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Win-win solutions for the climate and the ozone layer.

A simplified guide to the Special Report on HFCs and PFCs from the Intergovernmental Panel on Climate Change and the Technical and Economic Assessment Panel

Win-win solutions for the climate and the ozone layer

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A guide to the acronyms

CFCs – Chlorofluorocarbons have caused the greatest amount of ozone depletion. They are also powerful greenhouse gases. They will soon be almost completely phased out under the Montreal Protocol on Substances That Deplete the Ozone Layer.

HCs – Hydrocarbons are ozone- and climate-friendly substitutes for CFCs. They are flammable and toxic, however, which currently limits their applications.

HCFCs – Hydrochlorofluorocarbons were the first CFC substitutes to reach the market. Although much safer than CFCs, they do harm the ozone layer and contribute to global warming. They will therefore be phased out under the Montreal Protocol over the next several decades.

HFCs – Hydrofluorocarbons are completely ozone-safe substitutes. However, because they are powerful greenhouse gases, they are included in the Kyoto Protocol on climate change.

PFCs – Perfluorocarbons are completely ozone-safe substitutes. However, because they are powerful greenhouse gases, they are included in the Kyoto Protocol.

Introduction

After some 20 years of effective action under the Montreal Protocol on Substances that Deplete the Ozone Layer, governments are now addressing the fact that chlorofluorocarbons (CFCs) and some of the chemicals used as substitutes for them are greenhouse gases that together contribute significantly to global warming.

Policymakers face a serious dilemma. Stopping the destruction of the ozone layer is vital for protecting human health and vulnerable ecosystems. But minimizing climate change and its expected consequences for both man-made and natural systems is also essential. What can be done to tackle both the ozone and climate change challenges without making unacceptable trade-offs or compromises?

To answer this question, the governing bodies of the Montreal Protocol and the United Nations Framework Convention on Climate Change jointly requested a scientific and technical assessment. Working Groups I (science) and III (mitigation) of the Intergovernmental Panel on Climate Change (IPCC), together with the ozone regime's Technology and Economic Assessment Panel (TEAP), responded by producing a Special Report in April 2005 entitled "Safeguarding the ozone layer and the global climate system: issues related to hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs)".

Based on the most up-to-date scientific and technical literature available, the report concludes that it will indeed be possible to maintain the Montreal Protocol's momentum while achieving the goals of the Climate Change Convention and its Kyoto Protocol. It identifies a portfolio of solutions that – if energetically applied – could **cut the global warming contribution of CFCs and their replacements in half by the year 2015 compared to 2002 levels**. This reduction can be achieved even though global economic growth will boost demand for the functions traditionally provided by CFCs.

UNEP has produced this short public information booklet with the aim of making the Special Report's technical findings more accessible to the general reader.

CFCs → HCFCs → HFCs

Climate change and ozone depletion are essentially two separate issues, with their own sets of causes, impacts and solutions. Nevertheless, they are linked to one another in important ways by the chemistry of certain man-made gases and by the chemistry of the atmosphere.

The story begins in 1928, with the invention of CFCs. Chemically stable, non-toxic, non-corrosive, nonflammable and versatile, CFCs became increasingly important by the 1960s in refrigerators, air conditioners, spray cans, solvents, foams and other applications.

But because of their chemical stability, CFCs and other related substances remain in the atmosphere for many years. They gradually drift up into the stratosphere where they finally decompose, but not before catalyzing the destruction of the ozone molecules (O_3) that protect life on earth from solar radiation. In the mid-1980s, scientists discovered the Antarctic ozone "hole", revealing that the ozone layer had deteriorated much more than predicted. Alarmed, governments moved quickly to adopt the 1987 Montreal Protocol. The Protocol established strict schedules for phasing out CFCs – the prime culprits – and other ozone-destroying gases such as halons and carbon tetrachloride.

Corporations stepped up their research into substitutes for the soon-to-be-banned chemicals. Developing alternatives posed a real challenge, as CFCs in particular had come to play such a central role in so many products. But industry quickly succeeded in introducing hydrochlorofluorocarbons (HCFCs), which had already been under development, as the first generation of replacement chemicals.

Unfortunately, while much less destructive than CFCs, HCFCs also deplete the ozone layer. And, although much less potent than the CFCs they are replacing, HCFCs are greenhouse gases. This caused concern at a time when climate change was just starting to become a major global issue.

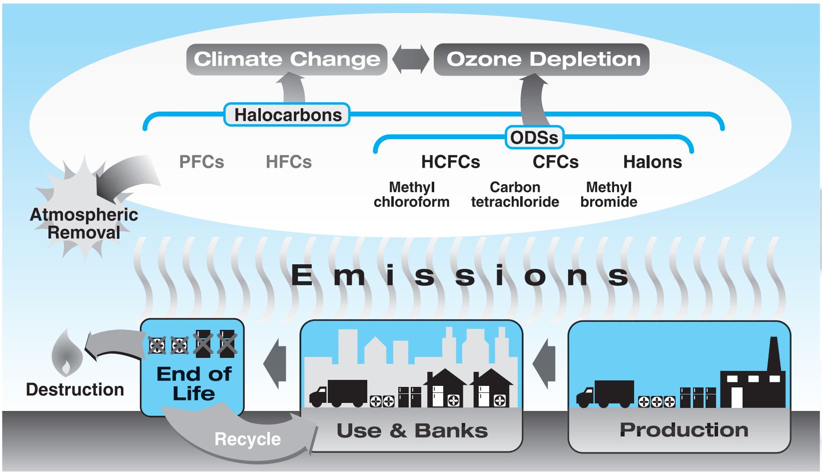
Recognizing that HCFCs were not completely ozone-safe, governments agreed to treat them as transitional substances to be phased out under the Montreal Protocol. Developed countries are to reduce HCFC consumption by 65% by 2010 and 99.5% by 2020. However, HCFC production continues to expand in developing countries, which have until 2016 to freeze their consumption of HCFCs and until 2040 to eliminate them completely.

In the 1990s, corporations started to market the second generation of CFC substitutes, notably hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs). HFCs and PFCs are 100% ozone-friendly, but because most of them are powerful greenhouse gases, they have been included in the basket of six gases whose emissions are controlled under the 1997 Kyoto Protocol on climate change.

Other chemicals currently seen as important alternatives, such as hydrocarbons (HCs), ammonia and carbon dioxide, have already been in use for a long time, particularly in refrigerating equipment. They are both ozone-friendly and climate-safe. However, due to their toxic and flammable qualities they are not yet fully compatible with all available technologies and applications.

Meanwhile, scientists discovered new links between climate change and ozone depletion. They found that the destruction of stratospheric ozone – which is itself a greenhouse gas – indirectly helps to cool the climate. However, the amount of indirect cooling is very likely less than the amount of warming caused directly by ozone-depleting greenhouse gases. In addition, these are two different mechanisms that do not simply offset one another. The net effect is different for each gas: ozone-depleting halons contribute mainly to cooling, while CFCs and HCFCs contribute much more to warming than cooling, and HFCs and PFCs contribute only to warming.

What this complex set of linkages boils down to is this: the transition from CFCs to HCFCs and later to HFCs provided a rapid first response to the ozone problem and eliminated most uses of the more-harmful CFCs. However, as recognized by the Montreal Protocol, HCFCs do eventually need to be phased out. The use of second-generation replacement chemicals, notably HFCs, also raises policy questions because of their role in climate change and their inclusion in the Kyoto Protocol. Fortunately, a growing number of technical and policy options are becoming available that can minimize the need for HFCs and protect both the ozone layer and the global climate.



Schematic diagram of how CFCs and their substitutes contribute to ozone depletion and climate change. Source: IPCC/TEAP Special Report, 2005.

A portfolio of solutions

Some of the available policies and measures for addressing the ozone-climate policy dilemma involve preventing CFCs and CFC replacements that are already in use from entering the atmosphere. Others seek to minimize the future demand for these greenhouse gases.

The specific solutions that are available vary from application to application. All of them will cost money. However, some solutions for replacing CFCs and their current substitutes appear to be relatively inexpensive when compared with options for reducing carbon dioxide and other greenhouse gases.

Emissions from yesterday's production

Virtually all ozone-depleting substances and their replacements are currently used in closed, or contained, systems. As a result, they are generally not emitted until years or even decades after being produced. Large amounts of CFCs still exist in refrigerators, air conditioners, insulating foams and chemical stockpiles, from which they can leak. When equipment is decommissioned, the chemicals are typically (and unfortunately) released into the atmosphere. In the technical literature, the chemicals contained in products or stored in tanks are defined as banks.

Based on measurements of changing atmospheric concentrations, a substantial proportion of current emissions of CFC-11 and CFC-12 – the two most common CFCs – come from these banks. Not surprisingly, global emissions of HFCs and HCFCs, which entered into use more recently than CFCs, are lower than their current reported production; nevertheless, banks of these substitute chemicals are still being built up. The risk is that they could be released into the atmosphere at a later date.

Reducing leaks from banks would substantially lower greenhouse gas emissions, benefiting both the ozone layer and the climate system. Most of the bank-related emissions that can be prevented between now and 2015 are from refrigeration. These emissions cuts could be achieved through improved and expanded operations for the recovery of equipment once it has reached the end of its useful life and for final destruction. Measures and technologies for reducing leaks and evaporation through improved containment could also be helpful.

Emissions from tomorrow's production

In addition to reducing emissions from banks, a number of options are available for reducing emissions from future production and future banks:

1. Reduce the amounts of harmful chemicals needed in any particular type of equipment;

2. Increase the use of ammonia, hydrocarbons (HCs) and other alternative substances that do not contribute to global warming; and

3. Adopt various emerging technologies that avoid the use of ozone-depleting or greenhouse gases. Determining which technology option is best for the climate can be difficult due to the limited quantity of published data and comparative analyses. Ideally, the indirect energy-related emissions of carbon dioxide (which can be significant) over the full life cycle of a piece of equipment should be factored in.

Policies and measures

Policymakers have at their disposal a range of policies, measures and instruments that can be used to discourage emissions from both past and future production. These include:

1. Regulations, such as performance standards, certification, restrictions and end-of-life management;

2. Economic instruments, including taxation, emissions trading, financial incentives and deposit refunds;

3. Voluntary agreements, notably voluntary reductions in use and emissions, industry partnerships and implementation of good practice guidelines; and

4. International cooperation mechanisms, such as the Kyoto Protocol's Clean Development Mechanism and (for phasing out CFCs in developing countries) the Montreal Protocol's Multilateral Fund.

Different applications, different solutions

The Special Report considers the most important options for minimizing the climate impact of CFCs and their replacements sector by sector. Looking out as far as the year 2015 (beyond which the results of technology innovation are difficult to predict), it reaches the following conclusions.

Direct greenhouse gas emissions from **refrigeration** can be reduced by 10-30% by 2015 (compared to 2002 levels). Improved energy efficiencies could also significantly reduce emissions from fossil fuels used for producing energy. Refrigerating equipment (and air conditioners) have so far largely used HCFCs to replace CFCs. Newer equipment is increasingly using replacements with zero ozone-depleting potential, including HFCs, ammonia and hydrocarbons.

Available solutions for full supermarket systems include replacing CFCs and HCFCs with alternative refrigerants, improving containment and adopting various innovative efficiency improvements. For food processing, cold storage and industrial refrigeration, HFCs will increasingly replace HCFC-22 and CFCs; the use of ammonia and a combination of ammonia and carbon dioxide is also expected to rise. In certain refrigerated transport applications, ammonia and hydrocarbons have already been commercialized. Similarly, domestic refrigerators are already well advanced in their transition to hydrocarbons in several parts of the world (in Europe, for example, they are already HFC-free).

Direct greenhouse emissions from **air conditioning and heating systems** can be reduced by improving the recovery of refrigerants from obsolete equipment, reducing the amount of refrigerant used, improving containment and using refrigerants with a reduced or negligible impact on the climate. It may also be possible to reduce indirect (energy-related) emissions through more energy-efficient systems and improved building designs that reduce heat gain or loss.

HFC mixtures, ammonia and some hydrocarbons are already being used as alternatives to HCFC-22 for many systems in developed countries. For mobile air conditioners, better containment, end-of-life recovery and recycling could reduce direct emissions of greenhouse gases (mainly HFCs) by up to 50%, or total direct and indirect emissions by 30-40%.

Because **foams** tend to have such long lifetimes, the greatest potential for reducing emissions from existing banks will occur after 2015; many banks of insulating foams contained in buildings will be decommissioned between 2030 and 2050. Today CFC-free foams are being produced with water, carbon dioxide, hydrocarbons, HFCs and (decreasingly) HCFCs.

Reducing emissions from **medical aerosols** has limited potential due to medical constraints, the relatively low level of current emissions and the high costs of alternatives. Non-medical aerosols and solvents also offer little potential because most remaining uses are critical to performance or safety.

Replacing the remaining halons still contained in **fire-protection** equipment also has limited potential. Current emission levels are low, and much of the transition to alternatives has already taken place.

The price tag

Efforts to minimize emissions of CFCs and their replacements will cost money. The estimated costs vary widely and depend on the type and size of each particular piece of equipment and the solution employed. In addition, much of the data needed to assess likely costs are proprietary and thus not available in published journals.

Nevertheless, the costs of a few options can be meaningfully assessed. Incinerators for destroying the HFC byproducts of HCFC manufacture could cost hundreds or thousands of dollars per unit. Some studies suggest that replacing HFCs in a household refrigerator could cost from zero to US$30, while replacing HFCs in an automobile air-conditioning unit could cost from US$48 to US$180. The costs for reducing emissions from bigger equipment, such as large-scale supermarket systems, would be much higher.

When compared to many other ways of reducing greenhouse gas emissions, some of these costs appear to be relatively low. In addition, some of the climate-friendly alternatives to CFCs will also reduce energy use, and thus yearly energy costs and associated carbon dioxide emissions.

Seizing opportunities

The history of the Montreal Protocol gives cause for optimism that greenhouse gas emissions from CFC substitutes can indeed be reduced by 2015. Under the Protocol, the phase out of ozone-depleting substances has proceeded faster and more cheaply than anyone expected. Sustaining the fruitful cooperation between science and industry that made this possible could lead to similar success in reducing the climate impacts of HFCs and PFCs.

Although HCFCs and HFCs are greenhouse gases, it is useful to keep in mind that the CFCs they replace had a much greater impact on both the ozone layer and the climate. As a result, the relative contribution that this group of chemicals made to global warming from 1990 to 2000 declined from 33% to 10% when compared to the emissions from fossil-fuel combustion.

Nevertheless, this means that emissions of CFCs and their substitutes still contribute around 5% of humanity's total greenhouse gas emissions from fossil fuels and other sources. This is a significant amount. Furthermore, under a business-as-usual scenario (which assumes that existing regulations and practices continue unchanged), the total combined direct greenhouse emissions of CFCs, HCFCs, HFCs and PFCs are projected to decline only slightly by 2015 compared to 2005. This is because the decline in CFCs will be almost balanced by the increased reliance on HCFCs and HFCs and by the higher overall demand for such substances in a growing global economy. (The use of PFCs as substitutes for ozone-depleting substances, however, is projected to decrease.)

Fortunately, the current best practices and recovery methods described in the IPCC/TEAP Special Report could – if more fully exploited than under a business-as-usual scenario – cut the global warming contribution of ozone-depleting substances and their greenhouse substitutes in half by 2015 (compared to 2002). About 60% of this potential involves HFC emissions, 30% involves HCFCs, and 10% involves CFCs.

Thanks to an accident of chemistry, CFCs and their replacements – which have virtually defined the modern lifestyle – have been implicated in not one, but two of today's most serious global challenges: the destruction of the ozone layer and climate change. The coming decade could provide a critical opportunity for moving beyond the consequences of this unforeseen coincidence.

About the Assessment Panels

The United Nations Environment Programme's **Technology and Economic Assessment Panel (TEAP)** supports the Parties to the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer. It provides objective and technical information about new technologies and substitutes for ozone-depleting substances. The TEAP and its Technical Options Committees engage some 200 experts around the world to produce a comprehensive assessment report every four years.

The TEAP also produces other reports, generally several per year, and establishes Task Forces to address specialized issues as they arise. Its rigorous approach to assessing the technological and economic literature relevant to ozone depletion has been widely recognized as a key reason for the Protocol's success.

The **Intergovernmental Panel on Climate Change (IPCC)** was established in 1988 by the World Meteorological Organization (WMO) and UNEP. Its mandate is to make policy-relevant assessments of the worldwide literature on the scientific, technical and socio-economic aspects of climate change. The IPCC's various assessment reports, special reports, technical papers and methodologies have become standard works of reference for climate change policymakers, experts and students.

The IPCC's First Assessment Report, completed in 1990, helped inspire governments to adopt the 1992 United Nations Framework Convention on Climate Change. Its Second Assessment Report was published in 1996 and played a key role in the negotiations that led to the 1997 Kyoto Protocol. The Third Assessment Report was released in 2001, and the Fourth Assessment Report will be finalized in 2007.

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