International Protection of the Ozone Layer

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The Ozone-Depletion Problem

Basic Issue Definition

In the stratosphere, the atmospheric layer between 10 and 50 kilometres above the earth's surface, ozone is continually created from molecular oxygen, and destroyed, by absorption of high-energy radiation from the sun and chemical reactions.[1] Though the resultant equilibrium concentration of ozone is small, only a few parts per million, it is sufficient to absorb most of sun's harmful 'Ultraviolet B' radiation, preventing it from reaching the earth's surface.[2] The ozone layer was discovered in 1913, and for most of the twentieth century has been of scientific interest for its effects on radiation and temperature in the atmosphere, and on the climate.

It was first suggested in the 1960s that human activities could alter the ozone layer, and the modern understanding of the threat of ozone depletion was first stated in 1974 in a paper by Molina and Rowland.[3] They hypothesized that the chlorofluorocarbons (CFCs), an extremely versatile and useful class of chlorine-containing industrial chemicals, could deliver chlorine to the stratosphere where it would catalyse the destruction of ozone, thereby reducing the amount present in equilibrium and increasing the amount of UV radiation reaching the earth's surface.

Higher surface UV could cause several kinds of harm to human health and ecosystems. The strongest and best-understood effect of increased UV-B exposure is an increase in non-melanoma skin cancers; other health effects of UV-B that are suspected or observed, but that are less well known in their causal mechanism, magnitude, or significance, include increases in cataracts, possible increases in melanoma skin cancers, and suppression of certain specific forms of immune response.[4] Increased UV-B also appears to be associated with reductions in the productivity of oceanic plankton, and may cause changes in terrestrial ecosystems, biogeochemical cycles, and tropospheric chemistry, though the precise nature and significance of these changes is not well understood.

Both the scientific understanding and the policy implications of ozone depletion have evolved with time, but the basic understanding of the problem remains largely as stated by Molina and Rowland. The basic policy problem is to manage the reduction and eventual elimination of human ozone-depleting substances (ODSs). As knowledge has advanced and uses of ozone-depleting chemicals have expanded, the set of relevant chemicals has broadened beyond the CFCs, to include many other stable chlorine-containing chemicals, as well as similar chemicals containing bromine, which is even more effective than chlorine at catalysing ozone destruction.

In the industrialized countries, the problem is being addressed by technological substitution and process change, substituting less or non-ozone-depleting alternatives for each use. In the less-industrialized countries, the problem is different and more difficult: it involves phasing down the existing, very limited capacity to produce and use ODSs, and avoiding expansion of new capacity, while meeting urgent development needs for the services these chemicals provide, particularly refrigeration. Other associated development issues include the effect of ODSs restrictions in the industrialized countries on exported-oriented industry in developing countries, and the implications for developing-country agriculture of restrictions on methyl bromide, the most recent ODS to come under pressure for controls.

Scientific Understanding: Remaining Uncertainties and Disputes

The basic scientific understanding of ozone depletion is that emissions of certain chemically stable, insoluble molecules containing chlorine or bromine mix thoroughly through the lower atmosphere and hence reach the stratosphere, where under ultraviolet radiation they break apart to release reactive chlorine or bromine atoms. These catalyse the destruction of ozone, turning it back into molecular oxygen.

As a consequence of this process, global average ozone reductions of about 5 per cent have been observed since the mid-1960s, with the largest reductions at temperate and polar latitudes. In north and south temperate latitudes, the downward trend in total ozone is about 4–5 per cent per decade. In the Antarctic, a different set of catalytic ozone-destruction processes occur, also due to chlorine and bromine from man-made chemicals. These processes, involving chemical reactions on the surfaces of polar stratospheric clouds that depend on the extreme cold of the Antarctic winter night, generate extreme ozone losses every spring (September and October). Ozone losses in this annual 'ozone

hole' have been up to 60 per cent, including near-total destruction of ozone between the altitudes of 14 and 19 km., over an area that sometimes extends to include the southern tip of South America. While some of the necessary conditions for a similar ozone collapse have been observed in the Arctic, no such severe Arctic losses have yet occurred, and the Arctic's different meteorology and warmer winters make them relatively unlikely.

A long-term trend in surface UV intensity has not been detected—such a trend would be difficult to detect because UV has not been monitored for enough years, and is subject to large variations from local meteorology—but local measurements of both ozone and UV show the expected association of lower ozone with higher UV, in both temperate and polar latitudes.

There are three key areas of scientific uncertainty and controversy. First, current stratospheric models under-predict the depletions that are observed at middle and high latitudes. Other reactive processes involving sulphate aerosols (which surged after the 1991 eruption of Mt. Pinatubo, and are probably associated with the large depletions observed in 1992 and 1993) are suspected, but these are not yet well modelled. Second, the extent of ozone depletion likely to occur in the Arctic cannot easily be predicted, principally due to the Arctic's less stable meteorology, and high inter-annual variability. Third, there remains substantial uncertainty in the global budget of methyl bromide, an ozone-depleter that comes from the ocean and from a few human sources, principally agricultural fumigation, biomass burning, and automobile exhaust from leaded gasoline. Uncertainty is particularly acute for the auto-emissions source, and the ocean sink.[5]

These uncertainties are of some, but limited, policy significance. But recent writings in the popular press, particularly in the United States, have claimed that far more serious scientific uncertainties and controversies exist. These writings typically mix real points of scientific dispute with outdated, refuted, or eccentric work, and employ a variety of rhetorical devices to argue or imply that the apparent scientific consensus on ozone depletion is in fact a conspiracy to suppress a large body of important dissent. These works have claimed, for example, that most chlorine in the stratosphere is natural in origin; that CFCs cannot rise to the stratosphere because they are heavier than air; and that the Antarctic ozone hole is a natural phenomenon that was observed as early as 1958. Because these writings have found sympathetic hearings among political actors interested in scaling back environmental regulation, they have gained wide circulation, and many people in America now believe, erroneously, that the ozone-depletion hypothesis has been refuted.[6]

The International Response to Ozone Depletion

Basic Instruments: Convention, Protocol, and Fund

After the ozone threat was hypothesized in 1974, there followed several years of controversy that culminated in domestic action in four countries to restrict CFCs in aerosol sprays.[7] At the same time, the first international discussions took place under United Nations Environment Programme (UNEP) and World Meteorological Organization (WMO) auspices, and a 1977 international meeting agreed on an 'International Plan of Action'. Formal negotiations for a treaty to restrict ODSs began in January 1982, and eventually yielded the 1985 Vienna Convention, the 1987 Montreal Protocol to the Convention, and its London (1990) and Copenhagen (1992) Amendments.[8] Further amendments were to be undertaken at the November 1995 meeting, held in Vienna to commemorate the tenth anniversary of the signing of the Vienna Convention.

International Rules of Conduct

The core rules established under the 1987 Protocol are national limits on the production and consumption of various classes of ODSs,[9] plus a commitment to assess these control measures at least every four years. In the original 1987 Protocol, five CFCs were to be cut by half and three halons to be frozen; each subsequent amendment has added more chemicals to the regulated list, while accompanying adjustments have made stricter and earlier the limits applying to already controlled chemicals. The 1990 amendments were the first to require complete elimination of certain substances: CFCs, halons, and methyl chloroform. The 1992 amendments included controls and eventual phase-outs of the hydrochlorofluorocarbons (HCFCs), chemicals whose main markets are as interim substitutes for CFCs, which deplete ozone by roughly 1 to 10 per cent as much as CFCs do.

The 1992 amendments also included provision for exempting essential uses of CFCs and halons from the phase-outs, and nominations for proposed essential uses were reviewed by the Technology Assessment Panel in 1994 and 1995. In 1994 many exemption applications were received and only a few were granted: none for halons, and three small uses for CFCs (inhalants for respiratory medication, solvents for rocket manufacture, and certain laboratory and analytic uses). In 1995 fewer exemption applications were received, and the Panel recommended a slightly modified set of exemptions, dropping laboratory and analytic uses and adding certain halon uses.[10]

Developing countries that consume less than 0.3 kilograms of ODSs per person per year are known as 'Article 5 countries', and are subject to less-stringent controls. For all substances controlled in the 1987 Protocol and the 1990 amendments (CFCs, halons, carbon tetrachloride, and methyl

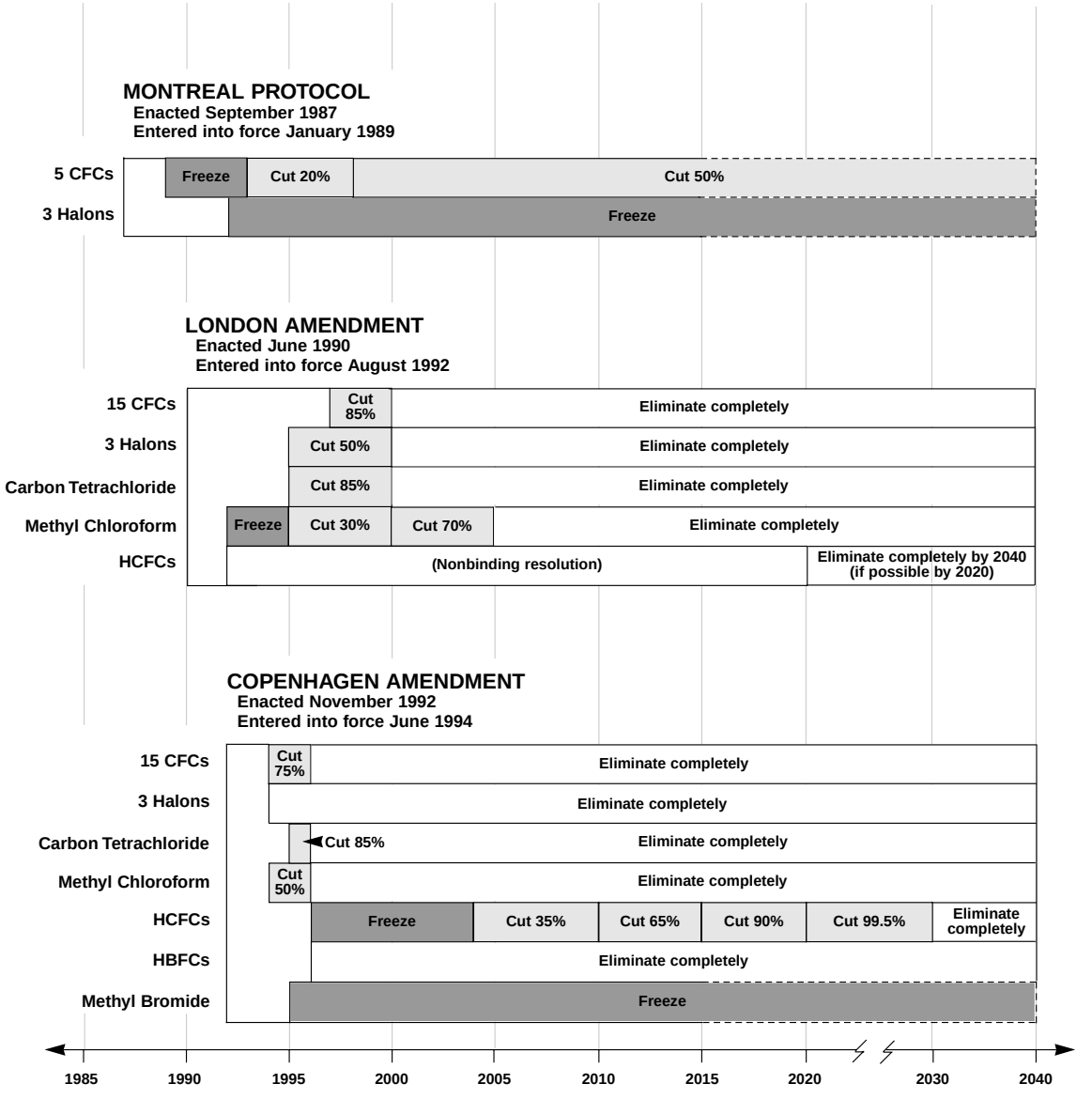

Fig. 1. Industrial–contry obligations to reduce ozone depleting substances

Note: This figure indicates the obligations that industrial countries have undertaken to control various ozone depleting substances under successive international agreements. Each bar shows the agreed control levels for a particular chemical compound or group of compounds from the date when the controls were enacted to the date when compound(s) must be eliminated completely; each section of the bar shows when a particular control level comes into effect. For instance, the Copenhagen Amendment, enacted in November 1992, requires industrial countries to cut CFCs 75 per cent (from their 1986 levels) by 1994 and to eliminate them altogether by 1996.

Source: Edward A. Parson and Owen Greene (1995), 'The Complex Chemistry of the International Ozone Agreements', *Environment*, 37/2 (Mar. 1995), 19.

chloroform), Article 5 countries' commitments are delayed by ten years compared to those of the industrialized countries. For methyl bromide and HCFCs, first controlled in the 1992 amendments, obligations for Article 5 countries are not yet specified.[11] Moreover, the large number of developing countries who have not yet ratified the 1992 amendments are bound only by the 1990 obligations, phasing out CFCs and halons by 2010 and methyl chloroform by 2015.

As an incentive for countries to join, the Protocol includes several restrictions on trade in regulated substances and related products with non-Parties. Bulk trade in restricted substances with non-Parties were prohibited in 1990 (imports) and 1993 (exports), while imports from non-Parties of products containing controlled substances were banned from 1992. In addition, the Protocol required Parties to consider banning imports of products *made with*, but not containing, controlled substances;[12] but Parties decided in 1993 that such restrictions were infeasible.[13]

A crucial innovation of the 1990 amendments was the establishment of a fund, supported by contributions from the industrialized-country Parties, to pay the extra or 'incremental' costs that Article 5 Parties incurred in reducing and eliminating ODSs. The negotiated size of the Fund was $US240 million total for the interim period 1991–3, and $US510 million for 1994–6, with national contributions derived from the UN scale of assessment.[14] Contributions are formally voluntary, though sometimes described as 'assessed'.

The core phase-out commitments, and the financial commitments associated with the fund, were identified in 1990 as crucial elements of a two-way deal. Indeed, a carefully worded passage in the 1990 amendments states that Article 5 Parties' 'capacity to fulfil' the control obligations 'will depend upon the effective implementation of the financial co-operation . . . and transfer of technology'.[15]

International Institutions and Implementation

The Protocol is governed by the Conference of the Parties, which meets annually with authority to amend the Protocol, following more frequent negotiating meetings of an 'Open-Ended Working Group'. Parties must consider revisions of the Protocol's core obligations at least every four years. A small Secretariat in Nairobi supports both Convention and Protocol.

At least one year before each review, Parties must establish expert panels to review current developments and report to them. The Panels—on Science, Technology and Economics, and Effects—include dozens to hundreds of international experts, serving as individuals. Each Panel reports recent progress, responds to specific questions from the Parties, and submits a report to the Parties which is also distributed publicly. Assessments were conducted in 1989, 1991, and 1994, each time reporting one year in advance of a major review meeting of the Parties. The assessments are believed to have been highly influential in Parties' reaching agreement on modifications of control measurements, including the decision to move to full phase-outs in 1990.[16]

The Protocol requires every Party to report its production, imports, and exports of every controlled substance, as well as amounts used as chemical feedstocks and destroyed by approved technologies. These reports are required first for a baseline year—1986 for substances first controlled in 1987, and 1989 for those first controlled in 1990—and annually thereafter. Though it was originally intended that all Parties would report separately, it was agreed in 1990 that because of the European single market, the EU would be permitted to report consumption, import, and export data jointly.

It is stated that for reasons of commercial confidentiality, nearly all these self-reported national data are kept confidential. The Secretariat publishes reports that present national production and (calculated) consumption figures only in aggregate for broad groups of regulated chemicals. Parties may view the detailed national data of other Parties, but only by specific request, while others may not view it under any conditions.

Implementation and compliance difficulties are addressed by the ten-member Implementation Committee. The Committee, established in 1990, meets two or three times each year to consider questions of implementation or possible non-compliance which either Parties or the Secretariat can bring to its attention. It invites countries whose implementation is questioned to appear, discusses the problems, seeks constructive resolution, and reports to the Conference of the Parties; it has no power to bring any stronger measures to bear against non-compliance. Thus far, the Committee has mostly concerned itself with difficulties implementing the Protocol's requirements to report data on national production and consumption. While there is some evidence that its work has improved levels of data-reporting, the Committee and its procedures had not, as of summer 1995, addressed substantive instances of non-compliance.

Supporting Phase-outs in Developing Countries

Though control obligations for Article 5 countries do not come into effect until at least 2000 (depending on which of the Protocol amendments a country has ratified), the Protocol's Multilateral Fund and its associated institutions are intended to start reducing consumption immediately, by identifying enterprise-level investment projects to reduce or eliminate ODSs in Article 5 countries, and funding their 'agreed incremental costs'.

The Fund is governed by an Executive Committee of the Parties, containing seven members each from Article 5 and non-Article 5 countries, which meets two or three times a year, supported by a Secretariat based in Montreal. The actual work of identifying, planning, and executing ODSs reduction projects is carried out by four 'Implementing Agencies': the World Bank, UN Development Programme (UNDP), UN Environment Programme (UNEP), and, since October 1992, the UN Industrial Development Organization (UNIDO), who work in collaboration with national officials

and under the direction of the Executive Committee. Specific policy decisions regarding what kinds of costs and activities to fund, on what terms, are made by the Executive Committee.

The process of carrying out Fund projects is as follows. The government of an Article 5 country, assisted by an Implementing Agency, prepares a 'country programme' that states present and projected use of ODSs and identifies opportunities for reduction.[17] The Executive Committee approves country programmes, after which (or sometimes before) Implementing Agencies bring forward proposed investment projects for Executive Committee approval, then implement them. Three of the four Implementing Agencies—the World Bank, UNDP, and UNIDO—undertake investment projects, while UNEP provides a variety of information and capacity-building services.

As of June 1995 total funds allocated to the Implementing Agencies were $US309 million, of which $US67m. had been disbursed. Of this total, that allocated to investment projects (the activities that directly phase out ODSs) was $US239m., of which $US32.6m. had been disbursed. Disbursement rates for Implementing Agencies ranged from 16 to 60 per cent, and for investment projects from 10 to 29 per cent.[18]

As of 1 June 1995, twenty investment projects had been completed, eliminating an estimated 1,455 tons of ODSs.[19] Of these, all were implemented by UNDP, and twelve reached completion in 1995. In addition to investment projects and country programmes, some funds are being spent on 'institutional strengthening', to build up national regulatory institutions responsible for meeting Protocol obligations, though concern has recently mounted that these expenditures may be superfluous in the smallest consuming countries.

Though for the first three years of the Fund's operation project proposals came forward slowly, the rate has recently increased sharply. Consequently, for the first time the money has not always been available to fund all projects brought forward. Recently, the Executive Committee has sought to prioritize projects by defining cost-effectiveness thresholds and asking the Secretariat to screen proposals. In the July 1995 meeting, the Secretariat screened out 90 of the 238 proposals brought forward, principally on grounds of insufficient cost-effectiveness. There has been some suggestion that project proposals are responding to the new criteria by biasing estimates of costs and amounts of ODSs to be phased out.

National Implementation

National Regulations and Legislation

By September 1995, 149 Parties had ratified the Montreal Protocol, 103 Parties the London Amendment, and 47 Parties the Copenhagen Amendment, which entered into force in June 1994. In addition, several non-Parties have chosen to escape the Protocol's trade sanctions by submitting data to show that they are meeting the same targets as Parties.

All OECD countries have passed laws or regulations to implement the phase-outs, with most moving ahead of international targets in at least some small way. Most national regulations operate through quantitative permits to produce or trade ODSs. In some nations these are fixed allowances; in others, they can be exchanged among enterprises, or traded among chemicals in proportion to their ozone-depletion potentials.

For example, in the United States, the Environmental Protection Agency (EPA) regulations of December 1993 set phase-out dates of 1994 and 1996 as required by the 1992 protocol amendments. In addition, the regulations set phase-out timetables for particular HCFCs, intended to meet the Protocol's aggregate HCFC limits, and require that methyl bromide use be eliminated by 2001.[20] Controls are implemented through production and import allowances, which are distributed to original producers and importers in proportion to their baselines, and can be traded across firms and between substances. Imports of reused or recycled substances do not require an allowance. In addition, ODSs are subject to a tax that increases up to their phase-out date. Other regulations prohibit venting CFCs or HCFCs, and require products made with ozone-depleters to carry a warning label.[21]

In Article 5 countries, given their low prior levels of consumption and their ten-year grace period, it is not surprising that consumption is increasing rapidly. No Article 5 countries have yet enacted laws or regulations to restrict ODSs, but the country programmes prepared for the multilateral fund contain a variety of phase-out commitments and objectives. In these programmes and elsewhere, many Article 5 countries declare their intention to eliminate ODSs before the 2010 deadline of the 1990 protocol amendments. For example, of the 40 countries that had country programmes approved by September 1994, 8 plan to eliminate CFCs by 1998 or earlier, and 13 more between 1999 and 2001; the highest-consuming countries tend to have later phase-out targets, though, so the average CFC phase-out target of Article 5 countries is 2007.[22]

Results of National Implementation

According to Parties' self-reported data and industry estimates, OECD countries have reduced CFCs far ahead of the Protocol's targets, to 36 per cent of the 1986 baseline level by 1993.[23] Except for Russia, halon production ceased in all developed countries in 1994 as required.[24] Both production and consumption increased substantially in Article 5 countries since 1986, as the Protocol permits, but

Table 1. World CFC consumption (kilotonnes)

	1986	1990	1992
USA	327	206	153
Japan	133	111	61
European Union	310	184	137
Other OECD	92	58	35
Former USSR	120	110	87
China	19	35.5	43[a]
Other Article 5[b]	53	46	14
Non-Parties	10	2	3
Unidentified to match world sales	69	49	240
World sales[c]	1,133	802	643

[a] 1991 figure
[b] UNEP data
[c] Industry estimates

Source: Selected entries from UNEP (1994), *Report of the Technology and Economics Assessment Panel*, table 2.1., 32.

have remained very small relative to the prior consumption of the industrialized world.[25]

Phase-downs have been much less successful in the transitional economies, though, particularly in Russia. While Russian ODS production dropped substantially after 1990, this reflected the general economic contraction of the transition rather than a shift to less ozone-depleting technologies. Russia's problems implementing the Protocol have been compounded by the break-up of the Soviet Union, which left many industrial facilities for ODSs and related products in new foreign countries, some of them non-Parties to the Protocol and hence subject to trade restrictions. According to 1995 estimates used by the Technology and Economics Assessment Panel, Soviet CFC consumption declined from 120 to 87 kilotonnes from 1986 to 1992, but increased its share from 11 to 15 per cent of the world total as the OECD decreased its consumption.[26] Russia did not phase out halon production in 1994 (after reporting to the 1993 Conference of the Parties that it would be unable to do so), and in 1995, together with four other transitional economies, appealed for a 4–5 year extension to the phase-out deadlines (to 1999 or 2000), accompanied by financial and technical assistance.[27] The Global Environment Facility has developed a country programme for Russia that aims at eliminating ODSs use by 1999 at a cost of US$90 million.[28] A May 1995 decree of the Russian government implements the trade and data-reporting requirements of the Protocol, and requires the Environment Ministry to develop an ODS phase-out schedule based on the results of Russia's appeal for the phase-out extension.

National Reporting and Implementation Review

Obligations to report data came into force before any obligations to reduce or eliminate ODSs, and it is only through Parties' reports that implementation of core commitments can be assessed. But reporting has been weak, with many Parties submitting consistently late or incomplete reports, or none.[29] At the time of the 1994 Conference of the Parties, only 46 of 114 Parties had reported 1993 data, while more than 40 had not even reported baseline-year data.

The sources of non-reporting or difficulty in reporting have been various. The European Union (EU) has asserted that the single market makes trade among member states into internal trade, so the EU Commission aggregates national figures to report trade between the EU in total and other states. Italy failed to report its production for several years due to domestic bureaucratic difficulties.[30]

Many states experience difficulties because their national statistical systems do not distinguish substances and products as finely as does the Protocol; nor does the international Harmonized Commodity System distinguish ODSs from other halogenated hydrocarbons, and enough extra codes will not be added despite the Parties' request.[31] If the number of distinct categories of chemicals, products, and activities that must be reported continues to increase, the limitations of statistical reporting systems will become even more serious.

In addition, many Article 5 countries simply lack the institutional capacity to gather and report data. A recent initiative by the Implementation Committee and the Fund Secretariat to provide funds for institutional strengthening seems to have yielded modest improvements in reporting-rates, though one may argue whether eliciting data reporting from the lowest-consuming countries is a worthwhile expenditure of resources and attention. A modestly aggressive stance in 1994 by the Implementation Committee towards the roughly forty states that had received assistance but still not reported yielded further improvements in reporting, but the effectiveness of the Implementation Committee in resolving serious compliance issues remains to be tested.[32]

Assessment of Current Levels of Implementation

Implementation of the currently negotiated ODS phase-outs has been highly successful in the OECD economies; of mixed but limited success (though the required phase-outs remain ambiguous) in the Article 5 countries; and unsuccessful to date in the economies in transition that produce ODSs. (Those, such as Poland, that import their consumption from OECD countries have no alternative to phasing down rapidly, though at potentially high cost.)

In the OECD countries, once the initial regulatory step was taken with the 1987 Protocol, implementation has largely

been driven by market forces. Once it became clear that certain ozone-depleters would eventually be eliminated, the manufacture and sale of the more costly and complex substitutes became advantageous for the producer industry, while user industries and entrepreneurs had strong incentives to seek technical innovations to use less, find substitutes, or change processes to eliminate the need. After a brief initial stand-off period, competition to be technically ahead and the first down learning-curves has driven phase-outs ahead of the required schedule. With localized exceptions, including a few small-use sectors that have been granted essential-use exemptions, continued implementation of currently agreed phase-outs in the OECD countries is not likely to pose significant problems.

The same commercial forces are driving some ODS reductions in Article 5 countries, even though these countries will come under no production or consumption limits for 10 years or more. These forces are strongest in export sectors, in large export-oriented countries, and in multinational firms; hence these tend to be the places where early conversion projects are being carried out. In other Article 5 countries, and in sectors containing smaller firms oriented to domestic production, implementation so far has proved difficult and is likely to remain so.

In the economies in transition, eliminating ODS production has not been high on any political agenda, so no plans have been carried out. The original Protocol measures, which required these countries to convert without assistance like the OECD, are now clearly inappropriate, and special measures and financial assistance are being negotiated.

Impact on the Problem

The effectiveness of the currently implemented measures to control ODSs can be directly measured, with a lag, by the concentrations of ODSs in the lower atmosphere and the concentrations of reactive chlorine and bromine in the stratosphere.

Recent controls have shown an observable effect; since 1992 the rates of growth of atmospheric concentrations of controlled substances have begun to decline, while the concentration of carbon tetrachloride has actually decreased.[33] In the same period, atmospheric concentrations of the most widely used alternatives to regulated ODSs have begun to increase sharply.

The future evolution of the problem is projected using numerical models that estimate future time-trends of stratospheric chlorine and bromine concentrations. Current projections based on the 1992 amendments show future stratospheric chlorine as in the solid line in Figure 2, and project that the stratosphere will return to 2 p.p.b. of chlorine, the concentration at which the ozone hole first appeared, by about 2045. These modelled projections of course depend on particular assumptions regarding future implementation of phase-outs of all ODSs, including the HCFCs and methyl bromide, for which global phase-outs have not yet been agreed. They also depend on assumptions of how high Article 5 country consumption will rise before their phase-out obligations come into force, and of the level of compliance with all present and future control measures.[34]

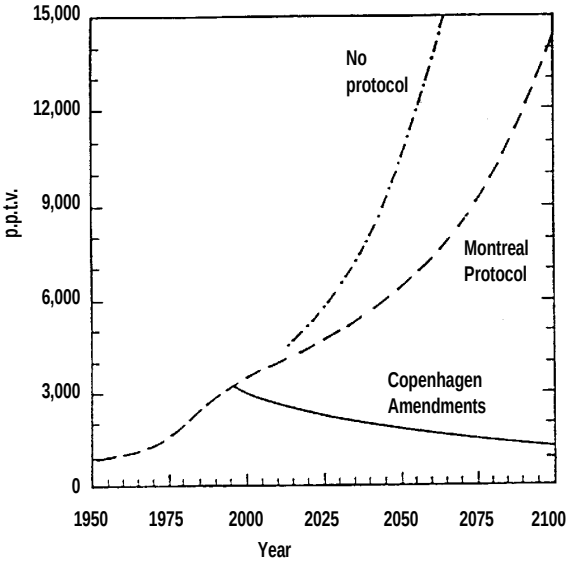

Fig. 2. Equivalent effective stratospheric chlorine

Note: Estimated equivalent effective stratospheric chlorine represented by case A (Copenhagen Amendments) compared to the provisions of the original 1987 Montreal Protocol, and a case with no international agreements on ozone-depleting gases (where a 3 per cent per year increase in global emissions of CFCs and methyl chloroform was assumed, less than known trends up to that time).

Source: World Meteorological Organization (1995), *Scientific Assessment of Ozone Depletion: 1994*, Global Ozone Research and Monitoring Project Report No. 37 (Geneva: WMO), xxxiv.

Barriers to Further Progress

A few barriers to further progress in implementing protection of the ozone layer are presently evident, while several others are likely to become serious within a few years. The most significant present difficulties are the black market in ODS imports that has appeared in several OECD countries, and a cluster of implementation and political difficulties around the management of the multilateral fund.

Substantial volumes of illegal CFC imports are entering both the USA and Europe, driven by taxes and supply shortages as production capacity is phased down. Estimates

of the size of the market, admittedly highly inexact, are between 5 and 10 kilotonnes in the USA and approximately 2.5 kilotonnes in the EU.[35] On cessation of production in 1996, CFC shortages for recharging existing equipment will likely increase the size of the black market. Most black-market CFCs are apparently manufactured legally in Russia or Article 5 countries, then fraudulently exported. The EU has responded by tightly restricting imports of any used ODSs, though the Protocol permits these.[36] Russia, in its May 1995 governmental decree, also sought to limit black-market trade, by requiring special licences for ODS exports beginning in 1996.[37] Industry co-operates actively in suppressing the black market, as black-market activities have reduced the profitability of current manufacture of legal (taxed) CFCs, and more expensive substitutes. The incentive for illegal ODSs trade will persist as long as production continues in some countries—either Article 5 countries with a ten-year grace period, or economies in transition with a negotiated extension—while others have ceased production and are experiencing shortages for the recharge of old equipment.

Implementation of ODS reductions in Article 5 countries is experiencing a variety of difficulties. The most obvious has been the slow implementation of multilateral fund investment projects, principally due to the World Bank's implementation procedures, which rely on financial intermediaries in host countries.[38]

More serious have been problems that are arising because of ambiguities in the original 1990 bargain that Article 5 countries would phase out ODSs if industrialized countries paid the incremental cost of doing so. Both sides of the transaction remain suspicious of the others' commitment. On the donors' side, presently agreed funds remain, by most estimates, substantially smaller than the total incremental costs of implementing presently agreed phase-outs in Article 5 countries. Moreover, the nominal size of the Fund includes substantial contributions from Eastern Europe and the former Soviet Union, most of whom have never paid and cannot reasonably be expected to, so the Fund is effectively a further 10 per cent smaller than its nominal size. Other countries, including a few rich OECD countries, have also shorted their obligations to the Fund in a variety of ways, including not paying at all, paying late, and making their contributions in promissory notes, depriving the Fund of interest income.[39]

From their side, Article 5 countries have strongly resisted any attempt to negotiate further tightening of controls on ODSs, and have pushed for broad interpretations of the kinds of projects and categories of costs that are deemed 'incremental'. Their obligations to phase out HCFCs and methyl bromide remain to be negotiated. Some Article 5 countries are aggressively producing and exporting ODSs, and even commissioning new CFC plants, under the guise of meeting their 'basic domestic needs' as permitted in the Protocol.[40]

Signs of strain have become clear at recent meetings of the Executive Committee, where for the first time insufficient funds have been available to authorize all projects that were ready to proceed. The immediate response has been to apply cost-effectiveness criteria to order projects for funding, but the problem of insufficient funds to do the job will only grow more acute over the next few years.

Implementation problems will surely increase from here. Even considering only the implementation of currently agreed measures, controls in the industrialized countries will become stringent and costly for the first time in 1996, including visible direct costs to consumers. The predictable consequence has already begun: a political backlash against the regime that includes spurious attacks on the scientific consensus about ozone depletion. The strongest initial attack has been against methyl bromide controls in the USA, which impose a phase-out not yet agreed in the Protocol;[41] but while political attacks against the core obligations of the Protocol, the phase-outs of CFCs and halons, lack industry support and have not gone far, visible consumer costs of regulation could boost this movement.

As costly and difficult national controls are implemented for the first time, the possibility that governments will have serious concerns about others' implementation will be greater, and the non-compliance procedures, in particular the Implementation Committee, are likely to be tested more strongly. Moreover, if controls are made more stringent, these difficulties will increase. More stringent controls will also be more complex, and as increasing stringency makes compliance more difficult, increasing complexity will make non-compliance harder to recognize and demonstrate. Further internationally negotiated controls are also likely to address such activities as ODSs recycling, recapture, and destruction. National programmes on these activities may be of highly uneven effectiveness, with the potential to harm effectiveness of the Protocol, and generate conflicts and calls for intrusive domestic monitoring. International registration and regulation of recycling plants have already been proposed, and similar oversight of the construction and operation of ODS destruction facilities is likely to be sought as soon as Parties are permitted to credit ODSs destroyed against their domestic consumption.[42]

The largest opportunity for further global reductions in ODSs lies in specifying and tightening the phase-out obligations of Article 5 countries, and in further measures to make effective the existing nominal phase-out obligations in the economies in transition. As the principal location of endeavour shifts from OECD to non-OECD countries, the basic character of the problem will change fundamentally.

The security of the agreement coupling global phase-outs

with financial and technological aid will become central. The present record of stinginess may have made the atmosphere for negotiating further tightening of the limits in Article 5 countries difficult. Moreover, the significance of the project implementation difficulties encountered so far is not clear. While it may simply show a need for large funding increases or reforms of the current system, it may point to fundamental obstacles not amenable to short-term solutions. Consequently, it could be that substantial advancing of Article 5 phase-outs is unfeasible, even if governments could agree on them.[43] The cost and feasibility of such advances do not depend only on policies and capacities in Article 5 countries, though; they clearly also depend on improvements in the capacity and skill of the Implementing Agencies, and may also depend on trade links. It has been suggested recently that OECD firms are lengthening the dependence of Article 5 and transitional countries on CFCs and other soon-to-be-banned ODSs, by selling them obsolete products and technology that depend on them.[44]

In general, the international management of ozone depletion has been consistently innovative, and fairly successful. Strong agreements to eliminate ODSs have been negotiated and, with a few exceptions, implemented in the industrialized countries ahead of schedule. Important innovations including the commitment to periodic review, the use of independent assessment panels, and the Multilateral Fund, have strongly influenced the content of subsequent agreements. The gains of present progress are already evident in the environment. But the job is far from finished, and in many senses only the easiest part has yet been done. The most instructive lessons of the ozone regime are those that will be obtained from the attempts to sustain and extend implementation over the next few years, as it becomes difficult.

Notes and References

1. An ozone molecule consists of three atoms of oxygen. Molecular oxygen, which makes up about 21% of the atmosphere, consists of two oxygen atoms.
2. UV-B is the highest-energy solar radiation that reaches the earth's surface, with wavelengths from 290 to 315 nm.
3. M. Molina and F. S. Rowland (1974), 'Stratospheric Sink for Chlorofluoromethanes: Chlorine Atom Catalyzed Destruction of Ozone', *Nature*, 249 (28 June), 810–12.
4. United Nations Environment Programme (1994), *Environmental Effects of Ozone Depletion: 1994 Assessment*, (Nairobi: UNEP, Nov.).
5. World Meteorological Organization (1995), *Scientific Assessment of Ozone Depletion: 1994*, Global Ozone Research and Monitoring Project Report No. 37 (Geneva: WMO), Ch. 10.
6. Examples of the 'ozone backlash' literature include R. A. Maduro and R. Schauerhammer (1992), *The Hole in the Ozone Scare* (Washington: 21st Century Science Associates); S. F. Singer (1994), '(N)O3 Problem', *The National Interest*, 36 (Summer), 73–6; and D. L. Ray and L. Guzzo (1990), *Trashing the Planet* (Washington: Regnery Gateway). In the 1995 US Congress, several legislators stated their intention to seek delay or reversal of previously enacted controls on ODSs, and at least two bills to this end were introduced (House of Representatives (H.R.) 2230, which would remove controls on methyl bromide, and H.R. 475, which would repeal Title VI of the Clean Air Act amendments of 1990).
7. The countries restricting CFC aerosols were Norway, Sweden, Canada, and the USA.
8. The history of negotiations and agreements is treated in Richard E. Benedick (1991), *Ozone Diplomacy* (Cambridge, Mass.: Harvard University Press); E. A. Parson (1993), 'Protecting the Ozone Layer', in Peter M. Haas, Robert O. Keohane, and Marc A. Levy (eds.), *Institutions for the Earth* (Cambridge, Mass: MIT Press); and Ian H. Rowlands (1993), 'The Fourth Meeting of the Parties to the Montreal Protocol: Report and Reflection', *Environment*, 35/6 July–Aug., 25–34.
9. Since consumption is difficult to track directly, the consumption limits in fact apply to a quantity calculated as the sum of domestic production and imports, less exports.
10. United Nations Environment Programme (1994), *1994 Report of the Technology and Economics Assessment Panel* (Nairobi: UNEP); United Nations Environment Programme (1995), *Report of the Eleventh Meeting of the Open-Ended Working Group*, UNEP/OzL.Pro/WG.1/11/10, Nairobi, 13 May 1995.
11. Article 5, para. 1 bis: for HCFCs and HBFCs, Article 5 countries' schedule and phase-out date are to be decided by 1996; for methyl bromide, a control schedule is to be decided by 1996, but the treaty language does not include the word 'phase-out'.
12. Montreal Protocol, Article 4. As this category would include many electronic goods, the stakes are higher and the detection problems more severe here than for kinds of trade controlled in Article 4.
13. Parties to the Montreal Protocol (1993), Decision V/17: Trade in products made with, but not containing, controlled substances.
14. The payment formula adjusts the UN scale of assessment to exclude non-Parties and Article 5 Parties, while maintaining the constraint that no nation be responsible for more than 25% of the total. The largest resultant contribution shares are 25% from the USA, 14.64% from Japan, 8.93% from Germany (and a total of 35.52% from the twelve member states of the pre-1995 European Union), and 7.89% from Russia.
15. Article 5, para. 5.
16. Parson, 'Protecting the Ozone Layer'.
17. Rajendra M. Shende (1993), 'Protecting the Ozone Layer: The Formulation of Country Programmes', *UNEP Industry and Environment* (Oct.–Dec.), 38.
18. These low disbursement rates can be misleading, since allocations sharply increased in 1994 and 1995, so for some agencies a large fraction of all allocated funds have come in the past twelve months.
19. Of this total, 15 projects (1,199 tonnes) were in foams, 4 projects (238 tonnes) in solvents, and 1 project (18 tonnes) in refrigeration. United Nations Environment Programme (1995), *Financial Reports of the Implementing Agencies, including Comments and Recommendations from the Fund Secretariat.* UNEP/OzL.Pro/ExCom/17/7/Add.1 (Montreal: UNEP, Multilateral Fund Secretariat, 2 July).
20. Methyl bromide regulations had to be enacted because of a provision of the 1990 Clean Air Act, which required that any substance found to be at least 20% as ozone-depleting as CFC-11 had to be phased out within seven years.
21. EPA-430-F-93-010; 58 FR 65046, 10 Dec. 1993. Agricultural products treated with methyl bromide are exempt from the labelling requirement.
22. ICF Incorporated (1994), *Report under Paragraph 8 of Article 5 of the Montreal Protocol* (Washington: ICF Inc., Dec. 23).

23. United Nations Environment Programme (1995), *1994 Report of the Technology and Economics Assessment Panel* (Nairobi: UNEP), table 2.1.
24. Ibid. 6.
25. United Nations Environment Programme (1994), *The Reporting of Data by the Parties to the Montreal Protocol: Report of the Secretariat*, UNEP/OzL.Pro.6/5 (Nairobi: UNEP, 15 July). Article 5 countries will of course account for essentially all global consumption once phase-outs are completed in industrialized countries.
26. United Nations Environment Programme (1995), *1995 Report of the Technology and Economics Assessment Panel*, table 2.1.
27. United Nations Environment Programme (1995), *Report of the Eleventh Meeting of the Open-Ended Working Group*, 25–6.
28. Global Environment Facility (1994), *Russian Federation Phase-Out of ODS: Phase 1* (Washington: GEF). Unpublished.
29. United Nations Environment Programme (1994), *The Reporting of Data by the Parties to the Montreal Protocol: Report by the Secretariat*; US General Accounting Office (1991), *International Environment: International Treaties are not Well Monitored*, (Washington: US General Accounting Office).
30. United Nations Environment Programme (1993), *Report of the Seventh Meeting of the Implementation Committee, Montreal Protocol*, UNEP/Ozl.Pro/ImpCom/7/2, Bangkok, 16 Nov., 3.
31. For technical reasons, the Customs Co-operation Council agreed to grant only a few additional customs codes for controlled products and substances, not enough to distinguish even all current categories of controlled goods. United Nations Environment Programme (1992), *The Reporting of Data by the Parties to the Montreal Protocol: Report by the Secretariat*, UNEP/Ozl.Pro.4/6 (Nairobi: UNEP, 26 Aug.); UNEP (1992), *A Note Regarding the Harmonized System Custom Code Numbers for the Products Listed in Annex D of the Amended Montreal Protocol*, UNEP/OzL.Pro.4/3 (Nairobi: UNEP).
32. United Nations Environment Programme (1994), *Report of the Implementation Committee under the Non-compliance Procedure of the Montreal Protocol*, UNEP/OzL.Pro/ImpCom/9/2 (Nairobi: UNEP, 5 Oct.).
33. Total tropospheric organic chlorine increased by only 1.6% in 1992, compared to 2.9% in 1992. World Meteorological Organization, *Scientific Assessment of Ozone Depletion: 1994*, ch. 1.
34. This time-path is from 'Scenario A' of the 1994 Science Assessment Panel, in which the assumptions are: precise OECD compliance with the 1992 amendments; Article 5 country use of ODSs growing for a few years then holding constant and declining to zero by 2006; and constant methyl bromide emissions from 1994 to 2100, World Meteorological Organization (1995), *Scientific Assessment of Ozone Depletion: 1994*, Global Ozone Research and Monitoring Project Report no. 37 (Geneva: WMO).
35. 'Illegal Imports of CFCs Increase as Production Ban Nears, U.S. Officials Say', *International Environment Reporter*, 2 Nov. 1994 and 31 May 1995; interviews with US Environmental Protection Agency (EPA), Customs, and IRS officials, July 1995.
36. *OzonAction*, 12 (Oct. 1994); *International Environmental Reporter*, 24 Aug. 1994, 692; *International Environment Reporter*, 2 Nov. 1994, 884.
37. *International Environment Reporter*, 14 June 1995.
38. United Nations Environment Programme, *Report of the Eleventh Meeting of the Open-Ended Working Group*, 13.
39. As at June 1995 Portugal and Kuwait had made none of their assessed contribution since the Fund's establishment, Canada and Italy still owed most of their 1994 contribution, and France, the UK, and Germany were making part or all of their contributions in promissory notes. (France and the UK had forced the issue, by unilaterally switching to promissory notes in 1993; after a subsequent Executive Committee decision authorizing promissory notes, Germany began to use them.)
40. United Nations Environment Programme, *Report of the Eleventh Meeting of the Open-Ended Working Group*, 26–7.
41. e.g. H.R. 2230 (104th Congress, 1st session), which would overturn EPA's regulation of methyl bromide and remove EPA's authority to regulate it except with the explicit consent of the US Department of Agriculture.
42. The European Union and the United States of America (1994), *Trade in Previously-Used Ozone Depleting Substances: A Draft Decision*, UNEP/OzL.Pro/6/CRP/Rev.1 (Nairobi: 5 Oct.).
43. ICF Incorporated, *Report under Paragraph 8 of Article 5 of the Montreal Protocol*, concludes that Article 5 phase-outs before 2000 are unfeasible, while phase-outs in 2000 would require total fund expenditures of $US5.4 billion, or present-value of $US3.8 billion discounted at 10% (Exhibit ES-7).
44. United Nations Environment Programme, *Report of the Eleventh Meeting of the Open-Ended Working Group*, 29.