

HFO refrigerant for long in the future Air Source Heat Pump

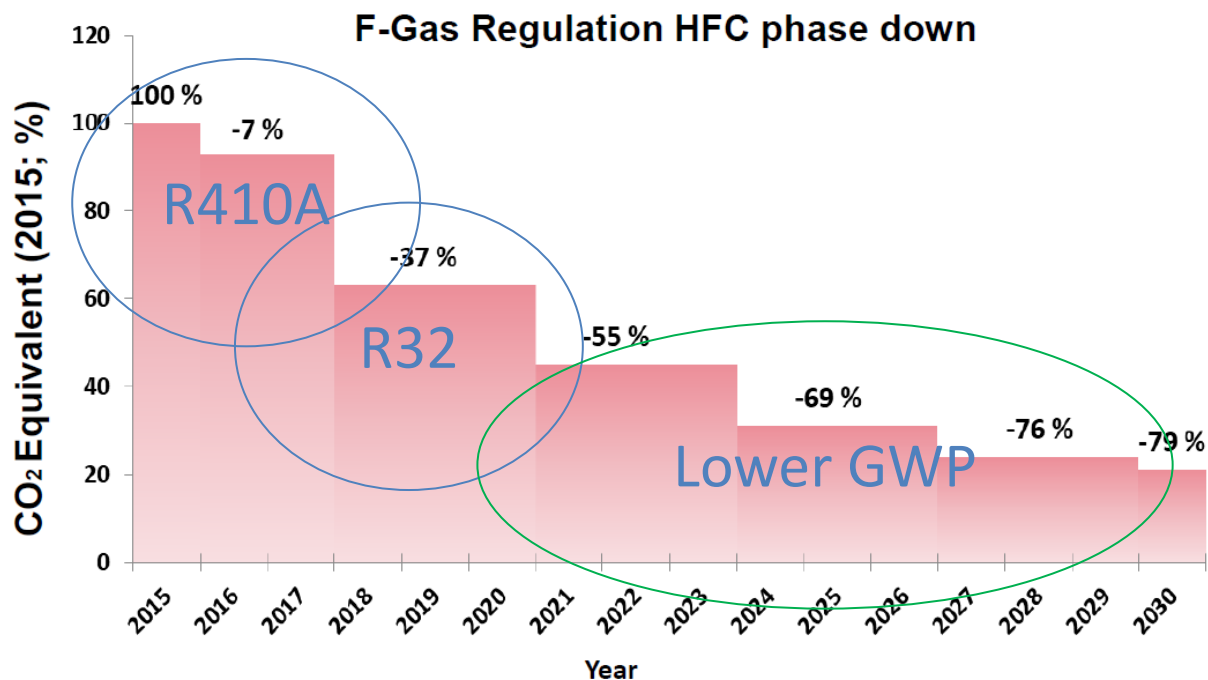
CONNECTING
HEAT PUMP
EXPERTS.



HFO refrigerant for long in the future Air Source Heat Pump

Loic Chereau

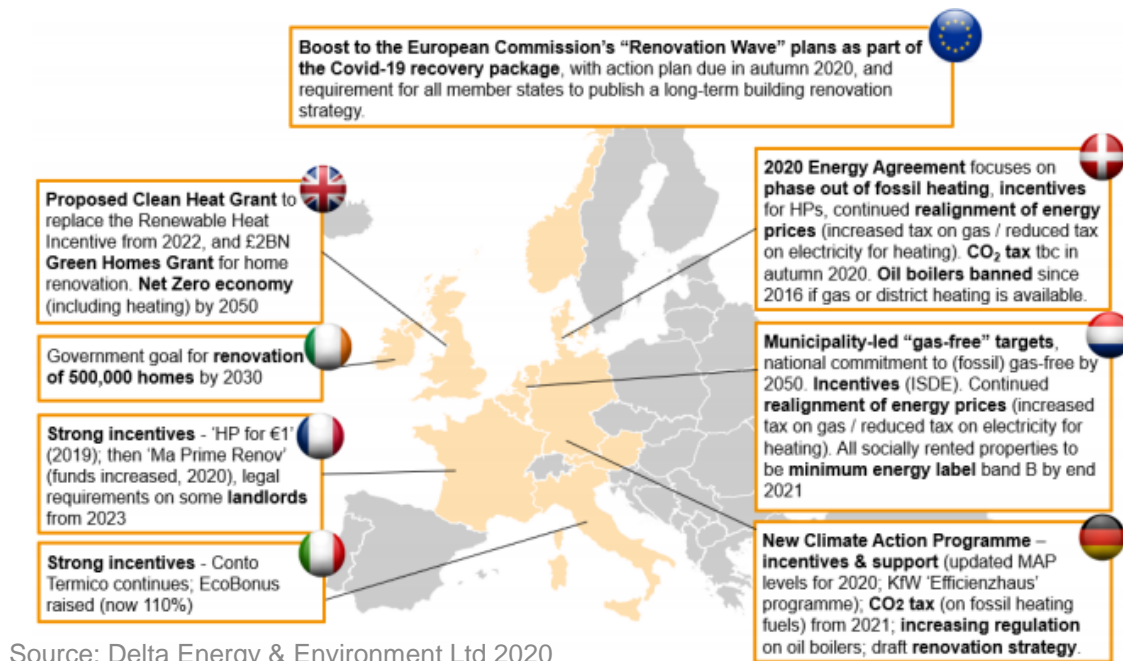
European Heat Pump dynamics and challenges



- EU Green Deal drive CO₂ reduction with F-Gas II regulation enforcement
- Heat pump sales are expected to grow strongly, supported by government subsidies and policies and/or decreasing costs to install and run
- Interim trend for R32 as a replacement for R410A with need to look long in the future
- Enable lower GWP alternative refrigerants to R410A and R32 as drop in/near drop in solutions



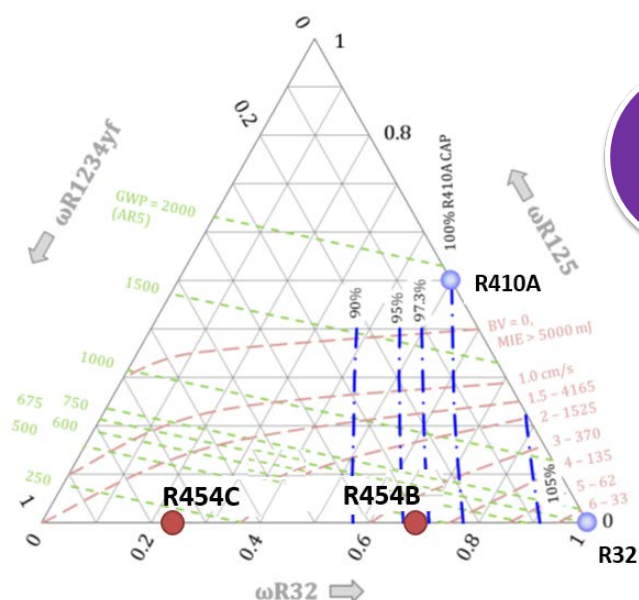
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Source: Delta Energy & Environment Ltd 2020

Long term horizon refrigerant selection Opteon™ platform

Refrigerant	Composition	GWP	Temp. Glide (oC)	Safety Class
R410A	R32/R125 (50/50 %wt)	2088	0.1	A1 / Fluid Group 2 (PED)
R32	R32 (100 %wt)	675	0	A2L / Fluid Group 1 (PED)
R452B - Opteon™ XL55	R1234yf/R32/R125 (26/67/7 %wt)	676	1	A2L / Fluid Group 1 (PED)
R454B - Opteon™ XL41	R1234yf/R32 (68.9/31.1 %wt)	466	1.5	A2L / Fluid Group 1 (PED)
R454C - Opteon™ XL20	R1234yf/R32 (78.5/21.5 %wt)	146	6	A2L / Fluid Group 1 (PED)
R1234yf- Opteon™ XL10	R1234yf (100 %wt)	< 1	0	A2L / Fluid Group 1 (PED)



R454B

GWP: 467 -76% vs R410A
-31% vs R32

R454C

GWP: 146 -91% vs R410A
-77% vs R32



Opteon™ refrigerants for heat pumps

- Air source HP (air-to-water): Opteon™ XL41 and Opteon™ XL20 for R410A and R407C replacement
- Water heater HP and mobile HP: Opteon™ XL20 and XL10 for R134a replacement. (*Opteon™ XP10 – R513A option)
- Industrial tumble dryer HP: Opteon™ XL20 and XL10 for R134a replacement where no flammable



Heat Pump safety standards and requirements



- European Safety standard EN378 (supports flammable refrigerants)
- Safety standard EN60335-2-40 for Heat Pump
 - IEC 60335-2-89 (Com. Ref.) since 2019 supports some flammable refrigerants A3 up to 0.5kg and A2L up to 1.2kg (LFL)
- National and Regional building codes prevails



A2L refrigerants can reduce the flammability risks compared to A3 (R290) given:

- A2Ls by volume is typically needed to form a flammable mix with air
- A2Ls develop much lower combustion energy and would need more volume to form a flammable mix with air compared with A3s.

Therefore A2Ls are less likely to form flammable concentrations, are harder to ignite making them safe to use with many electric components



Safety requirements to use A3 flammables are more stringent :

- Charge limits
- People skill to avoid hot surfaces / avoid ignition sources

PTAC: A2L vs A3 at m1 charge per UL-60335-2-40



R452B, 1920 grams, 47.4 g/sec
No mitigation
LFL = 11.9% v/v



R290, 114 grams, 21 g/sec
No mitigation
LFL = 2.1% v/v



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R1234yf



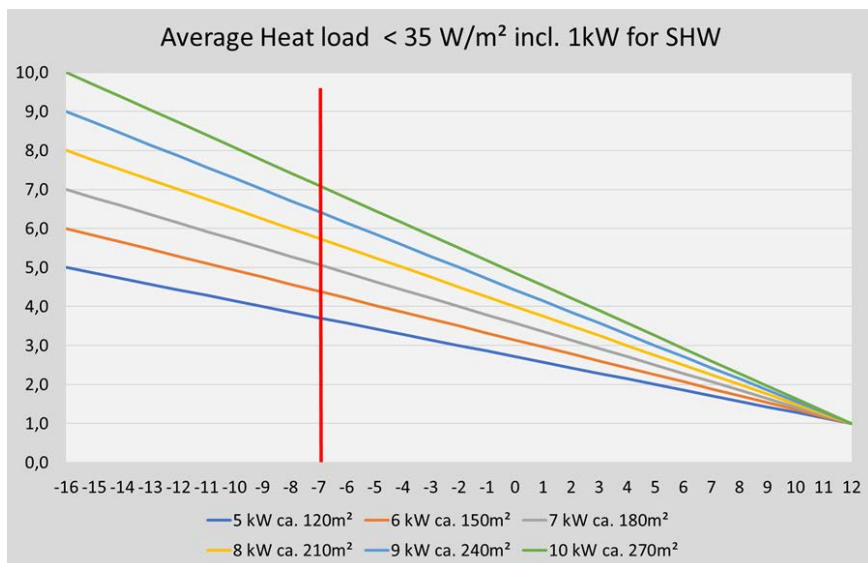
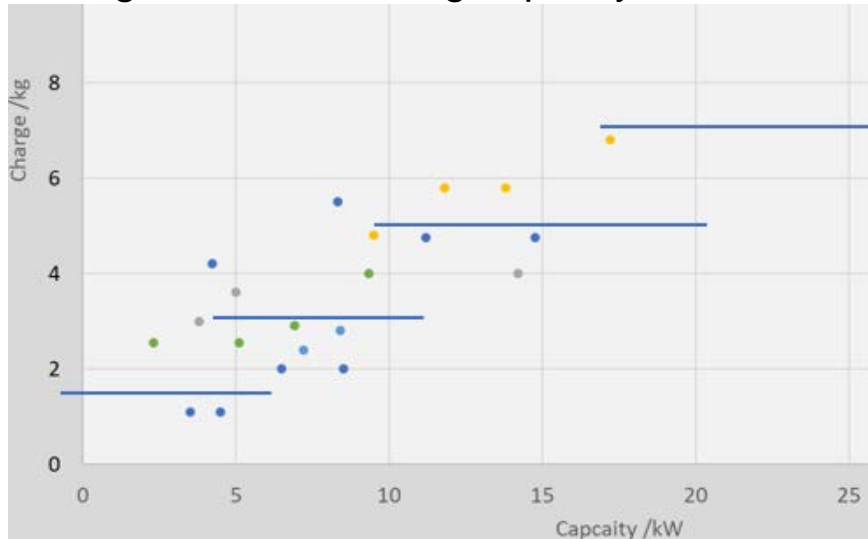
R32



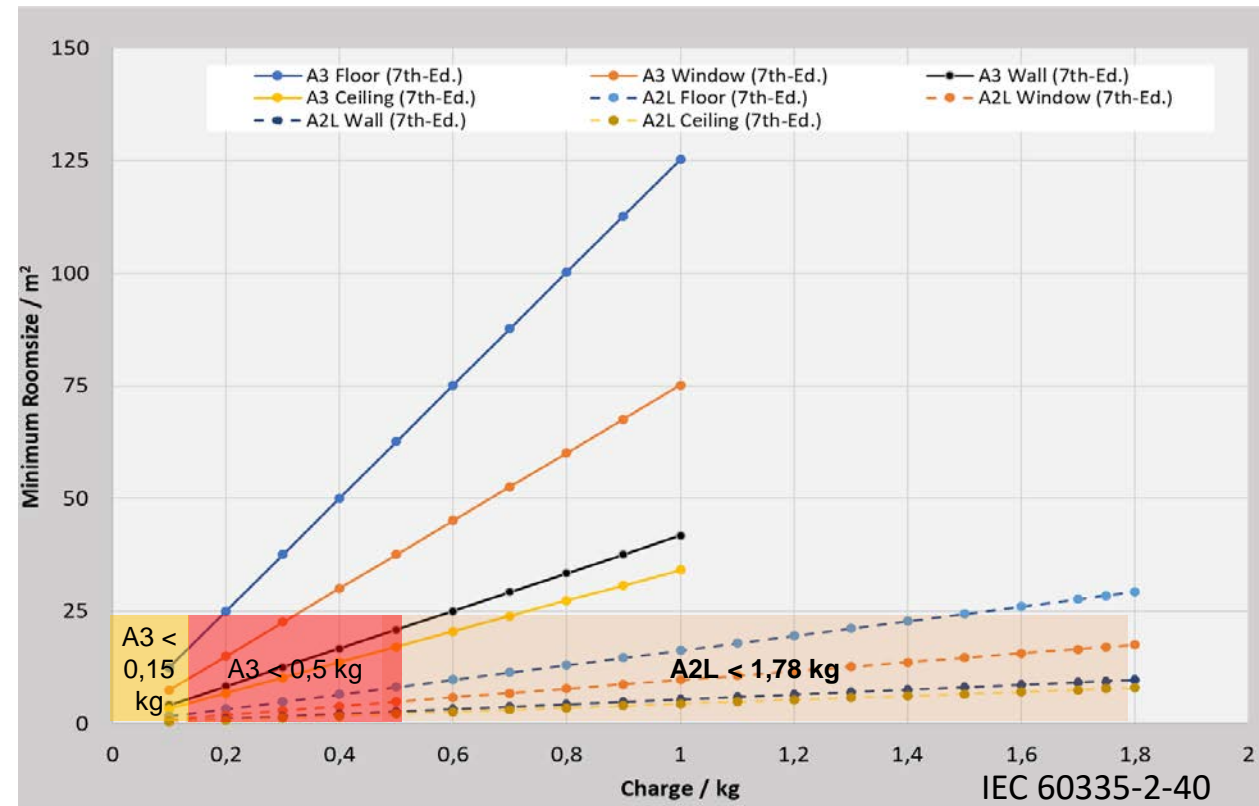
R290

Heat Pump safety standards and requirements

Charge size vs. heating capacity benchmark



- Industry is moving to Support Larger sizes for A3 but with strong limitation on area (m²) indoor
- A2L and A3 are on 2 different markets



<https://www.opteon.com/en/support/helpful-resources/charge-calculator>

Opteon XL41 (R454B) and Opteon XL20 (R454C) tests in AWHP

Alternative of R410A into a 8 kW air-to-water HP in drop-in performance with:

- 3 different refrigerants: R454B, R452B and R32
- 4 different conditions: A7/W55, A2/W55, A-7/W55 and A-15/W55

Alternatives of R407C with:

- 2 different refrigerants: R454B, R454C



Refrigerant charge sizes of R452B, R454B, R32 and R454C are between 8% and 15% than R410A, respectively. (Should improve heat exchanger efficiency with lower pressure drop)

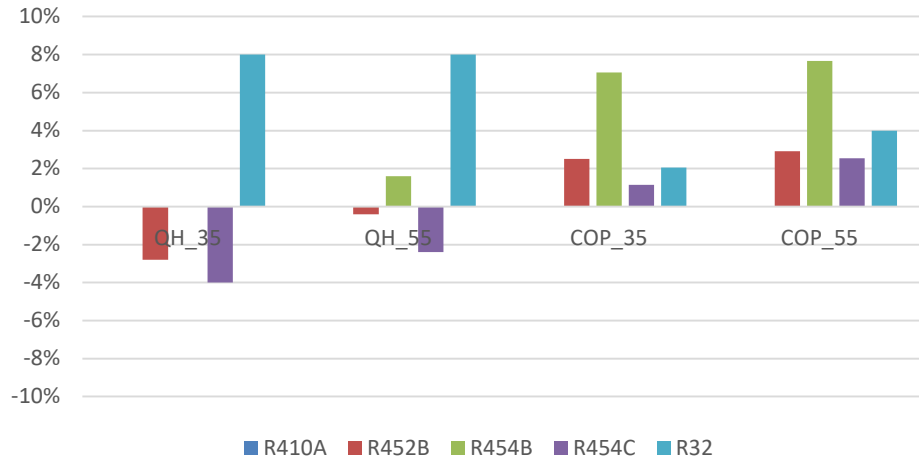


R452B, R454B and R454C allow the use of same POE lubricants as R410A

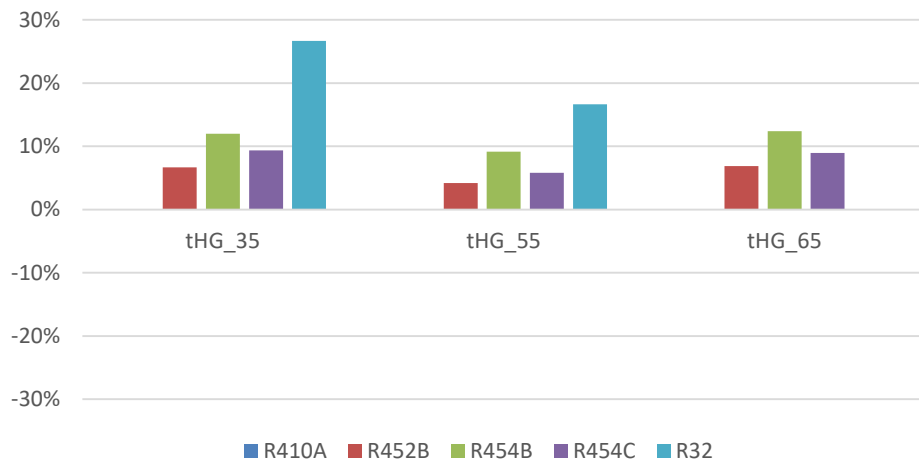


COP and Heating Capacity comparison

Heating and COP performance



Temperature discharge

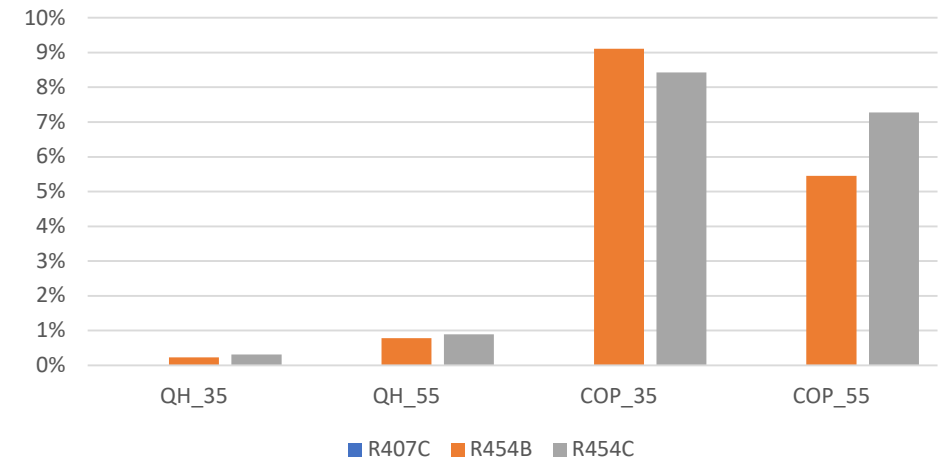


- R-454B has a better efficiency than R410A that provide good alternative to OEMs for lower GHG emissions
- R454C exhibit slightly higher COP than R410A that make a good option for long term
- The discharge temperature of R454B is approx. 8% higher than R-410A that is lower than compressor discharge temperature limit. Save replacement mitigation cost and should improve compressor longevity.

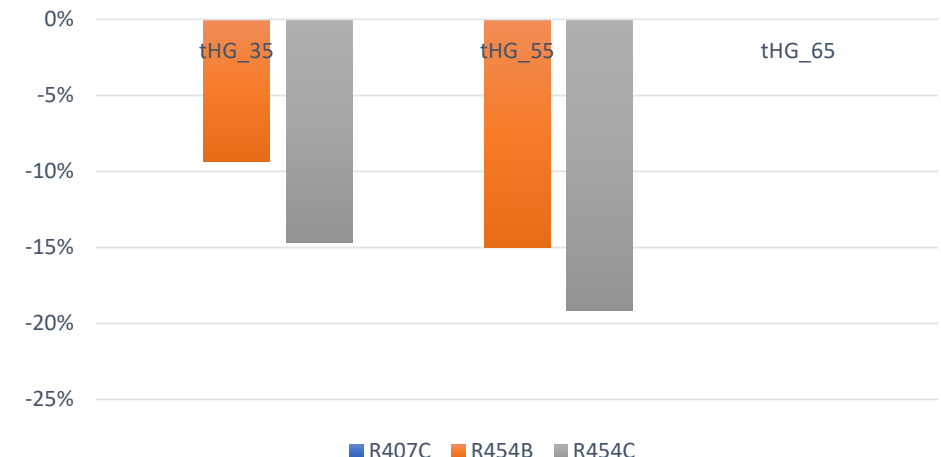
COP and Heating Capacity comparison

- R454B has a better efficiency than R407C that provide good alternative to OEMs at minimum design changes
- R454C exhibit slightly higher COP than R410A that make a good option for long term
- The discharge temperature of R454B is approx. 12% lower than R407C. Will require design optimization

Heating and COP performance



Temperature discharge



LCCP analysis

VDI 4650	Standard Outdoor Temperature /°C	R410A	R32	XL20 (R454C)	XL41 (R454B)
SCOP _H	-10	4,83	4,91	4,92	4,91
SCOP _H	-12	4,70	4,78	4,79	4,78
SCOP _H	-14	4,55	4,62	4,62	4,62
SCOP _H	-16	4,44	4,52	4,52	4,52
SCOP _W	-16	3,62	3,68	3,69	3,67
SCOP _{HP} (Total)	-16	4,25	4,32	4,33	4,32

Outdoor Temp. (°C)		R410A	R32	XL20 (R454C)	XL41 (R454B)
COP	-15	3,14	3,16	3,16	3,20
	-7	3,65	3,71	3,69	3,71
	2	4,45	4,52	4,52	4,52
	7	5,06	5,14	5,16	5,14
	12	5,86	5,95	6,00	5,95

Outdoor Temp. (°C)		Q _H	R410A	R32	XL20 (R454C)	XL41 (R454B)
Power Input (kW)	-15	12	3,82	3,80	3,80	3,75
	-7	7,32	2,01	1,97	1,98	1,97
	2	4,44	1,00	0,98	0,98	0,98
	7	2,88	0,57	0,56	0,56	0,56
	12	1,32	0,23	0,22	0,22	0,22

"COLD" Helsinki
"AVERAGE" Strassburg
"WARM" Athens

COLD	Outdoor Temp. (°C)	Hours/a	R410A	R32	XL20 (R454C)	XL41 (R454B)
Annual power consumption / kWh	-15	327,00	1.250	1.242	1.242	1.226
	-7	1260	2.527	2.486	2.500	2.486
	2	2731	2.725	2.683	2.683	2.683
	7	1240	706	695	692	695
	12	888	200	197	195	197
Total		6.446	7.407	7.302	7.311	7.287
Costs /kwh	0,24 €					
Annual Operating costs			1.777,74 €	1.752,54 €	1.754,74 €	1.748,82 €
AVERAGE	Outdoor Temp. (°C)	Hours/a	R410A	R32	XL20 (R454C)	XL41 (R454B)
Annual power consumption / kWh	-15	0,00	0	0	0	0
	-7	348	698	687	690	687
	2	1891	1.887	1.858	1.858	1.858
	7	1642	935	920	916	920
	12	1029	232	228	226	228
Total		4.910	3.751	3.692	3.691	3.692
Costs /kwh	0,24 €					
Annual Operating costs			900,25 €	886,19 €	885,77 €	886,19 €
WARM	Outdoor Temp. (°C)	Hours/a	R410A	R32	XL20 (R454C)	XL41 (R454B)
Annual power consumption / kWh	-15	0,00	0	0	0	0
	-7	0,00	0	0	0	0
	2	88	88	86	86	86
	7	1019	580	571	569	571
	12	2483	559	551	546	551
Total		3.590	1.227	1.208	1.201	1.208
Costs /kwh	0,24 €					
Annual Operating costs			294,50 €	289,98 €	288,35 €	289,98 €

The model outline the attractiveness with **3% reduction of the operating life-cycle costs with R454B and R454C vs. R410.**



Rem: Additional capital and maintenance cost to be added for the full LCCP costs.

A2Ls lower flammability vs. R290 will benefit ease of installation and maintenance

Summary

- A2L solutions for R410A replacement features good performance: selection is based on GWP and performance
 - Opteon [™] XL41 (R454B) showed the closest performances with R410A with a GWP < 675.
 - Opteon [™] XL20 (R454C) has the Lowest GWP between all A2Ls, whilst enable the R410A replacement with some redesign (Internal HEX, EVI)
- Recent adoptions by some key OEMs are demonstration the A2Ls benefit in Air Source HP and Chillers.

Thank you!

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