R744 und R290 für PKW Klima – Kompressoren und Systeme

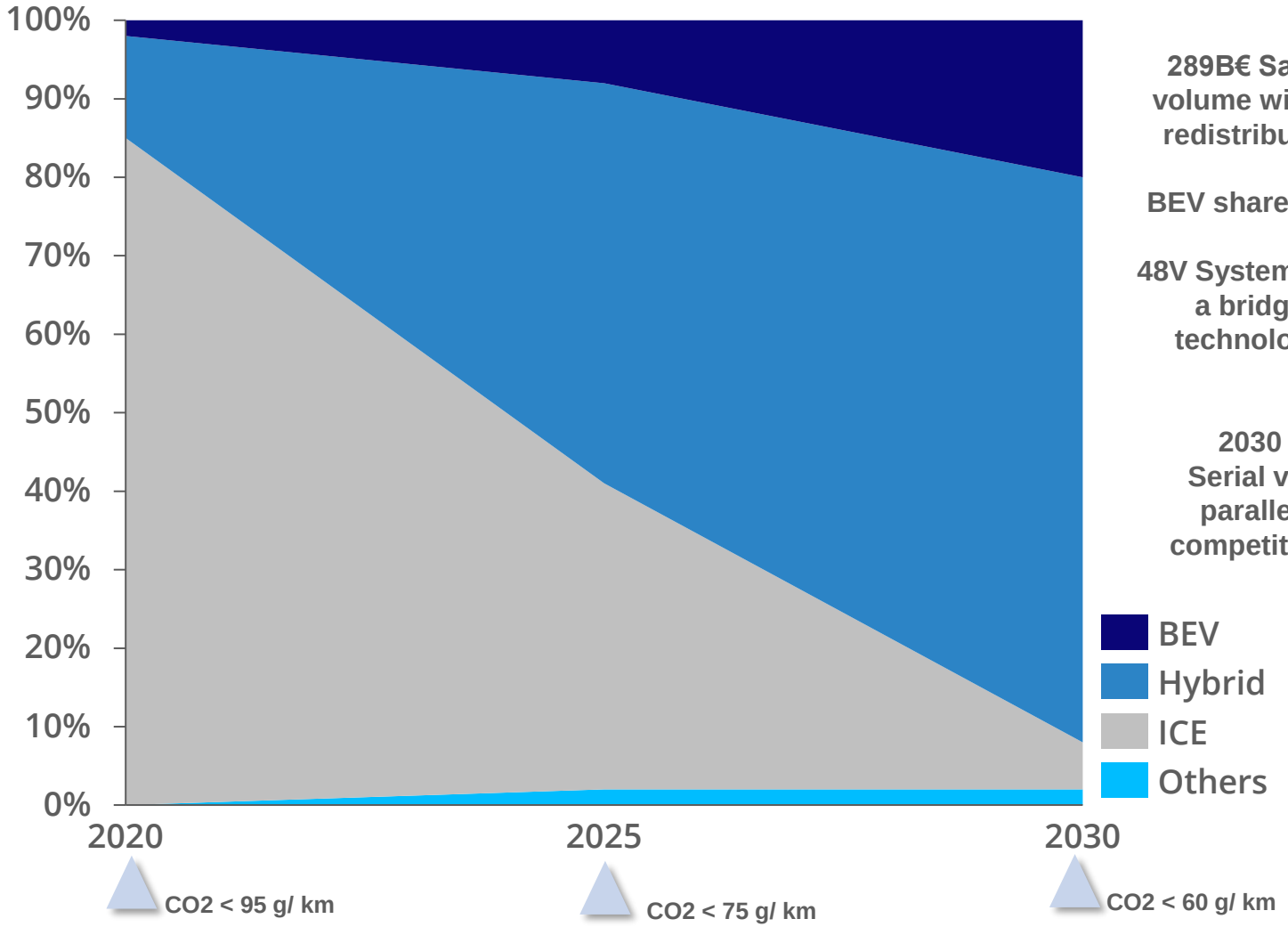
R744 and R290 for AC/HP – Compressors and Systems

October 2021, Team OE

Content

- Actual Market Situation and Trends
- General Impact on Vehicle Thermal Systems / Compressors
- System Approaches
- R290 and R744 vs. R1234yf
- Summary

Actual Market Situation and Forecast of Hybrid Vehicle Market Share Europe*



289B€ Sales volume will be redistributed

BEV share 20%

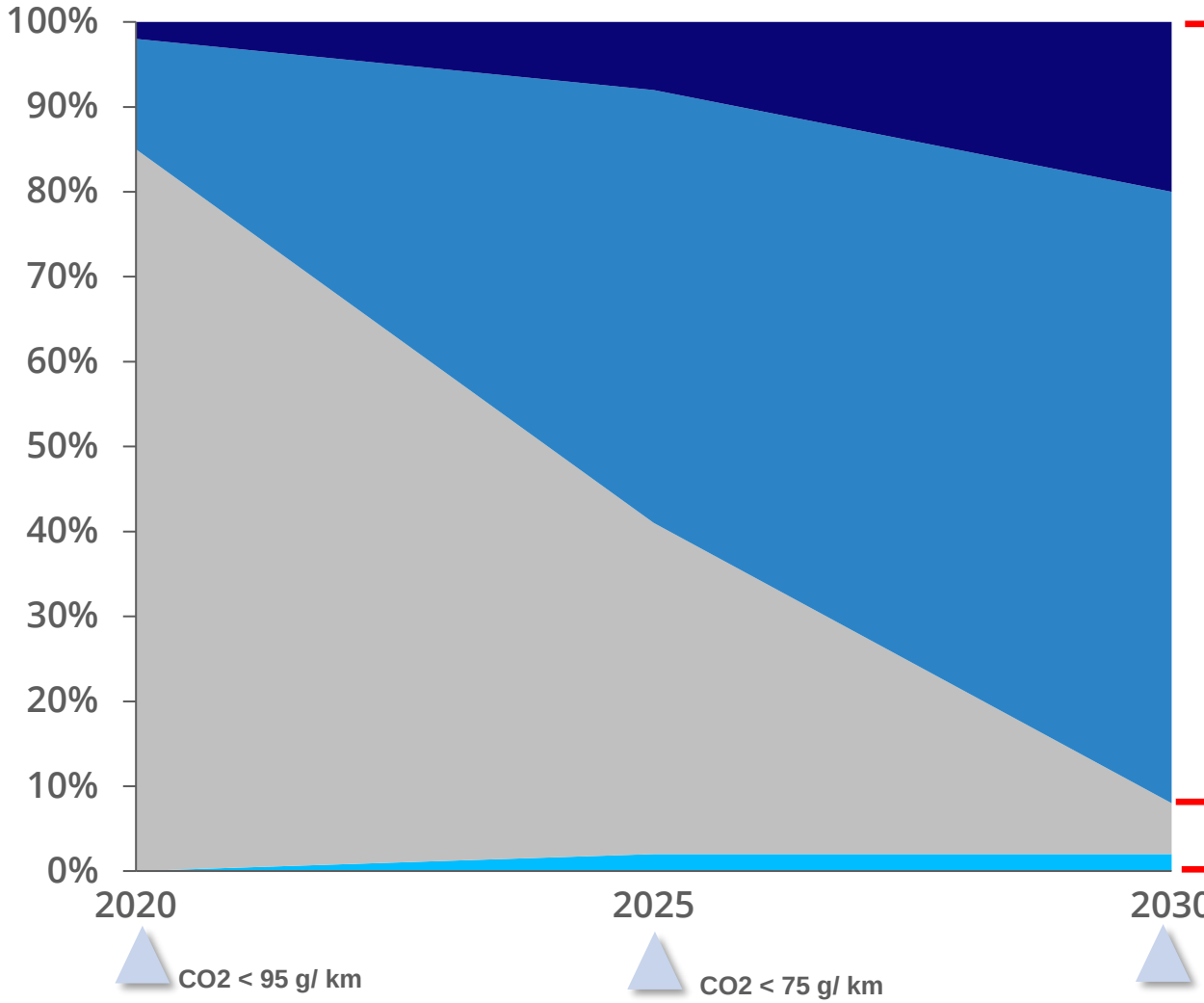
48V Systems are a bridge technology

2030 Serial vs. parallel competition

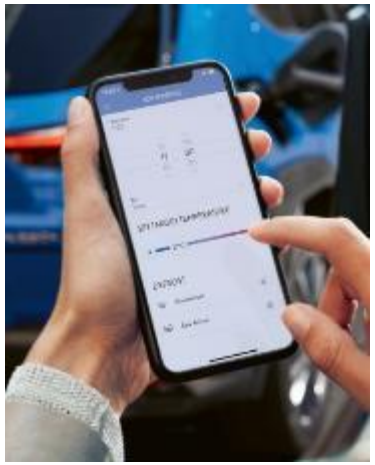
Europe will be a significant market for electrified vehicles. Major industry forecasts expect a steady increase of Hybrid Vehicle market share up 70 % until year 2030 due to tighter legislation on CO_2 emissions and the significant cost advantage of hybrid powertrains towards pure battery electric vehicles.

* source: Polarixpartner

Actual/Future Market Situation and impact on compressor technology



90% electrical driven compressors in 2030

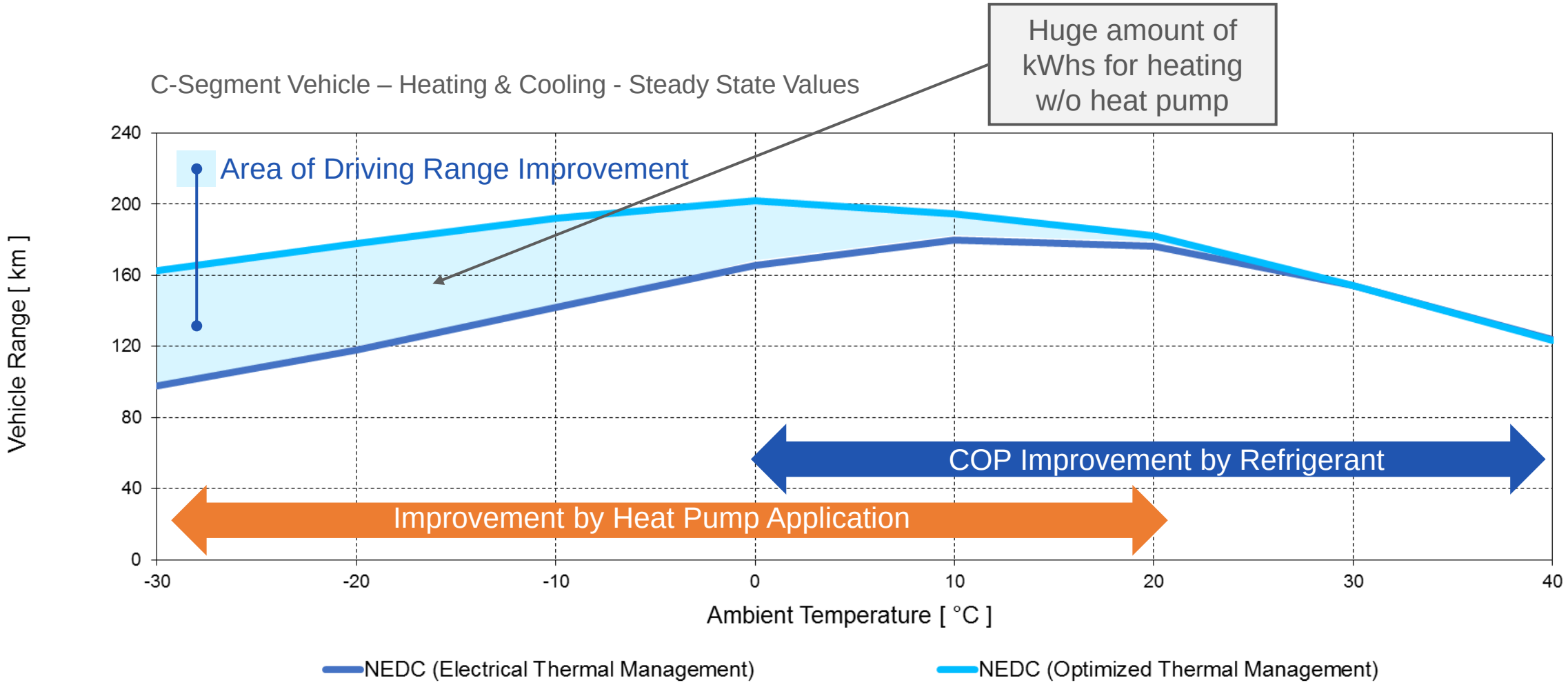


Remote / App access to AC / Heating

< 10% belt driven compressors

BEV
Hybrid
ICE
Others

Vehicle Driving Range Improvement Potential by Optimized Thermal Management



Compartment Heating Options for different vehicle types

	ICE Conventional	HEV	PHEV	BEV
ICE: Internal Combustion Engine	X	X	(X)	-
FFH: Fuel Fired Heater	X	X	(X)	-
PTC: Positive Temperature Coefficient	X	X	X	X
HP: Heat Pump	X	**X**	**X**	**X**

Electrical Heating Systems

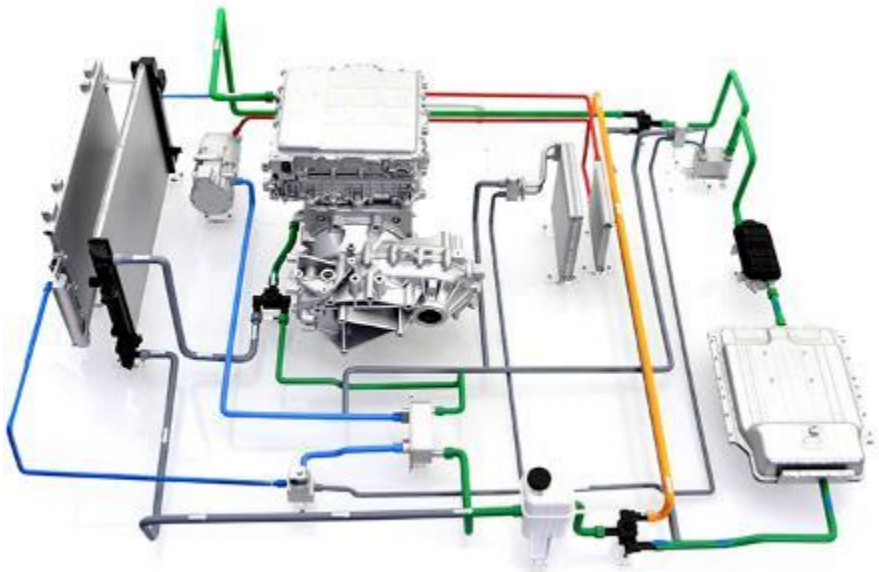
PTC Air Heater

HV PTC Water Heater

Fuel Fired Heater

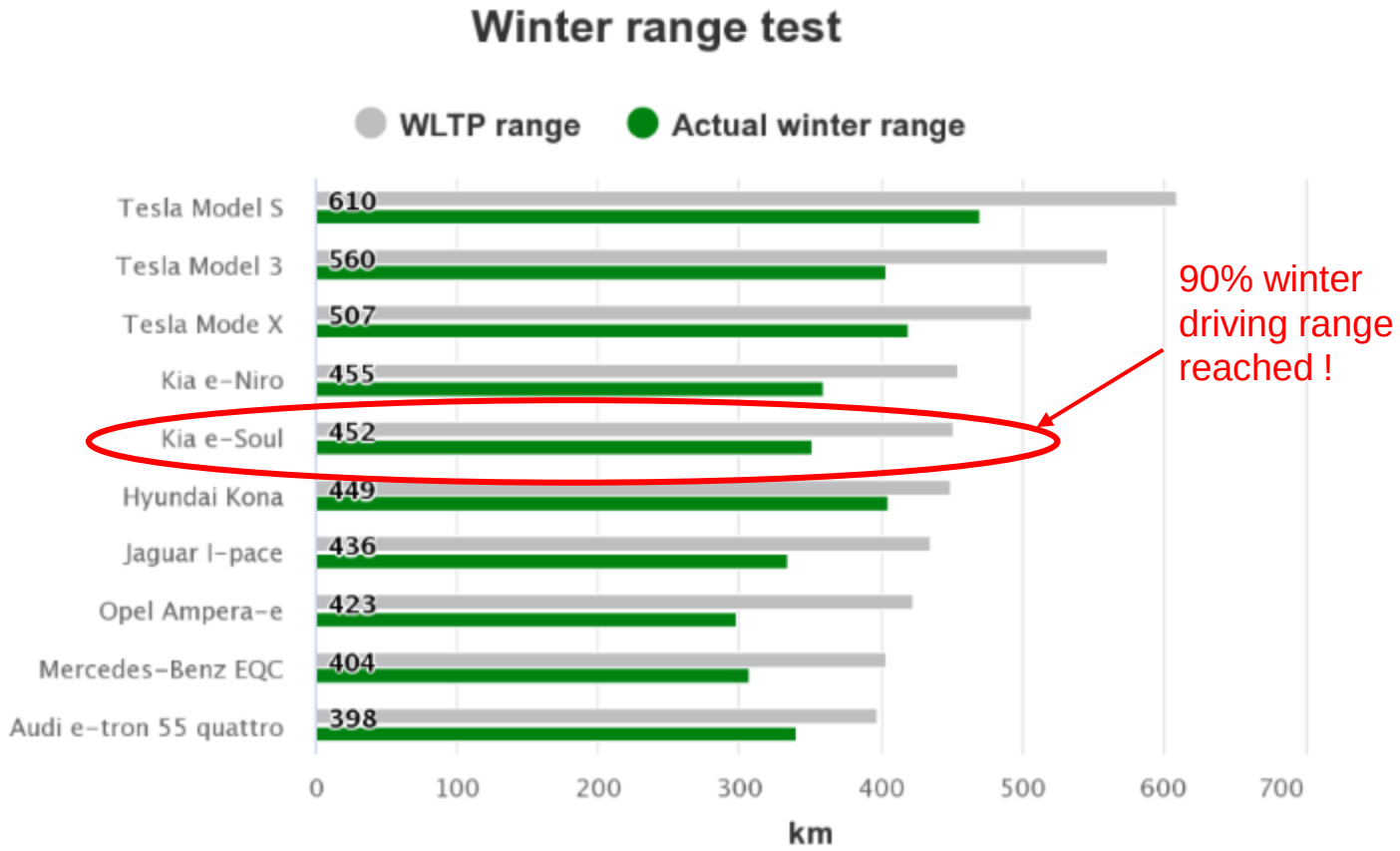
Heat Pump Systems

Hyundai Kona R1234yf HeatPump 2021



Good performing heat-pump but high BOM and cost effort needed

Remark: R744 heat pump has better COP potential compared to R1234yf



Source: HP-System, Winter Driving Range

IAA Munich 7.-12. September 2021 Obrist booth and meetings

OEMs and Tier 1 situation on refrigerants:

How long will R1234yf be allowed to be used (TFA) ?

What's to come after R1234yf

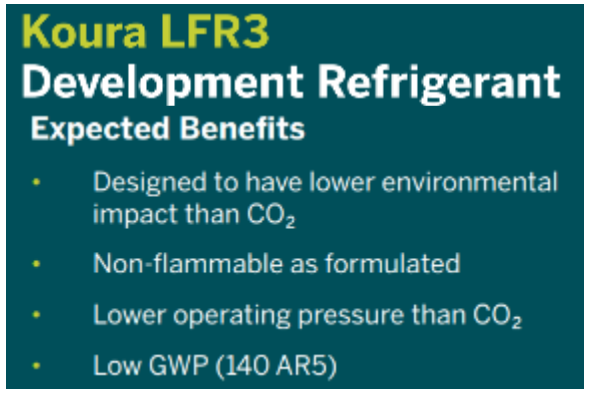
Blends or next chemical variants to come ?

How will China decide on refrigerant ?

Is R290 or R744 the better choice ?

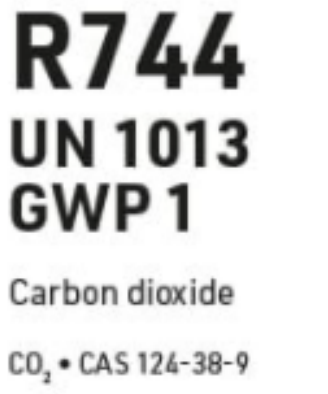
R134a / R1234yf

Blends / Next Chemicals ?



Propane R290

Carbon Dioxide R744



R744 is on the road Daimler S-Class 2017ff and Volkswagen ID.3 / ID.4

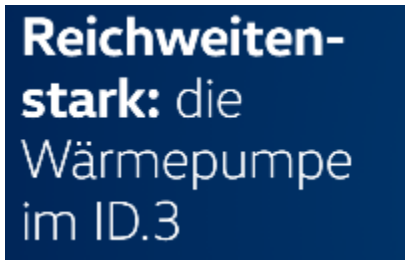
Daimler S-Class EU 2017 to 2020

R744 system AC only

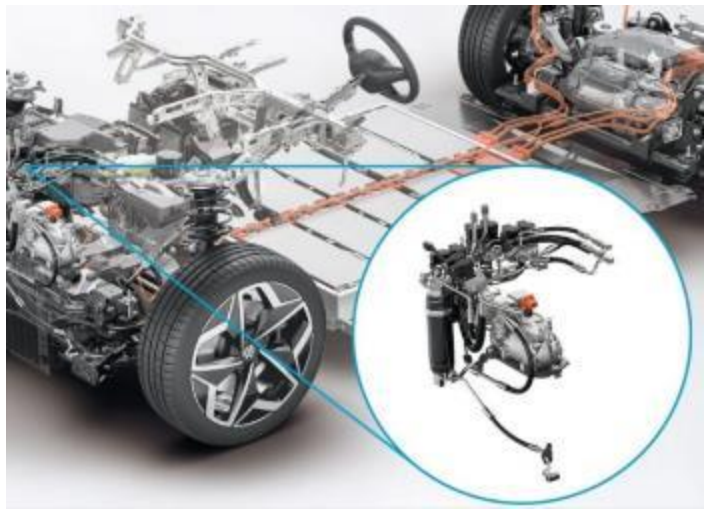
belt driven R744
compressor of Sanden

VW ID.3 / ID.4 2021 ff.

Optional R744 AC with heat pump



problems in
performance / COP



Increasing heating/cooling demand example compressor specification 2020

	minimaler Massenstrom	Lastfall 1	Lastfall 2	Wärmepumpe -10 °C	Wärmepumpe -20 °C
Verdichterdrehzahl [ ]	minimal	maximal	maximal	maximal	50%
Kälteleistung [kW]	-	>11	> 15	> 6	> 6,5
Kältemittelmassenstrom [kg/h]	< 25 kg/h	-	-	-	-
COP	> 5	> 2,5	> 2,5	> 2,5	> 2,5
Hochdruck/Saugdruck [bar]	4 / 3	15,6 / 3	16 / 4	22 / 1,2	16 / 2,5
Unterkühlung vor EXV [K]	5 ± 0,5				
Überhitzung vor EKK [K]	10 ± 0,5			80 % Dampf	80 % Dampf

- heat-pumps will come widely
- quick-charging eVehicles required huge peak cooling demands up to 15kW (!)
- heat-exchangers, air flows and compressors must grow in size

R134a / R1234yf

R744

R290

Increasing heating and cooling demand compressor impact

- Max. Speed higher — 8600 → 11.000 1/min (target conflict NVH)
- Displacement increase (e.g. R134a) — 27 → 34 → 45 → 50+ ccm (target conflict packaging)
- Vapour Injection Systems — optional / design modifications on compressor
- Ejectors in systems — no direct compressor impact

R134a / R1234yf

27 bis 50+ ccm

R744

5 bis 9 ccm

R290

20 bis 42cc

Scroll Compressor is state of art today for edriven platforms R1234yf/R744/R290

R134a / R1234yf

27 to 50+ ccm

R744

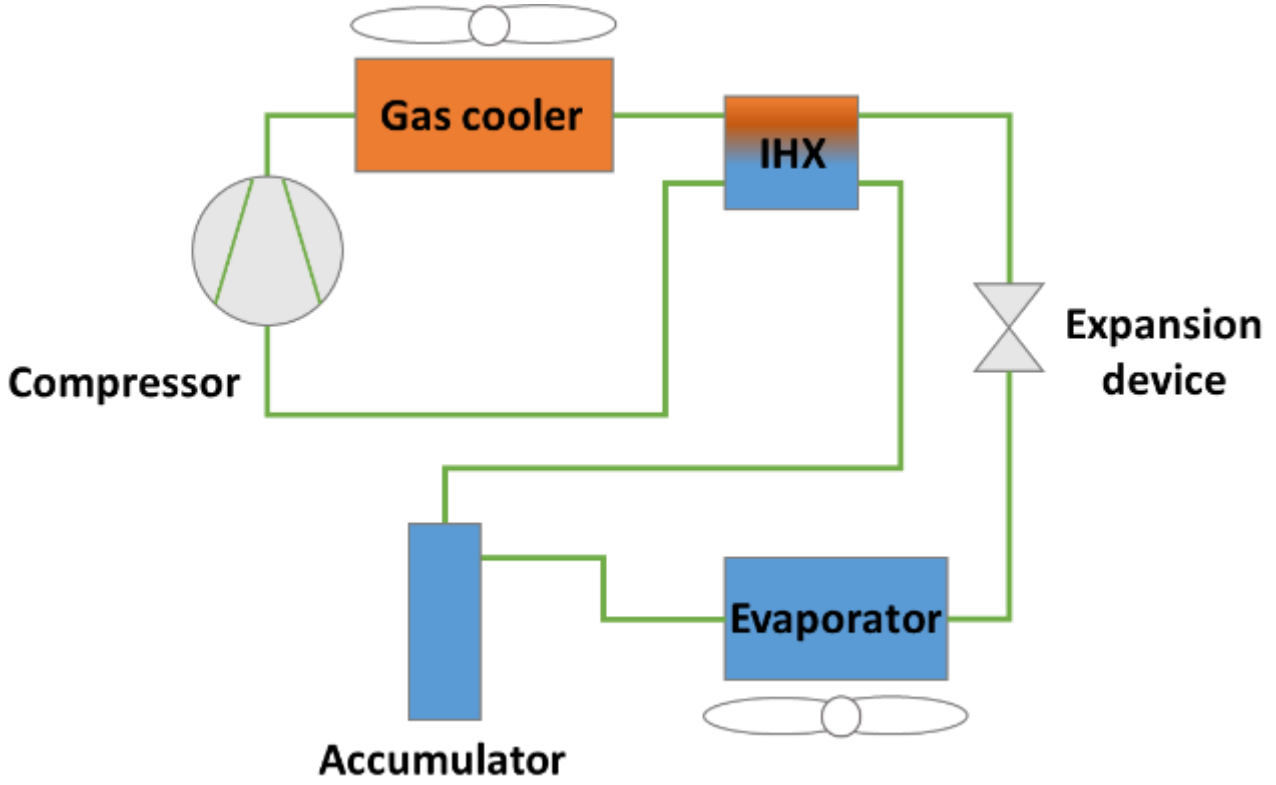
5 to 9 ccm

R290

20 to 42cc

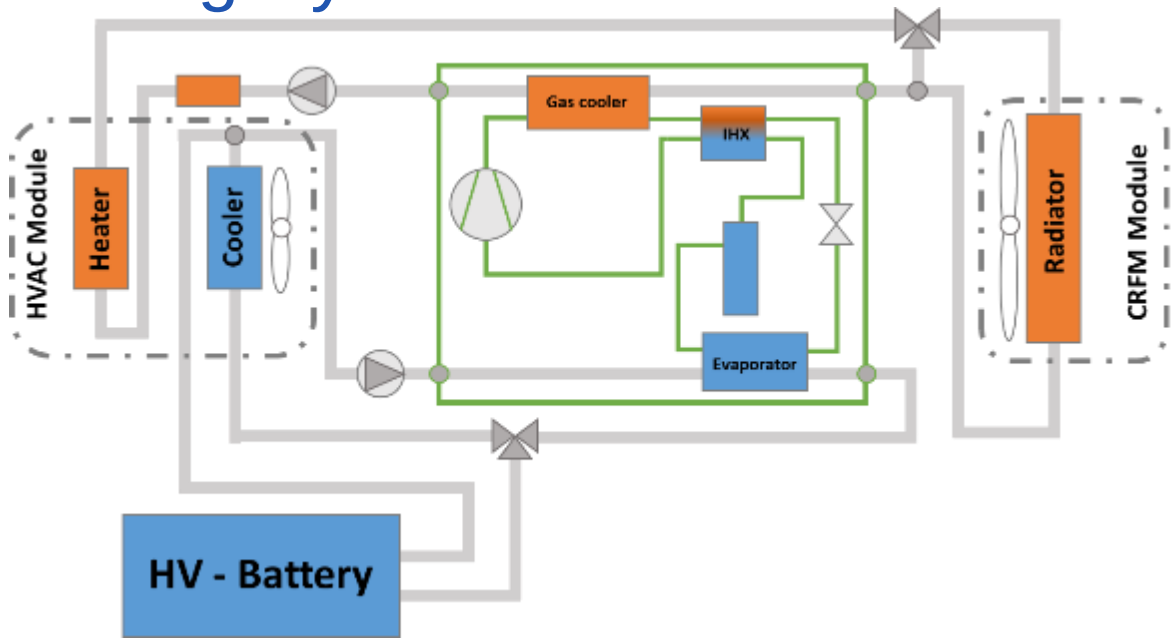
The Standard R744 A/C System AC-only as S-Class 2016

- Standard R744 A/C circuit with IHX and accumulator
- Accumulator positioned on low pressure side
- Internal heat exchanger after gas cooler and after evaporator
- Electrical expansions device for control and COP optimization
- Wide operating in trans-critical conditions (“gas cooler”)



Coolant-Based AC/HP/BatteryCooling Systems indirect/indirect

- New vehicle structures have more heat sources and heat sinks to cover
- Indirect systems with coolant and compact refrigerant loops are discussed / partly already in market (e.g. Tesla or BMW on condenser side)
- Simplification on refrigerant side, complexity moved to coolant
- Enabling ultra-compact modules and entry door for R290 with low charge amount
- Drawbacks on dynamic/BOM



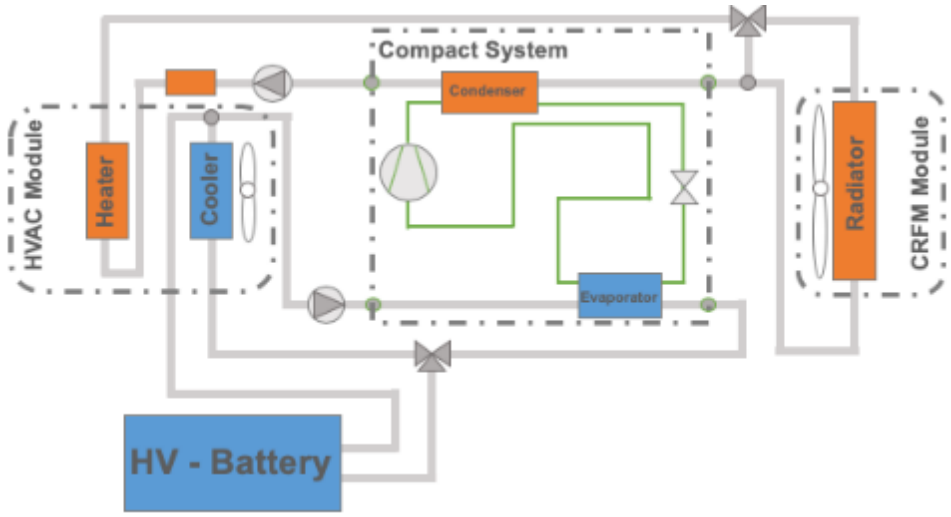
Example1: Hanon propane system

Example2: brose compact system

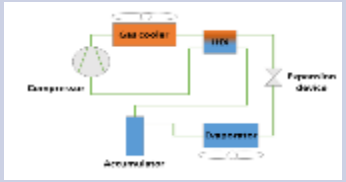
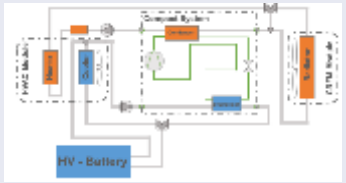
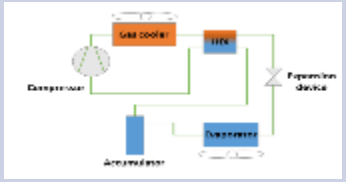
Example3: OE compact system

OE R290 Compact System indirect/indirect 6kW

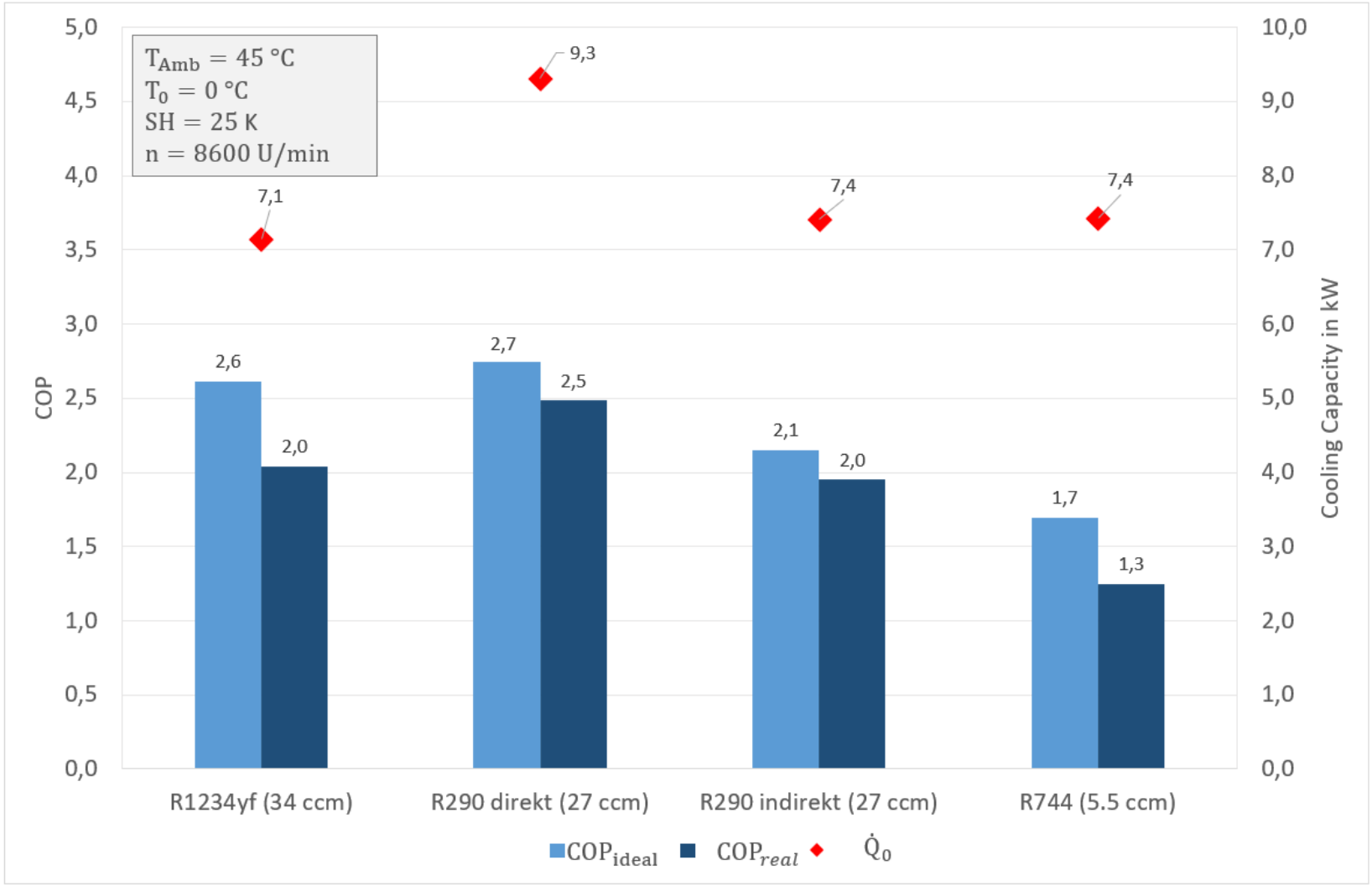
- 6kW heating and cooling reached and confirmed in testing
- 27cc OE eScroll R290
- Small/mid-size vehicle setup in first place
- Charge amount below 150g confirmed
- High integrated Al bracket with all refrigerant components – w/o any piping
- But: challenging dynamic / heat-up behaviour esp. at low ambient



Options for Future BEV A/C&HP Natural Refrigerant System Variants

System	Advantages	Disadvantages
R290 direct 	• Excellent Ref. for +/- temp • Best thermodynamic properties • Best system efficiency	• Flamability issue • R290 components within passenger compartment • No SNAP approval
R290 indirect 	• Low Ref. charge • Good thermodynamic properties • Additional Parts / longer BOM	• Flamability • 150gram vs. 500gram rule • No SNAP approval • Thermal/Dynamic losses – indirect losses • BOM / coolant side complexity
R744 direct 	• HP COPs very good • SNAP OK • In automotive mass production since 2016 • Established in stationary applications	• Charge amount determination AC/HP/BC • Trained Staff required • Hot ambient > 35°C low COP

Simulation Results AC-Max 45°C ambient R1234yf vs. R290 vs. R744



at hot ambient R744 has significant COP disadvantages

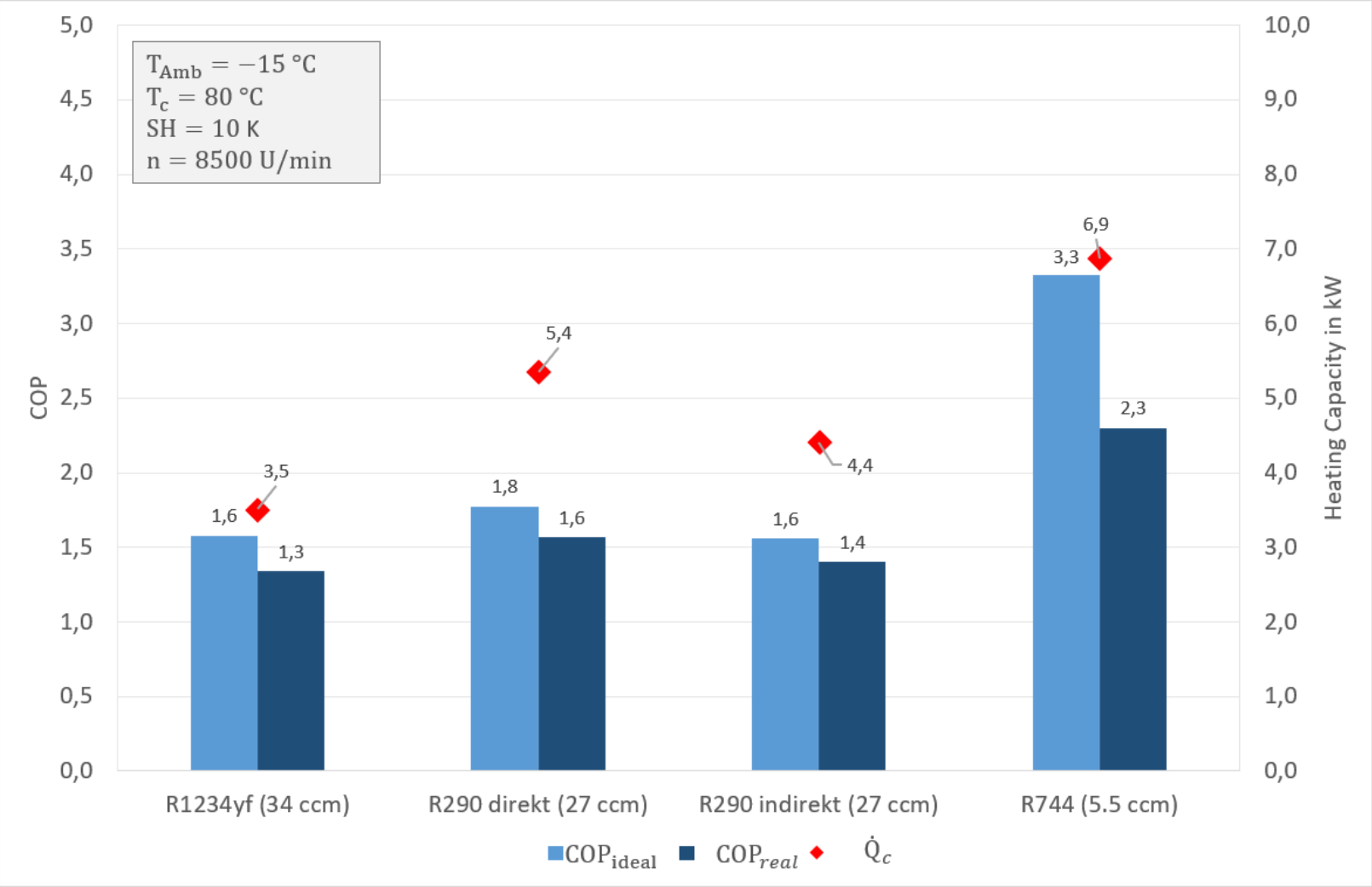
Cooling power > 7kW can be reached

R290 direct with best COP and max. cooling power

R290 indirect with same COP than R1234yf direct.

R744 in hot ambient (e.g. Dubai) requires add-on measures for COP improvements (e.g. Ejector, flash-gas, etc.)

Simulation Results HP-Max at minus 15°C ambient R1234yf vs. R290 vs. R744



R744 reaches best COP and highest peak heating power

R290 direct has better COP and significant max. heating power

NOTE: below minus 15degC ambient temperature R1234yf is operated below 1 bar abs. on suction side. Many OEM limit usage of R1234yf at low temperatures

Summary R290 and R744 Automotive Applications

R744
UN 1013
GWP 1
Carbon dioxide
CO_2 • CAS 124-38-9

- By TFA discussion OEMs and Tier1s are unsure on further usage of R1234yf
- Beside blends and next chemical inventions R290 and R744 are intensively discussed (again)
- R744 is already out there on the road with Daimler S-Class and VW ID.3
- R744 COP-wise in middle/colder climates well situated
- R744 works at hot climates but looses COP, ad-on features (e.g. Ejectors in discussion)
- R290 needs special attention towards safety (remark: R1234yf is flammable as well)
- Compact systems for R290 offer possibility on significant charge amount reduction, but loose efficiency and dynamic behaviour by that
- China could play a significant role in driving natural refrigerants for automotive applications
- Scroll compressor is state of art for all options of refrigerants and direct/indirect systems

Summary OEM 2021 Directions refrigerant choice and swap

R744
UN 1013
GWP 1
Carbon dioxide
CO_2 • CAS 124-38-9

OEM Type 1 – “I will wait on legal situation to come – no change until than”

OEM Type 2 – “I am preparing for R744, R290 or blend to replace R1234yf”

OEM Type 3 – “R744 COP at hot ambient is not sufficient, no option for me”

OEM Type 4 – “R290 safety not clear – I will not be the first mover”

OEM Type 5 – “I do the last change in refrigerant now to natural one”

Struggling with “world wide solution” – different safety / legal situation / ambient conditions esp. R290 legal/safety situations

A green AC/HP is not really used as a unique selling point, except increasing driving range in winter.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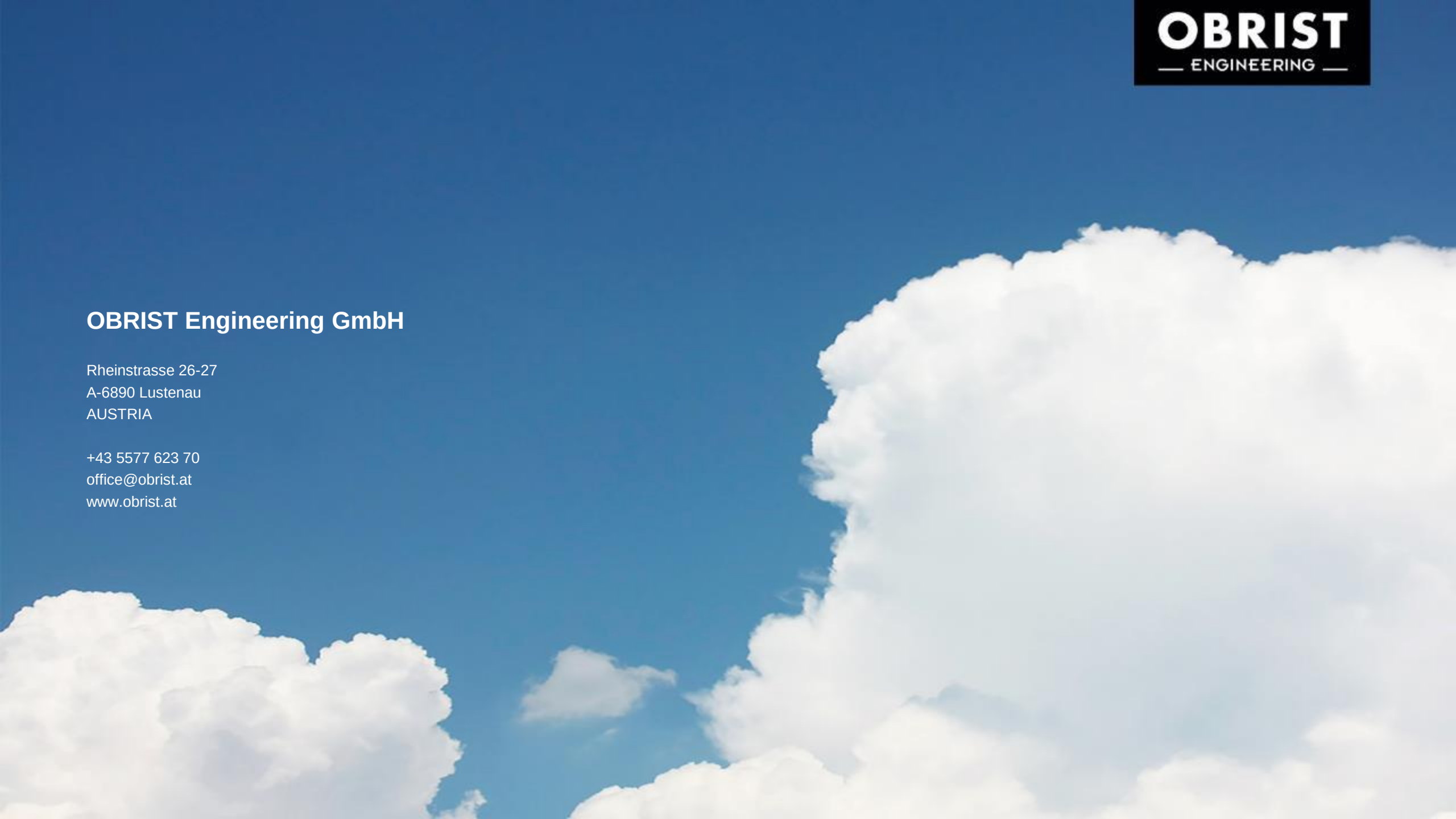

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