

BENEFITS OF HFC PRODUCTS

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ABSTRACT

HFCs have enabled the successful phase out of CFC use under the Montreal Protocol. However, HFCs, have been addressed by the Kyoto Protocol which requires the greenhouse gas emissions to be reduced due to their global warming potential. Life cycle metrics such as Life Cycle Climate Performance (LCCP) or Total Equivalent Warming Impact (TEWI) are found to best quantify overall climate change impact of various options. HFC-based technologies emerge as best choices in several applications as long as actions are taken to minimize emission levels. Comparisons are made on a common safety and cost basis, taking into account the potential societal and environmental benefits of HFCs and their alternatives. Energy efficiency is the most significant criteria for consideration as it has the greatest climate change impact. Where an application is made more energy efficient due to the use of HFC, less energy is consumed and thus less CO₂ is emitted. CO₂ produced in the generation of electricity persists in the atmosphere for centuries, while HFCs when emitted persist for 7-15 years. HFCs also present societal benefits in certain applications thanks to their non-toxicity and non-flammability. If one considers the societal benefits and total environmental impact along with responsible use principles to keep emissions low, HFCs facilitate a reduction in the net emission of greenhouse gases.

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INTRODUCTION

The production of chlorofluorocarbons (CFCs) in developed countries has been phased out as a result of implementation of the Montreal Protocol on Substances that Deplete the Ozone Layer. Signed in 1987, the Montreal Protocol sought to transition the world from dependence upon these unique products as a result of evolving scientific evidence linking them to stratospheric ozone depletion. Leading alternatives to CFCs included hydrochlorofluorocarbons (HCFCs), still ozone depleting but to a significantly lower degree and non-ozone depleting hydrofluorocarbons (HFCs). In a unique display of cooperation between regulators, industry and the environmental community, this Protocol was developed, new alternatives introduced and transitions implemented in a time scale not viewed as possible at the signing of the Protocol.

Climate change, aggravated by increased levels of greenhouse gases of man-made origin, has since become a serious environmental concern. This was addressed by the signing of the United Nations Framework Convention on Climate Change (UNFCCC) at the Rio Convention in 1992 and by the Kyoto Protocol signed in 1997. The Kyoto Protocol, sought to reduce, though not ban, emissions of a "basket" of greenhouse gases: CO₂, N₂O, CH₄, HFCs, PFCs and SF₆. Thus, while Montreal calls for a progressive ban on compounds, Kyoto calls for a reduction in emissions.

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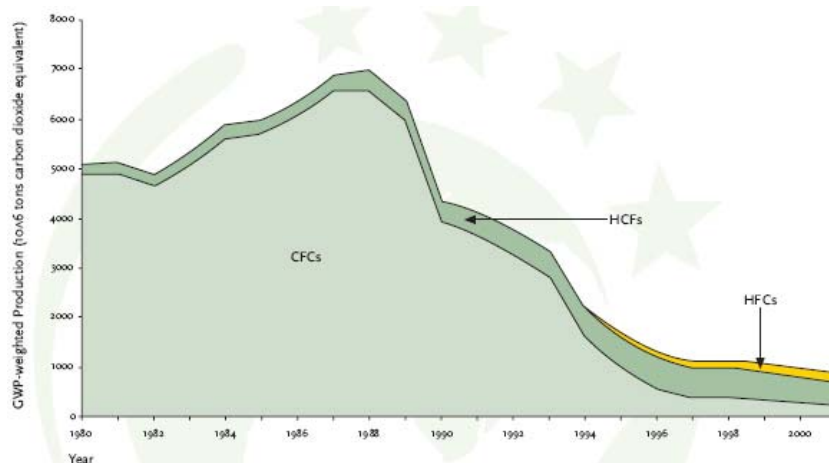
Two basic approaches are being considered in order to achieve HFC emissions reductions. One is to seek to avoid use of these compounds by use of others whenever possible. The other is to continue their use in appropriate applications and to seek to limit emissions via containment by proper design, use practices and end of life recovery and recycle. The “appropriate use” approach allows society the continued benefits inherent to HFCs: low toxicity and flammability, generally improved energy performance and operating efficiencies, and lower system costs. It was estimated by A.D. Little that the value provided to society by HFCs totals about \$US 36 billion annually.¹ Meanwhile, industry has pursued a campaign promoting responsible use, recovery, and even recycling of HFCs.

The European Climate Change Programme (ECCP) was established in June 2000 to help identify the most environmentally-, and cost-effective measures for the EU to meet its target under the Kyoto Protocol. The Working Group on Fluorinated gases concluded that containment, leakage prevention, reporting and promotion of good practice would be central to future measures on f-gases. DG Environment is currently considering whether a framework Directive should regulate fluorinated gases or whether to extend the Regulation 2037/2000 on Ozone Depleting Substance (ODS) to HFCs for monitoring and reporting provisions.

The ODS Regulation was created to implement the Montreal Protocol on phasing out CFCs and HCFCs. The Kyoto Protocol aim is to reduce emissions and not to phase them out. The logical follow up would be to implement two different EU measures dealing with the two very different aims of the Protocols.

PHASEOUT OF CFCs

Reduction of consumption of CFCs in developed countries has proceeded well since 1988. Data collected by the Alternative Fluorocarbon Environmental Acceptability Study (AFEAS), show the dramatic reduction of CFC use.² As these were replaced by HFCs and other alternatives with much lower Global Warming Potentials (GWPs), the total potential GWP has been greatly reduced (see figure below).



Developing countries, however, are still very dependent on CFCs although the shift is occurring gradually to HFCs. It is imperative that these countries do not receive a signal that HFCs are not viable which would justify their continued use of the ozone-depleting CFCs. This may occur if developed countries impose use restrictions or bans on HFCs.

GREENHOUSE GAS IMPACT AND ENERGY EFFICIENCY

On a global basis, greenhouse gas contributions from HFCs totaled only 0.4% in 1997 of all GHGs. This is forecast to increase to 1.8% in 2030.³ National levels will vary. For example, US data indicate HFCs being 0.8% in 2001 increasing to 2.3% of GHG contributions by 2030⁴ due to proportionately higher use and resultant emissions in the US. It should be noted that such analyses tend to overstate the net warming impact of HFC use given the significant contribution to energy savings possible in many applications.

Life cycle metrics, Total Equivalent Warming Impact (TEWI) and Life Cycle Climate Performance (LCCP) have been developed to more completely describe the true environmental impact of use of agents such as refrigerants and blowing agents in energy intensive applications.⁵ These analyses included both the direct contribution to climate change from emissions of the HFC agent during its use and end of life of the equipment/application as well as the global warming from the CO₂ associated with the energy consumed or saved by the equipment used. It therefore balances the GWP of the HFC with the efficiency of the refrigeration/air conditioning equipment or the performance of the thermal insulation. For energy intensive applications, it is a preferred metric for comparing options such as HFCs vs. hydrocarbons or ammonia in a particular application. It quantifies a net environmental impact over the life of the use of the equipment.

The report by the prestigious HFC and PFC Task Force of the UNEP TEAP stated: "Use of HFCs can contribute to efforts to meet the Kyoto targets in applications where HFCs have an energy efficiency advantage. Life cycle climate performance indexes are minimized by use of zero or low GWP agents, by minimizing emissions of higher GWP agents and by providing high operating efficiencies which reduce energy requirements for operation. The desire to utilize very low GWP agents has led to revival of the refrigerants that had been displaced with the invention of CFCs over 50 years ago. New design of components, use of secondary loops and introduction of requisite safety features help to manage the safety concerns introduced by flammable refrigerants. These can, in some applications, favorably achieve the desired lower LCCP. However, in many cases, the addition of the safety considerations compromises operating efficiencies.⁶ This issue was carefully noted by the Joint IPCC/TEAP Expert Group in their report, which summarized options to limit HFC emissions.⁷

The need to manage the inherent safety risks associated with hydrocarbons and ammonia also increase equipment costs. The World Bank, in administering the UNEP Multilateral Fund providing capital to developing countries in support of projects to transition from CFC use to non-ozone

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depleting agents, allows an additional capital increase totaling 30% for this purpose in order to provide a “level playing field”.⁸ Without this allowance, HFC projects would always prove more cost-effective vs. hydrocarbons and ammonia. Multinational producers of refrigeration and air conditioning equipment tend to prefer to utilize this additional capital, if available, to further optimize HFC-based designs. This would increase their operating efficiencies even more. The impact on climate of any technology results from the ‘direct’ emissions of greenhouse gases and the ‘indirect’ emissions from the generation of energy used over the expected life of the product. The indirect emissions are usually far more significant than direct emissions except in locations where electricity is generated from hydropower, nuclear, wind or solar.”⁹ On an equivalent safety and cost basis, HFC-based technologies provide superior energy efficiencies than other alternatives. This offsets the higher GWP of the HFC used in emission-limited systems. Energy efficiency is the key to minimize CO₂ emissions and to minimize investments needed in electricity generation and transmission infrastructure.

SAFETY

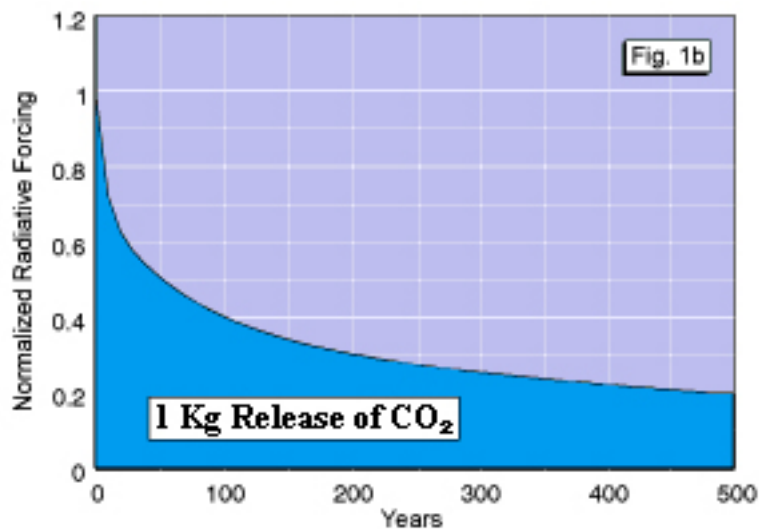
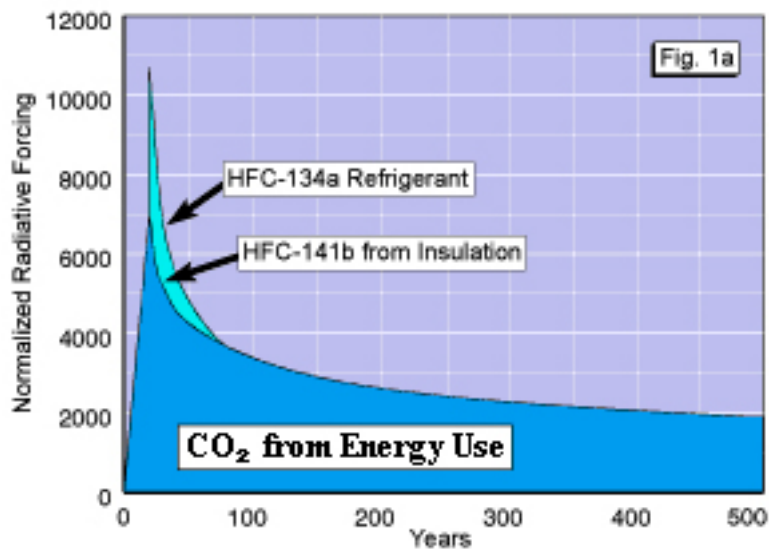
A major factor in the selection of HFCs is their inherent safety in use. Generally nontoxic and nonflammable, use of HFCs allows for simpler design and therefore lower costs. This, along with superior thermodynamic properties, translates into higher efficiency equipment and applications. The reduced potential for major accidents is a strong motivator as HFC-using equipment provides for needs in the home, in public buildings, transportation, etc with significant exposure to people. While other alternatives, including flammable products can have systems provide adequate safeguards for use; the potential still is present for serious incidents when proper procedures are not rigorously followed. This is of special concern with respect to maintenance practices. A significant leakage of a hydrocarbon refrigerant has potential for a major explosion and injury to innocent bystanders. Similarly, ammonia leaks have caused evacuations of areas remote from the buildings using this refrigerant option. Concern for such incidents in the face of recognized hazard potential, has contributed to the favored status of HFCs. Standard setting bodies, recognizing this potential for injury, have limited charge sizes of hydrocarbons. In certain regions in the world, however, pressure is being placed on standards agencies to loosen such restrictions to the risk of the public, the equipment users, workers, etc. Use of HFCs provides a real value to society especially in applications requiring higher volumes of refrigerant charges.

ATMOSPHERIC PERSISTENCE

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HFCs have the attribute of relatively short atmospheric lifetimes compared with the CFCs they replace. The most common HFCs have lifetimes of 7-15 years. This results in their disappearance from the atmosphere after release thereby ending their effect on climate change. This is in marked contrast with the exceptionally long lifetime of the primary greenhouse gas, CO₂. Pictured below taken from an AFEAS publication addressing TEWI¹⁰, is the duration of atmospheric radiative forcing (global warming impact) over time.

The spike early in the time frame represents the emissions of HFC-134a during use and end of life (20 years) and the sudden release of HCFC-141b blowing agent when the unit is destroyed assuming no capture of the HFCs. (Please note that HFCs need not be emitted at all if handled responsibly). These spikes model assumption of total release of installed refrigerant and destruction of the insulating foam with instantaneous release to the atmosphere. The impact of the HFC and HCFC disappear rapidly while that of the CO₂ persists for decades. This reinforces the primary concern being establishing improved energy efficiency for sustainable environmental solutions. HFCs, being exceptionally efficient in many cases are part of that solution.



HFC USES WITH SOCIETAL BENEFITS

Refrigeration

Air conditioning

Insulation

Cleaning of electronic components

Fire extinguishing

Metered dose inhalers

The unique properties of HFCs (energy efficient, nontoxic, nonflammable, etc) make them ideally suited for a wide variety of uses. They are superior refrigerants combining favorable thermodynamic properties with non-flammability thus optimizing energy efficiency and system costs. This is for a myriad of refrigeration and air conditioning applications. They produce the most effective insulating foams due to their low thermal conductivity and the excellent foam physical properties when HFCs are used as the blowing agent. They are used in niche high performance cleaning applications particularly when cleaning electronic components that may be energized. HFCs find use in high performance fire extinguishing systems designed to protect sensitive electronic or data processing equipment, archives or in regions requiring the ability to extinguish fires while allowing human presence (ie on ships). They are also preferred propellants for life saving applications such as propellants for metered dose inhalers for treatment of chronic pulmonary obstructive disorders (ie asthma). In these applications, amongst others, HFCs have high societal value and general bans on their use are contrary to public interests.

RESPONSIBLE USE OF HFCs

HFCs have unique properties that make them attractive for a variety of applications. However, there is a justified concern that such uses might proliferate to the extent that HFC emissions will grow rather than level out. Furthermore, there is concern that the early behaviors exhibited during the CFC introduction might also repeat causing HFCs to become a major greenhouse gas source. These concerns are without foundation and can be explained. The CFC proliferation and use practices occurred at a time when there was no knowledge of the environmental impact of those ozone-depleting compounds. Uses were emissive and volumes grew to high levels. If one examines the replacement pattern of CFCs, it is clear that less than 20% of the volume will occur as HFCs.¹¹ This reduced usage is due to several factors. First, in many sectors, not-in-kind alternatives have dominated. This is particularly true in aerosols (such as deodorant sprays), cleaning agents, and certain types of fire extinguishers. It should be noted that the higher cost of the more complex HFCs has also contributed to a reduced usage in cases where alternatives exist. Generally this is the case for the more emissive of applications. What has evolved is that HFCs are being chosen where the emission potential is reduced or, if emissive, the societal value justifies the environmental impact.

In the current major use areas of refrigeration and air conditioning, practices are dramatically changed. There has been some transfer to NIK refrigerants but the main reductions are due to far tighter systems, lower charge sizes, improved maintenance practices, regulations to properly maintain system tightness and recovery and recycle of refrigerant charges at end of life. There are many references quantifying reductions in leakage as well as outlining methods to further reduce emissions.¹²

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been formalized in several self-initiated voluntary agreements concerning HFC use. An excellent example of such an agreement is one produced by the Alliance, UNEP and the US EPA entitled "Responsible Use Principles for HFCs" [see Annex I]. It acknowledges the need to select HFCs for use where they provide health and safety, environmental, technical, economic or unique societal benefits. It addresses the need to minimize emissions during HFC production, use and disposal of using equipment and the need for recovery, recycle and/or destruction. The need for proper training of personnel is stated and the need to consider alternatives that are technically, economically and environmentally feasible. Sector specific principles are included for most of the major HFC use areas.

CONCLUSION

HFCs are low in toxicity and flammability, cost-effective, safe to use and in many applications, provide high energy efficiency. With responsible use, they are part of an environmental solution that should not be compromised but used judiciously.

HFCs are used in important applications in both developed and increasingly in developing countries including refrigeration, air conditioning, foam insulation, metered dose inhalers, technical aerosols, solvents and fire extinguishers. They are necessary for an orderly phase out of ozone depleting substances under the Montreal Protocol. HFCs are included in the basket of greenhouse gases under the Kyoto Protocol. They are low in toxicity and flammability, cost-effective, safe to use and in many applications, provide high energy efficiency. With responsible use, they are part of an environmental solution that should not be compromised but used judiciously. In this way, society will realize the unique benefits this class of compounds can provide while being in harmony with the environmental imperatives of elimination of anthropomorphic ozone depleting agents and minimizing climate change impacts. An outstanding informational brochure, prepared by the European Partnership for Energy and the Environment (EPEE), was submitted to the UNFCCC on this subject (www.epeeglobal.org).

- 1 [A.D. Little] <http://www.arap.org/adlitttle/toc.html>
- 2 [AFEAS data] - http://www.afeas.org/production_and_sales.html
- 3 [EIA] – "Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity" Energy Information Administration, October 1998, EIA Report No. SR/01AF/98-03
- 4 [EPA] – "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1996", U.S. Environmental Protection Agency, 235-R-98-06.
- 5 [AFEAS-TEWI] <http://www.afeas.org/tewi.html>
- 6 [A.D. Little] <http://www.arap.org/adlitttle/toc.html>
- 7 [IPCC/TEAP] – "Meeting Report of the Joint IPCC/TEAP Expert Meeting on Options for the Limitation of Emissions of HFCs and PFCs", p.6, 1999
- 8 [CAN] - "Ozone and Climate at the Crossroads- the Other Double Phase-Out" – p. 19, Climate Action Network, 2002
- 9 [HFC and PFC] – "The Implications to the Montreal Protocol of the Inclusion of HFCs and PFCs in the Kyoto Protocol", UNEP, October, 1999
- 10 [AFEAS-TEWI] <http://www.afeas.org/tewi.html>
- 11 [McFarland] – Mack McFarland, "Applications and Emissions of Fluorocarbon Gases: Past, Present and Prospects for the Future", Proceedings- Joint IPCC/TEAP Expert Meeting of Options for the Limitation of Emissions of HFCs and PFCs, May, 1999.
- 12 [Bivens] - Donald Bivens, "Refrigeration and Air Conditioning with Reduced Environmental Impact", Proceedings of the Joint IPCC/TEAP Expert Meeting on Options for the Limitation of Emissions of HFCs and PFCs. Petten, The Netherlands, May, 1999; [Calm] – James Calm, "Emissions and Environmental Impacts from Air Conditioning and Refrigeration Systems; [Corcoran/ Spatz/ Shankland/ Vink] – William Corcoran, Mark Spatz, Ian Shankland and Tim Vink,

ANNEX

RESPONSIBLE USE PRINCIPLES FOR HYDROFLUOROCARBONS (HFCs)

A Partnership

of the

U.S. Environmental Protection Agency (EPA)
The United Nations Environment Programme (UNEP)
and
The Alliance for Responsible Atmospheric Policy

March 25, 2002

The Alliance for Responsible Atmospheric Policy is an industry coalition, including many multinational companies, that was organized in 1980 to address the issue of stratospheric ozone depletion. It is currently comprised of nearly 200 manufacturers and businesses that rely on substitutes for ozone-depleting compounds, including HFCs. Today, the Alliance is a leading international industry voice that coordinates industry participation in the development of reasonable governmental policies regarding ozone protection and global climate change.

Responsible Use Principles for Hydrofluorocarbons (HFCs)

HFCs are used in important applications in both developed and developing countries including metered dose inhalers, foam insulation, refrigeration, air conditioning, technical aerosol products, solvents, and fire extinguishants.

HFCs are necessary for an orderly phase out of ozone depleting substances under the Montreal Protocol. HFCs are included in the basket of greenhouse gases under the Kyoto Protocol.

HFCs are low in toxicity, cost-effective, safe to use, and in many applications provide high energy efficiency.

Without responsible use, it is projected that by 2050 HFCs could account for up to 2% of total greenhouse gas contributions.

It is resolved by this partnership of governments, international organizations, and HFC-producing and using industries to apply worldwide the following Responsible Use Principles:

- Select HFCs for applications where they provide health and safety, environmental, technical, economic, or unique societal benefits
- Minimize HFC emissions to the lowest practical level during manufacture of the chemical, and during use and disposal of equipment using cost-effective technology

- Design and operate HFC-producing plants with the goal of achieving zero HFC emissions
- Engineer, operate and maintain HFC-using systems to minimize emissions and maximize energy efficiency
- Recover, recycle, reclaim and/or destroy used HFCs where technically and economically feasible
- Promote comprehensive technician training in HFC handling to assure compliance with regulations and stewardship practices
- Meet standards governing HFC equipment installation and maintenance, HFC transport and storage, and exceed such standards when appropriate
- Accurately report HFC production and promote models, that accurately estimate emissions
- Consider alternatives that are technically, environmentally, and economically feasible

HFCs Are Part of Balanced Solutions for Society

- Comprehensive national climate change plans use the basket approach to reduce emissions of the six principal greenhouse gases, including HFCs. With respect to HFCs, the plans should fully balance relevant environmental, safety, health, energy efficiency, and economic factors.
- Life Cycle Climate Performance (LCCP) is a tool that should be used to evaluate the environmental benefits of refrigeration, air conditioning and insulation.
- HFC emissions reductions are already occurring through voluntary actions and industry-government partnerships. Such partnerships are also jointly engaged in research, communication and other activities to find new technologies, designs and processes to enhance overall product viability, including energy efficiency and cost.
- The UNEP Technology and Economic Assessment Panel (TEAP) of the Montreal Protocol on Substances that Deplete the Ozone Layer (1999) concluded that HFCs are important to the current safe and cost-effective phaseout of CFCs in developing countries. They are essential substitutes for highly important uses of ozone-depleting substances and are also technically and economically necessary for phase out of HCFCs in developed and developing countries.
- The Intergovernmental Panel on Climate Change (IPCC) Third Assessment Report (2001) documented options for reducing emissions of HFCs and concluded that for some HFC applications, alternatives are not technically and economically feasible.
- The European Union's submission to the United Nations Framework Convention on Climate Change (July 1999), stated, "Action taken to reduce HFC emissions should not undermine the efforts to phase out ozone-depleting substances."
- A report by Arthur D. Little entitled Global Comparative Analysis of HFC and Alternative Technologies... (2002) found that HFCs are the preferred alternative to replace ozone-depleting substances where they provide superior overall technical, environmental, and safety benefits.

Sector-Specific Principles

Air Conditioning and Refrigeration

- Contain refrigerants in tight or closed systems and containers minimizing atmospheric releases
- Encourage monitoring after installations to minimize direct refrigerant emissions and to maintain energy efficiency
- Train all personnel in proper refrigerant handling
- Comply with standards on refrigerant safety, proper installation and maintenance (e.g., ASHRAE-15 and ISO-5149)
- Design, select, install and operate to optimize energy efficiency
- Recover, recycle and reclaim refrigerants
- Continue to improve equipment energy efficiency when cost effective

Fire Suppression

- Provide fire suppression products with high reliability and a goal of zero emissions except when used against fire
- Endorse rigorous standards in fire suppression system design, installation, commissioning, inspection and maintenance
- Provide advanced fire detection and extinguishing systems that minimize discharges
- Minimize emissions from testing and training; eliminate emissions where possible
- Recover, recycle, and reclaim fire extinguishants

Foam Insulation

- Provide safe and energy efficient insulation products to meet societal needs for energy conservation and to minimize carbon dioxide (CO₂) emissions
- Promote the reuse of insulation where technically and economically feasible to minimize end-of-life emissions
- Minimize foam insulation manufacturing emissions based on commercially viable technology

Household Refrigeration

- Contain refrigerants in tight systems and containers minimizing atmospheric releases
- Recover, recycle and reclaim refrigerants
- Minimize end of life emissions where technically and economically feasible
- Train all personnel in proper refrigerant handling
- Design, install and operate to optimize energy efficiency
- Minimize emissions during refrigerator manufacture

Producing HFCs

- Ensure worker and community safety by employing the highest standards of corporate responsibility
- Ensure product safety at all phases of manufacturing and during transport and storage
- Target zero fugitive emissions in plant design
- Minimize coproduct emissions where technically and economically feasible
- Promote recovery, recycling, and destruction
- Market HFCs to those applications that provide health, safety, environmental, technical, or economic benefit, or unique societal benefits
- Publish fluorocarbon production and sales data to support global modeling of atmospheric concentration profiles

Propellants

- Use HFC propellants where they promote health, environmental, technical, or economical advantage
- Handle by well-trained personnel
- Minimize losses during filling of containers

Solvents

- Use HFC solvents where environmental impact is offset by societal benefit
- Achieve the lowest economically practical emission levels
- Use enclosed systems with frequent monitoring for worker health and safety
- Recover, recycle and reclaim solvents
- Train all personnel involved in handling

Vehicle Air Conditioning

- Contain air conditioning refrigerants in tightened systems to minimize atmospheric releases
- Recover, recycle and reclaim all refrigerants
- Train service personnel in proper handling of air conditioning refrigerant
- Design equipment to minimize refrigerant amount
- Design, install and operate to maximize energy efficiency
- Minimize leakage of refrigerant during initial filling of vehicle air conditioners
- Continue research, development and evaluation of all alternatives
- Encourage recovery and recycling where the air conditioning system must be opened
- Encourage repair before recharge