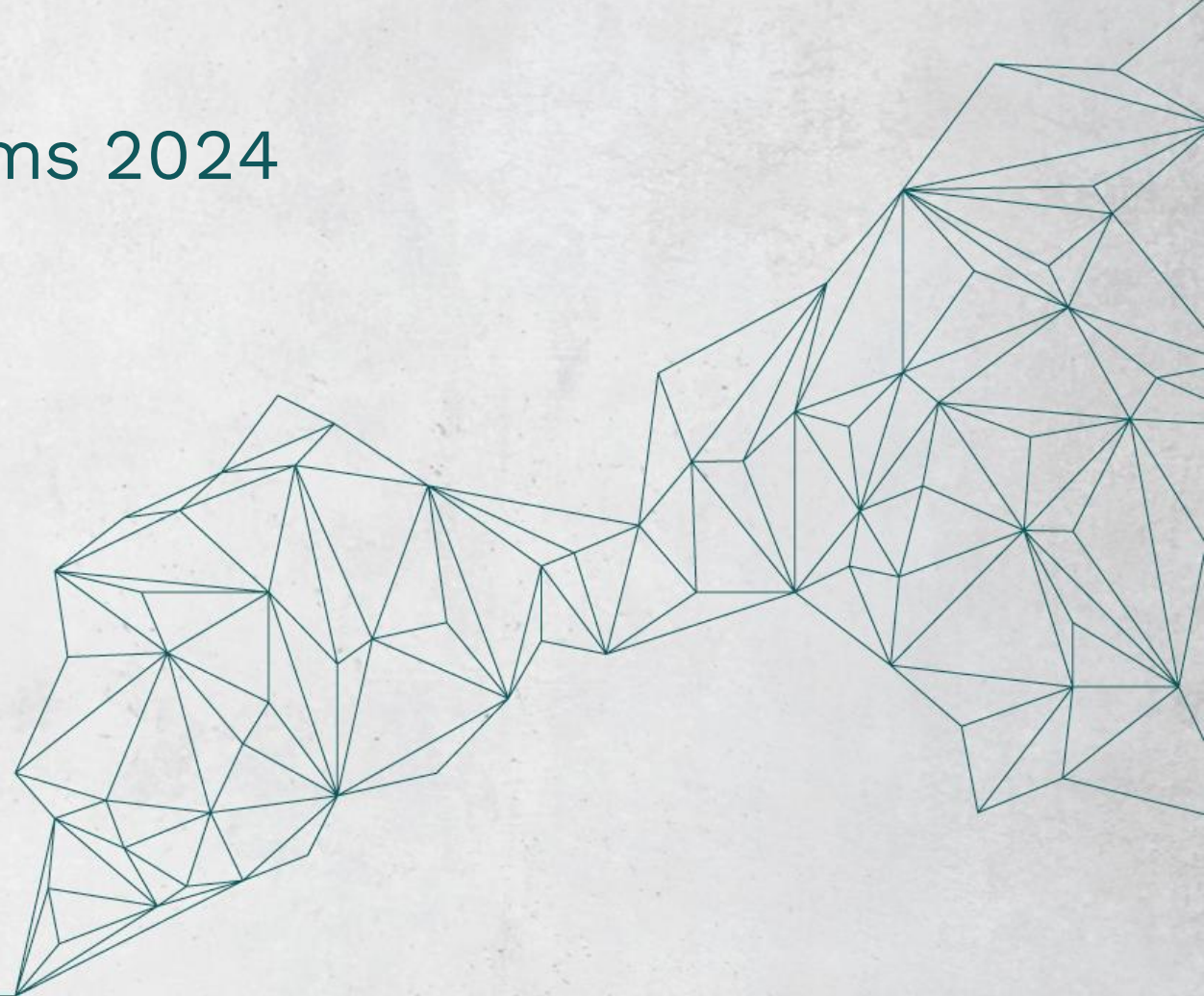


Hall 4A

Chillventa Specialist Forums 2024  
Chillventa Fachforen 2024

**CONNECTING  
EXPERTS.**



**ARKEMA**

**FORANE**  
REFRIGERANTS

**Forane® 32 vs R-454B:  
Which is the best choice?**

10/10/2024



# AGENDA

10/10/2024



Goal



Regulations leading to refrigerant changes



R-410A replacement choices



Refrigerant comparison – Properties, performance simulations, TEWI calculations, design and manufacturing considerations



Conclusion and Questions

**ARKEMA**

**GOAL**

10/10/2024

# Goal

→ Provide a fact-based comparison of R-32 vs R-454B to help OEMs decide which product best meets their application considering their thermodynamic properties, composition, capacities and efficiencies, flammability, charge size, compatibility and performance in a system.



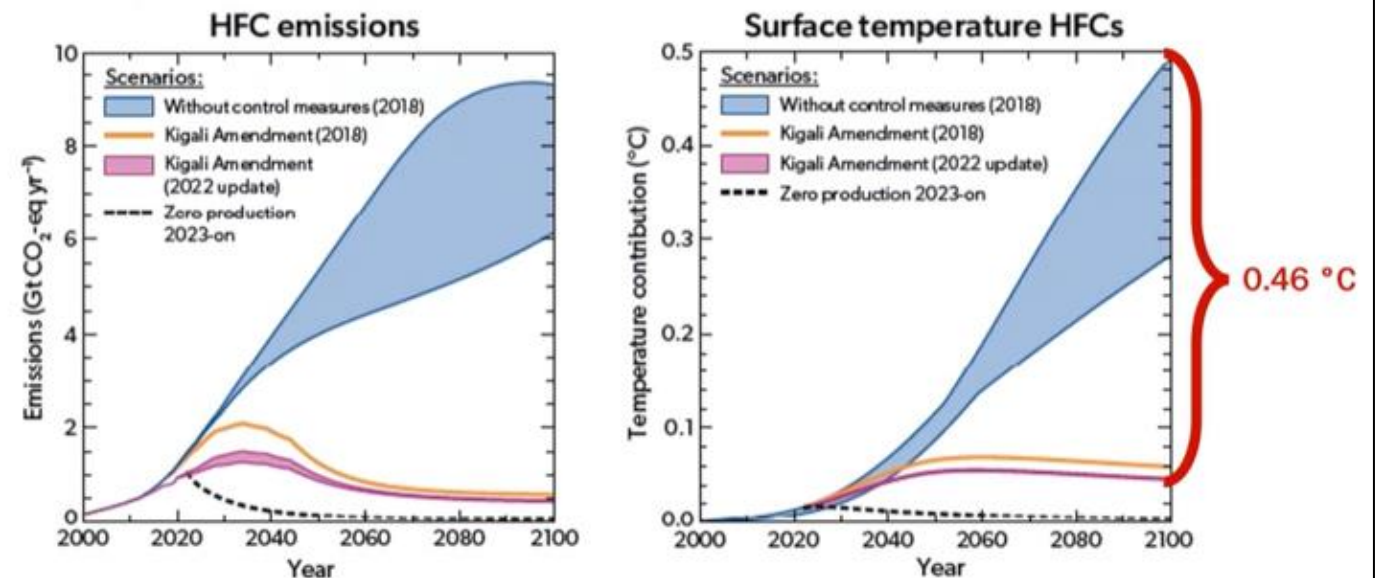


# REGULATORY

10/10/2024

# Global Phasedown of HFC's

- Goal of avoiding up to 0.5° C global warming by 2100
- HFC's have been used globally since the phase out of ozone depleting substances, but have high global warming potentials (GWP)
- Regulation globally is designed to reduce the use and emissions of HFC's





# Global Phasedown of HFC's



## → Montreal Protocol

- Multilateral agreement to protect the ozone layer
- Montreal Amendment – phase out of HCFC's
- Kigali Amendment – phase down of HFC's

## → F-Gas Regulations

- Reducing HFC's
- Expanding quota system
- Prevent emissions
- Better monitoring
- Capping production

## → USA EPA Regulations

### → AIM Act

- Allocation - phasedown HFC production & consumption
- Reclaim - manage use & reuse
- Technology Transfer - transition to alternatives



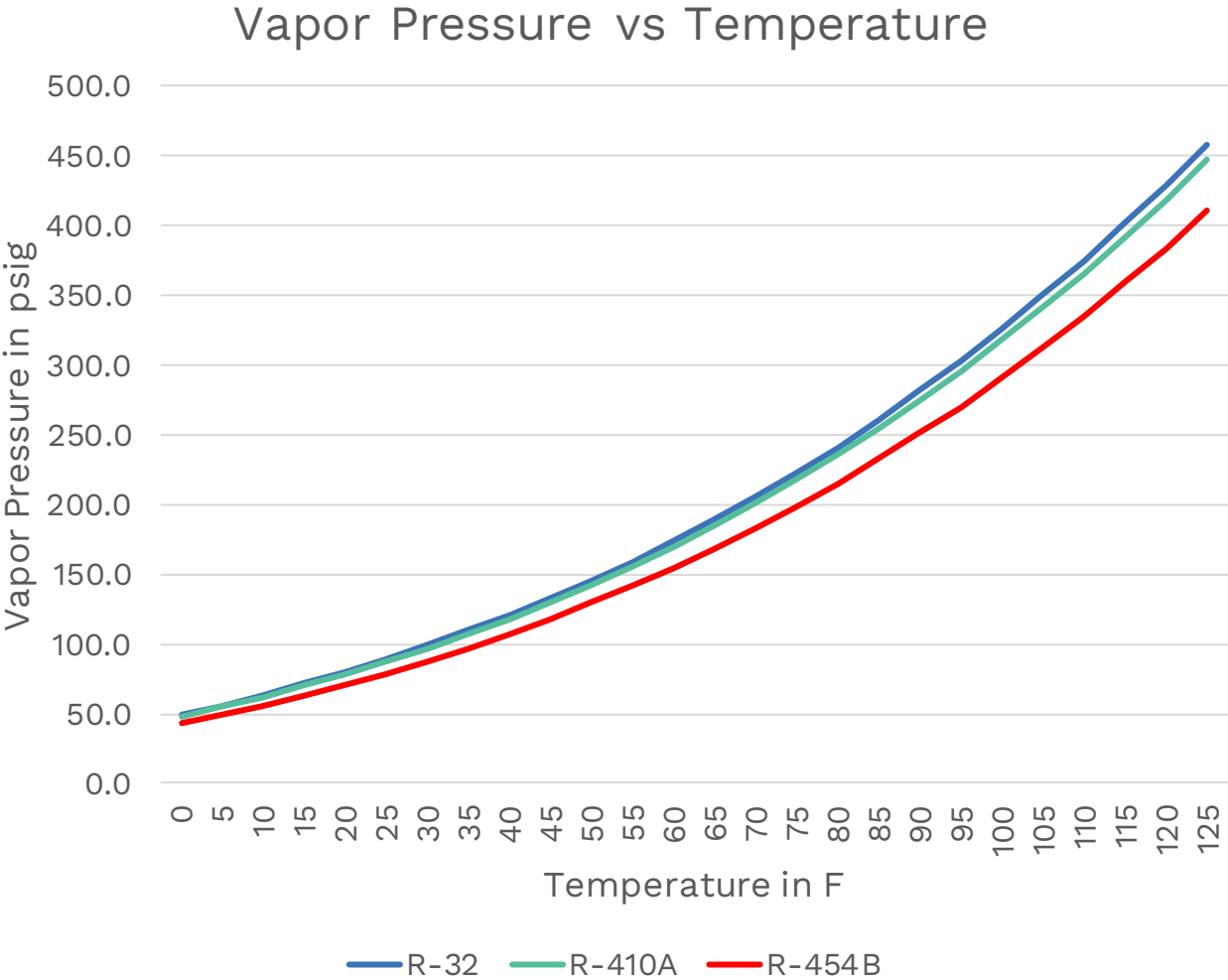
# PROPERTY COMPARISON

10/10/2024

# Refrigerant Property Comparison

Property	R-410A	R-32	R-454B
Composition	<b>R-32</b> (50%) R-125 (50%)	<b>R-32</b> 100%	<b>R-32</b> (68.9%) R-1234yf (31.1%)
ASHRAE 34 Safety Class	A1	A2L	A2L
GWP (AR4)	2088	675	465
Glide	~0.3 K	0 K	1.2 K
Stability and Compatibility	Good	Good	Good
Cost (vs R-410A)	Variable	↓	↑↑
Availability	Limited	Y	Y
Charge	Baseline	↓↓	↓
Efficiency (vs R-410A)	Baseline	↑	=
Capacity (vs R-410A)	Baseline	↑	=
PFAS	No	No	Yes

# Pressure-Temperature Comparison



T <F>	R-410A <psig>	R-32 <psig>	R-454B <psig>
0	48.2	49.3	42.7
15	70	71.4	62.6
30	97	99.1	87.4
45	130.1	133	117.8
60	170.1	174.1	154.6
75	217.9	223.2	198.7
90	274.5	281.3	251
105	340.9	349.7	312.5
120	418.3	429.36	384.3
135	508.3	521.8	468
150	613	628.8	565.4

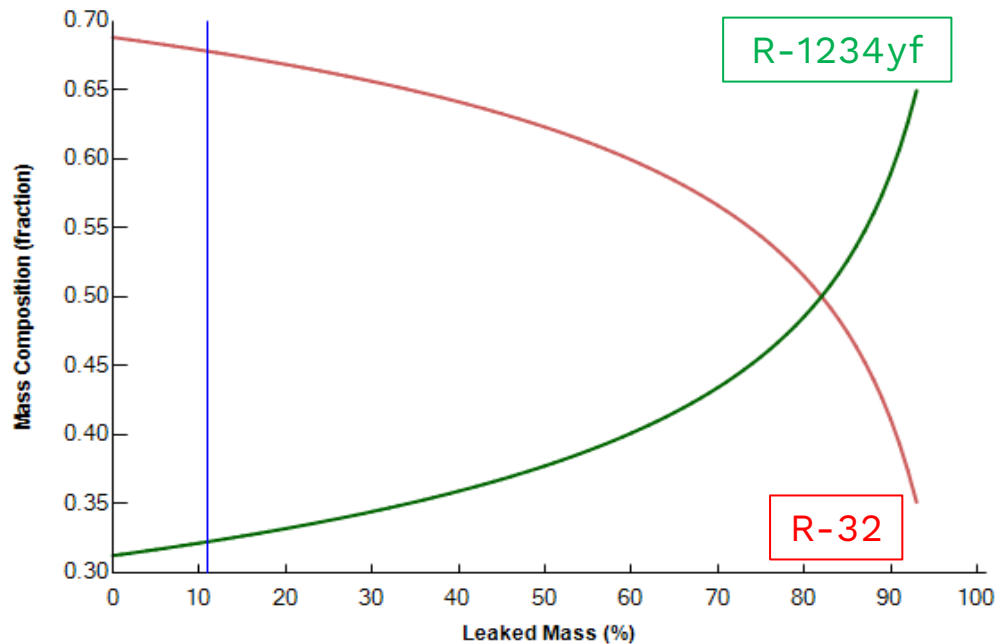
Data from NIST RefProp



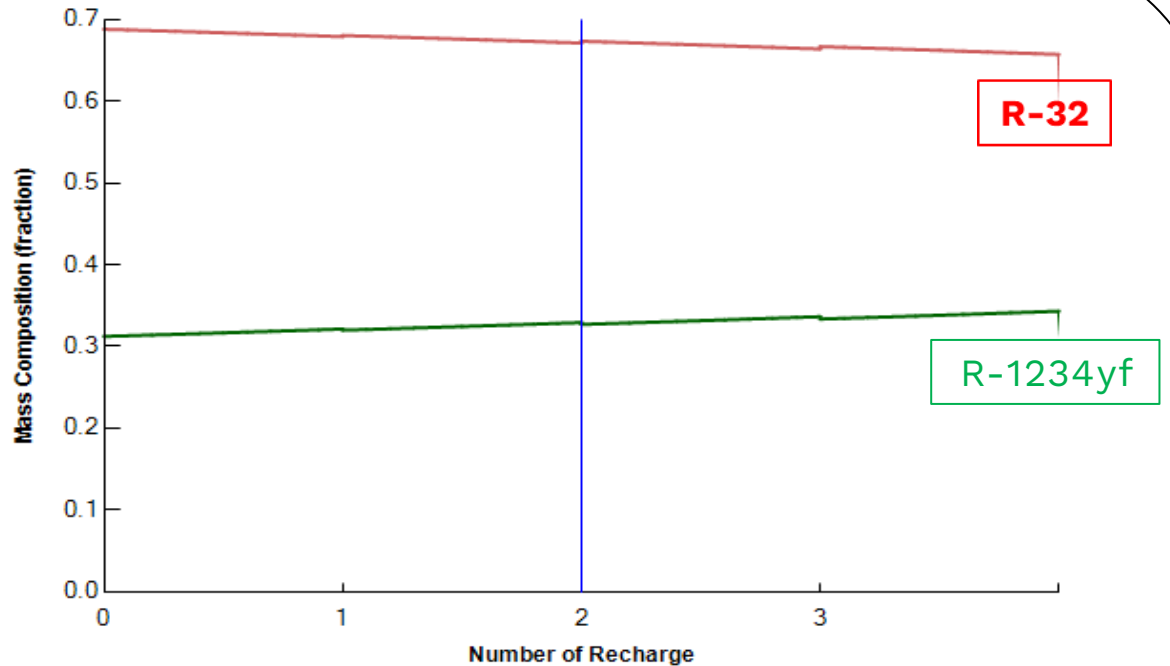
# LEAKS AND RECHARGING (GLIDE)

10/10/2024

# Composition Change Comparison



- Slow adiabatic vapor leak
- Will go out of spec (-1/+1%) after a 11% total mass loss

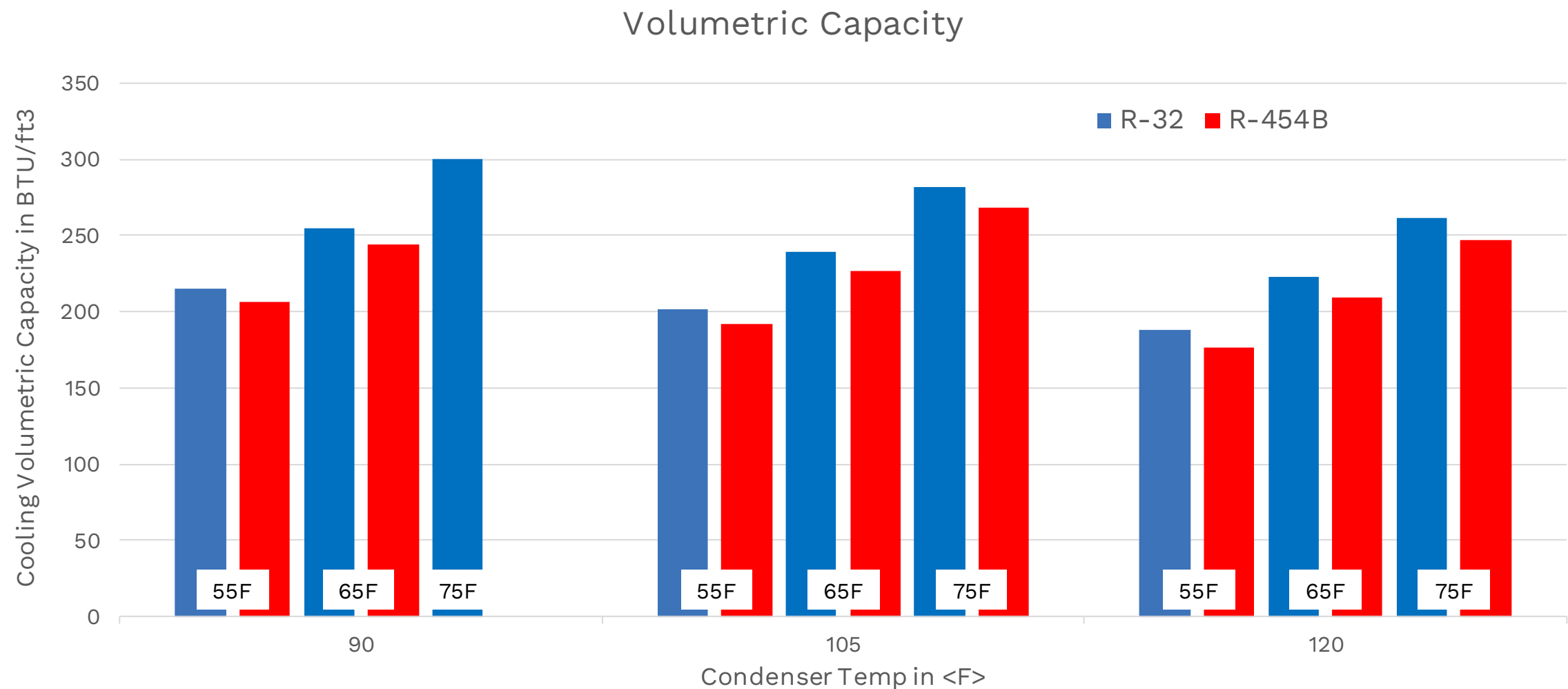


- Recharge after 10% loss
- Can recharge safely twice before goes out of spec

# PERFORMANCE COMPARISON

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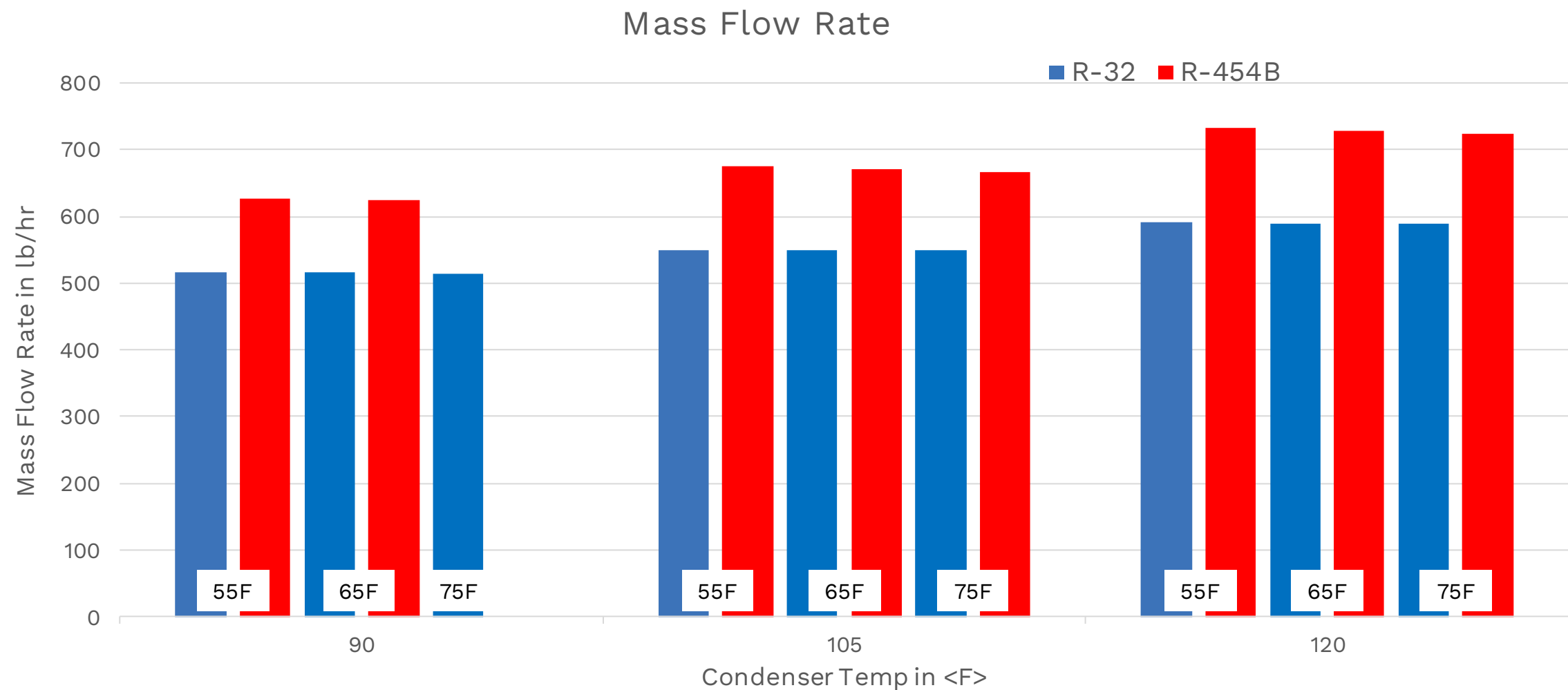
# Volumetric Capacity Comparison



Data from Cycle-D at stated conditions



# Refrigerant Mass Flow Rate Comparison



Data from Cycle-D at stated conditions

# TEWI COMPARISON

# TEWI Calculations



# TEWI Calculations

Direct emissions

$$= \text{GWP} \times \text{Charge} \times \left( \frac{\% \text{ leak rate}}{\text{System expected life}} \times \text{System expected life} + \left( 1 - \text{Recovery rate} \right) \right)$$

Data Assumptions	
GWP	R-32 = 675    R-454B = 465
Charge	R-32 = 15 lb (6.8 Kg) R-454B = 18 lb (8.2 Kg)
%leak rate	2% per year
System expected life	12 years
Recovery rate	85% charge recovery @ EOL (15% loss)

# TEWI Calculations: Indirect

Indirect emissions

=

Energy consumption

x

Electrical emission Conversion factor

Data Assumptions	
Energy Consumption Per year R-32 / R-454B	Philadelphia = 3,677/3,870 kWh Houston = 7,870/8,284 kWh Miami = 14,004/14,741 kWh Charlotte = 4,721/4,969 kWh
Electrical Emission Conversion Factor	USA weighted average = 1.54 lb/kWh 0.699 kg/kWh

Data from US EIA [www.eia.gov](http://www.eia.gov)

# TEWI Comparison per Location

Location	Direct R-32	Direct R-454B	Indirect R-32	Indirect R-454B	TEWI R-32	TEWI R-454B	TEWI DIFF
Philadelphia, PA	1.79	1.49	2.57	2.71	4.36	4.20	0.16
Houston, TX			5.50	5.79	7.29	7.28	0.01
Miami, FL			9.79	10.30	11.58	11.79	-0.21
Charlotte, NC			3.30	3.47	5.09	4.96	0.13

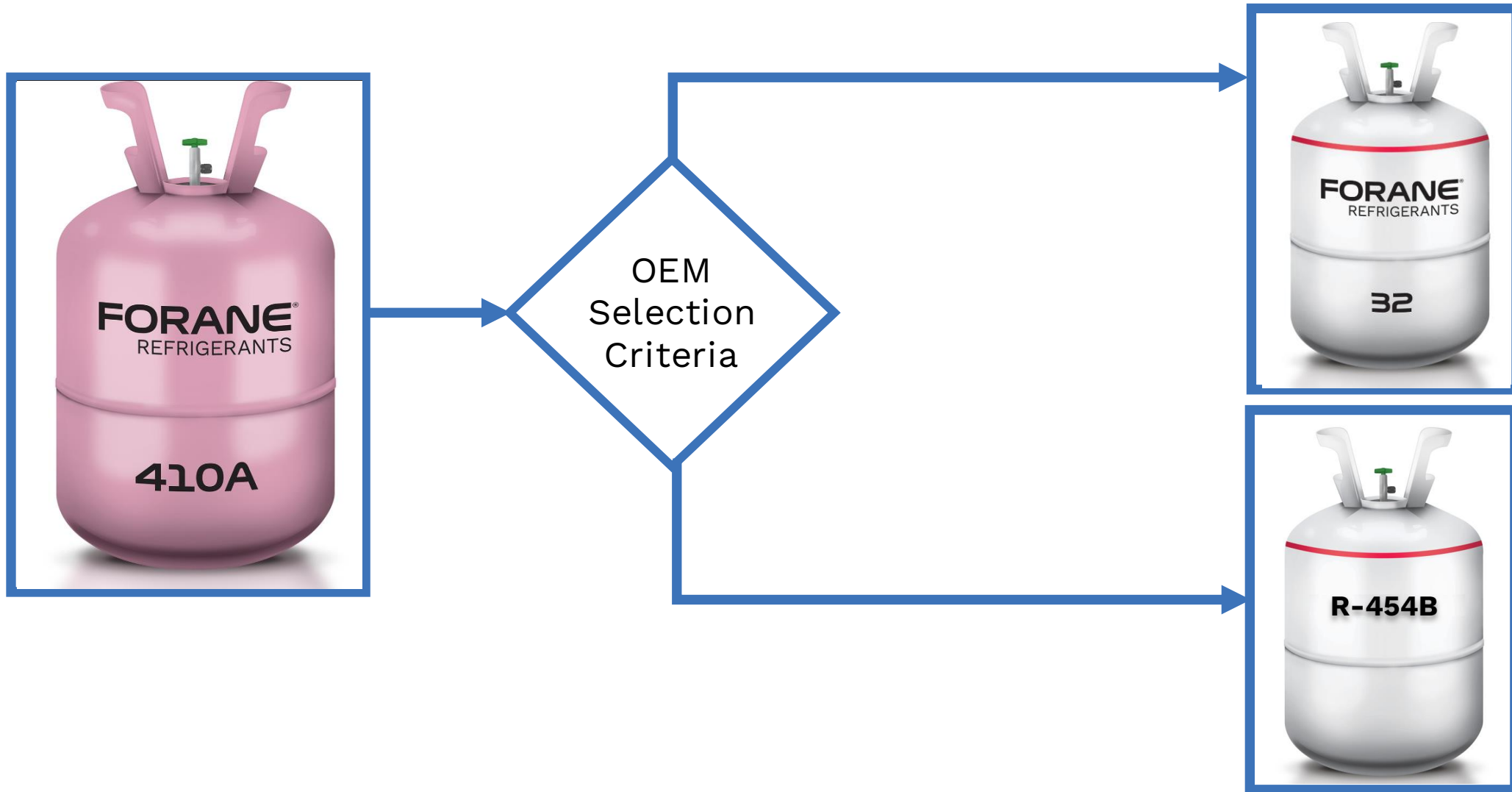
In MT CO<sub>2eq</sub>

- 1. TEWI for R-32 is favorable in hotter climates
- 2. Small differences overall in TEWI for both products

Assumptions:  
5 ton A/C unit, 16 SEER, 12 years, 15% loss @ EOL

# SELECTION CRITERIA

# R-410A's Leading Replacements – US HVAC





# Selection Criteria to Consider

## Compatibility with materials of construction

- Use of standard, common materials of construction

## Cost of the refrigerant

- Refrigerant cost vs. design changes

## Regulations and GWP

- Meet regulations now, later?
- PFAS regulations
- TEWI or LCCP

## Flammability

- $A1 < A2l < A2 < A3$

## Efficiency/Capacity

- Needed increase vs. R-410A designs

## Compatibility with current system design

- Flammability will require a set of changes
- Properties may require redesign of compressor and/or HX
- Opportunity for enhanced performance

# Selection Criteria

	R-32	R-454B
GWP	675	465
FLAMMABILITY	A2L	A2L
EFFICIENCY/CAPACITY	CHANCE FOR IMPROVEMENT	SAME
CURRENT DESIGN COMPATIBILITY	NO	YES WITH MODIFICATIONS
MATERIALS COMPATIBILITY	YES	YES
RETROFIT R-410A	NO	NO

## CONCLUSION

# Conclusions



Both products are good R-410A replacements in A/C



R-32 is best for new designs looking to build on performance gains in efficiency



R-454B is best for a simpler transition out of R-410A with low R&D in R-410A-like systems



New even lower GWP refrigerants may be needed in the future depending on availability and regulations



R-32 is an essential component either alone, or as part of a blend

# Thank You

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                                         www.Arkema.com



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