Global action for a cooler planet

THE MONTREAL PROTOCOL

INDIA'S SUCCESS STORY

OZONE CELL

MINISTRY OF ENVIRONMENT, FOREST AND CLIMATE CHANGE

GOVERNMENT OF INDIA

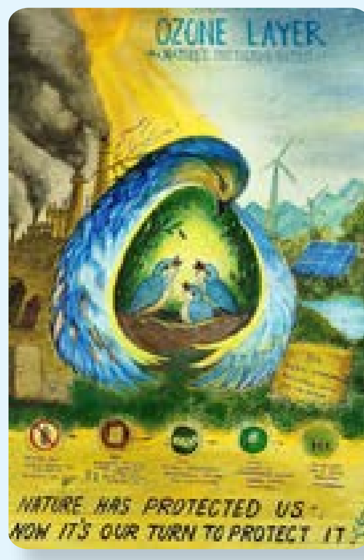
NEW DELHI, INDIA

Poster Making Competition

1ST PRIZE

Hiba Lulu Edayattu

Class – 10, Section A
MES Fathima Rahim
Central School,
Kaithapoyil, Kannoth PO,
Venchery-673580, Kerala



2ND PRIZE

Ananya

Class – 12
Stalwarts World School
Opposite Fortis Escorts Hospital,
Verka Bypass, Amritsar, Punjab

3RD PRIZE

Anwesha Halder

Class 10, Section A,
Balia Nafar Chandra Balika Vidyalaya
Nafar Chandra Naskar Road,
Balia, P.O – Garia, P.S – Narendrapur
PIN – 700084, South 24 PGS, West Bengal

Global action for a cooler planet

THE MONTREAL PROTOCOL INDIA'S SUCCESS STORY

सत्यमेव जयते

OZONE CELL
MINISTRY OF ENVIRONMENT,
FOREST AND CLIMATE CHANGE
GOVERNMENT OF INDIA
NEW DELHI, INDIA
SEPTEMBER, 2026

मंत्री
पर्यावरण, वन एंव जलवायु परिवर्तन
भारत सरकार

सत्यमेव जयते

MINISTER
ENVIRONMENT, FOREST AND CLIMATE CHANGE
GOVERNMENT OF INDIA

भूपेन्द्र यादव

BHUPENDER YADAV

MESSAGE

The Montreal Protocol on Substances that Deplete the Ozone Layer stands as a shining testament to what global unity and collective action can achieve. It is not merely an international treaty, but an active partnership for protecting planetary health that has consistently evolved to address our planet's most pressing atmospheric challenges. India's journey under the Montreal Protocol has been one of proactive leadership, successfully transforming international environmental compliance into a catalyst for promotion of domestic sustainable innovation and environmentally responsive development.

Our milestone success in phasing out Ozone Depleting Substances (ODS) ahead of international schedules is a proud story of national resolve, effective policy implementation, and industry collaboration. As we navigate the growing complexities of global climate change, the lessons from the Montreal Protocol, founded on shared responsibility and collaborative action, remain our guiding light. India is committed to leading the phase-down of Hydrofluorocarbons (HFCs) under the Kigali Amendment while ensuring sustainable and climate-friendly cooling.

India is actively working on the implementation of the actions recommended under the India Cooling Action Plan (ICAP) which also promotes the adoption of non-ODS and low-GWP technologies, improved energy efficiency, and climate-responsive approaches for sustainable cooling. This integrated approach is expected to generate significant environmental benefits while enhancing national technological capabilities and advancing a sustainable future.

On the 32nd World Ozone Day, India proudly reiterates its unwavering commitment to protecting the Ozone Layer and building a cooler, healthier, and more resilient planet for future generations.

(Bhupender Yadav)

पर्यावरण भवन, जोर बाग रोड़, नई दिल्ली–110003, फोन : (011)–20819190, 011–20819187, फैक्स : (011)–20819299
Paryavaran Bhawan, Jor Bagh Road, New Delhi-110003, Ph. : 011-20819190, 011-20819187, Fax : 011-20819299
ईमेल/E-mail : mefcc@gov.in

राज्य मंत्री
पर्यावरण, वन और जलवायु परिवर्तन
विदेश मंत्रालय
भारत सरकार
MINISTER OF STATE
ENVIRONMENT, FOREST AND CLIMATE CHANGE
EXTERNAL AFFAIRS
GOVERNMENT OF INDIA

कीर्तवर्धन सिंह
KIRTI VARDHAN SINGH

MESSAGE

India's remarkable success under the Montreal Protocol is rooted in a pragmatic, forward-looking, and balanced approach. We have consistently demonstrated to the global community that environmental stewardship and robust economic growth are not mutually exclusive, but must indeed progress together. Throughout this journey, our nation has made conscious, strategic choices to adopt non-ozone depleting substance, low-Global Warming Potential (GWP), and highly energy-efficient technologies, often establishing India as an early adopter and a pioneer in sustainable cooling practices.

The financial and technical mechanisms of the Protocol, particularly the Multilateral Fund, have been instrumental in facilitating our transition. India's active participation in its global governance underscores our commitment to cooperative climate action. Through successfully executed projects under the HCFC Phase-out Management Plans (HPMPs), we have systematically empowered our domestic industries, spanning from large corporations to vital Micro, Small, and Medium Enterprises (MSMEs) to adopt greener, sustainable alternatives smoothly.

As we embark on the phasedown of Hydrofluorocarbons (HFCs), we are building upon this foundation. The India Cooling Action Plan (ICAP) serves as our roadmap, harmonizing refrigerant transition, energy efficiency upgrades, and crucial skill development for our workforce.

This publication, **"Montreal Protocol: India's Success Story,"** highlights the collaborative spirit of our key stakeholders, industry, academia, research institutions, and civil society, whose collective dedication continues to drive India toward our shared sustainable development goals.

K.V.S.

(Kirti Vardhan Singh)

कार्यालय : 5वां तल, आकाश विंग, इंदिरा पर्यावरण भवन, जोर बाग रोड, नई दिल्ली-110003, दूरभाष : 011-20819418, 011-20819421, फैक्स: 011-20819207, ई-मेल : mos.kvs@gov.in
Office : 5th Floor, Aakash Wing, Indira Paryavaran Bhawan, Jor Bagh Road, New Delhi-110003, Tel.: 011-20819418, 011-20819421, Fax: 011-20819207, E-mail: mos.kvs@gov.in
कार्यालय : कर्तव्य भवन - 3, जनपथ, नई दिल्ली-110001, 011-24010779, 24010780
Office: **Kartavya Bhawan** - 3, Janpath, New Delhi - 110001, 011-24010779, 24010780
निवास : 23, बी.आर. मेहता लेन, नई दिल्ली-110001, दूरभाष : 011-23782979
Residence : 23, B.R. Mehta Lane, New Delhi - 110001, Tel.: 011-23782979

तन्मय कुमार
TANMAY KUMAR

सत्यमेव जयते

सचिव
भारत सरकार
पर्यावरण, वन और जलवायु परिवर्तन मंत्रालय
SECRETARY
GOVERNMENT OF INDIA
MINISTRY OF ENVIRONMENT, FOREST AND CLIMATE CHANGE

MESSAGE

The Montreal Protocol is globally recognized as one of the most successful international environmental treaties and its enduring success lies in its strong, science-based implementation framework. For India, translating this international mandate into domestic success has meant designing a structured, regulatory ecosystem where policies, compliance timelines, and strategic partnerships function in harmony.

Our operational strategy has consistently prioritized deep, sustained collaboration with industry associations and enterprises. By actively addressing their technical challenges and co-designing solutions, we have built an environment of trust and mutual accountability. The landmark phase-out of Hydrochlorofluorocarbons (HCFCs) is a direct triumph of this participatory model.

As we transition our focus to the phasedown of Hydrofluorocarbons (HFCs) under the Kigali Amendment, our priority is precise, institutional execution. We are strengthening regulatory frameworks while placing a strong emphasis on workforce upskilling through initiatives such as upgrading training infrastructure in Industrial Training Institutes (ITIs) and promoting indigenous development of low global warming potential (GWP) alternatives. This focus on sustainable technology is deeply intertwined with India's global call for Mission LiFE (Lifestyle for Environment). By prioritizing energy-efficient cooling solutions and raising grassroots awareness, we are empowering citizens to transition from mindless consumption to mindful, resource-efficient daily choices. The India Cooling Action Plan (ICAP) remains our overarching policy guide, ensuring our environmental strategies work in synergy with India's rapid economic expansion.

The *"Montreal Protocol: India's Success Story"* documents the dedicated efforts that continue to secure India's position as a global leader in environmental governance.

(Tanmay Kumar)

Place: New Delhi
Dated: September 7, 2026

इंदिरा पर्यावरण भवन, जोर बाग रोड, नई दिल्ली-110 003 फोन : (011)-2081-9408, 2081-9308, फैक्स : (011)-2081-9238
INDIRA PARYAVARAN BHAWAN, JOR BAGH ROAD, NEW DELHI-110 003, PH.: 011-2081-9408, 2081-9308, FAX : 011-2081-9238
E-mail : secy-moef@nic.in, Website : moef.gov.in

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1 OZONE LAYER

The small blue and green planet we call home is a very special and unique place. We live on the only planet in our solar system and possibly in the galaxy, where life is known to exist. All life exists within a thin film of air, water, and soil. This spherical shell of life is known as the biosphere. The biosphere can be divided into three layers: the atmosphere (air), the hydrosphere (water), and the lithosphere (rock and soil). It is the unique attribute of the earth's atmosphere that allows it to be a habitable place for humans, animals, microbes and plants, as we know them.

The atmosphere is a mixture of gases and particles that surround our planet. When seen from space, the atmosphere appears as a thin seam of dark blue light on a curved horizon.

Earth's Atmospheric Layers

Troposphere

The troposphere starts at the earth's surface and extends 8 to 14.5 kilometers (km) high (5 to 9 miles). This part of the atmosphere is the most dense. Almost all weather is created in this region.

Stratosphere

The stratosphere starts just above the troposphere and extends to 50 km (31 miles) high. The ozone layer, which absorbs and scatters the solar ultraviolet radiation, is in this layer.

Mesosphere

The mesosphere starts just above the stratosphere and extends to 85 km (53 miles) high. Meteors burn up in this layer.

Thermosphere

The thermosphere starts just above the mesosphere and extends to 600 km (372 miles) high. Aurora occur and satellites orbit in this layer.

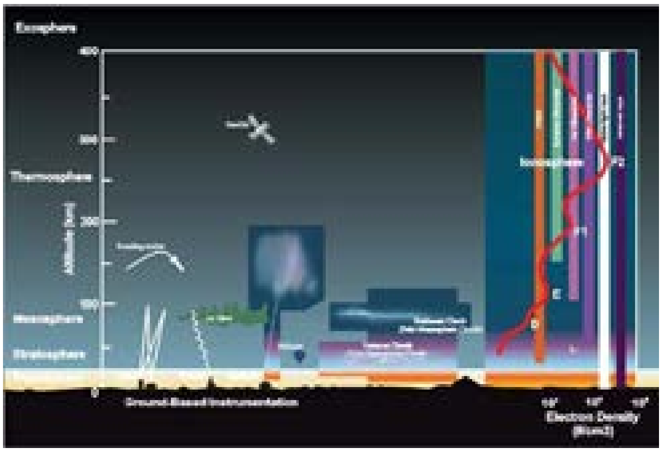
Ionosphere

The ionosphere is an abundant layer of electrons and ionized atoms and molecules that stretches from about 48 km (30 miles) above the surface to the edge of space at about 965 km (600 miles), overlapping into the mesosphere and thermosphere. This dynamic region grows and shrinks based on solar conditions and divides further into the sub- regions: D, E and F, based on what wavelength of solar radiation is absorbed. The ionosphere is a critical link in the chain of sun-earth interactions. This region is what makes radio communications possible.

Exosphere

This is the upper limit of our atmosphere. It extends from the top of the thermosphere up to 10,000 km (6,200 miles).

Earth's Atmospheric Layers

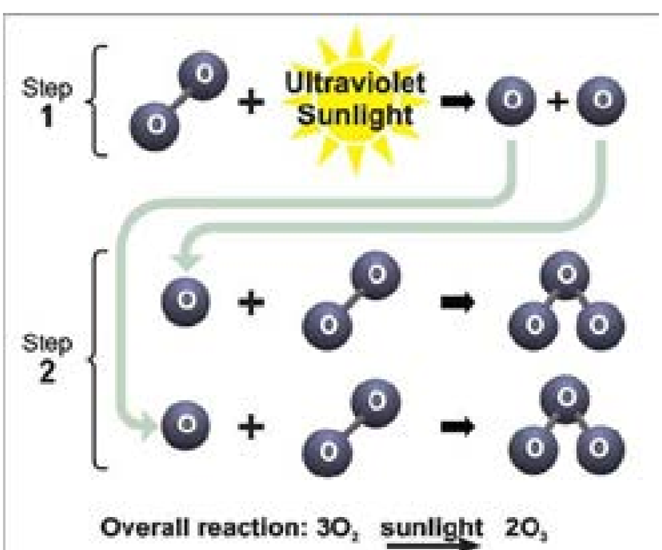


Source: The National Aeronautics and Space Administration (NASA)

Concentration of Ozone in the Atmosphere

Ozone is a tri-atomic molecule of oxygen formed from oxygen in the upper levels of the earth's atmosphere by high- energy ultraviolet (UV) radiation from the sun. The radiation breaks down oxygen molecules, releasing free atoms, some of which bond with other oxygen molecules to form ozone.

Stratospheric Ozone Production



About 90 per cent of all ozone formed in this way lies between 10 km and 50 km above the Earth's surface – this part of the atmosphere is called the stratosphere. Hence, this is known as the 'Ozone Layer.' Even in the ozone layer, ozone is present in very small quantities; its maximum concentration, at a height of about 17-25 km, is only 1 parts per million. The ozone layer was discovered in 1913 by the French physicists Charles Fabry and Henri Buisson.

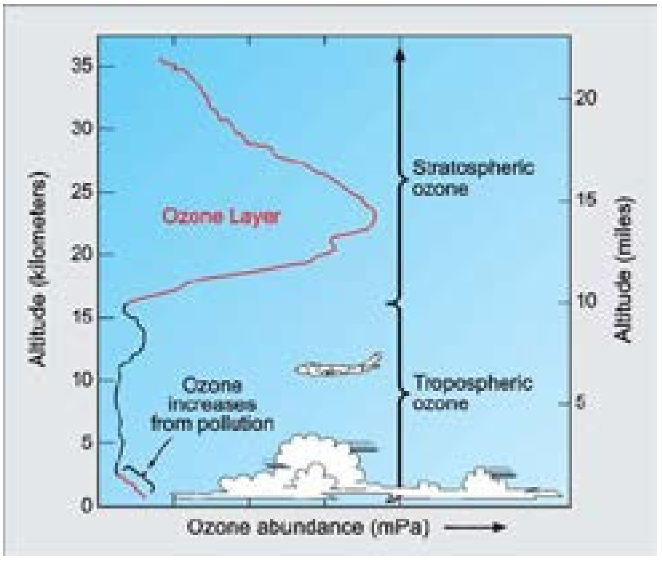
Since solar radiation is the strongest over the tropics, the global ozone is formed in tropics. However, strong solar radiation also causes rise of air to high altitudes and ozone is transported away from the equator towards the poles where it accumulates in the cold sub-polar regions. At the equatorial region formation and photochemical depletion of ozone take place simultaneously and ozone cannot accumulate in this region. In the polar region there is accumulation of ozone because photochemical depletion is low and due to transport of ozone from the equator. Therefore, in winter the highest ozone values are observed over the polar regions as long as there is no other disturbing influence.

Total ozone at any point from the earth's surface to the Stratosphere is quantified in Dobson Units (DU). One hundred DU equals the quantity of ozone that would form a 1mm thick layer at sea level if compressed at Standard Temperature and Pressure (STP).

Typical distribution of ozone is about 240 DU near the Equator with a maximum of 440 DU during early spring at high latitudes in the Arctic and 360 DU in the Antarctic. When the concentration of ozone, over any area, falls below 220 DU, we call it an Ozone Hole.

Ozone is an unstable molecule. High-energy radiation from the sun not only creates ozone, but also breaks itto oxygen, recreating molecular oxygen and free oxygen atoms. The concentration of ozone in the atmosphere depends on a dynamic balance between creation and destruction of ozone.

Concentration of Ozone in the Atmosphere



What is the Ozone Layer?

The ozone layer is a term used to describe the presence of ozone molecules in the stratosphere. The layer stretches around the earth like a bubble and acts as a filter for the harmful UV radiation (UV– B). UV–B radiation is a highly energetic light that originates from the sun and has severe impacts on human health and the environment.

Good and Bad Ozone

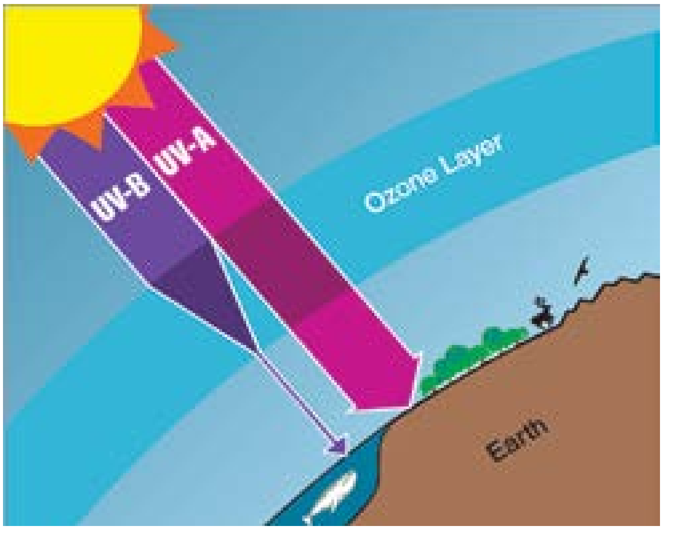
"Good" ozone is produced naturally in the stratosphere and is good because it blocks harmful UV radiations from reaching the earth's surface.

Ozone is also present in the lower levels of the atmosphere (i.e., the troposphere), but in much lower concentrations than in the stratosphere. Close to the earth's surface, most of the sun's high-energy UV radiation has already been filtered out by the stratospheric ozone layer and therefore the main natural mechanism for ozone formation does not exist in the troposphere.

However, elevated concentrations of ozone at ground level are found in some regions, mainly as a result of pollution. Burning of fossil fuels and biomass releases compounds such as nitrogen oxides and volatile organic compounds, usually found in car exhausts, which react with sunlight to form peroxy intermediates, which catalyses to form ozone. This is "bad" ozone. Bad ozone is an air pollutant and is bad because it is harmful to breathe and can damage crops, trees, other vegetation, plastics, rubbers etc.. Ground-level ozone is a main component of urban smog.

There is little connection between ground-level ozone and the stratospheric ozone layer. Whereas the stratospheric ozone shields the earth from the sun's harmful rays, ground-level ozone is a pollutant. Ozone, formed due to pollution at the earth's surface, cannot replenish the ozone layer. In addition, though ground-level ozone absorbs some UV radiation, the effect is negligible.

UV Protection by the Ozone Layer



Why is the ozone layer so important?

Ozone absorbs UV-B radiation from the sun. When an ozone molecule absorbs UV-B, it breaks apart into an oxygen molecule (O2) and a separate oxygen atom (O). Later, the two components can reform the ozone molecule (O3). By absorbing UV-B in the stratosphere, the ozone layer prevents harmful levels of this radiation from reaching Earth's surface.

Measurement of Ozone in the Atmosphere

Ozone is spread from the surface of earth upto the top of the stratosphere, 50 km, as a very thin layer. The question often asked is how is the concentration of ozone in this thin layer measured and quantified with reasonable accuracy.

Atmospheric ozone is measured both by remote sensing and by in-situ techniques.

Generally, the following three characteristics of atmospheric ozone are routinely measured by various monitoring systems:

(a) Surface ozone
(b) Total ozone over an area and
(c) The vertical profile of ozone.

Surface ozone is generally measured by in-situ techniques using optical, chemical or electro chemical methods. The most convenient method is the optical method which depends upon the strong absorption of UV light at 254 nanometers (nm). The absorption is measured in a UV cell at 254 nm against another cell containing air free from ozone. By comparing the two irradiation signals, it is possible to determine the concentration of ozone from 1 to 1000 parts per trillion (ppt) by volume.

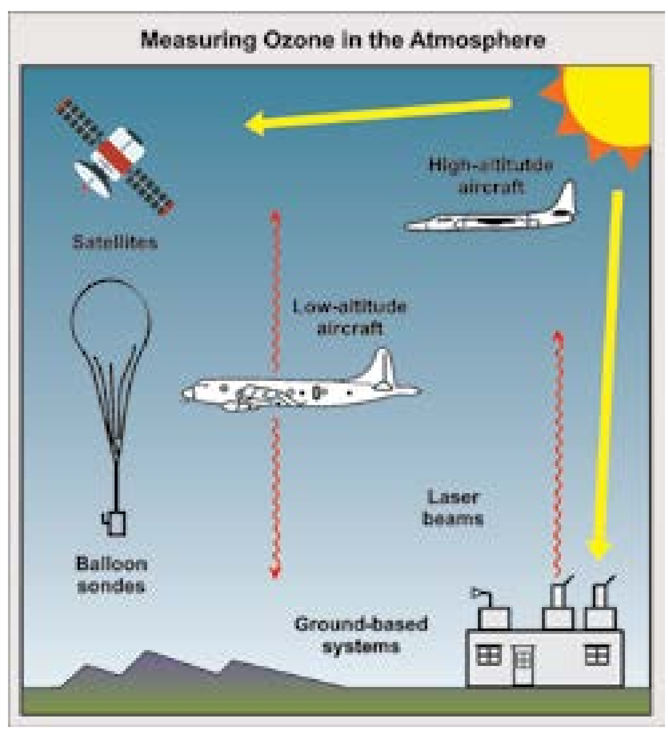
Total ozone is measured by remote sensing methods using ground-based instruments, measuring the intensity of absorption spectrum of ozone between 300 and 340 nm using direct sunlight or direct full moonlight and satellite-based instruments, measuring the solar UV radiation scattered back to space by the earth's atmosphere. The most commonly ground-based instruments by the World Meteorological Organization (WMO) global ozone network are the Dobson and Brewer Spectrophotometers.

The most accurate and best defined method for determining total ozone is to measure direct solar radiation from ground at UV wave bands between 305 and 340 nm.

Dobson instrument measures spectral intensities at three wavelength pairs and the Brewer spectrophotometer at five operational wavelengths. Moonlight as a source of UV radiation can also be used, but the accuracy is reduced due to lower intensity of light. For accuracy and comparison, all spectrometers are calibrated regularly at the National Oceanic and Atmospheric Administration (NOAA) subtropical high-altitude observatory at Mauna Loa, Hawaii where other interfering air pollutants like Sulfur dioxide (SO2), Nitrous Oxide (NOx), aerosols etc. are absent.

Vertical profile of ozone is measured with (a) Ozonesondes (b) Ground-based Dobson and Brewer Spectrophotometers using light from zenith sky during twilight using the Umkher inversion method and (c) laser radars (Light Detection and Ranging (LIDAR)).

Ozonesondes measure the concentration of ozone as a function of height by a wet chemical method (ozone liberating iodine when bubbled through potassium iodide solution and measured electro-chemically) during its balloon-borne ascent to an altitude of about 35 km (mid-stratosphere). They operate regularly in all climatic regions and have been the backbone of ozone profiling since 1960.



The latest method of vertical profiling of ozone is the LIDAR system in which a short laser pulse at a wavelength in the UV ozone absorption spectrum, is sent towards the zenith. Back scattered radiation is measured as a function of time which gives the height and its intensity gives the concentration of ozone. Two wavelengths are used, one of which is absorbed by ozone, and the other is not which serves as a reference. The concentration of ozone measured at different heights thus gives the vertical profile.

Ozone Measurement over India

Indian Meteorological Department (IMD) is the nodal agency to measure ozone levels in India. The IMD has established a National Ozone Centre. The centre maintains and controls a network of Ozone Monitoring Stations located at New Delhi, Ranichauri, Guwahati, Nagpur, Pune, Kodaikanal, Thiruvananthapuram, Vanarasi, Port Blair and Maitri (Antarctica). The ozone data measured is regularly sent to the World Ozone Data Centre, Canada.

Ozone Monitoring Network

The IMD National Ozone Centre is designated as a secondary regional ozone centre for Regional Association II (Asia). The centre maintains a network of ozone monitoring stations including Maitri and Bharati in Antarctica.

- Total columnar ozone measurement using Brewer and Dobson spectrometer at five locations.
- Surface ozone monitoring through a network of ten stations.
- Measurement of vertical distribution of Ozone using IMD Ozonesonde

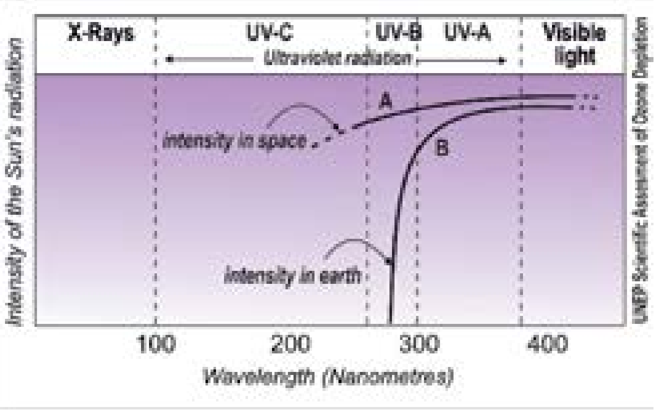
(Source: India Meteorological Department)

What is UV Radiation?

The sun emits radiation of varying wavelengths in the form of anelectromagnetic spectrum. The UV radiation is one form of radiant energy coming out of the sun. The various forms of energy, or radiation, are classified according to wavelength measured in nm. The shorter the wavelength, the more energetic the radiation. In order of decreasing energy, the principal forms of radiation are gamma rays, X-rays, UV rays, visible light, infrared rays, microwaves, and radio waves. The UV radiation, which is invisible, is so named because its wavelengths are less than those of visible violet radiation.

Of these, UV-B and UV-C being highly energetic, are harmful to life on earth; UV-A radiation being less energetic is relatively less harmful. Fortunately, UV-C radiation is absorbed strongly by oxygen and also by ozone in the upper atmosphere. As UV-B radiation is absorbed only by the stratospheric ozone (ozone layer) only 2-3% of it reaches the Earth's surface. The ozone layer, therefore, is essential for protection of life on earth by filtering out the dangerous part of the sun's radiation and allowing only the beneficial part to reach earth. Any disturbance or depletion of this layer would result in an increase of UV-B and UV-C radiation reaching the earth's surface leading to dangerous consequences for life on earth. The ozone layer, therefore, acts as the earth's sunscreen.

Range of Wavelengths of UV Radiations



A - Undisturbed Ozone Layer

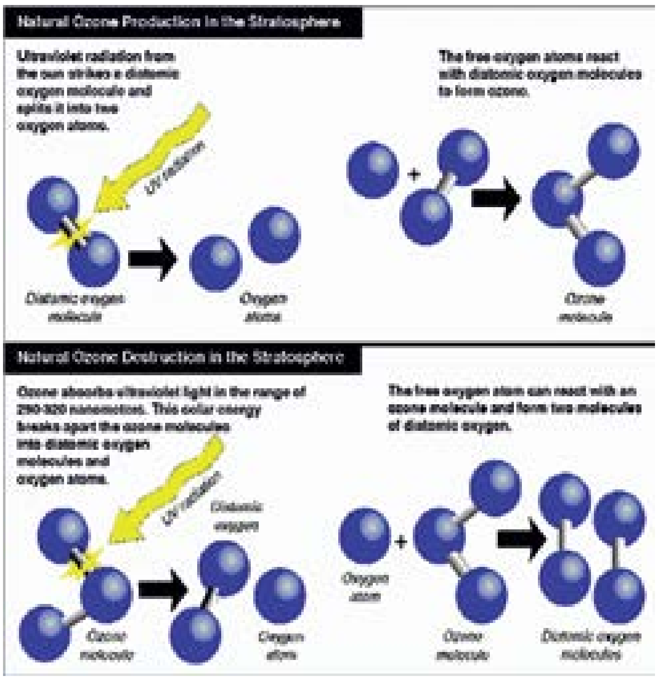
B - Disturbed Ozone Layer

Ozone Depletion

At any given time, ozone molecules are constantly being formed and destroyed in the stratosphere.

The total amount, however, remains relatively stable. The dynamic equilibrium between creating and breaking down ozone molecules depends on temperature, pressure, energetic conditions and molecule concentrations. The concentration of the ozone layer can be thought of as a stream's depth at a particular location. Although, water is constantly flowing in and out, the depth remains constant.

Natural Formation and destruction of Ozone

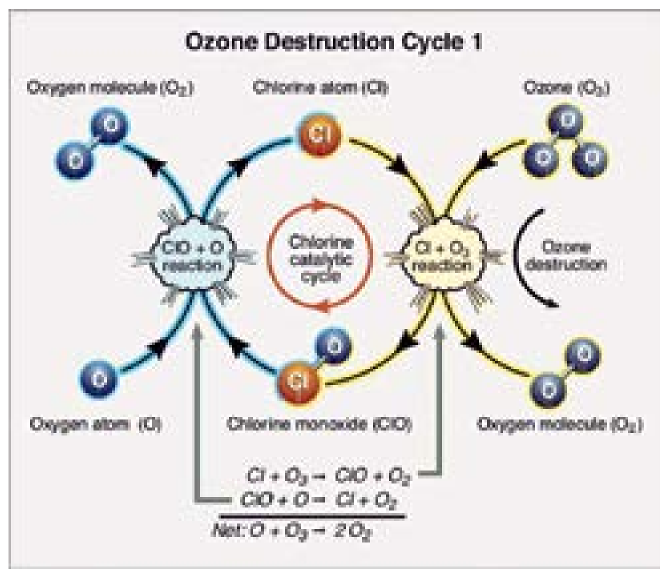


The concentrations of ozone vary naturally with sunspots, seasons, and latitudes. The processes of variation of ozone are well understood and predictable. Scientists have established records for several decades which show distribution of ozone during the natural cycles. It has been observed that each natural reduction in ozone levels has been followed by a recovery cycle. However, convincing scientific evidences have shown that the ozone layer is being depleted well beyond changes due to natural processes.

Ozone depletion occurs when the natural balance between the production and destruction of stratospheric ozone is shifted towards destruction. The equilibrium can be disturbed for instance by other molecules which react with the ozone molecules, thereby destroying them. If this destruction process is fast and the creation of new molecules is too slow to replace the destroyed ozone molecules, the equilibrium is upset. As a result, the concentration of ozone molecules is reduced. An upset in this equilibrium can have serious consequences for life on earth. Scientists are finding evidence of the changed balance. As a result, the concentration of ozone within the protective ozone shield is decreasing.

The balance between the natural processes of ozone production and destruction maintains a consistent ozone concentration in the stratosphere.

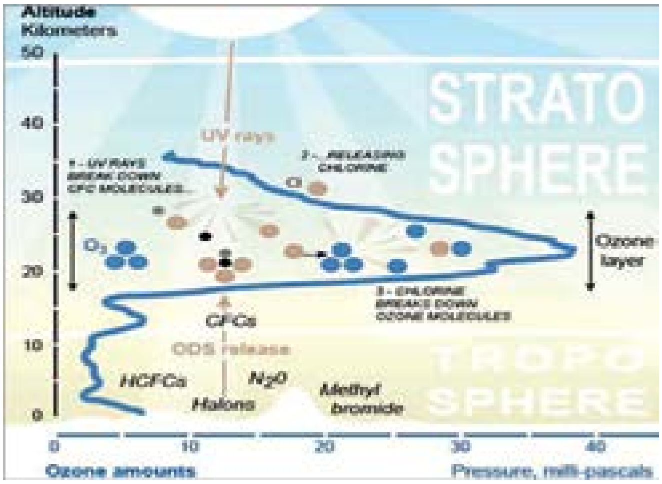
Reaction of Chlorine with Ozone



When very stable man-made chemicals containing chlorine and bromine enter into the atmosphere, and reach the stratosphere, these chemicals are broken down by the high-energy solar UV radiation and release extremely reactive chlorine and bromine atoms. These undergo a complex series of catalytic reactions leading to destruction of ozone.

Large fires, certain types of marine life and volcanic eruptions also produce chlorine molecules. These are chemically active but most of it gets converted into water soluble inorganic compounds which gets washed down by rain and only traces reach the stratosphere.

Process of Destruction of ozone



However, United States Environment Protection Agency (USEPA) experiments have shown that Chlorofluorocarbons (CFCs) and other widely used chemicals produce roughly 85% of the chlorine in the stratosphere.

It was also believed that large volcanic eruptions can have an indirect effect on ozone levels. Although, Mt. Pinatubo's 1991 volcanic eruption did not increase stratospheric chlorine concentrations, it did produce large amount of tiny particles called aerosols. These aerosols increase chlorine's effectiveness in destroying ozone.

The aerosols only increase depletion because of the presence of CFC-based chlorine. In effect, the aerosols increase the efficiency of the CFC siphon, lowering ozone levels even more than that would have otherwise occurred. Unlike long-term ozone depletion, this effect is however short-lived. The aerosols from Mt. Pinatubo have already disappeared, but satellite, ground based, and balloon data still show ozone depletion occurring closer to the historic trend.

Beginning of Threat to Ozone Layer

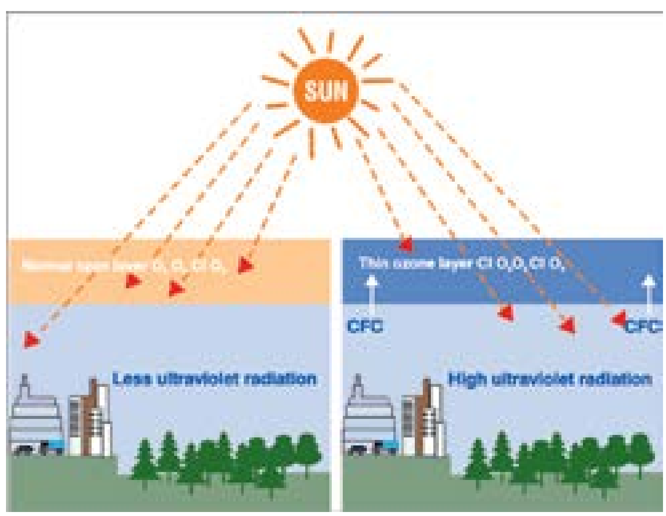
For over 50 years, CFCs were thought of as miracle substances. The first CFCs were created in 1928 as non- toxic, non-flammable refrigerants, and were first produced commercially in the 1930's by DuPont. The first CFC was CFC-12, a single carbon with two chlorines and two fluorines attached to it.

These have been used in many ways since they were first synthesized in 1928. They are stable, inert, non- flammable, low in toxicity, and inexpensive to produce. Over the period, CFCs have been used as aerosols, refrigerants, solvents and foam blowing agents in other smaller applications. Other chlorine and bromine-containing compounds include methyl chloroform, a solvent, Carbontetrachloride (CTC), an industrial chemical, halons, extremely effective fire extinguishing agents, hydrochlorofluorocarbons (HCFCs) mainly used as a refrigerant and foam blowing agent and methyl bromide, an effective fumigant used in agriculture and grain storage.

All of these compounds have very long atmospheric life which allow them to be transported by winds into the stratosphere.

During the past five decades, Ozone Depleting Substances (ODS) including CFCs, have been emitted into the atmosphere in large quantity resulting in depletion of the ozone layer and increased UV-B radiations on the earth's surface.

UV Radiations on Earth's Surface



The largest losses of stratospheric ozone occur regularly over the Antarctica every spring, leading to substantial increase in UV levels over the region.

A similar, though weaker, effect has been observed over the Arctic. There was enough evidence that ozone levels decrease by several percent in the spring and summer in both hemispheres at middle and high latitudes.

There is also a fall in ozone levels during the winter at these latitudes in the southern hemisphere. Higher levels of loss of ozone have been noticed since late 1970s.

In the early 1970s, researchers began to investigate the effect of various chemicals on the ozone layer, particularly CFCs, which contain chlorine. They also examined the potential impacts of other chlorine sources like chlorine from chlorination of water, industrial plants, sea salt and volcanoes etc. The chlorine released from such sources and from other sources readily combines with water and other chemicals and form compounds which do not reach the stratosphere. In contrast, CFCs are very stable and do not dissolve in rain. Thus, there are no natural processes that remove the CFCs from the lower atmosphere. Over a period of time, the CFCs diffuse into the stratosphere where these interact with UV rays of short wavelength which breaks them down.

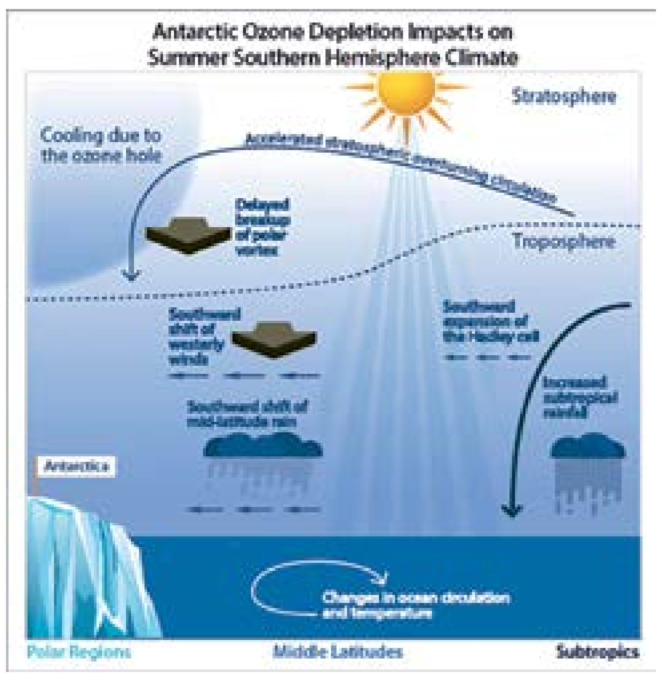
The CFCs are so stable that only exposure to strong UV radiation breaks them down. When that happens, the CFC molecule releases atomic chlorine. It has been estimated that one chlorine atom can destroy over 100,000 ozone molecules. The net effect is the destruction of ozone faster than its natural creation. To return to the analogy comparing ozone levels to a stream's depth, CFCs act as a siphon, removing water faster than normal and reducing the depth of the stream.

No one could imagine that these miracle chemicals could one day turn out to be substances harmful to life on earth. It all began when, at the first United Nations Human Environment Conference at Stockholm in 1972, questions were asked about the effect of jet aircraft on the upper atmosphere. It was known that high temperature jet exhausts contain an appreciable amount of nitrous oxide and it was also known that this substance can catalytically decompose ozone. The conference authorized the United Nations Environment Programme (UNEP) to address this issue and focus on the possible damage to the ozone layer by hundreds of supersonic aircrafts that were expected to be in operation by the late 1980s. UNEP was also entrusted with the task of finding out the effect of release of nitrous oxide from fertilizer manufacturing units on the ozone layer.

These investigations did not make much headway and were dismissed as false alarms.

The Antarctic Ozone Hole

The term "ozone hole" refers to a large and rapid decrease in the concentration of ozone molecules in the ozone layer. When the concentration of ozone over any area falls below 220 DU, it is called ozone hole. The Antarctic Ozone Hole occurs during the southern spring between September and November each year. The British Antarctic survey team first reported the hole in May 1985. The team found that for the period between September and mid November, ozone concentration over Halley Bay, Antarctic, had declined by 40% from levels during the 1960s. Severe depletion has been occurring since late 1970s.



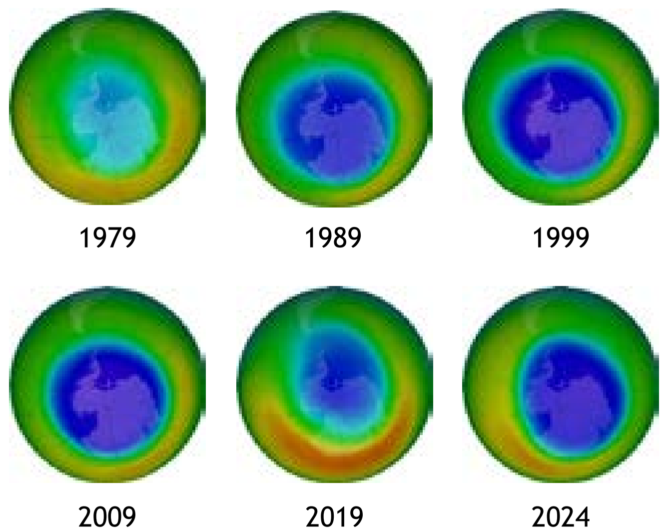
Schematic illustration of Southern Hemisphere climate impacts in austral summer associated with Antarctic ozone depletion. Ozone depletion has cooled the Antarctic stratospheric, leading to a delayed breakup of the stratospheric polar vortex and an accelerated stratospheric overturning circulation. Impacts have extended into the troposphere with the region of strong westerly winds and associated rainfall shifted southward, affecting the ocean circulation. The subtropical edge of the tropical circulation has also expanded poleward, leading to reduced precipitation in mid-latitudes and enhanced precipitation in the subtropics.

Source: World Meteorological Organization (WMO), Executive

Summary: Scientific Assessment of Ozone Depletion: 2018, World Meteorological Organization, Global Ozone Research and Monitoring Project - Report No. 58, 67pp., Geneva, Switzerland, 2018.)

The problem is worst in this part of the globe due to the extremely cold atmosphere and the presence of polar stratospheric clouds. The land under the ozone depleted atmosphere increased steadily to more than 20 million square (sq) km in the early 1990s and in the Antarctic spring of 1998, the area of the ozone hole exceeded 26 million sq km and also covered some populated areas of the southern hemisphere. The total ozone dropped to about 97 DU on 1 October 1998.

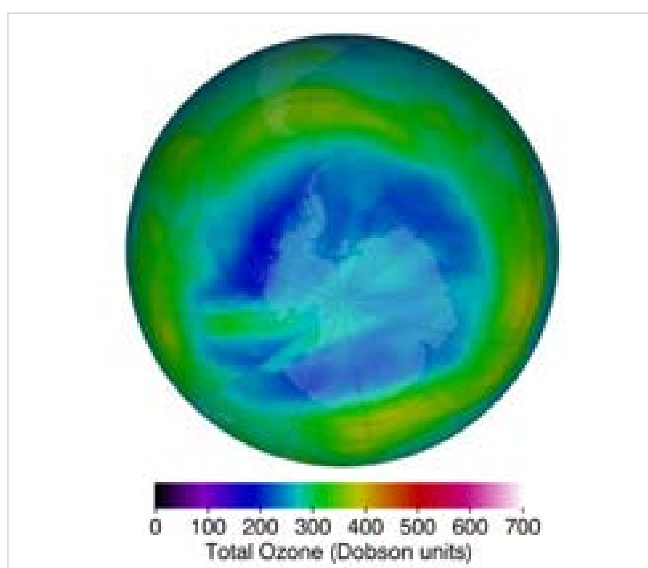
The Antarctic ozone hole grew to 28.4 million sq. km. in 2000. In the year 2002, a peculiar effect was seen, the ozone hole split into two but the total coverage was only 15 million sq km. In the year 2005, the size of ozone hole again increased to 27 million sq km. The ozone hole further grew to an extraordinary size, 29.3 million sq km in 2006. The size of ozone hole slightly started declining and in 2008 became equivalent to the size of North America and NOAA reported that ozone hole reached to 26.5 million sq km in September 2008. It was also observed that the total column of ozone dropped to its lowest count of 100 DU in September 2008. The size of Antarctic ozone hole in September 2009, September 2010, September 2011, September 2012, September 2013 and September 2014 were reported to be 24 million sq km, 22.2 million sq km, 25 million sq km, 18.5 million sq km, 21 million sq km and 24.3 million sq km respectively.



Changes in Ozone Concentration over Antarctica (1979-2024)

In the latest false-colour view of total ozone over the Antarctic pole the purple and blue depict show least ozone, and the yellows and reds more ozone.

August 2026

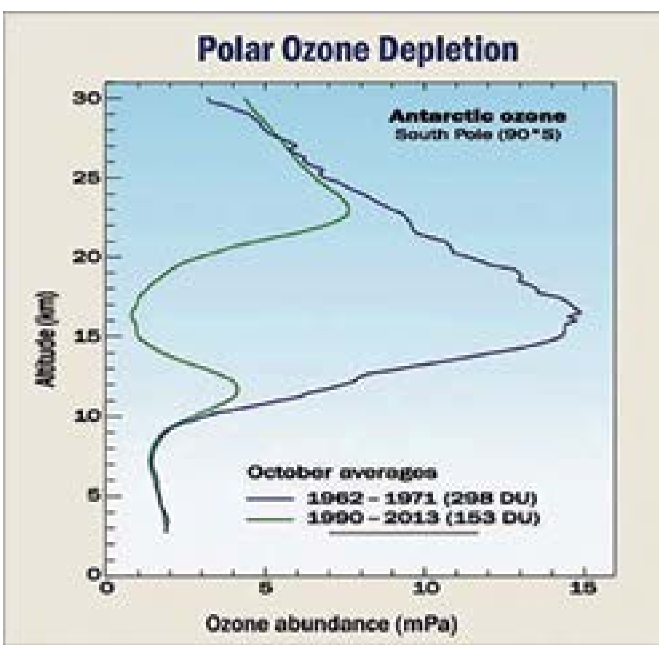


This indicates that the Montreal Protocol is working effectively and there is a gradual recovery of the ozone layer.

The decline of the ozone layer over the North Pole has also been reported. The effect has been ascribed to solar flares and record frigid temperatures in conjunction with manmade chemicals.

In addition, research has shown that ozone depletion occurs over the latitudes that include North America, Europe, Asia, and much of Africa, Australia and South America. Thus, ozone depletion is a global issue and not just a problem at the South Pole. It was also reported that some ozone depletion also occurs in the Arctic during spring in the northern hemisphere (March-May). Winter temperatures in the Arctic stratosphere are not persistently low for many weeks and this results in less ozone depletion.

Recent observations and several studies have shown that the size of the annual ozone hole has stabilized and the level of ODS has decreased by 4% since 2001. But chlorine and bromine compounds have long atmospheric life. Recovery of stratospheric ozone is not likely to be noticeable until 2020 or little later.



Environmental Effects of Ozone Depletion

As explained earlier, ozone acts as a shield to protect the Earth's surface by absorbing harmful UV- B and UV-C radiation. If this ozone is depleted, then more UV rays will reach the earth's surface. Exposure to higher doses of UV- B radiations will have effects on human health and impact flora and fauna of terrestrial as well as aquatic eco- systems.

Human health effects:

- Sunburns, premature ageing of the skin.
- UV radiation can damage several parts of the eye, including the lens, cornea, retina and conjunctiva.
- As per World Health Organization (WHO) 2002 report, a 10% decrease in stratospheric ozone could cause an additional 300,000 non-melanoma and 4,500 melanoma skin cancers in the world.
- More cataracts leading to damage to the eye resulting in blindness. Cataracts (a clouding of the lens) are the major cause of blindness in the world. Ten percent thinning of the ozone layer could cause 1.6 to 1.75 million more cases of cataract worldwide every year (WHO, 2002).
- Early findings suggest that exposure to UV radiation results in suppression of the human immune system, which may cause non- melanoma and skin cancer.

Adverse impact on agriculture, forestry and natural ecosystems:

- Several of the world's major crop species are particularly vulnerable to increased UV radiation, resulting in reduced growth, photosynthesis and flowering. Food production may reduce by about 1% for every 1% increase of UV-B radiation.
- The effect of ozone depletion on the Agriculture sector could be significant. Many agricultural crops sensitive to the UV-B radiation of the sun are rice, wheat, soybean, corn, sweet corn,

barley, oats, cowpeas, peas, carrots, cauliflower, tomato, cucumber, broccoli etc.

- A few commercially important trees have been tested for UV-B radiation sensitivity. Results indicate that plant growth, especially in seedlings, is more vulnerable to intense UV radiation.

■ **Damage to marine life:**

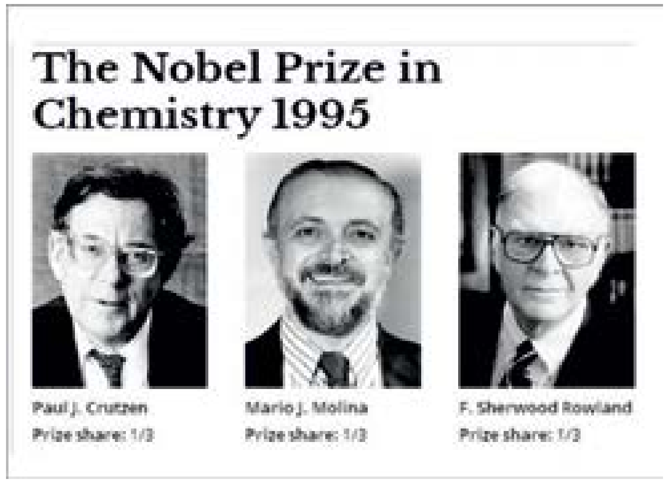
- Planktons are the first vital step in aquatic food chains. In particular, plankton (tiny organisms on the surface layer of oceans) are threatened by increased UV-B radiation.
- Decrease in plankton could disrupt the fresh and saltwater food chains, and lead to species shift.
- Marine fauna like lings (a variety of fish), juvenile stages of shrimp and crab have been threatened in recent years by increasing UV-B radiation under the Antarctic region. Loss of biodiversity in oceans, rivers and lakes could impact on aquaculture prospects.

■ **Materials:**

- Wood, plastic, rubber, fabrics and many construction materials are degraded by UV-B radiation.
- The economic impact of replacing and/or protecting materials could be significant.

The Real Alarm

In 1974, two United States (US) scientists Mario Molina and F. Sherwood Rowland at the University of California were struck by the observation of a British scientist, James Lovelock that CFCs were present in the atmosphere all over the world more or less evenly distributed by appreciable concentrations. They suggested that these stable CFC molecules could drift slowly up to the stratosphere where they may breakdown into chlorine atoms by energetic UV-B and UV-C radiations of the sun. The chlorine radicals thus produced can undergo a complex chemical reaction producing chlorine monoxide, which can attack an ozone molecule converting it into oxygen and in the process regenerating the chlorine atom again. Thus, the ozone-destroying effect is catalytic and a small amount of CFCs could destroy a large number of ozone molecules. Their basic theory was put to test by the National Aeronautics and Space Administration (NASA) scientists and found to be valid, ringing alarm bells in many countries and laying the foundation for international action.



The Nobel Prize for Chemistry in 1995 was awarded to Sherwood Rowland, Mario Molina and Paul Crutzen for their pioneering work in atmospheric chemistry, particularly concerning the formation and decomposition of ozone.

International Action

The first international action to focus attention on the dangers of ozone depletion in the stratosphere and its dangerous consequences in the long run on life on earth was initiated in 1977. A meeting of 32 countries in Washington D.C., USA initiated a Work Plan on action on protection of ozone layer with UNEP as the coordinator.

As experts began their investigation, data piled up and in 1985, in an article published in the prestigious science journal, “Nature” by Dr. Farman, pointed out that although, there was overall depletion of the ozone layer all over the world, the most severe depletion had taken place over the Antarctic. His findings were confirmed by satellite observations and offered the first proof of severe depletion of the ozone layer. These findings stirred the scientific community to take urgent remedial actions. A framework for such actions was designed and agreed in an international convention held in Vienna on 22 March 1985.

This, subsequently, resulted in an international agreement on 16 September 1987 on specific measures to be taken in the form of an international treaty known as the Montreal Protocol on Substances that Deplete the Ozone Layer. Under this Protocol, the first concrete step to save the ozone layer was taken by immediately agreeing to completely phase out the production and consumption of CFCs, halons, CTC and methyl chloroform as per the agreed schedule by the Parties to the Montreal Protocol.

Evolution of the Montreal Protocol

The urgency of controlling the ODS, particularly CFCs, was slow to pick up. The CFCs were so useful that society and industry, all over the world, were reluctant to give up the use of CFCs. However, even as the nations adopted the Montreal Protocol in 1987, new scientific findings indicated that the Protocol's control measures were inadequate to restore the ozone layer. In addition, the developing countries had a special situation, as they needed the technical and financial assistance to change over to non-ODS technologies.

Montreal Amendment enters into force

In response to the prospect of increasing ozone depletion, the governments of the world crafted the 1987 United Nations Montreal Protocol as an international means to address this global issue.

As a result of the broad compliance with the Protocol and its Amendments and adjustments and, of great significance, industry's development of "ozone-friendly" substitutes for the now-controlled chemicals, the total global accumulation of ODS has slowed and begun to decrease. In response, global ozone depletion is no longer increasing, and initial signs of recovery of the ozone layer have been identified. With continued compliance, we can expect substantial recovery of the ozone layer by the middle of the century. The day the Montreal Protocol was agreed upon, 16 September, is now celebrated as the International Day for the Preservation of the Ozone Layer.

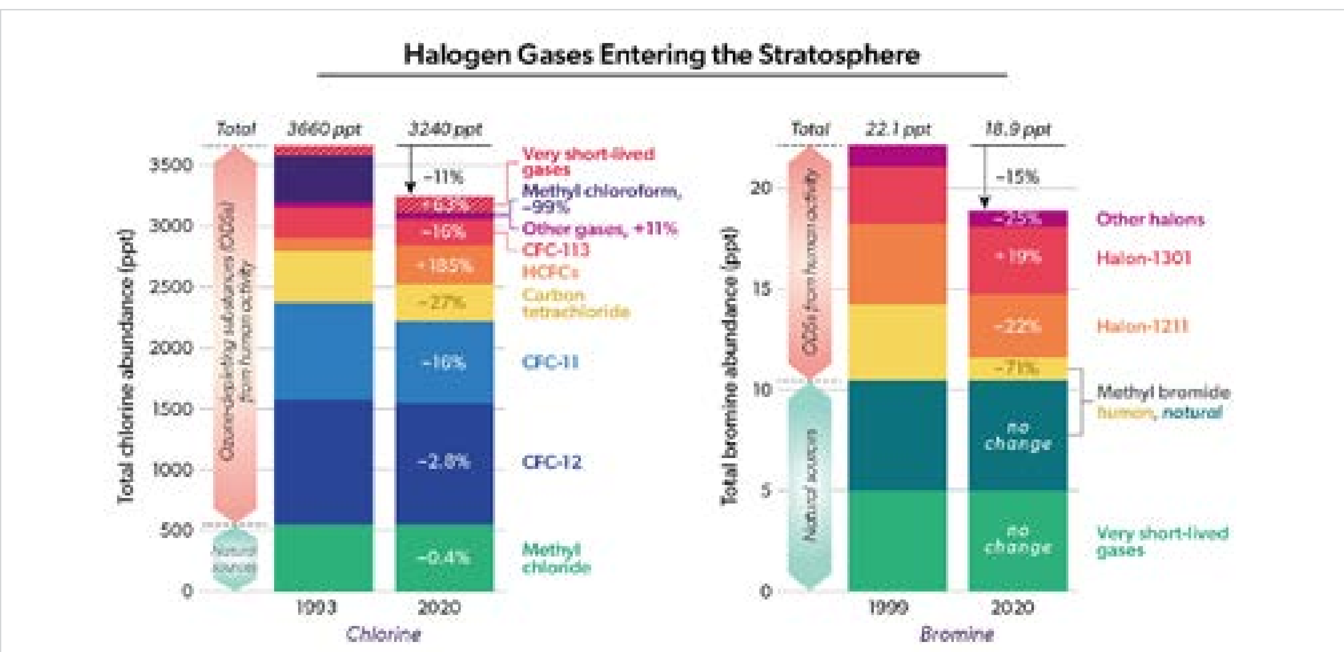
Meanwhile, the report of the Scientific Assessment Panel (SAP) of the Montreal Protocol, entrusted with the task of finding the extent of ozone depletion, showed that the actual harm to the ozone layer was much more than predicted by theoretical models. The control measures envisaged by the Protocol in 1987 would not be sufficient to arrest the depletion of the ozone layer. More urgent action was, therefore, necessary. Therefore, at the 2nd Meeting of the Parties (MOP) to the Montreal Protocol, in London, in 1990, 54 Parties as well as 42 non-Party countries agreed on a package of measures satisfactory to all. It was agreed that the 5 CFCs and 3 halons would be phased out by the year 2000 and other minor CFCs and CTC would be controlled and eventually phased out. A special provision was made to provide financial and technical assistance to the developing countries with an annual consumption of CFCs and halons less than 0.3 kg per capita (also called as Article 5 countries) in their efforts to phase out these harmful chemicals. These countries were also given a grace period of 10 years to phase out ODS.

In 1991, more alarming reports came up to show that the depletion of ozone is continuing in all altitudes except over the tropics. It was recognized that the phase-out of production and consumption of CFCs and halons would not be enough to control the depletion of ozone layer. Other fluorocarbon chemicals like HCFCs and methyl bromide, which are also ODS, need to be controlled. They have also been brought under the ambit of the Montreal Protocol in 1992 through Copenhagen amendment and defining the schedule of phase-out of HCFCs in 1999 through the Beijing Amendment. Further, the phase-out of production and consumption of HCFCs was accelerated in 2007 through an adjustment.

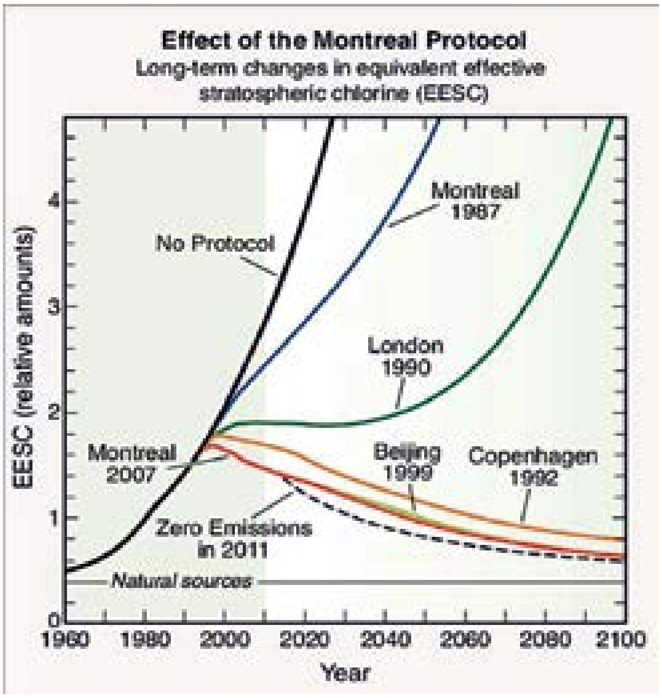
Equivalent Effective Stratospheric Chlorine (EESC)

The EESC is a metric for representing ODS levels in the stratosphere. It is calculated based upon three factors: surface atmospheric concentrations of individual ODS and their number of chlorine and bromine atoms, the relative efficiency of chlorine and bromine for ozone depletion, and the time required for the substances to reach different stratospheric regions and break down to release their chlorine and bromine atoms. As EESC continues to decrease in response to Montreal Protocol provisions, stratospheric ozone is expected to increase. The EESC does not include chlorine and bromine from very short-lived substances (VSLS).

As per scientific assessment report of ozone depletion in 2022, the EESC had declined from peak values by about 11% for polar winter conditions and by about 15% for mid-latitude conditions by year 2020. The release of total chlorine in the stratosphere from controlled and uncontrolled ODS declined by 420 ± 20 ppt (11.5%) between the 1993 peak (3660 ppt) and 2020 (3240 ppt). This long-term decrease was largely driven by decreasing abundances of CH3CCl3 and CFCs. Total bromine entering the stratosphere from controlled and uncontrolled ODSs declined by 3.2 ± 1.2 ppt (14.5%) between the 1999 peak (22.1 ppt) and 2020 (18.9 ppt). This long-term decrease was largely driven by decreasing abundances of CH3Br and halon-1211.



Source: World Meteorological Organization (WMO), Executive Summary. Scientific Assessment of Ozone Depletion: 2022, GAW Report No. 278, 56 pp., WMO, Geneva, Switzerland, 2022.



Source: ozone secretariat

Recovery of Ozone Layer

As a result of implementation of provisions/ measures under the Montreal Protocol, the atmospheric concentration of man-made substances containing chlorine and bromine has begun to decline. Chlorine/ bromine reached have the maximum levels in the stratosphere in the first decade of the 21st century, and ozone concentrations should correspondingly have been at their minimum levels during that time period. It is anticipated that the recovery of the Antarctic ozone hole has begun. But there is a slow rate of healing because of long atmospheric life of manmade chemicals like CFCs, CTC, halons, methyl chloroform, methyl bromide etc. January 2010 marked the end of global production of CFCs and halons under the Protocol, and January 2013 the universal control of ODS production and consumption.

Healing of ozone layer confirmed

The scientific assessment of ozone depletion in 2014 confirms that the ozone layer is healing and will return to pre-1980 levels by mid-century, thanks to actions taken by Parties under the Montreal Protocol.

The ozone layer today

The Montreal Protocol is widely lauded as a huge environmental success. Whilst the damage we have done to the ozone layer has not yet been undone, thanks to this agreement and the collaborative effort of nations around the world, there is scientific evidence that the ozone layer is healing itself and is expected to recover by the middle of this century.

The Montreal Protocol has also considerably reduced climate warming because many ozone- depleting substances are also potent greenhouse gases (GHG) that contribute to climate forcing when they accumulate in the atmosphere. Montreal Protocol controls have led to a substantial reduction in the emissions of ozone-depleting substances over the last two decades. These reductions, while protecting the ozone layer, have the additional benefit of reducing the human contribution to climate change. Without Montreal Protocol controls, the climate forcing due to ozone-depleting substances could now be nearly two-and-a-half times the present value.

Status of Ratification of Vienna Convention, Montreal Protocol and Amendments

S.No.	Particulars	Date of Enforcement	No. of Parties
1	Vienna Convention 1985	22.09.1988	198
2	Montreal Protocol, 1987	01.01.1989	198
3	London Amendment, 1990	08.10.1992	197
4	Copenhagen Amendment, 1992	14.06.1994	197
5	Montreal Amendment, 1997	10.11.1999	197
6	Beijing Amendment, 1999	25.02.2002	197
7	Kigali Amendment, 2016	01.01.2019	152

Multilateral Fund

With a view to assist the developing countries in their phase-out efforts, a Multilateral Fund (MLF) for the implementation of the Montreal Protocol was established in June 1990. The Fund is supported by a Secretariat, co-located with UNEP, but directly accountable to an Executive Committee (Ex-Com) consisting of seven non-Article 5 Parties and seven Article 5 Parties. This governance structure accomplished several key objectives. First, by co-locating the MLF Secretariat with UNEP but retaining its independence in a policy context, the Parties and their appointed Ex-Com were provided with direct control over the Fund's policies. Second, the balance of non-Article 5 and Article 5 Parties on the Ex-Com signalled a major departure from the historic donor-driven nature of funding bodies that reflected the spirit of equality.

The Fund is financing incremental costs for ODS phase out in Article 5 Parties. This provision of incremental costs, including cost of transfer of technology, incremental capital costs and incremental operating costs for switching over from ODS to non-ODS technologies enables the developing countries to phase out controlled substances. Enterprises which were using ODS- based technologies prior to cut-off dates are eligible for funding for conversion from ODS to non-ODS technology from the MLF for the implementation of the Montreal Protocol.

Establishment of a financial mechanism to provide technical and financial support to the developing countries to meet their compliance obligations to the Montreal Protocol, proved as the key to the success of the Montreal Protocol.

India being an Article 5 Party is eligible for technical and financial assistance from MLF to phase out ODSs and switch over to non-ODS technologies.

Alternatives to Currently Used Ozone Depleting Substances

During the last two decades intensive research has yielded a large number of substitute chemicals as replacements to CFCs, halons, CTC, methyl chloroform, methyl bromide and HCFCs.

These are summarised below on end-use basis:

Technology Options for Phase-out in Refrigeration and Air-conditioning (RAC) Sector

Sub-sector	ODS used	Preferred alternatives / substitutes
Domestic refrigerators	Refrigerant: CFC-12 Foam: CFC-11 HCFC-141b	Refrigerant: HFC-134a, HC-600a, Isobutane, HC blend, HFO-1234yf Foam Blowing Agents: Cyclopentane HFC-245fa, HFC-365mfc, HFO-1234ze Methyl Formate, Methylal, Solstice-LBA, FEA-1100
Refrigerated Cabinets (Deep Freezer, Ice-cream cabinets, Bottle coolers, Visi coolers)	Refrigerant: CFC-12 Foam: CFC-11 HCFC-141b	Refrigerant: HFC-134a, HC-600a HC-blend, CO_2Foam Blowing Agents: Cyclopentane, HFC-245fa, HFC-365mfc, HFO-1234ze, Methyl Formate, Methylal, Solstice- LBA, FEA-1100

Water Coolers	CFC-12 HCFC-22 (for bigger capacity)	HFC-134a, HC-blend, HC-290, HFO-1234yf
Mobile (car, bus, van, refrigerated trucks, train)	CFC-12 HCFC-22 (train)	HFC-134a, HFC-1234yf HFC-152a, CO_2 R-290, HFC-134a, HFO-1234yf, R-407C, blends of HFCs and HFOs
Central A/C Plants	CFC-11, CFC-12, HCFC-123, HCFC-22	HFC-134a, R-410A, R-407C, HFO-1234yf, HC-600a, Ammonia, HC-290, R454B
Process Chillers	CFC-12, HCFC-22	HFC-134a, R-404A, R-407F, Ammonia
Ice Candy Machines	CFC-12, HCFC-22	HFC-134a, R-407F, R-290, R-404A
Walk-in Coolers	CFC-12, HCFC-22	HFC-134a R-407F R-404A
Room A/C	HCFC-22	R-410A, HC-290, HFC-32, blends of HFCs and HFOs
Packaged A/C	HCFC-22	R-410A, R-407C, HFC-32, HC-290, HC-1270
Shipping	CFC-12, HCFC-22	HFC-134a, R-410A, CO_2

Alternatives with zero ODP viz. Hydrofluorocarbon - 134a (HFC-134a), R-404A, R-407C, R-410A and R-507A have been used in various applications in many countries especially in non-Article 5 countries. The low-Global Warming Potential (GWP) refrigerants like ammonia, Carbon-dioxide (CO2) and hydrocarbons are also used in some applications. Attempts are being made to use hydrocarbons like HC-290 and HC-1270 in a number of applications, including small capacity room air-conditioners. Recently, low-GWP HFCs, also known as hydrofluoroolifins (HFOs) are being applied in some applications.

Technology Options for Phase-out in Aerosol Sector

Sub-sector	**ODS Phased out**	**Preferred alternatives / substitutes**
Perfumes, Shaving Foams, Insecticides, Paints, etc.	CFC-11/ CFC-12	Hydrocarbon Aerosol Propellant (HAP), destenched LPG, Di-methyl Ether
Metered Dose Inhalers	CFC-11 CFC-12	Hydrofluoro-alkanes (HFAs)

Technology Options for Phase-out in Foam Sector

Sub-sector	ODS Phased out	Preferred alternatives / substitutes
Flexible Polyurethane Foam (PUF) Slabstock	CFC-11	Methylene Chloride
Flexible Moulded PUF	CFC-11	Water blown technology
Rigid PUF General Insulation	CFC-11 HCFC-141b	Cyclopentane, HFC-245fa, HFC-365mfc, HFO-1234ze, HFO-1233zd(E), Methyl Formate, Methylal , Solstice- LBA, FEA-1100
Thermoware	CFC-11 HCFC-141b	HFC-245fa, HFC-365mfc, Water, Methyl Formate, Solstice-LBA, FEA-1100
Thermoplastic Foams -EPE/EPPN Foams -Phenolic Foams	CFC-11, CFC-12 CFC-11	Hydrocarbons, CO_2
Phenolic Foams	CFC-11	Hydrocarbons

The CFC-11 with ODP of 1.0 as a foam-blowing agent was substituted first by a transitional technology based on HCFC-141b with 0.11 ODP. The HCFC-141b is now being replaced by zero-ODP and low-GWP foam blowing agents like cyclopentane, methyl formate and methylal. The HFC-based blowing agents like HFC- 245fa and HFC-365mfc have also been used in non-Article 5 countries. The proposed next generation of low-GWP foam blowing agents are likely to be HFOs-1234ze, HFO-1233zd(E), methyl formate, methylal, Solstice-LBA, FEA-1100 and Hydrocarbons.

Technology Options for Phase-out in Fire Extinguishing Sector

Sub-sector	ODS Phased out	Preferred alternatives / substitutes
Fire Extinguishers	Halon-1211, Halon-1301, Halon-2402	Portable type ABC powder, CO_2 Fixed type FM200, HFCs, NAF- SI/SIII, Novec 1230

Substitutes like ABC powder and HFC based for halon-1211 used in portable fire extinguishers have also been developed and used. Some global chemical producers have developed hexafluoro propane (HFC- 236fa) as an excellent substitute for halon-1211 fulfilling a long felt need. It is now being manufactured commercially.

Technology Options for Phase-out in Solvent Sector

Sub-sector	ODS Phased out	Preferred alternatives / substitutes
Electronic and Precision Cleaning	CFC-113 CTC Methyl chloroform	DI Water Aqueous cleaning process Semi-acqueous cleaning process, organic non-halogenated, solvents, perfluorocarbons

Coatings	CFC-113 Methyl chloroform	Aqueous solvents Trichloro ethylene
Manufacture of pesticides and pharmaceuticals	CTC	Ethylene-dichloride Monochloro-benzene
Metal cleaning	CTC	Trichloroethylene
Chlorinated	CTC	Aqueous rubber
Textile cleaning	CTC	Aqueous system, chlorinated solvents

During the last several years, due to intensive Research and Development (R&D) efforts, new solvents have been discovered and used as alternatives to ODS. First Hydroflouroethers (HFEs) were considered as alternative solvents. Although, satisfactory in many respects, these were very high- cost alternatives. Some patented non-ODS products have also been promoted as alternative solvents for electrical cleaning especially for tape head and disk drives (Video 40), flux removal and PCB cleaner (Deflex 160); degreasing agent (Cold kleen 110); adhesive sticker removing, computer disk cleaning (CD-150) etc. Although, these are patented products and their chemical compositions are not available but the trend is good.

2 INDIA'S COMMITMENT TO THE MONTREAL PROTOCOL

India became Party to the Vienna Convention for the Protection of the Ozone Layer on 18 March 1991 and the Montreal Protocol on Substances that Deplete the Ozone Layer on 19 June, 1992. The per capita consumption of the controlled substances in Annex A of the Montreal Protocol did not cross 20 g during 1995-97 (baseline), as against 300 g per capita limit for Article 5 Parties under the Protocol. India was self-sufficient in production of chemicals like CFCs, CTC, halons and HCFCs. India was mainly producing and using 9 of the 96 substances controlled under the Montreal Protocol. These are CFC-11, CFC-12, CFC-113, HCFC-22, halon-1211, halon-1301, CTC, Methyl Chloroform and Methyl Bromide.

India played a key role in the establishment of the MLF–the financial mechanism established under the Montreal Protocol through its London Amendment in 1990. India also played a pro- active role in the implementation of Montreal Protocol in the country. India had prepared a detailed Country Program (CP) in 1993 to phase- out ODS in accordance with its National Industrial Development Strategy. The objectives of the CP were to phase-out ODSs by accessing the Protocol's financial mechanism without undue economic burden to consumers, producers and equipment manufacturers using ODS. The other objectives of the CP were minimization of economic dislocation as a result of conversion to non-ODS technologies, maximization of indigenous production, preference to one-time replacement, emphasis on decentralized management and minimization of obsolescence. The CP was updated in 2006 taking into account the decisions of the Montreal Protocol and national policies.

The Government of India has entrusted the work relating to ozone layer protection and implementation of the Montreal Protocol on Substances that Deplete the Ozone Layer, to the Ministry of Environment, Forest and Climate Change (MoEF&CC). The MoEF&CC has set up the Ozone Cell as a National Ozone Unit (NOU) to render necessary services for effective and timely implementation of the Protocol and its ODS phase- out activities in India.

The MoEF&CC also constituted an Empowered Steering Committee (ESC), which is supported by two Standing Committees, namely the Technology and Finance Standing Committee (TFSC) and the Standing Committee on Monitoring. The ESC is Chaired by Ex-officio Secretary, Ministry of Environment Forest and Climate Change (MoEFCC) and comprising of representation from line ministries/departments to review the policies and implementation of projects/ plans and monitoring.

Although, ODS, especially CFCs and HCFCs were used in large scale in the developed countries since the1930s, India was slow to adopt these chemicals. The early use of these chemicals in India was in the Refrigeration and Air Conditioning (RAC) sector and CFCs and HCFCs needed for this sector were imported in the country. The use of CFCs and HCFCs in the refrigeration industry can be traced back to1960s. Other industries using CFCs and HCFCs,such as the foam manufacturing industry, aerosol industry etc., were developed only during last 35 to 40 years in the country. With the availability of CFC-11 and CFC-12 from indigenous production, started in 1968, the growth of consumption of CFCs and industry increased very rapidly.

When the CP was prepared, use of ODS as solvents is estimated to account for the maximum consumption, both in Metric Tonnes (MT) as well as Ozone Depleting Potential (ODP) tonne. The sectors RAC and Foam were the next large users, followed by Aerosol sector. The consumption of ODS in the Firefighting sector was relatively small in terms of MT.

Status of ODS Phase-out in India

India has phased out the production and consumption of CFCs, CTC and halons as of 1 January 2010 (except the use of pharmaceutical grade CFCs in manufacturing of Metered Dose Inhalers (MDIs) for Asthma and Chronic Obstructive Pulmonary Diseases (COPD) patients). India has also phased-out production and consumption of Methyl Chloroform and Methyl Bromide. A total of 384 projects have been approved and funded by the Ex-Com of the MLF for Implementation of the Montreal Protocol. A total amount of US$ 333,067,058 has been approved by the Ex-Com of the MLF to phase-out 48,242 tonne of ODSs.

Structured implementation framework supported by a robust regulatory framework and fiscal measures along with active cooperation of industry have led to India successfully meeting all the ODS phase-out targets of the Montreal Protocol, including the phase out of production and consumption of CFC, CTC, Halons, Methyl Chloroform as on 1 January 2010 for controlled applications.

Sector-wise Approved Projects as on 31st August 2024

Sector-wise break-up of the funds approved by the Ex-Com of the MLF for ODS phase-out projects in India is given in the table below:

Sector	No. of Projects	Funding (US$)	Phase out of ODP (in Tonne)
Aerosols Sector (CFC)	38	13,705,006	1,702
Foams Sector (CFC)	163	37,880,185	5,074
Firefighting Sector (Halons)	21	5,176,701	2,719
Institutional Strengthening	12	2,738,166	–
Refrigeration & Air Conditioning Sector (CFC)	87	31,827,256	3,983
Solvents Sector (including CTC production)	41	61,358,042	12,966
Production Sector (CFC and Halons)	15	84,228,000	20,107
HPMP Stage-I Preparation	1	570,000	–
HPMP Stage-I (HCFC-141b and HCFC-22)	1	21,294,490	342
HPMP Stage-II Preparation	1	490,000	–
Demonstration Project in Foam Sector Preparation (HCFC-141b)	1	30,000	–
HPMP Stage-II (HCFC-141b and HCFC-22)	1	44,911,459	769
HPMP Stage-III Preparation	1	450,000	–
Enabling activities for Hydro-fluorocarbons (HFC) phasedown under the Kigali Amendment	1	250,000	–
HPMP Stage-3	1	25,157,632	580
Preparation of 3 HFC Projects to demonstrate low GWP technologies	1	90,000	–
Project preparation for development and pilot testing of R-290 compress or manufacturing and design and development of micro-channel condensers for R-290 room air-conditioners	1	30,000	-

Sector	No. of Projects	Funding (US$)	Phase out of ODP (in Tonne)
Conversion from R-407C and R-410A to HFC-32 in the manufacturing of light commercial air-conditioning packaged and ducted air-conditioning units at Voltas Limited	1	422,561	–
Conversion of the manufacturing of commercial refrigeration appliances at Rockwell Industries Limited from HFC-134a to propane (R-290)	1	423,765	–
Technical assistance to enhance the energy efficiency of the converted equipment		150,000	–
Design and development of a pilot scale energy-efficient rotary compressor along with microchannel heat exchanger compatible with R-290 technology at Godrej & Boyce Mfg. Ltd., for use in manufacturing of room air conditioners	1	1,853,795	–
Project Preparation for use of R-290 in automotive systems	1	30,000	–
Total	391	333,067,058	48,242

Sector Phase-out Plans

CFC Production Sector Phase-out Project in India

The Ex-Com of the MLF in its 29th meeting held in November 1999 approved India's CFC Production Sector gradual phase-out project with a total grant amount of US$ 82 million to phase-out production of 22,588 ODP tonne of CFCs. The amount US$ 80 million was to be provided as a performance-based grant to CFC producers for meeting the CFC production phase-out targets. The remaining US$ 2 million was for the Technical Assistance (TA) component to establish a Project Management Unit (PMU) under the Ozone Cell to develop and implement monitoring, auditing and reporting mechanisms, in addition to conduct awareness and training programs. The World Bank was the lead implementing agency for the project. The has been designated as the implementing agency for the TA component. In this project, it was agreed to reduce total CFC production in accordance with the following agreed schedule:

Agreed Schedule for Phase-out of CFC Production

Year	CFC Production Quota (MT)	Phase-out Quantity (MT)
1999	22,588	-
2000	20,706	1,882
2001	18,824	1,882
2002	16,941	1,883
2003	15,058	1,883
2004	13,176	1,882
2005	11,294	1,882
2006	7,342	3,952
2007	3,389	3,953
2008	2,259	1,130
2009	1,130	1,129
2010	0	1,130

Accelerated Phase-out of CFCs

India agreed at the 54th meeting of the Ex-Com of the MLF held from 7 to 11 April 2008 in Montreal, Canada to accelerate the phase-out of production of CFCs by 1 August 2008 with an additional grant of US$ 3.17 million to the CFC producers. As per the decision, India agreed that it will produce not more than 690 MT of CFCs until 1 August 2008 primarily for the manufacturing of MDIs. India's CFC producers would sell no more than 825 MT of CFCs for MDI production in the years 2008 and 2009, comprising 690 MT of new production and 135 MT reprocessed from existing stock. India has completely phased-out the production and consumption of CFCs with effect from 1 August 2008, 17 months ahead of the agreed phase-out schedule except the use of pharmaceutical grade CFCs in manufacturing of MDIs. The Ex-Com of the MLF has released the total grant of US$ 3.17 million, the grant approved for accelerated phase-out of CFCs.

The National Strategy for Transition to Non-CFC MDIs and Plan for Phase-out of CFCs in the Manufacture of Pharmaceutical MDIs has been implemented successfully by United Nations Development Program (UNDP) as lead implementing agency, UNEP and the Government of Italy as cooperating agencies in close cooperation with the MDI manufacturing industry under the guidance of Ozone Cell, MoEF&CC.

Halon Production and Consumption Phase-out in India

The phase-out of consumption of halons in India was initiated as early as 1994. The 13th meeting of the Ex-Com of the MLF approved a demonstration project for evaluation of alternative technologies for halon, fire protection system and technical assistance for sectoral strategy with a funding of US$ 309,000. It followed with the approval of 14 individual investment projects by the Ex-Com of the MLF from 1995 to 1999 which resulted in phase-out of 1,768 ODP tonne of halons. These projects were successfully completed in 2001.

Subsequently, the Ex-Com of the MLF in its 34th meeting held in 2001 at Montreal approved US$ 2.6 million for complete phase-out of the production and remaining consumption of halons in the country. This project was successfully implemented and achieved the objective of complete phase-out of production and consumption of halons in India, as early as 2003.

The enterprises, producing halons have dismantled their production plants. At present, there is no halon production in India. The phase- out activities of production and consumption of halons in all the enterprises have been successfully completed.

Firefighting Industry Structure: There were two halon production facilities in India at M/s Navin Fluorine International Ltd. (NFIL) and M/s SRF Ltd. M/s SRF was producing halon-1211 and halon- 1301, while M/s NFIL was producing only halon- 1211. The total production capacity of halon in the country was 800 MT.

There were about 200 manufacturers of fire extinguishing equipments, of which over 85% were manufacturers of portable fire extinguishers in the country. Halons, which are potent ODS, were used only in about 5% of the fire extinguishing applications.

Halon Consumption: In 1991, the total consumption of halons in India was 750 MT, equivalent to 3,650 ODP tonne. This constituted 7.2% of India's total ODS consumption and almost 28% of the total consumption in ODP tonne. Imports accounted for 550 MT of the total consumption, while 200 MT was indigenously produced. The growth rate in this sector was forecasted at 15% annually.

Technology: As noted earlier, the use of halons in firefighting equipments constituted only about 5% of the fire-fighting applications in India. There were no drop-in replacement technologies identified. However, a wide variety of fire- extinguishing technologies were identified at the time of preparation of the CP, viz., ABC powder, carbon di-oxide (CO_2)-based systems, foam- based systems, inert gases, HFC-based systems, fast response sprinklers, etc. Among the priority actions identified to address the ODS phase-out in this sector were:

- Revision of national fire-extinguisher codes and standards to promote halon alternatives;
- Halon conservation program to limit emissions;
- Establishment of a halon management program, including halon banking.

Establishment of Halon Banking Facility: The production of halons has been phased-out globally at the early stage of the Protocol because of high ODP values of halons. Moreover, there is a large quantity of halons banked in fire-extinguishing equipments. The MoEF&CC has established National Halon Banking Facility at the Centre for Fire, Explosive and Environment Safety (CFEES), Defence Research and Development Organization (DRDO), Ministry of Defence, New Delhi with the financial assistance from the MLF of the Montreal Protocol. This facility has the capability to recover, recycle and store halons in existing equipment for future use. It is worth mentioning that all the three defence forces have also established their own halon banking facilities to meet future requirements.

CFC Phase-out in Foam Manufacturing Sector

The Foam Manufacturing sector was one of the major ODS- consuming sectors in India predominantly using CFC-11 as blowing agent. As of June 2002, 158 projects and activities were approved by the Ex-Com of the MLF to phase-out 4,401 ODP tonne of CFCs with a funding of US$ 29.36 million. These projects/ activities were successfully implemented and achieved the phase- out of CFCs in this sector.

The Ex-Com of the MLF, at its 37th meeting held in July 2002 approved the foam sector phase-out plan with a total funding of US$ 5.42 million to phase- out the remaining 612 ODP tonne of CFC- 11 in Foam Manufacturing sector. The UNDP was responsible for implementation of this plan. A total of 122 Foam Manufacturing enterprises under this sector plan have phased-out 702 MT of CFCs from their processes. The foam sector CFC phase-out plan has been successfully implemented and use of CFCs has been completely eliminated in Foam Manufacturing sector in the country.

Industry Structure: The survey of the Foam Manufacturing sector carried out at the time of preparation of CP in 1993 identified about 235 foam manufacturers in India using CFCs as blowing agents. About 20% of the enterprises were large/ medium size, while the rest were Micro, Small and Medium Enterprises (MSMEs) in the unorganized and informal sector.

The sub-sectors identified were rigid polyurethane foam, flexible polyurethane foam, integral skin polyurethane foams, thermoplastics foams (extruded polyethylene and polystyrene foams) and phenolic foams. An important sub-sector in the Foam sector, namely, the flexible slab-stock foam mostly converted from CFCs to methylene chloride as the blowing agent during 1980s due to economic reasons. The domestic refrigerator manufacturers were large and main users of CFCs in the rigid polyurethane foam sub-sector. Another important sub-sector within the Foam Manufacturing sector, the rigid polyurethane foam used in the production of insulated thermo-ware (flasks, casseroles, water-bottles, lunch-boxes, etc),was considered important due to the large number of MSMEs involved.

There were four major producers of polyol systems, who formed the main upstream source of raw materials for the polyurethane foam manufacturers and were meeting about half of the total demand. The remaining demand was met through imports.

ODS Consumption in Foam Sector: In 1991, the consumption of CFCs in Foam Manufacturing sector was 1,580 MT, predominantly CFC-11, which amounted to about 31% of India's total CFC consumption in the country. It was estimated that the demand for foam products would grow at 15- 20% annually until 2010. The Foam sector was therefore identified as a priority sector in India for initiating phase-out activities.

It was considered strategically important to support the conversion of manufacturing facilities of the polyol systems house(s) on a priority basis, to enable them to customize non-CFC formulations, thus facilitating CFC phase-out in the downstream foam manufacturers more economically. It was also recognized that there were large number of MSMEs operating in this sector, which could not be identified at the time of preparation of the CP. However, these were addressed subsequently.

The HCFCs like HCFC-141b, HCFC-142b and HCFC-22 are commonly used as interim substitutes to phase-out CFCs in foam manufacturing sector. The accelerated phase-out of HCFCs, as agreed at the 19th Meeting of the Parties (MOP) held in September, 2007, would require conversion of foam manufacturing facilities from HCFCs to non-ODS technologies, viz., hydrocarbons, hydrofluoroolefin (HFO), methylformate, methylal etc.

CFC Phase-out in RAC Sector

The phase-out of CFCs in RAC sector in India was initiated as early as 1993. As of July, 2002, a total of 47 investment and technical assistance projects were approved with a total funding of US$ 22.3 million leading to a total phase-out of 1,821 ODP tonne of CFCs. Subsequently, the Ex-Com of the MLF in its 38th meeting held in November 2002 approved a multi-year performance-based sector phase-out plan covering the Refrigeration (manufacturing) sector with a total funding of US$ 3.6 million to phase-out the remaining CFC consumption of about 535 ODP tonne. The UNDP was responsible for implementation of the commercial refrigeration component and the United Nations Industrial Development Organization (UNIDO) was responsible for implementation of the transport refrigeration sub- sector under this sector plan. A total of 157 enterprises for Commercial Refrigeration (manufacturing) sector and 39 enterprises in Transport Refrigeration (manufacturing) sector were identified during theimplementation of the plan. The sector phase-out plan has been successfully implemented and phased out the use of CFCs completely in the Refrigeration (manufacturing) sector in the country.

RAC Industry Structure: The RAC sector in India has a long history from the early years of the last century. Major investments in establishing manufacturing capacities started in 1950s. On the upstream side, there were only two compressor manufacturers exclusively for hermetic compressors. In addition, there were some appliance manufacturers dedicated facilities for manufacturing of hermetic compressors. However, there were several manufacturers of open-type compressors. Many other components of refrigeration systems were also manufactured in the country.

ODS Consumption in RAC Sector: In 1991, the total ODS consumption in the RAC sector in India was 1,990 MT. This constituted about 39% of India's total consumption of CFCs. About two-third of this consumption was estimated to be used in servicing of existing equipment. The growth rate in this sector was forecasted at 10-20% annually until 2010. The RAC sector was, therefore, identified as another priority sector in India for initiating phase-out activities.

National CFC Consumption Phase-out Plan (NCCoPP)

The Ex-Com of the MLF at its 42nd meeting held in April, 2004 approved the NCCoPP for the RAC servicing sector at a total funding level of US$ 6.388 million to phase-out 1,502 ODP tonne of CFCs. The Government of Germany (bilateral implementing agency) was responsible for implementation of this project as the lead Implementing Agency along with UNDP, UNEP, UNIDO and Government of Switzerland as cooperating implementing agencies. The Government of Switzerland was responsible for training activities and UNDP was responsible for equipment support. The UNEP was responsible for creation of awareness activities. Besides, UNEP was organizing customs and policy training activities in collaboration with National Academy for Customs, Indirect Tax and Narcotics (NACIN). The UNIDO jointly with UNDP was responsible for implementation of CFC phase-out activities in transport refrigeration.

The project's main focus was on training of refrigeration servicing technicians who were involved in servicing of RAC equipments based on CFCs and non-ODS alternatives. It also covered training for mobile air-conditioning (MAC), RAC equipments using open-type compressor (OTC) and specifically targeted the Railways as a key institutional user of CFC refrigerants. The project adopted a multi-pronged approach to achieve its targets. In addition to training and equipment support, awareness creation among the stakeholders and capacity building of customs officers on illegal ODS trade were included.

Information dissemination and creating awareness regarding CFC phase-out in India is of utmost importance to ensure the project's success. Various methods were employed to create awareness, viz., video film, posters, newsletter, flyers, dealer workshops, equipment support workshops, articles in newspapers and a dedicated website.

NCCoPP funded by the MLF for implementation of the Montreal Protocol, took over from the Indo-Swiss-German Project "Ecological Refrigeration (ECOFRIG)" and Indo-Swiss Project "Human and Institutional Development in Ecological Refrigeration (HIDECOR)". ECOFRIG began within the framework of Indo-Swiss-German Cooperation in 1992 with an objective to evaluate the hydrocarbon technology in RAC appliances for replacing CFCs. Both ECOFRIG and HIDECOR established a training setup including well- developed excellent training modules and a pool of trained trainers throughout the country. The HIDECOR's activities, initiated in 1998, were geographically restricted to selected states and the target group was limited to micro, small and medium size servicing enterprises in the RAC sector. The NCCoPP established training infrastructure including training cells in 15 states of India. It aimed to encourage good servicing practices among all RAC servicing enterprises, with a special focus on firms consuming more than 50 kg of CFCs per annum. A total of 955 recovery, recycling units were provided to the enterprises in four stages. Equipment support to 120 Industrial Training Institutes (ITI) was also provided.

Awareness generation workshops were conducted for servicing enterprises, so that most of the enterprises across the country could participate in the project and get the advantage of assistance provided under the Montreal Protocol to phase- out CFCs in the Servicing sector.

As stated earlier, the focus of NCCoPP activities was on training RAC servicing technicians. During training, the participants/ technicians were taught how to handle the alternative refrigerants, good servicing practices and emphasis was laid on recovery, recycling, reclamation and reuse of CFCs. Therefore, the training programs helped in creating a demand for recovered and reclaimed refrigerants. Over 20,000 technicians were trained under NCCoPP and its forerunner projects, ECOFRIG and HIDECOR. The requirement of CFCs was substantially decreased because of training on good service practices. The remaining requirement for servicing was addressed through reclamation and reuse of CFCs. A number of reclamation centres have been established at various locations in the country, viz., Bangalore, Chandigarh, Hyderabad, Ahmedabad, Jaipur, Kolkata, and Lucknow. The reclamation units have also been provided to the Indian Railways and defence forces.

The NCCoPP has been successfully implemented as per the schedule and achieved its objective of complete phase-out of CFCs.

Strategy for Solvent Sector to Phase-out ODS in MSMEs in India

The Ex-Com of the MLF in its 35th meeting held in December 2001, approved a project to prepare "Overall Strategy for the Solvent Sector to support the phase out of ODS in MSMEs in India" at a total cost of US$ 169,500 implemented by UNEP in consultation with the World Bank and UNIDO. This project was to assist India in developing an overall strategy for the solvent sector which would cover both non-investment and investment activities to support the phase-out of ODS in the solvent sector in India and assist India in meeting its 2005, 2007 and 2010 commitments for the solvent sector. The aim of the project, at the operational level, was to develop approaches for assisting MSMEs which use solvents in India through training, Solvent Alternative Technology Service (SATS), information dissemination and investment and non-investment activities.

The project was completed successfully by UNEP and submitted the report to the Ozone Cell and the World Bank. The outcomes of the strategy document were incorporated in the preparation of the National CTC Phase-out Plan prepared by the World Bank.

National CTC Phase out Plan

The Ex-Com of the MLF at its 40th meeting held in July 2003, approved the National CTC Phase out Plan at a total funding level of US$ 52 million to phase-out 11,553 ODP tonne of CTC production and 11,505 ODP tonne of CTC consumption. This included US$ 10 million under the bilateral assistance program with the Governments of Germany, France and Japan contributing US$ 2 million, US$ 3 million and US$ 5 million respectively.

Out of the total amount, US$ 28.5 million was allocated for CTC production phase-out, US$ 21.5 million for CTC consumption phase-out and US$ 2 million allocated for the TA component. The World Bank was the lead implementing agency, the governments of Germany, France and Japan (bilateral agencies) and UNIDO were cooperating agencies for implementation of the National CTC consumption phase-out activities. Besides, UNDP, on behalf of the Government of Japan, was responsible for executing conversion activities from CTC to non-ODS technologies in large and medium enterprises in metal cleaning sub-sectors.

Production Sector: The CTC producing enterprises, M/s. SRF Ltd., New Delhi, M/s. Chemplast Sanmar Ltd., Chennai, M/s. Gujarat Alkalies and Chemicals Ltd., Vadodara signed the performance agreement and submitted an Indemnity bond for meeting the production phase-out targets. M/s. Shriram Rayons Ltd., Rajasthan and M/s. National Rayon Corporation (NRC) Ltd., Mumbai have already closed down their production facilities. The production of CTC in the country was successfully phased out as of 1 January 2010, except co- production of CTC during the production of chloromethane. The co- produced CTC is being used only for feedstock applications.

Consumption Sector: CTC was used as feedstock primarily in the production of CFCs and DV Acid chloride. It was also used in India as a process agent and a solvent. For process agents, CTC was used in sectors such as chlorinated rubber, chlorinated paraffin, pharmaceutical, and agro- industries. It was used as a solvent in the textile, garment industries, metal cleaning etc.

In 2006, a total of 103 CTC projects, covering both process agent and solvent applications were identified and the phase out of CTC in these applications was taken up by the implementing agencies. The CTC consumption phase-out projects were successfully implemented and resulted in phase out of 2,080 ODP tonne of CTC. The consumption of CTC was phased out completely in the country since 1st January 2010, for controlled applications as per the Montreal Protocol schedule.

Technical assistance was provided to replace CTC used in stain removal work for small garment manufacturers and metal cleaning. The fast reduction in the supply of CTC increased price of the CTC significantly in the country and that motivated the MSMEs to move away from CTC. Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ) carried out extensive work in testing of alternatives that meet health, safety and environmental standards. A countrywide survey was carried out to identify MSMEs using CTC in the metal cleaning sub-sector. The survey identified 51 eligible MSMEs which were using CTC in metal cleaning. These enterprises were provided funding towards incremental capital and operating costs for phasing out of CTC in metal cleaning sub-sector. The achievement of CTC phase-out in two widely dispersed industry sectors, namely, garment manufacturing and metal cleaning has also been realized through awareness programmes and policy measures, especially those which influenced the availability and pricing of CTC and its alternatives.

The production and consumption of CTC completely phased-out for controlled applications as of 1 January 2010. Subsequently, the Ozone Cell, MoEF&CC carried out technical assistance activities, including awareness for sustaining the phase-out of CTC in different applications, except in feedstock use.

CFC phase-out in Aerosol Sector

Aerosols are widely used in several applications involving propellants, including perfumes, shaving foams, insecticides, pharmaceuticals, paints and inhalers. Both CFC-11 and CFC-12 were commonly used as propellants in this sector. By the end of 2002, a total of 26 investment and technical assistance projects were completed with a total funding of US$ 6.5 million, leading to a total phase- out of 637 ODP tonne of CFCs in the Industrial Aerosol Sector. The Ex-Com of the MLF in its 38th meeting held in November 2002, approved a terminal umbrella project in this sector with a funding of US$ 0.58 million to phase-out remaining CFC consumption of about 52 ODP tonne in this sector. The consumption of CFCs in the Aerosol sector had been completely phased-out as early as December 2003.

Industry Structure: The total production of aerosol containers in 1991 was estimated to be 45 million, of which over 90% used CFCs as propellants. About 200 aerosol manufacturers were identified, concentrating mainly in the western and northern parts of India. All enterprises were in the private-sector. A significant majority of these enterprises (about 70%) were MSMEs, many of which were in the informal sector, principally, manufacturing personal care products such as perfume and deodorant sprays.

ODS Consumption in Aerosol Sector: In 1991, the Aerosol sector consumed 1,100 MT of CFCs (about 40% CFC-11 and 60% CFC-12), which amounted to about 22% of India's total CFC consumption at that time. It was estimated that the demand for aerosol products would grow at 20% annually until 2000, 18% annually until 2005 and 15% annually until 2010. These estimates were based on considerations such as emerging customer base for personal care products, entry of multinational corporations in India leading to expansion of the manufacturing base in this sector, reduction in taxes on cosmetic aerosols, etc.

Technology: Hydrocarbon-based aerosol propellants were identified in most of the aerosol sub-sectors as the preferred substitute technology for phasing out CFCs, specifically, butane, destenched liquefied petroleum gas (LPG), etc.

The MSMEs predominantly used locally developed manual propellant filling machines, which were suitable for CFC propellants, but considered unsafe and unsuitable for hydrocarbon-based substitute propellants. Moreover, many of the MSMEs had manufacturing facilities in locations which could be considered unsafe for handling hydrocarbon-based propellants. Thus, safety measures for handling hydrocarbons, including safety training and audits were identified as important inputs, in addition to investments needed for conversions.

The consumption of CFCs in the Aerosol sector was completely phased out as early as December 2003, except use of pharmaceutical grade CFCs in manufacturing medical aerosols, MDIs for asthma and COPD patients.

National Strategy for Transition to non-CFC MDIs and Plan for Phase-out of CFCs in Manufacturing of Pharmaceutical MDIs

The "National Strategy for Transition to Non-CFC MDIs and Plan for Phase-out of CFCs in manufacturing of Pharmaceutical MDIs" was approved by the Ex-Com of the MLF in its 56th meeting held in November 2008, with a total funding of US$ 10.2 million to phase-out 704.03 ODP tonne of CFCs. This project articulated India's national strategy for transition to non-CFC MDIs gradually without affecting the asthma and COPD patients and the elimination of CFC consumption in manufacturing of MDIs in India.

The National Strategy for phase-out of CFCs in

MDIs had been implemented successfully by UNDP as lead implementing agency in association with Government of Italy (bilateral agency) and UNEP, in close cooperation with the MDI manufacturers under the guidance of Ozone Cell, MoEF&CC.

National Awareness Workshops were organized for the stakeholders, especially the MDI manufacturers and physicians treating asthma and COPD patients. A workshop on “Phase-out of CFCs in MDIs Transition Strategy Implementation and Adoption of CFC free Alternatives in India” was held on 5 October 2009, at the All India Institute of Medical Sciences (AIIMS), New Delhi in collaboration with Ministry of Health and Family Welfare (MoHFW) and UNEP. Another National Consultative Workshop on Policy and Regulations was organized on 20 May 2010, at Central Drugs Standard Control Organization, MoHFW, New Delhi. A regional awareness workshop on phase- out of CFCs in manufacturing of MDIs was organised on 1 October 2010, at Pune. These workshops were well attended by the stakeholders, including medical representatives. The medical representatives are the key stakeholders to create awareness among physicians across the country. During the workshops the MDI manufacturers shared that a number of CFC-free MDIs have been developed and placed in the market.

The pharmaceutical grade CFCs were needed during transition phase in 2010 and beyond by the MDI manufacturing industry. The same were obtained through the Essential Use Nomination (EUN) process of the Montreal Protocol for 2010. India submitted the EUN for 2010 for 350.6 MT of pharmaceutical grade CFCs and the 21st MOP held in November 2009 approved 343.6 MT of CFCs for India for 2010. India had also submitted the EUN for the year 2011 for 192.3 MT, but the same was withdrawn in consultation with MDI manufacturers as the progress made by MDI manufacturers was commendable and the MDI manufacturers decided not to seek any CFCs for manufacturing of MDIs for 2011 and beyond. The MDI manufacturers have converted all CFC-based MDI formulations to CFC- free and placed in the market. Currently, all the formulations of MDIs available in the market are CFC-free since 2011.

The 22nd MOP held in November 2010 congratulated India for its outstanding achievement in early phase-out of the use of pharmaceutical grade CFCs in manufacturing of MDIs.

The UNDP, as lead implementing agency, carried out an independent verification through a MDI International Expert in November 2012 for all the four MDI manufacturing facilities to verify the phase-out of use of CFCs in manufacturing of MDIs. The verification confirmed that conversion from CFC based MDIs to CFC-free MDIs has already been achieved in India.

A verification-cum-review of progress made by each of the manufacturers was undertaken by the MLF through an independent expert along with UNDP to ascertain the implementation of CFC phase-out in the manufacturing of MDIs in February 2014. It was reported that CFCs have been phased-out in manufacturing of MDIs in the country.

Accelerated Phase-out of HCFCs

The control schedule of the Montreal Protocol for Article 5 Parties for phase-out of HCFCs prior to the 19th MOP was as follows:

Consumption

- Base level: 2015
- Freeze: 1 January 2016
- 100% reduction: 1 January 2040

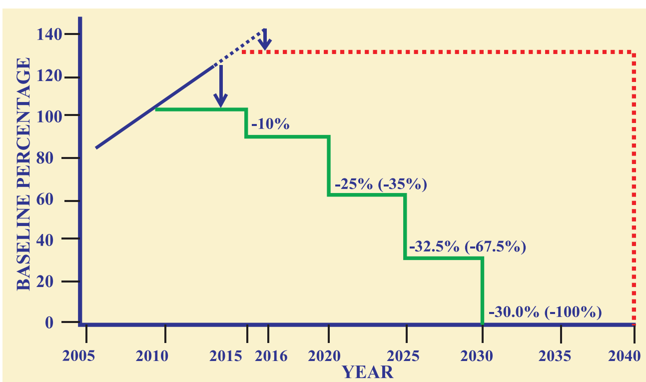
Production

- Base level: Average of production and consumption in 2015
- Freeze: 1 January 2016, at the base level for production
- 100% reduction: 1 January 2040.

The 19th MOP held in September 2007, took a decision to accelerate the phase-out of production and consumption of HCFCs for developed and developing countries. The new phase-out schedule for Article 5 Parties (developing countries) as per the decision ofthe 19th MOP is as follows:

- Base level: average of 2009 and 2010
- Freeze: 1January 2013
- 10% reduction: 1 January 2015
- 35% reduction: 1 January 2020
- 67.5% reduction: 1January 2025
- 100% reduction: 1 January 2030 with a service tail of 2.5% annual average during the period 2030-2040.

The accelerated phase-out schedule of HCFCs for Article 5 parties is also depicted below:-



Allowing for servicing an annual average of 2.5% during the period 2030-2040

The implementation of the accelerated phase out schedule for HCFCs was a challenging task, especially the Stage-I targets, the 2013 freeze and 10% reduction in 2015, in emerging economies like India where there was growth in the use of these chemicals. These chemicals are widely used in various applications including RAC manufacturing, foam manufacturing, RAC servicing and other sectors. There was a lack of availability of technically proven, economically viable and environment friendly technologies. The annual consumption growth of these chemicals has been in the range of 10% to 15%. In actual sense, this amounted to phase-out of 30% to 40% by 2015, which was quite significant reduction in a very short time frame. This necessitated a long- term vision and planning to successfully meet the obligations of the accelerated phase-out schedule of HCFCs.

India's HPMP

Considering the future activities relating to phase-out of HCFC production and consumption in India to meet the compliance target as per the accelerated phase-out schedule, the UNDP was designated as the Lead Implementing Agency for HCFC phase-out in consumption sector and UNEP, and GIZ as cooperating agencies of the governments of Germany and France etc.

HPMP Stage-I

The 56th meeting of the Ex-Com of the MLF held in November 2008 approved the preparation of HPMP Stage-I for India. Soon thereafter, detailed stakeholder consultative meetings including sectoral working group meetings for the foam manufacturing, RAC Manufacturing and RAC servicing sectors were held. Based on the outcome of these meetings, a "Roadmap for phase-out of HCFCs in India" describing the long-term vision and action plan including the policy instruments for phasing out of production and consumption of HCFCs in India was developed and launched in October 2009.

The HPMP Stage-1 for India was approved at the 66th meeting of the Ex-Com of the MLF held in April 2012 for achieving a total phase-out of 341.77 ozone depleting potential (ODP) tonnes from the starting point of 1,691.25 ODP tonne. The implementation of the Stage I was completed by 31 December 2017. The highlights of the achievements HPMP Stage-I include:

- **Polyurethane Foam manufacturing sector:** 15 large-sized enterprises in the Foam Manufacturing sector were assisted to phase- out their use of HCFC-141b. In addition, 15 system houses were also assisted in developing HCFC- free polyol formulations with low GWP blowing agents. These activities were implemented by UNDP in close cooperation with the Ozone Cell, MoEFCC.

- **Servicing Sector:** Under this sector training on good servicing practices was imparted to 11,276 technicians and 50 trainers on room air conditioners up to 2 tons capacity. Training programs were also organised for institutional users like Defence and Indian railways, that have substantial inventory of HCFC-based equipment/ appliances. The Servicing sector activities were implemented by GIZ in close cooperation with the Ozone Cell, MoEFCC.

- **Enabling Activities:** In collaboration with the NACIN, training materials were developed, 93 trainers were trained, 320 supervisory officers of Customs were trained, Refrigerant identifiers were procured and supplied to the customs ports border check points, RAC Service sector training videos were developed in five regional languages, Newsletter and videos on RAC servicing best practice were developed and distributed and Refrigeration and Air conditioning Service Sector Society (RASSS) was supported.

  The enabling activities were implemented by UNEP in close cooperation with the Ozone Cell, MoEFCC. Through its HPMP Stage I, India successfully met the 2013 target of freeze of HCFC Production and Consumption and 10% phase-out targets of HCFCs in 2015, resulting in an environmental benefit of net direct emission reductions of 3,071,260.5 t. CO2-eq.

HPMP Stage-II

Stage II of HPMP for India was approved at the 77th meeting of the ExCom of the Multilateral Fund for Implementation of the Montreal Protocol (MLF), for the period 2016 to 2024, to reduce HCFC consumption by 60% of the baseline of 1,608.20 ODP tonne. For HPMP Stage-II, the implementing agencies remained the same as for HPMP Stage-I. The UNDP is the lead implementing agency as also the agency for technology conversion from HCFC to non-HCFC and low GWP technologies in the foam and room air-conditioning manufacturing sectors. The GIZ is the implementing agency for servicing sector activities and UNEP for the enabling activities. All the three agencies implemented the respective activities in close cooperation with Ozone Cell, MoEFCC. The highlights of the achievements of HPMP Stage-II include the following:

- **Polyurethane Foam Manufacturing sector:** Consistent with the Ex-Com guidelines and the ODS (Regulation and Control), 2000 Amendment Rules 2014 of India, the Polyurethane foam sector was prioritized for phase-out actions for complete phase out of HCFC-141b by 1 January 2020. The blowing agents cyclopentane (C5), hydrofluoroolefins (HFO) and methyl formate (Ecomate) were selected for the conversions in the Foam Manufacturing sector. A total of 158 enterprises were assisted to phase-out for 2,630.11 mt of HCFC-141b. All companies were subject to on-site verification upon achieving the completion of conversion activities. In addition, a technical institute, Centre for Petrochemicals Engineering and Technology (CIPET) Government of India, having expertise in PU foam technologies was on-boarded to provide hand- holding technical support to the participating foam manufacturing enterprises under HPMP Stage-II. The technical institute, CIPET along with Ozone Cell, MoEF&CC provided technical support to enterprises under a competency enhancement framework.

- **Air Conditioning Manufacturing Sector:** In this sector, India phased-out 1,140 MT of HCFC-22 consumption in six (6) air-conditioning manufacturing enterprises that volunteered to participate in the HPMP Stage-II activities. The participating enterprises completed their conversions and are supplying HFC-32 based room air conditioners to the local market.

- **Servicing Sector:** 1,250 MT of HCFC-22 was also phased-out through activities in the servicing sector. Training on good servicing practices for 17,000 RAC service technicians was completed. Sixty trainers were trained through Training of Trainers (TOT) Programmes. Two Training of Trainers (TOT) Programs for ITI instructors were conducted. Institutional Training on good servicing practices was organized for officials of Delhi Metro Rail Corporation (DMRC). State-of-the-art RAC facility for training students of RAC trade at the Industrial Training Institutes (ITIs) is being established at 4 ITIs and 8 National Skill training Institutes in collaboration with the Directorate General of Training (DGT), Ministry of Skill Development and Entrepreneurship. Impact assessment technician trainings carried out under HPMP Stage-II was carried out. Knowledge products were developed, printed and widely disseminated, including among the training partners across the country. Syllabus for RAC service trade (ITIs) were updated to include alternative refrigerants including flammable refrigerants and good service practices.

- **Enabling activities:** Under the policy and enforcement component implemented in association with National Academy for Customs, Indirect Taxes and Narcotics (NACIN), 6 Training of Trainers, 12 Capacity building workshops for new customs officers and supervisory officers were organized and 1 Capacity building workshop for border control officials and key enforcement agencies was organized. Border dialogue with neighboring countries on specific Ozone Depleting Substance (ODS) trade related aspects was conducted.

  The following studies were conducted, reports published and widely disseminated to all concerned stakeholders including line ministries/ departments and agencies:

  - Study Report on "Passive & Low Energy Cooling Strategies for Achieving Thermal Comfort in India's Upcoming Affordable Housing."
  - Study report on "Sensitizing building construction community on passive cooling design, non-ODS, low GWP and energy efficient technologies."
  - Study Report on "Sustainable e-commerce cold chain infrastructure."
  - Study report on "Public Procurement Policies for Hiring Trained and Certified Refrigeration and Air-Conditioning Service Technicians."
  - Booklet on "Good Servicing Practices for Energy Efficient Operation of Room Air-Conditioners."
  - Study on "Public Procurement Policies for Refrigeration and Air-Conditioning Equipment using non-ODS based refrigerants."
  - Study on "Cold-Chain Sector in India for promoting Non-ODS and Low-GWP Refrigerants."
  - Assistance for the development of national standards to be framed by Bureau of Indian Standards (BIS) for low-GWP Refrigerants in association with Indian Institute of Technology (IIT), Delhi.
  - Service sector enterprises / technicians in RAC sector in association with M/s NTPC School of Business.
  - Reduction in GHG emissions through ODS phase-out under the Montreal Protocol implementation in India.
  - Guidebook On Sustainable Technologies for Infrastructure Relating to The Cold Chain Sector
  - Guidebook For Selection of Sustainable Refrigeration and Air Conditioning Equipment
  - Passive Cooling Strategies for Sustainable Buildings
  - Developed, published and disseminated awareness material widely, comprising:
    - Booklet on good service practices
    - Documentary & animated videos relating to India Cooling Action Plan including energy efficient cooling, Ozone Layer protection and India's success story in the implementation of the Montreal Protocol

- Newsletter for service technicians
- Posters on good servicing practices

Implementation of HPMP-Stage-II resulted in sustainable reductions of 8,190 MT or 769.49 ODP tonne of HCFC consumption from the starting point of 1,691.25 ODP tonnes by 2023, contributing to India's compliance well in advance with the control targets for HCFCs under the Montreal Protocol. The implementation of Stage-II resulted in net direct CO_2-equivalent emission reductions of about8,530,900 MT CO_2 eq. per year from 2023 onwards.

HPMP Stage-III

The HPMP Stage-III is to be implemented from 2023 to 2030 for the complete phase-out of HCFCs in line with the accelerated phase-out schedule of the Montreal Protocol for HCFCs.

As per the Ozone Depleting Substances (Regulation and Control) Rules, as amended in 2014, manufacture of all equipment or products using HCFCs has phased out on 1.1.2025. Accordingly, the use of HCFCs in all manufacturing sectors stopped by 31.12.2024. The activities in the RAC servicing sector would continue till 2040, as per the accelerated phaseout schedule of the Montreal Protocol.

The preparation of HPMP Stage-III for India was done after extensive stakeholder consultation comprising nodal line ministries/departments Central and State Pollution Control Boards and all the industry stakeholders through 6 awareness workshops conducted at Ahmedabad, Hyderabad, Chandigarh, Mumbai, Kolkata and Delhi to identify and include all eligible enterprises. Physical verification was carried out by M/s Ernst & Young, the third Party appointed by the United Nations Development Programme (UNDP) of all the identified enterprises to establish eligibility as per the guidelines of the Multilateral Fund (MLF). A total of 64 enterprises – (48 in the refrigeration manufacturing sector and 16 in the air- conditioning manufacturing sector) were found eligible for inclusion in the HPMP Stage -III.

In addition, activities relating to non-investment component comprising policy and enforcement capacity building, awareness activities including studies on adoption of non-ODS and low GWP alternatives were developed along with UNEP and servicing sector activities were developed in association with GIZ as part of the HPMP Stage- III.

The HPMP Stage-III was finalized after presenting the draft in a national stakeholder workshop and to the overseeing committee headed by Economic Adviser, MoEF&CC and comprising representatives from DPIIT, DCPC, MSME, DST and MSDE.

The HPMP Stage-III was approved at the 91st meeting of the Ex-Com of the MLF held during December 2022 with UNDP as lead implementing agency and agency responsible for technology conversion activities in the refrigeration and air-conditioning manufacturing sectors, UNEP as implementing agency for enabling activities and GIZ as implementing agency for the servicing sector activities.

Implementation of HPMP Stage-III will result in complete phase-out of HCFCs in line with the accelerated phase out schedule of the Montreal Protocol with sustainable reductions of 10,678.87 MT or 579.99 ODP tonne of HCFCs consumption from the starting point, contributing to India's compliance with the 2025 and 2030 control targets for HCFCs under the Montreal Protocol. In addition, the project will result in net direct CO_2 - equivalent emission reductions of about 19,239,929 tonnes CO_2 -eq. from 2030 onwards.

The HPMP Stage-III was apprised by the Department of Economic Affairs (DEA), Ministry of Finance, Government of India, in its Local Project Advisory Committee (L-PAC) meeting held on 22nd June 2023, after which approval was accorded for implementation.

The HPMP Stage-III is currently under implementation and comprises the following:

i) Investment component comprising technology conversion from HCFC to non-HCFC and low GWP technologies by 64 participating enterprises – (48 in the refrigeration manufacturing sector and 16 in the air- conditioning manufacturing sector). UNDP is the implementing agency for the investment component.

- To date, 49 enterprises have successfully completed their technology conversion, comprising 12 air-conditioning manufacturing enterprises and 37 refrigeration manufacturing enterprises. The completed conversions have been physically verified on-site by an independent third party appointed by UNDP, demonstrating significant progress in the transition towards low-GWP technologies in India's RAC manufacturing sector.

- Ozone Cell, MoEF&CC, onboarded CSIR-Central Mechanical Engineering Research Institute (CSIR-CMERI), Durgapur, under HPMP Stage-III to hand-hold participating MSMEs in the Refrigeration and Air-conditioning (RAC) manufacturing sector in accessing specialized equipment for transition towards non-HCFC and low-GWP technologies. To support this objective, a Technical Assistance Facility (TAF) is being established at CSIR-CMERI to provide participating enterprises with access to the required technical resources and facilities.

ii) Enabling Activities under HPMP stage-III comprising of policy and enforcement capacity building, studies on adoption of non-HCFC and low GWP alternatives including promoting energy efficiency, etc., and awareness generation is being implemented through UNEP. The following activities have been implemented as part of the enabling activities

- Capacity Building of Central and State Pollution Control Board (CPCB) officials: A training manual for pollution control board officials with respect to implementation of Montreal Protocol was developed and disseminated. Subsequently training workshops for CPCB and SPCB officials were conducted in states/UTs for developing their capacities on implementation of Montreal Protocol provisions.

- Customs capacity building activities: In collaboration with National Academy of Customs, Indirect Taxes & Narcotics (NACIN), 12 capacity building programs for new customs and enforcement officials, supervisory officers and trainers have been conducted.

Following four studies were completed:

- Techno-economic feasibility Study of District Cooling System (DCS) in India. The study evaluates the potential for District Cooling Systems (DCS) across Indian cities supporting its adoption as a sustainable and energy-efficient cooling solution in building sector.

- Study on Low-GWP alternative Technologies for Chillers in Large Air Conditioning Building.

- Study on best Practices for Installation and Maintenance of Ammonia/Low-GWP Alternative Technology in Cold Chain Infrastructure to promote safe and efficient installation and maintenance of low-GWP technology systems within India's cold chain infrastructure.

- Study on Low-GWP alternative technologies in the Transport Refrigeration Sector.

Following five studies are being undertaken:

- Study on promoting sustainable cooling in IT Data Centre.

- Study on Refrigeration Use and Cooling Operations in India's Convenience Stores.

- Study on Not-in-Kind (NIK)/ Indigenous Cooling Technologies in Refrigeration and Air-conditioning (RAC) Sector.

- Study on Promoting Participation of Women in the Refrigeration and Air Conditioning (RAC) Sector.

- Study on Local Cooling and Heating Practices in Rural India

Outreach and awareness:

Quarterly newsletters, educational videos, and nationwide awareness campaigns including school programs, targeted activity for gender mainstreaming, stakeholder workshops, and HCFC phase-out campaigns are being carried out.

iii) Servicing Sector activities comprises of training and certification of Refrigeration and Air Conditioning (RAC) service technicians, tools and training equipment support to Industrial Training Institutes (ITIs), and trained and certified service technicians.

Certification system for RAC service technicians has been approved by the National Council for Vocational Education and Training (NCVET) under the National Skill Qualification Framework (NSQF) of the Ministry of Skill Development and Entrepreneurship (MSDE) and is being implemented as part of the servicing sector component of the HPMP Stage-III.

GIZ, as implementing agency, has engaged 8 training partners for implementing training and certification activities for the RAC service technicians. The training curriculum is in line with the qualification pack approved by the NCVET and will include certification of the trained technicians. The Electronics Sector Skill Council of India (ESCCI), as awarding body registered with the NCVET, is conducting the assessment process for certification. Training and certification activities have been initiated for 25,000 RAC (Refrigeration and Air Conditioning) service technicians, with the target of completing the initiative by 2030.

In addition to the training activities carried out by GIZ, other agencies which conduct RAC training comprising AC manufacturers and other professional bodies/associates can also participate in the unified certification process of the NCVET. This will enable development of a pool of trained and certified RAC service technicians in the country.

Equipment support to Industrial Training Institutes (ITIs): Towards strengthening of training infrastructure in the ITIs, as part of the servicing sector activities under the HPMP Stage-III, equipment support has been provided to 119 ITIs across the country, as per the list finalized by the Directorate General of Training (DGT), Ministry of Skill Development and Entrepreneurship, considering regional and geographical balance. The training equipment supplied to the ITIs comprise: (i) Basic refrigeration and electrical cycle unit (Frost-free Refrigerator), (ii) Split A C Training Unit (compatible to Inverter technology) Capacity: 1.5 Ton, (iii) Commercial Refrigeration Training Unit, (iv) Industrial Refrigeration Unit for Rack Systems, and (v) Split AC Training Unit Metal Frame. A Committee comprising representatives from DGT, MSDE, UNDP, GIZ and Ozone Cell finalized the specifications for each of the equipment. UNDP, as implementing agency for this activity, was responsible for procurement of the equipment including supply installation and commissioning, training and handover of the above-mentioned 5 types of equipment to 119 ITIs. The implementation of RAC training equipment support to ITIs has been successfully completed. The training equipment has been integrated into RAC training curriculum and is being utilized for hands-on training of students and beneficiary ITIs.

Fiscal Measures

The Government of India has granted exemption from payment of Customs and Excise duties on capital goods required for ODS phase out projects funded by the MLF since 1995. In 1996, the Government of India further extended the benefit of Customs and Excise duty exemptions for ODS phase-out projects which were not funded by the MLF. The benefit is available subject to the condition that enterprise gives clear commitment for stop using the ODSs in all future manufacturing operations after the completion of implementation of project(s).

The benefit of duty exemption has been extended for new capacity as well as expansion of capacity with non-ODS technologies since 1997.

The Indian financial institutions have decided not to finance/re-finance new ODS producing/ consuming enterprises to discourage the use of ODSs in various applications.

The Tariff Advisory Committee (TAC), a statutory body under the Insurance Act, 1938 has decided to grant suitable discounts on fire insurance premiums if alternative fire extinguishing agents are used in place of halons in fire extinguishing systems.

Ozone Depleting Substances (Regulation and Control) Rules, 2000

In accordance with the National Strategy for ODS phase-out, the MoEF&CC, Government of India, has notified ODS (Regulation & Control) Rules, 2000 in the Gazette of India on 19 July 2000, covering various aspects, viz., production, consumption, export and import of ODSs. These rules have been subsequently amended from time to time. Most recent amendment being in 2019.

Important provisions of the ODS (Regulation and Control) Rules, 2000

These Rules prohibited the use of CFCs in manufacturing various products beyond 1 January 2003 except in MDIs and for other medical purposes. Similarly, use of halons was prohibited after 1 January 2001 except for servicing. Other ODS such as CTC and methyl chloroform and CFC for MDIs were allowed to be used upto 1January 2010. Further, the use of methyl bromide has been allowed upto 1January 2015. Since HCFCs are low- ODP substances and are also used as interim substitutes to replace CFCs, these are allowed to be used upto 1 January 2030 as per the Montreal Protocol accelerated phase-out schedule.

As per these Rules, there is a need for compulsory registration of ODS producers, manufacturers of ODS-based products, importers, exporters, stockists and sellers and the same provision is applicable to manufacturers, importers and exporters of compressors and other products containing ODS. They are also required to maintain records and file periodic reports for monitoring production and consumption of ODS.

Enterprises which have received financial assistance from MLF for the implementation of the Montreal Protocol for switch over to non-ODS technology have to register the date of completion of their project(s) and declare that the equipments used for ODS have been destroyed. Creation of new capacity or expansion of capacity of manufacturing facilities of ODS and ODS-based equipment have been prohibited. Purchasers of ODS for manufacturing products containing ODS, are required to declare the purpose for which ODS are purchased.

All imports and exports of ODS and products containing ODS require a license.

The recommendation of the MoEF&CC is essential before issuing any license for import and export of ODS and products containing ODS by the DGFT, Ministry of Commerce and Industry.

These rules also specify phase-out dates for different ODS in manufacturing of products using these ODS. In addition, these Rules also ban trade in ODS with non-Parties.

Amendments

The ODS (Regulation & Control) Rules, 2004, 2005, 2007, 2014 and 2019.

The 2001 Amendment extended the last date of registrations from one year to two years after the commencement of the Rules. The Amendment 2003 refers to a correction of a typographic error. The amendment 2004 specified the date of registration for substances listed in Group IV of Schedule I (CTC) and for substances listed in Group VI of Schedule I (HCFCs) on or before 31 December 2004 and on or before 19July 2007 respectively. Subsequently, the Rules were amended in 2005, the registration date for substances listed in Group IV of Schedule I (CTC) was extended upto 31st December 2005. The Rules were further amended on 18th September 2007. As per the amended rules, registration has been extended for substances listed under Group I, Group II, Group III and Group IV upto 31st December 2009, in case of substances in Group VI upto 31st December 2039 and in case of substances in Group VIII upto 31st December 2014 and the existing registered enterprises need not apply for renewal.

The draft of amendment of ODS (Regulation and Control) Rules was published in the Gazette of India in May 2013 for inviting comments/suggestions from the public on the draft Rules. Subsequently, the ODS (Regulation and Control) Amendment Rules, 2014 were published on 4 April 2014 in the Gazette of India. The salient features of the ODSs (Regulation and Control) Amendment Rules, 2014 are:

- The production and consumption of Group VI substances (HCFCs) has been proposed to be controlled according to the accelerated phase-out.
- Introduction of quota system by the Government for production and consumption of Group VI substances (HCFCs) for non-feedstock applications and monitoring and reporting system for all feedstock applications including use of CTC in order to comply with phase-out targets of the production and consumption of Group VI substances (HCFCs).
- Prohibition of issuance of license for import and export for Group I, Group II, Group III, Group IV and blends containing ODS including Group VI substances except recovered, recycled and reclaimed ODS or for EUN, if any or ODS for destruction or for feedstock applications.
- Prohibition of issuance of license for import of pre-blended polyols containing Group VI substances (HCFCs).
- Ban on creating new capacities to manufacture products made with or containing Group VI substances (HCFCs).
- In order to control the inventory of HCFC based refrigeration and air-conditioning equipments and reduce the consumption of HCFCs in servicing of these equipments in future years, import of air- conditioning and refrigeration equipments and other products using HCFCs from 1 July 2015 has been prohibited.
- Exemption for production of Group VI substances (HCFCs) for the Protocol approved feedstock uses in manufacturing of other chemicals, with negligible emissions, if any.

The 2019 amendment of the ODS (Regulation and Control) Rules, 2000, was published in the Gazette of India on 31 December 2019, inter alia prohibiting the issuance of import license for HCFC-141b from 1 January 2020.

Kigali Amendment to the Montreal Protocol

The Kigali Amendment to the Montreal Protocol was decided by the Parties to the Montreal Protocol at its 28th meeting held in October 2016 at Kigali, Rwanda for phase down of hydrofluorocarbons (HFCs), which were introduced as a non-ozone depleting alternative to support the timely phase- out of ODS, CFCs, HCFCs, etc. The HFCs are now widely used substances globally in various applications like air-conditioners, refrigerators, aerosols, foams and several other products and industrial processes. While HFCs do not deplete the stratospheric ozone layer, they have high global warming potential ranging from 12 to 14,800.

As per the agreed phase-down of HFCs under the Kigali Amendment, India will have to complete its phase down the production and consumption of HFCs in four steps from 2032 onwards with reduction of 10% from the baseline of production and consumption in 2032, 20% in 2037, 30% in 2042 and 85% in 2047 respectively. The baseline constitutes the average of production and consumption of HFCs for the period 2024-2026 and the freeze applicable for India is 2028. The details of the elements of the agreed HFC phase- down schedule for both developing and developed countries is as follows:

Details of the elements of the agreed HFC phase-down schedule are provided in table below:

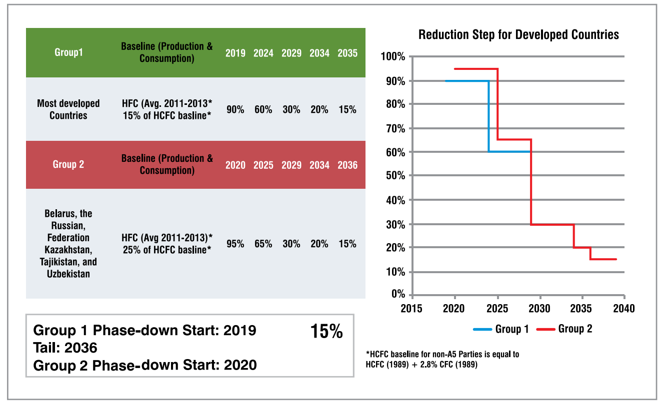
	A5 parties (developing countries) - Group 1	A5 parties (developing countries) - Group 2	Non-A5 parties (developed countries)
Baseline formula	Average HFC consumption for 2020-2022 + 65% of hydrochloro-fluorocar-bon (HCFC) baseline	Average HFC consumption for 2024-2026 + 65% of HCFC baseline	Average HFC consumption for 2011-2013 + 15% of HCFC baseline*
Freeze	2024	2028	-
1st step	2029 (10%)	2032 (10%)	2019 (10%)
2nd step	2035 (30%)	2037 (20%)	2024 (40%)
3rd step	2040 (50%)	2042 (30%)	2029 (70%)
4th step	-	-	2034 (80%)
Plateau	2045 (80%)	2047 (85%)	2036 (85%)

**For Belarus, Russian Federation, Kazakhstan, Tajikistan, Uzbekistan, 25% HCFC component of baseline and different initial two steps (1) % reduction in 2020 and (2) 35% reduction in 2025*

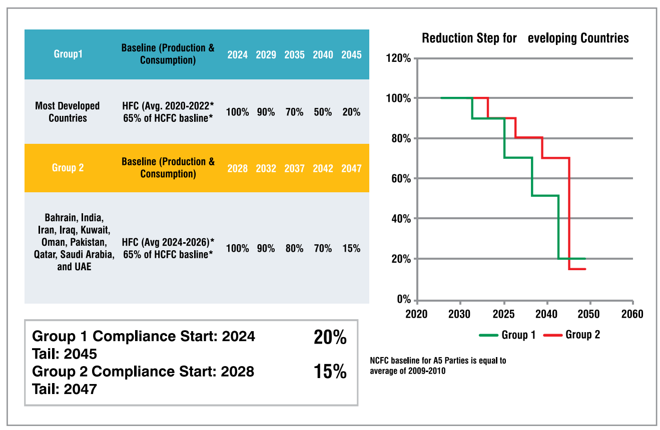
Notes

1. Group 1: Article 5 parties not part of Group 2
2. Group 2: Bahrain, India, the Islamic Republic of Iran, Iraq, Kuwait, Oman, Pakistan, Qatar, Saudi Arabia and the United Arab Emirates
3. Technology review in 2022 and every five years.
4. Technology review four to five years before 2028 to consider the compliance deferral of two years from the freeze of 2028 of Article 5 Group 2 to address growth in relevant sectors above certain threshold.

HFC Phase-down Schedule for Developed Countries



HFC Phase-down Schedule for Developing Countries



In September 2021, the Government of India ratified the Kigali Amendment after approval by the Union Cabinet. It was also decided that a National Strategy for the implementation of phase-down of HFCs, in consultation of Industry and other stakeholders, would be developed by 2023.

The Kigali Amendment came into force for India on 26 December 2021, the date on which the instrument of ratification was deposited with the UN Secretary General. In accordance with the Montreal Protocol provisions, the framework for licensing system and reporting obligations has been put in place after the first national stakeholder consultation held on 20 January 2022. The DGFT, Ministry of Commerce and Industry, the nodal agency for licensing for import/export of HFCs is implementing the licensing system for HFCs, based on the recommendations of the Ozone Cell, MoEFCC. Data reporting for HFCs commenced from 2022 along with other ODS as per provisions of Article 7 of the Montreal Protocol.

The following are the sectors and sub-sectors where HFCs are used:

i) Air-conditioning Manufacturing including room AC, light commercial, VRF systems and chillers;

ii) Refrigeration Manufacturing including commercial refrigeration (cooling cabinets, freezers including vaccine coolers and freezers, water coolers, cold rooms, fishing vessels);

iii) Process chillers (including food processing equipment);

iv) Mobile Airconditioning including buses, trains, etc.;

v) Foam Manufacturing;

vi) Firefighting manufacturing;

vii) Industrial Aerosols including cosmetics;

(viii) Meter Dose Inhalers.

The development of the national strategy for HFC phase-down comprises the following:

i) Outreach and awareness raising;

ii) Development of a National Strategy including policy framework for the implementation of the Kigali Amendment;

iii) Establishing a framework for implementing licensing, quota system, and reporting obligations related to HFCs.

Of the above three activities, activity (i) and (ii), i.e., outreach and awareness and development of National strategy including policy framework for implementation of the Kigali Amendment are going on in parallel. The third activity, namely establishing a legislative framework including quota system and amendment to the Ozone Depleting Substances (Regulation and Control) Rules to align with phase-down of HFCs can be commenced once the draft strategy for HFC phase- down is ready.

As part of the awareness and outreach component, 34 workshops comprising 18 workshops through physical mode and 16 workshops through virtual mode are being conducted across the country. These workshops are being organised in close cooperation with the concerned line ministries and departments comprising DPIIT, DCPC, MSDE, MSME, Ministry of Power including BEE and EESL, DST, CSIR, DRDO, CPCB, State Pollution Control Boards and the concerned industry associations concerned with the Montreal Protocol implementation. Till date, 23 awareness-cum- sensitization workshops have been completed. Sectoral HFC data is also being collected through these workshops. The details of the workshops conducted are as follows:

Place	Date
Delhi	22-Nov-2022
Ludhiana	1-Dec-2022
Chennai	15-Dec-2022
Guwahati	24-Dec-2022
Chandigarh	7-Jan-2023
Delhi	13-Jan-2023
Hyderabad	17-Jan-2023
Bengaluru	23-Jan-2023
Kolkata	27-Jan-2023
Lucknow	31-Jan-2023
Kochi	3-Feb-2023
Pune	7-Feb-2023
Vizag	18-Feb-2023
Indore	21-Feb-2023
Mumbai	24-Feb-2023
Ahmedabad	3-Apr-2023
Vadodara	4-Jun-2023

Details of Virtual workshops

Date
13-Dec-2022
10-Jan-2023
10-Feb-2023
10-Mar-2023
20-Mar-2023
12-Apr-2023

The development of strategy and policy framework comprises prioritizing the sectors and sub-sectors for HFC phase-down. The prioritization will be based on the consumption pattern of HFCs in various sectors and sub-sectors, availability of low GWP alternatives, capacities of the industry to adapt the low GWP alternative technologies considering their availability, technical feasibility, economic viability and safety related issues and keeping in view of the compliance obligations of the country.

The National Strategy for HFC phase down is under finalization.

Other Initiatives

HFC demonstration Projects

The Executive Committee of the Multilateral Fund for in its 87th meeting held from 28th June to 2nd July 2022 vide decision 87/50, approved the guidelines for the preparation of HFC phase-down plans for Article 5 countries. In line with these guidelines and considering the size of Indian market and the multitude of sectors present in the country, submitting projects for demonstrating transition from HFCs to low Global Warming Potential alternative technologies would help better understand the challenges associated in the technology conversion to low GWP alternatives during the HFC phase down under the Kigali Amendment.

The key sectors are refrigeration manufacturing and air-conditioning manufacturing, the two sectors in which currently high GWP HFCs are used and technically proven low GWP alternatives are available. Accordingly, the following project proposals approved submitted were approved by the Executive Committee at its 93rd meeting held from 15th-19th December 2023:

i) Conversion from R-407C and R-410A to HFC-32 in the manufacturing of light commercial air- conditioning packaged and ducted air-conditioning units at Voltas Limited.

   In the commercial air-conditioning sector, Voltas Limited converted its manufacturing line by phasing out 30.29 metric tonnes of R-407C and 4.62 metric tonnes of R-410A, transitioning to HFC-32. Through this demonstration project Voltas has achieved the 9.5% improvement in Energy Efficiency with R-32 refrigerant as compared to R-407C.

ii) Conversion of the manufacturing of commercial refrigeration appliances at Rockwell Industries Limited from HFC-134a to propane (R-290) including Technical Assistance to enhance the energy efficiency of the converted equipment.

   In the commercial refrigeration space, Rockwell Industries converted its two commercial refrigeration equipment manufacturing lines by phasing out 21.91 metric tonnes of HFC-134a and transitioning to natural, ultra-low GWP R-290. By integrating highly efficient components, Rockwell achieved significant energy savings of up to 42% across 15 newly developed R-290 models.

iii) Design and development of a pilot scale energy- efficient rotary compressor along with microchannel heat exchanger compatible with R-290 technology at Godrej & Boyce Mfg. Ltd., for use in manufacturing of room air conditioners. By engineering a pilot-scale, energy-efficient rotary compressor for R-290 air conditioners, Godrej achieved a 40% improvement in compressor performance.

   These projects have been successfully completed.

Other Initiatives

India Cooling Action Plan (ICAP)

India is one of the first countries in the World to have a comprehensive cooling action plan ICAP, that aims to provide an integrated vision towards cooling across sectors encompassing inter alia reducing cooling demand, refrigerant transition, enhancing energy efficiency and better technology options with a 20-year time horizon, i.e. 2037-38. Most importantly synergistic actions with respect to cooling across sectors will have a higher impact than actions taken in isolation. The goals set as per the ICAP are:

i) To reduce cooling demand across sectors by 20% to 25% by 2037-38,

ii) To reduce refrigerant demand by 25% to 30% by 2037-38,

iii) To reduce cooling energy requirements by 25% to 40% by 2037-38,

iv) To recognize "cooling and related areas" as a thrust area of research,

v) To train and certify 100,000 servicing sector technicians, synergizing with Skill India Mission.

The ICAP document is available at: http://ozonecell.nic.in/wp-content/uploads/2019/03/INDIA-COOLING-ACTION-PLAN-e-circulation-version080319.pdf

Towards achieving the above said goals, ICAP has short, medium and long-term recommendations. Six thematic working groups have been constituted, comprising (i) Space Cooling in Buildings, (ii) Cold Chain, (iii) Domestic manufacturing and Production Sector – Alternative Refrigerants and technologies, (iv) Servicing Sector, (v) Transport Air Conditioning (car, bus, train and metro Air conditioning) and (vi) Research and Development, for developing an action plan for operationalizing the recommendations of the ICAP.

There is no separate budget allocation for implementation of the recommendations of the ICAP. However, the ICAP proposes synergies with ongoing government programmes/schemes to maximize socio-economic co-benefits. Accordingly, towards operationalizing the recommendations, each thematic working group maps the recommendations with the on-going government programmes/schemes and list out actions to be undertaken for achieving the said goals including identifying the required policy and regulatory interventions.

The key action points for each of the thematic areas are as follows:

i) Space cooling in buildings

- Wider adoption of the following:
    - o Energy Conservation Building Code (ECBC) of the Bureau of Energy Efficiency (BEE) and ECBC-Residential-Eco Nivas Samhita (ECBC-R-ENS) in various building infrastructure construction schemes of Government.
    - o Advisory issued by BEE to preset minimum temperature of 24°C in all room air conditioners.
    - o Star and labelled programme of BEE for all refrigerators and air conditioners.
    - o Minimum Energy Performance Standards (MEPS) of BEE for refrigerators and room air conditioners.
- Promotion of energy efficient and low GWP refrigerant based air-conditioners. Government E-Market place (GeM) has created a green category of ACs in its protal.
- Implementation of Urban Development Plan Formulation (URDPFI) Guidelines in which 'cooling strategies' have been included.
- Promote passive cooling strategies encompassing natural and mechanical ventilation in building design including not-in-kind technologies comprising radiant cooling, indirect evaporative

cooling, solar vapour absorption machine (VAM), etc.

ii) Cold Chain Sector

- Promote use of non-ODS and low/lower global warming potential (GWP) and energy efficient cooling technologies in the government schemes relating to cold chain sector.
- Promote improved designs, cold chain components and equipment including proper insulation and energy-efficient cooling equipment.
- Cold chain industry to adopt codes/ standards while implementing the cold chain infrastructure projects.
- Implement design and operational guidelines for pack houses.
- Enhance competence of personnel associated with cold chain infrastructure in handling and use of low GWP and energy efficient technologies including flammable and toxic refrigerants.
- Training and certification of technicians associated with cold chain infrastructure in collaboration with Ministry of Skill Development and Entrepreneurship.

iii) Servicing Sector

- Unified Certification and training of service technicians in the refrigeration and air-conditioning (RAC), cold chain and Mobile Air conditioning (MAC) in collaboration with MSDE.
- Develop standardized training courses on emerging low GWP technologies.
- GeM to promote engagement of trained and certified service technicians amongst government departments and agencies.
- Incorporate safety standards for handling flammable and toxic refrigerants and social security schemes in the training curricula of service technicians.

iv) Indigenous Production and R&D (2 thematic areas clubbed)

- Bureau of Indian Standards (BIS) to develop and periodically update standards for various refrigerants including upcoming low GWP refrigerants.
- Develop and promote norms for testing and calibration of equipment for checking purity of refrigerants.
- Promote indigenous development of R-290 (propane) and R-600a (isobutane), the potential low GWP alternatives.
- Develop and implement monitoring mechanism with respect to disposable refrigerant cylinders.
- DST to recognize “Cooling” as a thrust area and promote R&D in the area of low GWP refrigerants and their applications.
- Academic and Research institutions to carry out R&D on cooling technologies including promoting Public Private Partnership (PPP) for interdisciplinary research for sustainable cooling.

v) Transport air-conditioning

- DST to promote R&D in the area of low refrigerant charge energy efficient Mobile Air conditioning (MAC) systems.
- BEE to Promote testing of vehicles with AC ON condition to provide realistic fuel efficiency and emissions profile for encouraging improved efficiency under the CAFE Standards.
- BEE to develop and promote green labelling systems for cars to promote energy efficient vehicles.
- Ministry of Road Transport and Highways (MoRTH) and Ministry of Housing and Urban

Affairs (MoHUA) to promote use of public transport including electric vehicles.

- Vehicle manufacturers/service workshops and associations to follow the CPCB guidelines for recycling/management of refrigerants generated from end-of-life vehicles/servicing.
- CPCB to develop standard operating procedure for management of refrigerants generated from end-of-life vehicles/ servicing.

A Steering Committee headed by the Secretary (MoEFCC) and with representatives for the concerned line Ministries/Departments oversees the progress of implementation of the action points and take steps as deemed necessary.

The ICAP has been appreciated internationally as an important policy initiative which has the potential to provide socio-economic and environmental benefits related to reduced refrigerant use, climate change mitigation and Sustainable Development Goals.

Participation in Montreal Protocol meetings

Representatives of MoEFCC participated in the following Montreal Protocol Meetings:

a) Thirty-Seventh Meeting of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer (MOP 37) held from 3-7 November 2025 at Nairobi, Kenya.

b) 97th and 98th Meetings of the Executive Committee

Key outcomes of the above said meetings are as follows:

Meeting of the Parties (MOP-37)

1) Membership of the Executive Committee of the Multilateral Fund for the year 2026

   - India has been elected as Member of the Executive Committee of the Multilateral Fund for the year 2026 representing Asia Pacific countries.

2) Terms of Reference (TOR) for Replenishment of the Multilateral Fund for the Triennium for 2027-2029

   - TOR for the study on replenishment of the Multilateral Fund (MLF) for the triennium 2027-2029 was finalised after incorporating the inputs provided by Indian representatives relating to (i) associated cash flows needed for the funding windows agreed by the Executive Committee (ExCom) of the MLF on issues like energy efficiency, inventories of unwanted refrigerants, etc, (ii) consideration long term sustainable strategy that would reduce dependence on HFCs and not just immediate targets and (iii) sustainability of phasedown for Micro, Small and Medium Enterprises (MSMEs).

3) Enhancing regional atmospheric monitoring of substances controlled by the Montreal Protocol

   - Indian representatives proposed that the evaluation of the suitability of potential sites for monitoring emissions of controlled substances situated within the regions and locations identified in the information provided by the Advisory Committee to the MOP 37, should be with the voluntary participation of and in full consultation with the concerned party. The proposal was accepted and included in the final decision on the issue.

4) Emissions of HFC-23

   Indian representatives proposed that the Technology and Economic Assessment Panel should carry out additional analysis on the following and present to the Parties for further consideration

   - Discrepancy between reported emissions and those derived from atmospheric measurements, including the methodologies applied.
   - A description of the information and data sources used, identifying any gaps or limitations.

- Information on methodologies adopted by parties for estimating and reporting HFC-23 emissions as well as best practices for improvements to minimize such emissions.

5) Further strengthening Montreal Protocol institutions

- The representative of the European Union introduced a proposal for a draft decision, set out in a CRP, focused on streamlining the information that parties provided to the Ozone Secretariat on their licensing systems, with the aim of strengthening such systems. The CRP requested the Secretariat to prepare a template for parties to use in providing information, including the elements of the licensing system required to be established and implemented under Article 4B of the Montreal Protocol, as well as other elements useful for information, by 30 September 2026. An informal group was established to discuss the CRP.

- Indian representatives proposed that It was not clear whether the proposal could really help parties to improve their capacity and address their current challenges. Developing specific template by the Ozone Secretariat for parties to provide information could be challenging, considering the nationals processes and circumstances of countries. It was also said that this could add additional burden to the countries. The proposal of India was supported by other Article-5 countries and the CRP was dropped.

97th and 98th Meetings of the Executive Committee

1) Funding request for preparation of Stage–1 of the Kigali HFC phase down Management Plan (KIP Stage-I) for India

- Funding request for preparation of Stage-I of the Kigali HFC Phase down Management Plan (KIP Stage-I) for India, including development of overarching and sectoral strategies for consideration was approved for US$450,000 by the ExCom at its 98th meeting.

2) Funding request for preparation of pilot HFC demonstration projects including enhancing energy efficiency

- Funding request for preparation of 3 energy efficiency projects for Blue Star Ltd, Voltas Limited and Kirloskar Chillers Ltd was approved for US$50000 and preparation of 2 pilot projects for demonstrating low GWP technologies, including enhancement of energy efficiency, was approved for US$60,000 for Birla Aircon Ltd and Ultrakool.

3) Financial closure and project completion report for HCFC Phase out Management Plan Stage-II

- Financial closure and project completion report for HCFC Phase out Management Plan Stage-II of India was considered and approved by the ExCom of the MLF.

Issuance of Production Quota for HCFC-22 Producers

The Ministry of Environment, Forest and Climate Change issues enterprise-wise production quota for HCFC-22 for non-feedstock applications to ensure compliance with the Montreal Protocol reduction schedule.

Submission of Data to Montreal Protocol Bodies

Data on production, export and import of Ozone Depleting Substances (ODSs) and Hydrofluorocarbons (HFCs) under Article-7 of the Montreal Protocol for the year 2024 was submitted to the Ozone Secretariat and data on production, consumption, export and import of ODSs and HFCs data under Country Programme Progress Report (CPPR) for the year 2024 was submitted to the Multilateral Fund Secretariat respectively.

The Standing Committee on Monitoring of the Empowered Steering Committee of the Montreal Protocol, chaired by the Ex-Officio, Chairman, Central Pollution Control Board (CPCB) and comprising representatives from concerned line Ministries involved in maintaining data on substances controlled under the Montreal Protocol, reviews the data compiled by the Ozone Cell and recommends the same for consideration and approval of the ESC, for submission to the Ozone Secretariat and MLF Secretariat respectively.

Registration of enterprises as per the provisions of the ODS (Regulation and Control) Rules and its amendments.

Awareness Generation

The Ozone Cell, MoEF&CC, the National Ozone Unit has undertaken comprehensive public awareness campaign to ensure that the industries and public at large are aware about the ill effects of ozone depletion, and undertake necessary ODS phase- out activities and support the policies to protect the ozone layer.

Material has been made available on the Ozone among the public. Instructional training videos for RAC service technicians in six different languages, viz., English, Hindi, Bengali, Kannada, Tamil and Gujarati have also been made available. Separately, as part of awareness generation and information dissemination activities the Ozone Cell has set up YouTube channel, Facebook and Twitter pages.

World Ozone Day

The United Nations General Assembly in 1995 adopted a resolution which proclaims 16 September as World Ozone Day, to commemorate the signing of the Montreal Protocol on Substances that Deplete the Ozone Layer. The Montreal Protocol came into force in 1987 and since then, 16 September of every year is celebrated as the World Ozone Day by the Parties to the Montreal Protocol.

India has been celebrating World Ozone Day on 16 September since 1995.

World Ozone Day 2025

The theme for World Ozone Day 2025 was "From Science to Global Action". The MoEF &CC, Govt of India celebrated the 31st World Ozone Day on 16th September 2025 in Delhi. Secretary, Ministry of Environment, Forest and Climate Change was the Chief Guest for the event. Resident Representative, UNDP India was also present during the event. The function was attended by more than 500 school children, Industries associated with Montreal Protocol implementation, Service technicians of Refrigeration and Air-conditioning (RAC), Partners associated with Montreal Protocol implementation, think tanks, Refrigerant gas Manufacturers, RAC and Foam manufacturing enterprises, implementing agency, technical assistance providers (CIPET) etc.

Key Highlights

i) To raise awareness among students about the importance importance of protecting the Ozone Layer, the National Museum of Natural History (NMNH) and the Ozone Cell of the Ministry of Environment, Forest and Climate Change (MoEF&CC) jointly organized national-level competitions for school children. The contests held in the two categories, Poster Making and Slogan Writing through a developed web portal. A total of 6,322 entries were received for the Poster Competition, while 2,428 entries were received for the Slogan writing category

ii) Release of Awareness Materials:

a) Release of winning entries of National-level Poster and slogan competitions for school children. In total 8,750 entries were received including both poster and slogan competition through a web portal developed for the purpose. The winning entries were finalized by a panel of judges.

b) 27th edition of "The Montreal Protocol: India's Success Story" highlighting India's achievements in the Montreal Protocol Implementation in phasing out of ODS till date.

c) Release of Publications

- Report on "Study on Low-GWP alternative technologies in the Transport Refrigeration Sector" provides a clear understanding of the current landscape, viable low-GWP alternatives, global best practices in the road-based refrigerated transport sector, which is the most widely used and relevant mode of refrigerated transportation in India. It will aim to build awareness across the cold chain ecosystem to promote the adoption of low-GWP and climate-friendly technologies and provide practical recommendations to facilitate the transition towards sustainable transport refrigeration sector.

- Report on "Study on Best Practices for Installation and Maintenance of Ammonia/ Low-GWP Alternatives Technologies in the Cold Chain Infrastructure" assessed best practices for the installation and maintenance of ammonia and other low-GWP refrigeration technologies in cold chain infrastructure. It reviewed existing practices, identified key challenges, and documented relevant national and global experiences. The study also provided practical recommendations to improve safety, efficiency, reliability, and the adoption of climate-friendly refrigeration technologies.

- Report on "Study on Low-GWP Alternative Technologies for Chillers in Large Air Conditioning Buildings" discusses low-GWP alternative technologies for chillers used in large air-conditioned buildings. It reviewed available technologies, their performance, energy efficiency, and applicability in Indian conditions. The study identified suitable alternatives and provided recommendations to support the adoption of energy-efficient and climate-friendly cooling solutions

- Report on "Techno-Economic Feasibility Study of District Cooling Systems in India" examined the potential applications, benefits, challenges, and key factors affecting adoption of district cooling systems in India. The study provided recommendations to support the development and adoption of efficient and sustainable district cooling systems in India.

iii) Documentary film on Equipment support to ITIs under HPMP stage-III;

iv) Animated video message on Ozone layer Protection by "Prakriti".

Website

The website of the Ozone Cell along with five project related websites were integrated into a single website and migrated to the National Informatics Centre (NIC) server. The website of Ozone Cell: https://ozonecell.nic.in is updated regularly.

MIS System for ODS phase-out activities

A comprehensive Management Information System (MIS) system for all activities relating to ODS phase-out including the regulatory framework under the ODS Rules, project implementation and monitoring has been developed. The MIS system was launched on the occasion of the World Ozone Day 2018 and in under implementation.

The MIS is fully operationalized and simplified provisions have been introduced for compliance by enterprises. These include registration and reporting for ODS as producer, user, importer, exporter and seller as per the various provisions of the ODS (Regulation and Control) Rules 2000 and its amendments. Provision for submission of quarterly and annual returns on ODS online by the enterprises has also been made in the MIS.

Activities related to the implementation of ODS Rules, 2000 and its amendments and Montreal Protocol

Activities related to the implementation of ODS Rules, 2000 and its amendments were carried out inter alia including registration, Regulation of export/ import, issuance of production quota, monitoring and reporting.

The statutory reporting under the Montreal Protocol under Article 7 has been completed and the CPPR submitted to the Secretariat of the MLF for the implementation of the Montreal Protocol.

Monitoring System in India

A detailed monitoring mechanism has been established by the Ozone Cell, MoEF&CC to ensure that the funding support provided from the MLF through implementing agencies is being fruitfully utilized by the enterprises. The key aspects relating to monitoring mechanism are as follows:

The MoEF&CC has constituted a Standing Committee on Monitoring under the Chairmanship of Chairman, CPCB with members from concerned Departments, Industry Associations and the Ozone Cell, MoEF&CC. The Committee reviews the data collected and analysed by the Ozone Cell, MoEF&CC from ODS producers, DGFT, DGCIS, etc., on production, imports, exports and user industry in the country. The production, import and export data is collated in the Article 7 format of the Montreal Protocol for submission to the Ozone Secretariat. The Standing Committee on Monitoring is an advisory body to the ESC. The Article 7 data thus vetted by the Standing Committee on Monitoring is submitted to the ESC for its approval and then it is submitted to the Ozone Secretariat.

The Ozone Cell has been convening regular meetings with representatives of the World Bank, UNDP, UNEP, UNIDO and Bilateral Agencies with a view to note the progress of implementation and to sort out short-term problems, which might occur during the implementation process. Further, Director, Ozone Cell, MoEF&CC is holding periodic meetings with industries to monitor their implementation progress for ODS phase-out.

Awards and Recognitions

The Ozone Cell of India has been conferred with several awards/ appreciations/ recognitions for successful implementation of the Montreal Protocol and its ODS phase-out activities.

Other activities

- Recommendations were issued to enterprises for import and export of ODSs and ODS based equipment for getting license from the DGFT.
- Data on production, consumption, export and import of ODS is being collected from various sources, collated and submitted to the Secretariat for the Vienna Convention and the Montreal Protocol (The Ozone Secretariat) and the CPPR to the Secretariat of the MLF for the implementation of the Montreal Protocol by the end of September each year as per the Article 7 of the Montreal Protocol.

Key to Success

India attributes its success in achieving rapid progress of ODS phase out on the following:

- Identifying the priority sub-sectors for early phase-out;
- Choosing wisely a project portfolio with the right mix of investment and non-investment activities;
- Involving key stakeholders early in the phase- out process at both planning and implementation levels;
- Sending clear messages from the Government to various stakeholders by notifying appropriate regulations and policies;
- Awareness raising activities for key target groups;

- Increasing the capacity of the Ozone Cell by its active involvement in the Regional.

Network of ODS officers and other international fora:

- To create awareness among the stakeholders producing and consuming HCFCs;
- Monitoring of production and consumption sectors for complete phase-out of ODS;
- Mechanism for more involvement of state-level organizations in ODS phase-out activities.

Release of “The Montreal Protocol: India’s Success Story” on the occasion of 31st World Ozone Day function held on 16th September, 2025 at New Delhi, India.

Release of “Poster” on the occasion of 31st World Ozone Day function held on 16th September, 2025 at New Delhi, India.

Release of “Techno-economic Feasibility Study of District Cooling Systems in India” on the occasion of 31st World Ozone Day function held on 16th September, 2025 at New Delhi, India.

Release of "Study on Best Practices for Installation and Maintenance of Ammonia/Low-GWP alternative Technologies in the Cold Chain Infrastructure" on the occasion of 31st World Ozone Day function held on 16th September, 2025 at New Delhi, India.

Release of "Study on Low-GWP alternative Technologies for Chillers in Large Air Conditioning Buildings" on the occasion of 31st World Ozone Day function held on 16th September, 2025 at New Delhi, India.

Release of “Study on Low-GWP alternative Technologies in the Transport Refrigeration Sector” on the occasion of 31st World Ozone Day function held on 16th September, 2025 at New Delhi, India.

Shri Bhupendra Yadav, Hon’ble Minister, Ministry of Environment, Forest and Climate Change, Government of India addressing (virtually) the participants, on the occasion of 31st World Ozone Day function held on 16th September, 2025 at New Delhi, India.

Mr. Tanmay Kumar, Secretary, Ministry of Environment, Forest and Climate Change, Government of India addressing the participants, on the occasion of 31st World Ozone Day function held on 16th September, 2025 at New Delhi, India.

School Students attending the 31st World Ozone Day function held on 16th September, 2025 at New Delhi, India.

3 INDIA'S ACHIEVEMENTS TO DATE OF THE MONTREAL PROTOCOL REGIME

Achievements

Contribution and achievements of India for the protection of the stratospheric ozone and implementation of the Montreal Protocol are multi- fold. The industries that were producing and consuming ODS were motivated by creating extensive awareness about the ill-effects of the ozone layer depletion in the early stage of the Montreal Protocol. Simultaneously, activities related to the Montreal Protocol were initiated as early as in 1989 by establishing a task force for evaluating the use of ODS and estimating sector wise consumption of ODS.

India not only developed and put in place policies/ regulations for phase-out of ODS as per the Montreal Protocol Schedule within the country, but also played a visionary role since the inception of the Montreal Protocol including in the key policy negotiations on behalf of the developing nations.

India debated extensively to make industrialized countries to realize their historic responsibility for production, consumption and emissions of ODS, that has caused the stratospheric ozone hole. Subsequently, India played a vital role for setting up the financial mechanism of the Montreal Protocol the MLF as early as 1990 to provide technical and financial assistance to the developing countries. Today, the financial mechanism has proved to be the key element in making the Montreal Protocol a successful Environmental Treaty.

India became a Party to the Vienna Convention for the Protection of the Ozone Layer on 18 March 1991 and the Montreal Protocol on Substances that Deplete the Ozone Layer on 19 June 1992 and since then, made outstanding contributions for the protection of ozone layer.

Comprehensive Ozone Depleting Substances (ODSs) (Regulation and Control) Rules, 2000 were developed and put in place under the Environment (Protection) Act 1986, which were utmost important for the successful implementation of ODS phase-out in a vast country like India. These rules set the deadlines for phasing-out of various ODSs. The unique feature of these Rules was banning the use of CFCs and halons in manufacturing of new equipment as early as from 1 January 2003. This not only helped achieve the early phase-out of CFCs and halons in the country, but also reduced the inventory of ODS-based equipment which resulted in reduction of servicing requirements.

Another significant achievement was phase-out of production and consumption of virgin halons as early as 2002, being high-Ozone Depleting Potential (ODP) chemicals.

India accelerated the phase-out of production and consumption of CFCs with effect from 1 August 2008, 17 months ahead of the Montreal Protocol schedule except use of pharmaceutical grade CFCs in manufacturing of Metered Dose Inhalers (MDIs) for asthma, COPD and other respiratory ailments within the country and other Article 5 Parties.

The phase-out of ODS in MSMEs, which were widely scattered were handled using an innovative approach, realizing that MSMEs have relatively a large share in Indian economy. Several sector-wise umbrella projects were formulated in a number of sectors, viz., Aerosol sector, Foam Manufacturing, Refrigeration Manufacturing, to cater to the needs of MSMEs. These enterprises were provided need-based appropriate equipment for converting their operations from ODS to non-ODS technologies. Safety issues in using flammable propellants like Hydrocarbon Aerosol Propellant (HAP) by small aerosol fillers were addressed adequately.

The phase-out of use of CFCs in Refrigeration and Air Conditioning (RAC) Servicing sector was an extremely challenging task because it involved the informal sector that comprissed a large number of very tiny enterprises. These enterprises were located throughout the country, including in small towns and rural areas. National CFC Consumption Phase-out Plan (NCCoPP) and its forerunning projects (Indo- Swiss-German Project "Ecological Refrigeration (ECOFRIG) and Human and Institutional Development in Ecological Refrigeration (HIDECOR) not only addressed this sector in a very effective manner by training more than 20,000 servicing technicians but also provided equipment support to a large number of enterprises. This was one of the significant achievements addressing the informal sector in the country.

Another challenging task was to phase-out the production and Consumption of CTC, especially in the Consumption sector which involved a large number of MSMEs and tiny enterprises using CTC as solvent. This sector was successfully addressed through an umbrella project and was provided technical assistance to replace CTC used in garment manufacturing as well as metal cleaning.

India successfully phased-out the production and consumption of CFCs, CTC, methyl choloroform and halons for controlled use as of 1 January 2010.

Another critical challenge was to phase out the use of pharmaceutical grade CFCs in manufacturing of MDIs. The "National Strategy for Transition to Non-CFC MDIs and Plan for Phase-out of CFCs in the Manufacture of Pharmaceutical MDIs" was implemented by the UNDP as lead implementing agency, in association with UNEP and the Government of Italy in close cooperation of MDI manufacturers under the guidance of Ozone Cell, MoEF&CC. The MDI manufacturers have done a commendable work and converted all the CFC- based formulations of MDIs to CFC-free and placed in the market as early as in 2011 with the due approval of Central Drug Standard Control Organization, Ministry of Health & Family Welfare (MoHFW). India sought pharmaceutical grade CFCs through EUN only for 2010 and withdrew the nominations for 2011 in consultation with MDI manufacturers. Accordingly, India informed the 22nd MOP to the Montreal Protocol that India would not seek any CFCs for manufacturing of MDIs through Essential Use Nomination (EUN) for 2011 and beyond. The 22nd MOP congratulated India for its outstanding contribution and achievement in this area.

The implementation of the National Strategy for Transition to non-CFC MDIs and Plan for Phase-out of CFCs in Manufacturing of Pharmaceutical MDIs has resulted successful phase-out of pharmaceutical grade CFCs in manufacturing of MDIs as of December 2012, 11 months prior to the schedule approved by the Ex-Com of the MLF. India was one of the first countries to switch over from CFC to non-ODS in MDI manufacturing.

Recognizing the importance and challenges in implementation of the accelerated phase-out of

HCFCs as per the decision of the 19th MOP held in September 2007, India initiated activities as early as 2008 and developed and launched the Roadmap for phase-out of HCFCs in India in October, 2009 describing the long-term vision and action plan.

The Ozone Depleting Substances (Regulation Control) Rules were amended to align with the accelerated phase out schedule of Montreal Protocol and are published during 2014.

The phase out of HCFCs is through implementation of the HCFC phase out Management Plans (HPMPs) and policy and regulatory measures.

India successfully met the 2013 target of freeze of HCFC production and consumption and 10% phase-out targets of HCFCs in 2015, as per the accelerated phase-out schedule of the Montreal Protocol.

Through the HPMP Stage-I, a total of 341.77 ODP tonne of HCFCs have been phased out, of which 310.53 OPD tonne is of HCFC-141b in the Foam Manufacturing sector and 31.24 ODP tonne is for HCFC-22 in the RAC Servicing sector, in accordance with the agreement between the Government of India and the Ex-Com of the MLF. The net direct emission reductions are thus 3,071,260.5 CO_2 eq. tonne.

The HPMP Stage-II was implemented from 2016-2024, under which reduction of 8,190 MT or 769.49 ODP tonne of HCFC consumption from the starting point of 1,691.25 ODP tonnes was achieved, contributing to India's compliance in advance with the control targets for HCFCs under the Montreal Protocol. The implementation of Stage-II resulted in net direct CO_2-equivalent emission reductions of about 8,530,900 MT CO_2 eq. per year from 2023 onwards.

In a significant first, amongst the Article 5 parties (developing countries) under the Montreal Protocol, India has been able to achieve the complete phase out of HCFC-141b in the foam manufacturing sector, as part of implementation of HPMP Stage-II. HCFC-141b is one of the most potent chemicals involved in stratospheric ozone depletion after the CFCs.

Notification amending the ODSs (Regulation and Control) Rules, 2000, was published in the Gazette of India on 31st December, 2019, inter alia prohibiting the issuance of import license for HCFC-141b from 1st January, 2020. With this notification, prohibiting the import of HCFC-141b, the country has been made free of HCFC-141b. Simultaneously, the use of HCFC-141b by foam manufacturing industry has also closed as on 1st January 2020 under the ODSs (Regulation and Control) Amendment Rules, 2014.

Recognizing the close linkages between the HCFC phase out, HFC phase down under the Kigali Amendment adopted during 2016 and the synergies with sustainable cooling, several studies with focus on promoting adoption of low GWP alternatives in building sector, cold chain sector, energy efficiency green procurement, standards for low GWP alternatives have been carried out. These study reports were published and widely disseminated amongst all the concerned stakeholders including line Ministries/ departments.

The training activities under the RAC service sector included upgradation of training syllabus, including of the RAC trade in the Industrial Training Institutes (ITIs) to include good service practices in handling of low GWP alternatives including flammable refrigerants.

Achievement of 1.1.2020 reduction target for HCFCs

In line with the accelerated phase out schedule of the Montreal Protocol for HCFCs to achieve 35% reduction target the production and consumption of HCFCs, India successfully achieved the reduction of consumption and production of HCFCs by 44% from the baseline. Independent verification by UNDP, the lead implementing agency for HPMP confirmed the same.

HPMP Stage III for India was approved in the 91st meeting of the Ex-Com of the MLF to phase out 10678.87 MT or 579.99 ODP tonne of HCFCs consumption from the starting point, contributing to India's compliance with the 2025 and 2030 control targets HCFCs under the Montreal Protocol.

HPMP Stage-III will be the last of the HPMPs for India, for assisting the country in achieving compliance with the Montreal Protocol 2025 and 2030 control targets as per the accelerated phase out schedule of the Montral Protocol.

Implementation of HPMP-Stage-III will result in net direct CO2-equivalent emission reductions of 19,239,929 tonnes CO2-eq. from 2040 onwards.

Besides the technology conversion activities, the HPMP Stage-III comprises the enabling activities and activities in the RAC servicing sector. Enabling Activities comprise policy and enforcement capacity building, studies on adoption of non- HCFC and low GWP alternatives including promoting energy efficiency, etc., and awareness generation and capacity building activities for various stakeholders including for pollution control boards. Servicing Sector activities comprise training and certification of 25000 Refrigeration and Airconditioning (RAC) service technicians, equipment support to Industrial Training Institutes (ITIs), trained and certified service technicians and certified service centers.

Certification system for RAC service technicians has been approved by the National Council for Vocational Education and Training (NCVET) under the National Skill Qualification Framework (NSQF) of the Ministry of Skill Development and Entrepreneurship (MSDE) and will be implemented as part of the HPMP Stage-III for training and certification of 25000 RAC technicians.

Towards strengthening of training infrastructure in the ITIs, as part of the servicing sector activities under the HPMP Stage-III, equipment support has been provided to 119 ITIs across the country, as per the advice of Directorate General of Training (DGT), Ministry of Skill Development and Entrepreneurship, considering regional and geographical balance The equipment supplied to the ITIs comprise: (i) Basic refrigeration and electrical cycle unit (Frost-free Refrigerator), (ii) Split A C Training Unit (compatible to Inverter technology) Capacity: 1.5 Ton, (iii) Commercial Refrigeration Training Unit, (iv) Industrial Refrigeration Unit for Rack Systems, and (v) Split AC Training Unit Metal Frame.

Kigali Amendment to the Montreal Protocol

The Kigali Amendment to the Montreal Protocol was decided by the Parties to the Montreal Protocol at its 28th meeting held in October 2016 at Kigali, Rwanda for phase down of Hydrofluorocarbons (HFCs) which have high global warming potential ranging from 12 to 14,000.

As per the agreed phase-down of HFCs under the Kigali Amendment, India will have to complete its phase down the production and consumption of HFCs in 4 steps from 2032 onwards with reduction of 10% from the baseline of production and consumption in 2032, 20% in 2037, 30% in 2042 and 85% in 2047 respectively. The baseline constitutes the average of production and consumption of HFCs for the period 2024-2026 and the freeze applicable for India is 2028.

Ratification of the Kigali Amendment by India

In September 2021, the Government of India has ratified the Kigali Amendment after approval by the Union Cabinet.

The Kigali Amendment came into force for India on 26th December 2021. Thereafter, framework for licensing system and reporting obligations has been put in place and data reporting for HFCs has commenced from 2022 along with other Ozone Depleting Substances as per provisions of Article 7 of the Montreal Protocol.

National Strategy for HFC phase down

The development of the national strategy for HFC phase down comprises the following:

(i) Outreach and awareness raising.

(ii) Development of a national Strategy including policy framework for the implementation of the Kigali Amendment.

(iii) Establishing a framework for implementing licensing, quota system, and reporting obligations related to HFCs.

As part of the awareness and outreach component, 23 workshops comprising 17 workshops through physical mode and 6 workshops through virtual mode in close co-operation with the concerned line Ministries and departments and the concerned industry associations concerned with the Montreal Protocol implementation.

The national strategy for HFC phase down is under finalization.

India Cooling Action Plan (ICAP)

Recognizing the cross cutting use of RAC technologies in various sectors and close linkage of energy efficiency with refrigerant transition during the HCFC phase out and phasing down HFCs, the Ministry of Environment, Forest and Climate Change has developed and launched the India Cooling Action Plan (ICAP).

The ICAP provides a perspective plan 20-year perspective plan and policy recommendations, to address the cooling requirement across sectors while providing for ways and means to provide thermal comfort and access to sustainable cooling to all, involving multi-stakeholders to synergize actions for addressing cooling demand across all areas: technology, manufacturing, energy efficiency and the environment, while reemphasizing the principles enshrined in the Country Programme of India for phase out of ODS i.e. to have minimum economic dislocation and obsolescence cost and maximize indigenous production to twin environment and economic gains.

Given the cross-cutting nature of cooling demand, the ICAP implementation proposes active collaboration among the relevant ministries as well as the private sector entities.

Action points relating to implementation of recommendations of ICAP for the six thematic areas Space Cooling in building sector, cold chain, Servicing Sector, Indigenous production, R&D and Transport Air Conditioning have been finalized after consultation with all the concerned Ministries/ Departments/ Agencies. After the approval of the Steering Committee, the action points have been circulated to the concerned Ministries/ Departments/Agencies for implementation.

A Steering Committee headed by Secretary (MoEFCC) and with representatives for the concerned line Ministries/Departments oversees the progress of implementation of the action points and take steps as deemed necessary

The ICAP has been appreciated internationally as an important policy initiative which has the potential to provide socio-economic and environmental benefits related to reduced refrigerant use, climate change mitigation and Sustainable Development Goals.

ICAP may accessed at https://ozonecell.nic.in/wp-content/uploads/2019/03/INDIA-COOLING- ACTION-PLAN-e-circulation-version080319.pdf

Indigenous capacity development including research on low global warming (GWP) chemicals

In order to promote indigenous manufacturing of low global warming potential chemicals and development of a robust R&D ecosystem the MoEFCC has collaborated with 8 Indian Institutes of Technology (Roorkee, Hyderabad, Kanpur, Patna, Banaras, Madras and Tirupati) to promote research and development of low global warming potential chemicals, including blends thereof, to be used as alternatives to substances controlled under the Montreal Protocol in line with industry requirements through engagement of research scholars. This would help in creating awareness for development and adoption on indigenous low global warming potential alternative technologies which could be deployed during the HFC phase down besides promoting “Make in India” initiative of the Government.

HFC Demonstration Projects

The Executive Committee of the Multilateral Fund for in its 87th meeting held from 28 June to 2 July

2022 vide decision 87/50, approved the guidelines for the preparation of HFC phase-down plans for Article 5 countries. In line with these guidelines and considering the size of Indian market and the multitude of sectors present in the country, submitting projects for demonstrating transition from HFCs to low Global Warming Potential alternative technologies would help better understand the challenges associated in the technology conversion to low GWP alternatives during the HFC phase down under the Kigali Amendment.

The key sectors are refrigeration manufacturing and air-conditioning manufacturing, the two sectors in which currently high GWP HFCs are used and technically proven low GWP alternatives are available. Accordingly, three project proposals approved submitted were approved by the Executive Committee at its 93rd meeting held from 15th-19th December 2023 and are under implementation, to be completed by December 2025.

Negotiations in Montreal Protocol Meetings

India has been pro-actively participating in the negotiations in the Montreal Protocol meetings on behalf of the developing countries, both at the Meeting of the Parties (MOP) and the Executive Committee (Ex-Com) of the Multilateral Fund (MLF).

The key issues of negotiation of the MOP include energy efficiency including financing of energy efficiency under the framework of the Montreal Protocol, replenishment of the multilateral fund and issues relating to implementation and enforcement of the Montreal Protocol including those relating to combatting illegal trade, HFC-23 by product emissions, CTC, QPS uses of Methyl Bromide.

The key issues of negotiation at the Ex-Com meetings include approval of cost funding guidelines for HFC phasedown in Article 5 countries, funding window for Pilot projects to maintain and/or enhance energy efficiency of replacement technologies and equipment in the context of HFC phase-down, enhanced funding for institutional strengthening projects, criteria for funding window for an inventory of banks of used or unwanted controlled substances and a plan for the collection, transport and disposal of such substances and contribution of HCFC phase out and HFC phase down towards sustainable cooling.

Other Initiatives

In addition to meeting the compliance obligations under the Montreal Protocol, the country, towards protection environment and the climate system, has also taken necessary steps for appropriate management and disposal of refrigerants at the end-of-life RAC equipment through necessary provisions in the E-waste Management Rules. Guidelines for Extended Producers Responsibility (EPR) for managing electronic waste and associated refrigerants by equipment manufacturers and environmentally sound facilities for handing, processing and scrapping of vehicles at the end of life, including management of refrigerant gases have also been farmed.

The hall mark for the success of Montreal Protocol implementation in the country is the very active participation of the stakeholders including the industry with the Ministry.

Website and MIS

The website of the Ozone Cell: https:// ozonecell.nic.in is updated regularly.

The comprehensive Management Information System (MIS) system for all activities relating to ODS phase-out including regulatory framework under the ODS (Regulation and Control) Rules 2000 and its amendments is fully operationalized and simplified provisions have been introduced for compliance by enterprises with respect to registration and reporting of ODS including submission of online quarterly and annual returns.

Awards and Appreciations received

The Ozone Cell of India has been conferred with several awards/appreciations/recognitions for successful implementation of the Montreal Protocol and its ODS phase-out activities.

4 HOW CAN YOU HELP TO PROTECT THE OZONE LAYER?

Twenty Questions and Answers about the Ozone Layer

Q. 1. What is ozone, how is it formed, and where is it in our atmosphere?

Ozone is a gas that is naturally present in our atmosphere. Each ozone molecule contains three atoms of oxygen and is denoted chemically as O3. Ozone is found primarily in two regions of the atmosphere. About 10% of Earth's ozone is in the troposphere, which extends from the surface to about 10–15 kilometers (6–9 miles) altitude. About 90% of Earth's ozone resides in the stratosphere, the region of the atmosphere between the top of the troposphere and about 50 kilometers (31 miles) altitude. The part of the stratosphere with the highest amount of ozone is commonly referred to as the "ozone layer". Throughout the atmosphere, ozone is formed in multistep chemical processes that are initiated by sunlight. In the stratosphere, the process begins with an oxygen molecule (O2) being broken apart by ultraviolet radiation from the Sun. In the troposphere, ozone is formed by a different set of chemical reactions that involve naturally occurring gases as well as those from sources of air pollution.

Q.2. Why do we care about atmospheric ozone?

Ozone in the stratosphere absorbs a large part of the sun's biologically harmful UV radiation. Stratospheric ozone is considered "good" ozone because of this beneficial role. In contrast, ozone formed at earth's surface in excess of natural amounts is considered "bad" ozone because it is harmful to humans, plants, and animals. Natural ozone near the surface and in the lower atmosphere plays an important beneficial role in chemically removing pollutants from the atmosphere.

Q.3. How is total ozone distributed over the globe?

The distribution of total ozone over the earth varies with location on timescales that range from daily to seasonal. The variations are caused by large- scale movements of stratospheric air and the chemical production and destruction of ozone. Total ozone is generally lowest at the equator and highest in the polar regions.

Q.4. How is ozone measured in the atmosphere?

The amount of ozone in the atmosphere is measured by instruments on the ground and carried aloft on balloons, aircraft, and satellites. Some instruments measure ozone remotely over long distances by using ozone's unique optical absorption or emission properties. Other instruments measure ozone locally by continuously drawing air samples into a small detection chamber.

Q.5. What are the principal steps in stratospheric ozone depletion caused by human activities?

The initial step in the depletion of stratospheric ozone by human activities is the emission, at Earth's surface, of gases that contain chlorine and bromine and have long atmospheric lifetimes. Most of these gases accumulate in the lower atmosphere because they are relatively unreactive and do not dissolve readily in rain or snow. Natural air motions eventually transport these accumulated gases to the stratosphere, where they are converted to more reactive gases. Some of these gases then participate in reactions that destroy ozone. Finally, when stratospheric large-scale circulation patterns return this air to the lower atmosphere, these reactive chlorine and bromine gases are removed from Earth's atmosphere by rain and snow.

Q.6. What emissions from human activities lead to ozone depletion?

Certain industrial processes and consumer products result in the emission of ozone-depleting substances (ODSs) to the atmosphere. Principal ODSs are manufactured halogen source gases that are now controlled worldwide by the Montreal Protocol. These gases bring chlorine and bromine atoms to the stratosphere, where they destroy ozone in chemical reactions. Important examples are the chlorofluorocarbons (CFCs), once used in almost all refrigeration and air conditioning systems, and the halons, which were used as fire extinguishing agents. Current ODS abundances in the atmosphere are known directly from air sample measurements.

Q.7. What are the reactive halogen gases that destroy stratospheric ozone?

Chlorine and bromine containing halogen source gases that enter the stratosphere arise from both human activities and natural processes (Q6). When exposed to ultraviolet radiation from the Sun, these halogen source gases are converted to other gases that also contain chlorine and bromine. Some of the gases act as chemical reservoirs, which can then be converted into ClO and BrO, the two most important reactive gases that participate in catalytic reactions that destroy ozone.

Q.8. What are the chlorine and bromine reactions that destroy stratospheric ozone?

Reactive gases containing chlorine and bromine destroy stratospheric ozone in "catalytic" cycles made up of two or more separate reactions. As a result, a single chlorine or bromine atom can destroy many thousands of ozone molecules before it leaves the stratosphere. In this way, a small amount of reactive chlorine or bromine has a large impact on the ozone layer. A special situation develops in the polar regions in the late winter/early spring season where large enhancements in the abundance of the most reactive gas, chlorine monoxide, leads to severe ozone depletion.

Q.9 Why has an "ozone hole" appeared over Antarctica when ozone-depleting substances are present throughout the stratosphere?

Ozone-depleting substances are present throughout the stratospheric ozone layer because they are transported great distances by atmospheric air motions. The severe depletion of the Antarctic ozone layer known as the "ozone hole" occurs because of particular meteorological and chemical conditions that exist there and nowhere else on the globe. The very low winter temperatures in the Antarctic stratosphere cause polar stratospheric clouds (PSCs) to form. Specific chemical reactions that occur on PSCs, combined with the isolation of polar stratospheric air inside the polar vortex, allow chlorine and bromine reactions to produce the ozone hole over Antarctica in springtime.

Q.10. How severe is the depletion of the Antarctic ozone layer?

Severe depletion of the Antarctic ozone layer was first reported in the mid-1980s. Antarctic ozone depletion is seasonal, occurring primarily in late winter and early spring (August-November). Peak depletion occurs in early October when ozone is often completely destroyed over a range of altitudes, thereby reducing total ozone by as much as two-thirds at some locations. This severe depletion creates the "ozone hole" apparent in images of Antarctic total ozone made using satellite observations. In most years the maximum area of the ozone hole far exceeds the size of the Antarctic continent.

Q.11. Is there depletion of the Arctic ozone layer?

Yes, significant depletion of the Arctic ozone layer now occurs in most years in the late winter and early spring period (January- March). However, Arctic ozone depletion is less severe than that observed in the Antarctic and exhibits larger year-to-year differences as a consequence of the more variable meteorological conditions found in the Arctic polar stratosphere. Even the most severe Arctic ozone depletion does not lead to total ozone amounts as low as those seen in the Antarctic, because Arctic ozone abundances during early winter before the onset of ozone depletion are much larger than those in the Antarctic. Consequently, an extensive and recurrent "ozone hole", as found in the Antarctic stratosphere, does not occur in the Arctic.

Q.12. How large is the depletion of the ozone layer outside of polar regions?

The abundance of total ozone between 60°S and 60°N is now about 2–3% below the amount present during 1964–1980. The abundance of total ozone in this region declined steadily throughout the 1980s due to the increases in reactive halogen gases in the stratosphere resulting from human activities. In the early 1990s, due to additional ozone loss that followed the 1991 eruption of Mount Pinatubo, total ozone between 60°S to 60°N was depleted by 5% relative to the 1964–1980 average, the maximum depletion observed over the past six decades. In both hemispheres, total ozone depletion is small near the equator and increases toward the poles. The larger depletion at higher latitudes, particularly in the Southern Hemisphere, is driven in part by the late winter/early spring destruction of polar ozone, which influences ozone at lower latitudes following the breakdown of the polar vortex in each hemisphere.

Q.13. Do changes in the sun and volcanic eruptions affect the ozone layer?

Yes, factors such as changes in solar radiation and the formation of stratospheric aerosol particles after explosive volcanic eruptions do influence the ozone layer. Global ozone abundances vary by 1–2% between the maximum and minimum of the 11-year solar cycle. The abundance of global ozone decreased by about 2% for a few years after the June 1991 eruption of Mount Pinatubo, due to volcanic enhancement of stratospheric sulfate aerosols. However, neither factor can explain the observed decrease in global total ozone or the severe ozone depletion observed in polar regions over the past half century. The primary influence on long-term changes in total global ozone is the abundance of stratospheric halogens.

Q.14. Are there controls on the production of ozone-depleting substances?

Yes, the production and consumption of ozone-depleting substances (ODSs) are controlled under a 1987 international agreement known as the "Montreal Protocol on Substances that Deplete the Ozone Layer" and its subsequent amendments and adjustments. The Protocol, now ratified by 198 parties, establishes legally binding controls on the global production and consumption of ODSs. Production and consumption of controlled ODSs by developed and developing nations will be almost completely phased out by 2030.

Q.15. Has the Montreal Protocol been successful in reducing ozone-depleting substances in the atmosphere?

Yes, as a result of the Montreal Protocol, the overall abundance of ozone-depleting substances (ODSs) in the atmosphere has been decreasing for the past two decades. If the nations of the world continue to comply with the provisions of the Montreal Protocol, the decrease will continue throughout the 21st century. Those gases that are still increasing in the atmosphere, HCFC-22 (CHF_2Cl) and HCFC-141b (CH_3CCl_2F), will begin to decrease this decade if compliance with the Protocol continues. However, it is only after midcentury that the abundance of ODSs is expected to fall to values that were present before the Antarctic ozone hole was first observed in the early 1980s, due to the long atmospheric lifetime of these gases.

Q.16. Does depletion of the ozone layer increase ground-level UV radiation?

Yes, UV radiation at earth's surface increases as the amount of overhead total ozone decreases, because ozone absorbs UV radiation from the sun. Measurements by ground-based instruments and estimates made using satellite data provide evidence that surface ultraviolet radiation has increased in large geographic regions in response to ozone depletion.

Q.17. Is depletion of the ozone layer the principal cause of climate change?

No, ozone depletion is not the principal cause of global climate change. Ozone depletion and global climate change are linked because both ozone-depleting substances and their substitutes are greenhouse gases. The best estimate is that stratospheric ozone depletion has led to a small amount of surface cooling. Conversely, increases in tropospheric ozone and other greenhouse gases lead to surface warming. The effect on global climate change from stratospheric ozone depletion is small compared to the warming from the greenhouse gases responsible for observed global climate change. Since the early 1980s, the Antarctic ozone hole has contributed to changes in Southern Hemisphere surface climate through effects on the atmospheric circulation.

Q.18. Are Montreal Protocol controls of ozone-depleting substances also helping protect Earth's climate?

Yes. Many ozone-depleting substances (ODSs) are also potent greenhouse gases that contribute to global warming when they accumulate in the atmosphere. Montreal Protocol controls have led to a substantial reduction in the emissions of ODSs over the last two decades. These reductions, while protecting the ozone layer, have the additional benefit of reducing the human contribution to climate change. Without Montreal Protocol controls, the global warming due to ODSs could now be nearly three times the present value. With the 2016 Kigali Amendment to the Montreal Protocol, climate protection was extended to include controls on HFCs, which do not deplete ozone but contribute to global warming.

Q. 19. How has the protection of climate by the Montreal Protocol expanded beyond the regulation of ozone-depleting substances?

At the 28th Meeting of the Parties to the Montreal Protocol held in Kigali, Rwanda, in October 2016, the Montreal Protocol was amended to control the production and consumption of hydrofluorocarbons (HFCs). The Montreal Protocol phaseout of chlorofluorocarbons (CFCs) led to the temporary use of hydrochlorofluorocarbons (HCFCs). The subsequent phaseout of HCFCs led to expanded long-term use of HFCs, because HFCs pose no direct threat to the ozone layer. However, HFCs are greenhouse gases and therefore contribute to climate change. Limiting the production and consumption of those HFCs with high global warming potentials is projected to avoid 0.3 to 0.5°C of global warming over this century. The Kigali Amendment marks the first time the Montreal Protocol has adopted regulations solely for the protection of climate.

Q.20. How is stratospheric ozone expected to change in the coming decades?

Recovery of the global ozone layer from the effects of ozone-depleting substances (ODSs) is expected around the middle of the 21st century, assuming global compliance with the Montreal Protocol. Recovery will occur as ODSs and reactive halogen gas abundances in the stratosphere decrease in the coming decades. In addition to responding to ODSs, ozone abundances will increasingly be influenced by climate change. The impacts of future climate change on the ozone layer will vary between the tropics, midlatitudes, and polar regions, and strongly depend on future emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). During the long recovery period, large volcanic eruptions could temporarily reduce global ozone amounts for several years.

5 OZONE IN OUR ATMOSPHERE

SYNTHESIS OF THE 2022 ASSESSMENT REPORTS OF THE SCIENTIFIC ASSESSMENT PANEL, THE ENVIRONMENTAL EFFECTS ASSESSMENT PANEL AND THE TECHNOLOGY AND ECONOMIC ASSESSMENT PANEL

Introduction

1. The Scientific Assessment Panel, the Environmental Effects Assessment Panel and the Technology and Economic Assessment Panel are charged with providing periodic assessments within their areas of expertise to the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer. This report provides a high-level synthesis of the 2022 assessment reports of the three panels. The scientific and technological issues associated with the Montreal Protocol, along with the climate and environmental benefits of the Protocol, are highlighted herein and discussed in detail in the individual assessment reports of these panels:

   Scientific Assessment Panel

   Environmental Effects Assessment Panel

   Technology and Economic Assessment Panel

2. This report provides updated information highlighting the success of the Montreal Protocol in limiting the growth in the atmospheric abundances of ozone-depleting substances (ODS) and hydrofluorocarbons (HFC), thereby reducing stratospheric ozone depletion, avoiding additional contributions to climate change and protecting the environment. The indications that those actions are leading to ozone recovery are increasingly clear, especially for ozone in the upper stratosphere and over the Antarctic region. With the implementation of the 2016 Kigali Amendment to the Montreal Protocol to phase-down HFC, a significant amount of future climate warming will be avoided, adding to that avoided due to the decline in ODS production and consumption under the Protocol.

3. Significant impacts on human health, and the environment caused by stratospheric ozone

depletion and the resulting increases in UV radiation have been avoided because of the Montreal Protocol. Since full recovery of the ozone layer will take several decades, long- term monitoring of ODS, HFC, ozone and UV radiation continues to be essential.

Key findings

I. Actions taken under the Montreal Protocol have continued to decrease atmospheric abundances of controlled ozone-depleting substances and advance the recovery of the stratospheric ozone layer.

4. The atmospheric abundances of both total tropospheric chlorine and total tropospheric bromine from long-lived ODS have declined since the 2018 Assessment. The observed rates of decline in tropospheric chlorine and tropospheric bromine in substances controlled under the Montreal Protocol were 15.4 ± 4.1 ppt Cl yr-1 and 0.18 ± 0.05 ppt Br yr-1 respectively, close to the Baseline scenario from the 2018 Assessment. Tropospheric chlorine from very short-lived gases, whose sources are mainly anthropogenic and which are not controlled under the Montreal Protocol, increased by 2.1 ± 0.6 ppt Cl yr-1.

5. Progress on ODS phase-out continues to be made in every residential, commercial, industrial, agricultural, medical, and military sector, with the production and consumption of ODS having been phased out from many applications worldwide.

   - The phase-out of the consumption and production of hydrochlorofluorocarbon (HCFC)-22 is essentially complete in non-Article 5 parties and is progressing in Article 5 parties.

   - Significant progress has been made to phase out the use of HCFC in foams. There are alternative foam blowing agents (FBAs) in use commercially today in nearly every foam application.

   - Phase-out of controlled uses of methyl bromide (MB) is virtually complete, but significant quarantine and pre-shipment (QPS) uses remain, as these are currently exempted from Montreal Protocol controls. Alternatives have nevertheless been identified, and are in use in some countries, for a good proportion of these uses.

   - The phase-out of controlled substances in sterilization uses is considered complete. Technically and economically feasible alternatives are commercially available for all aerosol uses, although not all alternatives are suitable across all applications in all locations.

   - Alternative low GWP refrigerants are available for all refrigeration, air- conditioning and heat pump (RACHP) applications, which account for the majority of all HCFC and HFC emissions. These alternatives are being widely applied in some applications and regions, but accessibility is still a major hindrance for the widescale adoption of lower GWP refrigerants and progress towards goals of the Kigali Amendment phase-down schedules.

6. Evidence for ozone recovery, consistent with these declines in ODS abundances, has strengthened.

   - Total column ozone (TCO) in the Antarctic continues to recover, notwithstanding substantial interannual variability in the size, strength, and longevity of the ozone hole, which is driven by interannual variability in meteorology.

   - Outside of the Antarctic region (from 90°N to 60°S), the limited evidence of TCO recovery since 1996 has low confidence.

   - TCO is expected to return to 1980 values around 2066 in the Antarctic, around 2045 in the Arctic, and around 2040 for the near-global average (60°N-60°S).

7. Trends in stratospheric ozone vary with altitude as well as geographic region.

- Outside of the polar regions, observations and models are in agreement that ozone in the upper stratosphere continues to recover.
- In contrast, ozone in the lower stratosphere has not yet shown signs of recovery.
- Models simulate a small recovery in mid-latitude lower-stratospheric ozone in both hemispheres that is not seen in observations. Reconciling this discrepancy is key to ensuring a full understanding of ozone recovery.

8. As yet, there is no published evidence that lockdowns associated with the COVID-19 epidemic impacted the trends in atmospheric abundances of ODSs or their replacements or that they have impacted stratospheric ozone. Supply shortages of low-GWP alternatives in some sectors are understood to have started in 2020 due to COVID-19 related supply chain and logistics issues, raw material shortages, manufacturing issues, and severe weather, at the same time as increasing global demand. While these supply issues are less severe now, these will need careful monitoring as extended shortages in supply could delay transition away from HFCs across the various sectors of use.

II. The Montreal Protocol contributes to environmental sustainability and human health and well-being, in line with many Sustainable Development Goals

9. The Montreal Protocol continues to contribute to the implementation of many of the United Nations SDGs by protecting the stratospheric ozone layer and contributing to the mitigation of climate change. These SDGs address the areas related to climate change, air and water quality, biodiversity and ecosystems, sustainable production and consumption, food security, contaminants and materials, and human health. Thus, the Montreal Protocol has wide-ranging significance for sustainability by protecting human health and maintaining healthy, diverse ecosystems on land and in the water.

10 Surface levels of solar ultraviolet-B radiation (UV-B) would have increased world-wide without the Montreal Protocol, and these changes would have been the greatest in polar regions (e.g., the Antarctic mid-summer UV index would have increased from 3 to 33 between 1975 and 2065). Further, a modelling study with an extreme scenario estimated that the impact of large increases in UV-B radiation on terrestrial vegetation in a world without the Montreal Protocol would have drastically reduced the photosynthetic uptake of carbon dioxide by plants. This reduction in carbon sequestration would have, in turn, increased atmospheric carbon dioxide levels, resulting in an additional rise of global mean surface temperature of 0.5-1.0°C by 2100.

11. By safeguarding the earth from extreme UV-B radiation, the Montreal Protocol is playing a key role in protecting human health. One modelling study compared the Montreal Protocol, as amended and adjusted, with the extreme scenario of unregulated ODS emissions increasing at a rate of 3% per year throughout the twenty-first century. This analysis estimated that 11 million cases of melanoma, 432 million cases of basal cell and squamous cell carcinoma (keratinocyte cancers), and 63 million cases of cataracts (the leading cause of blindness globally) were avoided for people born in the United States between 1890-2100 because of the Montreal Protocol. Approximately half of these cases are avoided because of the amendments and adjustments made to the original 1987 Montreal Protocol. The Montreal Protocol has also made it possible to continue to receive the beneficial health effects (e.g., vitamin D production and improved immune system function) of moderate exposure to sunlight through spending time outdoors.

12. Solar UV radiation causes photodegradation of plastics, which ultimately results in fragmentation and the formation of micro- and nanoplastics (particles less than 5 mm and

0.1 micron in diameter, respectively). The implementation of the Montreal Protocol has likely prevented increases in the generation of microplastics in the environment, although the amount of this reduction and its biological consequences remain uncertain.

III. The significant decreases in projected HFC emissions from the provisions of the Kigali Amendment will substantially protect future climate.

13. The HFC are increasingly used as ODS alternatives in refrigeration and air conditioning, in the aerosols and foam sectors, and as fire suppression agents. While they do not contain ozone-depleting chlorine or bromine, they are greenhouse gases. The Kigali Amendment, which was adopted in 2016 and came into force in 2019, sets schedules for the phase-down of the global production and consumption of specific HFCs. Although radiative forcing from HFCs is currently small, the Kigali Amendment is designed to avoid unchecked growth in emissions and the associated warming that would have arisen from the projected increases in demand in coming decades.

14. The atmospheric abundances of most currently measured HFC continue to increase, as was projected in the baseline scenario of the 2018 Assessment. Global emissions of HFC, which originate from both Article 5 and non-Article 5 parties, increased by 18 per cent between 2016 and 2020 in carbon dioxide (CO_2)-equivalent units.

15. Current projected HFC emissions are lower than those projected in the 2018 Assessment. The 2020–2050 cumulative emissions in the 2022 updated Kigali Amendment scenario are 14–18 Pg CO 2 -eq lower than in the corresponding scenario in the previous Assessment. The new scenario follows national controls on the consumption and production of HFC in non-Article 5 countries, reflects lower reported consumption in China, is based on updated historical information on the use of HFCs in non-Article 5 countries, uses observed mixing ratios through 2020 as a constraint, and includes assumptions about reduced use of HFC for commercial and industrial refrigeration. The new scenario also assumes that all countries adhere to the provisions of the Kigali Amendment.

16. Annual average surface warming from HFC is expected to be 0.04°C in 2100 under the updated 2022 Kigali Amendment scenario, compared to 0.3–0.5°C without control measures. A more rapid phase-down of HFC than that required by the Amendment would further limit climate change from HFC.

17. The global HFC-23 emissions of 17.2 ± 0.8 kt yr–1 in 2019 derived from atmospheric observations are substantially higher than the emissions of 2.2 kt yr–1 in that year derived from activity-based estimates. These activity-based estimates are derived from UNFCCC emission reports, information on production and emissions abatement submitted under the Montreal Protocol, and the estimated effect of national regulations. The atmospheric HFC-23 levels are inconsistent with the substantial rise in emissions abatement reported to the UNFCCC.

18. The HFC-23 emissions are expected to grow in the coming decades. The HFC-23 is released as a by-product of HCFC-22 production and other processes. These other processes include production of HFC-32, the manufacture of TFE/HFP from HCFC-22 feedstock, the production processes of other fluorocarbons (e.g., for HFC-125, HFC-134a, HFC-143a), and some steps of HFO production.

19. The planned HFC phase-down under the Kigali Amendment, as well as regional regulations, are driving industry towards low-GWP HFC alternatives and innovative applications, especially with respect to refrigeration, air conditioning and foams. However, the

range of new, lower GWP products creates challenges in finding the best solution for each application, taking into consideration factors such as flammability, toxicity, availability, cost, accessibility, operating conditions, and other properties.

20. Trifluoroacetic acid (TFA), is a breakdown product in the atmosphere of some HFCs, HCFCs, HFOs and HCFOs and fluoroketones (FKs). The TFA formed in the atmosphere is rapidly deposited in precipitation and, on reaching the surface (soil or water), it forms salts with alkali metals (e.g., sodium, potassium, calcium). The TFA salts are unreactive and have long environmental lifetimes but are easily excreted by animals and therefore do not bioaccumulate in the food chain. Like other mineral salts, TFA salts accumulate in oceans and salt-lakes. The formation of TFA in the atmosphere is expected to increase in the coming decades due to increased use of HFO and HCFO. While TFA continues to be found in the environment, including in remote regions, concentrations are so low that it is currently judged very unlikely to have adverse toxicological consequences for humans and ecosystems. Continued monitoring and assessment are nevertheless advised due to uncertainties in the localized deposition of TFA and its potential effects on some untested marine organisms.

IV. Improvements in energy efficiency during the HFC phase-down have the potential to accelerate and further increase the climate benefits from the Kigali Amendment

21. There is a rapidly increasing global demand for refrigeration and air conditioning. Improved energy efficiency in new refrigeration, air conditioning and heat pump (RACHP) equipment synchronously with HFC phase- down could serve to moderate energy use, potentially doubling the climate benefit from the HFC phase-down. This could make a cost- effective and near-term contribution to the path to net zero GHG emissions. Early conversion to efficient RACHP equipment containing low GWP alternatives can reduce energy costs and avoid the build-up of high GWP HFC refrigerant banks.

22. Technology developments are proceeding at pace, and RACHP equipment using low and medium GWP refrigerants with increased energy efficiency is available in all sectors, but not necessarily accessible in all countries.

V. Successful actions by the Parties have reversed the upward trend of unexpected emissions observed between 2013 and 2017

23. While the 2018 Scientific Assessment found that global CFC-11 emissions unexpectedly increased in the 2013-2017 period, the 2022 Scientific Assessment concluded that global CFC-11 emissions declined after 2018. The initial CFC-11 emissions increase led to a number of scientific investigations and policy responses. Consequently, CFC-11 emissions decreased to 45 ± 10 Gg in both 2019 and 2020. This decrease suggests the elimination of most of the unexpected emissions occurring in the years after 2012.

24. A large fraction of the unexpected CFC-11 emissions originated from eastern China. This finding is based on available regional observations from several east Asia sites. The decline of CFC-11 emissions from eastern China since 2018 explains 60 ± 30% of the observed global emission decrease. While the global network of surface observation stations provides estimates of total CFC-11 emissions, the network is too geographically sparse to fully assess regional emissions.

25. Emissions from the CFC-11 banks alone could not explain the 2013-2017 unexpected increase, indicating unreported CFC-11 production and use in this period. This production was most likely used for closed-cell foams. Unreported production may also have occurred earlier, in the 2007 to 2012 period.

26. Regional observations suggest some CFC-12 emissions may have been associated with the unreported CFC-11 production. Uncertainties in emissions from banks and gaps in the observing network are too large to determine whether all unexpected CFC-12 emissions have ceased.

VI. Carbon tetrachloride abundances continue to decline at a slower rate than expected based on previous trends

27. Carbon tetrachloride (CCl_4) atmospheric abundances continued to decrease, but at slower rates than expected based on previous trends. Global CCl4 emission estimates based on atmospheric observations averaged 44 ± 15 Gg yr-1 in both 2016 and 2020.

28. Regional CCl4 emissions from eastern China over the period 2013–2019 show year-to-year variability likely related to CFC-11 production. Emissions increased after 2013, reaching 11.3 ± 1.9 Gg yr–1 in 2016, and decreased to 6.3 ± 1.1 Gg yr-1 in 2019.

29. Production of CCl_4 has increased in recent years due mainly to growing demand for feedstock use for production of HFCs, HFOs/ HCFOs, and perchloroethylene. Increasing CCl_4 production is likely to continue because of the increasing demand for HFO/HCFOs. Most emissions arise from CCl_4 production, handling, supply chain, and usages. Additional CCl_4 emissions likely arise from non- chloromethane production, such as the vinyl chain production process, which is identified as a new potential source of CCl_4 emissions.

VII. The atmospheric abundances of a number of minor ozone-depleting substances have been increasing; cumulatively, those substances may eventually have an impact on stratospheric ozone

30. Global abundances of the minor species CFC-13, CFC-112a, CFC-113a, CFC-114a, and CFC-115 increased from 16.0 ± 0.3 ppt in 2016 to a total of 17.2 ± 0.3 ppt Cl in 2020. Atmospheric observations confirm that eastern Asia is a substantial source region. These findings likely indicate an increase or stabilization of the emissions of these relatively low abundance compounds. Some of these unexplained emissions are likely occurring as leaks of feedstocks or by-products, and the remainder is not understood. These species have a minor impact on stratospheric chlorine loading and stratospheric ozone depletion.

31. The production and usage of short-lived chlorinated solvents are not controlled by the Montreal Protocol, and some are used in large amounts. Their impact on stratospheric ozone, and their ozone depletion potentials (ODPs), vary depending on the season and location of emissions. Emissions of these substances could grow in the future even as emissions from long-lived ODSs decline. Important examples of short-lived chemicals that are used as feedstocks are CHCl (chloroform), $CHCl=CCl_2$ (trichloroethene or TCE), and $CCl_2=CCl_2$ (perchloroethene or PCE). Sustained increases in anthropogenic chlorinated very short-lived substance (VSLS) emissions, as seen for CH Cl over the last two decades, would lead to more stratospheric ozone depletion in the future.

32. Dichloromethane (CH_2Cl_2, or DCM) (180-day lifetime) is the main component of VSLS chlorine. Its atmospheric abundance continued to increase between 2016 and 2020 with a slightly lower growth rate than prior to 2016. This increase primarily results from a growth in CH2Cl2 emissions in Asia. Given market trends in chemical production and DCM usage, global DCM production and atmospheric concentrations are currently not expected to increase significantly in the next few decades. The DCM is used mainly as a solvent (such as in pharmaceutical manufacturing, paint stripping, adhesives) and as a foam-blowing agent, and is also used as feedstock for HFC-32 production. In recent

years, there has been a decrease in solvent use in some regions (e.g., EU and US) and a substantial increase in others (e.g., in South and East Asia). The DCM feedstock use for HFC-32 production is increasing globally. Future global trends are difficult to predict. With the toxicity profile of DCM, general solvent uses are being increasingly regulated. Nevertheless, there is currently increasing global capacity to produce DCM to supply solvent and feedstock uses.

33. The estimated input of chlorine from VSLSs to the stratosphere in 2020 increased by about 10 ppt since the last Assessment and amounts to 130 ± 30 ppt, contributing about 4% of the total chlorine input. Brominated VSLSs, with mainly natural sources, contribute 5 ± 2 ppt to stratospheric bromine and show no long-term changes.

34. New evidence suggests that VSLS iodine, mostly from natural sources, is transported to the stratosphere, contributing 0.3–0.9 ppt iodine in particulate or gas-phase form. No observational trend estimates exist.

VIII. Production, by-production, feedstock use and intermediates

35. Since 2002, total reported ODS production has increased by a small amount, with increased production for feedstock uses offsetting the decrease in production for controlled emissive uses. The overall increase in ODS feedstock uses through the last decade has been mostly due to the increase in HCFC feedstock uses, particularly HCFC-22, while uptake of HFOs is driving a more recent increase in carbon tetrachloride feedstock use.

36. Emissions during chemical manufacturing results from products, co-products, by- products, feedstock, or intermediates.

    - By-production of controlled substances in production processes occurs through over- or under-reaction enroute to the intended product, the presence of impurities undergoing reactions, and unintended side reactions.

    - Intermediates are the chemical building blocks that raw materials pass through when being chemically transformed into products. Emission rates are much lower for intermediates than for the final product.

37. Several production processes generate HFC-23 by-production and emissions, including during the production of HCFC-22 and HFC-32. Production processes of other fluorocarbons can also result in HFC-23 by-production, although at lower rates. (See also Section III above.)

38. HCFC-22 is mainly used as feedstock to produce tetrafluoroethylene (TFE) and hexafluoropropylene (HFP), which are used in fluoropolymer production. The manufacture of TFE/HFP from HCFC-22 feedstock generates by-production and emissions of HFC-23 and PFC-c-318 (c-C4F8), and both have a very high GWP. These combined emissions as CO2 equivalent, without consideration of their possible abatement, are larger than the estimated emissions of HFC-23 from HCFC-22 production.

39. The current combined GWP-weighted emissions of CFCs plus HCFCs are comparable to those of HFCs. Reductions in future emissions of CFCs and HCFCs would require addressing emissions from banks and from production, by-production, and feedstock use. Global emissions of long-lived HFC-23, largely a by-product of HCFC-22 production, are likely to grow unless abatement increases or feedstock use of HCFC-22 decreases.

IX. While halon atmospheric abundances are declining slowly, there remains a demand for halon-1301 which may not be met in the future without new production

40. Tropospheric bromine from halons has decreased from a peak of 8.5 ± 0.1 ppt in 2006 to 7.3 ± 0.1 ppt in 2020. Halon-1211, halon- 2402, and

halon-1202 abundances continued to decline between 2016 and 2020. The rate of change of halon-1301 remained indistinguishable from zero. In 2020, it was the most abundant halon in the atmosphere.

41. Halon-1301emissions appear to be higher than anticipated from a fixed bank of fire suppression uses suggesting other source(s) of emissions such as from its feedstock production and use. Conversely, these higher emissions could be due to a higher rate of emissions from the halon-1301 bank than anticipated. If this is the case, the bank of halon-1301 could be significantly less than that required to fill ongoing needs.

42. Demand for halons for fire-fighting uses persists and will ultimately exceed the supply from available banks without the implementation of alternatives. There are continuing long-term uses of halon (e.g., in oil and gas facilities, nuclear facilities and military installations) and growing demand from civil aviation for halon-1301 owing to the lack of replacements for engine and cargo compartment fire-fighting applications in new aircraft. The current, estimated run-out timeframe of between 2030 and 2049, when halon-1301 would be no longer available, means that the civil aviation industry (and others) must look to their own stockpiles of halon-1301 to avoid grounding aircraft because of a lack of appropriate fire protection. New designs in the military sector may only be able to use halon-1301 or high- GWP HFCs to meet stringent design/life-safety requirements.

43. The HFC phase-down regulations in non-Article 5 parties are having a bigger impact on the cost and availability of HFC fire suppressants than initially anticipated owing to their high GWP and the availability of a low-GWP fluoroketone suitable for some applications. As the supply of newly produced HFCs for fire protection decreases in response to phase-down regulations, HFC recycling will become even more important to fulfill demand.

X. Quantifying ODS and HFC banks and the time- course of their continued emissions is important in determining the pace of ozone layer recovery and potential impacts on climate.

44. Monitoring the banks of controlled substances and assessing their accumulation in equipment and products is important due to the potential impact of their uncontrolled emissions on ozone depletion and climate. A bank is defined as the total amount of controlled substances contained in existing equipment, stockpiles, foams, and other products not yet released to the atmosphere. This includes the “reachable” bank, also referred to as “active” bank, which includes those controlled substances contained in equipment or products in use and thus potentially reachable or accessible for management upon entering the waste stream at its end-of-life (EOL). In contrast, the “non- reachable” or “inactive” bank denotes substances that have been landfilled or illegally dumped along with the equipment or product.

45. Effective management of active ODS and HFC banks aims to minimize the global impacts associated with the release of ODS and HFC by minimizing emissions, and by supporting HFC phase-down through recovering HFC for recycling, reclamation and reuse. Environmentally sound destruction of surplus or contaminated ODS and HFC at EOL is encouraged by the Montreal Protocol because it avoids unnecessary emissions and protects the stratospheric ozone layer and/or the climate. ODS and HFC banks in A5 parties, particularly in the refrigeration and air conditioning and foams sectors, are growing rapidly and will dominate global bank volumes by the early 2030s, resulting from declining banks in non-Article 5 parties and the rapid uptake of HFC-containing equipment in Article 5 parties. For the refrigeration and air conditioning and foams sectors, a combined estimated total of 6,000 ktonnes of ODSs and HFCs are contained in the active bank in 2022,

important in determining the pace of ozone equaling 16 $GtCO_2$ equivalent.

XI. Atmospheric concentrations of methyl bromide have not declined since 2016

46. Methyl bromide (CH_3Br) average global atmospheric abundances have varied annually between 6.5 ppt and 6.9 ppt during 2016–2020 with no clear overall trend. Northern Hemisphere abundances are approximately 0.8 ppt higher than in the Southern Hemisphere. Phase-out of controlled, non- exempted (i.e., non-QPS) uses of methyl bromide is reported to be virtually complete. Parties report that more than 99.8% of the baseline consumption of 66,428 tonnes for these controlled applications has been phased out by 1 January 2023. This means that methyl bromide is currently used almost exclusively because large future increases in both CO and for QPS applications, with consumption remaining generally stable at 10,000 tonnes per year and concentrated in about 17 consuming countries.

47. Economically and technically feasible alternatives are available for QPS and could replace about 40% of current uses. Recapture and/or recycling methyl bromide could avoid about 70% of methyl bromide emissions arising from QPS use; however, this technology is costly and there is little incentive to adopt it. Reduction in emissions for all remaining uses of methyl bromide for QPS, together with identification and stopping any unreported uses, are considered important factors to returning concentrations in the atmosphere to natural levels. Owing to the relatively short lifetime of methyl bromide in the atmosphere (0.7 years), adoption of any suitable alternatives and in some cases adoption of recapture/destruction would have immediate benefits in reducing its atmospheric concentration.

XII. The timing and extent of the recovery of stratospheric ozone depends on future concentrations of both ozone-depleting substances and greenhouse gases.

48. Model simulations show that the future recovery of the ozone layer outside of the polar regions will be governed mostly by GHGs, assuming continued adherence to the Montreal Protocol. The wide range of possible future levels of CO_2, CH_4, and N_2O is an important limitation to providing accurate future projections of ozone globally and for the ozone hole, as well as in other geographic regions. Total column ozone returns to 1980 values sooner for scenarios that assume larger emissions of GHG (higher climate forcing) than scenarios with smaller GHG emissions (lower climate forcing).

49. For 60°S–60°N, simulations show that total ozone recovers to the 1980 level more rapidly under a higher climate forcing scenario because large future increase in both CO2 and CH4 tend to increase Ozone. Under a low climate forcing scenario, the models project that ozone over 60°S–60°N may not reach the 1980 level by the end of this century. In this low climate forcing simulation, future declines in total ozone driven by rising N O outweigh the small future ozone increases caused by CO2 and CH4. For a medium climate forcing scenario, total ozone over 60°S–60°N is projected to return to the 1980 level around year 2040.

50. In addition to changes in ODS and GHG concentrations, projections of future ozone levels also depend on other factors that influence atmospheric chemistry and composition.

   - Future commercial supersonic or hypersonic aircraft fleets could cause stratospheric ozone depletion through their emissions of substantial amounts of water vapor and nitrogen oxides (NOx) into the immediate benefit in reducing its atmospheric concentration.

   - Rocket launches presently have a small effect on total stratospheric ozone (much less than 0.1%). However, rocket systems using new propellants (e.g., hydrogen and methane) and increased launch frequencies could exert a substantial influence in the future. In addition, the demise of space hardware on re-entry through the atmosphere may have implications for stratospheric chemistry and composition that would lead to effects on ozone.

- Changes in stratospheric aerosol and water vapor from explosive volcanic eruptions would lead to increased ozone depletion and changes in stratospheric circulation. Ozone will become less sensitive to volcanic injections as ODS concentrations decline in coming decades.

- The intentional injection of sulfate aerosols into the stratosphere is being studied as a possible option for reducing climate warming and associated impacts. Model simulations show that injections have the potential to produce changes in ozone from chemical and dynamical processes, with the magnitude and sign of these changes depending strongly on the injection scenario and the state of climate change from anthropogenic activities.

XIII. Stratospheric ozone depletion and climate change are linked.

51. As reported in previous Assessments, ODSs are powerful greenhouse gases that lead to surface warming. Ozone itself is also a greenhouse gas and its changes impact climate. Increases in CO2 and decreases in ozone both tend to cool the stratosphere (while future increases in ozone have a warming tendency); cooling of the stratosphere away from polar regions slows the rate of ozone destruction, leading to higher ozone concentrations in the stratosphere.

52. The estimated rate of long-term cooling in the global middle and upper stratosphere (0.6 K decade-1) based on observations is similar to revious Assessments. The long-term trends are primarily driven by increasing CO_2 and stratospheric ozone. In the future, increasing GHGs and the effects of ozone recovery would have opposing effects on stratospheric temperature and circulation.

53. New evidence suggests that ozone recovery has caused changes in the observed trends of the southern hemisphere atmospheric circulation between the ozone depletion and recovery periods. Model simulations support the attribution of these changes to ozone recovery. These results provide evidence that southern hemisphere circulation trends have responded to the recovery of Antarctic ozone due to the Montreal Protocol.

54. While there are no detectable surface impacts long-term Arctic ozone changes, new evidence shows that for individual years low springtime Arctic ozone can amplify existing stratospheric circulation anomalies and their influence on tropospheric circulation and surface climate.

55. New evidence confirms that ozone depletion is unlikely to have driven the observed high-latitude sea-surface temperature cooling and changes in Antarctic sea ice since 1979.

XV. Compliance with Protocol provisions ensures the protection of stratospheric ozone and climate.

56. Full compliance with the Montreal Protocol provisions contributes to ozone recovery and climate protection (as noted above).

    - Total column ozone (TCO) returns to 1980 values around 2066 in the Antarctic, around 2045 in the Arctic, and around 2040 for the near-global average.

    - In 2020, the Montreal Protocol has led to the avoidance of 0.17 ± 0.06°C global surface warming and 0.45 ± 0.23°C of Arctic surface warming. Projections show that by mid-century the Protocol will likely avoid 0.79 ± 0.24°C compared to a scenario with uncontrolled ODS emissions.

- The Kigali Amendment avoids 0.3–0.5°C of warming by 2100.

57. Successful collaboration of experts across the Assessment Panels on science and technology has led to coordinated research and analyses to provide answers on sources of unexpected emissions of CFC-11 that occurred from 2013 to 2017. This issue highlights the need for vigilance to sustain compliance to guarantee the recovery of the ozone layer and maximize the speed of recovery.

58. Additional options for action to hasten the recovery of the ozone layer and protect the climate include the elimination of the remaining ODSs and their emissions, such as emissions from feedstock uses, by-product emissions, methyl bromide from QPS applications, VSLSs, and banks of controlled substances. These would individually lead to small-to-modest ozone benefits; collectively, they would advance ozone recovery by a maximum of 16 years.

XVI. Scientific, technical, and environmental policy considerations.

59. If ODS feedstock emissions as currently estimated were to be eliminated in future years, the return of mid-latitude equivalent effective stratospheric chlorine (EESC) to 1980 abundances could be advanced by almost 4 years, largely due to reductions in CCl_4, and simultaneously reduce total climate forcing from ODSs. Better understanding and monitoring of emissions of controlled substances from production, by-production, and feedstock use, is important given the contribution to overall global emissions.

60. In 2021, nearly all reported methyl bromide production was for QPS purposes, which is an uncontrolled use under the Montreal Protocol. Alternatives to methyl bromide are available, as are recapture technologies, that would lead to a reduction in emissions. Eliminating future emissions of methyl bromide from QPS applications currently allowed by the Montreal Protocol would accelerate the return of mid-latitude EESC to 1980 abundances by two years (as noted in previous Assessments).

61. Emissions of anthropogenic very short-lived chlorine substances, dominated by dichloromethane (DCM), continue to grow and contribute to ozone depletion. If DCM emissions continue at their current level, they would deplete approximately 1 DU of annually averaged global TCO. Elimination of these emissions would rapidly reverse this depletion.

62. Anthropogenic N_2O emissions are now the largest of the uncontrolled ODS emissions, as other larger emission sources (CFC-11, CFC- 12 and CFC-113) have been phased out. A 3% reduction in anthropogenic N2O emissions, averaged over 2023–2070, would lead to an increase in annually averaged global TCO of about 0.5 DU over the same period, and a decrease of about 0.04 Wm–2 in radiative forcing, averaged over 2023–2100.

63. With increasing ODS and HFC banks in Article 5 parties, particularly in the refrigeration and air conditioning and foams sectors, quantities potentially available for recovery and management are expected to increase in Article 5 parties. The refrigeration, air conditioning and heat pump (RACHP) sector dominates HFC consumption, and it is estimated to be responsible for around 95% and 80% of the consumption in Article 5 parties and globally, respectively. Timely efforts to establish and finance EOL management capacity to prevent HFC emissions could have a significant impact, given the predicted size and growth of these banks in larger Article 5 parties. Addressing the barriers to the transboundary movement of EOL ODSs and HFCs will be important in supporting preferential recovery/recycling and environmentally sound destruction of EOL ODSs and HFCs, thereby minimizing their emissions.

64. Under the Kigali Amendment, parties are progressing with national regulations to phase- down HFCs, which is spurring market demand for lower-GWP alternatives and higher efficiency equipment. Even so, the range of new, lower-GWP alternatives creates challenges in finding the best solution for each application, considering factors such as flammability, toxicity, availability, cost, accessibility, and the equipment and system operating conditions.

- Ultralow-, low-, and/or medium-GWP alternative refrigerants are available for all RACHP applications and are being widely applied in some RACHP applications and regions. Accessibility is still a major hindrance for the widescale adoption.

- Most ultralow-, low-, and medium-GWP refrigerants have different flammability classes (lower flammability, flammable, and higher flammability). As such, the RACHP sector continues to update the relevant safety standards to enable their use (e.g., increased allowable flammable refrigerant charge limits for self-contained commercial refrigeration, air-to-air air conditioning, and heating-only heat pump applications).

- Addressing active banks containing high-GWP and energy-inefficient RAC equipment can further contribute to reducing energy demand and the servicing tail of unwanted high GWP refrigerants.

- Supply shortages of low-GWP alternatives in some sectors have eased with new production capacity of HFO and HCFO alternatives, but these shortages have delayed transitions away from HFCs across the various sectors of use. Future sufficiency of supply to meet growing demand due to the HFC phase-down will need to be monitored to avoid future disruptions.

- In most Article 5 parties, but especially in low- and very low-volume consuming countries, the majority of ODS and HFC refrigerants are used for servicing, so ensuring support for proper training and servicing would reduce direct emissions of ODS and HFC refrigerants and reduce the loss in energy efficiency in RACHP equipment over the lifetime of the equipment.

- In specific foam applications some challenges remain, particularly for smaller enterprises in some Article 5 parties due to the availability, safety, and cost of some lower-GWP alternatives as well as product performance requirements.

- While global consumption of HFCs for production is relatively small, it is increasing for electronics manufacturing, and the alternatives to HFCs currently include other fluorinated gases, many of which have higher GWPs.

- Transition away from high-GWP HFC-pressurized metered dose inhalers (pMDIs) is a major undertaking with serious potential public health risks unless it is carefully managed.

65. Atmospheric monitoring station networks provide observations of global surface concentrations of long-lived ODS and HFC resulting from anthropogenic emissions. However, gaps in regional atmospheric monitoring limit the scientific community's ability to identify and quantify emissions of controlled substances from many source regions.

66. Several space-borne instruments providing vertically resolved, global measurements of ozone-related atmospheric constituents (e.g., reactive chlorine, water vapour, and long-lived transport tracers) are due to be retired within a few years. Without replacement of these instruments, the ability to monitor and explain changes in the stratospheric ozone layer in the future will be impeded.

67. The impact on the ozone layer of stratospheric aerosol injection (SAI), which has been proposed as a possible option to offset global warming, has been assessed following the terms of reference for the 2022 Scientific Assessment Panel report. Important potential consequences, such as deepening of the Antarctic ozone hole and delay in ozone recovery, were identified. Many knowledge gaps and uncertainties prevent a more robust evaluation at this time.

68. Heightened concerns about the twenty-first century ozone layer include impacts of:

    - further increases in nitrous oxide (N_2O), methane (CH_4), and CO_2 concentrations;
    - rapidly expanding ODS and HFC feedstock use and emissions;
    - continued and even increased use of methyl bromide for QPS use;
    - climate change on total column ozone in the tropics;
    - extraordinary wildfires and volcanic eruptions;
    - and the increased frequency of civilian rocket launches and the emissions of a proposed new fleet of supersonic commercial aircraft.

69. While our knowledge of the effects of UV radiation is improving, there remain many challenges in adequately assessing the interactive effects of future changes in surface solar UV radiation and climate on human health, food security, ecosystem health and biodiversity. These challenges are in part due to uncertainty of how the effects of gradual climate change and periodic extreme climate events will alter UV irradiation at the Earth's surface and subsequently affect species' adaptation and ecosystem structure and function in a rapidly evolving environment. There is thus a clear need to include solar UV radiation with other climate change factors in experimental and modelling studies of human health and aquatic and terrestrial ecosystems to enable a more robust assessment of the environmental effects from changes in UV radiation under different future global climate scenarios.

National level online Poster making competition organized on the occasion of 32nd World Ozone Day, 2026.

First Prize Winning Entry

Name : Hiba Lulu Edayattu
Class : 10, Section A
School : MES Fathima Rahim Central School
State : Kerala

Second Prize Winning Entry

Name : Ananya

Class : 12

School : Stalwarts World School

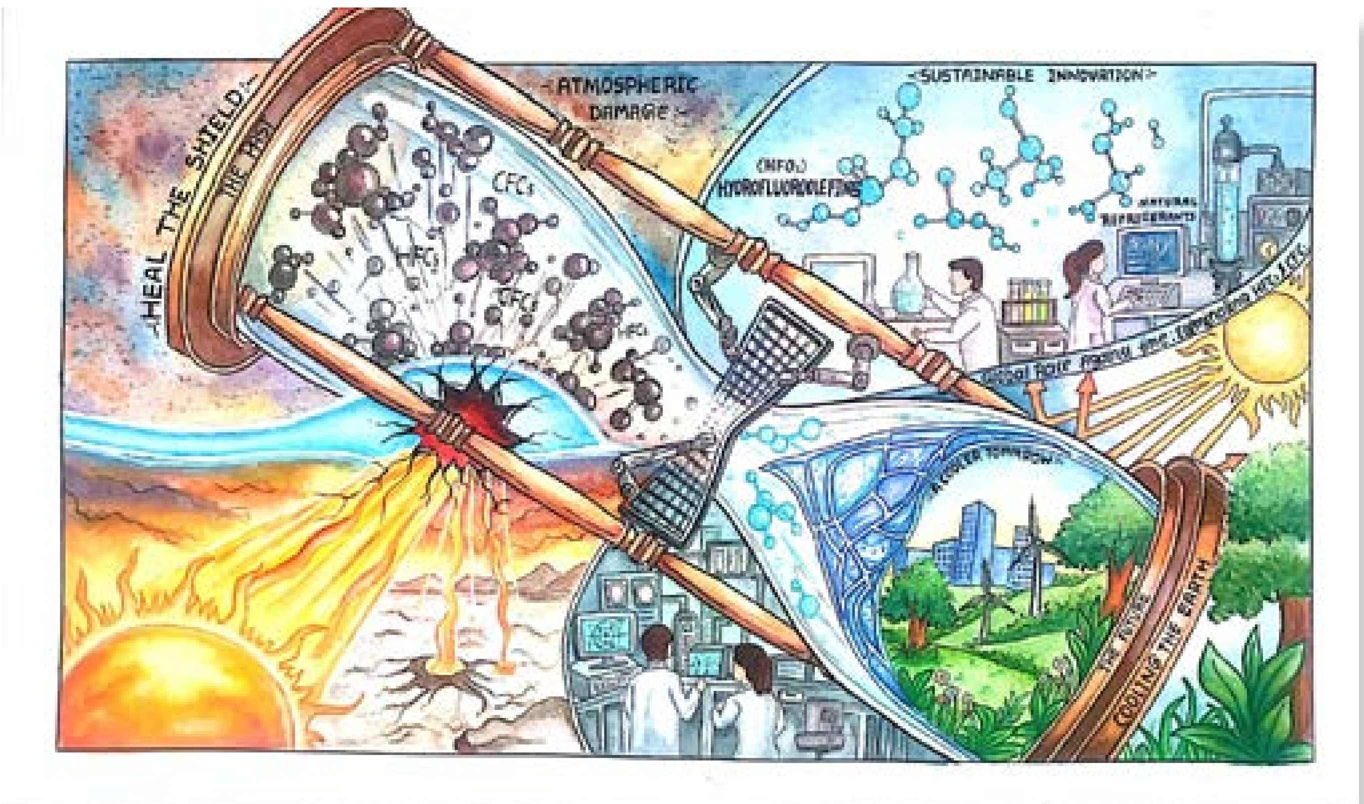
State : Punjab

Third Prize Winning Entry

Name	:	Anwesha Halder
Class	:	X, Section – A
School	:	Balia Nafar Chandra Balika Vidyalaya
State	:	West Bengal

Consolation Prize Winning Entry

Name : Samarth Navnath Pawar
Class : 9, Section - B
School : New English School
State : Maharashtra



Consolation Prize Winning Entry

Name : Piyush Kumar Sahu
Class : X, Section – A
School : Odisha Adarsha Vidyalaya
State : Odisha

Consolation Prize Winning Entry

Name : Edha. G
Class : 8, Section – F
School : GHSS Chayoth
State : Kerala

National level online Slogan Writing competition organized on the occasion of 32nd World Ozone Day, 2026.

First Prize Winning Entry

Name : Saee Sachin Mahadik
Class : X, Section - A
School : Navyug Marathi Madhyamik Vidyalaya
State : Maharashtra

" ODS और HFCs का घटे प्रहार, ओजोन सुरक्षित, सुरक्षित संसार। "

Second Prize Winning Entry

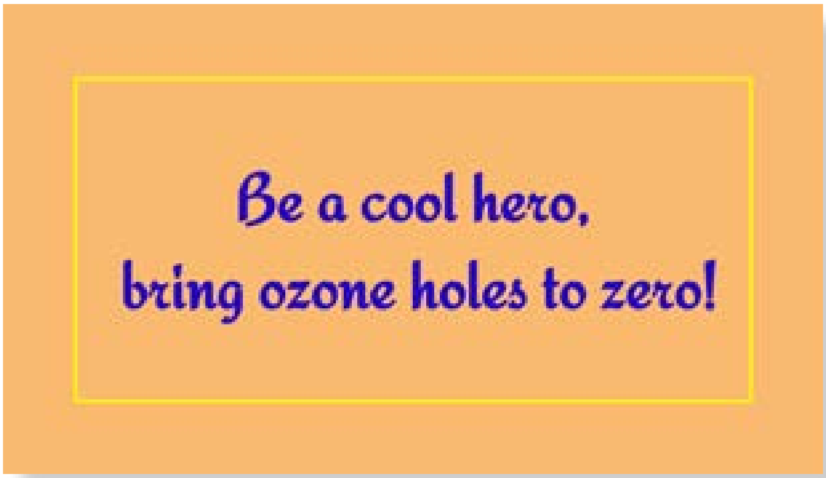
Name : Nitish Vanshkar
Class : 12, Section - K
School : Govt. Excellence Higher Secondary School
State : Madhya Pradesh

Third Prize Winning Entry

Name : Dhruvika
Class : IX
School : Stalwarts World School
State : Punjab

Consolation Prize Winning Entry

Name : Bipasha Kumari
Class : XI, Section - B
School : Holy Cross School
State : Jharkhand



Consolation Prize Winning Entry

Name : Arijit Das

Class : XI, Section – Science

School : Howri Dinanath High School

State : West Bengal

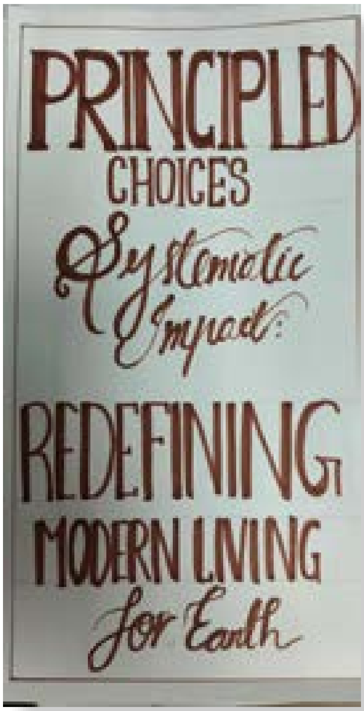
Consolation Prize Winning Entry

Name : Anubhav Soni

Class : 11, Section - A

School : P. M. Shri School, J.N.V. Chisda

State : Chhattisgarh



Consolation Prize Winning Entry

Name : Tanmay Kumar Mohanty
Class : XII, Section – Commerce
School : D. A. V. Public School, CSPUR
State : Odisha

Consolation Prize Winning Entry

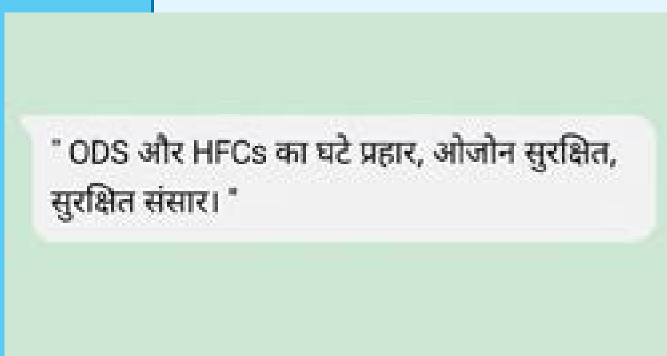
Name : Debasmita Layek
Class : IX, Section – A
School : Indpur Sarojini Balika Vidyalaya
State : West Bengal

Slogan Writing Competition

1ST PRIZE

Saee Sachin Mahadik

Class – X, Section – A
Navyug Marathi
Madhyamik Vidyalaya
Ladvali, Tal – Mahad, Dist. Raigad,
Maharashtra



2ND PRIZE

Nitish Vanshkar

Class – 12, Section – K
Govt. Excellence Higher
Secondary School, Venkat No. 1
Prem Nagar, Dhawari, Dist. Satna,
Madhya Pradesh

3RD PRIZE

Dhruvika

Class – IX
Stalwarts World School
Opposite Fortis Escorts Hospital,
Verka Bypass, Amritsar, Punjab

SEPTEMBER 2026

WHOM TO CONTACT TO LEARN MORE ABOUT OZONE

Ozone Cell
Ministry of Environment, Forest and Climate Change
Government of India
1st Floor, 9 Institutional Area, Lodhi Road, New Delhi-110003
Tel.: 011-2464 2176
Website: http://ozonecell.nic.in