# The Four R's for R R R R Responsible Responses to Refrigerant Regulation

**These four R's for air conditioning and refrigeration identify ways that users of refrigerants, along with manufacturers and their equipment, can affect future options. From the latest scientific evaluations to special taxes to industry politics, the future of refrigerants is fraught with challenges. In this guest commentary, the author reports from the front, makes three recommendations for smart decisionmaking, and notes one phaseout that may be too hasty.**

BY JAMES M. CALM, P.E.

What we refer to as "new" or "alternative" refrigerants are not really new anymore. Refrigerant 123 (R-123, first commercialized in 1989) replaced R-11 and has logged more than 100,000 chiller-years of successful service. R-134a (introduced the following year) replaced R-12 and R-500 in diverse applications including appliances such as refrigerators, mobile air conditioners, some commercial refrigeration, and screw and centrifugal chillers. R-22 (produced since 1936) use increased in medium- and low-temperature refrigeration, and it remains the primary refrigerant for unitary equipment. The switch from R-22 to R-410A in new equipment is underway, with completion expected in five or six years. R-404A and R-507A (both introduced in 1993) replaced R-502 in commercial refrigeration, especially for low-temperature (such as frozen foods) use. Other replacements and service fluids are summarized in Table 1. There are more than 100 additional refrigerants — mostly blends — in use, but their aggregate market share is very small. The table addresses only those refrigerants that have obtained standard designations.

The "alternatives" have become the norm for new equipment in many applications and in conversions for some old equipment. The deceptive ease of the transition masks the enormous investments made by chemical and equipment manufacturers to identify substitutes, develop safety and application data for them, redesign products and service practices, develop and qualify new lubricants and other fabrication material, and test and rate new equipment.

Industry deserves recognition for the progress made thus far and for having improved both performance and safety in the process. Equipment manufacturers, as well as installing and servicing technicians, warrant special acknowledgment for reducing emissions, to levels at which phaseout might not have been necessary for some retired refrigerants had there been no other emissive applications.

Although stockpiled and recovered chlorofluorocarbon (CFC) refrigerants remain available for service of old systems, the best reasons for replacement of equipment still using CFCs are significant improvements in efficiency — with next-generation equipment — and resulting cost savings.

Hydrocarbons, primarily isobutane, now dominate in refrigerators in some countries. Likewise, use of ammonia and hydrocarbons (such as propane and propylene) is increasing, most notably in some European countries. While further use of carbon dioxide is exciting, for example in

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**Older and "Alternative" Refrigerants**

| CFC or HCFC | Existing equipment (may require conversion) | | | | New equipment | |
|---|---|---|---|---|---|---|
| R-11 | R-123 | | | | **R-123** | R-245fa |
| R-12, R-500 | R-134a | R-401A | R-401B | R-401C | **R-134a** | R-227ea |
| | R-405A | R-406A | R-407D | R-409B | R-245fa | **HCs** |
| | R-412A | R-413A | R-414A | R-414B | | |
| | R-415A | R-416A | R-418A | R-420A | | |
| R-22 | R-407C | R-411A | R-411C | R-417A | **R-407C** | R-407E |
| | R-419A | | | | **R-410A** | R-410B |
| | | | | | **???** | HCs |
| R-113 | None | | | | Any replacement | |
| R-114, R-400 | R-124 | R-236fa | E245cb1 | R-401A | R-236fa | E245cb1 |
| R-502 | R-402A | R-402B | R-403A | R-403B | **R-404A** | R-407A |
| | R-404A | R-407A | R-407B | R-408A | R-507A | R-509A |
| | R-409A | R-411B | R-411C | R-507A | HCs | |
| R-13B1 | R-410A | R-410B | | | **R-410A** | R-410B |
| R-13, R-503 | R-23 | R-508B | | | R-23 | **R-170** |
| | | | | | R-508A | R-508B |

Other and special purpose refrigerants include:

- **R-717 (ammonia)** in food and beverage processing, industrial refrigeration, absorption ($NH_3/H_2O$).
- **R-718 (water)** in absorption cycles ($H_2O$/LiBr), industrial steam recompression, and vacuum vapor-compression.
- **R-729 (air)** in Brayton cycles specialty uses.
- **R-744 (carbon dioxide)** in low stage of cascade systems especially with ammonia, commercial and transport refrigeration, mobile air conditioners, and heat pump water heaters.
- R-704 (helium) and R-7131 (xenon) in Stirling cycles in refrigerators, special purposes, and thermoacoustic refrigeration.
- **Hydrocarbons** (HCs) in diverse uses, primarily in equipment with very small charges such as refrigerators and refrigerator-freezers (note that R-170 above is ethane).
- **Cryogenic fluids** (such as helium and argon) in ultra-low temperature refrigeration.

Refrigerants highlighted in bold are those the author believes will be the long-term survivors as others are phased out.

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**TABLE 1. Older and "alternative" refrigerants.**

the low stage of cascaded refrigeration systems, its benefits often are overstated for broad application.

Although still underway, the transition has gone so smoothly that most refrigerant users are unaware of the regulatory and political challenges facing many of the replacements. The mantra of ozone protection was to switch to use of hydrochlorofluorocarbon (HCFC) or hydrofluorocarbon (HFC) options, the former on an interim basis.

Several key applications still rely on HCFCs, notably R-22 for more than 90% of unitary air conditioners and heat pumps, and R-123 for more than two-thirds of new centrifugal chillers.

HCFCs are scheduled for phaseout in new equipment in the U.S. by 2010 and 2020, respectively, with further production allowances to support service needs. For R-123, production for service is allowed until 2030 in developed countries and until 2040 in developing countries. Neither the Montreal Protocol nor regulations in

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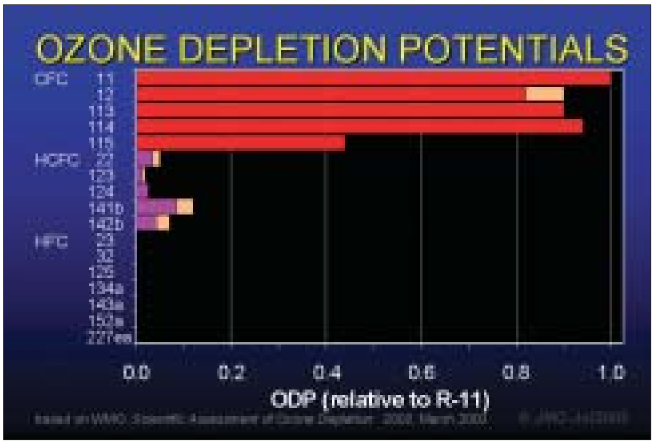


**FIGURE 1. Ozone depletion potentials (ODPs) of common CFC, HCFC, and HFC refrigerants (based on WMO, "Scientific Assessment of Ozone Depletion: 2002," March 2003).**

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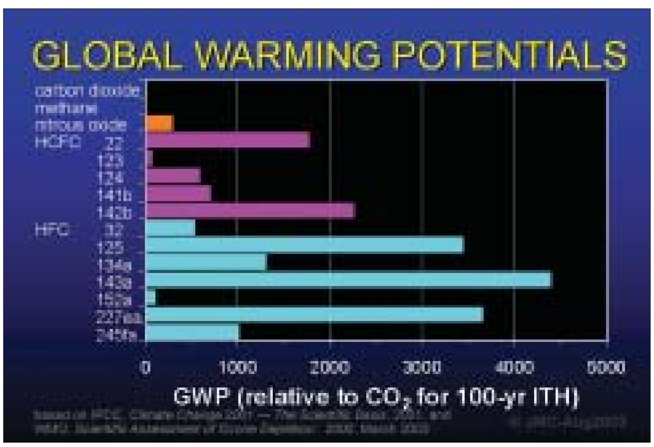


**FIGURE 2. Global warming potentials (GWPs) of common HCFC and HFC refrigerants (based on IPCC, "Climate Change 2001 — The Scientific Basis," 2001, and WMO, "Scientific Assessment of Ozone Depletion: 2002," March 2003).**

the USA, and most other countries, restrict further use of existing installed, stockpiled, or reclaimed HCFCs for future service, so there should be more than enough for anticipated service needs.

Some countries and environmentalists now are clamoring for phaseout of HFCs to mitigate global warming. The more extreme of them champion bans of all fluorochemicals — well beyond refrigerants, blowing agents, solvents, propellants, and fire suppressants — to also eliminate use in such products as synthetic fabrics (such as Gore-Tex) and coatings for cookware (such as Teflon).

The pressures facing fluorochemicals, and specifically HFC refrigerants, are evident in control measures already in place in a number of European countries. They include special labeling, taxes weighted by global warming potentials (GWPs) scheduled phaseouts (as early as 2003 for domestic refrigeration in Switzerland and 2006 for most uses in Denmark), and outright prohibitions for some applications. The European Commission (EC) has approved a draft regulation on marketing, use, and containment of HFCs. Among other measures, the proposal requires periodic inspections for leakage by qualified professionals, annually for small systems and more frequently for large equipment. It also calls for eventual phaseout of R-134a in mobile systems such as automobile air conditioners.

The overwhelming majority of refrigerant use, and all fluorochemical refrigerant use, is in closed systems that need not release refrigerants for operation. The refrigerants inside systems do not deplete stratospheric ozone. They also do not act as greenhouse gases, though more significant emissions of carbon dioxide and other greenhouse gases from related energy use do. The costs and service needs are lower and efficiency and capacity higher in systems without leaks.

Nevertheless, there is scientific evidence that the atmospheric concentrations of some alternatives are increasing more rapidly than explained by reported and attainable emission rates. That suggests that users can influence the future acceptability and ultimate fate of alternative refrigerants through responsible use by:

- Selecting refrigerants that have very low ozone depletion (ODP) and GWP: Such refrigerants typically also have short atmospheric lifetimes, thereby reducing accumulation in the atmosphere and affording protection from additional concerns (Figures 1 and 2).
- Minimizing emissions in manufacture, packaging and repackaging, transport, storage, installation (charging), service, and equipment retirement (recovery): The dramatic reductions in chiller losses (Figure 3) — from an annualized rate of up to a third of the charge per year three decades ago to less than 0.5% per year in the best equipment today — illustrate the potential. That translates to recovery of approximately 90% of the initial charge at equipment retirement instead of a full new charge every three years. Past uses of refrigerants to blow out condensate lines and clean coils are not only unacceptable, but also illegal in the U.S. and some other countries. Further reductions are possible with future improvements, greater care in handling and service, and immediate response to known leaks. Additional reductions are possible with strategic changes in service frequency for internal and withdrawal procedures. For example, scheduling oil changes based on periodic laboratory analyses of samples avoids excessive changes, each of which releases some refrigerant.
- Supporting scientific determination of control measures: Opposition to justified measures erodes confidence in the industry as a responsible player and thereby weakens influence to preserve sensible options. Also, regulatory perversion for temporary market advantage can only backfire, both for similar reasons and by confusing regulators and customers.

The last point warrants explanation. The air conditioning and refrigeration industry generally espouses use of analyses that include the global warming impacts of both refrigerant releases (sometimes referred to as "direct effect") and other greenhouse gas emissions from associated energy use (sometimes referred to as "indirect effect," though that term has other meanings in atmospheric science). Such analyses include Total Equivalent Warming Impact (TEWI), Life-Cycle Warming Impact (LCWI), Life-Cycle Climate Performance (LCCP), Net Warming Impact (NWI), and a number of variants.

These analyses are useful tools, but are also prone to misuse by deliberate or inadvertent distortion of underlying operating assumptions, system boundaries, and data. HFC emissions are

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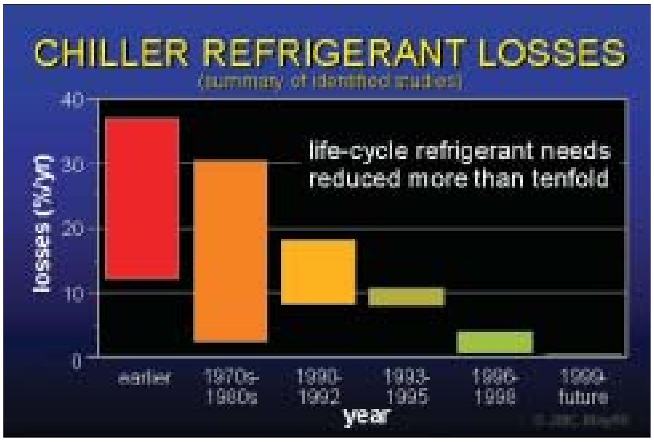


**FIGURE 3. Progress in reducing refrigerant emissions from leakage, purge venting, and other operating and service losses.**

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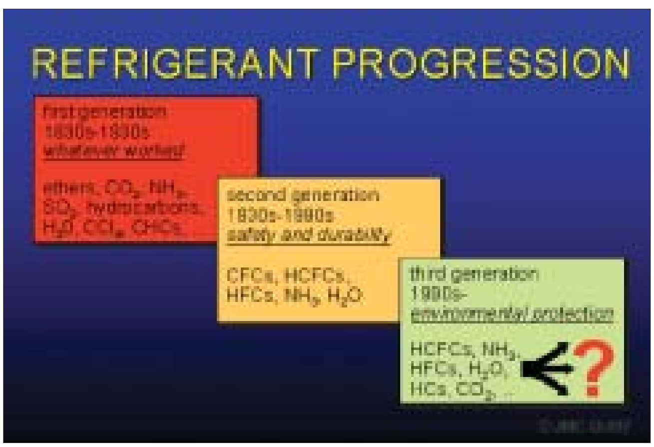


**FIGURE 4. Refrigerant generations and their defining characteristics.**

small today, 1% to 2% of controlled greenhouse gas releases measured as carbon dioxide equivalent, but this fraction is mounting and there is concern that future levels will increase several fold.

Two of the four centrifugal chiller manufacturers in the U.S. employ R-123. As such, there is a commercial advantage for some to support and some to oppose reconsideration of its currently planned phaseout. However, this refrigerant offers an opportunity to base regulatory policies on scientific evidence, since a reprieve from phaseout for chiller use would have imperceptible impact on the ozone layer and would avoid an increase of 9% to 20% in energy-related greenhouse-gas emissions.

R-123 is one of the few controlled substances for which there is a clear environmental rationale for retention as a chiller refrigerant, but that distinction is being distorted in negative marketing and lobbying. A successful campaign to preserve this unique HCFC would set a key precedent for future decisions on HFCs, namely to consider them scientifically on compound-by-compound and application-by-application bases. Alternative restriction of the entire chemical class risks removal of sensible choices along with offensive substances.

The scientific case for a reprieve for R-123 is documented in the technical literature, including articles in some of the most prestigious scientific and engineering journals. Moreover, the final conclusion of the 1998 World Meteorological Organization (WMO) "Scientific Assessment of Ozone Depletion," part of an international effort prepared pursuant to the Montreal Protocol, states that "the issues of ozone depletion and climate change are interconnected; hence so are the Montreal and Kyoto Protocols… decisions regarding controlling HFCs may affect decisions regarding the ability to phase out ozone-depleting substances."

The Joint Intergovernmental Panel on Climate Change – Technical and Economic Assessment Panel (IPCC-TEAP) "Expert Meeting on Options for the Limitation of Emissions of HFCs and PFCs," in 1999 noted that "phaseout of HCFC-123 will increase... global warming by 14-20%… as contrasted to less than a 0.001% increase in peak bromine-chlorine loading." Although controversial, the working group agreed "that HCFC-123 use warrants examination for chillers based on its negligible impact on ozone depletion and strong benefit in reducing global warming."

The 2002 assessment "Report of the Refrigeration, Air-Conditioning, and Heat Pumps Technical Options Committee (RTOC)," prepared under the auspices of the United Nations Environment Program (UNEP), stated that "HCFC-123 has a favorable overall impact on the environment that is attributable to five factors: (1) a low ODP, (2) a very low GWP, (3) a very short atmospheric lifetime, (4) the extremely low emissions of current designs for HCFC-123 chillers, and (5) the highest efficiency of all current options." This international assessment cites studies showing that "continued use of HCFC-123 in chillers would have imperceptible impact on stratospheric ozone while offering significant advantages in efficiency, thereby lowering greenhouse gas emissions from associated energy use."

The transition to and outcome for third generation refrigerants, as depicted in Figure 4, is underway. Upcoming decisions will determine the long-term viability of the current options. Manufacturers and users of refrigerants and equipment can influence their future by selecting refrigerants with low ODP and low GWP, minimizing emissions, increasing system efficiency, and supporting scientific determination of control measures. That future depends on responsible stewardship of remaining options, both in use and advocacy. **ES**

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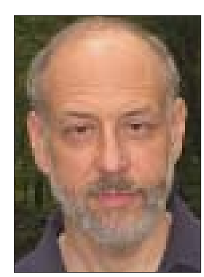

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