

2018 Ozone2Climate Industry Roundtable



The place of R-513A in the phase-out of R-22. Application to screw chillers

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Summary

- General context
- Currently used technologies for chillers
- How to replace R-22 while keeping energy efficiency?
 - Need to use lower pressure fluids (category of R-134a)
- Comparison between R-134a and its alternatives.
- Criteria for choice
 - importance of analyzing life time CO₂eq emissions
- Advantages of R-513A

General Context: What is changing ?

- **Environmental constraints on fluids:** The elimination of ODS's is completed or ongoing per the Montreal Protocol.
- Now additional Constraints on GWP (EU « F-Gas », Kigali Amendment)
 - Mandatory reduction of HFC's with high GWP.
- Potential alternative Fluids:
 - HFC's with lower GWP
 - HFO's
 - HFC/HFO blends → Learn where and how to use blends properly
 - « Natural » Fluids (Ammonia, CO2, Hydrocarbons)
- More stringent **energy efficiency requirements** (EU « Ecodesign », regional standards, requirements from Kigali)
- **Safety consideration**
 - « Old » refrigerants were mostly non flammable
 - Many potential alternatives are flammable
 - ... and often mildly flammable, like R-32, HFO's, some HFC/HFO blends
 - New « 2-L » flammability class
 - Ongoing revisions of safety standards and codes.

Chillers: Currently used Refrigerants and Technologies

Main focus of
this presentation



Typical refrigerants and compressor types depending on cooling capacity				
kW	R-22	R-123	R-410A	R-134a
< 400	Scroll	/	Scroll	/
< 1500	Screw	Centri	Screw	Screw
< 6000	Centri	Centri	/	Centri
Up to 20000	Centri	/	/	Centri

	Status of Refrigerants				
		R-22	R-123	R-410A	R-134a
		HCFC		HFC	
	ODS	Yes		No	
	GWP	1760	79	1900	1300
Use Today	Art.2	X	X	X	X
	Art.5			X	X
Future	Global	Phase Out		Phase Down	

All 4 dominant fluids used in chillers
now subject to phase out or phase-down !

Dilemma: how to replace R-22 for chillers ?

- R-22 is a very efficient fluid for many applications, including chillers.
- High energy efficiency is needed, especially for large capacity chillers.
- But there exists no fluid combining:
 - Capacity in same range as R-22.
 - Similar cycle efficiency.
 - Little or no glide (needed for high efficiency).
 - Acceptable safety.

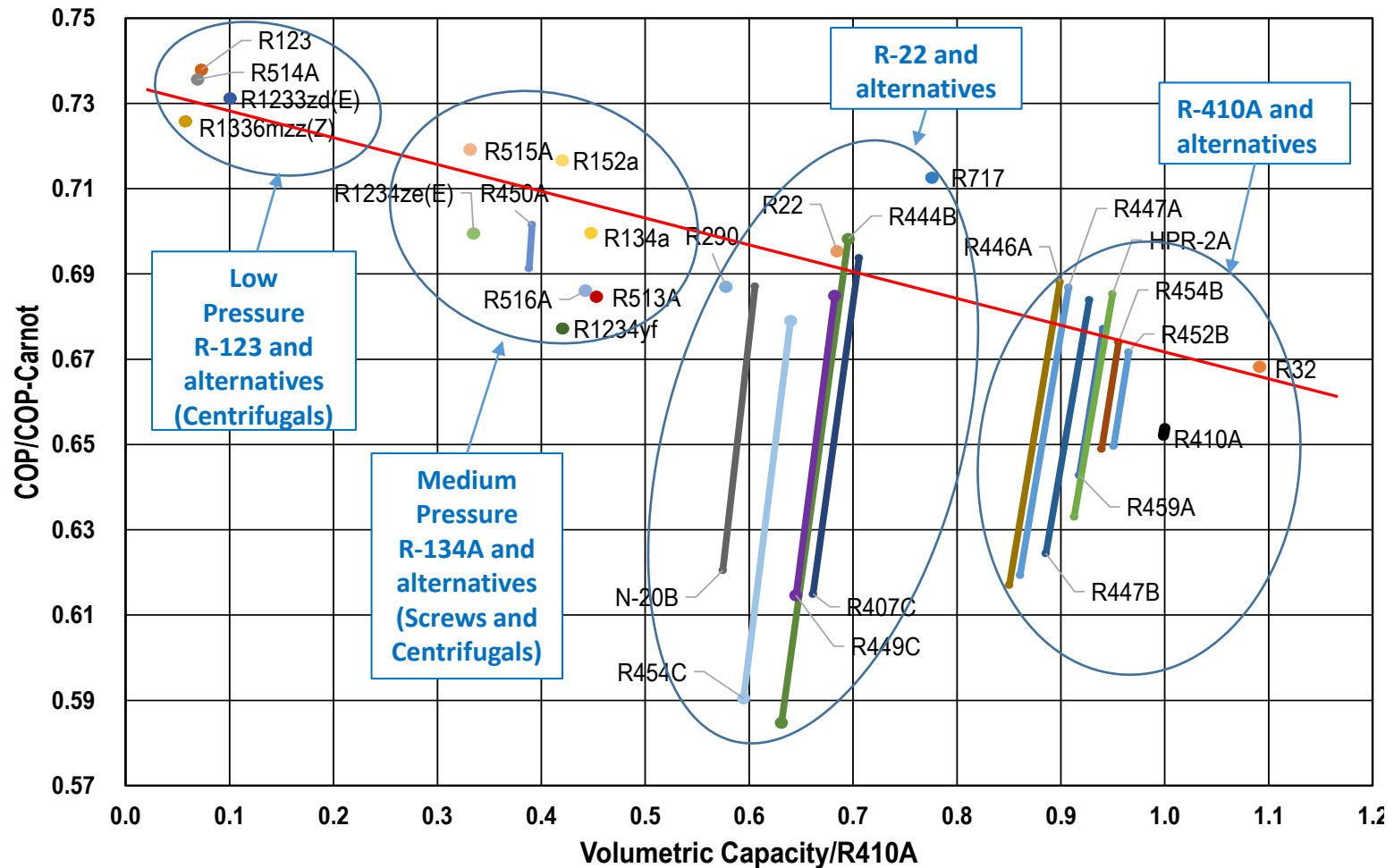
→ No direct replacement of R-22 for chillers exists at this stage.
→ A change of fluid category is needed.
→ Significant design change of units.
→ For high efficiency, it must be a lower pressure fluid.

How to optimize Energy Efficiency ?

- **Keep the best of existing technologies**, including
 - High efficiency compressors.
 - Enhanced cycles (liquid subcooling, economizers).
 - Variable speed motors.
- Use **refrigerants with high cycle efficiency**.
- Use the **best heat exchanger technologies**:
 - Evaporators :
 - D-X evaporators no longer used: less efficient.
 - Mostly flooded or falling film.
 - Condenser:
 - Air cooled: In-tube condensation (often micro-channel)
 - Water cooled: Shell and tube with external condensation.

WARNING ! With state of the art evaporators and water-cooled condensers, blends with glide induce large performance penalties → must be avoided

Refrigerants: overview of proposed alternatives



→ Alternatives to R-22 have either safety issues (Ammonia, R290), or unacceptable high glide.

→ Fluids with lower pressure (like R-134a or R-123) have better COP, and also lower GWP.

Dilemma: how to replace R-22 chillers ?

- R-22 is a highly efficient fluid for chillers, widely used with screw compressors. But there exists no fluid combining:
 - Compliance with new environmental requirements
 - Capacity in same range as R-22.
 - Similar cycle efficiency.
 - Little or no glide (required for good exchangers).
 - Acceptable safety.
- Therefore:
 - No direct replacement of R-22 for chillers exists at this stage.
 - A change of fluid category is needed.
- Higher pressure fluids have lower COP and higher GWP.

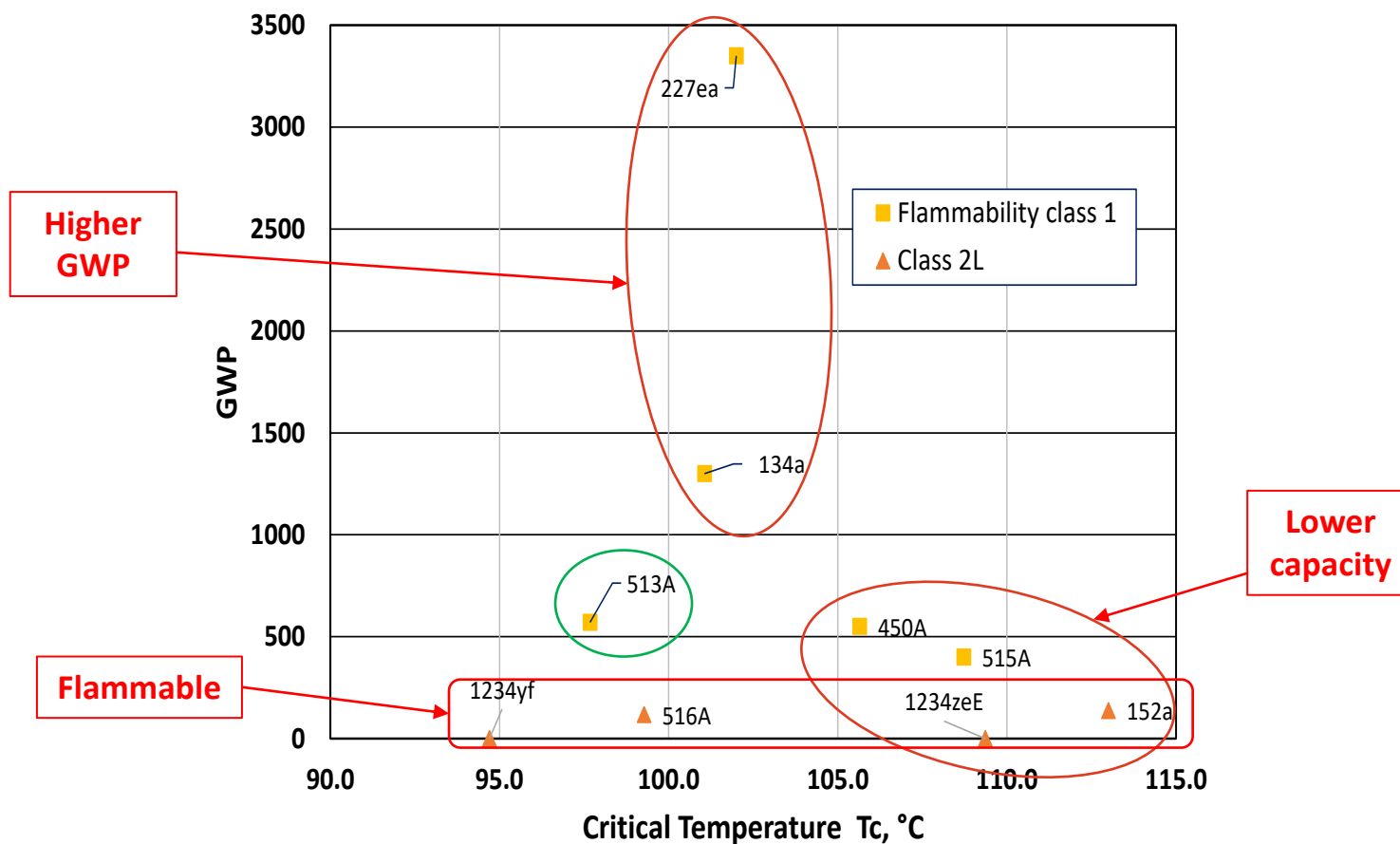
→ For high efficiency and low GWP, alternatives to R-22 must be lower pressure fluid, in the category of R-134a.

→ But this requires significant design change of units.

Zoom on R-134a and its alternatives

R-N°	At 40°C		GWP 100		Safety Class	Compositions by mass				
	Press.	Glide				134a	1234yf	1234ze	152a	227ea
	Bar-a	K	(AR5)	AR4						
227ea	7.0	/	3350	3220	A1					100
515A	7.6	/	400	380	A1			88		12
1234zeE	7.7	/	6	1	A2L			100		
450A	8.9	0.63	550	601	A1	42		58		
152a	9.1	/	138	124	A2				100	
134a	10.2	/	1300	1430	A1	100				
516A	10.5	0.01	131	140	A2L	8.5	77.5		14	
513A	10.7	/	570	630	A1	44	56			

Comparisons GWP / Flammability

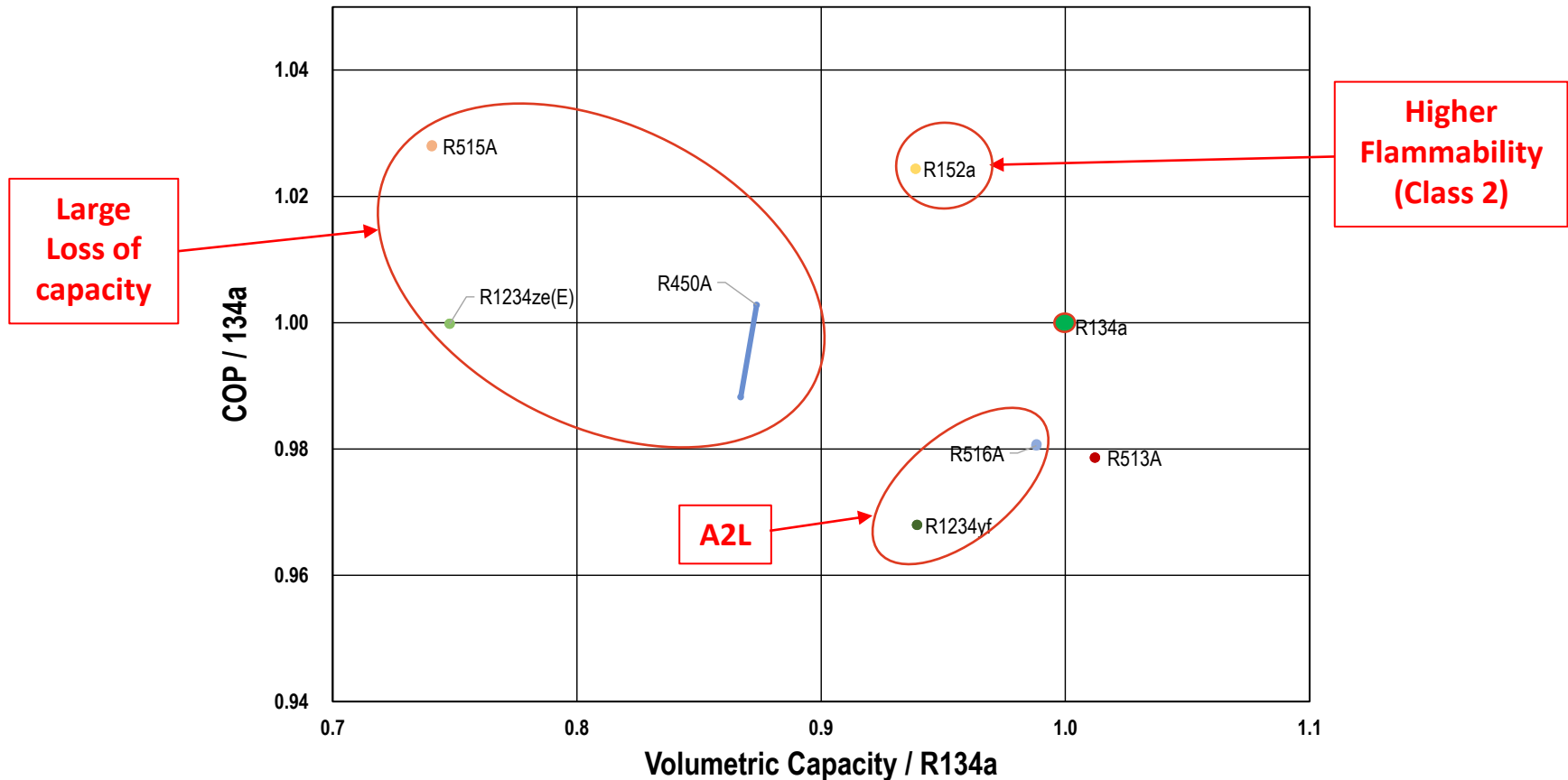


R-513A is best compromise of non-flammable, and low GWP without big loss in capacity

What is R-513A ?

- **A non-flammable drop-in alternative to R-134a, with GWP as low as possible.**
 - The blend is **azeotropic** (behaves as a pure compound).
 - Cooling capacity very close to R-134a.
- A blend of HFC R-134a and HFO R-1234yf. Respective mass composition 44 / 56%.
- The HFO is mildly flammable (A2L), but mixed with enough non-flammable R-134a → blend non-flammable.
- The HFO has near-zero GWP. The GWP (AR-4) of R-134a is 1300. The resulting GWP of the blend is 570 → 44% of GWP of pure R-134a.
- **Is R-513A an alternative to R-22?**
 - **No:** like R-134a, its cooling capacity is about 40% lower than R-22.
 - → is not a possible retrofit to R-22 in existing systems.
- **But** new systems using R-513A are suitable for applications that were formerly using R-22, like in chillers, or in D-X systems when the evaporating pressure is not too low ($>-15^{\circ}\text{C}$).

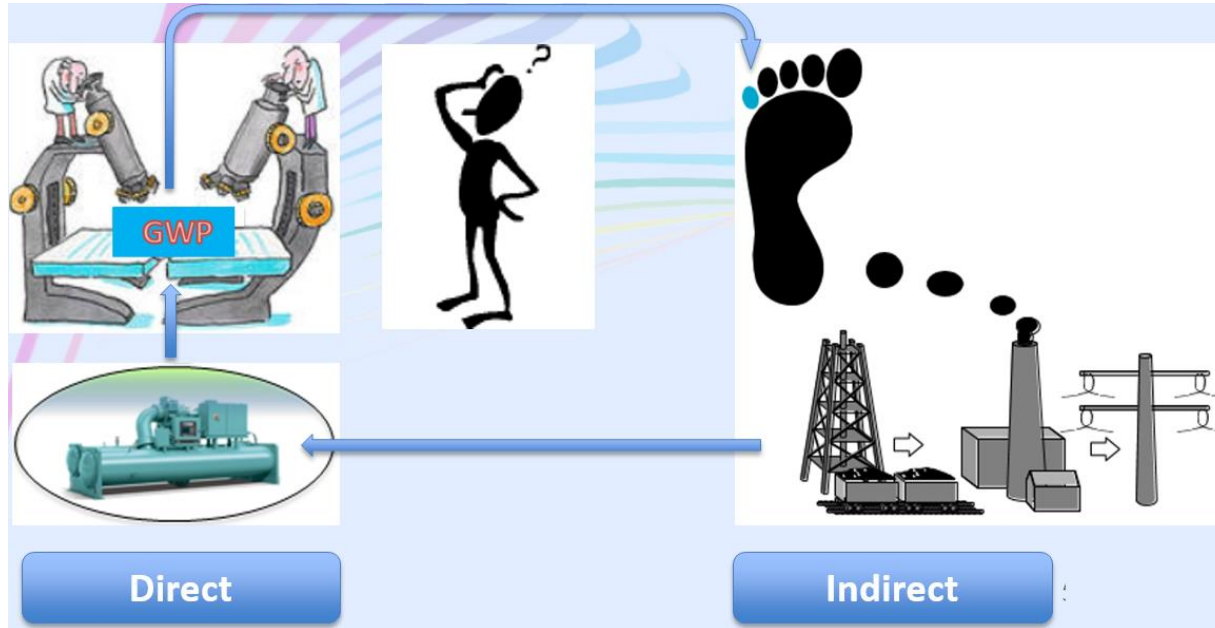
Capacity and COP Comparisons



R-513A is best compromise of non-flammable, and low GWP without big loss in capacity. Yet, theoretical COP 2% lower than R-134a (confirmed by test results)

Ambiguities

- For reduction in Greenhouse gasses emissions, major focus on the GWP of fluids.
- But « indirect » emissions from energy consumption often account for more than 90% of total emissions.
- For relevant decisions, more emphasis is needed on Life Cycle approaches (« TEWI » ou « LCCP ») including both sources of emissions:
 - Direct (leakage of fluid)
 - Indirect (energy consumption).



Guiding Principles

- Stability
- Efficiency
- Capacity
- Low GWP



- Availability
- Cost of ownership
- Customer preference
- Intellectual property
- Regulatory certainty
- Adjacent sector demand

- Safety code compliance
- Operator training
- Insurance cost
- Reliability
- Legal risk

Dilemma: R-513A or 134a ?

- Both are non-flammable, with nearly equal capacity.
- R-513A has lower GWP, but about 2% more energy consumption.
- Depending on the application of the chiller, the total CO_{2eq} life cycle emissions (LCCP) can still be lower with R-134a in spite of higher GWP.
- LCCP comparison for the application is a useful tool to decide between both fluids.
- A chiller built for R-134a can generally be retrofitted to R-513A (to be confirmed by supplier of chiller).

Chillers built for R-134a are future-proof if replacement of R-134a becomes necessary for reasons of local legislation, or cost of refrigerant.

Conclusions

- There is no alternative nearly equivalent to R22 to be efficiently used in screw chillers.
- To keep the energy efficiency, a lower pressure fluid must be used (R-134a or equivalent).
- All the alternatives to R-134a are either
 - flammable (class 2L or even class 2 for R-152a)
 - ...or (and) have substantial loss of capacity.
- Only the blend R-513A is non-flammable, with capacity nearly equivalent to R-134a.

→ R-513A is a most interesting option to replace R-22 (and R-134a) in screw chillers.

Thank you
for your attention



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