# Future Refrigerants

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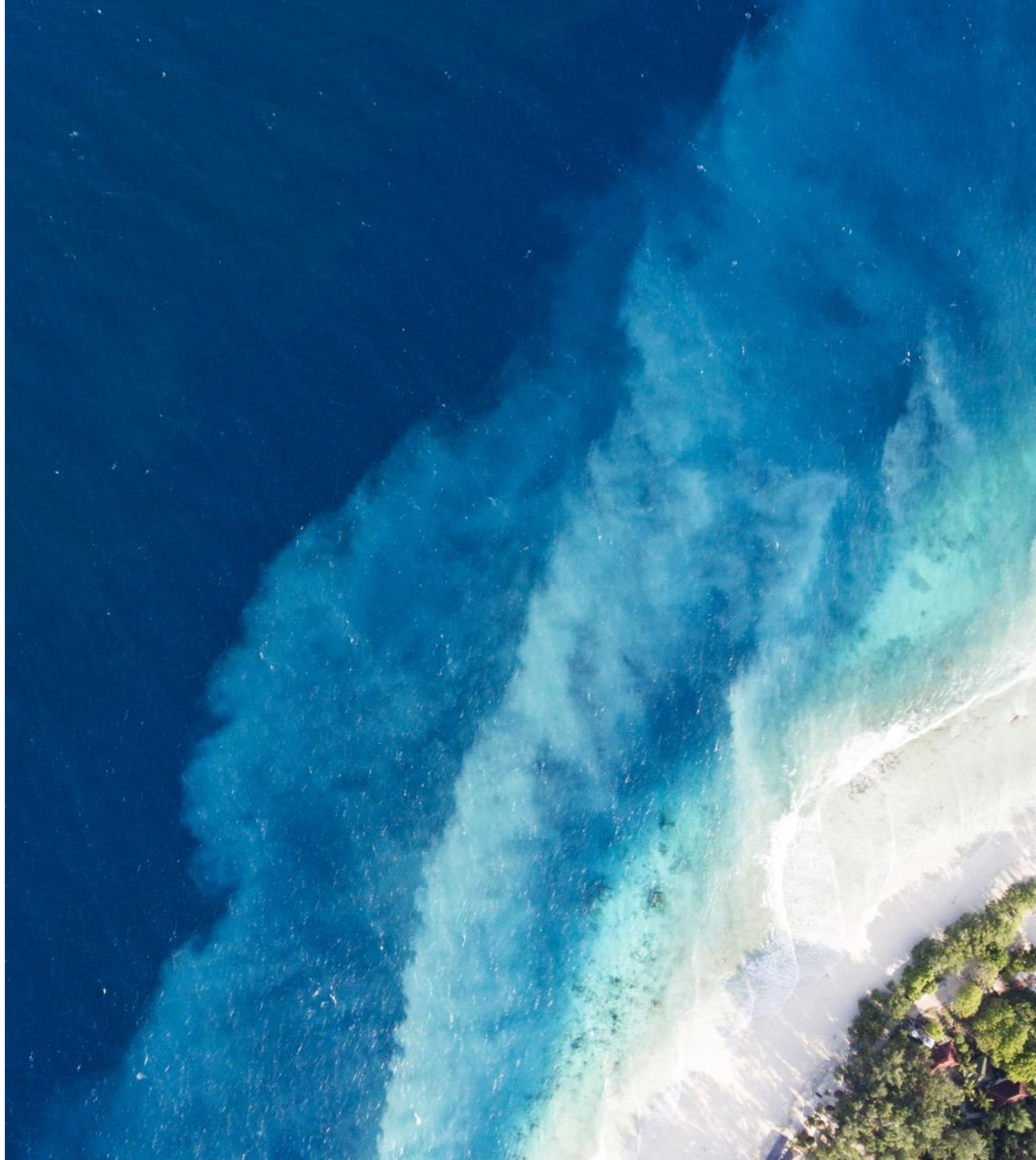
EmiratesGBC
مجلس الامارات للأبنية الخضراء
Emirates Green Building Council

TRANE TECHNOLOGIES

# Agenda

- Overview
- Montreal Protocol – Kigali Amendment
- Regulatory Update
- Comparison of Alternatives
- Refrigerates and Applications
  - Data Center
  - Electrification of Heating
- Summary



# Overview

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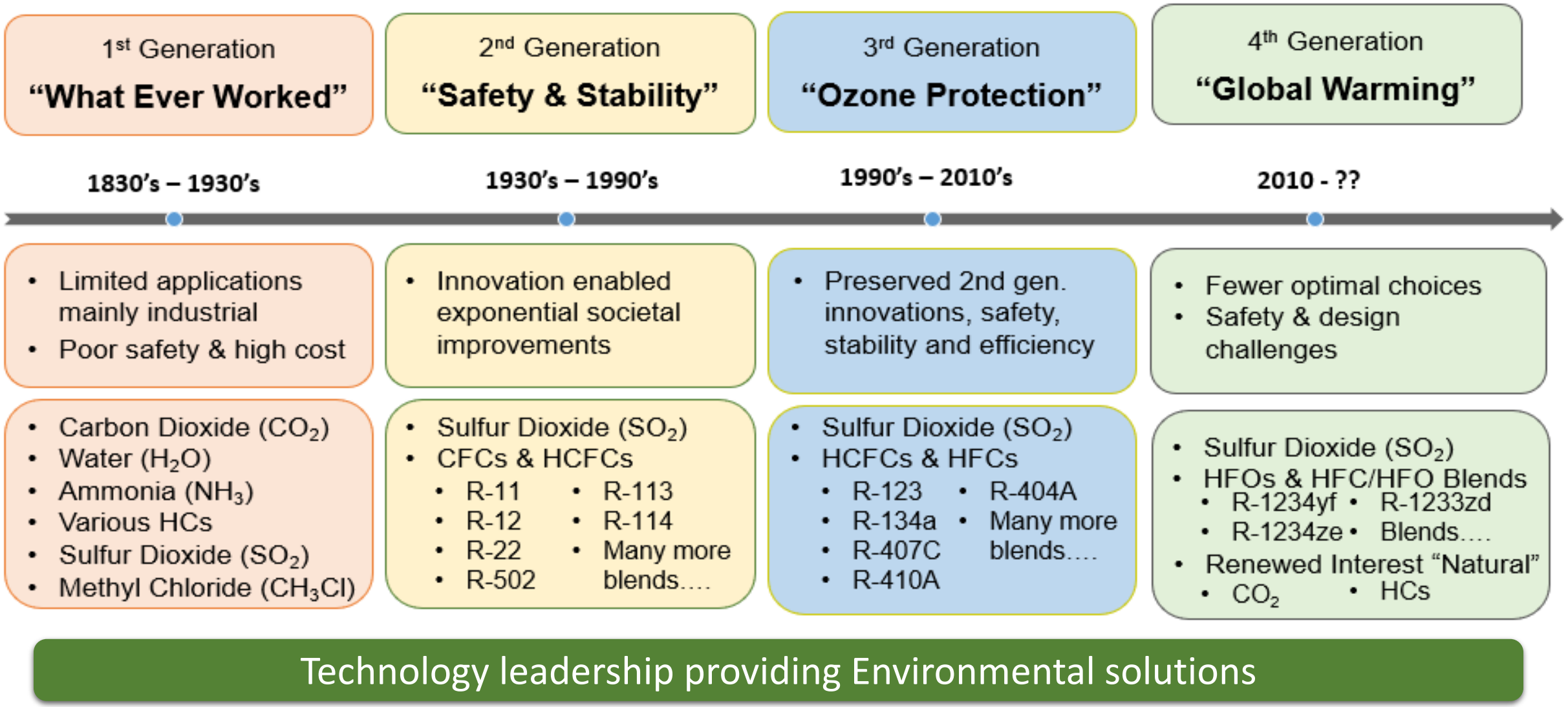



Technology leadership providing Environmental solutions

# Overview

**Past**
R-12, R-11, R-113, R-22, & more…

Low-ODP or no ODP ⇨ ODP

**Transitional**
R-134a, R-410A, R-407C, R-123, R-404A, & more…

Reduced GWP & ODP ⇨ GWP

R134a
OPD: 0
GWP: 1300

**Lower GWP Solutions**
R-513A, R-32, R-452B, R-454B, R-466A, & more…

R513A
OPD: 0
GWP: 700

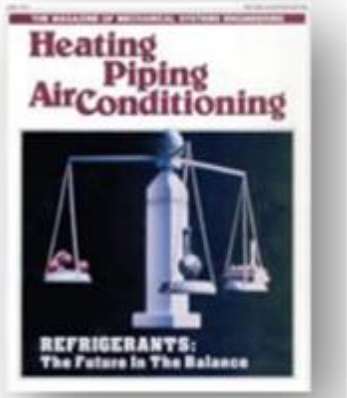
Lowest GWP & ODP ⇨ Best Balance

R11233zd
OPD: 0
GWP: <1

**Ultra-Low GWP Solutions**
R-1234yf, R-1234ze, R-1233zd, R-514A, & more…

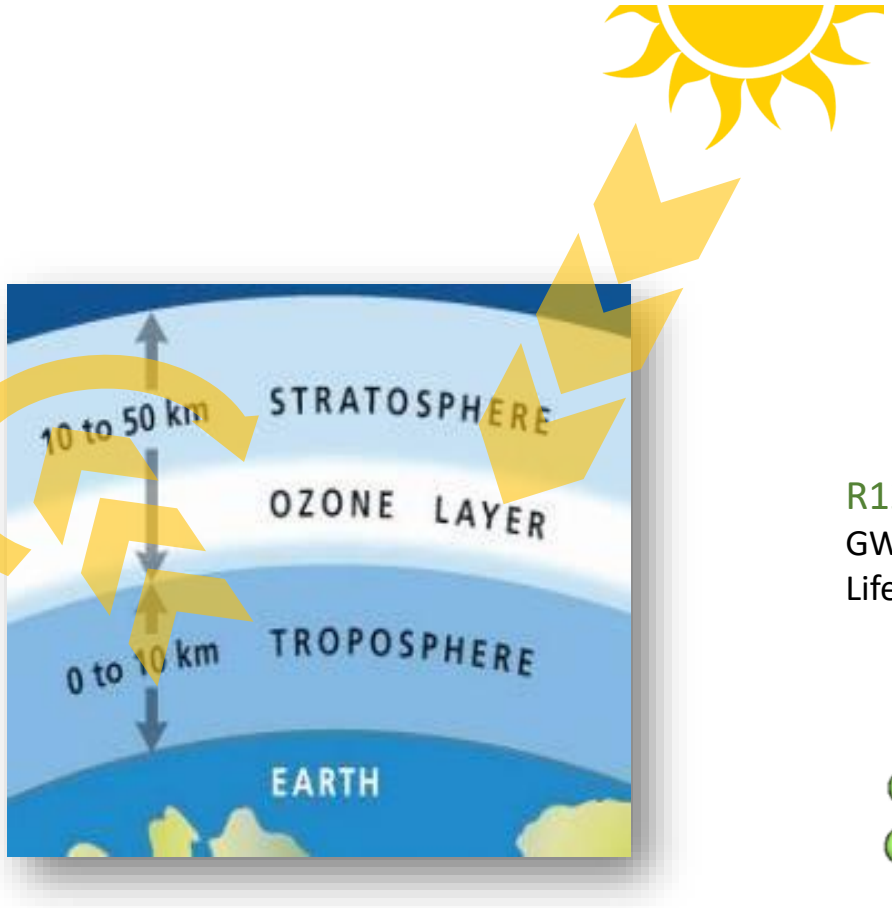
*Discussions on balancing ozone depletion, global warming, emissions, and energy efficiency as all being equally important.*

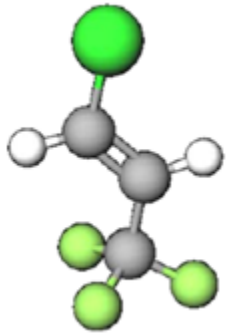
- As stated in 1991 Trane Article for HPAC Magazine.



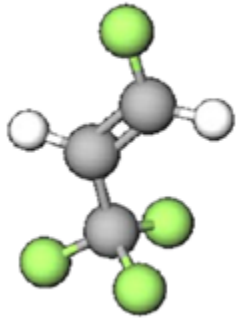

Balanced approach minimizes overall environmental impact

# Overview

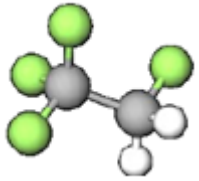


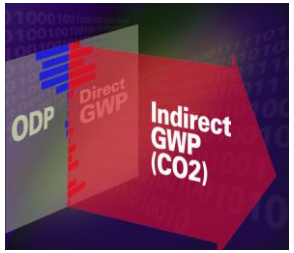
R1233zd
GWP: 1
Lifetime: 29 days



R1234 ZE
GWP: 1



R134a
GWP: 1300
Lifetime: 15 years




Atmospheric lifetime is key factor

# Montreal Protocol
# Kigali Amendment

# Montreal Protocol – Kigali Amendment

**The Kigali Amendment to the Montreal Protocol: HFC Phase-down**

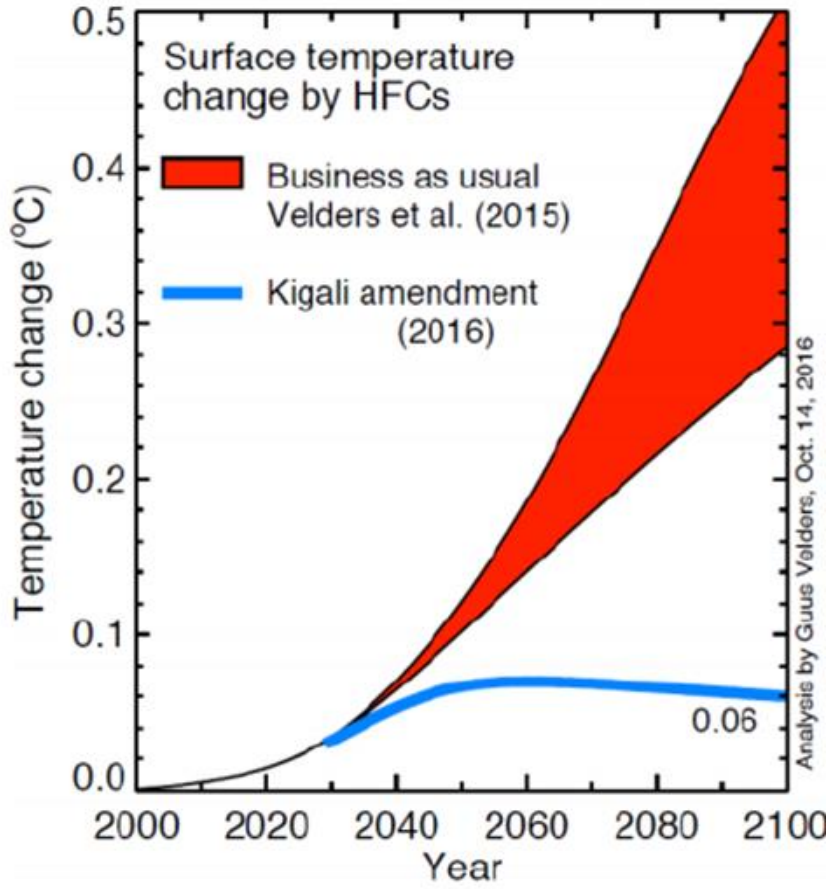

Photo by IISD/ENB | Kiara Worth

http://ozone.unep.org/countries/ratifications

The Kigali Amendment provides a global template to phase down the use of HFCs in an orderly fashion.

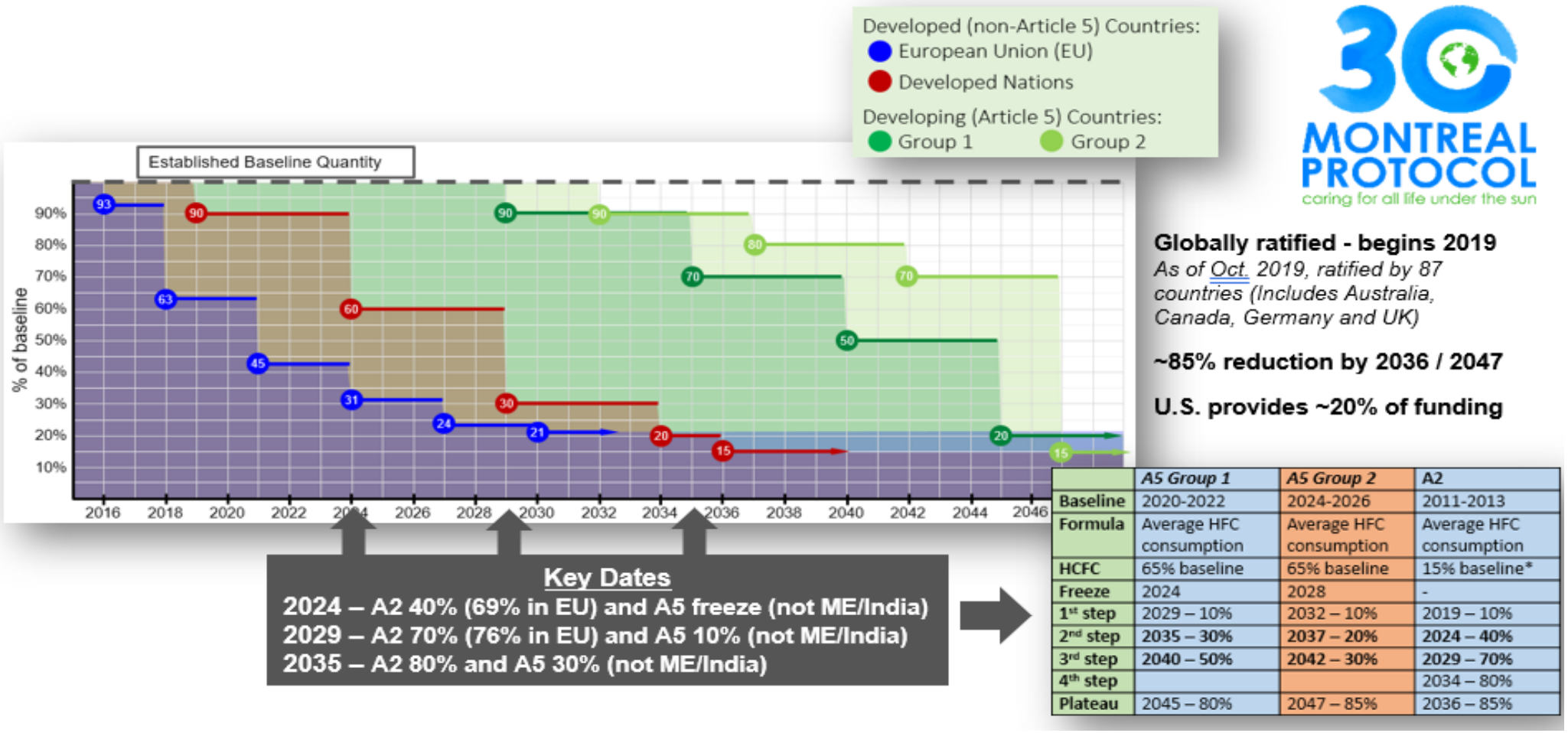
# Montreal Protocol – Kigali Amendment

- Phase down of HFCs, not phase out
- Avoids 80 Billion Metric Tons of Carbon Dioxide equivalent cumulatively through 2050
- Expected to avoid 0.5 °C of Global Temperature rise by year 2100 while continuing to protect Ozone layer




Kigali Amendment avoids 80 Billion MT $CO^2$

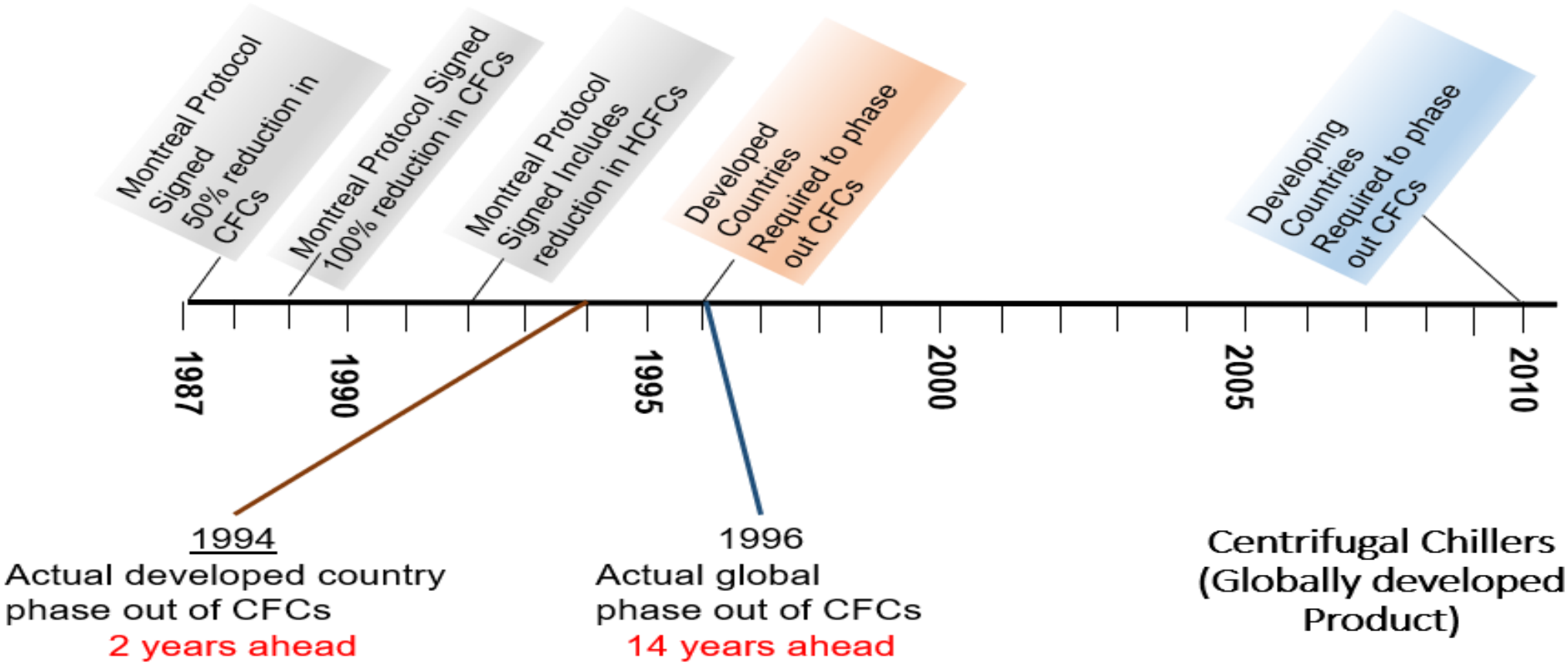
# Montreal Protocol – Kigali Amendment




| | A5 Group 1 | A5 Group 2 | A2 |
|---|---|---|---|
| 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 – 40% |
| 3rd step | 2040 – 50% | 2042 – 30% | 2029 – 70% |
| 4th step | | | 2034 – 80% |
| Plateau | 2045 – 80% | 2047 – 85% | 2036 – 85% |

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

# Montreal Protocol – Kigali Amendment




Change in Developing Countries can be faster than expected!

# Regulatory Update

# Regulatory Update


SNAP
SIGNIFICANT • NEW • ALTERNATIVES • POLICY

FOR IMMEDIATE RELEASE: December 1, 2016

www.epa.gov/snap

## FACT SHEET

## Final Rule 21 - Protection of Stratospheric Ozone: Significant New Alternatives Policy Program New and Changed Listings

# Regulatory Update

## CHANGE OF LISTING STATUS

| End-Uses | Substitutes | Date of Change of Status |
|---|---|---|
| **Air Conditioning** | | |
| Centrifugal chillers (new) | FOR12A, FOR12B, HFC-134a, HFC-227ea, HFC-236fa, HFC-245fa, R-125/134a/600a (28.1/70/1.9), R-125/290/134a/600a (55.0/1.0/42.5/1.5), R-404A, R-407C, R-410A, R-410B, R-417A, R-421A, R-422B, R-422C, R-422D, R-423A, R-424A, R-434A, R-438A, R-507A, RS-44 (2003 composition), and THR-03 | Unacceptable, except as otherwise allowed under a narrowed use limit, as of January 1, 2024 |
| Centrifugal chillers (new) | HFC-134a for military marine vessels | Acceptable, subject to narrowed use limits, as of January 1, 2024 |
| Centrifugal chillers (new) | HFC-134a and R-404A for human-rated spacecraft and related support equipment | Acceptable, subject to narrowed use limits, as of January 1, 2024 |
| Positive displacement chillers (new) | FOR12A, FOR12B, HFC-134a, HFC-227ea, KDD6, R-125/134a/600a (28.1/70/1.9), R-125/290/134a/600a (55.0/1.0/42.5/1.5), R-404A, R-407C, R-410A, R-410B, R-417A, R-421A, R-422B, R-422C, R-422D, R-424A, R-434A, R-437A, R-438A, R-507A, RS-44 (2003 composition), SP34E, and THR-03 | Unacceptable, except as otherwise allowed under a narrowed use limit, as of January 1, 2024 |
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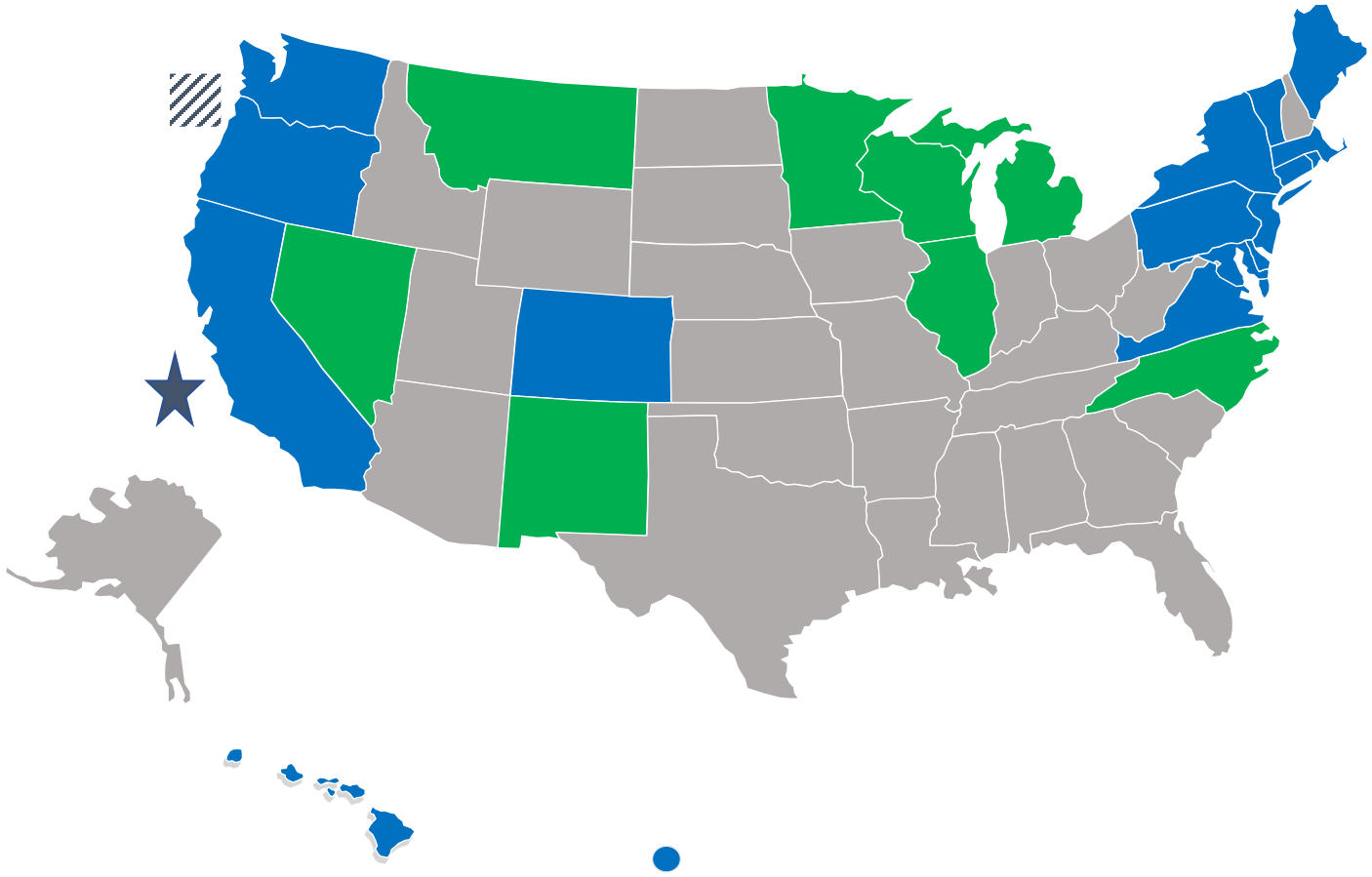
# Regulatory Update



- Member of the US Climate Alliance
- Member of US Climate Alliance and adopted HFC transition dates or announced actions to regulate
- Pursuing restrictions on direct HVAC systems
- Codes allow A2Ls in all products

CA, CO, DE, MA, MD, NJ, NY, WA, VA and VT adopted HFC SNAP-sector transition dates

CT, RI are developing regulations

HI, ME, OR have introduced legislation to adopt transition dates

## Climate Alliance

- 25 states (55% U.S. population / 60% U.S. GDP)
- Short Lived Climate Pollutant Challenge includes HFCs

## EPA SNAP 20/21

- Commercial refrigeration
- Chillers (2024)
- Foams

# Regulatory Update

- CARB adopted mandate to reduce HFC emissions 40% from 2013 baseline by year 2030
- CA adopted U.S. EPA SNAP 20 and 21 rules
  Chillers transition from R134a/R407A/R410A by January 1, 2024
- CARB analysis show that SNAP 20 and 21 rules phase out dates will provide 24% of reductions needed
- CA proposing additional regulations:
  - Proposed < 750 GWP limit for new chillers in 2024
  - Proposed < 750 GWP limit for new unitary/VRF/residential in 2023
- Refrigerant management regulations to align with EPA section 608
- Will evaluate whether bulk HFC phase down is needed to meet 40% reduction target

CALIFORNIA AIR RESOURCES BOARD

# Regulatory Update

## US American Innovation AND Manufacturing Act

- The AIM ACT mandates a 15-year phasedown of HFCs at a national level for the first time, administered by EPA, and aligned with the Kigali schedule.
- It requires EPA to implement an 85 percent phasedown of the production and consumption of HFCs, so they reach approximately 15 percent of their 2011-2013 average annual levels by 2036.
- It also authorizes EPA to adopt sector-specific use restrictions.
- It mostly does NOT preempt existing or developing state HFC programs.

EPA Moves Forward with Phase Down of Climate-Damaging Hydrofluorocarbons | U.S. EPA News Releases | US EPA

# Regulatory Update

## European Union

- Few product bans in place
  Phase-out of GWP > 750 by 2025 (mini-splits)
- Aggressive allocation restrictions for HFCs
- Refrigerant price driving transition rather than product bans

## Canada

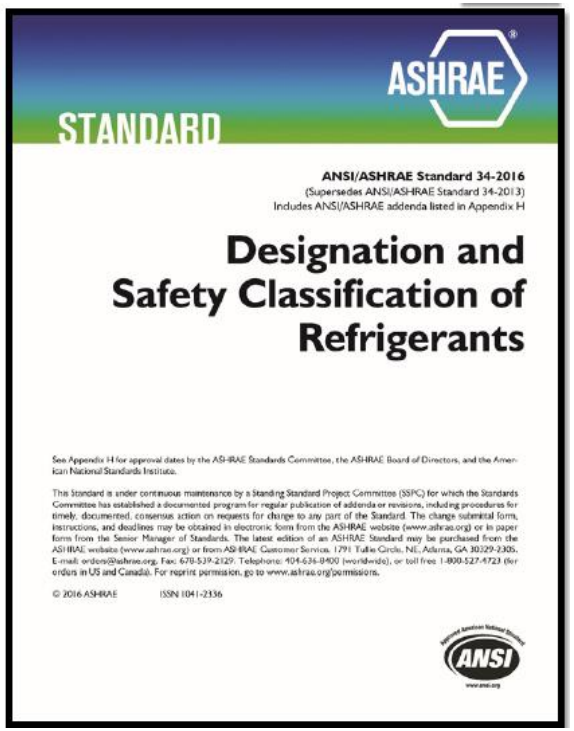
- Industrial Refrigeration:
  Phase-out of GWP > 2200 by 2020
- Transport Refrigeration:
  Phase-out of GWP > 2200 by 2025
- HVAC Chillers:
  Phase-out of GWP > 750 by 2025
- Bulk HFC phase down (quota allocated)

## Japan

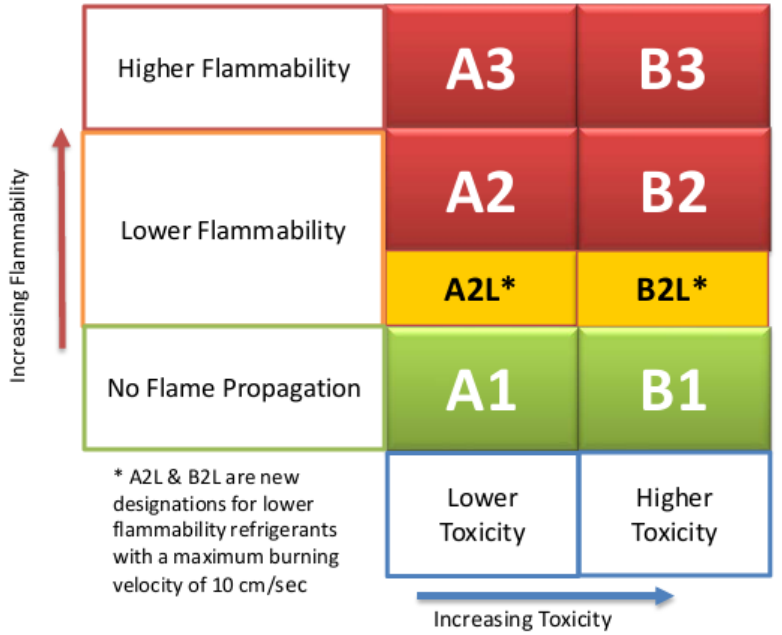
- Mini-Splits:
  Phase-out of GWP >750 by 2018
- Commercial Split (not VRF):
  Phase-out of GWP >750 by 2020
- Centrifugal Chillers:
  Phase-out of GWP >100 by 2025

Each country develops own regulations to meet HFC reductions

# Regulatory Update



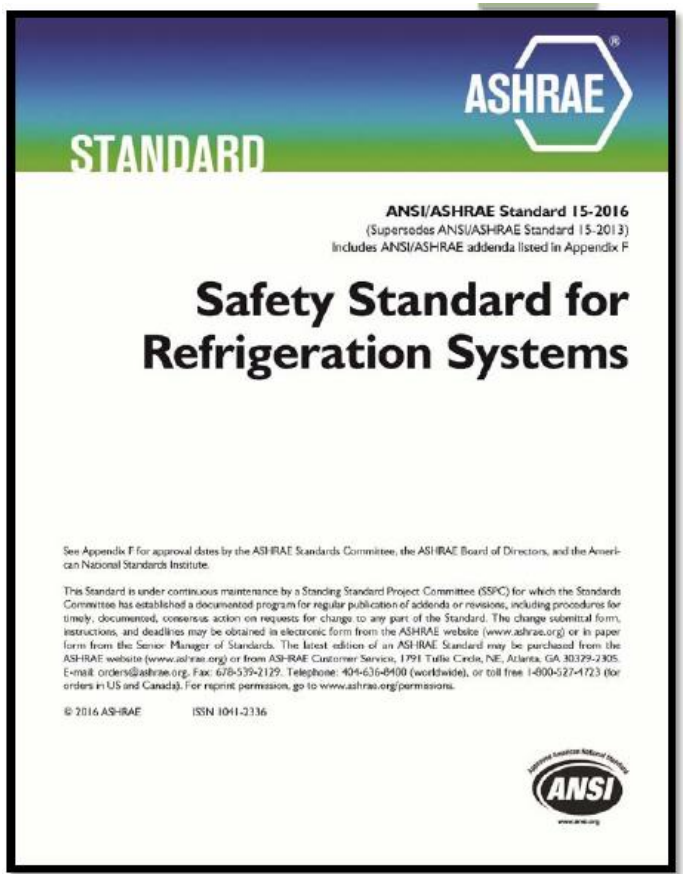

- ASHRE 34 standard
- Designation of Refrigerants
- Classification of Refrigerants




ASHRAE standard 34 updated to accommodate new classes

# Regulatory Update

- ASHRE 15: Application standard
- Gives basic rules of how and where refrigerant can be used based on safety classification developed by ASHREAE 34 standard
- Building codes use the application design guidelines developed by ASHRAE 15




Building Codes updated to include New Generation refrigerants

# Comparison of Alternatives

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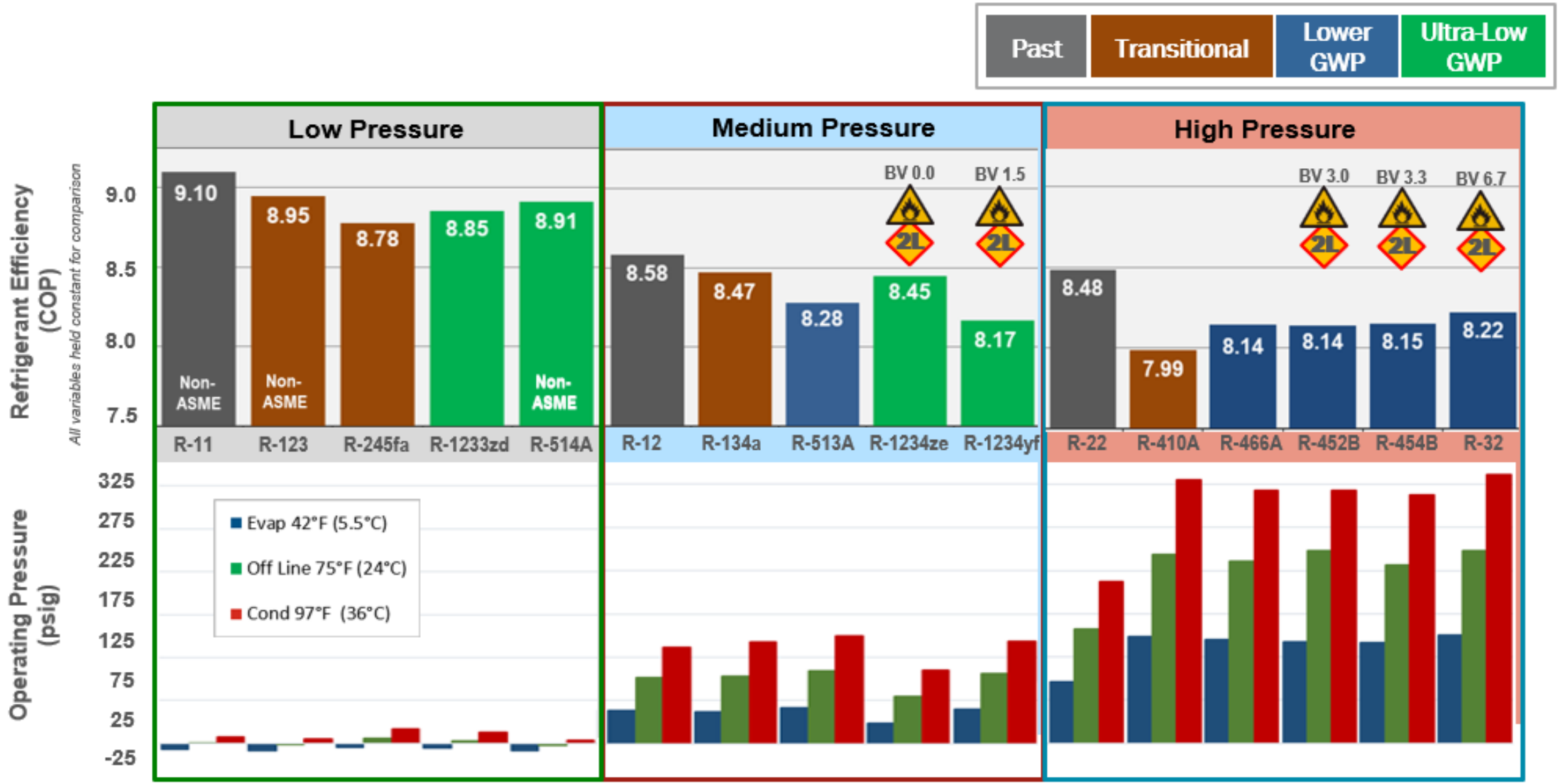

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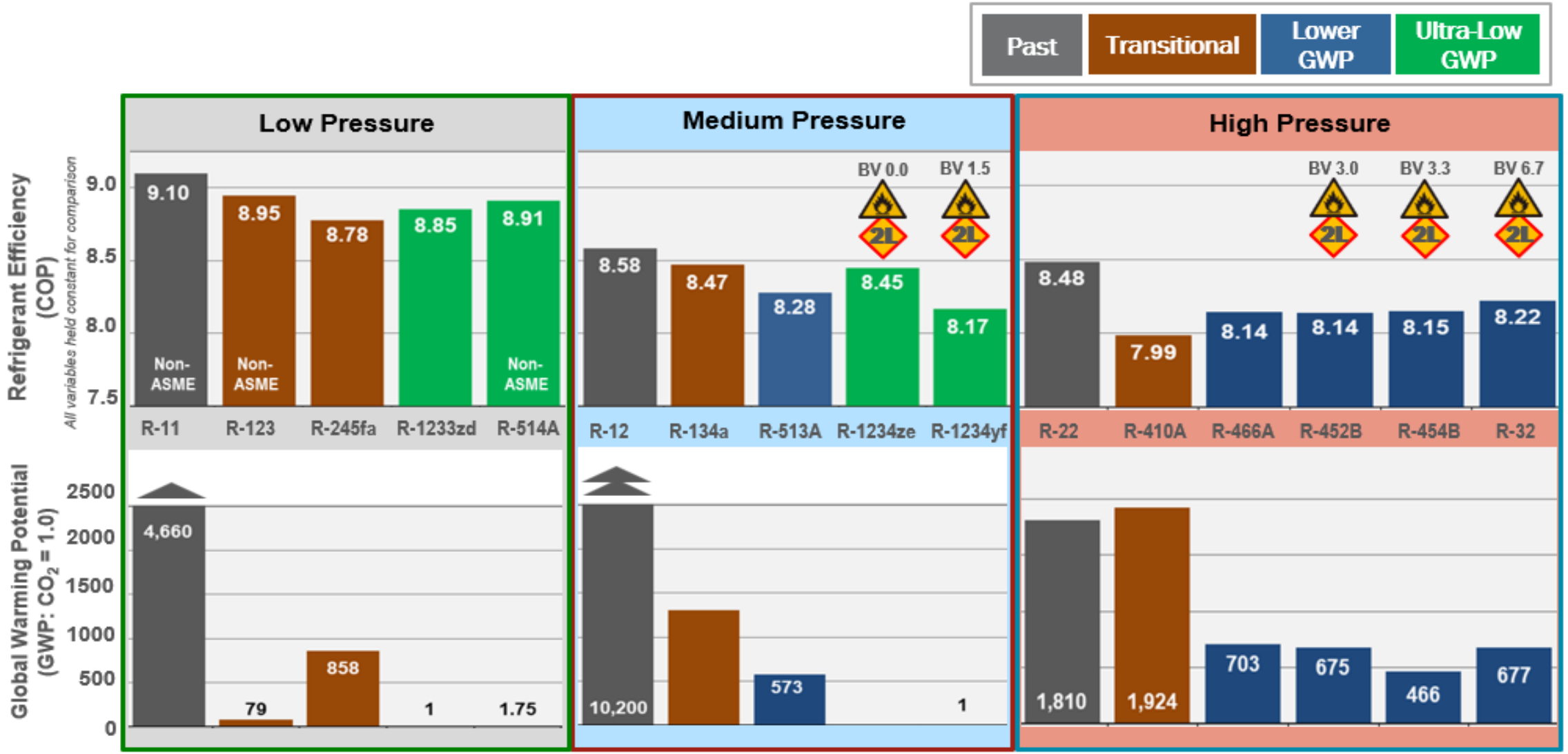

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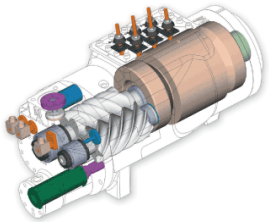
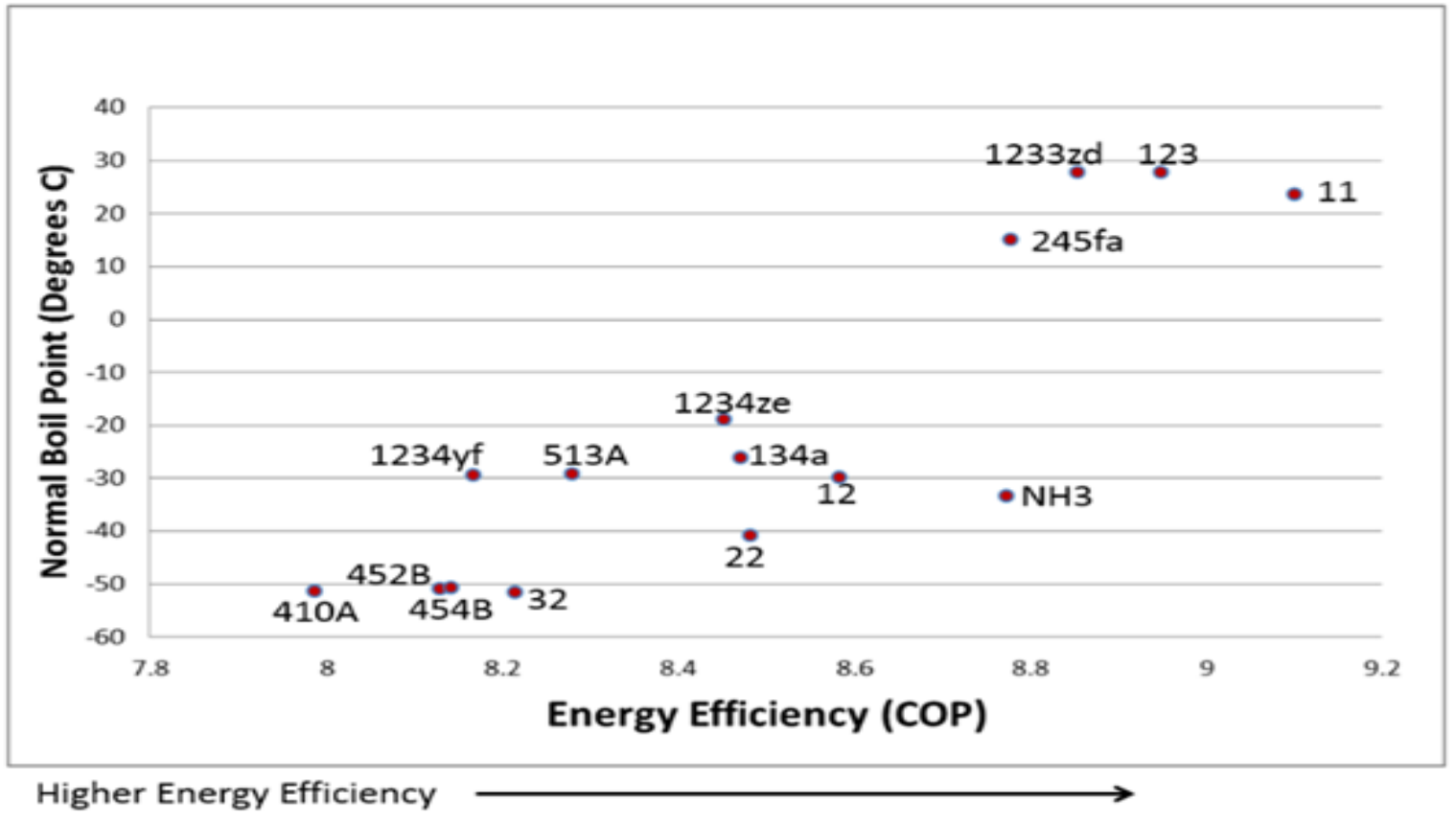





Lower pressure refrigerants trend to be more efficient

# Comparison of Alternatives

## Large Tonnage Chillers

- Low and medium pressure refrigerants
- Best possible efficiencies
- Globally designed products
- 30+ year design life

## Medium Tonnage Chillers

- Medium and high pressure refrigerants
- Medium efficiencies
- Globally and regionally developed products
- 20 year design life

## RAC and Unitary

- High pressure refrigerants
- Lower efficiency
- Locally developed products
- 10-15 years design life

# Refrigerates and Applications

- Data Center
- Electrification of Heating

# Refrigerants and Data Center

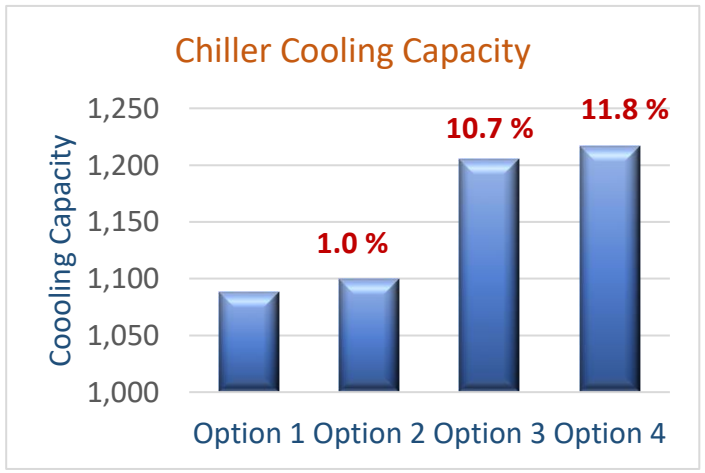
## 2. Changes in Data Center Environments

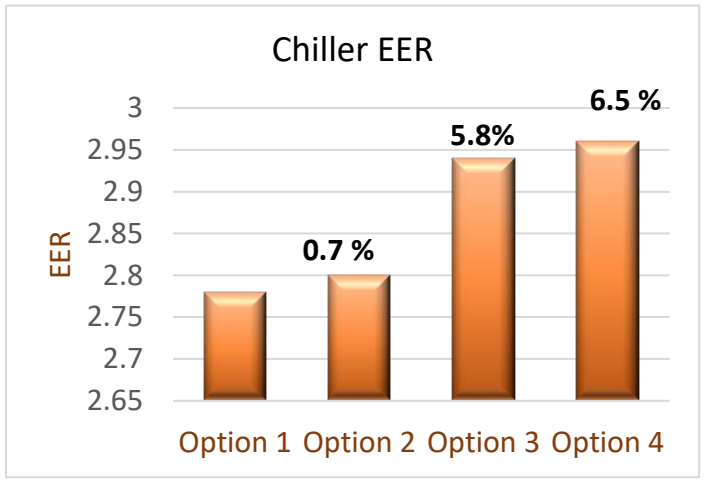
Changes to data center environmental conditions are being driven by the need to save energy and reduce operational expenses. One of the largest operational expenses in delivering IT is the cost of energy. In a traditional data center, cooling costs alone can easily represent 25% or more of total energy costs [5]. Many data centers now run several degrees warmer compared to 10 or 15 years ago to save on cooling costs [6]. New energy saving technologies such as air-side economization and water-side economization are growing in adoption, whose hours of beneficial use increase as computer room temperatures increase.

# Refrigerants and Data Center

| Option | Design conditions | | | | Chiller Selection | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Evap EWT | Evap LWT | Amb | Capacity | Cooling Capacity | | Power Input | EER | |
| | °C | °C | °C | KW | KW | | KW | KW/KW | |
| Option 1 | **26** | **18** | 48 | 1,200 | 1,088 | | 391.8 | 2.78 | |
| Option 2 | **28** | **18** | 48 | 1,200 | 1,099 | 1.0% | 392.5 | 2.8 | 0.7% |
| Option 3 | **30** | **22** | 48 | 1,200 | 1,205 | 10.7% | 410.4 | 2.94 | 5.8% |
| Option 4 | **32** | **22** | 48 | 1,200 | 1,216 | 11.8% | 410.8 | 2.96 | 6.5% |

- Cooling Capacity and EER increase with increasing LWT and ΔT
- R1234ze enabled chiller selection with higher Leaving Water Temp
- Trends in DC design to increase WT providing opportunity for Energy saving

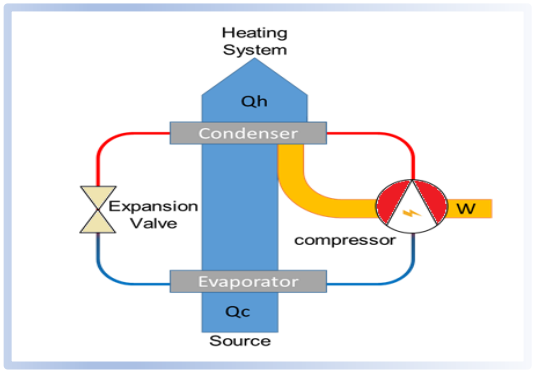


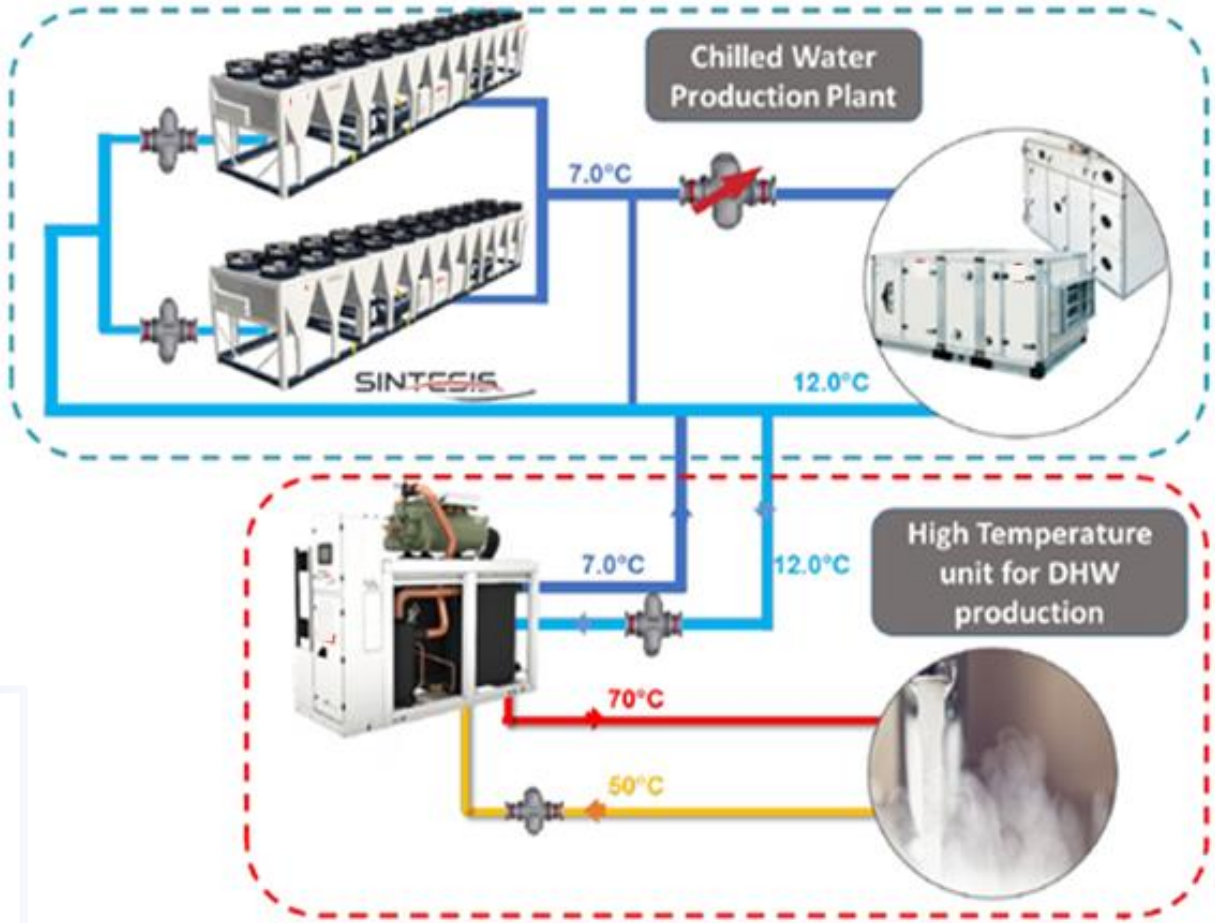



# Refrigerants and Heating



- Building have simultaneous need for cooling and heating (space heating, Domestic Hot Water (DHW), ventilation reheat)
- Sources of hating:
  - Fossil fuel (boilers)
    Direct emissions, Efficiency < 100%
  - Electric calorifiers
    1 KW Electric → 1 KW thermal
  - Heat Pumps
    1 KW Electric → 3 KW thermal



# Refrigerants and Heating

## General Information

| | | | |
|---|---|---|---|
| Cooling capacity gross | 48.06 tons | Heating capacity gross | 275.05 kW |
| Cooling capacity net | 168.66 kW | Heating capacity net | 275.88 kW |
| Gross EER | 1.664 kW/kW | Gross COP | 2.707 kW/kW |
| Net EER | 1.641 kW/kW | Net COP | 2.684 kW/kW |
| ETAsc | 240.00 % | SCOP-MT | 194.00 % |
| SEPR-MT | 4.55 | SCOP-LT | Not applicable |
| SEPR-HT | Not applicable | Sound power | |
| Refrigerant | R1234ze | Sound pressure | |
| Nr of circuit | 1 | Topss version | 225 |
| Nr of compressors | 1 | Data generation date | 7/10/2019 |
| Refrigerant charge | 42 kg | Aesthetic and sound attenuation package | Without |
| Oil charge | 7.00 L | | |

## Evaporator Information

| | | | |
|---|---|---|---|
| Evaporator application | Comfort cooling | Evap fluid type | Water |
| | | Evap fluid concentration | 0% |
| Evap entering temp | 12.0 C | Evap fouling factor | 0.017600 m2-deg C/kW |
| Evap leaving temp | 7.0 C | Evaporator size | Evaporator B |
| Evap flow rate | 8.06 L/s | Min flow evap | 4.80 L/s |
| Evap pressure drop | 15.8 kPa | Max flow evap | 38.60 L/s |

## Condenser Information

| | | | |
|---|---|---|---|
| Unit application | Heat pump - >50C | Cond fluid type | Water |
| | | Cond fluid concentration | 0% |
| Cond entering temp | 65.0 C | Cond fouling factor | 0.044000 m2-deg C/kW |
| Cond leaving temp | 70.0 C | Condenser size | Condenser A |
| Cond flow rate | 13.41 L/s | Min flow cond | 2.74 L/s |
| Cond pressure drop | 30.0 kPa | Max flow cond | 38.60 L/s |
| | | Cond number of plates | 240 |

## Electrical Information

| | |
|---|---|
| Unit power supply | 400/50/3ph |
| Total power | 101.60 kW |

$$TEER = \frac{168.6+275}{101.6} = 4.39$$

- Without HP:
  Cooling: 50 TR X1.5 KW/TR = 75 KW
  Heating: 275 KW
  **Total: 350 KW**
- With HP: 101 KW
- Estimated Energy Saving:
  350 - 100 = 250 KW
  2 Nos X 250 KW X 4 hours
  = 2,000 KWh/ day


Summary

# Summary

- HFCs are green house gases and are being phased down as per Montreal Protocol – Kigali Amendment
- Each country ha its own regulations to comply with the required reductions
- EU is leading HFCs phase down
- HFOs such as R1233zd, R1234ze and R514A provide excellent Environmental solutions as it has 0 ODP and ultra low GWP ~ 1
- R1233zd refrigerant provided excellent opportunity for bigger chillers capacity, less footprint, more energy efficiency, lower leakage rates and lower emission

- Change in developing countries is expected to be faster than expected
- New refrigerants such as R1234ze provided opportunities for Energy saving in applications such as higher supply water temp in Data Centers
- New refrigerants such as R1234ze provided opportunities for decarbonization of buildings and electrification of heating. Technology of Heat Pumps provide hot water for DHW
- “What we do to our planet comes back to us”