CO2 heat pumps applied to modern electric buses

Michael Sonnekalb (Konvekta)

webinar, June 29th 2020

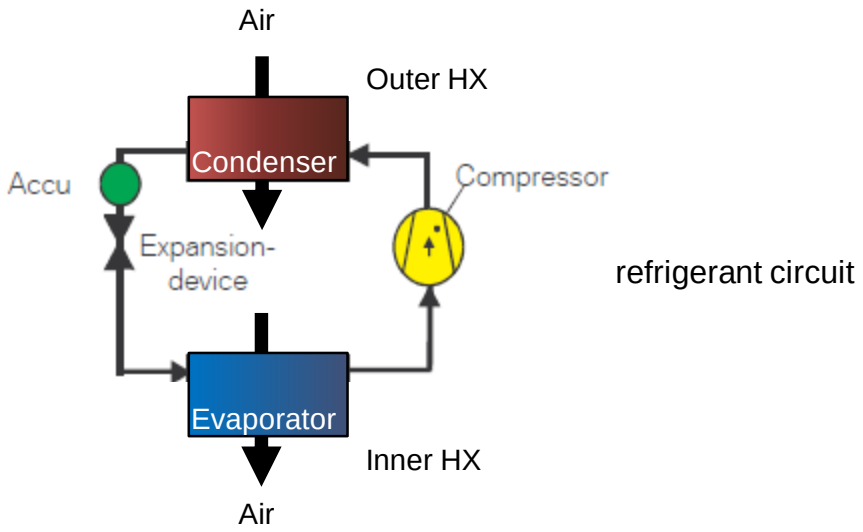
euramon

refrigerants delivered by mother nature

Different heat pump systems

Direct system air to air

- highest efficiency
- lowest safety level
- complex refrigerant circuit



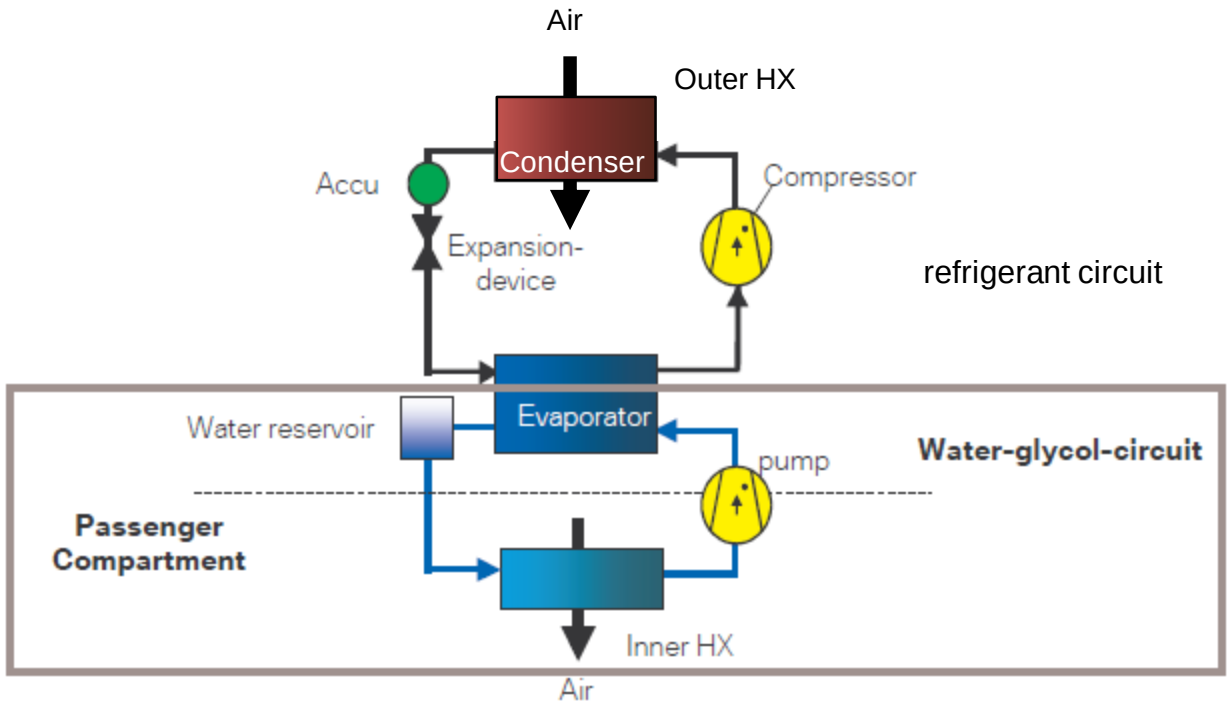
refrigerant circuit

direct system

Different heat pump systems

Indirect system air to water

- lower efficiency
- higher safety level
- complex water circuit

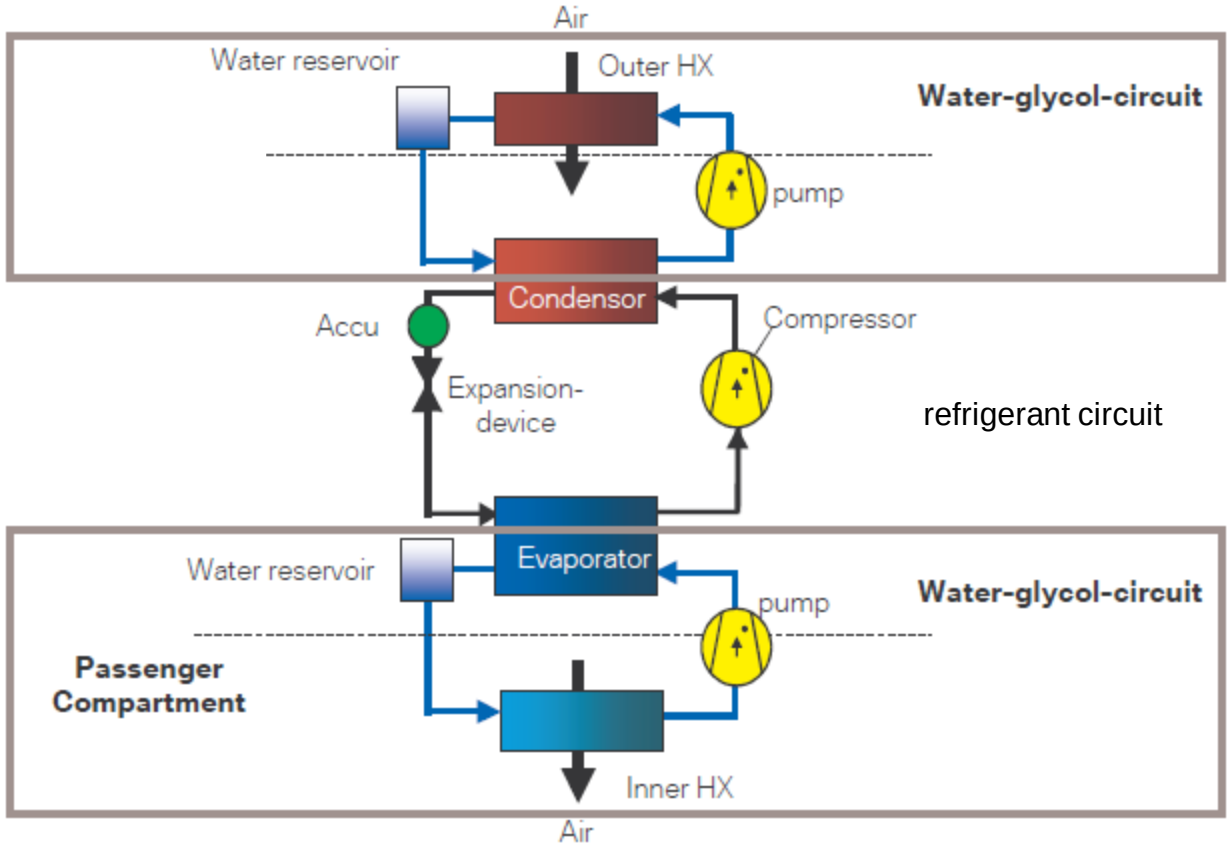


indirect system

Different heat pump systems

Double indirect system water to water

- lowest efficiency
- highest safety level
- complex water circuits
- most compact refrigerant circuit
- lowest refrigerant charge

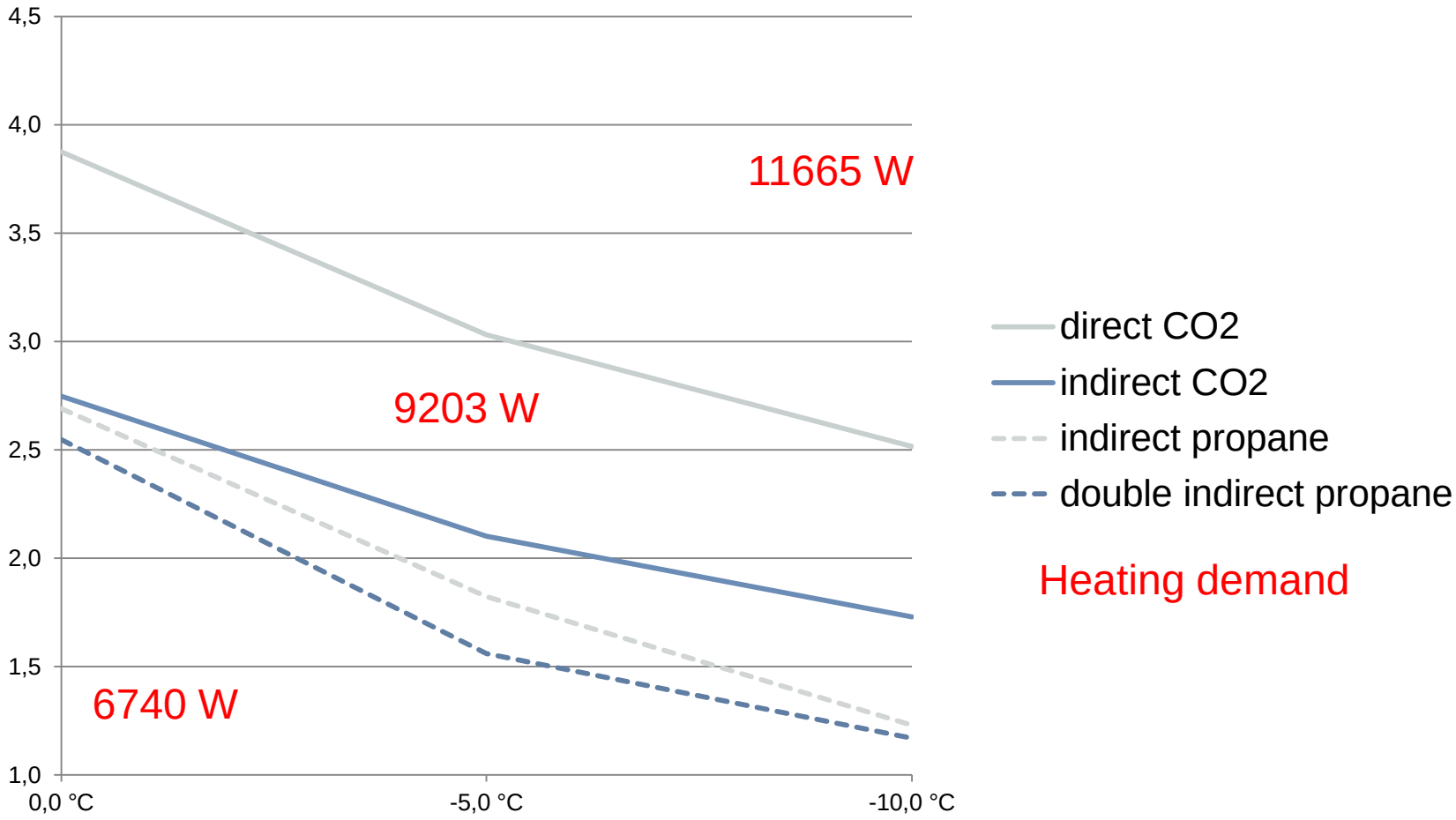


double indirect system

Different heat pump systems

Simulation results

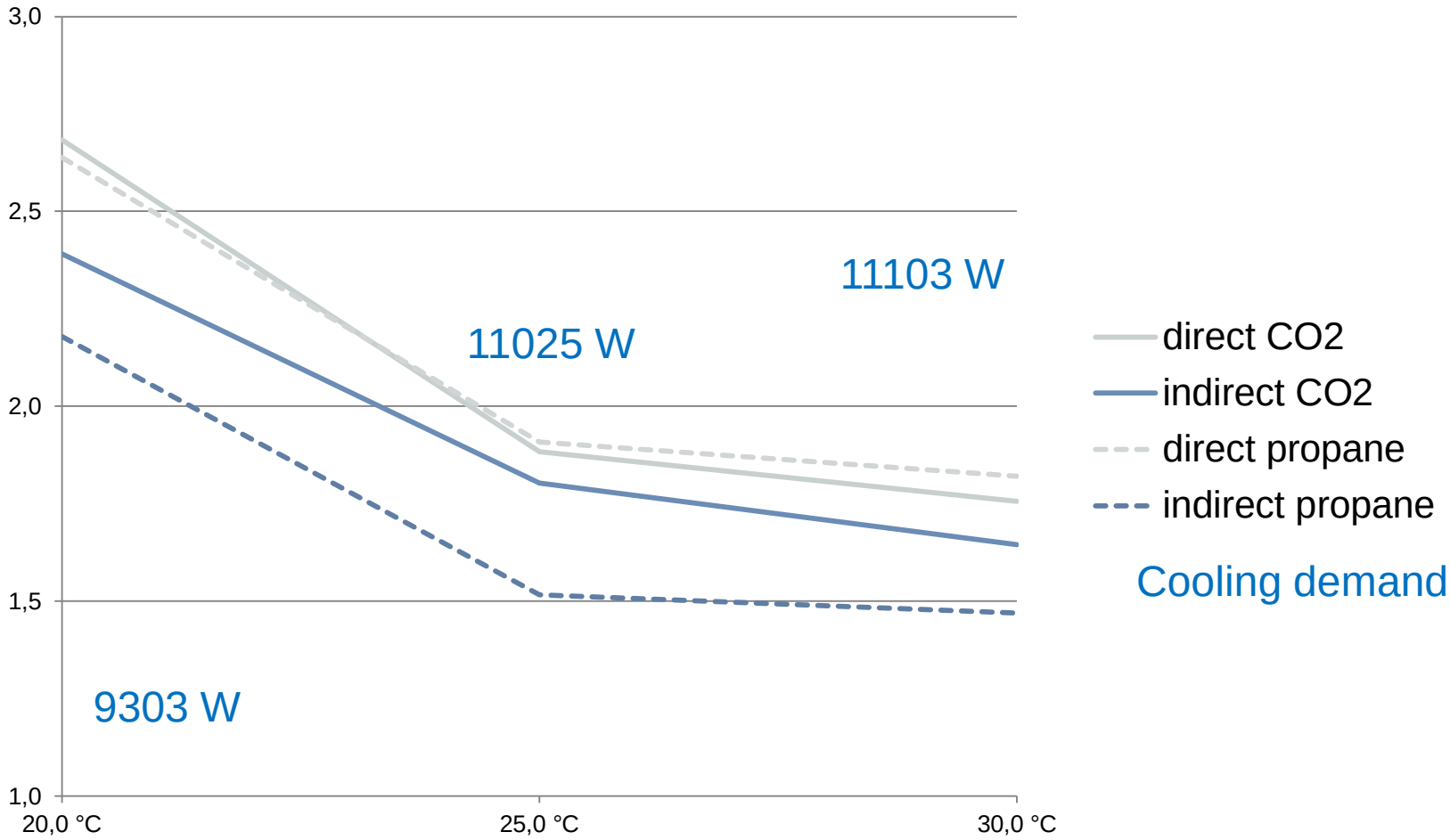
- Using compressor polynoms (EN 12900) from Bitzer
- Constant UA-values for all HX
- Constant pressure losses in lines and HX 50 kPa
- 2000 m³/h air inner HX
- 7300 m³/h air outer HX
- 2000 ltr./h water



Different heat pump systems

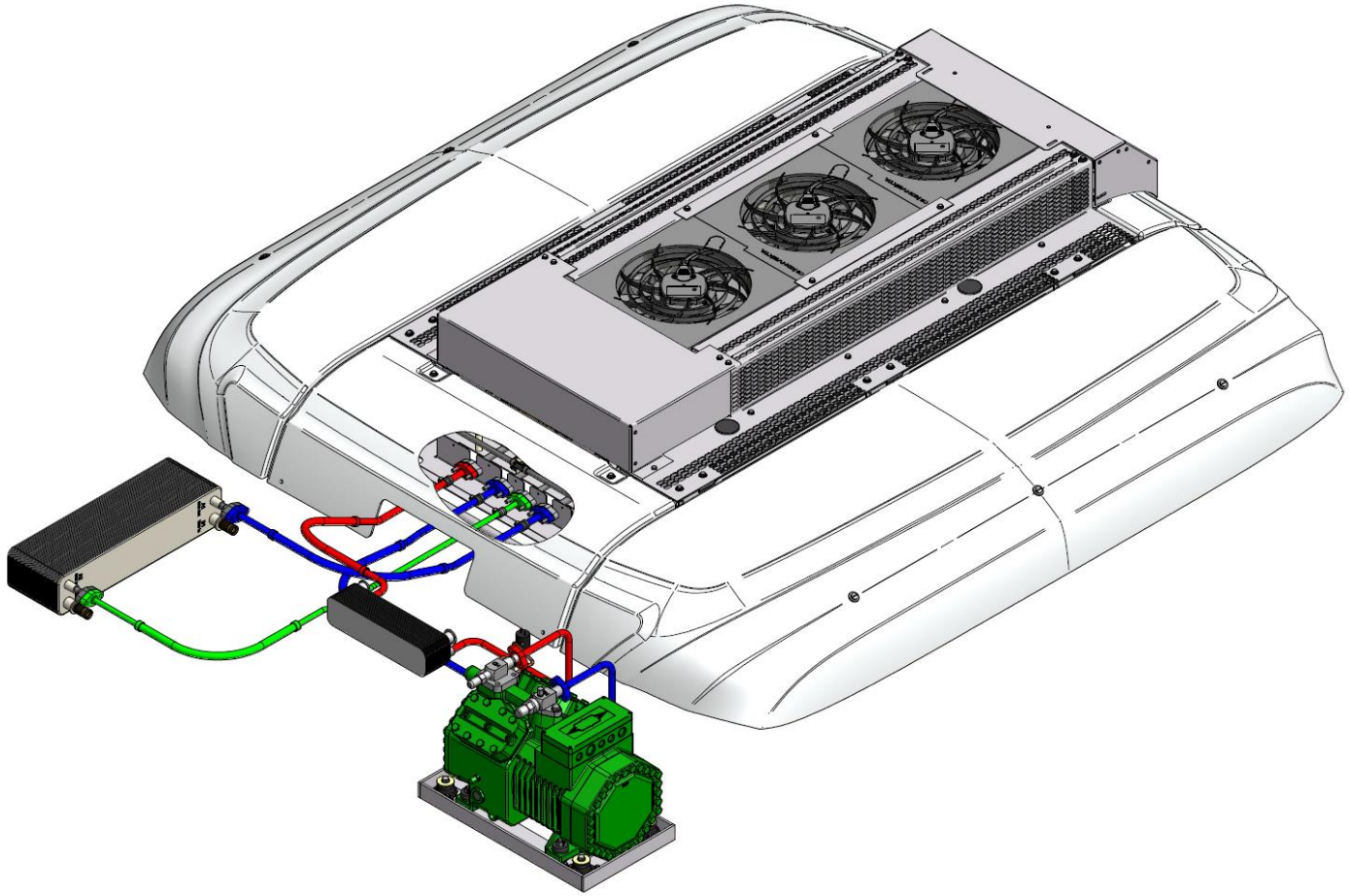
Simulation results

- Using compressor polynoms (EN 12900) from Bitzer
- Constant UA-values for all HX
- Constant pressure losses in lines and HX 50 kPa
- 2000 m³/h air inner HX
- 7300 m³/h air outer HX
- 2000 ltr./h water



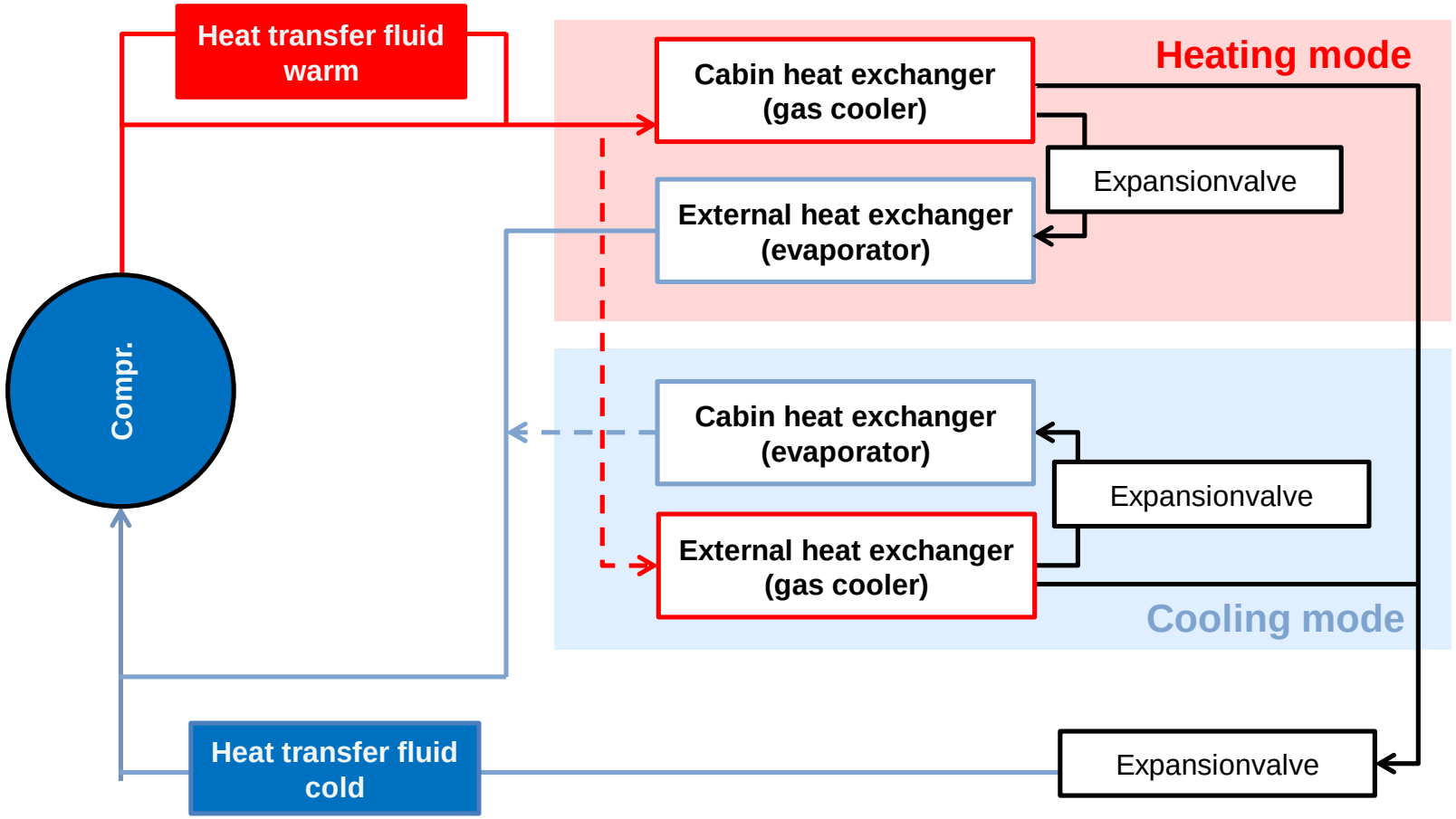
Konvekta UL500 CO2 heat pump

- high efficiency
- natural refrigerant R744 / CO_2
- combines direct system air-to-air heat pump with indirect system heat transfer fluid for remote heating and cooling (driver) and waste heat collection



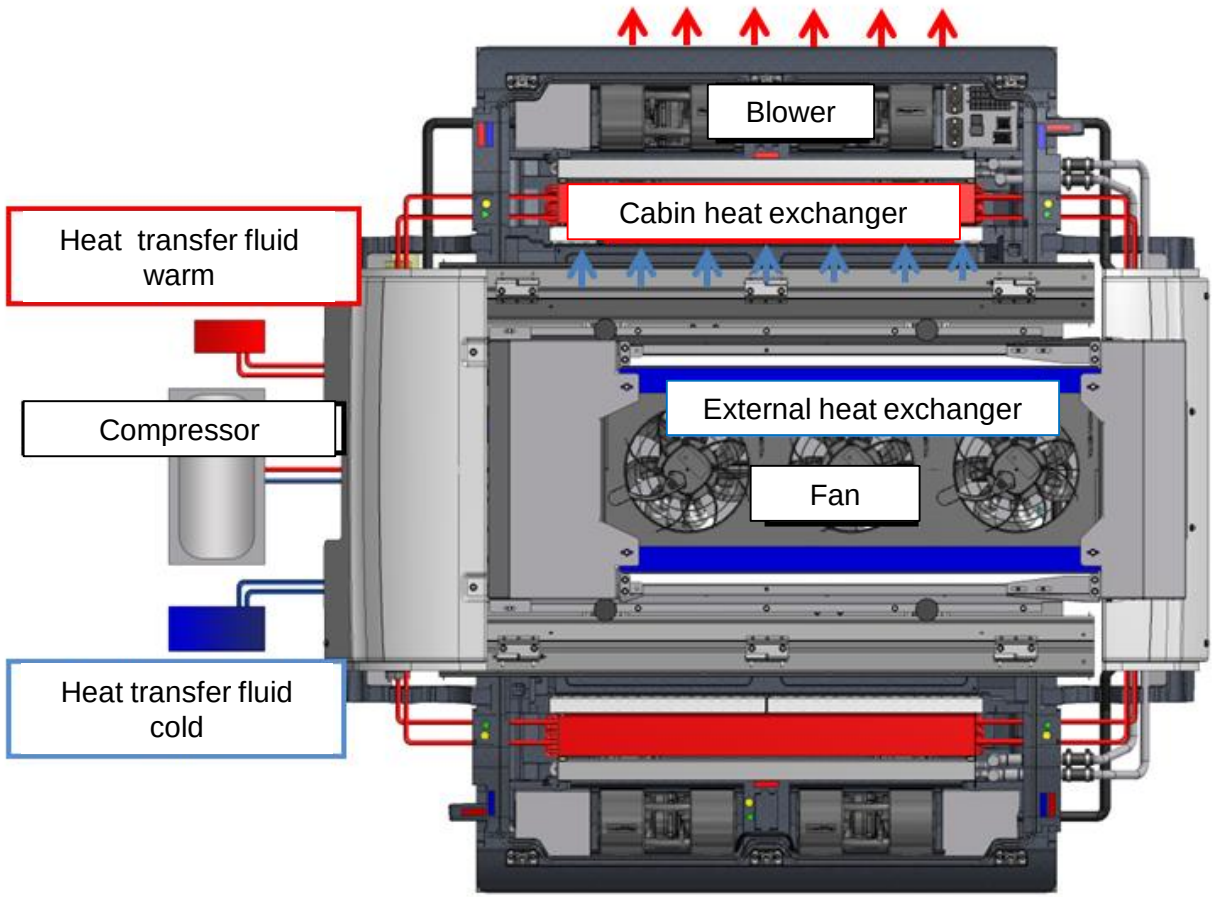
Konvekta UL500 CO2 heat pump system

- high efficiency
- natural refrigerant R744 / CO_2
- combines direct system air-to-air heat pump with indirect system heat transfer fluid for remote heating and cooling (driver) and waste heat collection
- separate HX-tubes and lines for heating and cooling circuit
- fast switching between both modes possible



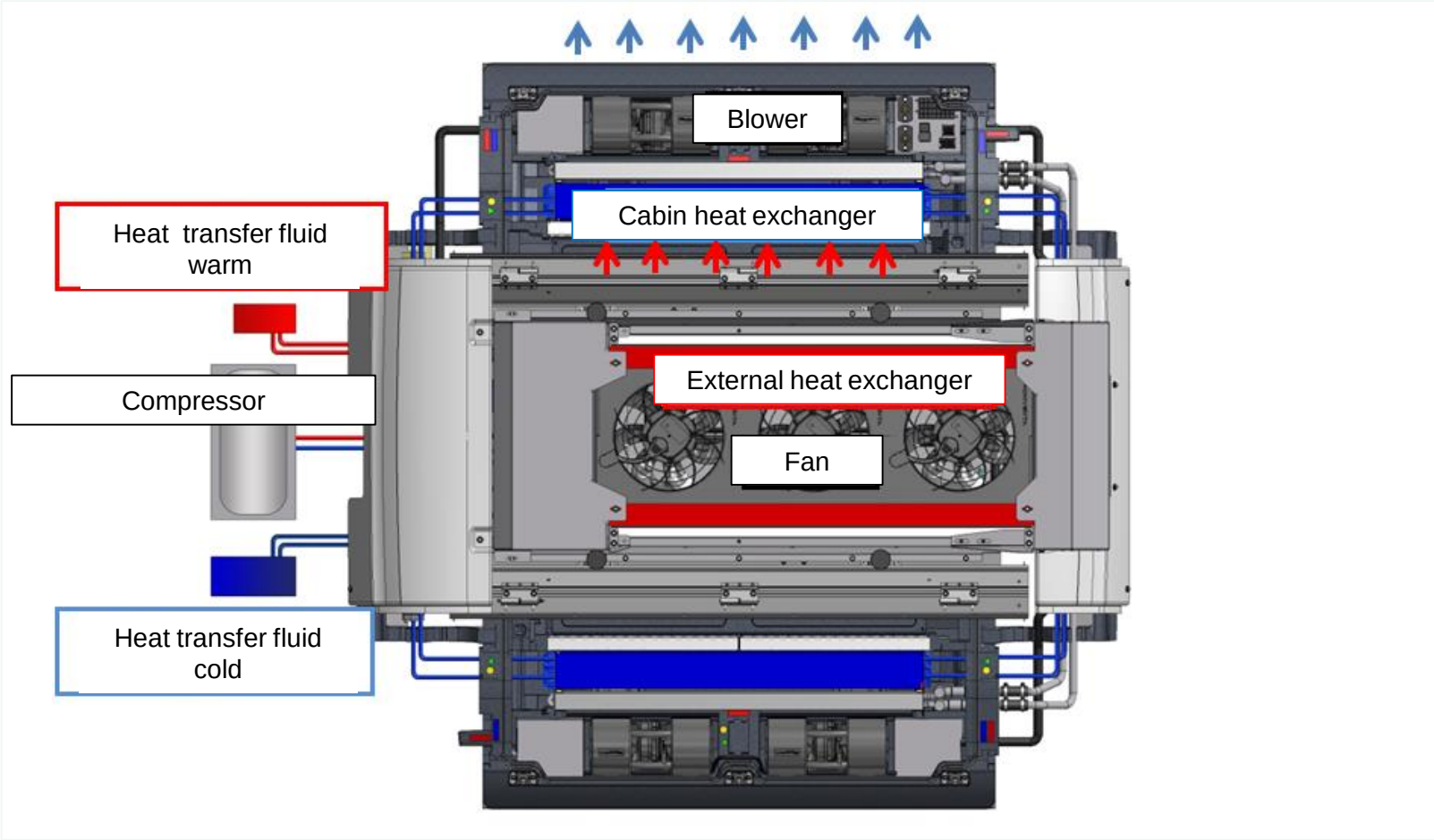
Konvekta UL500 CO2 heat pump system

- Heating mode



Konvekta UL500 CO2 heat pump system

- Cooling mode



Konvekta CO2 heat pump – 1st and 2nd generation

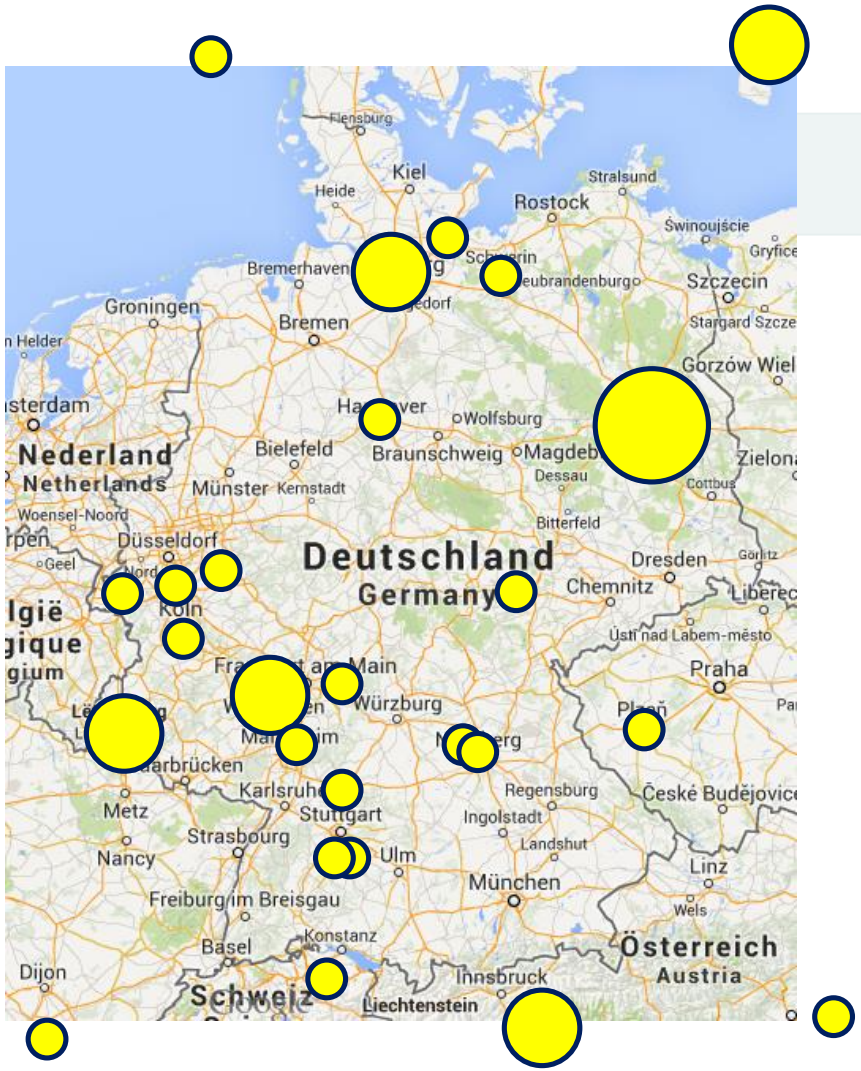
- 1st generation
  - built up in 2012 (EURO championship in Poland)
  - Direct system air-to-air heat pump with cold and hot water supply
  - Using same HX-tubes for heating and cooling
  - Using a reversing valve
- 2nd generation
  - change in 2015
  - change of the **compressor** type
  - Direct system air-to-air heat pump with cold and hot water supply
  - Using **separate** HX-tubes for heating and cooling
  - Using **not** a reversing valve **but** fast switching solenoid valves

- **Urban transport Klagenfurt STW 8,9m Solaris**
  2 city tours of 100 km per day with recharging between the tours and over night
- **Heating**
  Hot water is supplied to convectors and to the driver‘s HVAC module.
  Hot air is suplied to the air ducts in the roof.
- **Cooling**
  Cold water is supplied to cool electric components and to the driver‘s HVAC module.
  Cold air is suplied to the air ducts in the roof.

Konvekta CO2 heat pump – 2nd generation SOP in 2019

- 2nd generation
  - Tested since in 2015
    - Climatic chamber
    - Field tests in public transport
    - Oem winter test in Sweden
    - Oem summer test in Spain
  - Tests with 4 compressor types of different manufacturers
  - Tests with frequency inverter
  - SOP in 2019 with 2 oems and 2 different compressor manufacturers

Buses equipped with CO2 heat pump



Diesel buses with CO2 air condition	90
Electric buses with CO2 heat pump	260
Aachen	7
Berlin	116
Hamburg	34
Hannover	4
Heilbronn	1
Jena	3
Köln/Koblenz/Wuppertal	3
Lübeck	6
Mannheim/Heidelberg	3
Nürnberg/Fürth	8
Offenbach	2
Reutlingen/Tübingen	5
Schwerin	3
Wiesbaden	10
France	3
Italy	10
Luxembourg	14
Norway	6
Austria	1
Sweden	16
Switzerland	4
Czechia	2

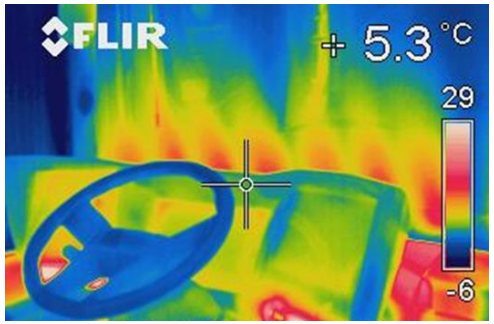
Electric bus heat up measurements

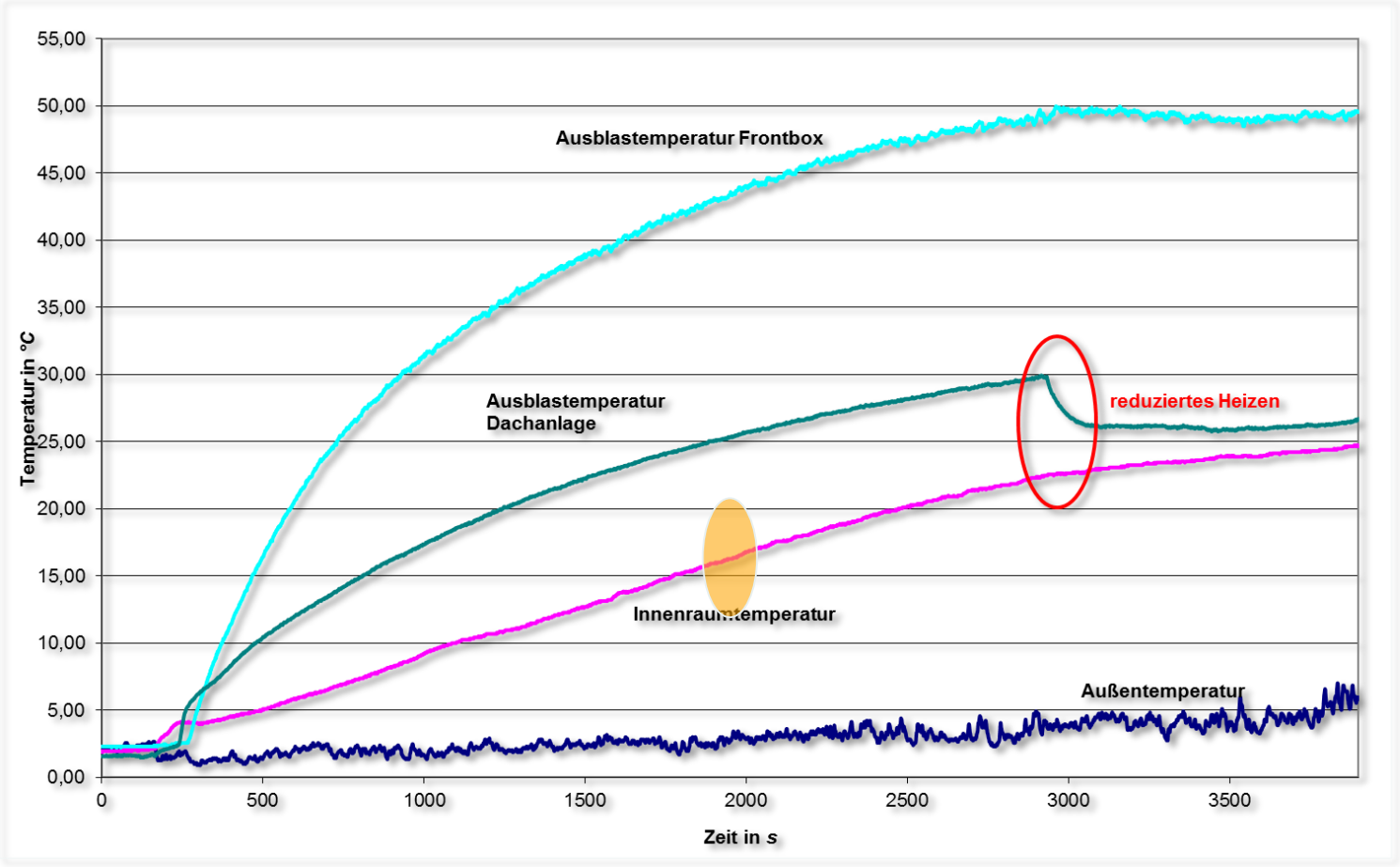
after 15 minutes:

- supply air 16°C
- return air 8,5 °C
- supply air driver 30 °C

after 30 minutes:

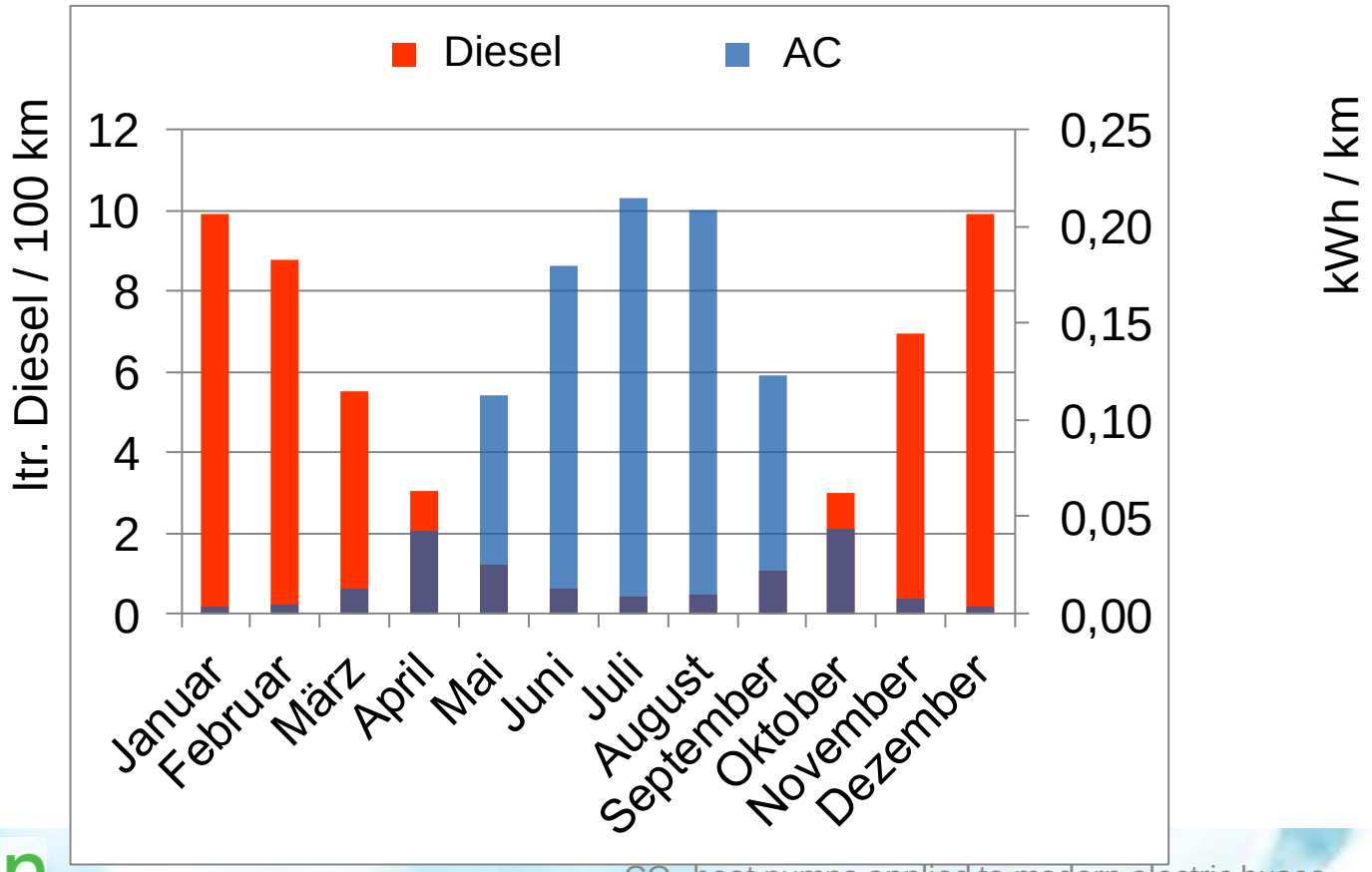
- supply air 20°C
- return air 17,5 °C
- supply air driver 43 °C





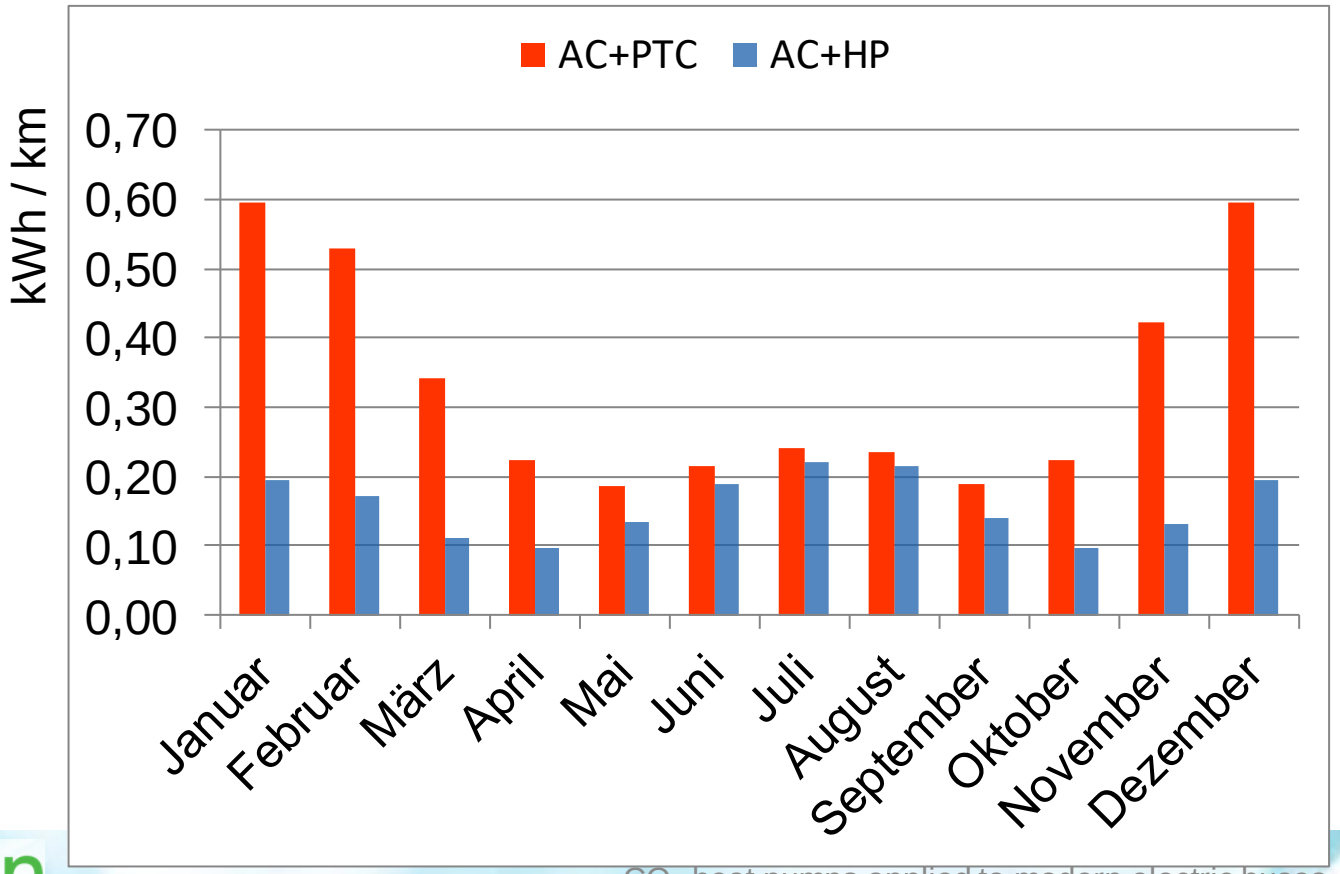
HVAC energy consumption of a city bus (simulated)

Darmstadt, 12m electric city bus with air condition and Diesel heater,
11 km/h average speed, 19 hours operation



HVAC energy consumption of a city bus (simulated)

Darmstadt, 12m electric city bus with air condition and electric heater (AC+PTC) versus reversible heat pump (AC+HP),
11 km/h average speed, 19 hours operation



michaelsonnekalb@konvekta.com

euramm n

refrigerants delivered by mother nature