



# HFCs: A Critical Link in Protecting Climate and the Ozone Layer

A UNEP Synthesis Report



Published by the United Nations Environment Programme (UNEP), November 2011

Copyright © UNEP 2011

ISBN: 978-92-807-3228-3

DEW/1469/NA

This publication may be reproduced in whole or in part and in any form for educational or non-profit services without special permission from the copyright holder, provided acknowledgement of the source is made. UNEP would appreciate receiving a copy of any publication that uses this publication as a source.

No use of this publication may be made for resale or any other commercial purpose whatsoever without prior permission in writing from the United Nations Environment Programme. Applications for such permission, with a statement of the purpose and extent of the reproduction, should be addressed to the Director, DCPI, UNEP, P.O. Box 30552, Nairobi 00100, Kenya.

#### **Disclaimers**

Mention of a commercial company or product in this document does not imply endorsement by UNEP or the authors. The use of information from this document for publicity or advertising is not permitted. Trademark names and symbols are used in an editorial fashion with no intention on infringement on trademark or copyright laws.

We regret any errors or omissions that may have been unwittingly made.

© Images and illustrations as specified.

#### **Citation**

This document may be cited as:

UNEP 2011. HFCs: A Critical Link in Protecting Climate and the Ozone Layer. United Nations Environment Programme (UNEP), 36pp

A digital copy of this report can be downloaded at [http://www.unep.org/dewa/Portals/67/pdf/HFC\\_report.pdf](http://www.unep.org/dewa/Portals/67/pdf/HFC_report.pdf)



UNEP promotes environmentally sound practices globally and in its own activities. This publication is printed on 100% recycled paper using vegetable based inks and other eco-friendly practices. Our distribution policy aims to reduce UNEP's carbon footprint.



# **HFCs: A Critical Link in Protecting Climate and the Ozone Layer**

A UNEP Synthesis Report

November 2011



# Acknowledgements

The United Nations Environment Programme (UNEP) would like to thank the Steering Committee, all the lead authors, reviewers and the Secretariat for their contribution to the development of this report.

The following individuals and/or organizations have provided scientific input to the report. Authors have contributed to this report in their individual capacity and their organizations are mentioned for identification purposes.

## **Steering Committee Members:**

Joseph Alcamo – Chair (UNEP), Marco Gonzalez (UNEP), Sylvie Lemmet (UNEP), Kaveh Zahedi (UNEP), Rajendra Shende (TERRE Policy Centre, India).

## **Lead Authors:**

A.R. Ravishankara - Coordinator (National Oceanic and Atmospheric Administration – NOAA, USA), Guus J.M. Velders (National Institute for Public Health and the Environment – RIVM, The Netherlands), M.K. Miller (Touchdown Consulting, Belgium), Mario Molina (Centro Mario Molina, Mexico and University of California, San Diego, USA).

## **Scientific and Technical Reviewers:**

Roberto R. Aguilo (Universidad Nacional de Luján, Argentina), Stephen O. Andersen (Institute for Governance & Sustainable Development – IGSD, USA), Atul Bagai (UNEP), Guangming Chen (China Institute for Refrigeration, China), Didier Coulomb (International Institute of Refrigeration, France), John Daniel (National Oceanic and Atmospheric Administration – NOAA, USA), David A. Fahey (National Oceanic and Atmospheric Administration – NOAA, USA), Neil Harris (University of Cambridge, United Kingdom), Sanjeev Jain (Indian Institute of Technology, India), Sitaram Joshi (National Bureau of Standards and Metrology, Nepal), Janusz Kozakiewicz (Industrial Chemistry Research Institute, Poland), Janos Maté (Greenpeace International), Mack McFarland (Dupont, USA), John N. Muthama (University of Nairobi, Kenya), Stefan Reimann (Swiss Federal Laboratories for Materials Science and Technology – Empa, Switzerland), Agustin Sanchez (SEMARNAT,

Mexico) William Sturges (University of East Anglia, United Kingdom), Donald Wuebbles (University of Illinois, USA), Syed M. Zubair (King Fahd University, Saudi Arabia).

## **Contributors of Information/Data:**

John Daniel (National Oceanic and Atmospheric Administration – NOAA, USA), Stephen Montzka (National Oceanic and Atmospheric Administration – NOAA, USA), Stefan Reimann (Swiss Federal Laboratories for Materials Science and Technology – Empa, Switzerland), Paul Newman (NASA Goddard Space Flight Centre, USA), David A. Fahey (National Oceanic and Atmospheric Administration – NOAA, USA).

## **Editorial Support:**

Joseph Alcamo (UNEP), Alison Colls - Science Editor (Icicle Climate Communications, Switzerland), Sunday A. Leonard (UNEP).

## **UNEP Secretariat:**

Sunday A. Leonard - Project Management, Harsha Dave, Linda Duquesnoy, Ron Witt.

## **Production Team:**

Hilary Barnes (Robsondowry Ltd), Pourn Ghaffapour (UNON), Gideon Mureithi (UNON), Paul Odhiambo (UNON), Neeyati Patel (UNEP), Audrey Ringler (UNEP).

## **Layout and Printing:**

UNON, Publishing Services Section,  
ISO 14001:2004 - certified.

# Contents

<b>Acknowledgements</b>	<b>3</b>
<b>Glossary</b>	<b>5</b>
<b>Foreword</b>	<b>8</b>
<b>Executive summary</b>	<b>9</b>
<b>1. Montreal Protocol and ozone layer protection</b>	<b>13</b>
1.1 The Montreal Protocol has successfully protected the ozone layer	13
1.2 The Montreal Protocol is gradually phasing out ODSs	14
1.3 The Montreal Protocol is working as expected and intended	16
1.4 HFCs are substitutes for ODSs	16
1.5 Many HFCs are potent greenhouse gases	17
<b>2. Climate benefits of the Montreal Protocol</b>	<b>18</b>
2.1 Actions under the Montreal Protocol have reduced and avoided emissions of important greenhouse gases	18
2.2 Actions under the Montreal Protocol have reduced radiative forcing by ODSs	18
2.3 Some of the climate benefits of the Montreal Protocol have been offset	18
2.4 The climate benefits of the Montreal Protocol are greater than the Kyoto target	19
<b>3. HFCs and climate change</b>	<b>20</b>
3.1 The atmospheric abundances of HFCs are increasing rapidly	20
3.2 Equivalent CO <sub>2</sub> emissions of HFCs are still small compared to other emissions but increasing rapidly	20
3.3 The current contribution of HFCs to climate forcing is small but rapidly growing	20
3.4 Different types of future HFC emissions scenarios have been constructed	22
3.5 HFC emissions have the potential to become very large and at least partly offset the climate benefits of the Montreal Protocol	22
3.6 The radiative forcing of HFCs is also projected to significantly increase	23
3.7 HFC emissions also have indirect climate effects	24
3.8 Different HFCs have different atmospheric lifetimes and vary in their ability to influence climate	24
3.9 A scenario in which only low-GWP HFCs are used has a low climate influence	26
<b>4. Alternatives to high-GWP HFCs</b>	<b>27</b>
4.1 Methods for reducing the influence of high-GWP HFCs on climate have been identified	27
4.2 Low-GWP alternatives offer the potential to minimize the influence of high-GWP HFCs on climate	27
4.3 Low-GWP alternatives are already in commercial use	29
4.4 More alternatives are under development	29
4.5 Case study: Alternatives adopted by manufacturers of household refrigeration and small air-conditioning units	30
4.6 Case study: Technical developments in vehicle air-conditioning systems	30
4.7 Case study: End-user companies pledge to use low-GWP technologies	31
4.8 There are barriers to the adoption of low-GWP alternatives but also many ways to overcome them	31
4.9 There is no 'one-size fits all' alternative to high-GWP HFCs	33
4.10 Going forward	33
<b>References</b>	<b>34</b>

# Glossary

**Article 5 Countries:** Any party of the Montreal Protocol who is a developing country and whose annual per capita consumption of the controlled substances is below the limits set in Article 5 of the Protocol.

**Atmospheric lifetime:** Time it takes for 67% of a molecules to be removed from the atmosphere in the absence of emissions.

**Atmospheric mixing ratio:** The fractional composition of a chemical in the atmosphere relative to the sum of all air molecules in the atmosphere.

The mixing ratio of a chemical is the number of molecules of X in a unit volume divided by the number of air molecules in a unit volume. Mixing ratios are usually expressed as parts-per-million (ppm), parts-per-billion (ppb), or parts-per-trillion (ppt).

**Carbon dioxide equivalent (CO<sub>2</sub>eq):** A simple way to place emissions of various climate change agents on a common footing to account for their effect on climate.

A quantity that describes, for a given mixture and amount of greenhouse gas, the amount of carbon dioxide that would have the same global warming ability, when measured over a specified timescale.

**Chlorofluorocarbons (CFCs):** Molecules containing carbon, fluorine, and chlorine. CFCs are the major ozone depleting substances already phased out by the Montreal Protocol. Many CFCs are potent greenhouse gases.

**Drop-in alternatives:** Substances that can be used in existing equipment with very little or no modification to the equipment. Drop-in replacements were used to quickly replace CFCs. Examples include use of HCFC-22 in air conditioners. Such replacements are also possible with some HFCs.

**Global Warming Potential (GWP):** A relative index that enables comparison of the climate effect of the emissions of various greenhouse gases (and other climate changing agents). Carbon dioxide, the greenhouse gas that causes

the greatest radiative forcing because of its overwhelming abundance, is chosen as the reference gas.

GWP is also defined as an index based on the radiative forcing of a pulsed injection of a unit mass of a given well-mixed greenhouse gas in the present-day atmosphere, integrated over a chosen time horizon, relative to the radiative forcing of carbon dioxide over the same time horizon. The GWPs represent the combined effect of the differing atmospheric lifetimes (i.e., how long these gases remain in the atmosphere) and their relative effectiveness in absorbing outgoing thermal infrared radiation. The Kyoto Protocol is based on GWPs from pulse emissions over a 100-year time frame.

**20-year GWP:** Global warming potential (see above) calculated for a time horizon of 20 years.

**100-year GWP:** Global warming potential (see above) calculated for a time horizon of 100 years.

**GWP Weighting:** A mathematical product of the emissions in tonnes and the GWP of a substance. GWP weighting is used routinely to evaluate the relative climate impact of emissions of various gases (by mass).

**Hydrochlorofluorocarbons (HCFCs):** Chemicals that contains hydrogen, fluorine, chlorine, and carbon. They do deplete the ozone layer, but have less potency compared to CFCs. Many HCFCs are potent greenhouse gases.

**Hydrofluorocarbons (HFCs):** Chemicals that contains hydrogen, fluorine, and carbon. They do not deplete the ozone layer and have been used as substitutes for CFCs and HCFCs. Many HFCs are potent greenhouse gases.

**Indirect climate effects:** A metric that accounts for climate effects caused by the use of a product, such as increased energy consumption.

Additional climate forcing due to the energy used, or saved, during the application or product lifetime, as well as the energy used to manufacture the product, and any ODSs or HFCs used. For example, insulating foam

products in buildings and appliances reduces energy consumption, whereas refrigeration and air-conditioning systems consume energy over their lifetimes. Analyses of the total potential climate impact of specific products can be estimated by life cycle climate performance (LCCP) or similar models that account for all direct and indirect contributions.

**Indirect radiative forcing:** A metric that accounts for effects on the climate system of a given agent as a result of changes induced in other climate forcing agents. For example, the climate effects of ozone layer depletion caused by ODSs.

In this report, indirect radiative forcing refers to the change in ozone radiative forcing due to the addition of ODSs. Stratospheric ozone losses are generally thought to cause a negative radiative forcing, cancelling part of the increased radiative forcing arising from the direct influence of the halocarbons. The magnitude of the indirect effect is strongly dependent on the altitude profile of the halogen-induced ozone loss and will vary depending on the source gas considered.

**Intervention scenarios:** A scenario where action is taken to change the amount of emissions of a given chemical.

**Non-article 5 countries:** Developed countries.

**Not-in-kind alternatives:** Products or technologies not using halocarbons. Not-in-kind alternative technologies achieve the same product objective without the use of halocarbons, typically by using an alternative approach or unconventional technique. Examples include the use of stick or spray pump deodorants to replace CFC-12 aerosol deodorants; the use of mineral wool to replace CFC, HFC or HCFC insulating foam; and the use of dry powder inhalers (DPIs) to replace CFC or HFC metered dose inhalers (MDIs).

**Ozone Depletion Potential (ODP):** A measure of the extent of ozone layer depletion by a given ozone depleting substance, relative to that depleted by CFC-11. (CFC-11 has an ODP of 1.0).

There are many variants of ODPs. In this report, we use only the steady-state ODP, which is used by the Montreal Protocol. Steady-state ODP is defined by the time-integrated change of global ozone due to a unit mass emission of the ODS at the Earth's surface, relative to that from a similar emission of a unit mass of CFC-11.

**Radiative Forcing:** A measure of how a climate forcing agent influences the energy balance of Earth, with a positive value indicating a net heat gain to the lower atmosphere, which leads to a globally average surface temperature increase, and a negative value indicating a net heat loss.

Radiative forcing is the instantaneous change in the net, downward minus upward, irradiance (expressed in  $\text{W m}^{-2}$ ) at the tropopause due to a change in an external driver of climate change, such as, a change in the concentration of a greenhouse gas (e.g., carbon dioxide), land use change, or the output of the Sun. Radiative forcing is computed with all tropospheric properties held fixed at their unperturbed values, and after allowing for stratospheric temperatures, if perturbed, to readjust to radiative-dynamical equilibrium.

**Short-lived climate forcers:** Substances (mainly chemicals) that influence climate but whose influence is quickly reduced once their emissions cease. These molecules are quickly removed from the atmosphere.

**Stratospheric ozone:** Ozone ( $\text{O}_3$ ) present in the stratosphere located between roughly 15 and 45 km above Earth's surface.

**Transitional substitute:** Substitutes for CFCs, Halons, and few other ODSs that were introduced with the idea

预览已结束，完整报告链接和二维码如下：

[https://www.yunbaogao.cn/report/index/report?reportId=5\\_9781](https://www.yunbaogao.cn/report/index/report?reportId=5_9781)

