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AN ECONOMIC FRAMEWORK FOR COORDINATING CLIMATE POLICY WITH THE MONTREAL PROTOCOL

*by Stephen J. DeCanio and Catherine S. Norman**

INTRODUCTION

This article proposes a method to account for the concurrent environmental benefits of stratospheric ozone protection and greenhouse gas ("GHG") reductions when evaluating investments in new technologies. The method demonstrates how the phaseout of ozone-depleting substances ("ODSs") under the Montreal Protocol can be consistent with climate policy when the global warming potential and energy-efficiency characteristics of substitute technologies are fully considered. This approach would increase investment to rapidly phase out ODSs, resulting in significant environmental benefits by avoiding both climate change and increased incidence of harmful ultraviolet radiation. This article illustrates the possibility of gains from coordinating global warming and ozone depletion policies through a modification of the Montreal Protocol on Substances that Deplete the Ozone Layer to allow production and consumption of HCFC-123 when GHG emissions are reduced to near zero levels and these emissions are offset by collecting and destroying ODSs contained in existing equipment and foam — sources of ODS emissions that are not currently controlled.

THE KYOTO PROTOCOL AND MONTREAL PROTOCOL DISCONNECT

Although the physical and chemical processes responsible for depletion of the stratospheric ozone layer and climate change are related,[1] coordination between the Montreal Protocol and the global effort to avoid "dangerous anthropogenic interference"[2] in the climate system has been limited and unsystematic. The Montreal Protocol does not properly take account of the global warming impacts of the ODSs it regulates or the greenhouse gas hydrofluorocarbons ("HFCs") that are chemical replacements for some applications. The Kyoto Protocol, on the other hand, excludes from its list of controlled substances those covered by the Montreal Protocol. As such, economic incentives under Kyoto cannot be applied to a more rapid phase-out of ODS greenhouse gas production and consumption, or to the collection and destruction of ODSs contained in refrigeration and air conditioning equipment and thermal insulating foam.[3] One could argue that this construction of the Kyoto list of controlled substances implicitly empowers the Montreal Protocol to address the global warming impacts of the substances it regulates; however, this option has not yet been exercised by the Parties to the Montreal treaty. More significantly, the Multilateral Fund of the Montreal Protocol has no access to Clean Development Mechanism funds under the Kyoto Protocol, and the emissions trading options of Kyoto cannot be applied directly to ODSs.

COORDINATING ENVIRONMENTAL EFFORTS

Given the interaction between the stratospheric ozone layer and the climate system, and the fact that all the ODSs regulated by the Montreal Protocol (with the exception of halons) are powerful GHGs,[4] coordination of the two regulatory regimes is necessary to effectively address the environmental concerns at stake. Yet, it is not easy to see how this can be done in practice. For example, how might the environmental and economic desirability of two projects, both of which affect greenhouse gas emissions and emissions of ODSs, be compared?

The net benefits from the climate change mitigation and ozone layer protection aspects of the projects are extraordinarily difficult to quantify.

The net benefits from the climate change mitigation and ozone layer protection aspects of the projects are extraordinarily difficult to quantify.[5] The aggregate benefits can be monetized only by making highly contestable assumptions about the "value of a statistical life" across countries in different stages of development. A method for comparing costs and benefits across generations has not been agreed upon. A major component of the benefit of climate stabilization depends on what assumption is made about risk aversion (and not all those affected can be presumed to share a common degree of risk aversion). Estimates of the cost of greenhouse gas reductions range from negative to positive, with the magnitudes of the positive cost estimates differing by a factor of four.[6] Even if the aggre-

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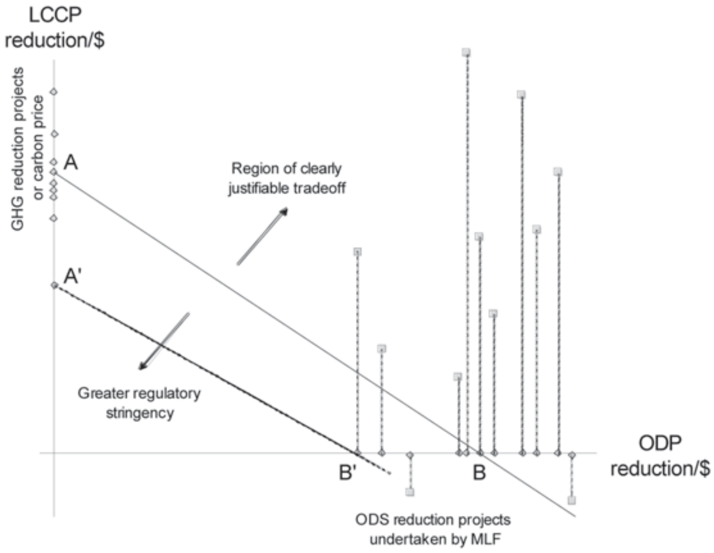
gate impacts were known with more certainty than seems possible with today's knowledge, the response curves of impacts to changes in GHG or ODS emissions are almost certainly non-linear. Therefore, the marginal effect of specific projects cannot be inferred from aggregate impacts. More fundamentally, it is debatable whether cost-benefit analysis is the appropriate tool for analysis of problems that are global in scope, non-marginal in impact, cover centuries of time, and involve the fate of non-human species as well as human beings.[7]

Nevertheless, real money has been and is being spent to reduce both ODS and GHG emissions. (It should be noted at the outset that this article will ignore those emissions-reduction projects that can be undertaken at a pure profit by private-sector firms or governmental agencies. These "no regrets" opportunities should be seized regardless of their environmental benefits and are uncontroversial from a policy perspective.)[8] The current expenditures for emissions reductions provide a benchmark of the "political willingness to pay" ("PWTP") of present-day governments.[9] Political willingness to pay demonstrates collective decisions to finance the most important functions of society such as homeland security, national defense, public health, education, and environment even when traditional cost-benefit calculations are inappropriate or impossible. Although the decisions to invest in ozone layer protection and climate change mitigation have been made independently, the expenditures on these projects provide a basis for estimating the current level of combined regulatory stringency of the two Protocols.

Developing a Common Economic Framework

Consider a two-dimensional mapping of project characteristics with reductions in ozone depletion potential ("ODP") per dollar spent on one axis and reductions in "life-cycle climate performance" ("LCCP")[10] per dollar on the other. Data on the money spent to eliminate or reduce ODSs are available in the database maintained by the Multilateral Fund operating under the Montreal Protocol,[11] or from case studies of ODP reduction projects undertaken by firms or government entities. From these data, it is possible to infer the maximum PWTP to reduce ODP, as well as various measures of the central tendency of PWTP. Similarly, information is available on the cost of GHG reduction projects undertaken by private firms, international projects certified under the Clean Development Mechanism of the Kyoto Protocol, and the prices of CO_2 emissions permits traded on the European Climate Exchange. The ODP or LCCP reductions per dollar spent on these projects can be represented in the kind of diagram familiar to economists by points along the two axes as shown in Figure 1. The circles on the axes represent the emissions changes per dollar of the different projects (either ODP or LCCP reductions).[12] The square "dots" reflect the fact that most ODP reductions have also reduced the global warming impact. This occurs because either the replacement technologies use gases with a lower direct global warming potential than the CFCs they replaced, or the new technologies have been more energy-efficient, or both. Nevertheless, it is possible for an ODP reduction to be associated with an increase in GHG emissions so that the "improvement" in LCCP/$ is negative. Cases of this type would show square dots below the horizontal axis.

Figure 1 - Balancing ODS and GHG Reductions

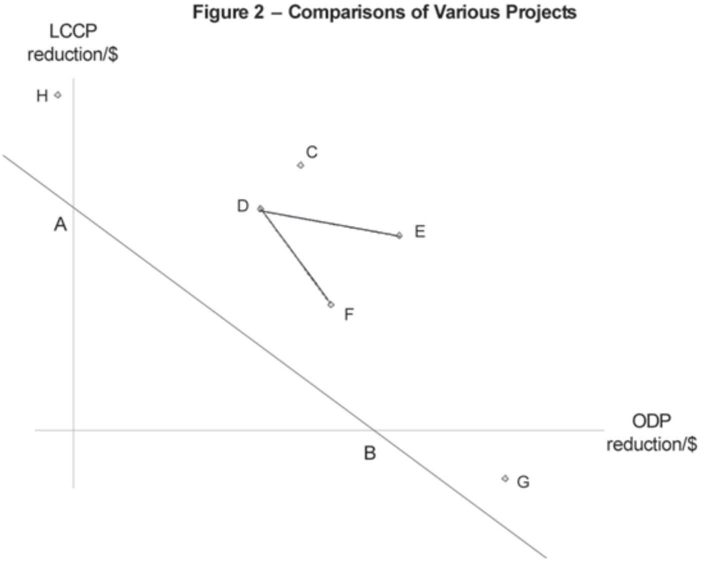


The diagonal line AB, in Figure 1, is drawn to reflect the combined degree of stringency implicit in the two regulatory regimes. This line connects the central tendencies (*e.g.*, the means or medians) of the distributions of the LCCP reduction project points and the ODP reduction project points. Shifting the AB line towards the origin represents an increase in regulatory stringency; if the axes had been drawn in units of \$/ODP reduction and \$/LCCP reduction, increasing regulatory stringency would be expressed by a movement away from the origin.[13] The slope of AB is a rough measure of the dollar tradeoff between LCCP reductions and ODP reductions embodied in current levels of PWTP.

The tradeoff line could also have been drawn in other ways. For example, the dotted line A'B' connects the most expensive emissions reduction projects.[14] It could be maintained that A'B' more accurately reflects the PWTP frontier than AB because all projects currently funded lie above and to the right of A'B'. Alternatively, if it were decided under the successor to Kyoto that there should be, for example, a global emissions charge of \$125/tonne of CO_2, the anchoring point of the AB line on the vertical axis would be at 0.008 (=1/125) with the LCCP axis scaled in tonnes of CO_2 equivalent per dollar.

The area above and to the right of the AB line (or of the A'B' line, if the more inclusive definition of PWTP is being used as the standard) represents those projects that are "clearly justified" at the current levels of regulatory stringency of the two Protocols, while projects falling in the area below and to the left of the line AB (or A'B') are not so clearly justified. This is not to suggest that projects on the axes below point A or to the left of point B should not have been undertaken. Indeed, if A and B are central tendencies, a considerable number of projects will lie on either side of these points by definition. It may also be the case that PWTP has not yet caught up with the socially desirable degree of emissions reductions, so a shift of line AB (or A'B') down and to the left would improve general welfare. Note also that if only the Montreal Protocol proceeds to a complete phase-

Figure 2 – Comparisons of Various Projects



out of the substances controlled under it, the line AB would rotate about point A until it coincides with the vertical axis. Similarly, a complete ODS phaseout under A'B' would pivot on A' until the point B' coincides with the origin.

Practical Policy Applications of a Common Economic Framework

This conceptual framework offers two advantages. First, it enables policy makers to evaluate projects with both global warming and ozone-protection benefits in a unified way, given the current levels of regulatory stringency implicit in the two Protocols. Second, this framework shows how projects might be compared in the cases in which one is not preferable to the other along both dimensions. Thus, in Figure 2, Project C is preferable to Project D because C results in more cost-effective reductions in both ODP and LCCP. But what about comparisons between Project D and Project E, or between Project D and Project F? All three lie in the region above and to the right of line AB, so in one sense all three should be undertaken at current levels of regulatory stringency. However, E is preferable to D at the current tradeoff rate between LCCP/$ and ODP/$ as indicated by the slope of AB. On the other hand, D is preferred to F at the AB tradeoff rate, but F could be preferred to D if the slope of the tradeoff line were steep enough (*i.e.* sufficiently negative). Figure 2 also shows the case of point G, a project with a large enough ODP-reduction potential to be worth undertaking even though it has an undesirable global warming impact.

This analytical framework has direct applicability to some of the immediate issues that need to be considered in strengthening the Montreal Protocol. For example, the use of HCFC-123 in large chillers has up to a 13.5 percent energy efficiency advantage over the best alternatives.[15] HCFC-123 also has a significant refrigerant emission advantage because it is a liquid at atmospheric pressure and temperature and operates at a partial vacuum in air conditioning equipment. On the other hand, HFC-134a (the best competing alternative) is a gas at atmospheric pressure and temperature and operates at high pressure in air conditioning equipment, increasing the risk of uncontrolled emissions. The ODP of HCFC-123 is very low (0.012) but not zero, while HFC-134a has an ODP of essentially zero.[16] HCFC-123 is scheduled for complete phaseout in 2030 in the developed countries (with a 99.5 percent phaseout by 2020). However, HFC-134a is not controlled under the Montreal Protocol, but rather is controlled under the Kyoto Protocol as one of the basket of greenhouse gases. HFC-134a has also been targeted by the European Union for phaseout in automobile air conditioners.[17] The lack of coordination between Montreal and Kyoto could discourage building owners from selecting HCFC-123 systems as the environmentally superior technology. With the substantial energy efficiency advantage and near-zero refrigerant emissions over the 30-year lifetime of a large chiller, selection of HCFC-123 instead of HFC-134a in this application would fall in the region above the line AB because of the very large LCCP gain from the greater energy efficiency of the HCFC-123 chiller. This is illustrated by point H in Figure 2, with the very small ODP of the HCFC-123 chiller compared to an HFC-134a chiller indicated by the placement of H slightly on the negative side of the ODP/$ axis.[18]

Worldwide, in both developed and developing countries, there are approximately 65,673 — 105,076 CFC chillers containing 24,173 — 38,676 ODP-weighted tonnes of CFC.[19] If all of these CFC chillers were immediately replaced with HCFC-123 chillers, global greenhouse gas emissions would be significantly reduced. Destruction of the CFCs in the old equipment could offset the lifecycle HCFC-123 emissions not only for the replacement chillers, but also for chillers required in new construction for decades to come. Mindful of the continuing climate benefits, by the time the offsets run out the ozone layer is expected to have largely recovered and might tolerate some ODS emissions.

The framework proposed in this article would automatically incorporate policies designed to allow for destruction credits associated with permission to use ODSs, either in a Montreal-only framework or in an integrated framework requiring destruction sufficient to move a project to a combined regulatory stringency boundary. Thus, in the preceding example of the HCFC-123 chiller, the welfare improvement would be unambiguous (regardless of the slope of AB) if the HCFC-123 used in the chiller were offset by destruction of an equivalent or greater amount of ODP. As such, HCFC-123 chillers are unequivocally environmentally superior if designed and maintained for superior energy efficiency and near-zero refrigerant emissions offset by collection and destruction of ODSs currently contained in existing equipment and foam products.

This example shows how the Montreal Protocol could be strengthened with an accelerated ODS phaseout while at the same time contributing to climate protection by reducing greenhouse gas emissions. All that is required is that controls for developed countries and financing for developing countries guide the choice of alternatives and substitutes for ODSs towards those technologies offering the lowest LCCP. In addition, as in the chiller example, companies should be permitted to offset HCFC-123 emissions by destruction of other ODSs when significant improvements in energy consumption are available.

CONCLUSION

Several policy guidelines emerge from this approach. First, it is environmentally and economically superior to choose alternatives or substitutes for ODSs that are ozone-safe (zero ODP) *and* that also have lower direct and indirect greenhouse gas emissions. Second, it can be economically preferable to choose alternatives or substitutes to ODSs that have a small impact on ozone (non-zero ODP) *if* it is judged, based on current or projected future PWTP, that the resulting lower direct and indirect greenhouse gas emissions justify the ozone depletion. Third, it is unequivocally preferable both economically and environmentally to choose alternatives or substitutes to ODSs that have a small impact on ozone (non-zero ODP) *provided* that impact is offset by destruction of existing "legacy" ODS, the destruction of which is not mandated by the Montreal Protocol and which is not already required to be destroyed by other national or regional legislation, *and if* the replacement technologies result in lower direct and indirect greenhouse gas emissions.

Using a unified analytical framework, we have shown how it is possible to combine the political willingness to pay to protect the ozone layer and mitigate greenhouse gas emissions. This approach can be applied to both the current effort to strengthen the Montreal Protocol and the search for consensus on how to move beyond Kyoto to mitigate climate change. Practical applications of this approach would favorably shift investment toward technology that satisfies broad criteria of environmental protection and sustainable development and would use emissions trading to reduce the cost of both ozone and climate protection while expanding the flexibility of business choice. Economic considerations should never obscure the ethical principles that must primarily guide these policies, but by eliminating perverse incentives and avoiding expensive mistakes, economics has an important role to play in promoting cost-effectiveness. The approach outlined here retains the flexibility and openness to new scientific understanding that have been hallmarks of the Montreal Protocol's success. In building on what has been accomplished thus far, our obligation to future generations requires nothing less than effective and intelligent integration of measures for protection of the ozone layer and stabilization of the climate system.

Endnotes: An Economic Framework

[1] UN Env't Programme, *The Implications to the Montreal Protocol of the Inclusion of HFCs and PFCs in the Kyoto Protocol* (Oct. 1999), *available at* http://www.uneptie.org/ozonaction/information/mmcfiles/4254-e-teap99hfcpfc.pdf (last visited Jan. 27, 2007); *see also* Intergovernmental Panel on Climate Change (IPCC), *Safeguarding the Ozone Layer and the Global Climate System: Issues Related to Hydrofluorocarbons and Perfluorocarbons* (2005), *available at* http://arch.rivm.nl/env/int/ipcc/pages_media/SROC-final/SpecialReport-SROC. html (last visited Feb. 6, 2007) [hereinafter IPCC/TEAP Report]; *see also* Stephen O. Andersen, *Ozone and Climate Instruments — the Dilemma's in the Detail*, OzonAction, No. 46, 6 (Dec. 2003); Stephen O. Andersen & Jose Pons, *Two Protocols: One Integrated Solution*, OzonAction, Sept. 2005, at 8.

[2] Implementation of the UNFCCC thus far has been through the Kyoto Protocol, through various domestic initiatives by the United States, Australia, and other nations that have not ratified Kyoto, and through bilateral or multilateral projects involving China, India, and other developing countries that are not presently committed by Kyoto to any specific reductions in their greenhouse gas emissions. United Nations Framework Convention on Climate Change ("UNFCCC") website, http://unfccc.int (last visited Feb. 13, 2007).

[3] Some halogenated chemicals, in particular hydrofluorocarbons ("HFCs") and perfluorocarbons ("PFCs"), are explicitly included in Kyoto. *See* Kyoto Protocol to the United Nations Framework Convention on Climate Change arts. 11, V, Annex A, Dec. 10, 1997, 37 I.L.M. 22, *available at* http://unfccc.int/resource/docs/convkp/kpeng.html (last visited Feb. 13, 2007) (containing Articles II and V lists which exclude substances covered by Montreal, and Annex A lists substances controlled under Kyoto).

[4] IPCC/TEAP Report, *supra* note 1, at 6.

[5] Computations of the net losses from ozone depletion and global temperature increases have been published. For the ozone case, *see* Stephen J. DeCanio, *Economic Analysis, Environmental Policy, and Intergenerational Justice in the Reagan Administration: The Case of the Montreal Protocol*, Int'l Envtl. Agreements: L & Pol. 299, 299-321 (2003); for climate, *see* Climate Change 1995: Economic And Social Dimensions Of Climate Change 178-224 (Cambridge University Press 1996); Climate Change 2001: Impacts, Adaptation, And Vulnerability 913-967 (Cambridge University Press 2001); Stern Review On The Economics Of Climate Change 150 (HM Treasury), *available at* http://www.hm-treasury.gov.uk/media/8AC/ CC/Chapter_6_Economic_modelling.pdf (last visited Feb. 13, 2007).

[6] Terry Barker & Paul Ekins, *The Costs of Kyoto for the U.S. Economy*, The Energy J. 3d Q., at 53-71 (2004); *see also* Stephen J. DeCanio, Economic Models Of Climate Change: A Critique (Palgrave Macmillan 2003).

[7] On the limitations of cost-benefit analysis. *See* Frank Ackerman & Lisa Heinzerling, Priceless: On Knowing The Price of Everything And the Value of Nothing (The New Press 2005); *see also* Stephen J. DeCanio, *Is Economics the Wrong Language for Addressing Climate Policy?* (Nov. 16-17, 2006) *available at* http://www.aceee.org/conf/06modeling/ucsb.pdf (last visited Feb. 13, 2007).

[8] Interlaboratory Working Group on Energy-Efficient and Clean-Energy Technologies, Scenarios For A Clean Energy Future, Oak Ridge National Laboratory and Lawrence Berkeley National Laboratory, ORNL/CON-476 and LBNL-44029 (Nov. 2000), *available at* http://www.ornl.gov/sci/eere/cef/ (last visited Feb.13, 2007); World Resources Institute, Ozone Protection in The United States: Elements Of Success (1996), *available at* http://www.wri.org/climate/pubs_description.cfm?pid=2692 (last visited Jan. 19, 2006).

[9] Stephen J. DeCanio and Catherine S. Norman, *Economics of the 'Critical Use' of Methyl Bromide under the Montreal Protocol*, 23 Contemp. Econ. Pol. 376, 376-393 (2005).

[10] The "life-cycle climate performance" ("LCCP") is a measure of the total effect on GHG emissions of a change in technologies, including both the direct global warming impact of the emissions and differences in indirect emissions due to differences in the energy efficiency of the technologies over their lifetimes. Reduction of LCCP mitigates climate change. LCCP is more comprehensive than the earlier concept of "total equivalent warming impact" ("TEWI"), which ignored the energy embodied in product materials, the greenhouse gas emissions during chemical manufacturing, and the impacts of weight on energy consumption of mobile equipment. *See* William R. Hill, *North America Projects to Develop Standard Tests for MAC Efficiency*, presentation at International Energy Agency Workshop, "Cooling Cars with less Fuel" (Oct. 23–24, 2006), *available at* http://www.iea.org/Textbase/work/workshopdetail.asp?WS_ID=247 (last visited Jan. 4, 2007); S. K. Fischer et al., *Energy and Global Warming Impacts of CFC Alternative Technologies* (1991), *available at* http://www.ciesin.org/docs/011-459/011-459.html (last visited Jan. 19, 2007) (containing description of the original TEWI methodology).

[11] This institution finances the "agreed incremental cost" of ODS replacement

Endnotes: An Economic Framework *on page 82*

Endnotes: An Economic Framework

continued from page 44

projects in developing countries with contributions from the developed countries according to the UN funding formula. *See* Stephen O. Andersen & Madhava Sarma, Protecting the Ozone Layer: The United Nations History (Earthscan Publications 2002). Richard Benedick, Ozone Diplomacy: New Directions in Safeguarding the Planet (2d Revised ed., Harvard University Press 1998).

[12] The "data points" shown in Figure 1 are indicative only. Plotting the thousands of actual projects that have been undertaken would entail a significant empirical effort, and is the subject of ongoing data collection. Note also that the larger the LCCP reduction per dollar (*i.e.*, the farther up the vertical axis), the greater the environmental benefit.

[13] The choice of whether to use ODP/$ and LCCP/$ or $/ODP and $/LCCP as units on the axes is arbitrary. The substantive application of the methodology being proposed here is not affected, so long as consistency is maintained in describing the projects. Of course, the tradeoff line could have curvature, but that is a second-order consideration that will not be discussed here.

[14] Note that AB and A'B' are not necessarily (or even likely to be) parallel.

[15] Press Release, TRANE Extends Energy Efficiency Advantage of Earth-Wise™ CenTraVac™ Chillers (Dec. 16, 2005), *available at* http://www.trane.com/commercial/homepage/ pdf/PR_EWchillers1205.pdf (last visited Feb. 13,

2007); *see* STEPHEN O. ANDERSEN & DURWOOD ZAELKE, INDUSTRY GENIUS: INVENTIONS AND PEOPLE PROTECTING THE CLIMATE AND FRAGILE OZONE LAYER, 173-174 (Greenleaf Publishing 2003) (providing a calculation showing that the maximum theoretical coefficient of performance (COP) for HCFC-123 is 7 percent greater than for HFC-134a).

[16] *See* Technical and Economic Assessment Panel, 2002 REPORT OF THE REFRIGERATION, AIR CONDITIONING AND HEAT PUMPS TECHNICAL OPTIONS COMMITTEE, *available at* http://ozone. unep.org/teap/Reports/RTOC/RTOC2002.pdf (last visited Jan. 06, 2007) (stating the ODP value for HCFC-123 is the modeled value — considered to be most indicative of environmental impact); *see also* UN Env't Programme, SCIENTIFIC ASSESSMENT OF OZONE DEPLETION: 2002, *available at* http://ozone.unep.org/Publications/6v_science%20assess%20panel.asp (last visited Feb. 13, 2007) (stating that the upper bound on the ODP of HFC-134a is $<1.5 \times 10^{-5}$).

[17] United Kingdom, Department of Trade and Industry (DTI), *Regulation EC No 842/2006 of the European Parliament and of the Council on certain fluorinated greenhouse gases* (Nov. 9, 2006), *available at* http://www.dti.gov.uk/innovation/sustainability/fgases/page28889.html (last visited Jan. 11, 2007).

[18] Donald J. Wuebbles and James M. Calm, *An Environmental Rationale for Retention of Endangered Chemicals*, 278 SCIENCE 1090, 1090-1091 (1997) (arguing for modification of the Montreal Protocol to allow *de minimus* ODP if the global warming benefit is large enough).

[19] Technical and Economic Assessment Panel, *supra* note 16, at 108. This conservative range is based on the estimates for the United States, Canada, and India given in that report, and the judgment that "[p]erhaps this accounts for 25–40 percent of the CFC chillers in service around the world." Details of the calculation are available from the authors. The 2002 REPORT notes that "[a]ccurate inventories of equipment in service around the world, and the types and amounts of refrigerants used in these chillers, are not available," so this sort of rough estimate may be the best that can be done in the absence of better data. Interestingly, the 1994 REPORT OF THE ECONOMIC OPTIONS COMMITTEE [of the TEAP], using different sources and methods, estimated the 2007 inventory of CFC-11 in commercial chillers to be 26,583 tonnes, which is within the range given in the text.