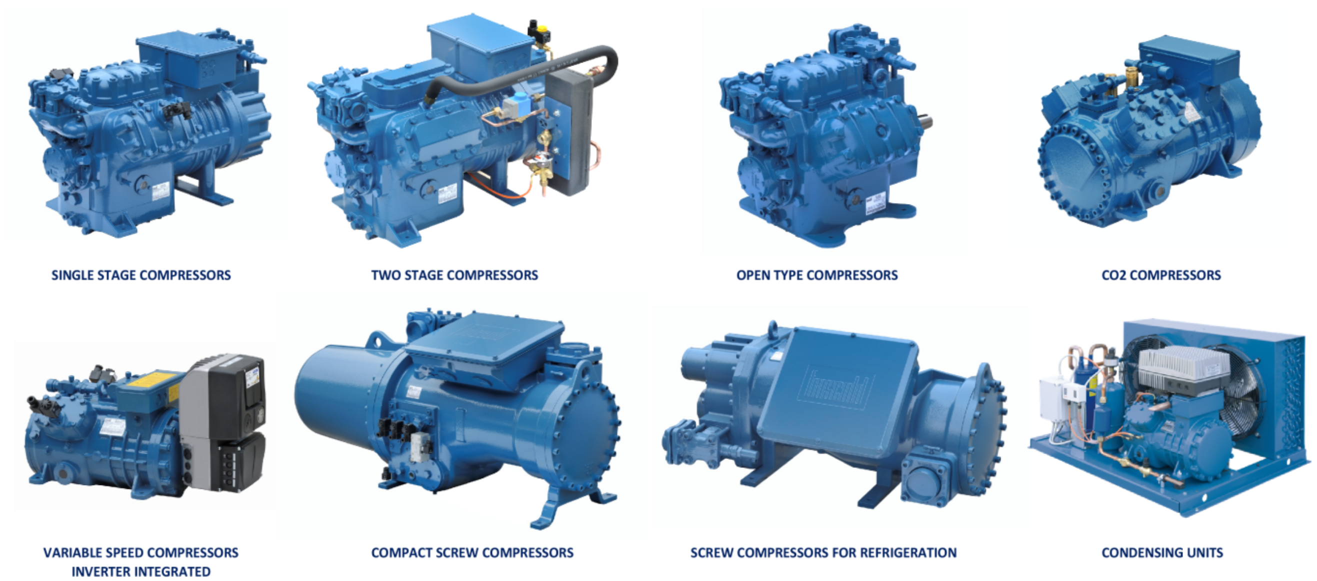
ATMO sphere CHINA

Business Case for Natural Refrigerants

11-12/04/2018 – Beijing

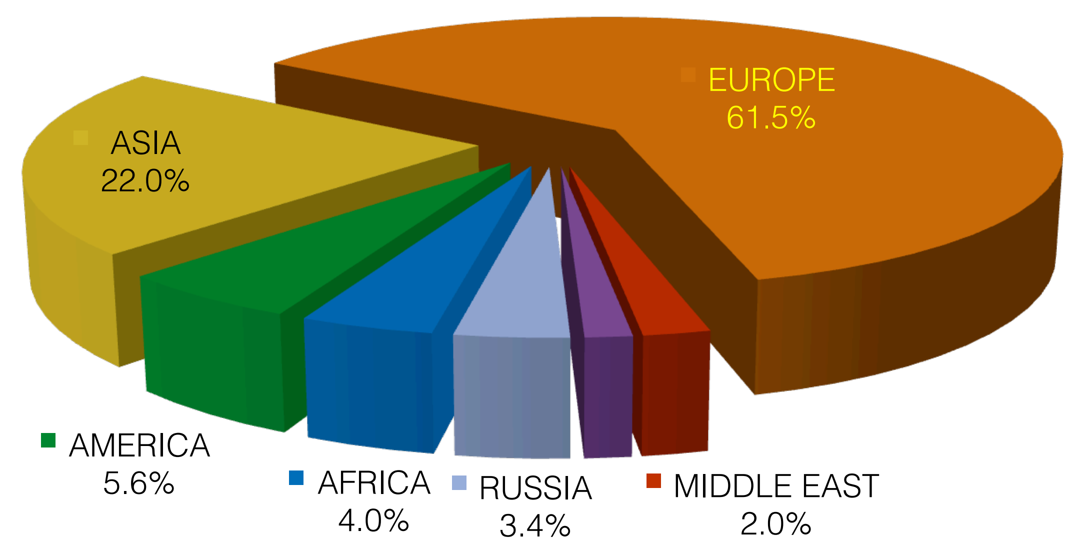
YEARLY SIMULATION OF CO_2 REFRIGERATION SYSTEMS FOR SUPERMARKET APPLICATIONS

FRASCOLD SPA



Frascold in numbers

Location Milan (Italy)
Production 53.000 m^2
Compressors 60.000 per year
Turnover 48 Mio € (2016)



富士豪中国 - FRASCOLD SPA

3 offices:
- Beijing,
- Shanghai
- Guangzhou

Stock for compressors and spare parts

21 distributors all over China

Service and Technical support

Website **www.frascold.net**

PRESENTATION OUTLINE

- Purpose
- System description
  - P&I diagram
  - p-h diagram
- Model description
  - Control zones
  - Temperature and load profile
- Results
- Next steps
- Conclusions

PURPOSE

Understand how to select CO_2 booster system considering loads, system configuration and yearly temperature profile in order to provide a guidance for CO_2 most promising market worldwide in the years to come: China

Analyze and compare two CO_2 system configurations according to yearly based performances.

Two trans-critical CO_2 refrigeration system configurations for supermarket applications are studied:

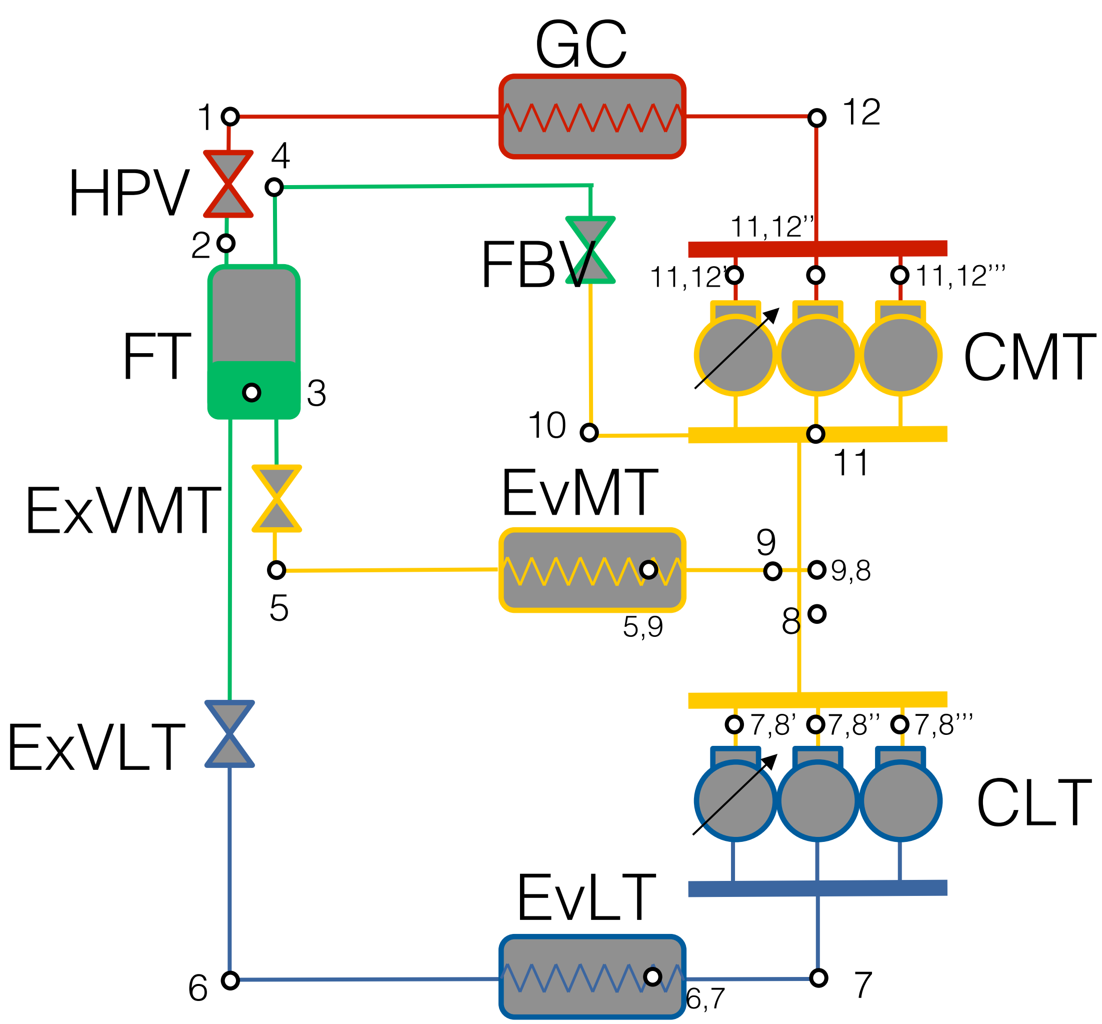
- booster system with FGB
- booster system with parallel compression

In both configurations, possibility to recover part of heat rejected at condenser/gas-cooler for sanitary hot water production and space heating is considered.

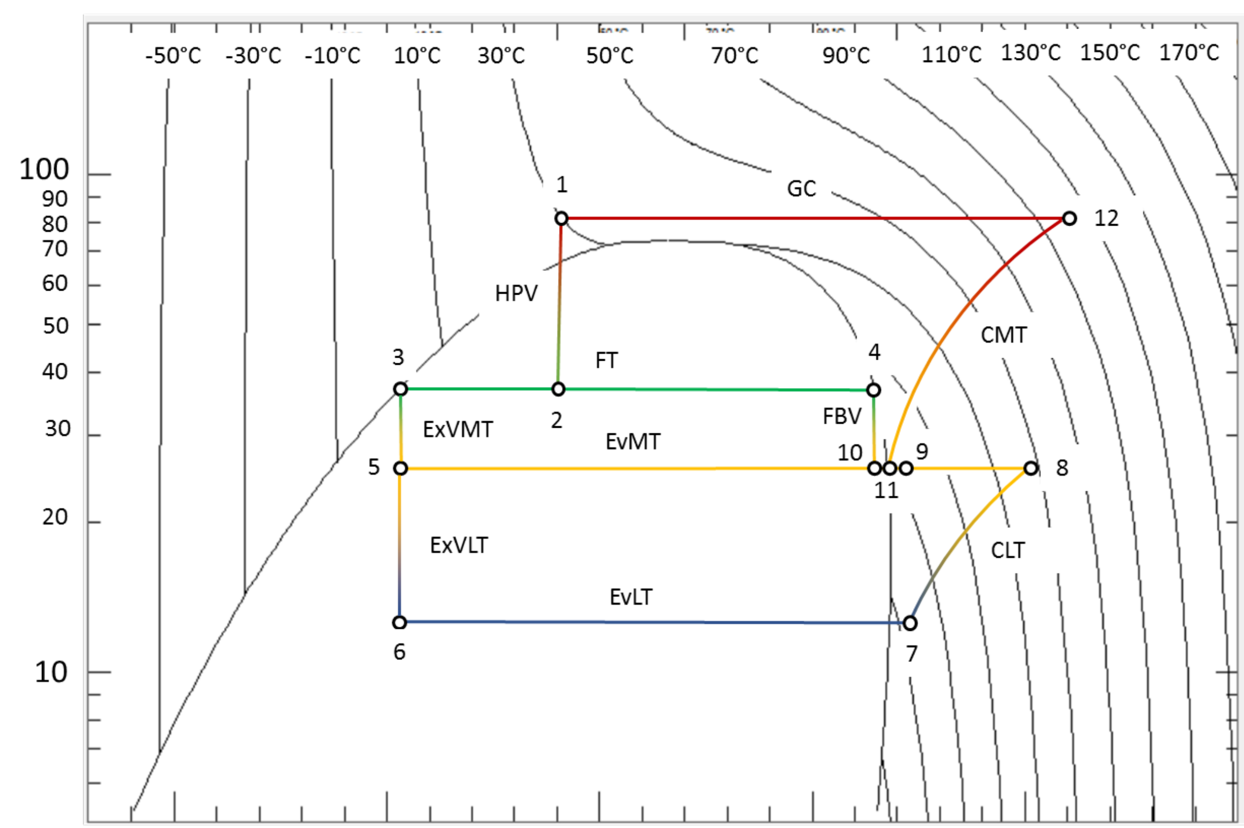
A theoretical analysis of system cycles is carried out where boundary conditions and compressor efficiencies are based on field-measurements of existing systems .

SYSTEM DESCRIPTION – P&I AND p-h DIAGRAMS

CO_2 transcritical booster system with Flash Gas By-pass (FGB)

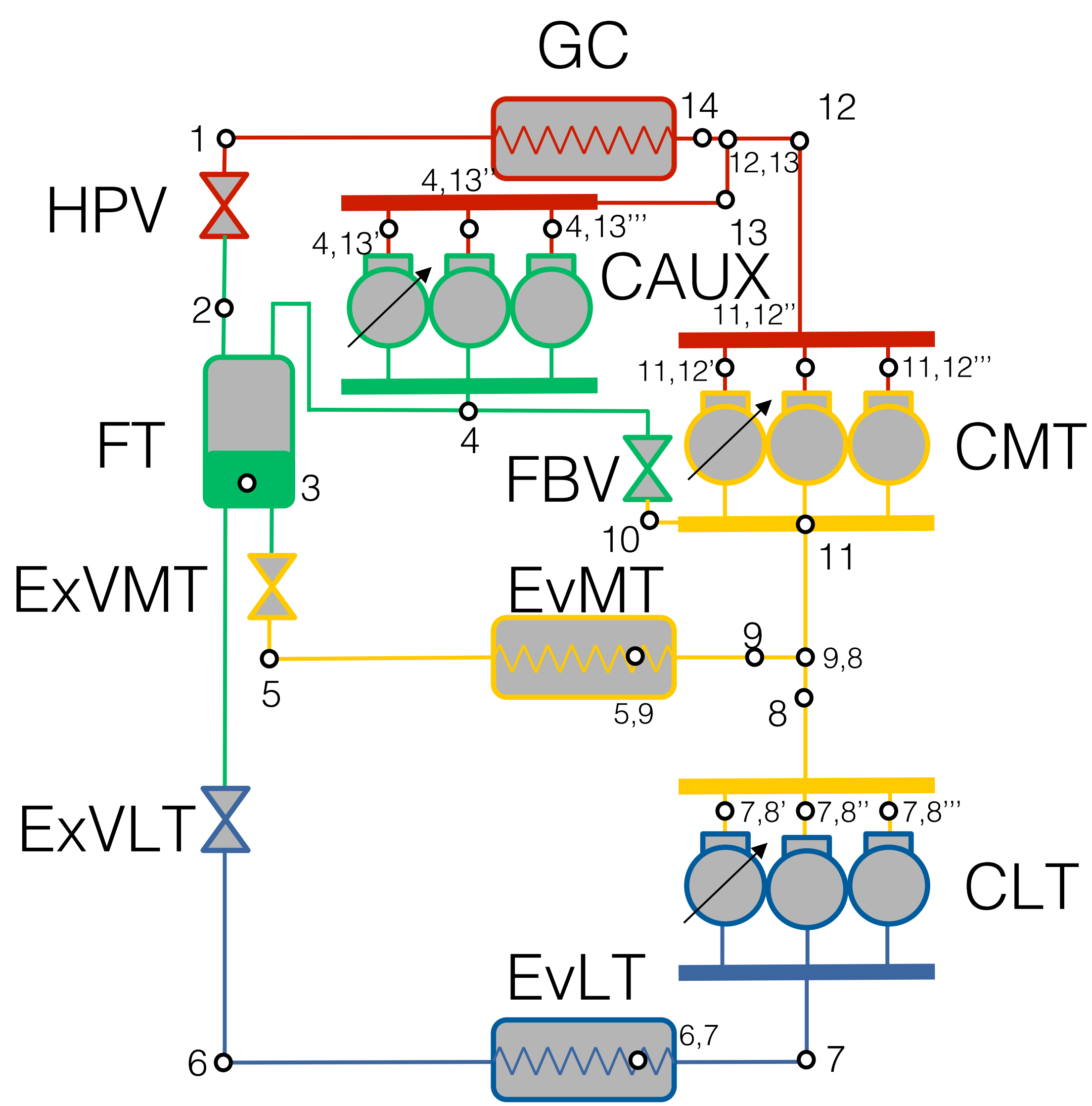


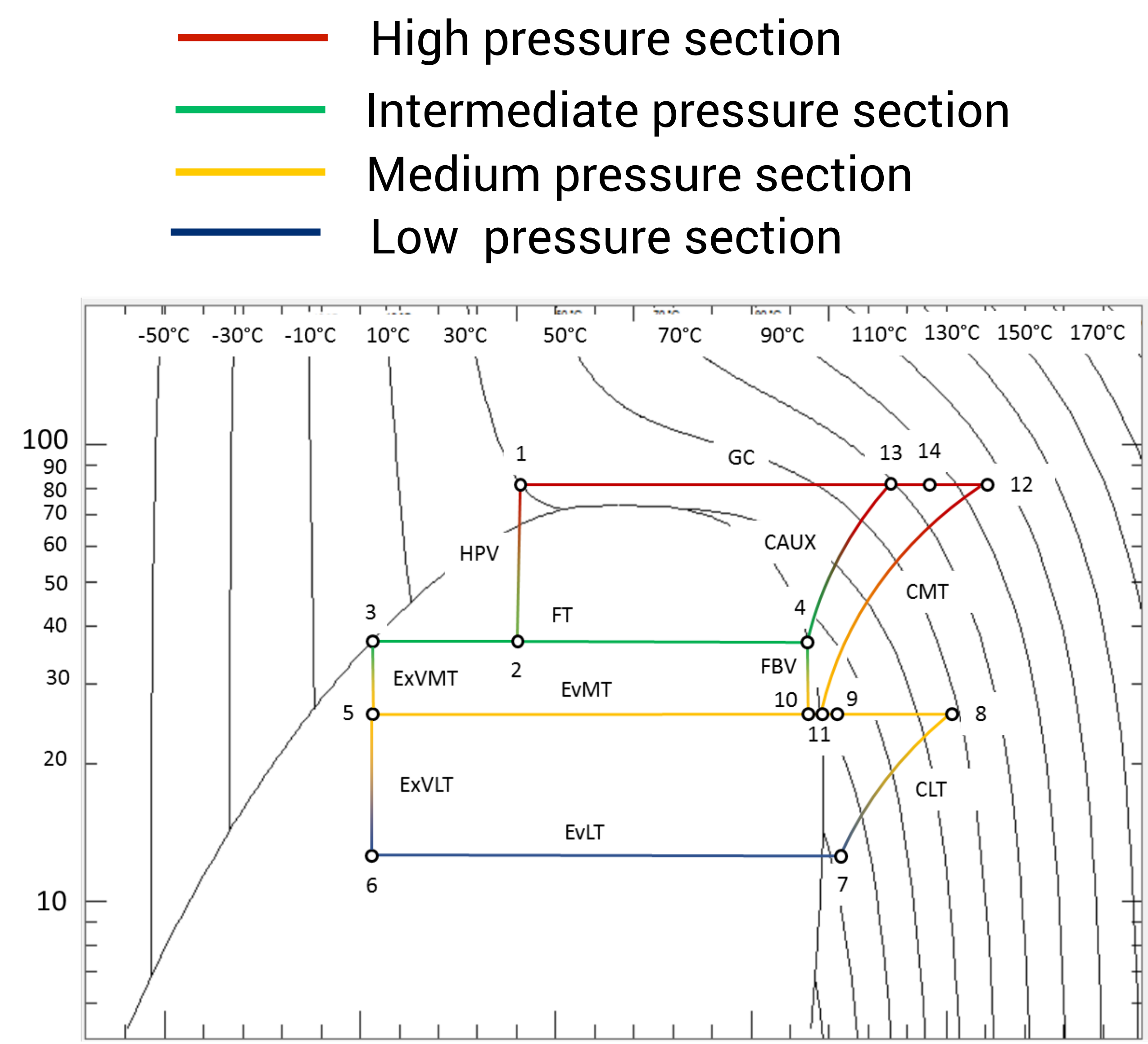
High pressure section
Intermediate pressure section
Medium pressure section
Low pressure section



SYSTEM DESCRIPTION – P&I AND p-h DIAGRAMS

CO_2 transcritical booster system with FGB and parallel compression (FGB+ECO)





MODEL DESCRIPTION : LOCATIONS

Simulations for three cities, representing three weather conditions:

- Bejing
- Shanghai
- Guangzhou

Chinese Standard Wheather Database

Database developed by Dr. Jiang Yi, Department of Building Science and Technology at Tsinghua University and China Meteorological Bureau.

MODEL DESCRIPTION : MODEL PARAMETERS

A steady-state model of refrigeration cycle is developed in Matlab® to simulate hourly performance of four investigated solutions across a year. Compressors efficiency curves as well as working conditions assumptions for condenser/gas-cooler and evaporators are based on field-measurements of an existing supermarket refrigeration system.

MT Evaporators
Evaporation temperature [-7°C]
Useful supeheating [5 K]
Pipe-superheating [-3 K ÷ 8 K]

LT Evaporators
Evaporation temperature [-32°C]
Useful supeheating [5 K]
Pipe-superheating [9 K ÷ 20 K]

Flash Tank
Intermediate pressure (FT) [38 bar]

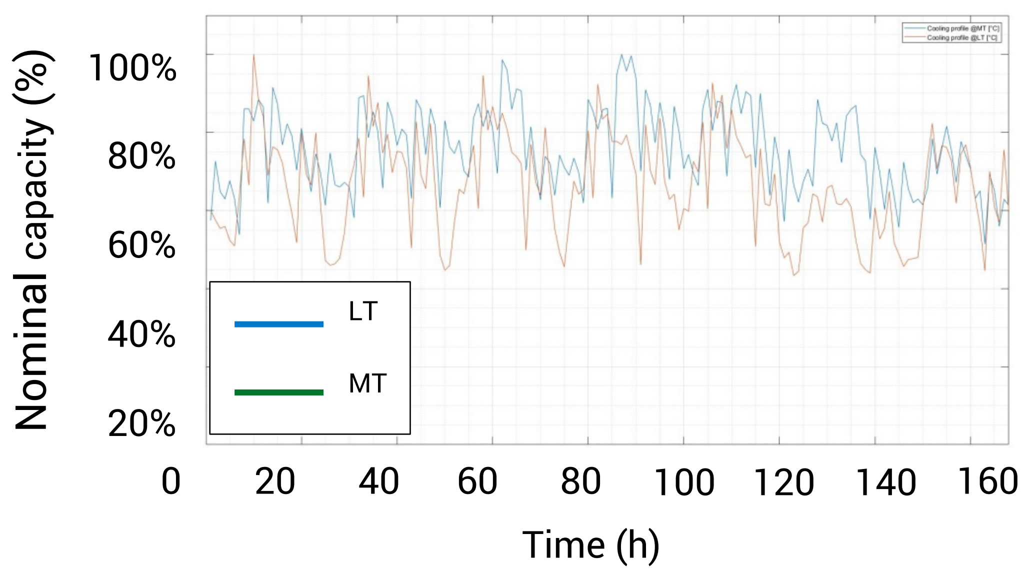
MT Compressors
2x S15-12TK @ fixed speed
1x S15-12TK @ variable frequency [30 Hz ÷ 85 Hz]

LT Compressors
2x A1.5-3SK3 @ fixed speed
1x A1.5-3SK3 @ variable frequency [30 Hz ÷ 85 Hz]
(with booster parallel compression)
2x A2-4SK3 @ fixed speed
1x A2-4SK3 @ variable frequency [30 Hz ÷ 85 Hz]

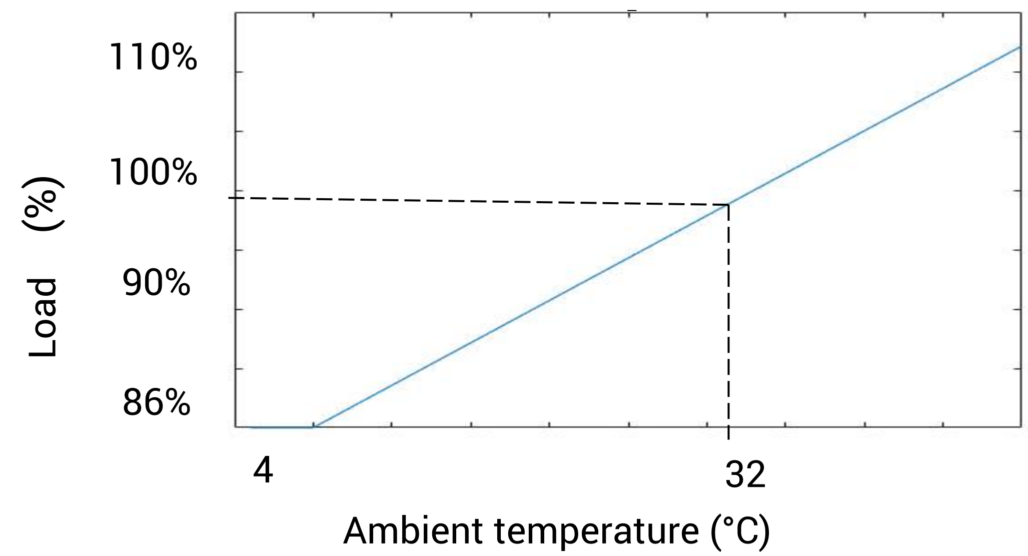
AUX Compressors
3x Q5-4TK @ fixed speed
1x Q5-4TK @ variable frequency [30 Hz ÷ 85 Hz]

MODEL DESCRIPTION: LOADS CORRECTION

Weekly cooling capacity profile



Ambient temperature



Pack Calculation Pro, IPU, v 4.20 (2017)

Hourly cooling load fraction is corrected by 0,5% for each Kelvin of difference in external air from its design value (32°C) and for external temperature lower than 4°C correction factor is considered at constant value of 0.86.

Heat recovery

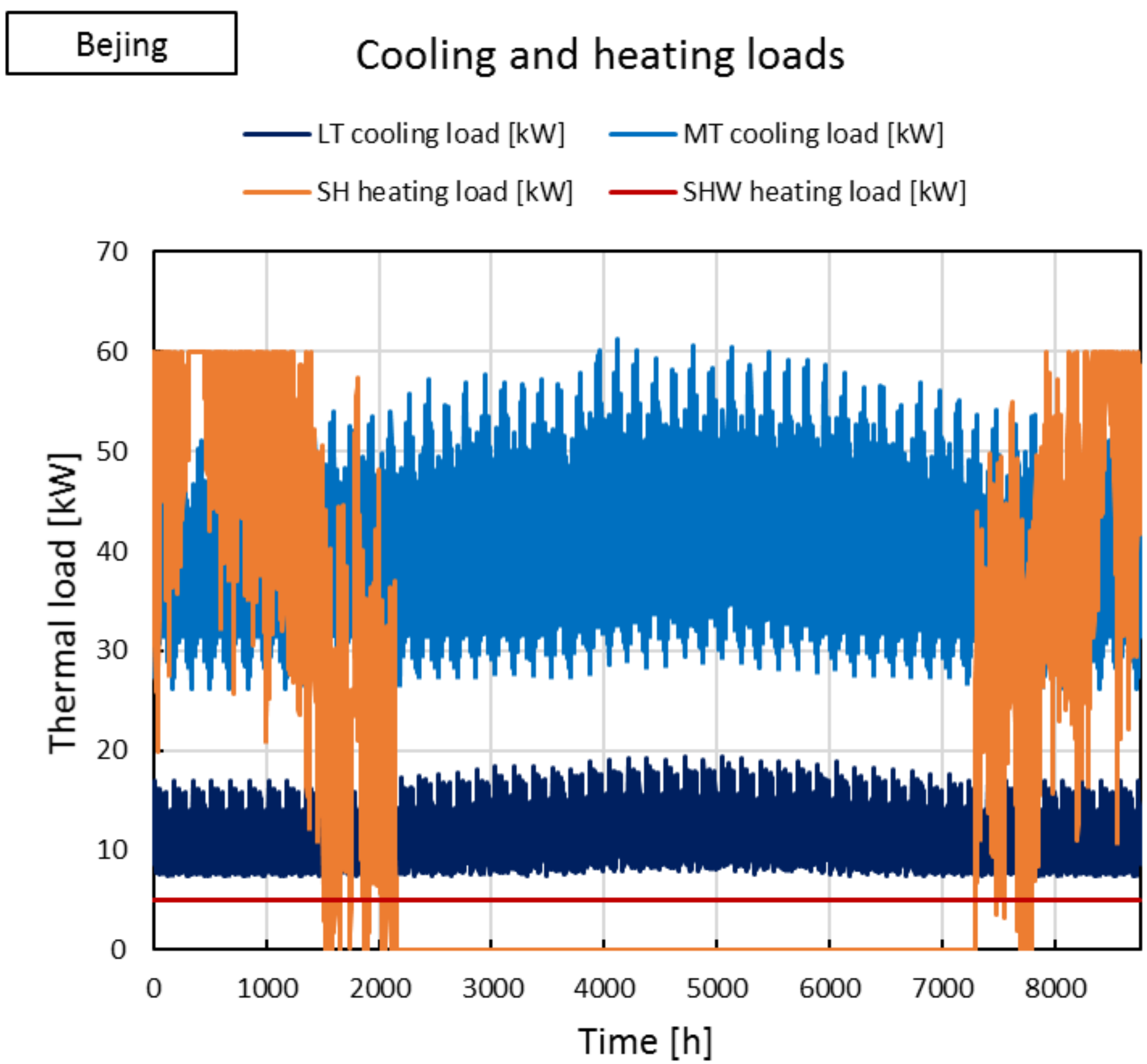
<u>Sanitary hot water production (SHW):</u>

Constant heating load

Qn,SHW = 5 kW

CO_2 temperature above 55°C

MODEL DESCRIPTION : COOLING AND HEATING LOAS

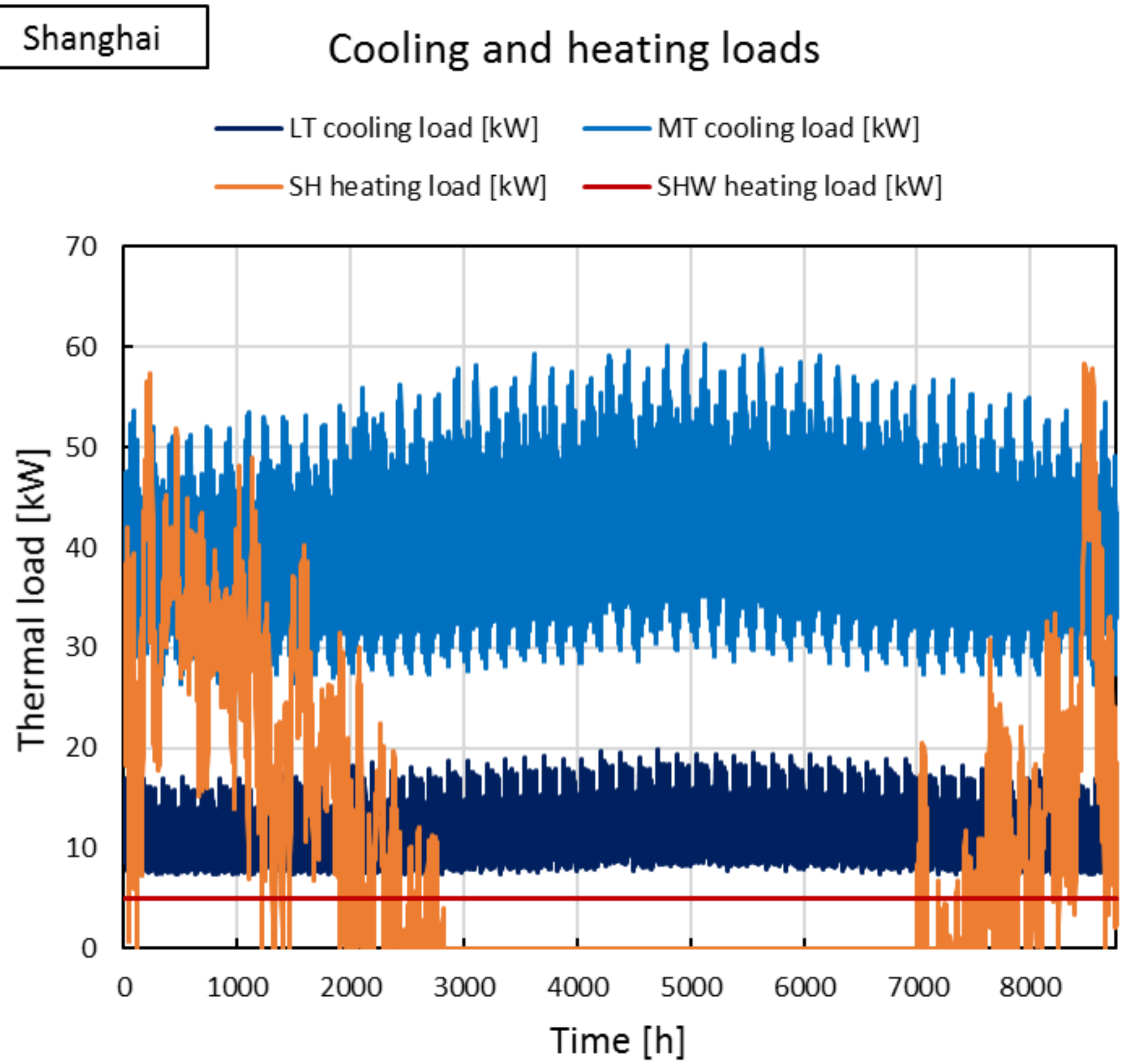


Cooling and heating loads are considered over a full year after model correction depending on climate zone.

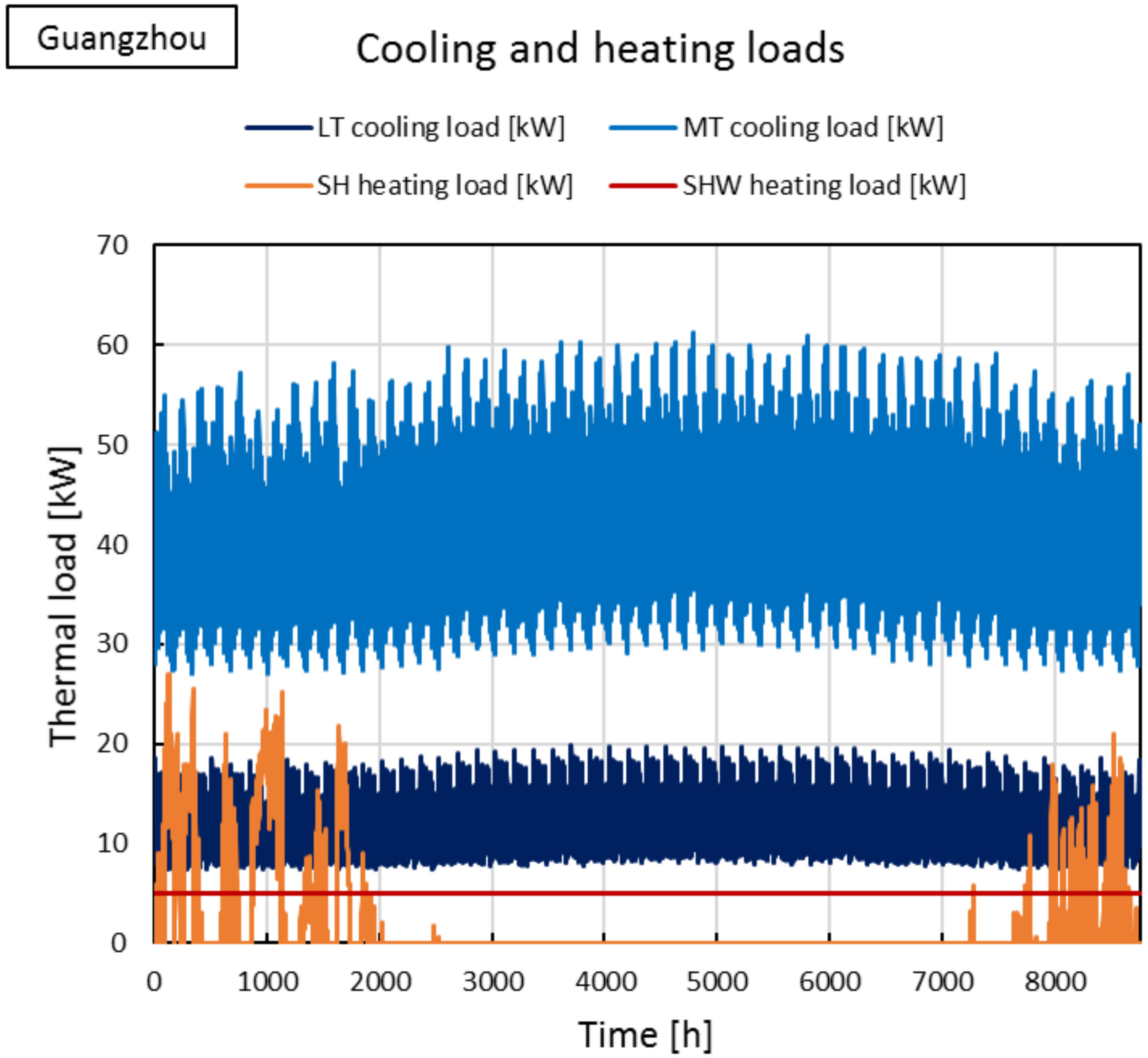
Heating load for Sanitary Hot Water Production is not influenced by ambient temperature

MODEL DESCRIPTION : COOLING AND HEATING LOAS

Shanghai



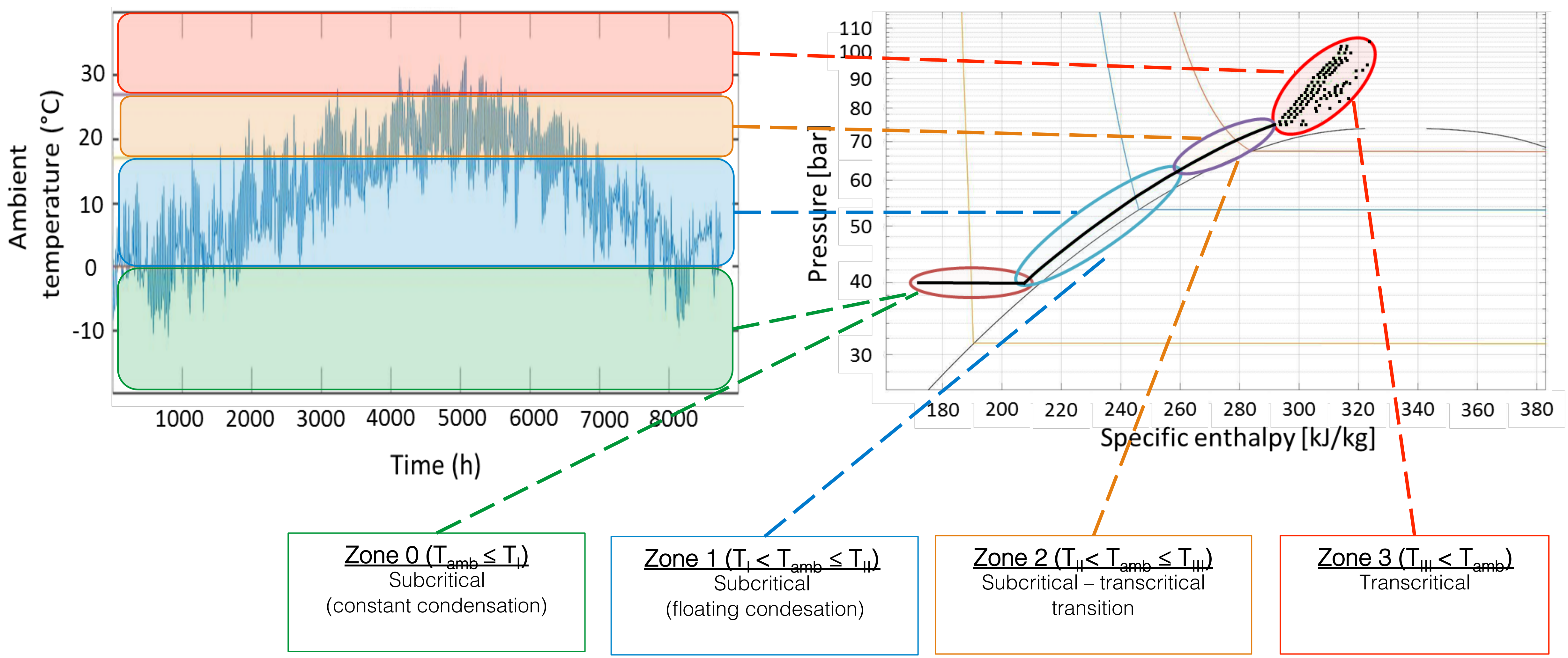
Guangzhou



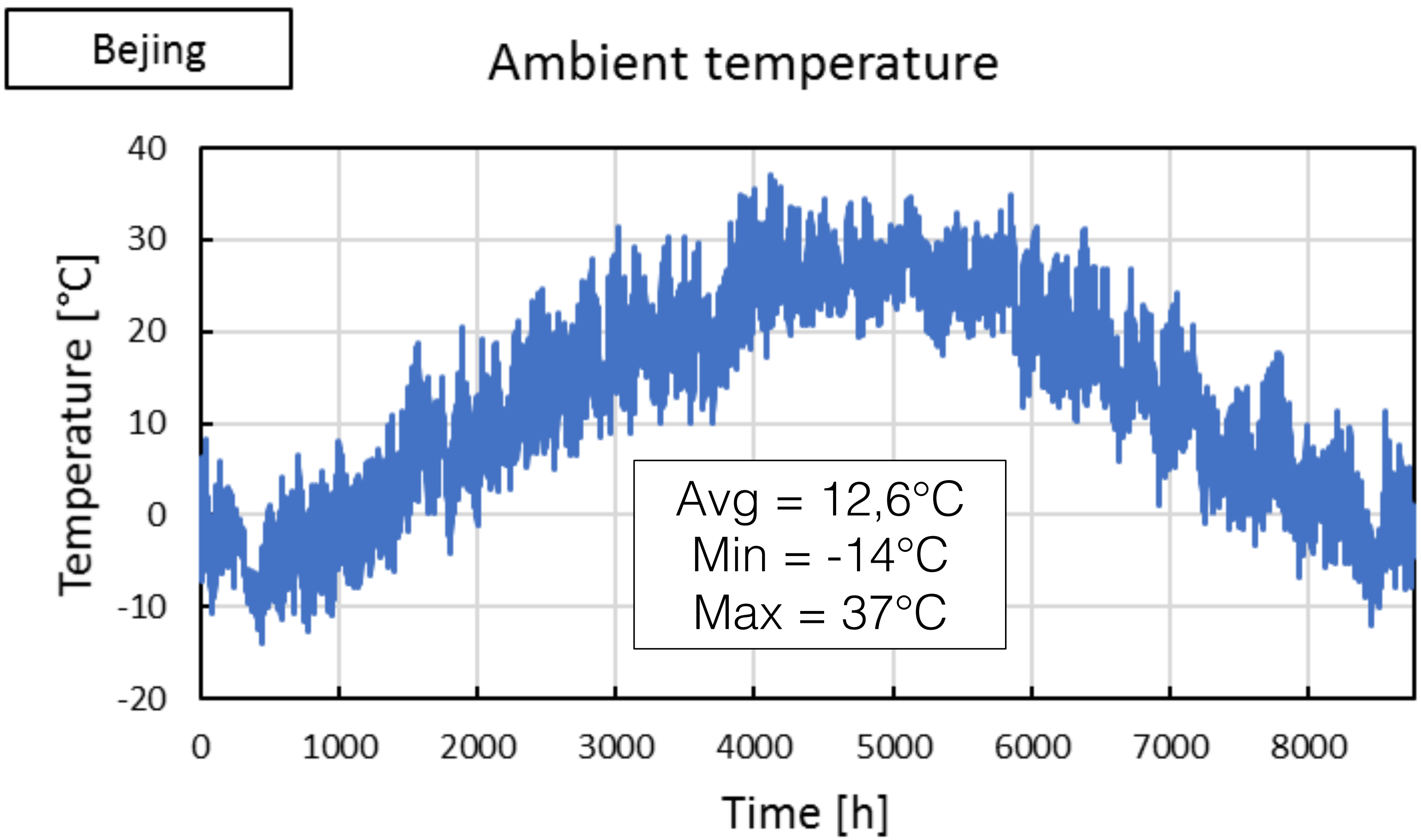
MODEL DESCRIPTION: HP CONTROL STRATEGY

<u>Gas cooler/condenser</u>

- Control zones depend on the approach point temperature difference at the Gas Cooler
- Transition region crossing boundaries between zones

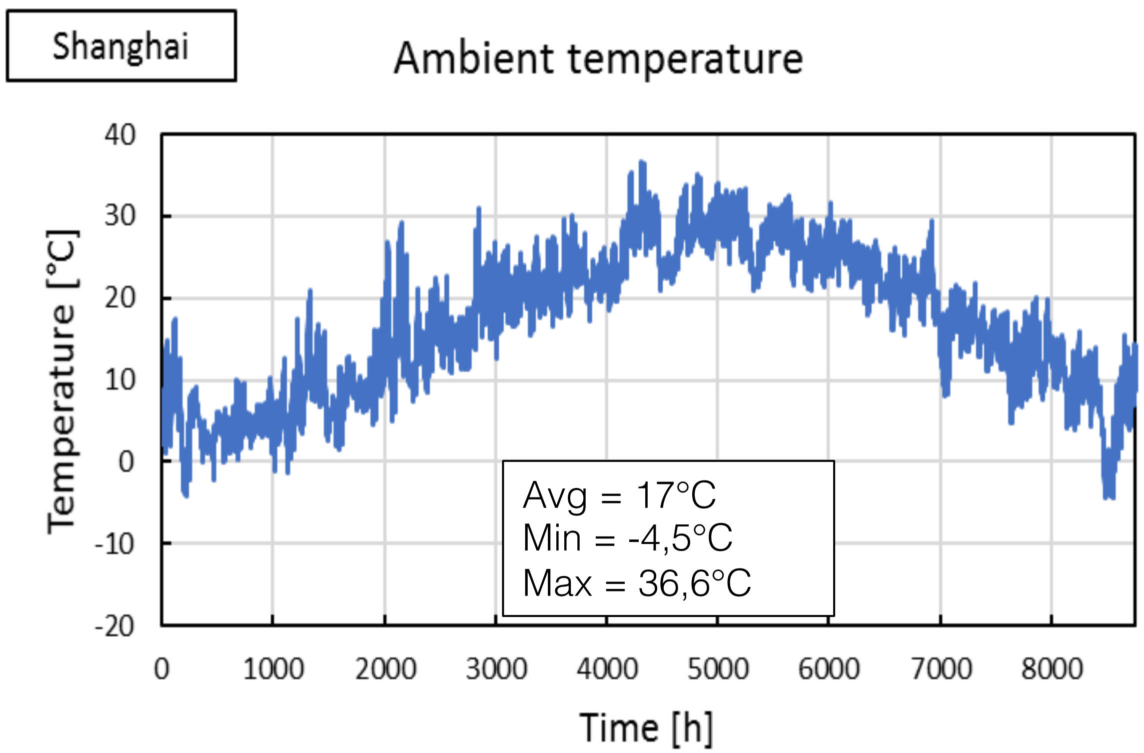


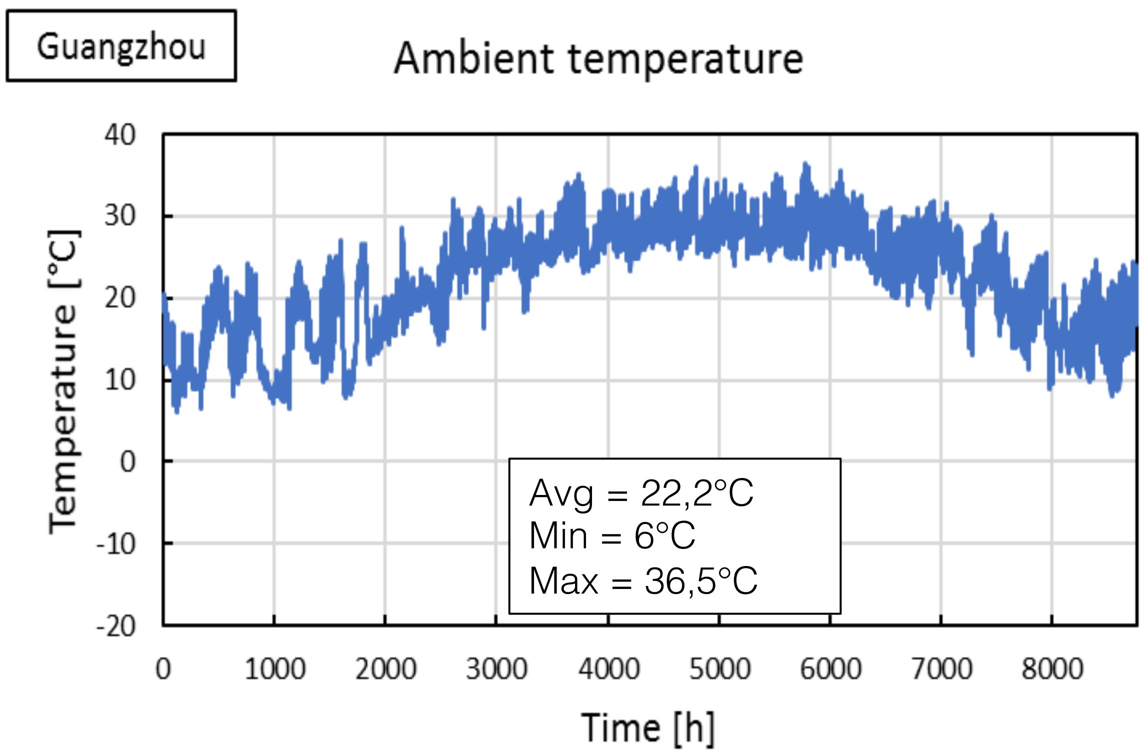
MODEL DESCRIPTION: TEMPERATURE PROFILE



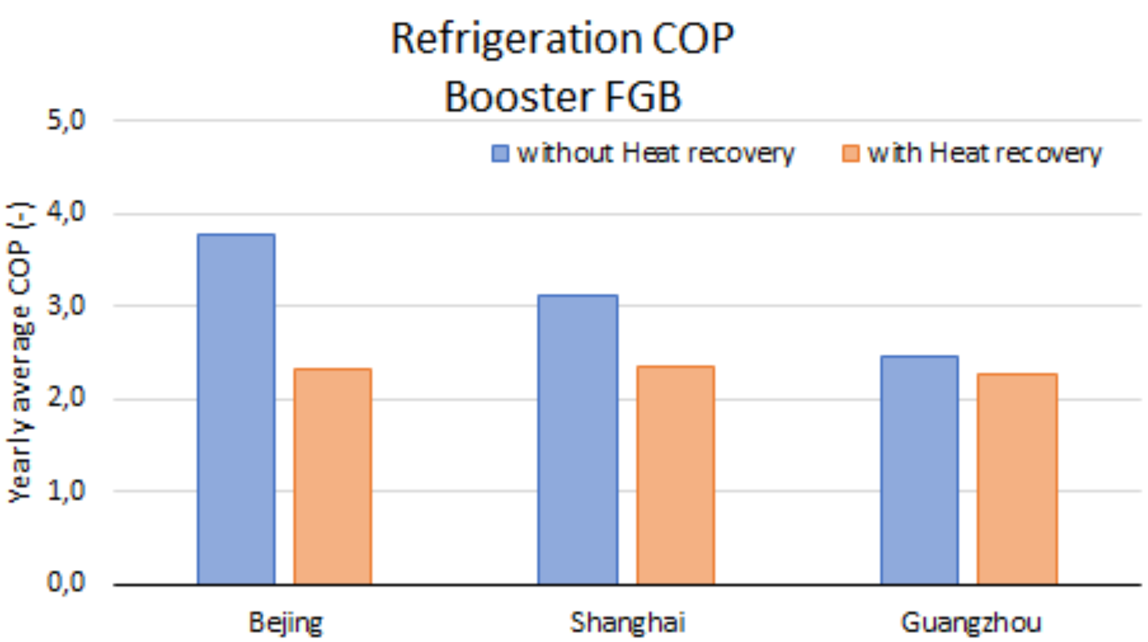
Temperature profile during year 2017 in Beijing, Shanghai and Guangzhou

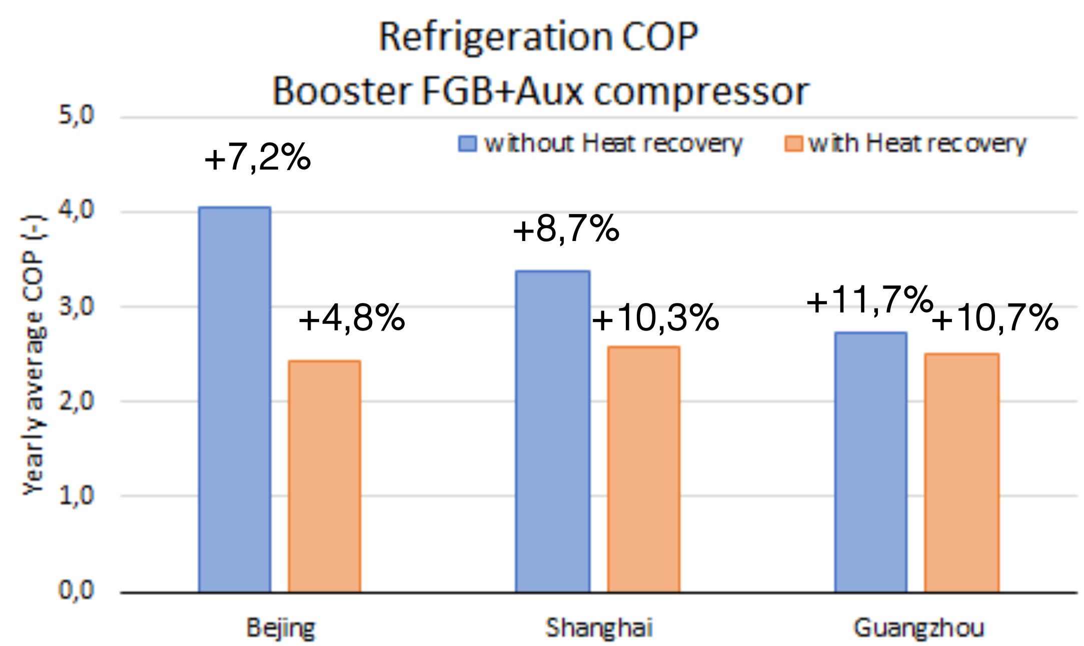
MODEL DESCRIPTION: TEMPERATURE PROFILE

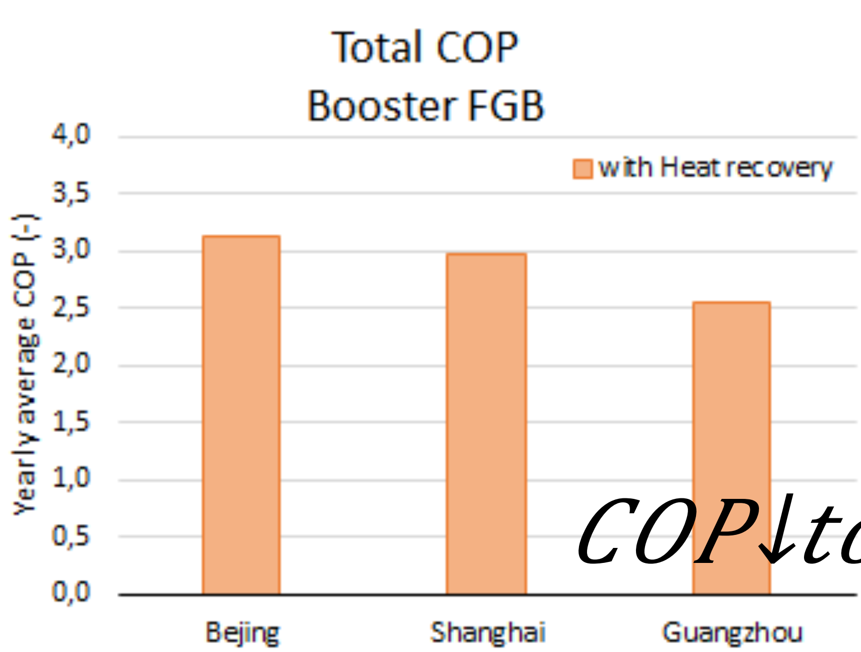


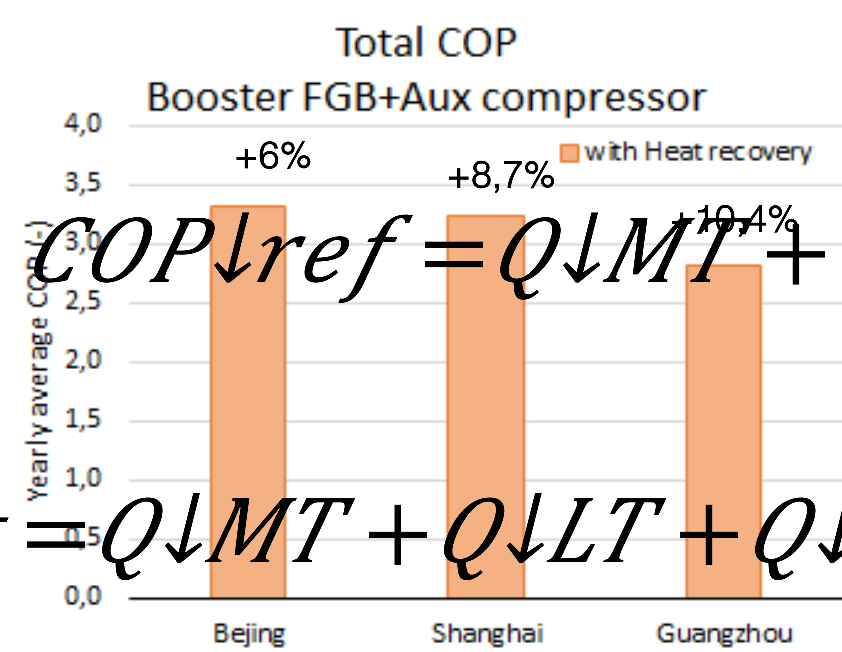


RESULTS : YEARLY AVERAGE COP





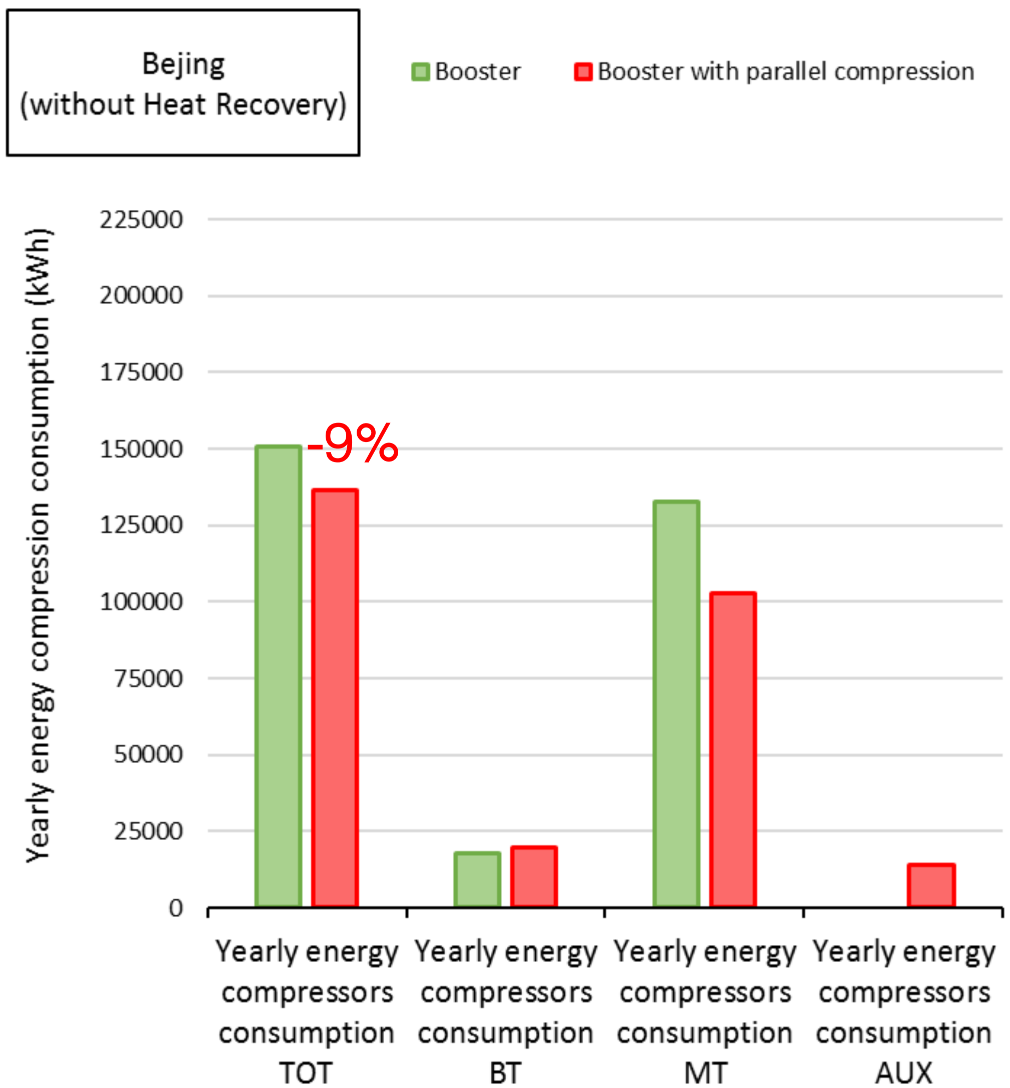


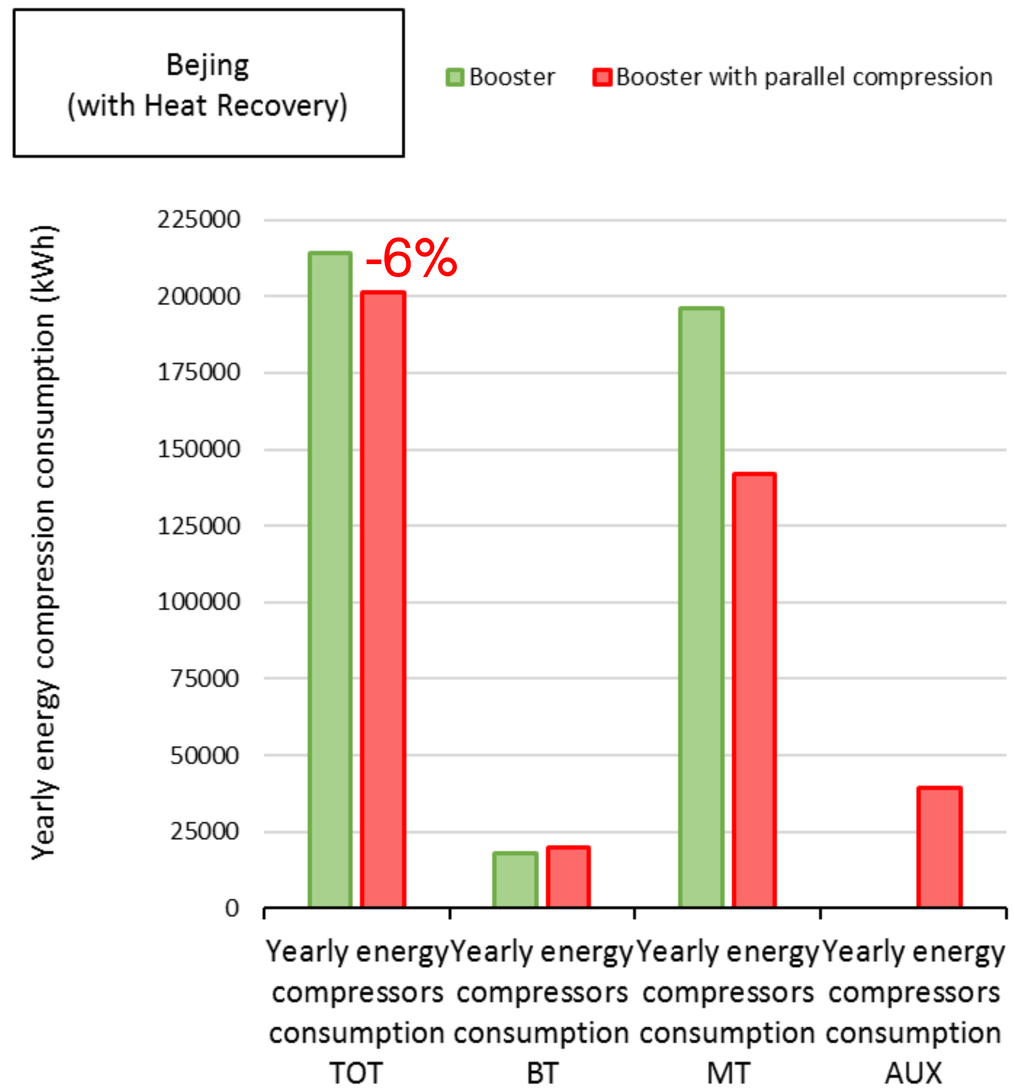


$$COP_{ref} = Q_{MT} + Q_{LT} / W_{CMT} + W$$

$$COP_{tot} = Q_{MT} + Q_{LT} + Q_{SH} + Q_{SHW} / W$$

RESULTS YEARLY ENERGY COMPRESSORS CONSUMPTION





<u>COST SAVING</u>

Without heat recovery

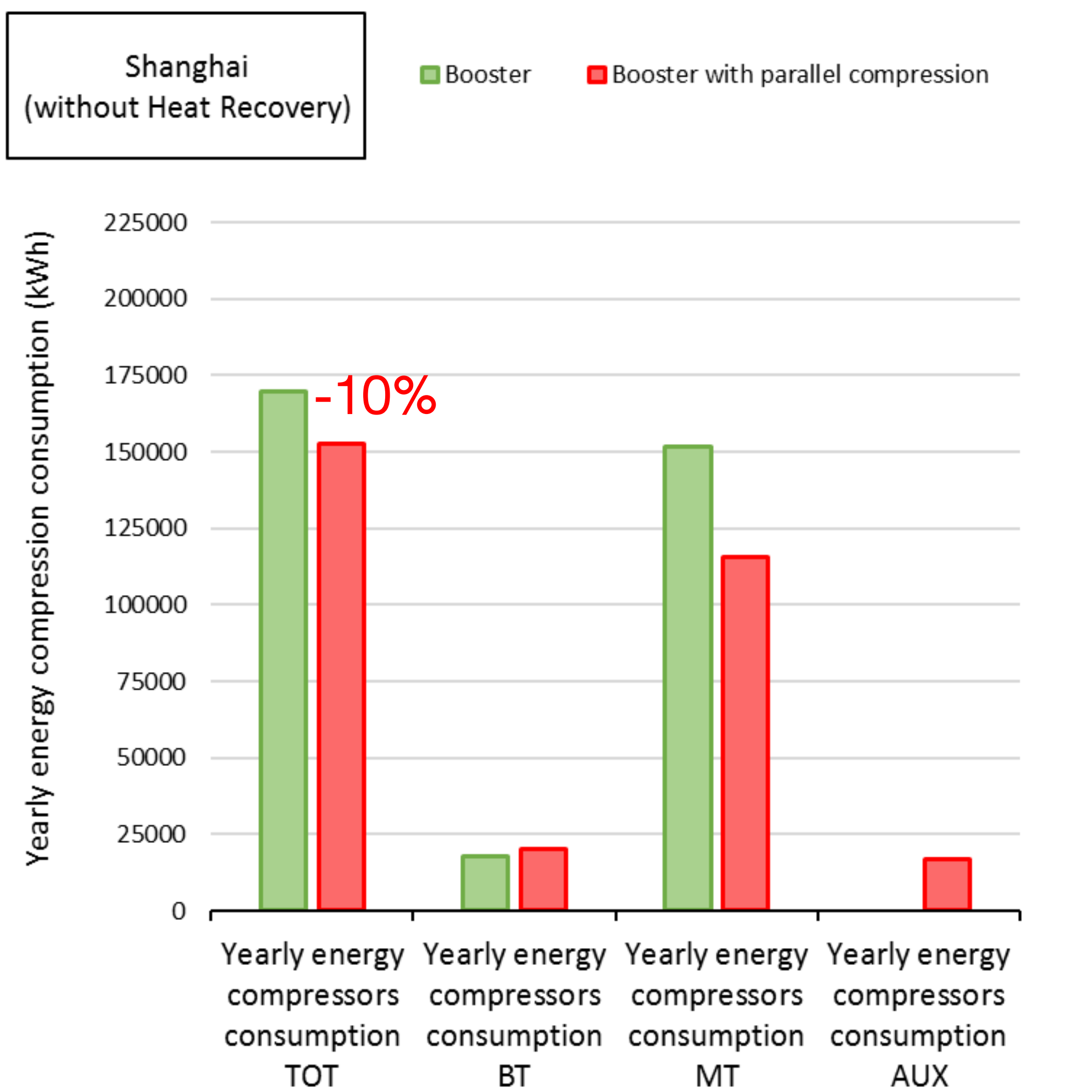
FGB vs ECO 14280 kWh x 0.11 €/kWh ≈ 1600 €/year

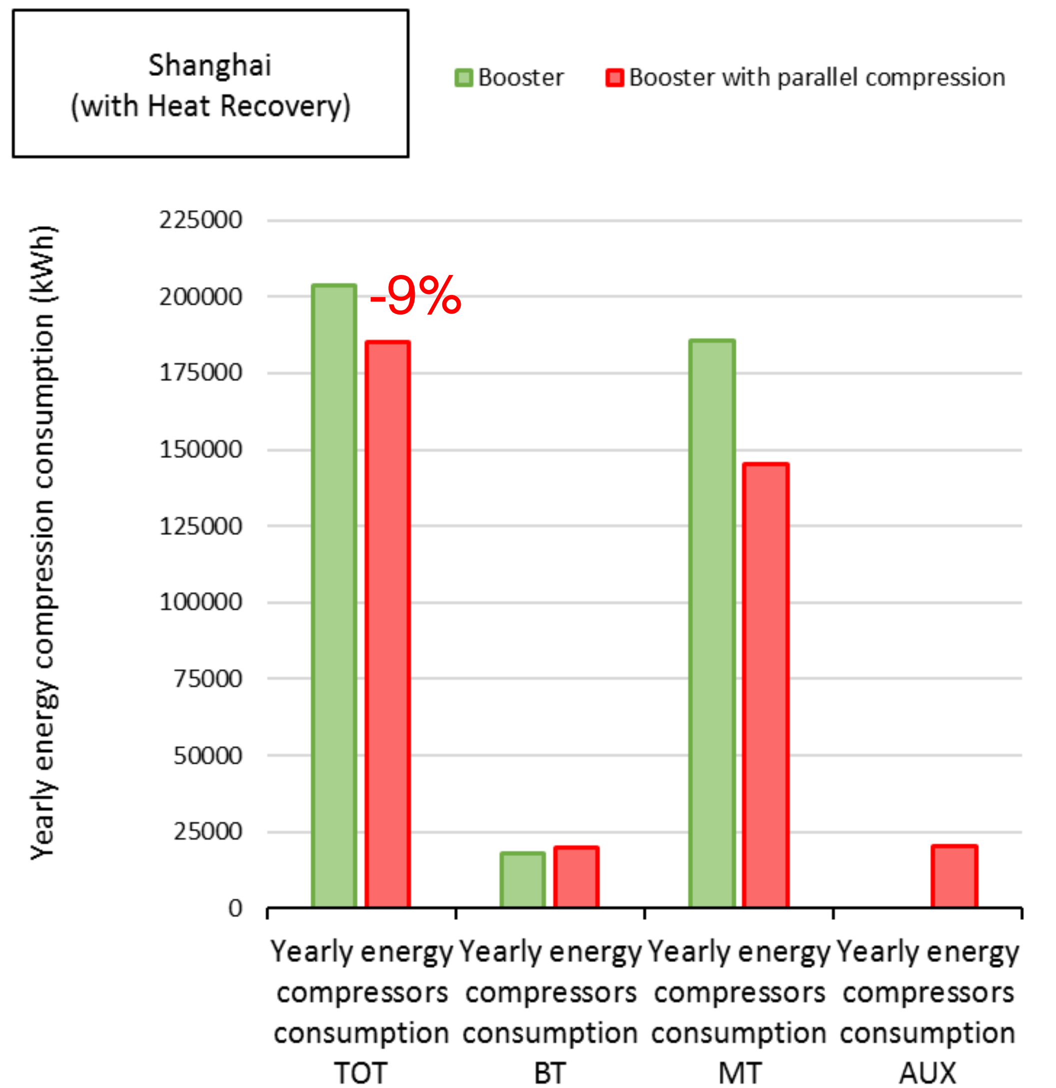
<u>COST SAVING</u>

With heat recovery

FGB vs ECO 13040 kWh x 0.11 €/kWh ≈ 1400 €/year

RESULTS YEARLY ENERGY COMPRESSORS CONSUMPTION

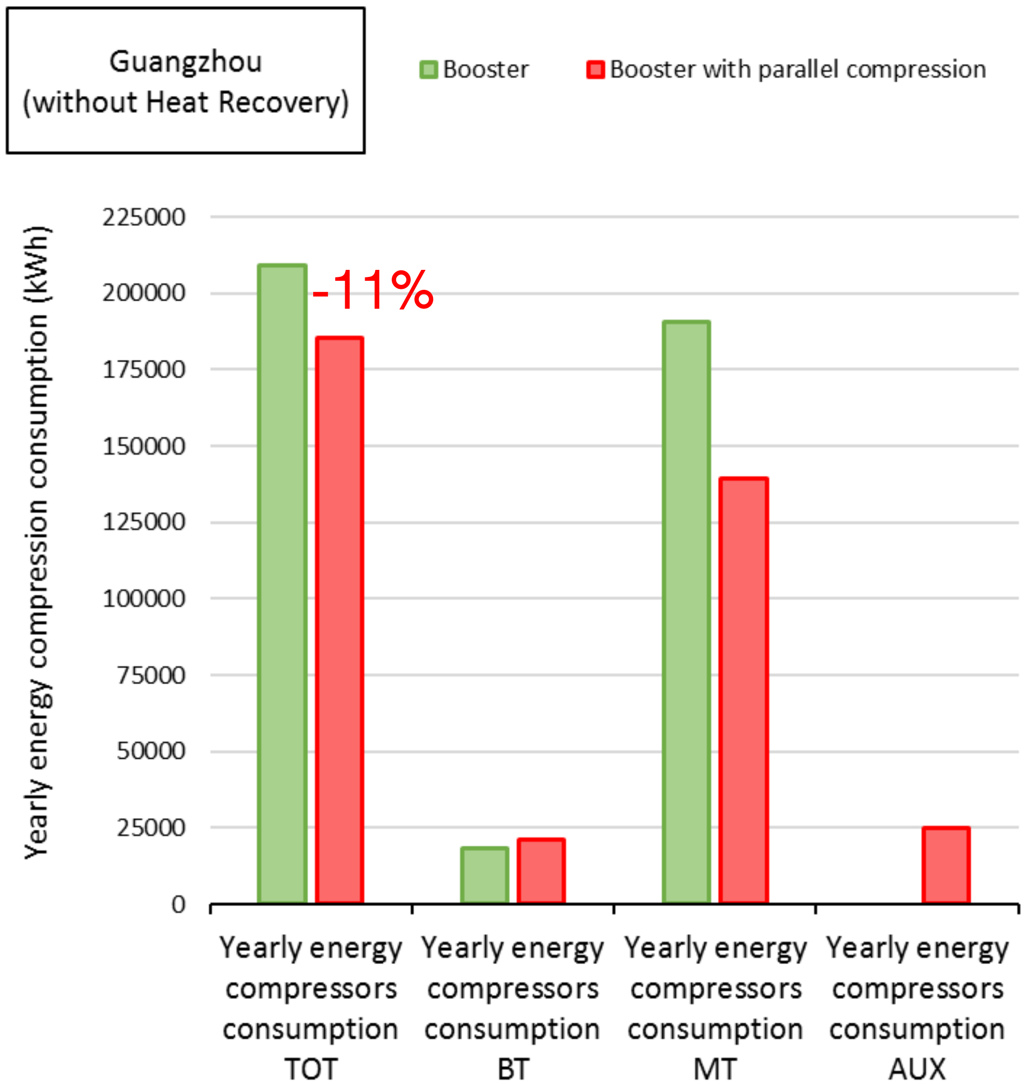


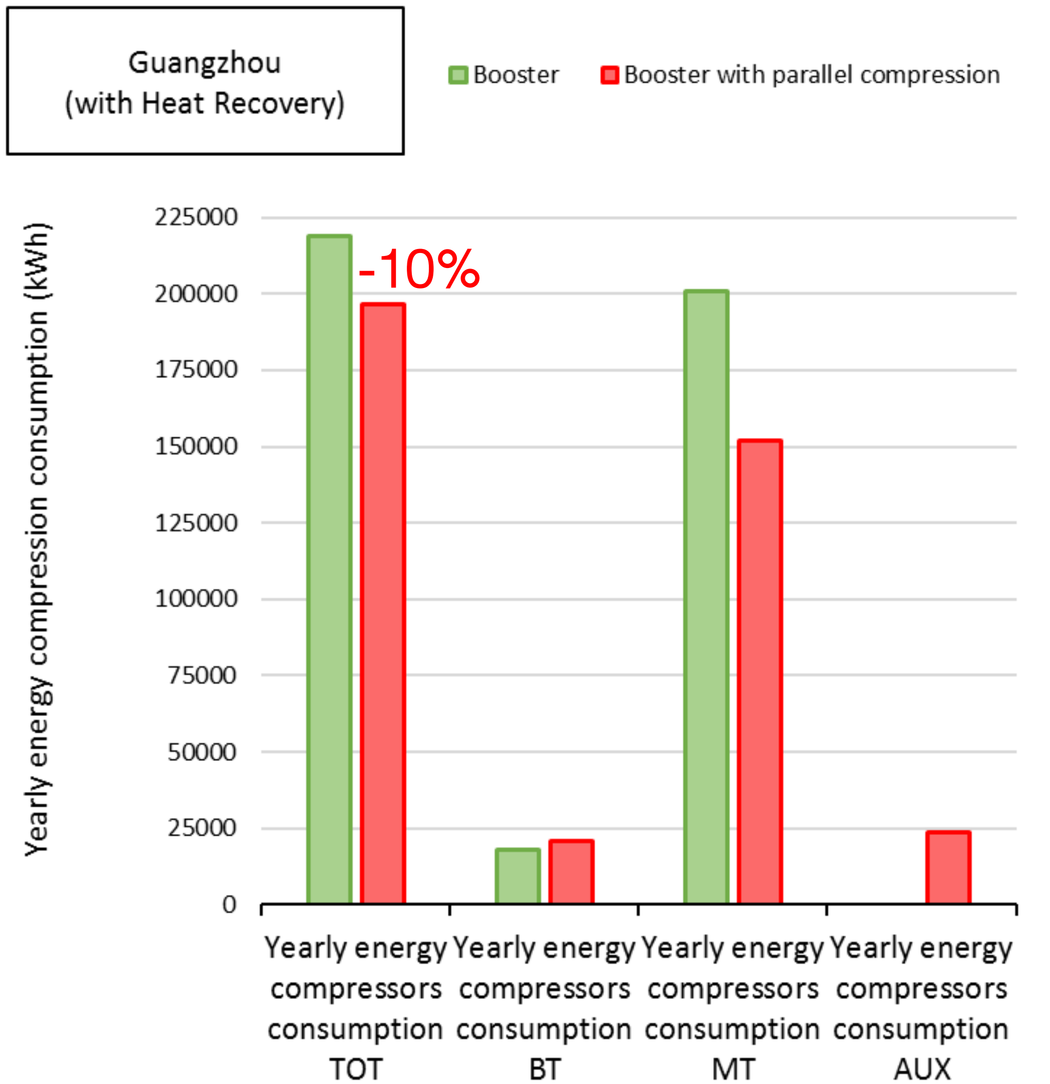


COST SAVING
Without heat recovery
FGB vs ECO 17020 kWh x 0.11 €/kWh ≈ 1900 €/year

COST SAVING
With heat recovery
FGB vs ECO 18410 kWh x 0.11 €/kWh ≈ 2000 €/year

RESULTS YEARLY ENERGY COMPRESSORS CONSUMPTION



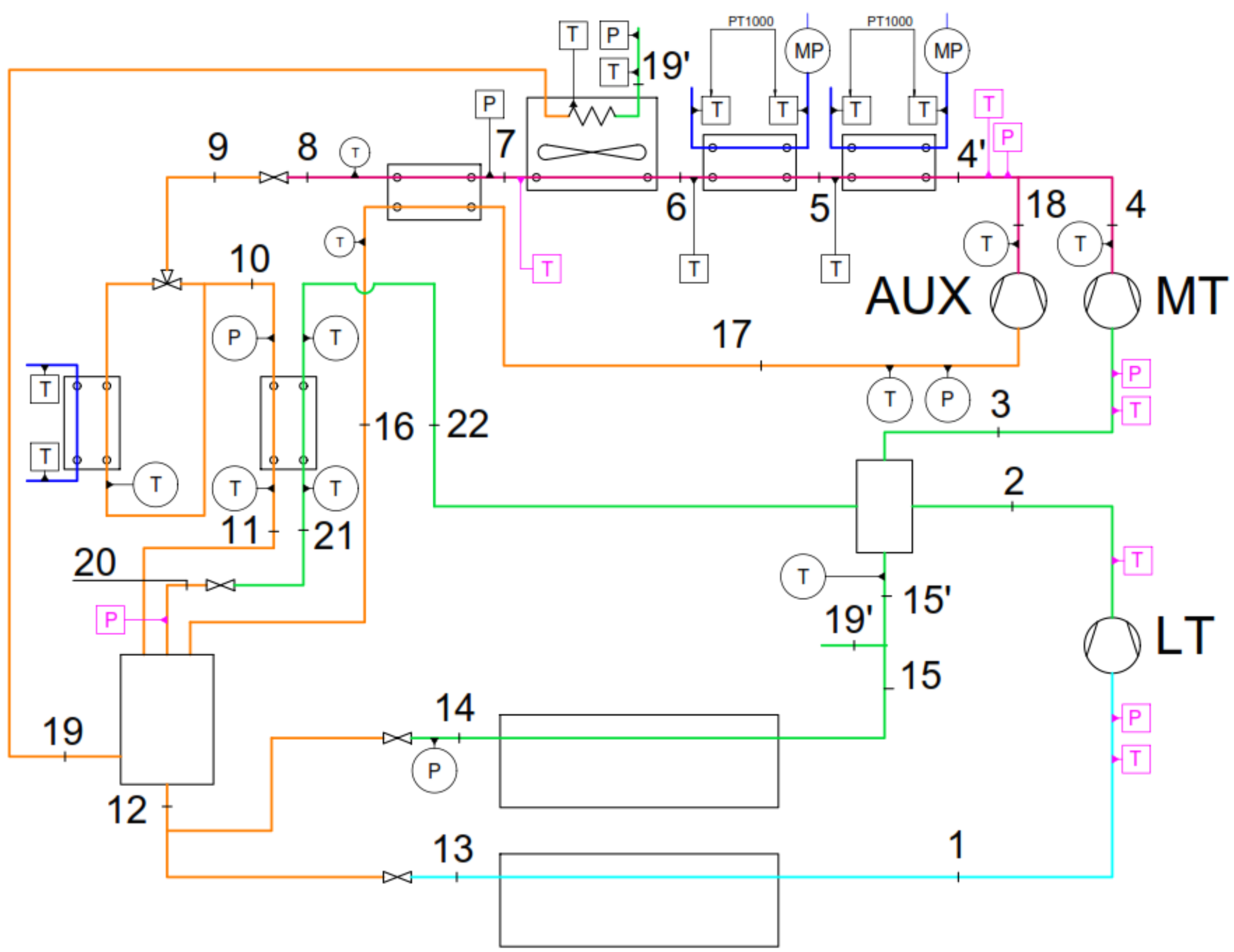


<u>COST SAVING</u>
Without heat recovery
FGB vs ECO 23720 kWh x 0.11 €/kWh ≈ 2600 €/year

<u>COST SAVING</u>
With heat recovery
FGB vs ECO 22330 kWh x 0.11 €/kWh ≈ 2500 €/year

NEXT STEPS

Model results will be validated by monitoring a real system where redundant laboratory instruments will be installed: flow meters, pressure and temperature gauges, current analyzers.



CONCLUSIONS

In order to select the most suitable CO_2 system in terms of cost and efficiency it is recommended to perform a yearly-based performance simulation considering temperature profile

In this study a comparison between transcritical booster cycle with Flash Gas Bypass (FGB) and FGB with parallel compression (FGB+ECO) in three cities of China has been analized

Use of auxiliary compressors to remove vapor from flash tank allows higher yearly performance. More extreme winter conditions (lower ambient temperatures in winter and higher in summer) -like those experienced in Bejing- require more heat recovery for space heating

Energy savings in compressor consumption are strongly dependent on the temperature profile of the location

The described method could be used as a reference guide for current evauations from Chinese OEM looking at CO_2 technology for commercial refrigeration

ATMO sphere CHINA

Business Case for Natural Refrigerants

11-12/04/2018 – Beijing

Thank you very much!