Montreal Protocol and Its Impact on HCFCs and HFCs in INDIA

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What is the Challenge?

Ozone Depletion

Global Warming

ODP

GWP
Stratospheric Ozone Depletion

• The ozone layer is located in the stratosphere, high above the earth’s surface.

• The ozone layer is formed by ultraviolet (UV) light from the sun acting on oxygen molecules.

• The ozone layer is often referred to as a protective layer because it absorbs and scatters ultraviolet light from the sun, preventing some of the harmful ultraviolet light from reaching the earth’s surface.
Figure 2-1. Location of the stratosphere, far above the earth’s surface.
Stratospheric Ozone Depletion

• Chlorofluorocarbons (CFCs) gradually float up to the stratosphere, where the chlorine reacts with the ozone, causing it to change back into oxygen.

• When the ozone layer decomposes, more UV radiation penetrates to the earth’s surface.

• Stratospheric ozone depletion is a global concern, and it will take the cooperation of many nations to bring this process under control.
Ozone layer depletion

1. Ultra-violet rays split a chlorine atom away from the CFC (chlorofluorocarbon) molecule.
2. The chlorine atom breaks up an ozone molecule, making a hole in the ozone layer.
3. The molecules left behind are chlorine monoxide and oxygen ($O_2$).

Ozone-depleting chemicals:
- CFCs (aerosols, refrigerants, solvents)
- HCFCs (aerosols, refrigerants, solvents)
- Halons (fire extinguishers)
- Methyl bromide (pesticides)
Figure 2-3. How chlorofluorocarbons (CFCs) destroy the ozone layer.
Stratospheric Ozone Depletion

The health and environmental concerns caused by the breakdown of the ozone layer include:

• Increase in skin cancers
• Suppression of the human immune response system
• Increase in cataracts
• Damage to crops
• Damage to aquatic organisms
• Increase in global warming
Global warming fast facts

**GWP**: Measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide \((CO_2)\).

- Carbon dioxide levels in the atmosphere are at 406.5 ppm as of 2017, their highest levels in 650,000 years.
- Average global temperature is up 1.7 degrees F (0.94 degrees C) since 1880.
- The minimum expanse of Arctic summer sea ice has declined 13.3 percent per decade since the 1980s.
- Land ice has declined at the poles by 286 gigatons a year since 2002.
- Global sea level has risen 7 inches (176 millimeters) in the past century.
The Montreal Protocol

• The Montreal Protocol is a response to the global nature of ozone depletion.

• On September 16, 1987, in Montreal, 24 nations and the European Economic Community (EEC) signed the Montreal Protocol on substances that deplete the ozone layer.

• Most of the nations that are major producers and consumers of CFCs and halon signed the agreement.
The Montreal Protocol

Figure 2-4. The ozone depletion process.
Montreal Protocol

An agreement/mechanism to reduce and eliminate the production and consumption of Ozone Depleting Substances

Parties must freeze, reduce and phase out their production and consumption of ODS according to a specific step-wise schedule.

Developed and developing countries have different phase out schedules

The Multilateral Fund (MLF) started operating in 1991, to assist developing country Parties to comply with the control measures set out in the Protocol.

The financial assistance to developing countries covers the agreed incremental costs, which must be determined on the basis of the indicative list of categories of incremental costs (ILCIC) adopted by the Parties to the Montreal Protocol.
Ozone depleting substances

1. Chemicals that potentially deplete the ozone layer
2. Contain chlorine or bromine atoms
3. Have long atmospheric life

Examples:
- Chlorofluorocarbons (CFCs) e.g. CFC-12 (aka R-12 or F-12)
- Halons (Bromochlorofluorocarbons) e.g. Halon 1301
- Carbon tetrachloride
- Methyl chloroform
- Hydrochlorofluorocarbons (HCFCs) e.g. HCFC-22 (aka R-22 or F-22)
- Hydrobromofluorocarbons (HBFCs)
- Bromochloromethane
- Methyl bromide
Ozone Depleting Potential

• The amount of damage done to the ozone layer is different for different chemicals.

• The destructive capacity of a chemical depends (amongst other factors) on the number of chlorine or bromine atoms in a molecule and how long the chemical persists in the atmosphere before being broken down itself.

• The ozone-depleting potential (ODP) is a relative measure and describes how harmful a substance is relative to CFC-11.

• CFC-11 is assigned an ozone-depleting potential (ODP) of 1.0. Therefore, a chemical with an ozone-depleting potential of 2.0 is twice as harmful as CFC-11 and a chemical with an ODP of 0.2 is approximately one-fifth as harmful as CFC-11.
Montreal Protocol

- India became party > 17th September 1992

- CFC Phase-out > 1st Aug 2008 for RAC
  INDIA HAS PHASED OUT PRODUCTION & CONSUMPTION OF CFCs, CTC & HALONS as of 1st January 2010 (except some Pharma applications)

- HCFC Phase-out for Article 5 countries:
  - Base level : Average of 2009 and 2010
  - Freeze : January 1, 2015 - ACHIEVED
  - 35% Reduction : January 1, 2015 – ACHIEVED

- 67.5% Reduction : January 1, 2025
- 100% reduction : January 1, 2030 with a service tai of 2.5% annual average during the period 2030-2040
Accelerated phase-out of HCFCs

- In September 2007, the Parties to the Montreal Protocol agreed to accelerate the phase-out of HCFCs, bringing the final phase-out date forward by 10 years for Developed and Developing countries.

Baseline = average ODP weighted 2009, 2010 HCFC consumption
This is Very Confusing
Refrigerants

Chlorine / Fluorine / Hydrogen
Refrigerants Category

The Bad

The Ugly

The Good
Sustainable Technologies:
- Environmentally benign
- Safe in use
- Affordable
Kigali Amendment to MP
HFC Phase Down

HFCs have Zero ODP and high GWP (4 to 12,400)
## Non-Article 5 Countries

### Summary

<table>
<thead>
<tr>
<th></th>
<th>Non- Article 5 (Main Group)</th>
<th>Non- Article 5: Belarus, the Russian Federation, Kazakhstan, Tajikistan &amp; Uzbekistan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline Calculation</strong></td>
<td>Average production/consumption of <em>HFCs</em> in 2011, 2012 &amp; 2013</td>
<td>Average production/consumption of <em>HFCs</em> in 2011, 2012 &amp; 2013</td>
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<tr>
<td></td>
<td><em>plus 15%</em> of <em>HCFC</em> baseline production/consumption</td>
<td><em>plus 25%</em> of <em>HCFC</em> baseline production/consumption</td>
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<td><strong>Reduction steps</strong></td>
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<tr>
<td>Step 1</td>
<td>2019</td>
<td>2020</td>
</tr>
<tr>
<td></td>
<td>10%</td>
<td>5%</td>
</tr>
<tr>
<td>Step 2</td>
<td>2024</td>
<td>2025</td>
</tr>
<tr>
<td></td>
<td>40%</td>
<td>35%</td>
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<td>Step 3</td>
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<td>2029</td>
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<tr>
<td></td>
<td>70%</td>
<td>70%</td>
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<tr>
<td>Step 4</td>
<td>2034</td>
<td>2034</td>
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<tr>
<td></td>
<td>80%</td>
<td>80%</td>
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<tr>
<td>Step 5</td>
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<tr>
<td></td>
<td>85%</td>
<td>85%</td>
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</table>
Non-Article 5 Countries

Phase-down schedule

- Non Article 5 (main group)
- Non Article 5: Belarus, the Russian Federation, Kazakhstan, Tajikistan and Uzbekistan

% of baseline

2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037

and thereafter
# Article 5 Countries

## Summary

<table>
<thead>
<tr>
<th></th>
<th>Article 5 Parties: Group 1</th>
<th>Article 5 Parties: Group 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline Years</strong></td>
<td>2020, 2021 &amp; 2022</td>
<td>2024, 2025 &amp; 2026</td>
</tr>
<tr>
<td><strong>Baseline Calculation</strong></td>
<td>Average production/consumption of HFCs in 2020, 2021, and 2022</td>
<td>Average production/consumption of HFCs in 2024, 2025, and 2026</td>
</tr>
<tr>
<td></td>
<td><em>plus 65% of HCFC baseline production/consumption</em></td>
<td><em>plus 65% of HCFC baseline production/consumption</em></td>
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<td><strong>Reduction steps</strong></td>
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<td>Freeze</td>
<td>2024</td>
<td>2028</td>
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<tr>
<td>Step 1</td>
<td>2029</td>
<td>10%</td>
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<tr>
<td>Step 2</td>
<td>2035</td>
<td>30%</td>
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<tr>
<td>Step 3</td>
<td>2040</td>
<td>50%</td>
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<tr>
<td>Step 4</td>
<td>2045</td>
<td>80%</td>
</tr>
</tbody>
</table>
Article 5 Countries

Phase-down schedule

- Article 5 - Group 1
- Article 5 - Group 2 (Bahrain, India, Iran, Iraq, Kuwait, Oman, Pakistan, Qatar, Saudi Arabia, and the United Arab Emirates)
ISHRAE Position Document

on

Refrigerants for Indian Refrigeration &
Air Conditioning Industries -

Challenges & Responsibilities
COMMERCIAL: 40% of electricity is consumed by air-conditioning.

The contribution to global warming due to refrigerants is only 3 to 5% considering the product life cycle. Therefore, due consideration ought to be given for the selection of refrigerants to achieve higher efficiency, which is also regulated in India. In order to satisfy the environmental regulations, one has to address factors such as flammability, toxicity, cost etc.
The following tools are used to assess the sustainability of any RAC system using a chosen refrigerant (UNEP, 2014b).

**Total Equivalent Warming Impact (TEWI):** It refers to the combination of direct (release of refrigerant) and indirect (energy consumption) effect which can be evaluated to determine the TEWI of the refrigeration and air-conditioning equipment.

**Life Cycle Climate Performance (LCCP):** Life Cycle Climate Performance considers the overall environmental performance of a product, providing a framework of "cradle to grave" environmental responsibility. LCCP relates to a defined system and provides a comparative measure rather than one that has any absolute significance. This includes the extraction of the raw materials, the manufacture of intermediate products, the manufacture of the substance itself, the phase of use, and waste disposal.

The basic contributors to LCCP are CO₂ emissions due to energy use and the direct warming impact of emissions. For a range of HFC applications, detailed comparisons of LCCP have been made between HFC based systems and non-HFC based alternative systems/technologies.
### Table 1: Environmental, Thermo-physical and Safety Data of Select Refrigerants (UNEP, 2014b)

<table>
<thead>
<tr>
<th>Refrigerant</th>
<th>Chemical Formula</th>
<th>Environmental Parameters</th>
<th>Thermo-physical &amp; Safety Parameters</th>
</tr>
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<tbody>
<tr>
<td></td>
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<td>ODP</td>
<td>GWP</td>
</tr>
<tr>
<td>CFC-11</td>
<td>CCl₃F</td>
<td>1.00</td>
<td>5160</td>
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<tr>
<td>CFC-12</td>
<td>CCl₂F₂</td>
<td>0.82</td>
<td>10300</td>
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<tr>
<td>HCFC-22</td>
<td>CHCl₂F₂</td>
<td>0.04</td>
<td>1780</td>
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<tr>
<td>HCFC-123</td>
<td>CF₂CHCl₂</td>
<td>0.01</td>
<td>79</td>
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<td>HCFC-142b</td>
<td>CH₃CF₂Cl</td>
<td>0.06</td>
<td>2070</td>
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<tr>
<td>HFC-23</td>
<td>CHF₃</td>
<td>0</td>
<td>12500</td>
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<tr>
<td>HFC-32</td>
<td>CH₂F₂</td>
<td>0</td>
<td>704</td>
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<tr>
<td>HFC-125</td>
<td>C₂HF₅</td>
<td>0</td>
<td>3450</td>
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<tr>
<td>HFC-134a</td>
<td>CH₂FCF₃</td>
<td>0</td>
<td>1360</td>
</tr>
<tr>
<td>HFC-143a</td>
<td>C₂H₃F₄</td>
<td>0</td>
<td>5080</td>
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<tr>
<td>HFC-152a</td>
<td>C₂H₆F₂</td>
<td>0</td>
<td>148</td>
</tr>
<tr>
<td>HFC-1234yf</td>
<td>C₂H₆F₄</td>
<td>0</td>
<td>&lt;1</td>
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<tr>
<td>HFC-1234ze</td>
<td>C₂H₆F₄</td>
<td>0</td>
<td>&lt;1</td>
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<tr>
<td>R-407C (HFC-32/HFC-125/HFC-134a - 23/25/53 wt%)</td>
<td>0</td>
<td>1600</td>
<td>1700</td>
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<tr>
<td>R-410A (HFC-32/HFC-125 - 50/50 wt %)</td>
<td>0</td>
<td>2100</td>
<td>2100</td>
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<tr>
<td>HC-290 (Propane)</td>
<td>C₃H₈</td>
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<td>~20</td>
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<td>HC-600a (Isobutane)</td>
<td>C₄H₁₀</td>
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<td>~20</td>
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<td>HC-1270 (Propylene)</td>
<td>C₃H₆</td>
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<td>R-717 (Ammonia)</td>
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<td>R-718 (Water)</td>
<td>H₂O</td>
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<tr>
<td>R-744 (Carbon dioxide)</td>
<td>CO₂</td>
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<td>1</td>
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</tbody>
</table>

**Class 1** - no flame propagation  
**Class 2** - LFL > 0.10 kg/m³ and heat of combustion < 19 MJ/kg  
**Class 2L w/ burning velocity < 10 cm/s**  
**Class 3** - LFL < 0.10 kg/m³ or heat of combustion > 19 MJ/kg  
where LFL is the lower flammability limit

Class A with PEL > 400 PPM  
Class B with PEL < 400 PPM  
where PEL: Permissible Exposure Limit
<table>
<thead>
<tr>
<th>Sector</th>
<th>Current Refrigerants Used</th>
<th>Alternative Refrigerants</th>
<th>Low GWP Refrigerants (GWP &lt; 750)</th>
<th>ISHRAE Assessment of Low GWP options for India</th>
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<tbody>
<tr>
<td>Large ACs</td>
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<tr>
<td>VRF ACs</td>
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<tr>
<td>Ducted, Packaged, Roof Top</td>
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<tr>
<td>Mobile AC</td>
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<tr>
<td>Car, Van</td>
<td>HFC-134a</td>
<td>HFC-152a, R-744, R-444A, R-445A</td>
<td>HFC-1234yc, R-744</td>
<td>HFC-1234yc, R-744</td>
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<tr>
<td>Bus, Truck, Train</td>
<td>HCFC-22, R-134a, R-407C</td>
<td>R-744, R-450A, R-513A,</td>
<td>HFC-1234yc, R-744</td>
<td>HFC-1234yc, R-744</td>
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<td>Chillers</td>
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<tr>
<td>Screw</td>
<td>HCFC-22, HFC-134a</td>
<td>HFC-134a</td>
<td>HFC-1234ze, HC-1270</td>
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<td>Centrifugal</td>
<td>HFC-134a, HCFC-123</td>
<td>HFC-134a</td>
<td>HFC-1234ze, HCFO-1233zd, HFC-1336mzz</td>
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</tr>
</tbody>
</table>
ISHRAE POSITION ON REFRIGERANTS

ISHRAE is committed to the following:

- Environmental parameters are more critical than the traditional thermo-physical, thermodynamic and engineering parameters for the choice of refrigerants.
- To protect the environment, promote the use of refrigerants with zero ODP and low GWP, wherever suitable alternatives are available.
- For climate change benefits, energy efficiency is a key parameter for a given application.
- Use of flammable and toxic refrigerants mandates special requirements with respect to safety for systems and installations, for the place where they are located, and for the community who use or handle them.
- Develop and use advanced design and installation codes, guidelines and practices to reduce the direct refrigerant emissions.
- Develop and use advanced practices and standard operating procedures and guidelines as well as use appropriate tools and trained personnel to minimise refrigerant losses during installation, operation, maintenance and decommissioning.
- Promote recovery, recycle, reclamation and destruction through appropriate mechanisms.
- Train personnel and support student community, through information dissemination and collaborative research, towards responsible use of refrigerants.
- Promote sustainable RAC practices with a holistic approach.
Applications impacted

Refrigerants
Foams
Fire
Solvent (cleaning, Essential Oils etc)
Propellant (industrial, Cosmetic and Medical)
Etching (semiconductor and glass bottle)
ORC etc
Thank You

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