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EXPERIMENTAL AND EMPIRICAL EVALUATION OF THE ANNUAL EFFICIENCY FOR A TRANS-CRITICAL R744 BOOSTER SYSTEM IN ASIAN CLIMATE CONDITIONS

Oliver Javerschek, BITZER Kühlmaschinenbau GmbH

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- Experimental and empirical study of a CO_2 booster system
- Comparison of systems
  - Optimized R404A / R404A system
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  - CO_2 booster system
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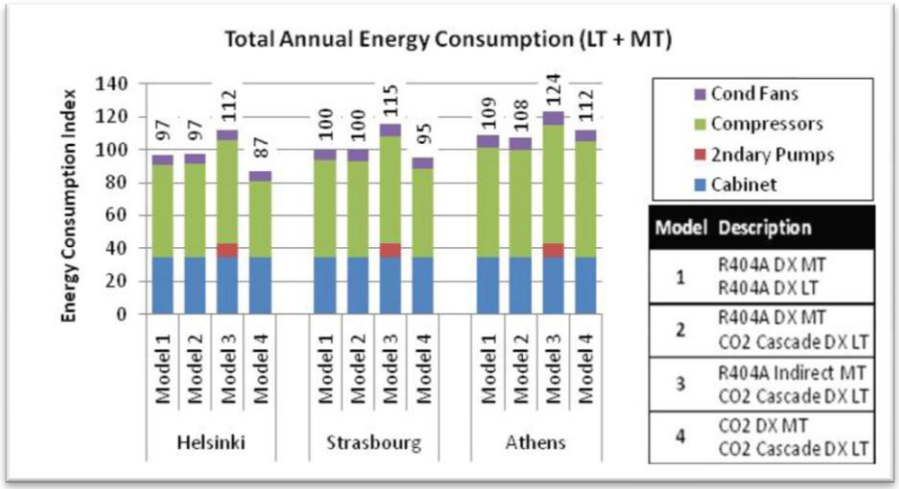
Motivation

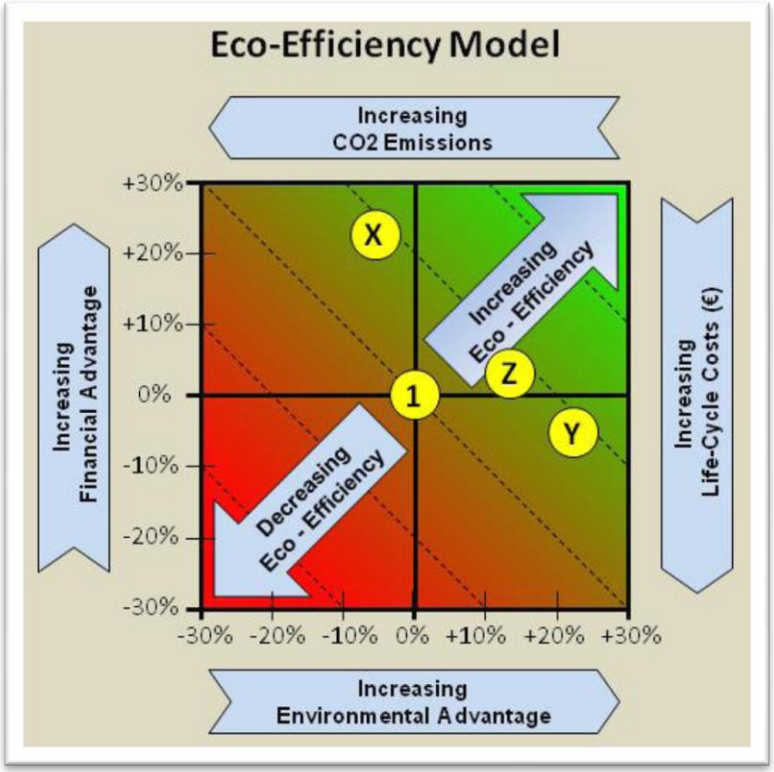
Motivation of the study

Eco-efficiency study

Analytical comparison of supermarket refrigeration systems

- R404A DX MT - R404A DX LT
- R404A DX MT - CO_2 Cascade DX LT
- R404A Indirect MT - CO_2 Cascade DX LT
- CO_2 DX MT - CO_2 Cascade DX LT



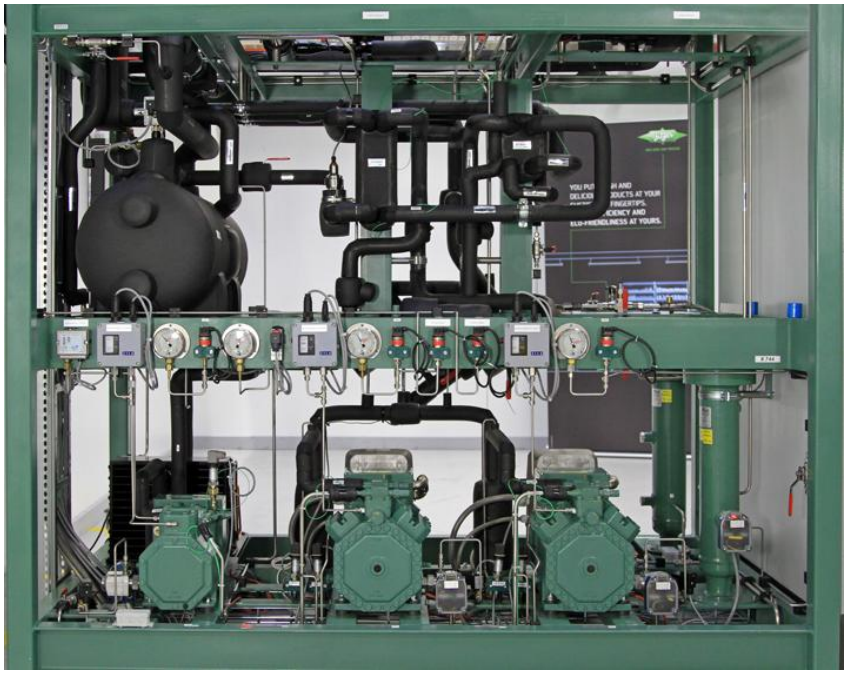


* Thurnham, Timothy 2010, Eco-Efficiency Study of Supermarket Refrigeration, SKM Enviros, London

Experimental and empirical study of a CO_2 booster system

Applied CO_2 booster system

- State-of-the-art CO_2 booster system of the 2nd generation
  - Oil management, flash gas bypass, IHX (flash gas ↔ liquid)
  - Water-cooled co-axial gas cooler allows the simulation of various ambient conditions
  - Without heat reclaim, parallel compression, two-stage gas cooler and peak load unit
- Realistic MT / LT load simulation by means of electrical heaters

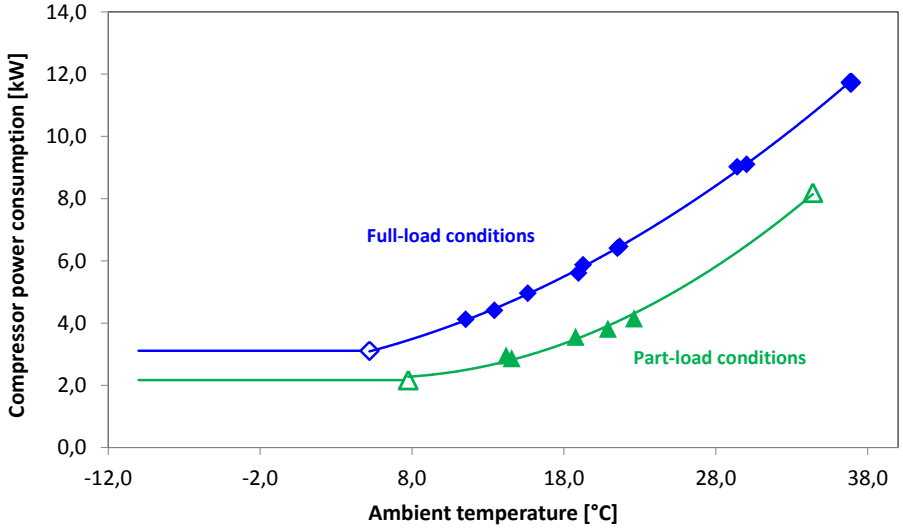


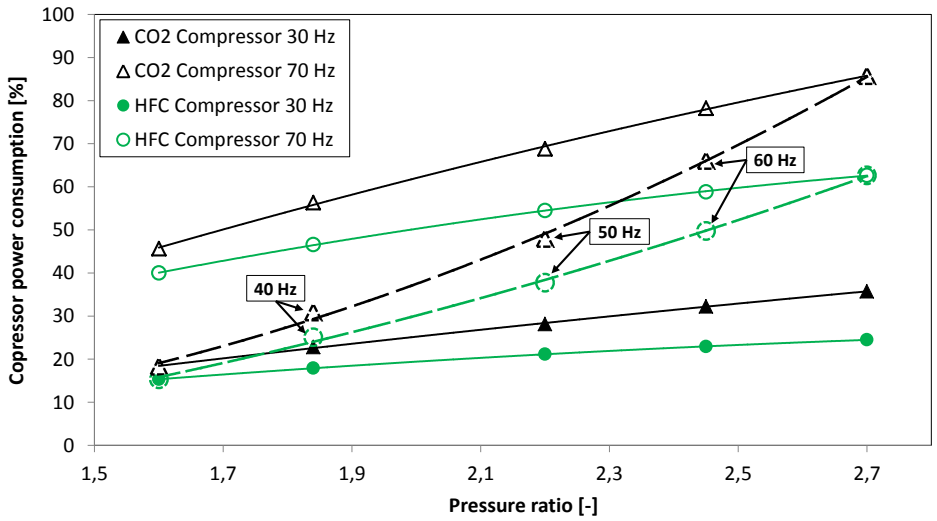
Reference

Compressors Papiernička´2013

EXPERIMENTAL EVALUATION OF THE SEASONAL ENERGY EFFICIENCY RATING FOR A TRANS-CRITICAL R744 BOOSTER SYSTEM IN VARIOUS CLIMATE CONDITIONS

Oliver JAVERSCHEK[a], Manuel REICHLE[b]
BITZER Kuehlmaschinenbau GmbH, Eschenbrünnlestr.15,
71083 Sindelfingen, Germany
[a] +49.(0)7031.9325244, oliver.javerschek@bitzer.de
[b] +49.(0)7031.93254206, manuel.reichle@bitzer.de





Comparison of systems

Boundary conditions

SKM ENVIROS

Appendix A - Modelling Assumptions

Table A1: Assumptions – Thermodynamic Model ("State of Art" conditions)

Variable	Model 1 MT	Model 1 LT	Model 2 MT	Model 2 LT	Model 3 MT	Model 3 LT	Model 4 MT	Model 4 LT
Refrigerant	R404A	R404A	R404A	CO_2		CO_2	CO_2	CO_2
System type	DX	DX	DX	DX Cascade			DX	DX Cascade
Cabinet cooling load (kW)	60	16	60	16		16	60	16
Cabinet air temperature (°C)	+2	-24	+2	-24	+2	-24	+2	-24
Evaporating temperature (°C)	-8	-36	-8	-32	-11	-32	-6 °C	-32
Head pressure control setting (saturated temperature, °C)	25	25	25	N/A	25	N/A	15	N/A
Cascade heat exchanger TD (K)	N/A	N/A	N/A	5	N/A	5	N/A	5
Condenser/gas-cooler								
• Surface area (m2)	340	110	470	N/A	500	N/A	260	N/A
• Air flow rate (m3/s)	13	4	18		20		15	
• Fan power (kW)	3.3	1.0	4.6		4.9		3.4	
Evaporator superheat (K)	5	5	5	5	5	5	5	5
Suction return temp (°C)	10	-5	10	-5	10	-5	10	-5
Suction line pressure drop (MPa)	0.013	0.013	0.013	0.013	0	0.013	0.013	0.013
Discharge line pressure drop (MPa)	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
Liquid line pressure drop (MPa)	0.040	0.040	0.040	0.040	0.040	0.040	0.040	0.040
Condenser outlet subcooling (K)	2	2	2	0	2	0	0.5	0

R134a

!

CO_2 booster

Full Load
MT: 14 kW
LT: 2 kW

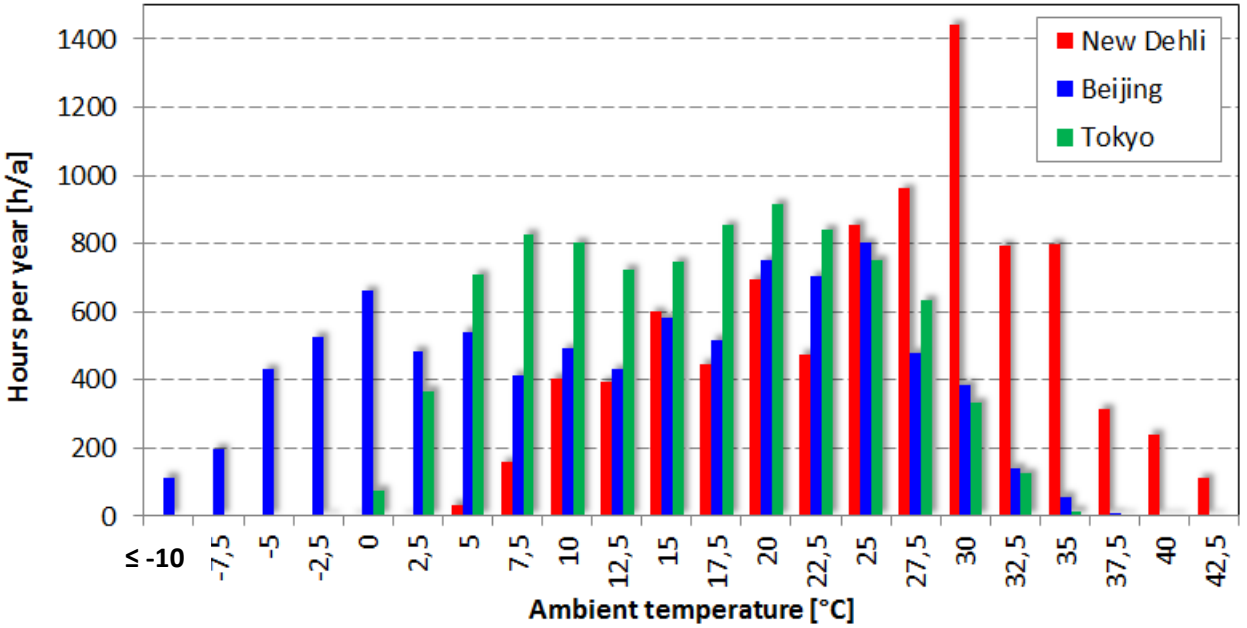
tc min = 15 °C

Insulation of receiver and liquid line, selection of EEX for small Δp

HFC's: BITZER NEW ECOLINE VARISPEED
CO_2: VARISPEED compressors in the MT stage

Calculation of the annual efficiency

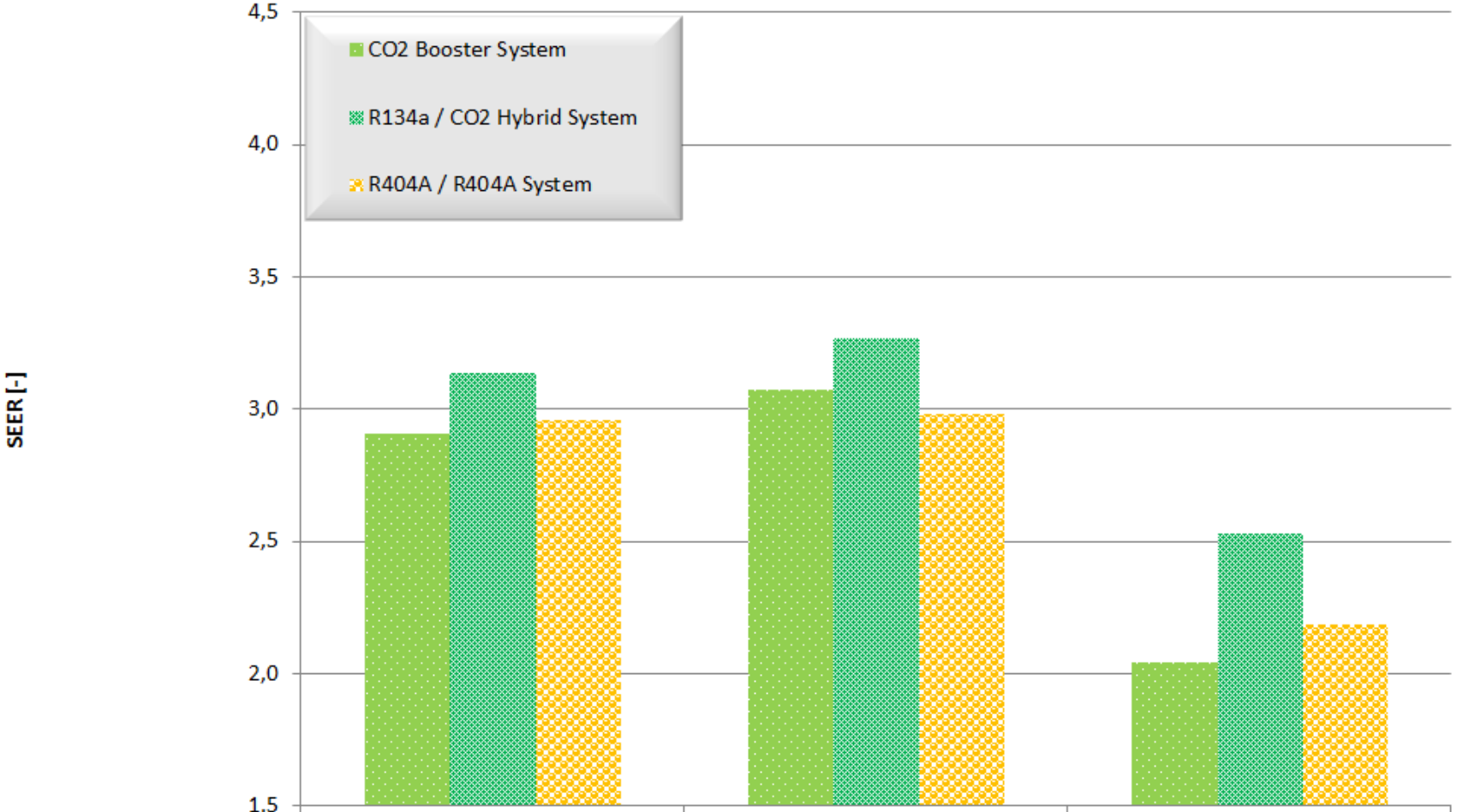
- Applied weather data (ASHRAE 2009, Weather Data Viewer 4.0)
- Results based on cooling capacity and power input of the compressors only
- Annual efficiency based on a SEER calculation acc. to prEN 14825



$$SEER = \sum_{j=1}^{22} \frac{Q(j) * h(j) * DG(j)}{P(j) * h(j)}$$

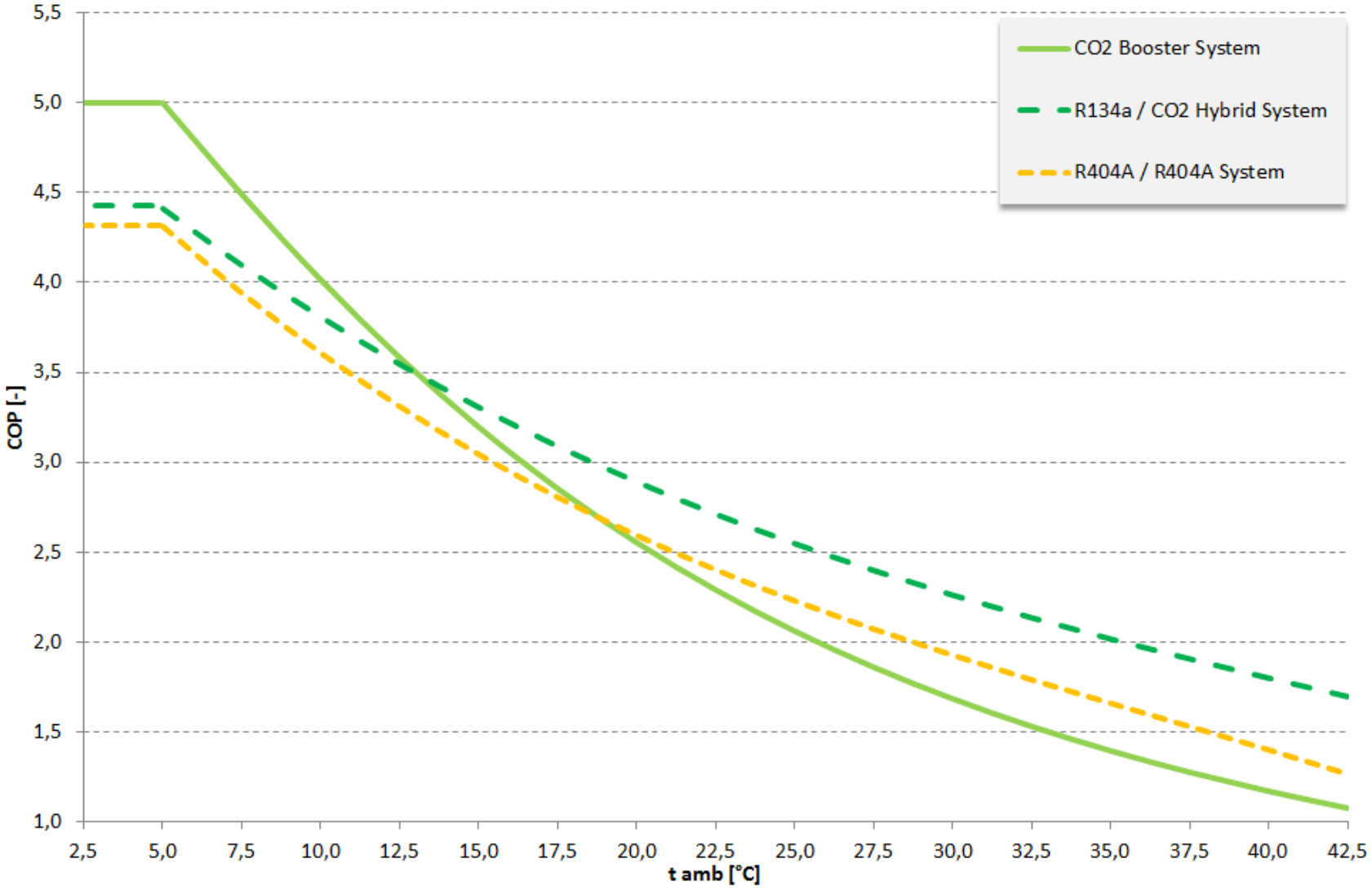
Results

Annual efficiency for Asian climates



	Tokyo	Beijing	New Dehli
CO2 Booster System	2,91	3,07	2,04
R134a / CO2 Hybrid System	3,14	3,27	2,53
R404A / R404A System	2,96	2,99	2,19

COP as function of the ambient temperature



Summary

Summary

- Classification of the annual efficiency of a state-of-the-art CO_2 booster system by an experimental and empirical study
- Calculation of the annual efficiencies for optimized HFC systems
- Out of the three solutions considered: An optimized hybrid system with R134a and CO_2 shows the best annual efficiencies in the chosen Asian climates
- Applying a CO_2 booster system of the 3rd generation is beneficial for the discussed climates

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Thank you very much!