Greening of Industry under the Montreal Protocol

Background Paper

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

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1. INTRODUCTION

The issues of ozone depletion and climate change have been at the forefront of the international community's environmental agenda for a number of years. It is now generally accepted that man-made chemicals and human activities are having a significant adverse impact on the global climate.

The ozone layer over the Antarctic has steadily weakened since measurements began in the 1980s. By 2003, the size of the ozone hole peaked at some 28 million square kilometres, making it the second largest on record.

The phase-out of CFCs, which have a high global warming potential, has resulted in a significant reduction of carbon dioxide (CO_2)-equivalent emissions.

The side event to the International Conference on Green Industry in Asia, organized by UNIDO, will shed light on how the phase-out of CFCs solely through the Organization's projects in more than 85 developing countries during the last 15 years has resulted in reduction of the climate impact of industry by the net equivalent of 360 million tons of CO_2 annually. The recently adopted accelerated phase-out programme of the Montreal Protocol should open the way to a further drastic reduction of ozone-depleting and greenhouse gas emissions.

2. ENVIRONMENTAL IMPACT

2.1. Ozone depletion

A number of commonly used chemicals have been found to be extremely damaging to the ozone layer. Halocarbons are chemicals in which one or more carbon atoms are linked to one or more halogen atoms (fluorine, chlorine, bromine or iodine). Halocarbons containing bromine usually have much higher ozone-depleting potential (ODP) than those containing chlorine. The man-made chemicals that have provided most of the chlorine and bromine for ozone depletion are methyl bromide, methyl chloroform, carbon tetrachloride and families of chemicals known as halons, chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs).

The scientific confirmation of the depletion of the ozone layer prompted the international community to establish a mechanism for cooperation to take action to protect the ozone layer. This was formalized in the Vienna Convention for the Protection of the Ozone Layer, which was adopted and signed by 28 countries, on 22 March 1985. In September 1987, this led to the drafting of The Montreal Protocol on Substances that Deplete the Ozone Layer.

The principal aim of the Montreal Protocol is to protect the ozone layer by taking measures to control total global production and consumption of substances that deplete it, with the ultimate objective of their elimination on the basis of developments in scientific knowledge and technological information.

Table 1. Examples of ozone depleting potentials

Chemical	*Common name*	*ODP*
Chlorodifluoromethane	HCFC-22	0.05
1,1,1 trichloroethane	methyl chloroform	0.12
Monochloropentafluoroethane	CFC-115	0.60
Trichlorofluoromethane	CFC-11	1.00
Carbon tetrachloride	carbon tetrachloride	1.10
Bromochlorodifluoromethane	Halon 1211	3.00
Bromotrifluoromethane	Halon 1301	10.00

Source: Ozone Secretariat Handbook 2006

The Montreal Protocol is structured around several groups of ozone-depleting substances. The groups of chemicals are classified according to the chemical family and are listed in annexes to the Montreal Protocol text.

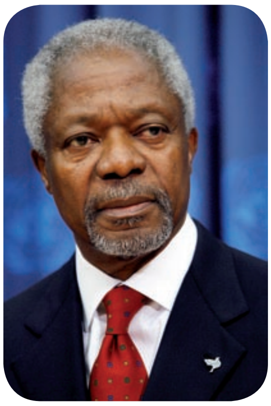
The Montreal Protocol requires the control of nearly 100 chemicals, in several categories. For each group or annex of chemicals, the Treaty sets out a timetable for the phase-out of production and consumption of those substances, with the aim of eventually eliminating them completely.

The timetable set by the Montreal Protocol applies to consumption of ozone depleting substances. Consumption is defined as the quantities produced plus imported, less those quantities exported in any given year. There is also a deduction for verified destruction.

Percentage reductions relate to the designated base-line year for the substance. The Protocol does not forbid the use of existing or recycled controlled substances beyond the phase-out dates.

There are a few exceptions for essential uses where no acceptable substitutes have been found, for example, in metered dose inhalers (MDI) commonly used to treat asthma and other respiratory problems or halon fire-suppression systems used in submarines and aircraft.

Implementation of the Montreal Protocol progressed well in developed and developing countries. All phase-out schedules were adhered to in most cases, some even ahead of schedule. In view of the steady progress made under the Protocol, already in 2003, former United Nations Secretary-General Kofi Annan stated "Perhaps the single most successful international agreement to date has been the Montreal Protocol". His views are shared widely in the international community.



"Perhaps the single most successful international agreement to date has been the Montreal Protocol." - Kofi Annan, Former Secretary-General of the United Nations

Attention focused initially on chemicals with higher ozone-depletion potentials including CFCs and halons. The phase-out schedule for HCFCs was more relaxed due to their lower ozone-depletion potentials and because they have also been used as transitional substitutes for CFCs.

The HCFC phase-out schedule was introduced in 1992 for developed and developing countries, the latter with a freeze in 2015, and final phase-out by 2030 in developed countries and 2040 in developing countries.

In 2007, Parties to the Montreal Protocol decided to accelerate the HCFC phase-out schedule for both developed and developing countries. The current schedule reflecting this latest decision is set out in table 2.

Table 2. Summary of Montreal Protocol controls for ozone-depleting substances

Ozone-depleting substances	*Phase-out schedule for developed countries*	*Phase-out schedule for developing countries*
Chlorofluorocarbons (CFCs) annex A, group I	Phased out end of 1995[a]	Total phase-out by 2010
Halons annex A, group II	Phased out end of 1993	Total phase-out by 2010
Other fully halogenated CFCs annex B, group I	Phased out end of 1995	Total phase-out by 2010
Carbon tetrachloride annex B, group II	Phased out end of 1995[a]	Total phase-out by 2010
Methyl chloroform annex B, group III	Phased out end of 1995[a]	Total phase-out by 2015
Hydrochlorofluorocarbons (HCFCs) annex C, group I	Freeze from beginning of 1996[b] 35 % reduction by 2004 75 % reduction by 2010 90% reduction by 2015 Total phase-out by 2020[c]	Freeze in 2013 at a base level calculated as the average of 2009 and 2010 consumption levels 10 % reduction by 2015 35 % reduction by 2020 67.5 % reduction by 2025 Total phase-out by 2030[d]
Hydrobromofluorocarbons (HBFCs) annex C, group II	Phased out end of 1995	Phased out end of 1995
Methyl bromide (horticultural uses) annex E, group I	Freeze in 1995 at 1991 base level[e] 25 % reduction by 1999 50 % reduction by 2001 70 % reduction by 2003 Total phase-out by 2005	Freeze in 2002 at average 1995-1998 base level[e] 20 % reduction by 2005 Total phase-out by 2015
Bromochloromethane (BCM). annex C, group III	Phase-out by 2002	Phase-out by 2002

[a] With the exception of a very small number of internationally agreed essential uses that are considered critical to human health and/or laboratory and analytical procedures.
[b] Based on 1989 HCFC consumption, with an extra allowance (ODP-weighted) equal to 2.8 per cent of 1989 CFC consumption.
[c] Up to 0.5 per cent of base-level consumption can be used until 2030 for servicing existing equipment, subject to review in 2015.
[d] Up to 2.5 per cent of base-level consumption can be used until 2040 for servicing existing equipment, subject to review in 2025.
[e] All reductions include an exemption for pre-shipment and quarantine uses.

2.2. Climate impact

Stratospheric ozone depletion is directly related to the issue of climate change. Ozone and some ozone-depleting substances, especially CFCs, are greenhouse gases. Ozone depletion produces an indirect cooling effect, while an abundance of ozone-depleting substances results in warming of the atmosphere. These two climate-forcing mechanisms do not simply offset one another. The interaction between these two processes is more complicated.

Table 3. Examples of global warming potentials

Chemical	*GWP (100-yr)*
CFC-11	4,750*
CFC-12	10,900*
Carbon tetrachloride	1,400*
Halon-1211	1,890*
Halon-1301	7,140*
HCFC-22	1,810*
HFC-23	14,800*
HCFC-141b	725*
HFC-134a	1,430*
R-410A	2,100
R-407C	1,800

* Intergovernmental Panel on Climate Change, fourth assessment report, Working Group 1

Many CFCs, HCFCs and HFCs being released into the atmosphere manifest themselves as effective greenhouse gases because they absorb infrared radiation going out from the earth's surface. Halocarbons can be much more efficient in absorbing radiant energy than CO_2. Global warming potential (GWP) is used to measure the warming impact of specific chemicals. GWPs[1] of some common halocarbons are shown in table 3.

As an example, one kilo of refrigerant emissions (R410A) has the same greenhouse impact as some two tons of carbon dioxide, which is the equivalent of running an average vehicle for 10,000 kilometres.

2.1.2. Direct climate impact

The environmental impact discussed so far is related to the direct impact on ozone depletion and/or global warming of chemicals released into the atmosphere, either

[1] GWP is an index comparing the climate impact of a greenhouse gas with that of the same quantity of CO_2 emitted into the atmosphere over a fixed time.

naturally or as a result of human activities. For example, methane is released by animals, thus causing a natural climate impact, whereas refrigerants can be released as a result of human activity during the servicing of equipment.

In refrigeration and air-conditioning systems, refrigerants can leak during normal operation, if the system is not adequately sealed or during maintenance, when systems are dismantled or disposed of at the end of their lifetime.

Similarly, in the production of open-cell foams such as those used for cushioning furniture, the blowing agent is released into the atmosphere after the foam has been formed. Once it has been released, the direct impact caused on the environment is based on the mass of chemical released and its ozone-depleting and global-warming potentials.

2.1.3. Indirect climate impact

However, any system or process that requires an input of energy derived from fossil fuels has an indirect impact on greenhouse gas emissions. This is because burning fuel to generate heat or electricity results in CO_2 emissions, and CO_2 is a major greenhouse gas.

The indirect impact is particularly important in relation to refrigeration and air-conditioning systems, since these consume significant amounts of electrical power during their lifetimes, which may be more than 20 years. For insulating foams, the contribution to energy-saving is an even more important factor, in view of the potential for even longer lifetimes.

The total environmental impact attributed to refrigeration or air-conditioning systems containing ODSs over their life cycles is, therefore, a factor in the direct emissions of greenhouse gases and ozone-depleting substances from equipment and the global-warming impact of electrical energy consumed in its lifetime. These considerations are in addition to the impact of carbon emissions related to manufacture, transportation and destruction of plant and chemicals.

As with ozone-depleting substances, the environmental impact caused by greenhouse gas emissions can occur directly or indirectly, and emissions can take place naturally or as a result of human activity. For example, driving a car powered by petrol results in direct emissions of CO_2 into the atmosphere through exhaust from the engine. Methane is produced naturally by the decomposition of organic matter in wetlands or by livestock.

Indirect emissions result from the use of electrical energy, which is derived from fossil fuels. The impact on greenhouse gas emissions is considered indirect because burning fuel to generate heat or electricity results in CO_2 emissions at the power station and not at the point of use of the electricity.

Some forms of electricity generation, such as nuclear, hydroelectric, solar, wind and wave, do not result in the release of CO_2. The proportion of electricity generated in this way varies considerably from country to country. Furthermore, for other forms of power generation, the amount of CO_2 released per unit of electricity generated varies depending on the type of fuel (coal, oil, gas, etc.) and efficiency of the plant. To precisely quantify impact in respect of indirect CO_2 emissions of a certain application is impossible. However, general assumptions are made on the basis of an average number of kilograms of CO_2 per kilowatt on a country-by-country, regional or global basis.

Refrigeration and air-conditioning systems, which consume significant amounts of electrical power during their lifetime, have a significant indirect environmental impact, as do insulating foams that can save substantial quantities of energy, i.e., reduce CO_2 emissions.

2.3. Overall life-cycle environmental impact

A number of methods of calculating the total effect on global warming have been developed which take into account the direct and indirect effects of systems that use and potentially emit greenhouse gases. One such method is total equivalent warming impact (TEWI).

2.3.1. Total equivalent warming impact (TEWI)

TEWI enables designers and contractors to estimate the equivalent CO_2 emission into the atmosphere from system leakage (direct emission) and energy consumption (indirect emission).

Based on the high percentage of fossil fuels used in power stations, the average European CO_2 release is around 0.6 kg per kilowatt hour (kWh) of electrical power generated.

As methods of generating power vary, so does the global warming impact per kWh. For example, coal-fired generation will release between 0.6 and 0.8 kg of CO_2 per kWh, whereas hydro and nuclear power generation has a negligible emission of CO_2.

The energy required for the operation of a system has an indirect impact on global warming. The criteria used to estimate the total equivalent warming impact can be summarized as follows:

$$\text{TEWI} = \underbrace{(\text{GWP} \times L_a \times n)}_{\text{(direct)}} + \underbrace{(E_a \times \beta \times n)}_{\text{(indirect)}}$$

where:

GWP = global warming potential
L_a = leakage rate (kg) per annum
n = number of years
E_a = energy consumption (kWh per annum)
ß = CO_2 emissions per kWh
TEWI = CO_2 (kg)

Refrigeration and air-conditioning systems can account for 10-20 per cent of total electricity consumption in developed countries.

Research on TEWI has shown that the impact on global warming will be greater from energy consumption than from release of refrigerants for most applications.

Current and future technological advances for improving the energy efficiency of refrigeration and air-conditioning systems will play a decisive role in reducing emissions.

2.3.2. Life-cycle climate performance

A disadvantage of the TEWI approach is that it does not take into consideration energy consumed and other emissions related to manufacture and transportation of the refrigerants or blowing agents.

The life-cycle climate change performance (LCCP) methodology builds on the TEWI approach, to provide a holistic approach to estimating all greenhouse gas emissions related to the lifetime operation of a system. Hence, LCCP has become the more accepted methodology.

The LCCP approach provides a more accurate estimate of climate impact in the situation where different alternative fluids, such as refrigerants, are compared for a given application.

LCCP incorporates all the TEWI factors, as well as accounting for GWP of emitted chemicals used in manufacture of the operating fluids. LCCP also accounts for energy used for production of operating fluids. The embodied energy is expressed in CO_2-equivalent.

In most cases, manufacturer's literature quotes annual leakage rates of refrigerants on the order of 4-5 per cent of original charge per year.

However, the actual refrigerant emissions or leakage depend greatly on the standard of installation as well as quality and regularity of servicing. It is quite common for poorly maintained systems to consume significantly higher volumes of refrigerants.

Qualitative research indicates that 15 per cent of charge is a more realistic figure, particularly for split systems, where multiple connections and pipe-runs create more opportunities for leaks. Self-contained units manufactured and tested in the factory environment feature negligible leakage rates.

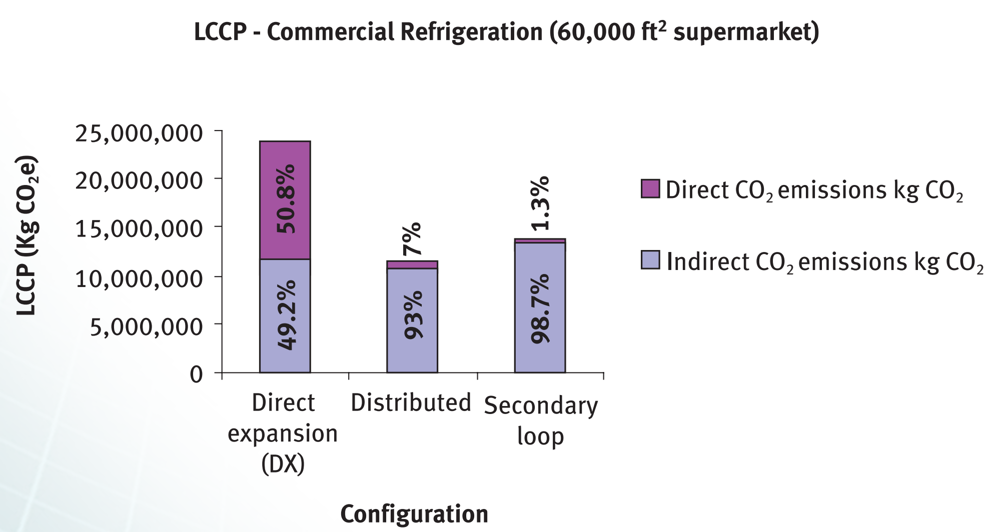
Commercial refrigeration causes more refrigerant emissions of CO_2-equivalent than any other refrigeration application. Centralized systems with long piping circuits have led to considerable refrigerant charges (1,000-2,000 kg), resulting in significant losses when a leak or rupture occurs.

Over the last 10 years, a number of technical improvements have been made to limit refrigerant emissions and their environmental impact as well as reduce the refrigerant charge, by developing indirect systems and employing refrigerants with lower GWPs.

Refrigerant recovery and recycling and environmentally friendly destruction play an important role in reducing in the life-cycle climate performance of a system, as the overall leakage of a system includes emissions that occur during service and repair.

The following figure shows an example of the LCCP analysis for different refrigeration systems used on commercial supermarkets.

Figure 1. LCCP analysis for different refrigeration systems



Source: American Refrigeration Institute.

2.4. Net environmental impact of insulation foams

In the case of insulation materials for buildings such as polyurethane foam, the environmental impact of manufacturing it is a factor to be considered. However, the overall environmental impact of manufacturing and using foam involves three factors (see table 4).

Table 4. Environmental impact of manufactured insulation

Indirect	The indirect greenhouse gas emissions associated with the energy used to make the insulation. Referred to often as "embodied or embedded energy"	Negative
Direct	The direct impact of losses of the halocarbon blowing agent from the insulation during its manufacture, use, and at the time of disposal	Negative
Indirect	The reduction in heating and/or cooling energy used in the building where the insulation is applied and associated reduction of greenhouse gas emissions	Positive

Some experts have claimed that the use of halocarbon-blown foam insulation has a relatively positive impact on climate, with the reduction in emissions related to electrical heating or cooling being greater than the CO_2-equivalent halocarbon emissions.

For typical blowing-agent loss rates for insulation levels found in high-performance houses, marginal payback times can be in excess of 100 years using halocarbon blowing agents but are only 10–50 years using non-halocarbon blowing agents. With a fixed thickness of insulation, the difference in heating energy savings using insulation with different blowing agents is generally only a few percentage points, despite differences in thermal conductivity of as much as 66 per cent.

3. CONTRIBUTION OF UNIDO TO GREENING THE INDUSTRY THROUGH MONTREAL PROTOCOL PROJECTS

3.1. Healing the ozone layer

UNIDO was selected as an implementing agency of the Montreal Protocol (MP) and started to implement MP projects in 1993. The Organization has been working in 87 developing countries. According to the latest official data of the Multilateral Fund Secretariat, UNIDO has implemented 1,217 projects, with a total value of US$ 514 million, phasing out 69,302 ODP tons of annual consumption and production of ozone depleting substances in small and medium sized and large enterprises in the industrial, agricultural and refrigeration-servicing sectors. Most of the projects have been completed that assisted developing counties in meeting their obligations under the Montreal Protocol by phasing out consumption and production of ozone-depleting substances with an impact of 62,252 ODP tons as shown in table 5.

Table 5. ODS phase-out in developing countries

Number of countries	87
Number of projects approved	1,217
ODS phase-out impact in annual consumption, ODP tons	54,230
ODS phase-out impact in annual production, ODP tons	15,072
Total annual impact, ODP tons	69,302
Annual impact of projects already completed	62,252

3.2. Climate benefits

The main aim of the Montreal Protocol was to heal and remedy the damage to the ozone layer as quickly as possible. In the first phase of the Protocol, priority was given to phase-out of the most forceful ozone depleting substances. The climate implication of the phase-out process has gained increasing attention in recent years, although the Multilateral Fund has financially not supported this aspect until now. This situation is expected to change in the future.

As the industrial arm of the United Nations system, UNIDO has ushered in innovations and focused progressively on the introduction and widespread application of natural substances as alternatives to man-made ozone-damaging chemicals. These natural compounds consist mainly of various hydrocarbons, liquid carbon dioxide, water and steam. As well as natural, they are environmentally friendly. Moreover, their climate impact is considerably less than that of many other man-made alternatives. They are readily adaptable to many applications in the refrigeration and foam manufacturing industry as well as for pest control in some agricultural sectors.

Table 6 shows how the phase-out solely of CFCs through projects implemented by UNIDO, has resulted in the reduction of climate impact of industry in the respective developing countries by some 360 million tons of CO_2 net equivalent annually.

Selection of alternatives is carefully considered in close cooperation with the counterpart. At the time of implementation of projects in particular countries there have been applications where introduction of hydrocarbons or liquid carbon dioxide has not been possible. This has often been due to safety and/or cost implications or, simply, lack of availability of appropriate technology or market acceptance of the new final product containing flammable chemicals. In such cases, alternatives with zero (e.g., HFC) or substantially reduced (e.g., HCFC) ozone-depleting potentials have been introduced. HFCs and HCFC are, however, greenhouse gases. Table 6 below takes into consideration this phasing-in effect.

Table 6. Climate Impact of Montreal Protocol Projects of UNIDO

	Tons	*GWP*	*CO_2 (tons)*
ODS			
CFC-11	8,643	4,750	41,054,250
CFC-12	4,267	10,900	46,510,300
Total	12,910		87,564,550
HFC/HCFC Replacement		***CO_2 equivalent phased in***	
HCFC-141b	2,327	725	1,686,988
HCFC-142b/HCFC-22	196	2,050	401,800
Total	2,523		2,088,788
AEROSOL			
ODS		***CO_2 equivalent phased out***	
CFC-11	958	4,750	4,550,500
CFC-12	3,201	10,900	34,890,900

AEROSOL			
ODS		***CO_2 equivalent phased out***	
CFC-114	8	10,040	80,320
Total	4,167		39,521,720
HFC/HCFC Replacement		***CO_2 equivalent phased in***	
HCFC-134a	714	1,430	1,021,020
Total	714		1,021,020
REFRIGERATION			
ODS		***CO_2 equivalent phased out***	
CFC-11	10,211	4,750	48,502,250
CFC-12	5,502	10,900	59,976,160
CFC-113	212	6,130	1,299,560
Total	15,925		109,777,970
HFC/HCFC Replacement		***CO_2 equivalent phased in***	
HCFC-141b	1,583	725	1,147,820
HFC-134a	2,211	1,430	3,162,159
HCFC-22	32	1,810	57,920
Total	3,827		4,367,899
PRODUCTION			
ODS		***CO_2 equivalent phased out***	
CFC-11	1,436	4,750	6,821,000
CFC-12	12,169	10,900	132,642,100
CFC-113	400	6,130	2,452,000
Total	14,005		141,915,100
HFC/HCFC Replacement		***CO_2 equivalent phased in***	
HCFC-22	6,803	1,810	12,312,525
Total	6,803		12,312,525
Grand total phased out	CO_2 equivalent tons		378,779,340
Grand total phased in	CO_2 equivalent tons		19,790,232
Net climate impact	CO_2 equivalent tons		358,989,108

There is an additional climate benefit that has not been considered in this calculation. In most cases, during the conversion process the product, as well as the production process, has been thoroughly reviewed. Frequently, it has been possible to reduce waste and production loss and bring to the market such goods as refrigerators or compressors that have increased energy efficiency. In domestic applications, the main electrical energy consumers are refrigerators, freezers and air conditioners.

Any energy saving in this area amounts to considerable benefits because of the number of these appliances as well as their many hours of daily operation and relatively long life span. Lack of reliable data, however, precludes qualifying this important aspect.

3.3. Type of interventions for greening industry

The key to the success of the Montreal Protocol is that it focuses its assistance in a well balanced manner on institutional strengthening, capacity building, awareness raising, policy and legislation as well as investment activities, at the level of enterprises, manufacturing and servicing industries and agriculture.

3.3.1. Institutional strengthening

UNIDO has assisted 12 developing countries to establish and operate their ozone units in a sustainable manner. These are the focal points and coordinators of all ozone activities within the countries. To monitor and ensure compliance, the ozone units collect data on use, consumption, production, destruction, import, export and domestic sales of ozone-depleting substances by enterprises as well as at sectoral and national levels. The data are stored, analyzed, monitored and reported to the Ozone Secretariat and Multilateral Fund for assessing of compliance of the countries with their MP obligations. The units initiate legislative measures, preparation and adoption of strategies, policies, standards, bans and codes of good practices related to phase-out of ozone-depleting substances. All countries supported by UNIDO have import quotas and a licensing system as well as other legislation related to ozone-depleting substances. These are major tools to achieve and maintain sustained reduction and compliance.

3.3.2. Awareness

With the assistance of the Fund and UNIDO, regular awareness programmes have been conducted in many countries and regions to disseminate information on the aims and successes of the Montreal Protocol, in general, as well as in specific areas of the national economy. The stakeholders are regularly informed of the latest alternative technologies, processes and alternatives. Exchange of information and experience represents a vital tool for progress in this area.

3.3.3. Eco-labelling and energy classification

As part of public awareness raising, many enterprises have introduced special eco-labelling on their products, informing consumers that the product does not contain ozone-depleting substances.

During the process of conversion, refrigerator manufacturers have received training on operation of new technological equipment, production and labour safety, especially handling of flammable alternatives such as hydrocarbons. This has involved study tours to developed countries, during which stakeholders have used the opportunity to study the manufacturing and sale practices of those countries. As a result, in some countries assisted by UNIDO, such as China, energy classification and labelling of domestic appliances have been introduced. This orientates consumers towards purchase of more energy-efficient products. The energy classes are reviewed periodically, with increasingly stringent criteria introduced to keep pace with development of industry. The climate benefits are, thus, continuously growing.

3.3.4. Investment and technology transfer

The largest portion of the Multilateral Funds resources was allocated to practical enterprise-level interventions. Existing ODS-related production facilities, technologies and products had to be converted to environmentally friendly ones reducing ozone depletion drastically and, wherever possible, to zero. The technology transfer was not only successful but remarkably fast. Thanks to the framework created by the Montreal Protocol, it was the first time that developing countries followed so rapidly the technological advances of industrial nations. In several cases, enterprises in developing nations were even ahead of the ones in technically advanced developed countries in adaptation of the most environmentally friendly technologies.

In the refrigeration industry, the development of domestic refrigerators using hydrocarbon insulation foam blowing agent (cyclopentane) and refrigerant (isobutane)—both featuring zero ozone-depleting and minimal global warming effects—was concluded in Germany at the beginning of the 1990s. By 1994, UNIDO launched projects that introduced hydrocarbon foam insulation technologies in several domestic refrigerator enterprises in Egypt, Iran (Islamic Republic of) and Jordan. As early as 2005, UNIDO began to transfer fully hydrocarbon-based domestic refrigerator manufacturing technologies (cyclopentane and isobutane) and isobutane compressors to Chinese enterprises. At the time, these very advanced technologies had not yet been applied outside Europe. Currently, 85 per cent of Chinese domestic refrigerators are produced using this technology. A similar situation came about in Europe and Japan only recently.

In the foam industry, in addition to cyclopentane blown rigid foam technologies, UNIDO pioneered transfer of liquid carbon dioxide blown flexible foam technology. These developments had generated their first results in only a handful of industrialized countries when UNIDO had already formulated the first series of projects to transfer this environmentally benign technology to countries in North Africa. Many difficulties were encountered but, in the end, the efforts paid off. The companies now own and successfully master most of the advanced technology currently available in this sector of industry. UNIDO has also transferred the most ecological butane-blowing technology to extruded polyethylene and polyurethane insulation foam film and board manufacturers in China.

The conversion of manufacturing technologies has been accompanied by redesign of products and major components, which have contributed to improved product performance after conversion. In case of refrigeration equipment, for instance, thickness of insulation, design of refrigeration circuits, selection of components and refrigerant charge have been optimized to reduce the energy consumption of the appliances.

4. THE NEW CHALLENGE AND OPPORTUNITY: HCFC PHASE-OUT

4.1. Acceleration of phase-out of HCFCs

Production and consumption of HCFCs in developing countries, particularly in air conditioning, the refrigeration sector and foam industries, have grown significantly over the past five years. Without taking remedial action, growth is expected to continue.

Based on 2006 consumption trends, the Multilateral Fund has estimated that global production and consumption of HCFCs could double by 2015 adding to the dual challenges of ozone depletion and climate change. The level of HCFCs and their emissions, therefore, poses a significant challenge in reducing ozone depletion.

In September 2007, the Parties to the Montreal Protocol agreed to accelerate phase-out of HCFCs bringing the final date forward by ten years in Article 5 countries (Decision XIX/6).

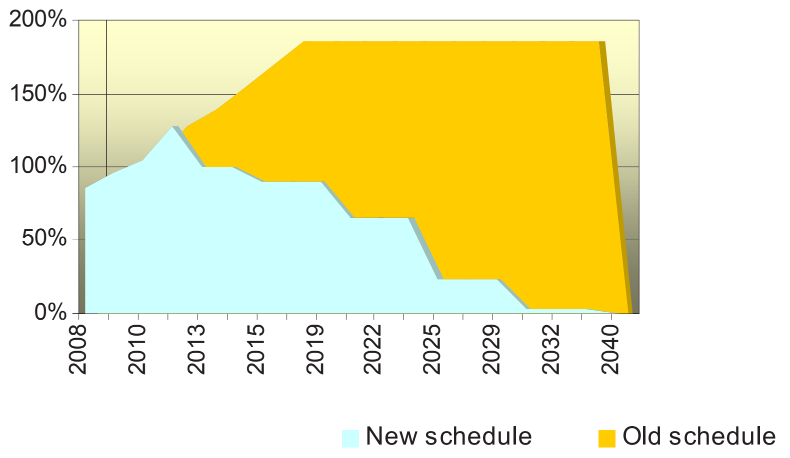
The September 2007 adjustments to the Montreal Protocol oblige Article 5 countries to take action as soon as possible to freeze their base lines—average for the years 2009 to 2010—HCFC production and consumption levels in 2013, and as a first step, reduce by ten per cent their production and consumption of HCFCs by 2015.

Table 7 below shows the accelerated phase-out schedule for Article 5 countries and the graph shows how this compares to the previous schedule.

Table 7. Revised phase-out schedule for HCFCs in Article 5 countries

Step	*Year*
Baseline	2009-2010
Freeze	2013
10 % reduction	2015
35 % reduction	2020
67.5 % reduction	2025
97.5 % reduction	2030
Average 2.5 % for servicing tail only	2030-2039
100 %	2040

Figure 2. Old and new HCFC phase-out schedules



4.2. HCFC phase-out and climate change

The choice of HCFC phase-out technology has an impact on the environment in a number of ways. One is related to ozone depletion from phase-out of ozone-depleting substances. But the global warming impact could be negative, neutral or positive relative to the existing technology depending on a number of factors.

A number of the potential alternatives to HCFCs—HFCs and HFC blends—have greater global warming potentials than HCFCs. Their use entails, therefore, a rise in the direct global warming impact of a system assuming that leakage rates remain the same. However, direct emissions can be reduced if the amount of HFC used is reduced by minimizing refrigerant leakages.

The other factor to be taken into account is the indirect impact resulting from the energy consumption of the system. If a system is made more energy efficient by using more efficient substitutes or changing the operation mode, then less CO_2 emissions will occur in power generation. It is possible, therefore, that, over the lifetime of a system, the phase-out of HCFC will have a net positive global warming impact.

If a system is less energy-efficient than the previous HCFC-based system, there will be a net negative global warming impact arising from the energy component of the comparison, although this may be offset by gains in the area of direct emissions.

The analysis of the overall environmental impact of HCFC phase-out decisions is complex, so that there is no universal solution for all situations or operating conditions. When developing HCFC phase-out strategies, full account must be taken of both environmental impacts.

Currently, the main challenge is that the long-term, financially viable, widely available and environmentally safe alternative technologies are still under development in many fields. The research and development are fast but deadlines for compliance are also pressing.

UNIDO is prepared to take up this challenge and work hand-in-hand with developing countries, the scientific community and industry to find appropriate answers to the pressing needs of ecologically sustainable industrial development—to make a good match between the economic goals, market demand and global environmental benefits in the interest of the current and future generations. This side event is an important milestone in this effort.

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