Water-to-water and brine-to-water heat pumps”*

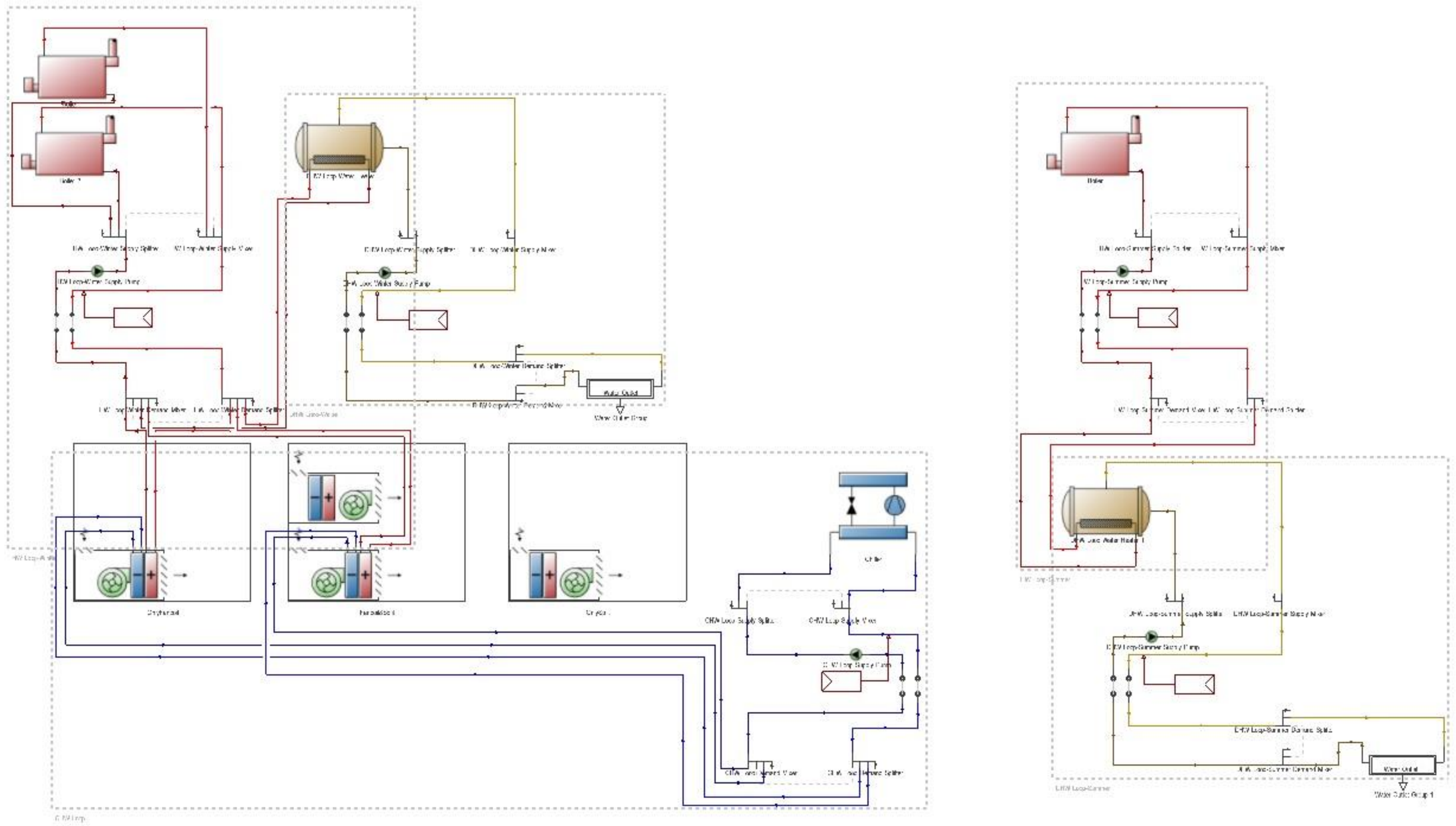
# Heat Pump vs Boiler

# Heat Pump vs Boiler (Case study)

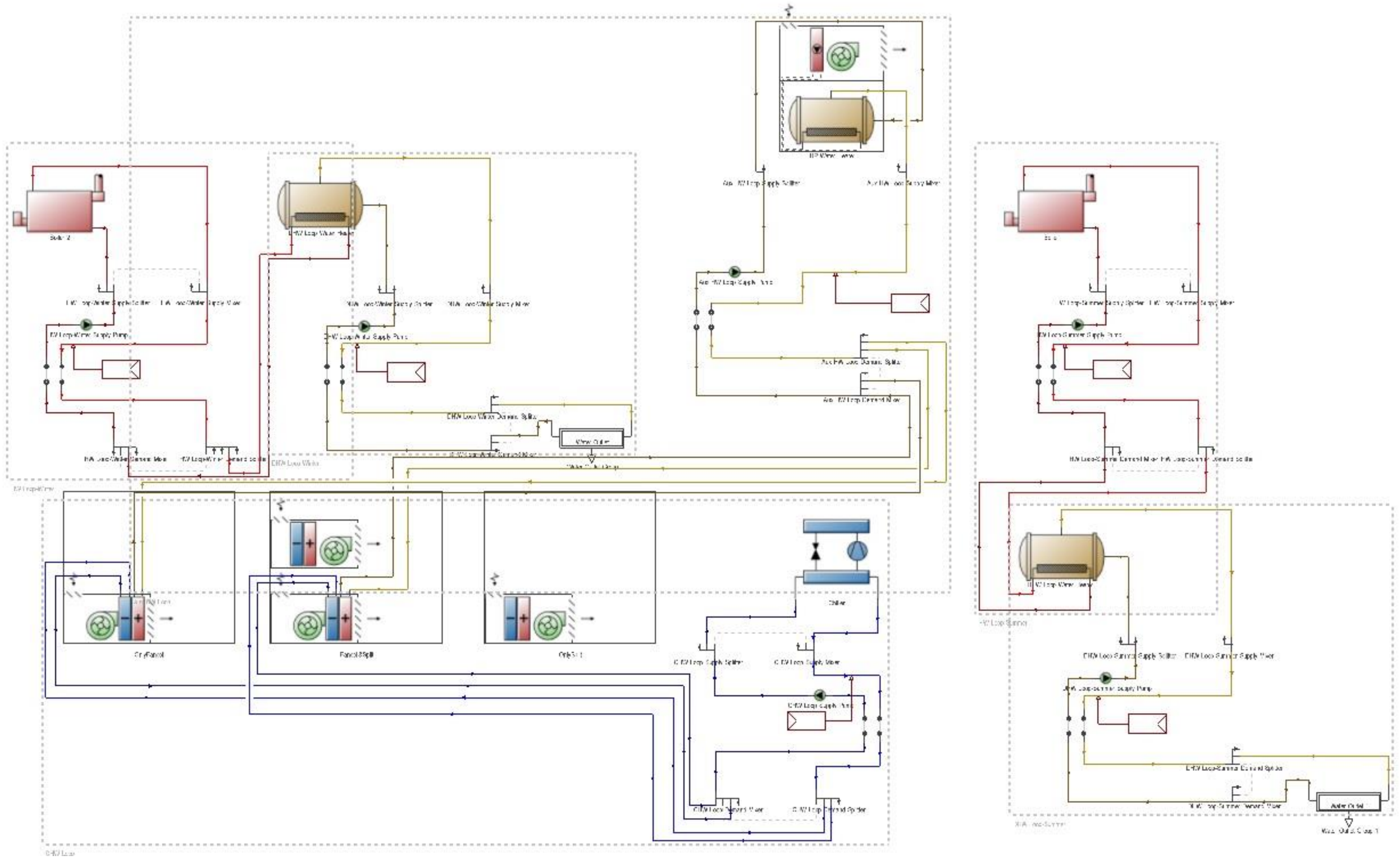




# Heat Pump vs Boiler (Case study)



Existing System

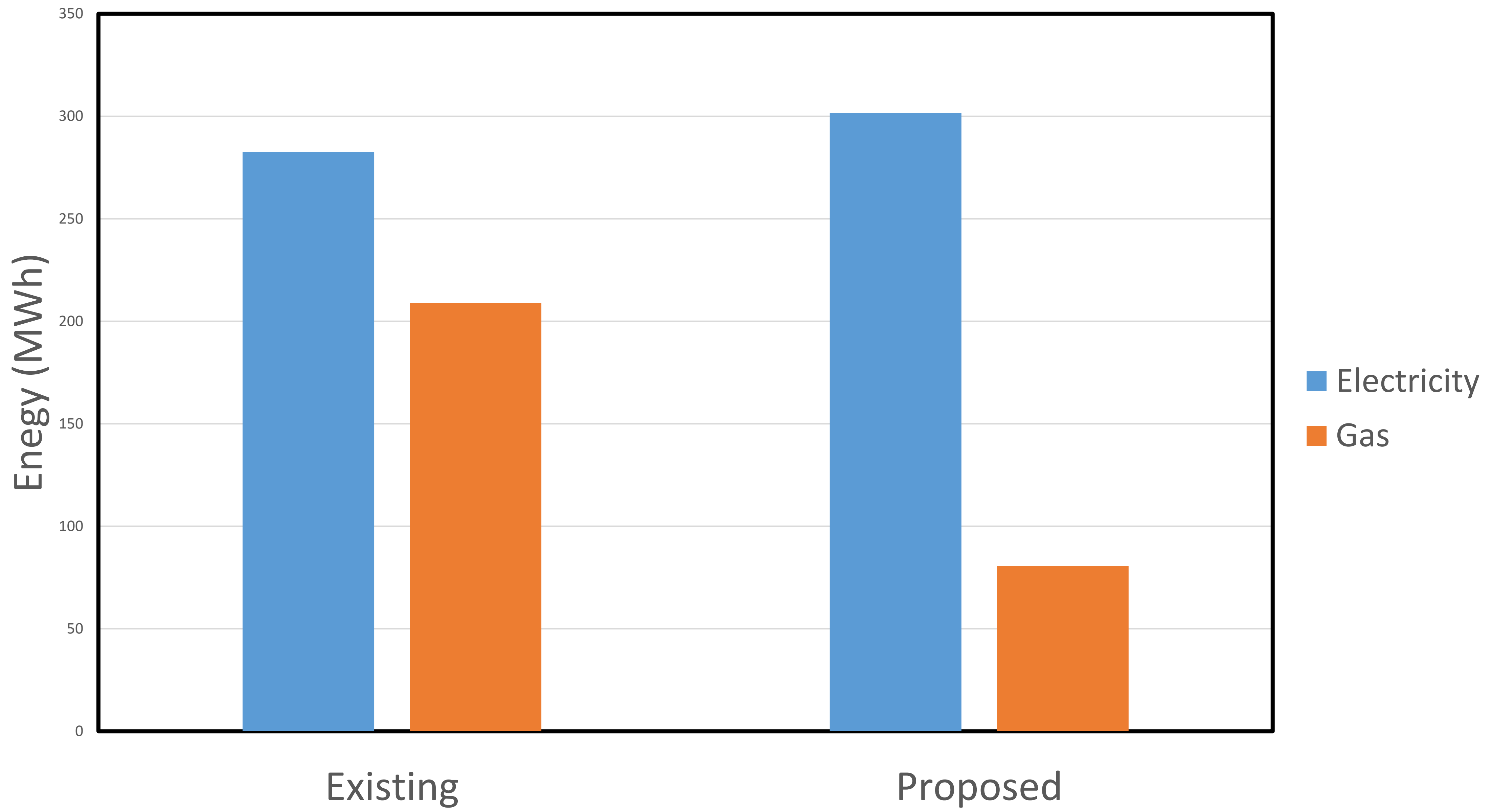


Proposed System



ASEH

# Heat Pump vs Boiler (Case study)




**Existing System**

$$PE = 3 \times 282.59 + 209.3 = 1057.03\ MWh$$

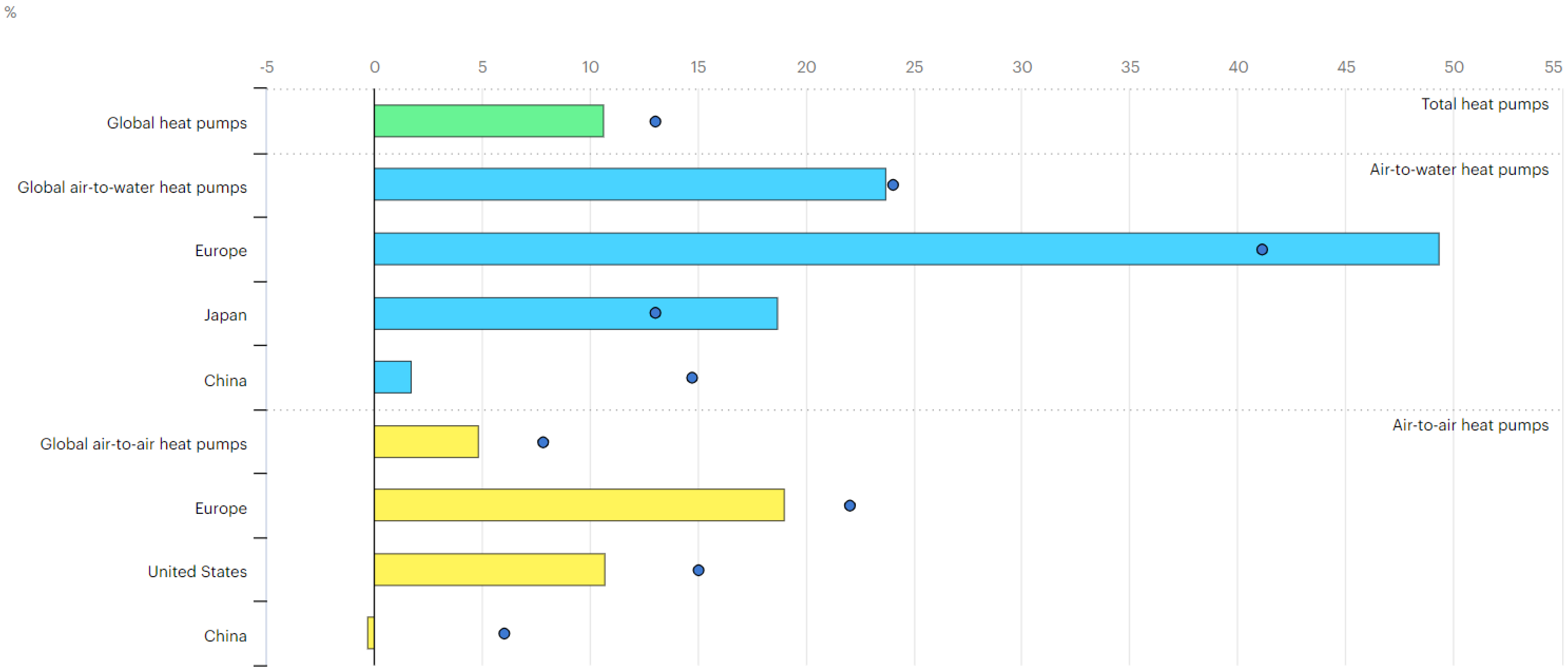
**Proposed System**

$$PE = 3 \times 301.57 + 80.67 = 985.38\ MWh$$

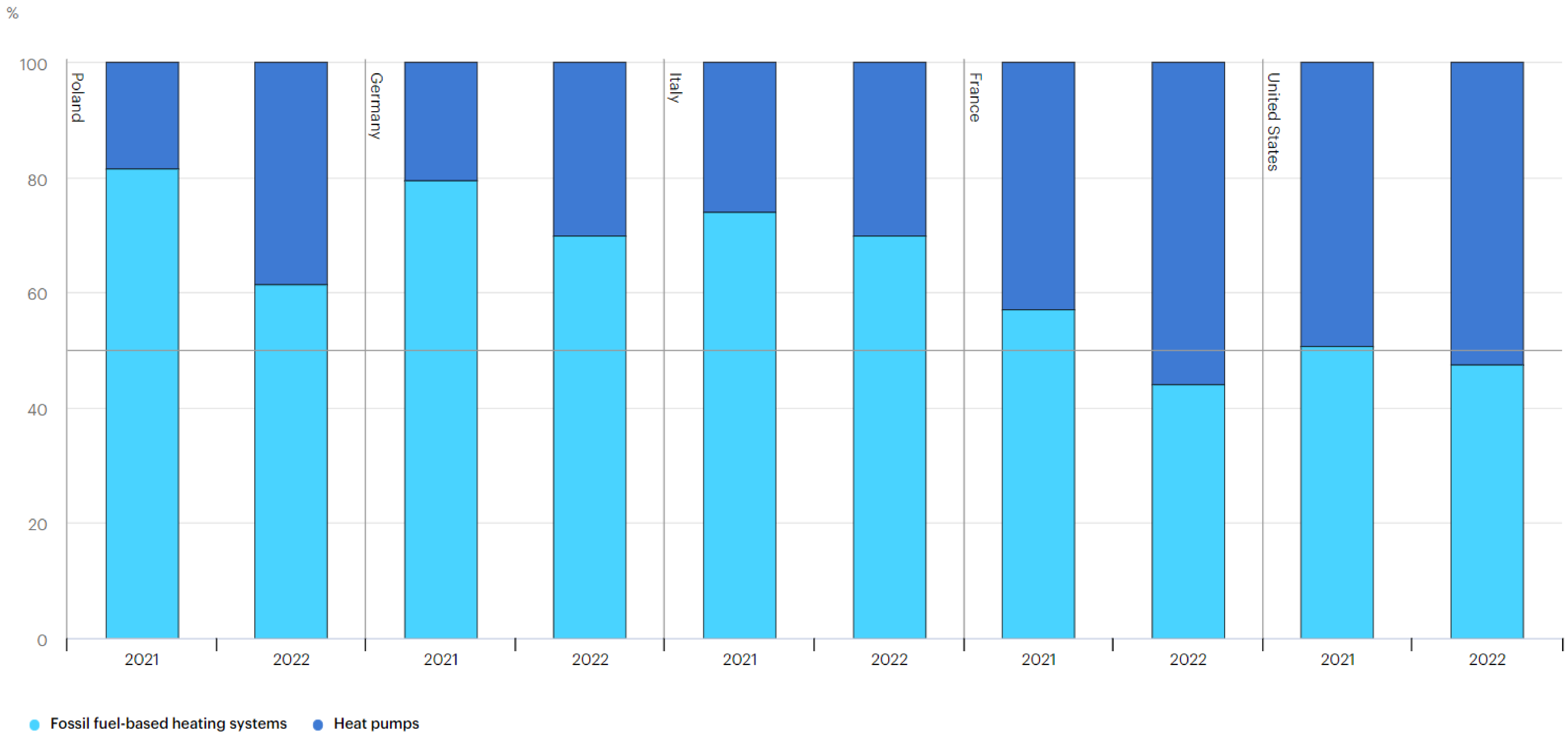
# / Conclusion

# Conclusion

- Global sales of heat pumps grew by 11% in 2022, according to the latest IEA analysis.



# Conclusion


%
100
80
60
40
20
0
Poland
Germany
Italy
France
United States
2021
2022
2021
2022
2021
2022
2021
2022
2021
2022
Fossil fuel-based heating systems
Heat pumps

# Thank You!

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