Refrigerant Update

THE NEXT TRANSITION HAS BEGUN



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History of HVAC/R Refrigerants

1st Generation	2nd Generation	3rd Generation	4th Generation
"What Ever Worked"	**"Safety & Stability"**	**"Ozone Protection"**	**"Global Warming"**
1830's – 1930's	**1930's – 1990's**	**1990's – 2010's**	**2010 - ??**
• Limited applications mainly industrial • Poor safety & high cost	• Innovation enabled exponential societal improvements	• Preserved 2nd gen. innovations, safety, stability and efficiency	• Fewer optimal choices • Safety & design challenges

• Carbon Dioxide (CO_2)
• Water (H_2O)
• Ammonia (NH_3)
• Various HCs
• Sulfur Dioxide (SO_2)
• Methyl Chloride (CH_3Cl)
	• Sulfur Dioxide (SO_2)
	• CFCs & HCFCs
	  • R-11
	  • R-12
	  • R-22
	  • R-502
	  • R-113
	  • R-114
	  • Many more blends….
		• Sulfur Dioxide (SO_2)
		• HCFCs & HFCs
		  • R-123
		  • R-134a
		  • R-407C
		  • R-410A
		  • R-404A
		  • Many more blends….
			• Sulfur Dioxide (SO_2)
			• HFOs & HFC/HFO Blends
			  • R-1234yf
			  • R-1234ze
			  • R-1233zd
			  • Blends….
			• Renewed Interest "Natural"
			  • CO_2
			  • HCs

Societal demands continue to drive refrigerant innovations

World Taking Action!

Montreal Protocol Agreement Made

October 15, 2016

BBC

NEWS

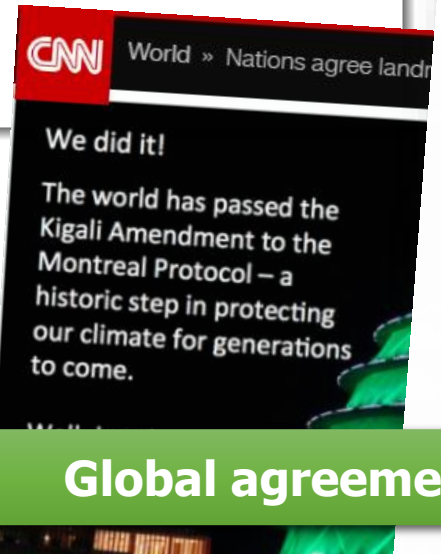
Climate change: 'Monumental' deal to cut HFCs, fastest growing greenhouse gases

By Matt McGrath
Environment correspondent

15 October 2016 | Science & Environment



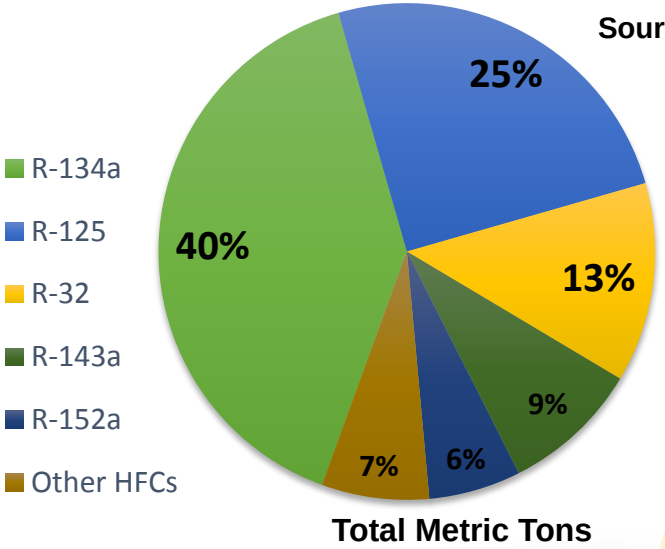






Global agreement made!

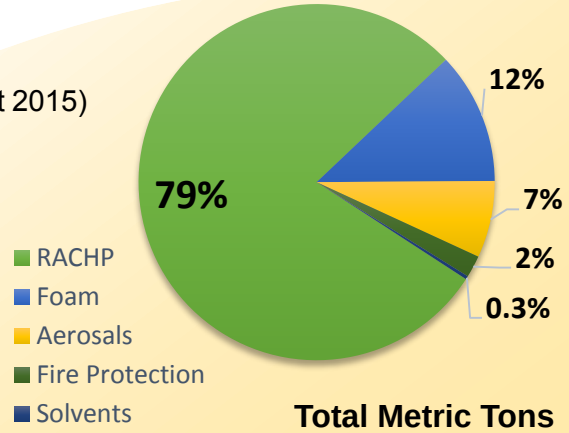
Global Consumption of HFCs



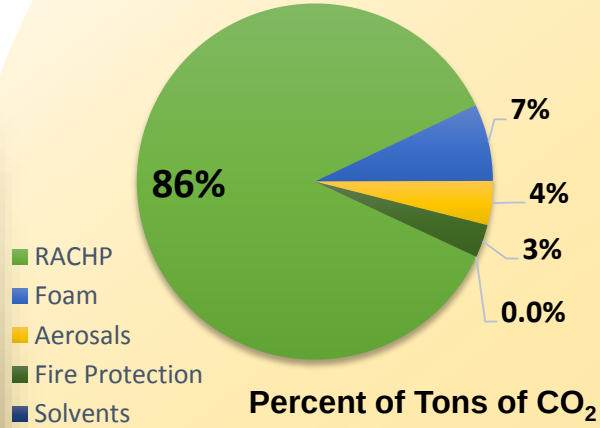
Total Metric Tons

Source: UNEP Ozone Secretariat Fact Sheet 2
"Overview of HFC Market Sectors" (Oct 2015)

Markets Using HFCs

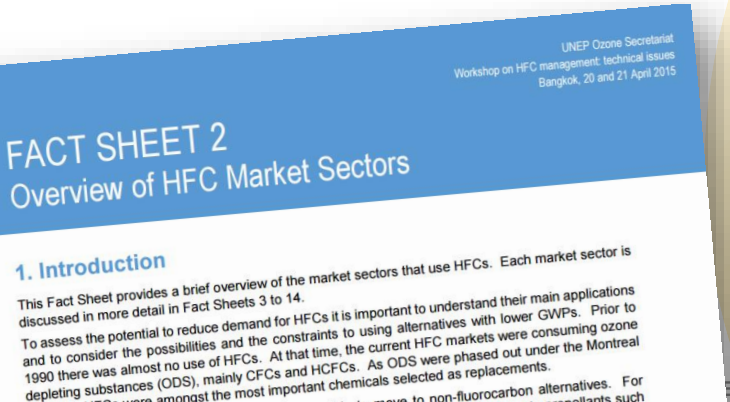


Total Metric Tons



Percent of Tons of CO_2

Market	Key HFCs	GWP
RACHP	R-404A R-410A R-407C HFC-134a	3922 2088 1774 1430
Aerosols	HFC-134a HFC-152a HFC-227ea	1430 124 3220
Foams	HFC-134a HFC-245fa HFC-365mfc / HFC-227ea	1430 1030 960 - 1100
Fire protection	HFC-227ea HFC-125 HFC-23	3220 3500 14800
Solvents	HFC-4310mee	1640



UNEP Ozone Secretariat
Workshop on HFC management: technical issues
Bangkok, 20 and 21 April 2015

FACT SHEET 2
Overview of HFC Market Sectors

1. Introduction

This Fact Sheet provides a brief overview of the market sectors that use HFCs. Each market sector is discussed in more detail in Fact Sheets 3 to 14.

To assess the potential to reduce demand for HFCs it is important to understand their main applications and to consider the possibilities and the constraints to using alternatives with lower GWPs. Prior to 1990 there was almost no use of HFCs. At that time, the current HFC markets were consuming ozone depleting substances (ODS), mainly CFCs and HCFCs. As ODS were phased out under the Montreal

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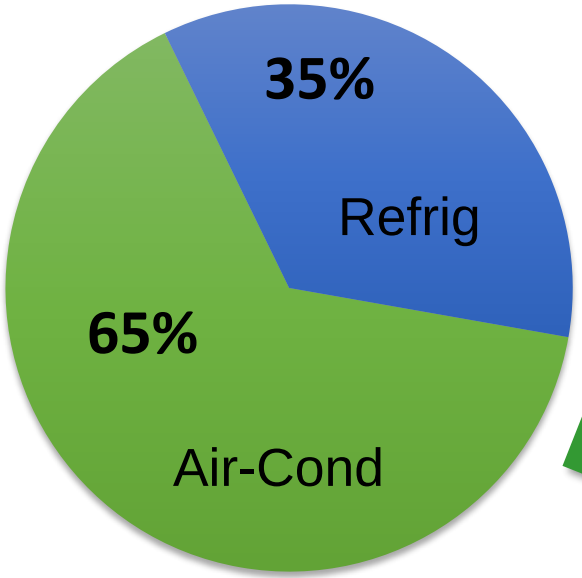
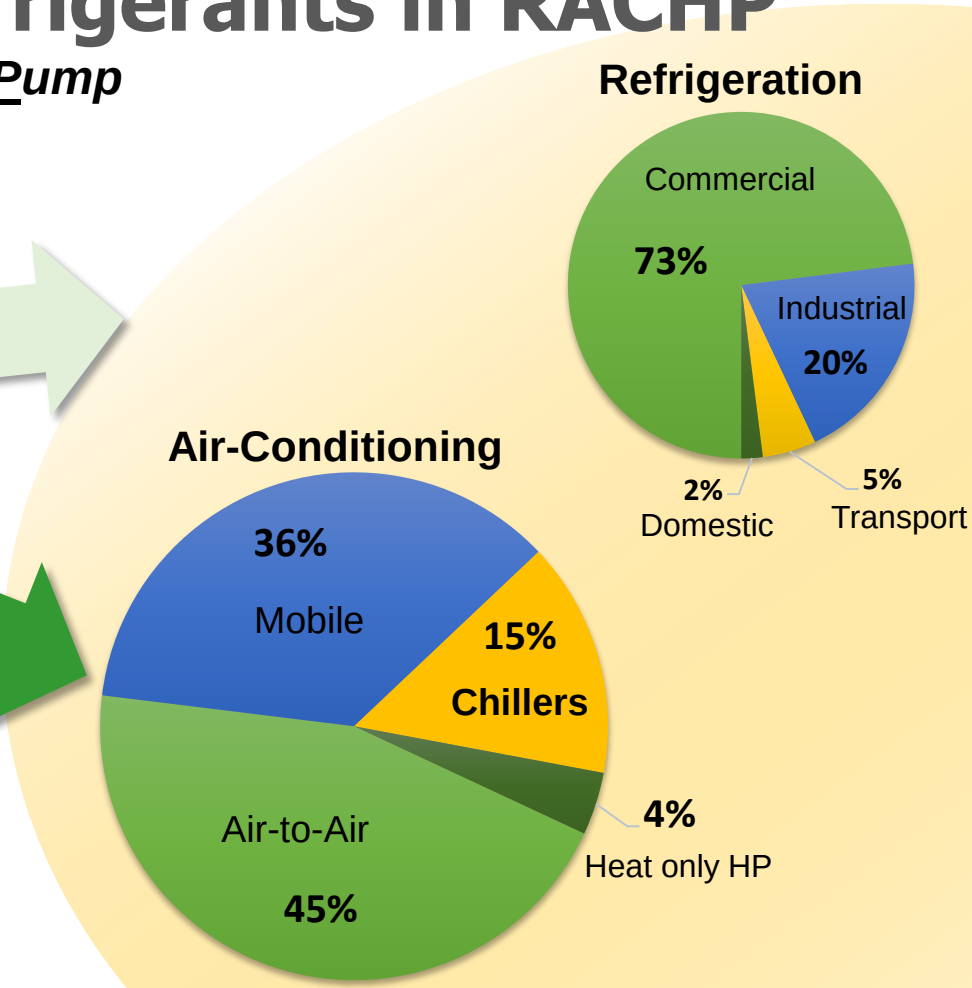
Global HFC use of Refrigerants in RACHP

Refrigeration, Air-Conditioning, Heat Pump





Source: UNEP Ozone Secretariat Fact Sheet 2
"Overview of HFC Market Sectors" (Oct 2015)

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Montreal Protocol HFC Amendment Agreement!

Kigali Amendment drives global transitions based on GWP

October 15, 2016

	A5 Group 1 (Developing Countries)	*A5 Group 2 (Developing Countries)*	Non-A5 *(Developed Countries)*
Baseline	2020-2022	2024-2026	2011-2013
Formula	Average HFC consumption	Average HFC consumption	Average HFC consumption
HCFC	65% baseline	65% baseline	15% baseline*
Freeze	2024	2028	-
1st step	2029 – 10%	2032 – 10%	2019 – 10%
2nd step	2035 – 30%	2037 – 20%	**2024 – 45%**
3rd step	**2040 – 50%**	**2042 – 30%**	**2029 – 70%**
4th step			2034 – 80%
Plateau	2045 – 85%	2047 – 85%	2036 – 85%

*** For Belarus, Russian Federation, Kazakhstan, Tajikistan, Uzbekistan 25% HCFC component of baseline and different initial two steps – (1) 5% reduction in 2020 and (2) 35% reduction in 2025**

http://www.coolingpost.com/world-news/nations-agree-global-phase-down-of-hfcs/

Notes:

1. **Group 1: Article 5 parties not part of Group 2**
2. **Group 2: GCC, India, Iran, Iraq, Pakistan**
3. **Technology review in 2022 and every 5 years**
4. **Technology review 4-5 years before 2028 to consider the compliance deferral of 2 years from the freeze of 2028 of Article 5 Group 2 to address growth in relevant sectors above certain threshold.**

UNEP

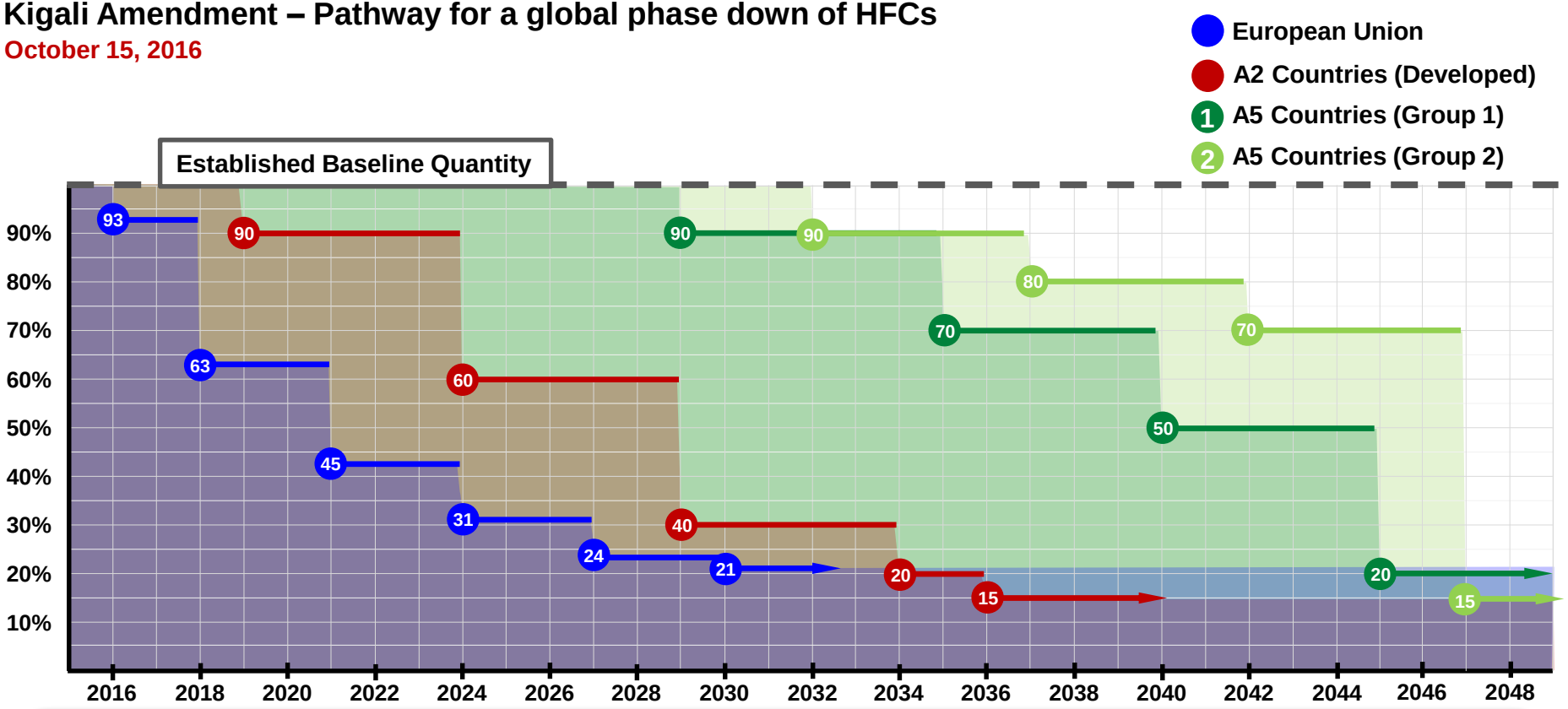
* http://www.unep.org/NewsCentre/default.aspx?DocumentID=27086&ArticleID=36286

Agreement goes into effect 1/1/19 if ratified by at least 20 countries*

Montreal Protocol HFC Amendment

Kigali Amendment – Pathway for a global phase down of HFCs

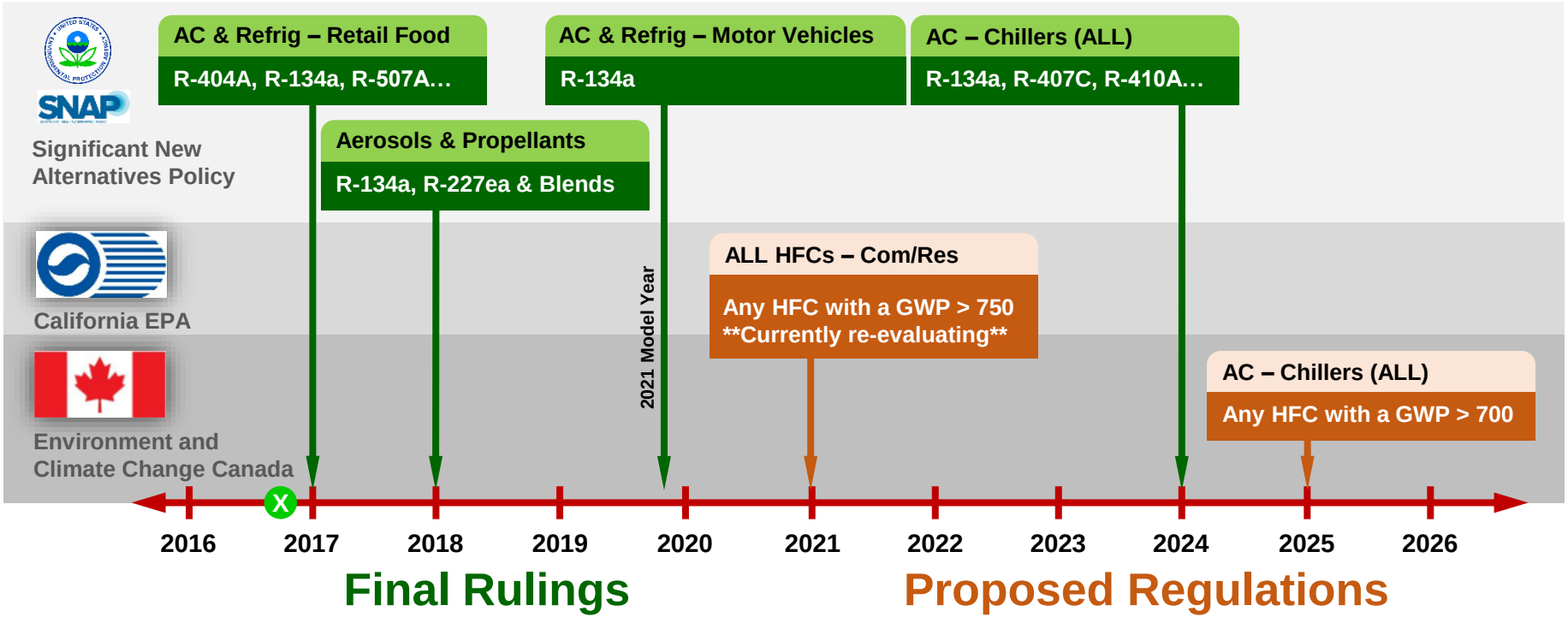
October 15, 2016



Cap and phase down of HFCs starting in 2019 for developed nations

Review of Current and Pending Regulations

Ban on shipment of new equipment with HFCs

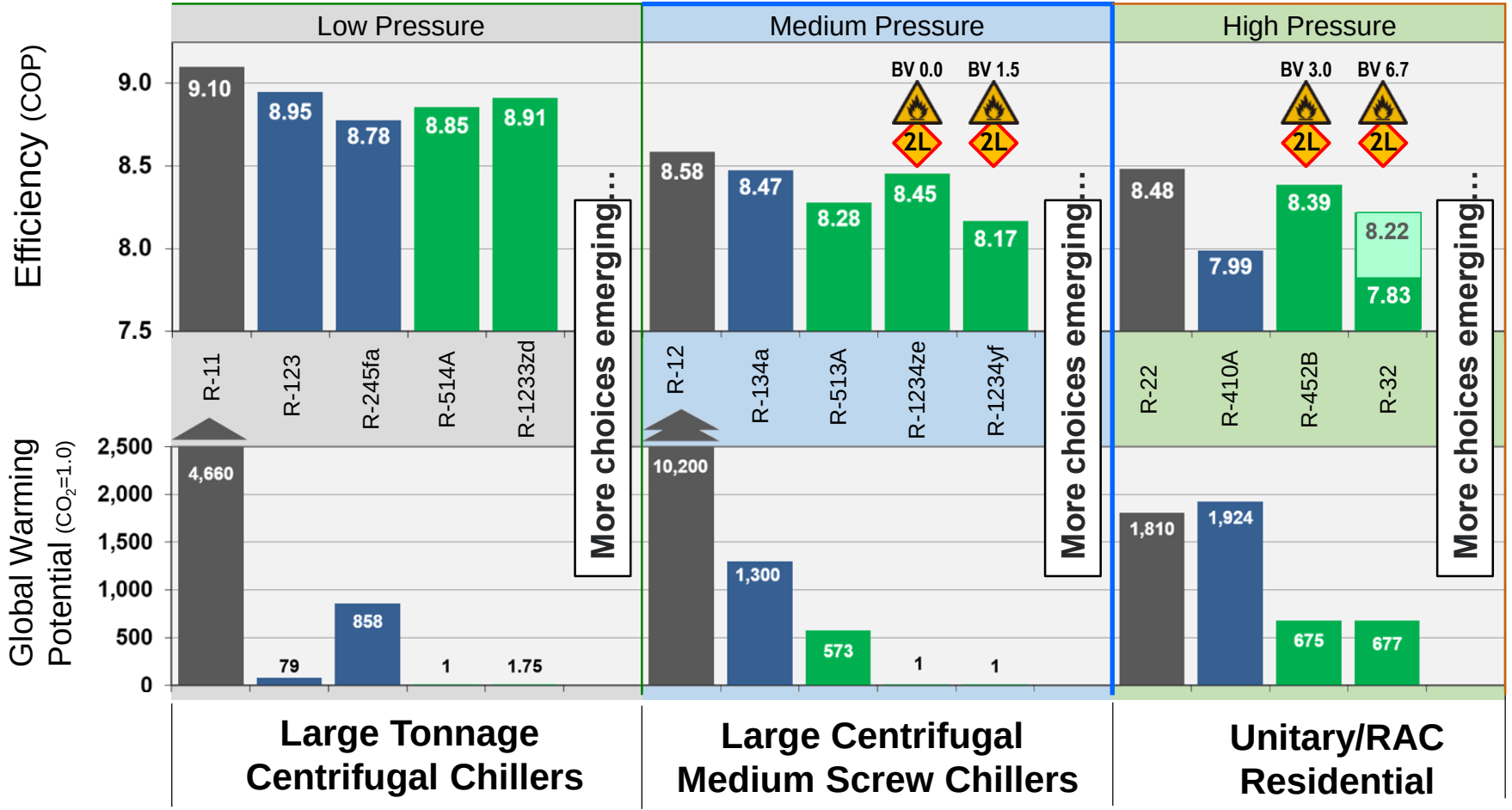


HFC phase-out dates for high-GWP refrigerants in US & Canada

With choices now available…

HVAC Industry Next Transition Begins…

Past | Present | Future



***GWP** Values are per AR5 of the 2013 UN climate report*
***BV** represents **"Burning Velocity"** of 2L refrigerants range from 0-10 cm/sec.*

Chiller Refrigerants

Screw Chillers

Flammable:

R-1234ze (GWP < 10)

Non Flammable:

R-513A (GWP = 573)

Centrifugal Chillers

Flammable:

R-1234ze (GWP < 10)

Non Flammable:

R-1233zd (GWP < 10)

R-513A (GWP = 573)

ASHRAE/AHRI Flammability test will guide final choices
Is a GWP of 300 low enough if it is non flammable?
2L refrigerants in air cooled chillers to be approved soon

Areas to Exceed Current Efficiencies

- Scroll compressors (Unitary/RAC)
  - Moving from R-410A to R-452B or R-32 will result in a 3-4% efficiency improvement
- Screw compressors (Air and water cooled chillers)
  - Moving from R-134a to R-1234ze will result in no loss in energy efficiency
- Centrifugal Compressors (Large tonnage water cooled chillers)
  - Moving from R-134a to R-1233zd or R-514A will result in a 7-10% efficiency improvement

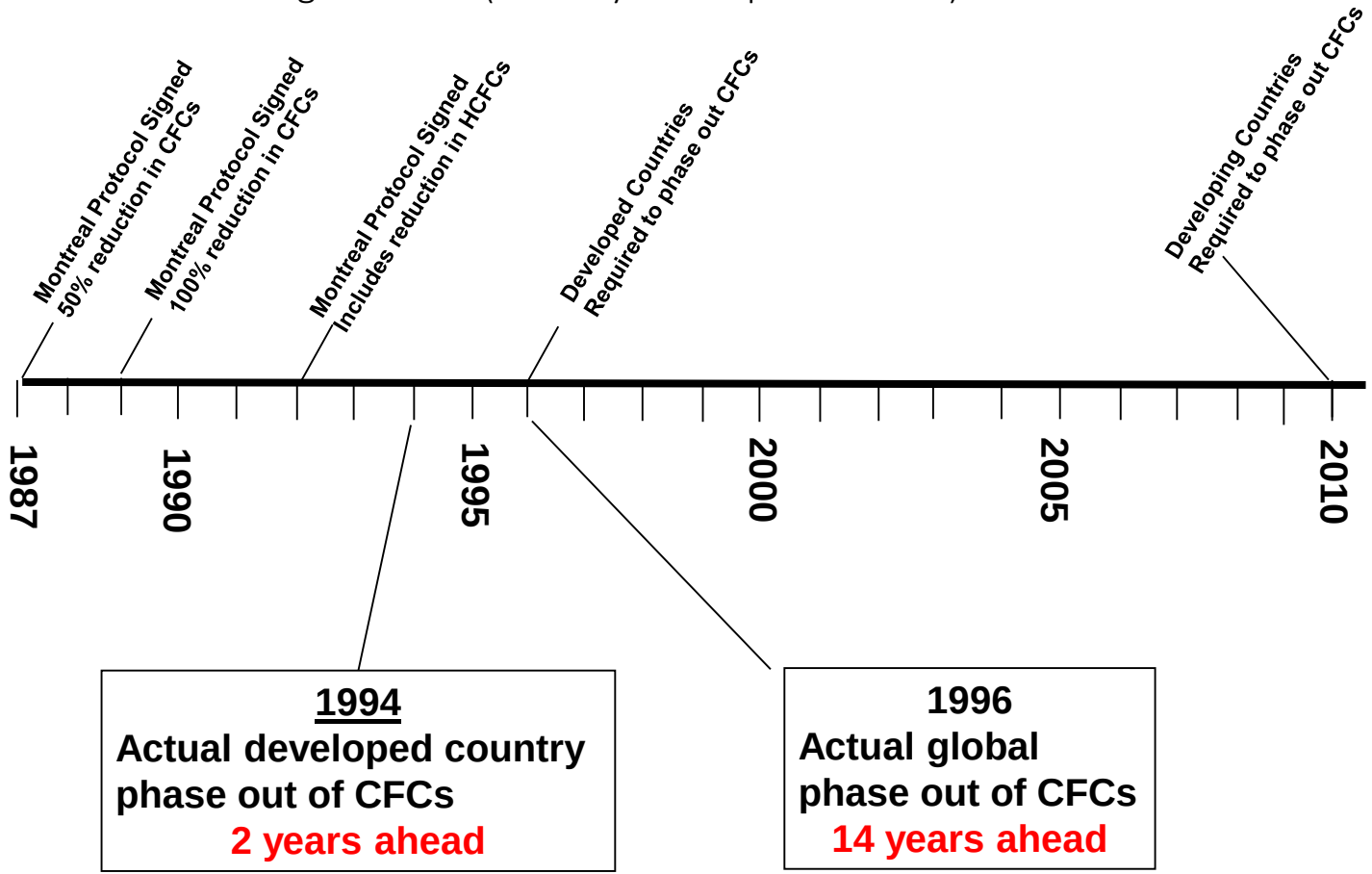
Smart technology transitions will result in efficiency improvements

How Fast Will the Transition Be?

- Heavy investment begins now that the Kigali Agreement is done
- Larger tonnage chillers are global products, and the world will closely follow the Article 2 countries
- Smaller tonnage (Unitary/RAC) will be more localized in the transition
- Newer technology will become cheaper, as old technology becomes more expensive.
- Rapid transition occurs when new technology becomes the cheap technology

CFC Chiller Phase-Out Regulation vs Actual

Centrifugal Chillers (Globally developed Product)



What is the Best Way to Proceed?

- Opportunities exist to sustain or improve energy performance with next generation refrigerants
- The Kigali agreement will accelerate investment in new technology
- The transition to next generation solutions will be faster than you think
- Global products will transition faster than localized products
- Industry and government need to work together to find the best path for phase down opportunities
- Advanced notice, and direction from the government is critical!
- How fast?
  - Moving too fast will cause price challenges
  - Moving too slow could cause technology dumping

"If you aim at nothing, you will hit is every time"…Zig Ziglar

Refrigerant Choices & Comparison

Screw & Centrifugal Technology Options

	Low Pressure			Medium Pressure			
	R-123	**R-1233zd**	**R-514A**	**R-134a**	**R-513A**	**R-1234yf**	**R-1234ze**
Flammability	Non **(1)**	Non **(1)**	Non **(1)**	Non **(1)**	Non **(1)**	Slight **(2L)**	Slight **(2L)**
Toxicity	Higher **(B)**	Lower **(A)**	Higher **(B)**	Lower **(A)**	Lower **(A)**	Lower **(A)**	Lower **(A)**
Fluid Efficiency	8.95 COP	8.85 COP	8.91 COP	8.47 COP	8.28 COP	8.17 COP	8.45 COP
Capacity Change	1	~35% Gain	~5% Loss	1	Similar	~5% Loss	~25% Loss
GWP	79	1	2	1300	573	1	1



Chiller efficiency impacted by refrigerant choice



Questions?

Thank you for your time and attention!