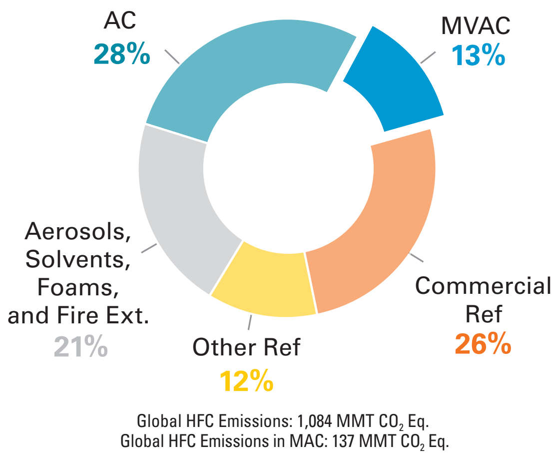
TRANSITIONING TO LOW-GWP ALTERNATIVES
in Motor Vehicle Air Conditioning

Background

This fact sheet provides current information on low global warming potential (GWP)[1] alternative refrigerants to high-GWP hydrofluorocarbons (HFCs) for use in motor vehicle air conditioning (MVAC) systems. HFCs are powerful greenhouse gases (GHGs) with GWPs hundreds to thousands of times more potent per pound than carbon dioxide (CO_2); however, more low-GWP alternatives are becoming available.

Globally, approximately 80% of HFCs are emitted in the refrigeration, air conditioning (AC), and MVAC sectors, with the remainder accounted for by the foam-blowing, aerosols, fire suppression, and solvents sectors. While developed nations have historically accounted for the majority of global HFC emissions, total HFC emissions in developing nations are projected to quadruple by 2030. This rapidly increasing rate of HFC emissions is largely driven by the increased demand for refrigeration and AC, particularly in the tropical climates of much of the developing world, and the transition away from ozone depleting substances (ODS). Emissions from MVAC systems occur as HFCs are released to the atmosphere throughout the lifecycle of equipment—i.e., during operation, servicing, and at end-of-life.

Figure 1. Global HFC Emissions in 2020 by Sector



Source: Estimates based on U.S. EPA (2013).

MVAC Systems

MVAC systems are used to cool passenger compartments of motor vehicles, including cars, vans, and trucks.[2] MVAC system components are located in the vehicle engine compartment and ventilation system and charged during vehicle manufacture. The main components are connected by flexible refrigerant lines. Table 1 lists the typical capacity, refrigerant charge, and annual leak rate for MVAC systems.

Table 1. Typical MVAC System Characteristics

System Location	Vehicle Market	Capacity (kW)	Refrigerant Charge (kg)	Annual Leak Rate (%)
Engine compartment and ventilation system	Cars, vans, and trucks	3 – 5	0.4 – 0.8	2 – 10

Source: UNEP (2015b).

[1] GWP is a measure of a substance's climate warming impact compared to CO_2.

[2] AC systems for ships are not addressed by this fact sheet. AC on ships is provided by chillers and other large commercial AC systems.

Global MVAC Market Growth

Motor vehicle AC is a large HFC-consuming sector in developing nations and is expected to dramatically increase, especially in rapidly emerging economies where new vehicle sales have been growing significantly and AC is becoming a standard vehicle feature. Between 2005 and 2015, for example, sales of new vehicles grew at an average annual rate of 16% in China and 10% in India. Studies predict that the estimated number of MVAC units in developing countries will dramatically increase from 200 million units in 2010 to 1 billion units by 2050.

Improved Servicing and End-of-Life Practices

Refrigerant emissions from MVAC equipment occur during operation (i.e., system leaks), servicing (i.e., due to loss of refrigerant during connection and disconnection of refrigerant lines), and end-of-life (i.e., equipment disposal). Emissions could also occur if the MVAC system is otherwise compromised, such as during an automobile accident.

Small amounts of refrigerant can be lost due to leakage during the use of the MVAC system based on the characteristics of joints and gaskets. Operational losses typically increase throughout the lifetime of the equipment due to wear and vibrations.

During servicing events and end-of-life, the extent of refrigerant losses depends on various factors including the existence of and compliance with refrigerant recovery laws, the technical efficiency of refrigerant recovery equipment, and the proficiency of technicians' service practices. Often MVAC systems are serviced by do-it-yourself (DIY) owners rather than professional technicians, which can lead to increased refrigerant emissions during the charging procedure, as well as from the release of unused refrigerant remaining in the refrigerant can (known as the "heel") or due to a lack of leak repair on the part of the DIY user.

Improvements in the technologies and practices associated with the use of MVAC refrigerants by manufacturers, technicians, and consumers; the introduction of alternative refrigerants and technologies; implementation of refrigerant recovery laws and standards; and market/policy drivers that provide financial incentives for recovery may help to offset most HFC refrigerant emissions from MVAC systems.

HFC Alternatives and Market Trends

Some MVAC systems in use contain ozone depleting refrigerant CFC-12, which is being phased out globally under the *Montreal Protocol*. Almost all new units sold today contain HFC-134a which is thousands of times more potent than CO_2 on an equal mass basis. A number of lower-GWP alternative refrigerants are available and currently in use or under development for use in new MVAC systems—including CO_2, HFO-1234yf, and HFC-152a. These alternatives are described in Table 2.

Table 2. GWPs and Global Use Status of Low-GWP MVAC Refrigerants[a]

Refrigerant	GWP[b]	Flammability Classification[c]	Cars, Vans, and Trucks
HFC-152a	124	2	☐+
HFO-1234yf	4	2L	◆+
R-744 (CO_2)	1	1	☐+

[a] ◆ = Available now, ☐ = Under development, + = U.S. EPA SNAP-approved, subject to use conditions

[b] GWP values are from IPCC Fourth Assessment Report (2007) and U.S. EPA (2015c).

[c] Refrigerants are classified by flammability according to ASHRAE Standard 34 and ISO 817. A classification of 1 represents no flame propagation; 2 represents lower flammability; 2L represents lower flammability with a maximum burning velocity of ≤10 cm/s; and 3 represents higher flammability.

[4] HFOs (hydrofluoroolefins) are unsaturated HFCs (i.e., containing a carbon-carbon double bond).

HFO-1234yf

- In use in certain models of cars, vans, and trucks in 40 countries, including Member States of the European Union (EU), the United States, Japan, China, Saudi Arabia, Turkey, Israel, and the United Arab Emirates
- Cooling performance and fuel use is comparable to HFC-134a
- Under evaluation for secondary loop systems in a demonstration project in India
- Suitable for systems where safety regulations permit use of a lower flammability refrigerant

Carbon Dioxide (CO_2, R-744)

- High pressure refrigerant being considered by automobile manufacturers; systems operate at 5 to 10 times higher pressure than other passenger vehicle AC systems
- Global car manufacturers developing CO_2 MVAC systems for passenger vehicles
- Cooling performance, energy efficiency, and fuel use comparable to HFC-134a systems in temperate climates; efficiency may drop in hotter climates

HFC-152a

- Prototype systems are under evaluation globally, including a joint project with an Italian and German OEM using a double loop system
- Under evaluation for secondary loop systems in a demonstration project in India
- Good energy efficiency and cooling performance, but requires additional safety requirements and system changes compared to standard HFC-134a systems due to flammability

Alternative Technologies

In support of the movement to improve the efficiency of vehicles and reduce overall GHG emissions, alternative MVAC technologies are under development, often in parallel with advances in alternative car propulsion technologies (e.g., hybrid, all-electric vehicles), including:

- **Phase change material (PCM) technology** stores cold in the evaporator of the MVAC system that can be released when the compressor is not running (e.g., in hybrids)
- **Secondary loop systems** allow the safe use of mildly flammable refrigerants (e.g., HFC-152a and HFO-1234yf) as the entire refrigerant loop is located in the engine compartment, rather than in the air distribution system that is connected to the passenger compartment
- **Reversible heat pump systems** operate to provide both heating and cooling in the vehicle's passenger compartment
- **Sorption heating and cooling** is based on the re-use of waste heat (e.g., exhaust gas or cooling jacket) and also offers opportunity of long-term thermal storage
- **Thermoelectric heating and cooling** uses couples of material that generate electric energy to operate as heat pumps providing active cooling or heating

Case Study: Secondary Loop Systems to Replace HFC-134a in MVACs

A demonstration project financed by the Climate and Clean Air Coalition (CCAC) is currently evaluating the use of HFC-152a and HFO-1234yf refrigerants in secondary loop MVAC systems. The project—which is being conducted by TATA Motors Limited (India), MAHLE (Germany), and the Institute for Governance and Sustainable Development (IGSD)—aims to reduce refrigerant consumption and emissions while increasing fuel efficiency of MVACs. HFO-1234yf and HFC-152a are listed as acceptable for use in MVACs (subject to use conditions) by the U.S. EPA's Significant New Alternatives (SNAP) program, and qualify under the European Union F-Gas regulations as acceptable with GWP less than 150.

Secondary loop systems offer a design solution that allows the safe use of mildly flammable refrigerants while optimizing energy efficiency in high ambient temperature climates, because the refrigerant is contained in components located in the engine compartment, rather than in the air distribution system (which is connected to the passenger compartment). Energy efficiency is increased by engaging the compressor during deceleration to lower the temperature of the coolant and then delivering that cold to the passenger compartment when needed by controlling the pump and fan. The thermal ballast also maintains passenger comfort with "stop/start" systems that turn off the engine during short stops in traffic and restarting the engine when traffic moves.

Based on results from the demonstration vehicle, the use of these low-GWP refrigerants in the secondary loop technology can significantly reduce GHG emissions from MVACs in several ways: first, any leaked refrigerant has a lesser climate impact due to its lower GWP than HFC-134a; second, the amount of refrigerant required in the primary loop of a secondary loop system is much less than that of a conventional direct expansion system (20% less for HFO-1234yf and 40% less for HFC-152a), meaning that significantly less refrigerant will be leaked overall; and third, life-cycle leak rates are significantly lower than conventional MVAC systems due to use of shorter hoses, fewer fittings, and integrated components.

Future Outlook

Together, the suite of known alternative chemicals, new technologies, as well as better process and handling practices, can significantly reduce HFC use in both the near- and long-term. Many countries are transitioning to lower-GWP alternatives in MVAC applications while satisfying the various international energy efficiency, safety, and environmental standards. The equipment manufacturers and chemical producers for the MVAC industry are continuing to work on developing new alternatives that can be marketed worldwide. Although much work remains to fully develop and adopt some of these low-GWP alternatives and some unknowns still remain, the affected industries have proven through the ODS phaseout that they can move quickly to develop low-GWP alternatives that protect the environment.

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