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for Responsible Atmospheric Policy

POLICY AND TECHNOLOGY CONSIDERATIONS FOR HFCs

Advancing Ozone and Climate Protection Technologies: Significant Progress, Continuing Challenges and Opportunities

September 2014 Update

AGENDA

- History of relevant policies
- Projected growth in HFC emissions
- New and proposed policy on HFCs
- Current technology development and potential barriers
- Regulatory challenges moving forward

HOW HAS THE SITUATION CHANGED IN 20 YEARS?

20 Years Ago

Fluorocarbons and equipment production was in the non-A5 countries

Market growth in A5 countries was slow

GWP was of little concern

Today

Some A5 countries are major fluorocarbon producers

Rapid market growth in A5 countries

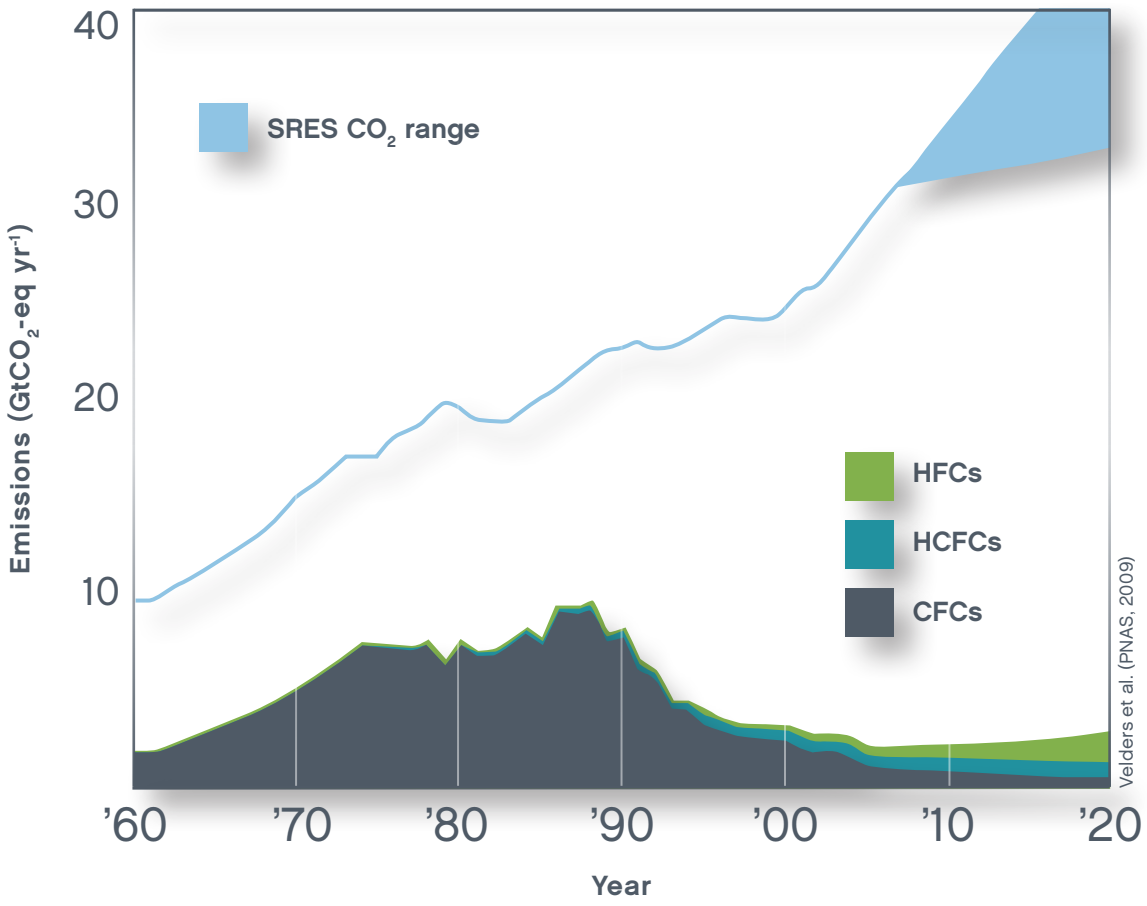
GWP is a major concern

The situation today remains the same for many non-A5 countries. Some A5 countries are now major producers of fluorocarbons and manufacturers of products and equipment.

Great work has already been done to reduce the climate change impact of fluorocarbons

NOW WE ARE DOING MORE

Reduced GWP Impact of Fluorocarbons[1]



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HFC POLICY EVOLVING AT A RAPID PACE

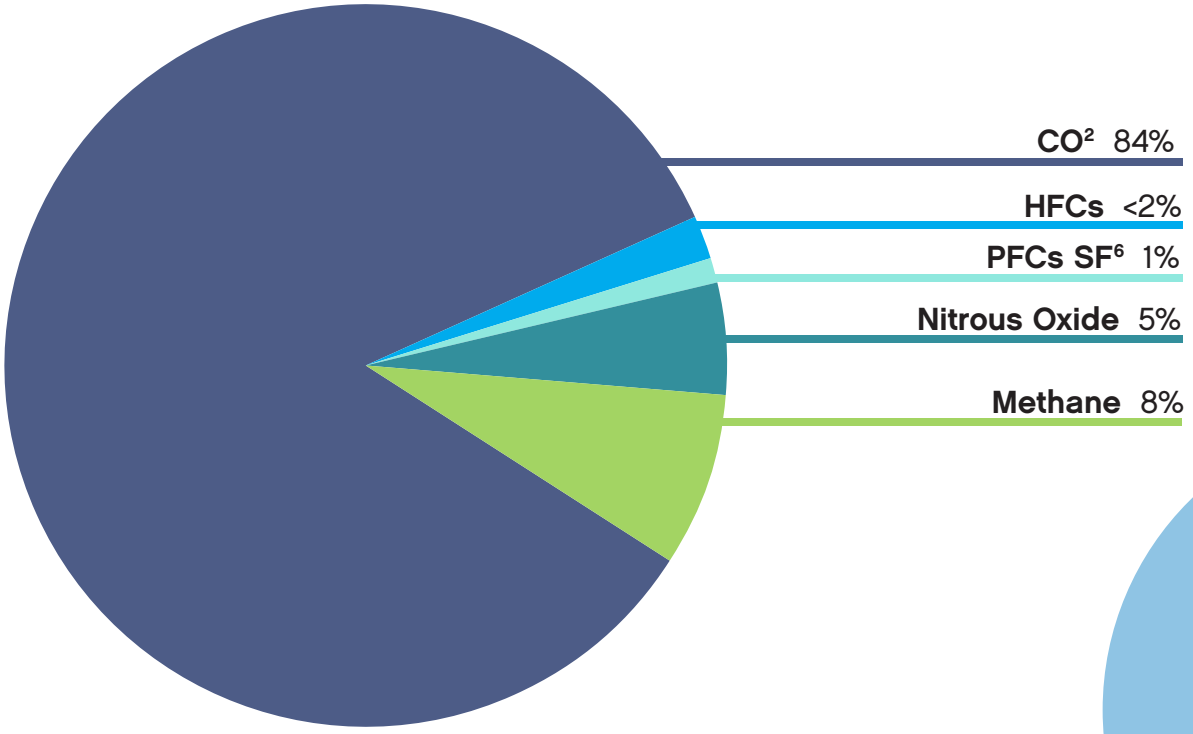
WHEN WILL IT HAPPEN?

Potential sharp growth in HFC emissions is driving new and proposed global and regional policies

- European Union approved F-gas regulation to phase down HFCs 79% by 2030 and ban certain applications using refrigerants above a specified GWP as well as aerosols and foams
- Climate and Clean Air Coalition (CCAC) pledges to reduce HFC use
- US Supreme Court continues to affirm US EPA authority to regulate greenhouse gas emissions
- MAC Directive in Europe and the US greenhouse gas CAFE incentive is causing a shift away from HFC-134a in automotive applications
- US is proposing a SNAP delisting of high GWP HFCs for consumer aerosols, various froam blowing end uses, commercial refrigeration and mobile AC
- Japan has passed HFC legislation and is preparing F-gas initiatives for a phase-down to begin in 2015
- Montreal Protocol: Multiple amendment proposals seek to reduce HFCs through the mechanisms of the successful ozone protection treaty
- A number of high level international statements have called for an HFC phase down under the Montreal Protocol

The complexities that come with an HFC phase down require a unified, global approach

GREENHOUSE GASES: CONTRIBUTION TO GLOBAL CLIMATE CHANGE



HFCs are potent greenhouse gases, but account for <2% of the total. Growth rate of HFCs is the largest concern.

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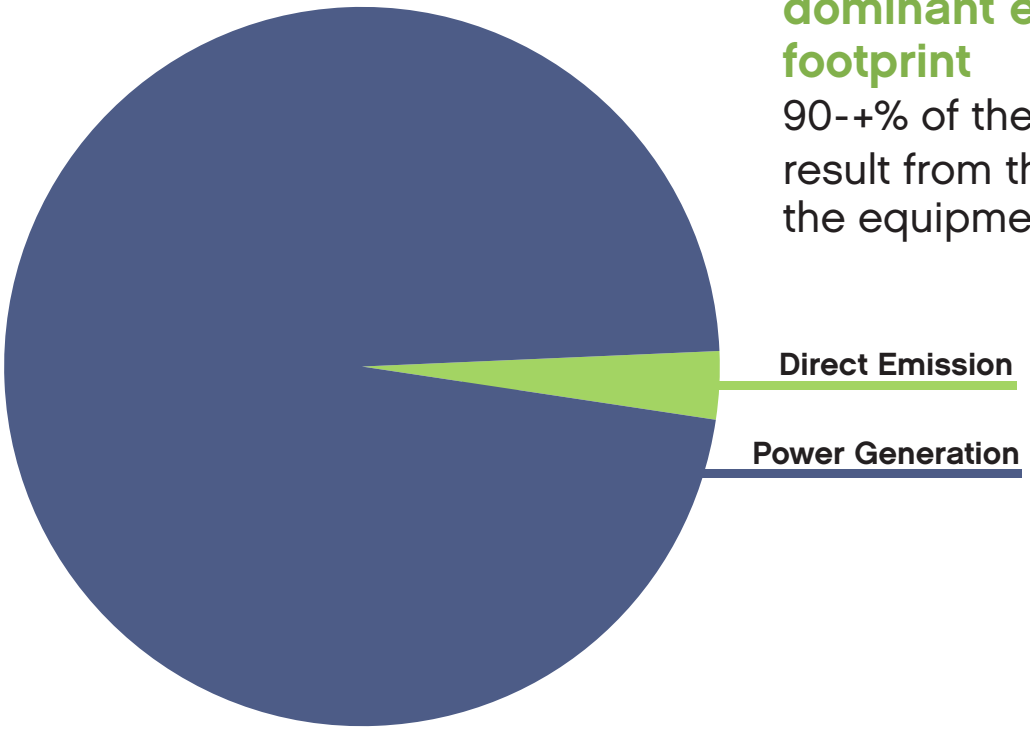
EFFICIENCY IS IMPORTANT

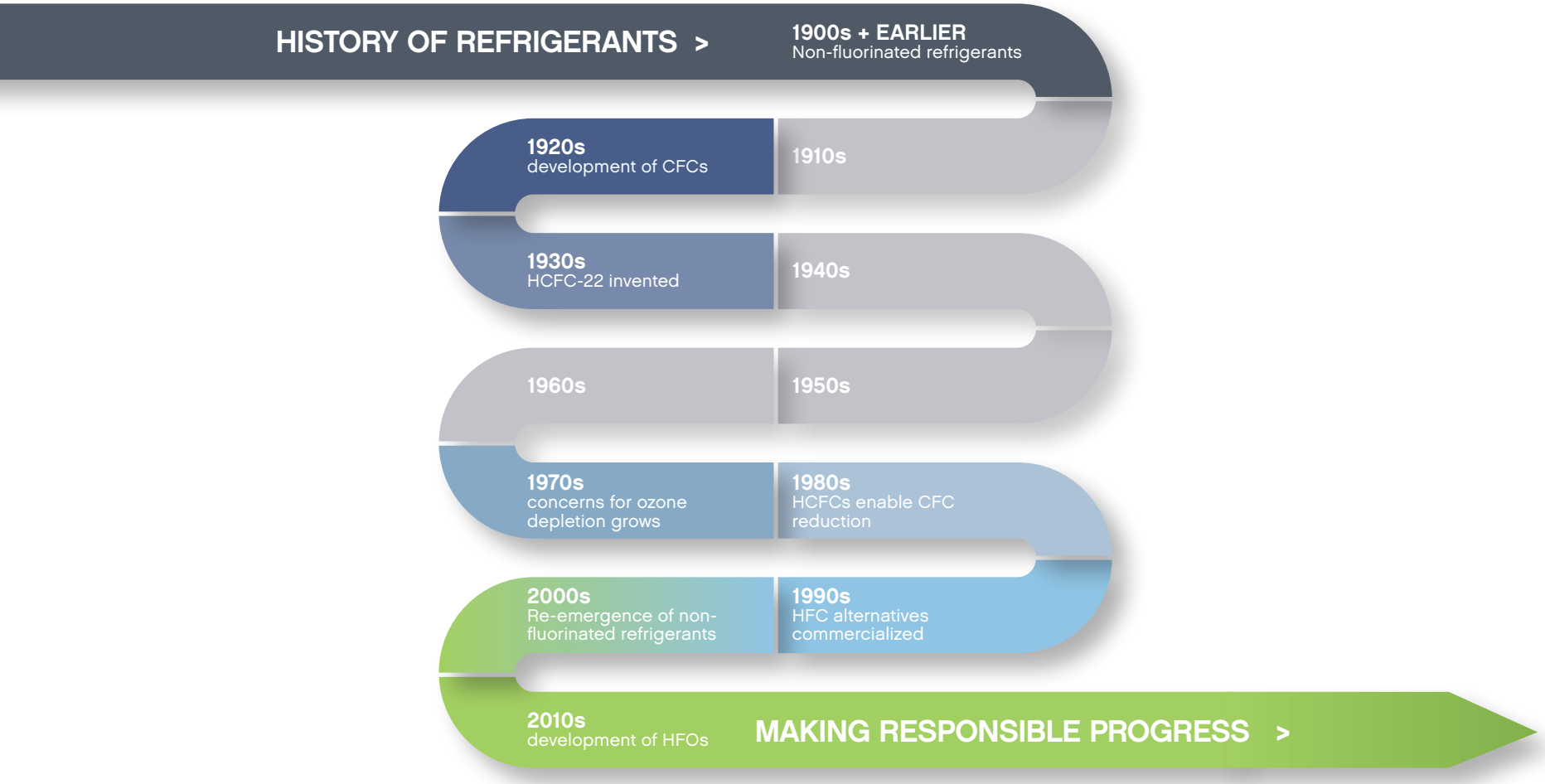


The indirect effect of HVACR equipment efficiency has a dominant effect on its carbon footprint

90-+% of the CO_2 equivalent emissions result from the power generated to run the equipment

When choosing lower GWP refrigerants, the energy efficiency of the resulting equipment is critical.

GENERATIONS OF REFRIGERANTS



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HFCs ARE USEFUL GASES

Global recognition that HFCs are produced for specific purposes, have value, and should be regulated as products, not just emissions

- In HVAC&R applications, HFCs are contained and can provide advantages in performance and energy efficiency in certain applications
- Inclusion with "waste" GHGs in a cap-and-trade scenario could cause unintended price and availability problems
- Mechanisms of the Montreal Protocol have proven effective
- Phase-down, not a phase out is needed to ensure the best solutions and smooth market transitions while ensuring the availability of important HVAC&R services

Phasedown approach which allows time for industry transition is the best solution

THE ACHIEVABLE GWP LEVEL WILL DEPEND ON EQUIPMENT TYPE, APPLICATION, AND RECOVERY

"High" and "Low" GWP are relative terms and dependent on:

- Applications (mobile or stationary)
- Average leak rate from the equipment
- Recovery rate at the end of life
- Safety requirement (flammability and toxicity)
- Performance requirements

95% of global HFC use is currently between 700 and 4000 GWP

New generation products generally have GWPs between < 1 and 700

THE ROLE OF SAFETY STANDARDS AND CODES ON REFRIGERANT OPTIONS

Safety and affordability are critical

- Hydrocarbons (flammable) are safe and efficient in some applications
- Slightly flammable (2L) refrigerants are safe and efficient in some applications
- Non-flammable solutions are still needed for some applications

Choose the right refrigerant for each application. Industry and government cooperation is needed for quick and appropriate safety standard and code adoption.

DEVELOPING NEW SOLUTIONS IS COMPLEX

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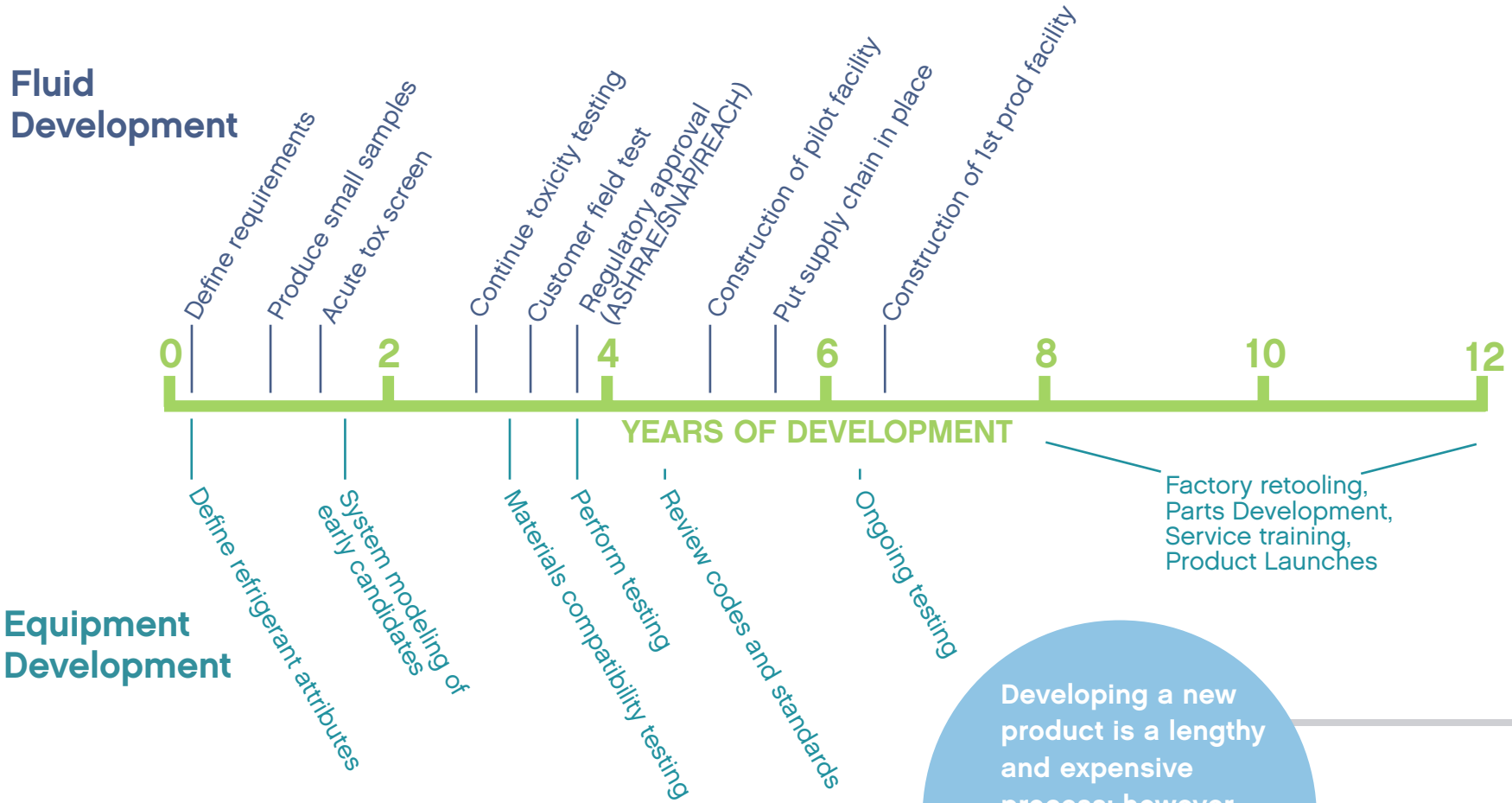
DEVELOPMENT TIME LINES FOR NEW PRODUCTS



Developing a new product is a lengthy and expensive process; however, tremendous innovation is underway.

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NEXT GENERATION LOW-GWP REFRIGERANTS

Low GWP Fluorocarbons:

HFO-1234yf

- Ultra-Low GWP (< 1), low toxicity, slightly flammable.
- Leading candidate to replace HFC-134a in mobile/ automotive applications
- Potential replacement for HFC- 134a in stationary AC and refrigeration
- Applications in HVAC

HFO-1234ze/HFO-1233zd/HFO-1336mzz/Other HFOs

- Beneficial properties for foam blowing, waste heat recover, aerosols, and solvent applications
- Potential solutions in refrigeration
- Potential solution for chillers and other HVAC equipment

HFC and HFO/HFC Blends

- Potential for lower-GWP fluids with better performance for many HVAC and foam applications
- Evaluations and trials ongoing for stationary air conditioning and refrigeration applications

Non-fluorinated Refrigerants:

- Often referred to as “natural” refrigerants
- Great solution for the right applications, but not right for all applications. Use when appropriate.
- Safety/Efficiency/LCCP/Affordability need to be considered

Solutions exist. Flexibility is needed to ensure that the right solutions continue to be developed.

LOW-GWP INNOVATION IN THE FOAM INDUSTRY

Manufacturers and potential manufacturers of HFOs are reporting that their commercialization timelines are on schedule.

The gaseous blowing agent, HFO-1234ze is commercially available globally with most use currently in Europe

- Extruded Polystyrene Foam
- One Component Polyurethane Foam

Large scale commercial production of HFO-1233zd is taking place with several commercial uses announced

- Appliances (US, China)
- Spray Foam (US, EU, Japan)

HFO-1336mzz is expected to be available in small scale by the end of 2014 and larger commercial quantities by 2016

- Spray foam

WHAT ARE SOME EXAMPLES OF WHEN...

Flammable refrigerants can be a good solution?

- Smaller charge application
- Industrial refrigeration and process cooling

Non-fluorinated refrigerants can be a good solution?

- Low temperature refrigeration
- Locations where some safety risks can be mitigated
- Unique solutions for waste heat (absorption)
- Cascade systems

HFOs and HFCs can be a good solution?

- Large commercial and unitary HVAC
- Refrigeration in populated areas where strict safety is required
- Conversion and retrofit
- Specialty device applications
- High performance foams where insulation is important (e.g. refrigeration, food transport)
  - Waste heat recovery
  - Cascade systems
  - Automotive
  - Aerosols & solvents applications

IS A 79-85% GWP WEIGHTED REDUCTION POSSIBLE FOR HFCs?

Large industries that use HFCs have already identified ultra-low GWP Alternatives:

- Automotive/Mobile AC: HFO-1234yf/HFO-HFC blends GWP = < 1–150
- Foam Blowing Industry: HFOs GWP < 1
- Solvents Industry: HFO-1234ze GWP <1

The appliance industry will likely use hydrocarbon and HFO refrigerants

The HVAC&R industry will employ various solutions:

- HFO, HFC, and HFO/HFC blends (GWP = < 1–700) for most new equipment and retrofit/service

The fire suppression, metered dose inhaler and certain technical aerosol applications may continue to use HFCs at some level

Low GWP alternatives are now available for the solvents industry

New technology continues to be developed and commercialized

SUMMARY

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Significant climate change mitigation has already been achieved in fluorocarbon applications

Policy changes drive technology development

The complexities of an HFC phasedown require a unified, global approach

Significant innovation is underway in the HVAC&R value chain

Significant HFC reduction is possible, but we need:

- Adequate development time
- Flexibility in design and application
- Refrigerant management and supply for service over life of equipment
- Ability to use higher GWP solutions when the application needs it
- Montreal Protocol institutions provide the best model for effectice HFC phasedown