Testimony of
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United States Senate

Committee on Environment & Public Works

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"The Case of the Montreal Protocol: Science Serving Public Policy"

Since 1994, I have been President of the National Council for Science and the Environment (NCSE), an organization dedicated to improving the scientific basis for environmental decision making that is supported by over 500 universities, scientific societies, state and local governments, corporations, chambers of commerce, foundations and civic organizations.

During the 1980s, I served under President Reagan as Deputy Assistant Secretary of State for Environment, Health and Natural Resources. In 1985, I was designated by Secretary of State George Shultz and then-Assistant Secretary John Negroponte to be chief U.S. negotiator for a treaty to regulate certain chemical substances suspected of depleting the stratospheric ozone layer. I later wrote a book on the subject, *Ozone Diplomacy*, which was published by Harvard University Press (1991, revised ed. 1998) and Kyogo Chosakai (Japan, 1999), and was later selected by McGraw-Hill for an anthology of environmental classics of the twentieth century.

Introduction: An Historic Agreement

The ozone history illustrates the critical role that science and scientists can play in the development of public policy under conditions of risk and uncertainty. Yet, when the negotiations began on the treaty to control use of chlorofluorocarbons (CFCs), few gamblers would have wagered that they could succeed.

CFCs and their related bromine halon compounds seemed to be ideal man-made chemicals. Invented in the 1930s, they are stable, nontoxic, nonflammable, non-corrosive, and relatively inexpensive to produce – all qualities that made them uniquely suited for a myriad of consumer and industrial applications. Over the years, they found more and more uses in thousands of products and processes – in pharmaceuticals, cosmetics, spray cans, agriculture, petroleum, microchips, electronics, automotive, defense, aircraft, insulation, plastic foam, aerospace, telecommunications, refrigeration, and air conditioning, to name a few. CFCs became virtually synonymous with modern standards of living.

The scientific, economic, technological and political issues involved in the negotiations were staggeringly complex. Billions of dollars of international investment and hundreds of thousands of jobs worldwide were involved in production and consumption of CFCs and halons. Powerful governments in Europe, Japan and the Soviet Union aligned with global economic interests in adamant opposition to controlling CFCs, maintaining that technological alternatives were nonexistent or too costly or unfeasible.

The then-twelve nation European Community (EC) was the primary opponent of action. Its ozone position was based largely on the self-serving data and contentions of a few major companies – including Britain's Imperial Chemical Industries (ICI), France's Atochem, and Germany's Hoechst. European industry's primary objective was to preserve their market dominance and to avoid the costs of switching to alternative products for as long as possible. Epitomizing the close EC industry-government linkages, company executives often served on official delegations. Indeed, during the protocol negotiations we actually came across an official EC instruction drafted on an Atochem corporate letterhead.

Most other governments and peoples were unaware or indifferent to an arcane threat occurring 30 miles above the earth's surface. As an Indian diplomat admonished me early in the negotiations: "Rich man's problem – rich man's solution."

Perhaps most significant of all, during the negotiations the arguments for controlling CFCs rested on unproven scientific theories. The science remained speculative, based on projections from still-evolving computer models of imperfectly understood atmospheric processes – models that yielded varying, sometimes contradictory predictions each time they were refined.

Despite the significant growth in emissions of CFCs, thirty years of recorded measurements had not demonstrated any statistically meaningful ozone depletion over mid-latitudes. The models did not even predict global depletion, with existing levels of emissions, for at least the next twenty years. Moreover, not only was there no evidence of increased levels of UV-B radiation reaching earth's surface, but such measurements as existed actually showed reduced radiation.[1] During the negotiations, the seasonal "ozone hole" over Antarctica, while alarming, was considered by most scientists to be an anomaly, since it did not conform to the theoretical ozone depletion models and could possibly have had other than anthropogenic causes.

Nevertheless, after contentious international negotiations, compounded by unexpected late controversy from within the U.S. administration, a strong control treaty was signed in Montreal in September 1987. The treaty signing attracted worldwide media attention, and it was hailed in the United States Senate as "the most significant international

[1] D.Albritton et al., *Stratospheric Ozone: The State of the Science and NOAA's Current and Future Research* (Washington DC: National Oceanic and Atmospheric Administration, 1987), p.9; WMO, *Atmospheric Ozone 1985: Assessment of Our Understanding of the Processes Controlling Its Present Distribution and Change* (Geneva, 1986), chapter 14.

environmental agreement in history."[2] President Reagan became the first head of state to endorse the Montreal Protocol, characterizing it as “a monumental achievement of science and diplomacy,”[3] and the treaty was unanimously ratified by the Senate.

Perhaps the most extraordinary aspect of the Montreal Protocol was that it imposed substantial short-term economic costs in order to protect human health and the environment against speculative future dangers -- dangers that rested on scientific theories rather than on proven facts. Unlike environmental agreements of the past, this was not a response to harmful developments or events, but rather preventive action on a global scale.

Within less than six years after the negotiations began in late 1986, the Montreal Protocol had been ratified by more than 100 (later over 180) nations. Gradually unfolding scientific evidence of damage to the ozone layer led to major revisions of the protocol, expanding the list of controlled chemicals from 8 to over 90 and considerably strengthening timetables for reduction and phase out of the dangerous chemicals.[4] A veritable technological revolution was unleashed that within a few years transformed entire industries. The protocol also created the first-ever global environmental fund to assist poorer nations, and promoted an unprecedented North-South collaboration in developing and diffusing new technologies that have now made most ozone-depleting substances obsolete.

Even so, it was a near thing. For decades after their discovery, no one had suspected that these multifaceted wonder-chemicals could cause any harm. They had been thoroughly tested by customary industrial standards and declared completely safe. Possible effects thirty miles above the earth had simply never been considered. And, because the CFCs and halons have such long atmospheric lifetimes, their deleterious impacts will still be felt for decades, even after new emissions cease.

The Montreal Protocol is generally considered to be the most successful environmental treaty in history. The heads of the World Meteorological Organization (WMO) and the United Nations Environment Programme” (UNEP) stated that “the action to defend the ozone layer will rank as one of the great international achievements of the century.”[5] Given the threats to human life and the global economy that have been averted through this landmark treaty, few would challenge their statement as hyperbole.

The Role of Science and Scientists

[2] U.S. Senate, Committee on Foreign Relations, *Ozone Protocol*, Executive Report 100-14, Feb. 19, 1988, p.61.
[3] “President Signs Protocol on Ozone-Depleting Substances,” *Department of State Bulletin*, June 1988, p.30.
[4] R. Benedick, *Ozone Diplomacy: New Directions in Safeguarding the Planet* (Cambridge, MA. and London: Harvard University Press, rev. ed. 1998), provides a history and analysis of the ozone issue and the Montreal Protocol negotiations.
[5] G.O.P.Obasi and Elizabeth Dowdeswell, Foreword to R. Bojkov, *The Changing Ozone Layer*, Geneva: WMO/UNEP, 1995.

Unquestionably the indispensable element in the success of the Montreal Protocol was the role of science and scientists. Without the curiosity and courage of a handful of researchers in the mid-1970s, the world might have learned too late of the hidden dangers linked with rapidly expanding use of CFCs.

Ozone, whose existence was unknown until 1839, has been characterized as "the single most important chemically active trace gas in the earth's atmosphere."[6] Two singular characteristics of this remote, unstable, and toxic gas make it so critical to human society. First, certain wavelengths of ultraviolet radiation (UV-B) that can damage DNA and the immune system and can cause cancer in living cells are absorbed by the thin layer of ozone molecules scattered throughout the atmosphere; the harmful radiation is thus prevented from reaching the earth's surface. And second, differing quantities of ozone at different altitudes have major implications for global climate. In sum, human health, agriculture and livestock, fisheries, biological diversity, and many materials would be significantly impacted by damage to the ozone shield. The ozone layer, at its historic natural concentrations and diffusion, is essential to life as it currently exists on earth.

In 1973, two University of Michigan scientists, Richard Stolarski and Ralph Cicerone, in the course of examining possible effects of chemical emissions from National Aeronautics and Space Administration (NASA) rockets, theorized that chlorine in the stratosphere could unleash a complex chain reaction that would continually destroy ozone over a period of decades. Fortunately, very little "free chlorine" was thought to exist at that altitude.[7]

However, a year later, Mario Molina and Sherwood Rowland at the University of California, Irvine, became intrigued with some peculiar properties of chlorofluoro-carbons. They discovered that, unlike almost all other gases, CFCs were not chemically destroyed or rained out in the lower atmosphere, but rather migrated slowly up into the stratosphere. There they remained for many decades -- some variants for more than a century. The two researchers concluded that the man-made CFCs, which are not naturally present at this altitude, are eventually broken down by radiation and thereby release large quantities of free chlorine.[8]

The combined implications of these two hypotheses were nothing less than sensational: *the protective ozone shield would be seriously compromised.* The enhanced levels of ultraviolet radiation that would then penetrate the atmosphere and reach earth's surface could have potentially disastrous impacts. The Rowland-Molina hypotheses unleashed a firestorm of criticism and controversy in the scientific and business communities. They

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[6] D. Albritton et al., *Stratospheric Ozone: The State of the Science and NOAA's Current and Future Research* (Washington, D.C.: National Oceanic and Atmospheric Administration, 1987), p.1.

[7] R.S. Stolarski and R.J. Cicerone, "Stratospheric Chlorine: A Possible Sink for Ozone," *Canadian Journal of Chemistry* 52 (1974).

[8] M.J. Molina and F.S. Rowland, "Stratospheric Sink for Chlorofluoromethanes: Chlorine Atomic Catalyzed Destruction of Ozone, *Nature* 249 (1974).

were later vindicated by the 1995 Nobel Prize in Chemistry (together with Paul Crutzen of the Max Planck Institute), but it is worth noting that the first popular book on this subject, published in 1978, was entitled *The Ozone War*.[9]

Astonishingly, the research paths leading to the suspicion that the stratospheric ozone layer was in jeopardy had been serendipitous. The scientists had not set out intentionally to condemn chlorofluorocarbons. Notwithstanding the initial controversy, the serious theoretical dangers prompted a wave of new scientific research over the following years.

It would be difficult to exaggerate the complexity of the research effort. Ozone itself amounts to considerably less than one part per million of the total atmosphere, with 90 percent of it located above six miles in altitude. The intrinsically unstable ozone molecules are continually being created and destroyed by complex natural forces involving solar radiation and interactions with even more minute quantities of other gases. Moreover, stratospheric ozone concentrations can fluctuate on a daily, seasonal, and solar-cyclical basis, and there are significant geographical as well as altitudinal variations

Amidst all these fluxes, scientists faced a formidable challenge in predicting, and then detecting, the minuscule "signal" of the beginning of a possible long-term downturn in stratospheric ozone as postulated by the theory. This necessitated the development of ever more sophisticated computer models to simulate the stratospheric interplay among radiative, chemical, and dynamic processes such as wind and temperature, for decades and centuries into the future. In addition, intricate observation and measuring devices had to be created and fitted onto aircraft, satellites, and rockets to monitor remote gases in quantities as minute as parts per trillion.

To fully understand the implications of a diminishing ozone layer, scientists had to venture far beyond atmospheric chemistry: they had to examine our planet as a system of interrelated physical, chemical and biological processes on land, in water, and in the atmosphere – processes that are themselves influenced by economic, political, and social forces. The Montreal Protocol thus became a truly multi- and interdisciplinary effort. Over the years, researching the dangers and solutions involved not only chemists and physicists, but also meteorologists, oceanographers, biologists, oncologists, economists, epidemiologists, soil chemists, toxicologists, agronomists, pharmacologists, botanists, entomologists, and electrical, chemical, automotive and materials engineers.

The Protocol in Transition

Even as the negotiators were hammering out the final compromises in Montreal in September 1987, an unprecedented international scientific expedition was under way in Antarctica. Using specially designed equipment placed in balloons, satellites, a DC-8 flying laboratory, and a converted high-altitude U-2 spy aircraft, scientists were tracking stratospheric chemical reactions and measuring minute concentrations of gases.

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[9] L. Dotto and H. Schiff, *The Ozone War* (Garden City, NY: Doubleday, 1978).

Preliminary results, announced about two weeks after the protocol's signing, indicated high stratospheric chlorine presence and the worst-ever seasonal drop in Antarctic ozone. Six months later, in March 1988, a joint NASA-NOAA press conference released the Ozone Trends Panel Report, a comprehensive international scientific assessment of all previous air- and ground-based stratospheric trace gas measurements, including those from the 1987 Antarctic expedition. The conclusions were stunning: no longer a theory, ozone layer depletion had at last been substantiated by hard evidence. The analysis established that between 1969 and 1986, stratospheric ozone over heavily populated regions of the northern hemisphere, including North America, Europe, and the Soviet Union, China, and Japan, had diminished by small but significant amounts. And CFCs and halons were now implicated beyond dispute -- including responsibility for the ozone collapse over Antarctica.

The new scientific findings were profoundly disquieting. The most alarming implication was that the models on which the Montreal Protocol was based had proven incapable of predicting either the chlorine-induced Antarctic phenomenon or the extent of ozone depletion elsewhere. Most probably, therefore, they were *underestimating* future ozone losses.

Scientific studies now indicated that if existing atmospheric concentrations of chlorine and bromine were merely stabilized, the Antarctic ozone loss would be permanent. In order for ozone levels over Antarctica gradually to recover, and to avoid possibly crossing similar unforeseen thresholds in the future, it would be necessary to restore atmospheric chlorine concentrations (then at three parts per billion and rising) to levels at least as low as those prevailing in the early 1970s, namely, two parts per billion.

The original CFCs and halons would be phased out more rapidly than any of the negotiators at Montreal could have dreamed possible.

Although the work of protecting the ozone layer is still not completely finished, the major challenges have been successfully addressed. The industrialized countries have either phased out, or are in process of phasing out, all of the major ozone-depleting substances as well as the less-damaging transitional chemicals. Developing countries have also accepted phase-out schedules as a great wave of new technologies is being diffused around the world.

Now, the ozone layer is slowly beginning to recover.

Lessons for Science

Without modern science and technology, the world would have remained unaware of an ozone problem until it was too late. Science became the driving force behind ozone policy, but it was not sufficient for scientists merely to publish their findings. In order for the theories to be taken seriously and lead to concrete policies, scientists had to interact closely with government policy makers and diplomatic negotiators. This meant that they had to leave the familiar atmosphere of their laboratories and assume an unaccustomed shared responsibility for the policy implications of their research. The history of the Montreal Protocol is filled with instances of scientific panels being called upon to analyze and make informed judgments about the effectiveness and consequences of alternative remedial strategies and policy measures.

International scientific consensus was also essential. In effect, a community of scientists from many nations, dedicated to scientific objectivity, experienced through their research a mutual concern for protecting the planet's ozone layer that transcended divergent national allegiances. The development of an accepted common body of data and analysis was the prerequisite for a political solution among negotiating governments whose initial positions seemed irreconcilable.

In 1984, a remarkable international collaborative research effort was launched by the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA), in cooperation with the WMO, UNEP, the Federal Aviation Administration, the German Ministry for Research and Technology, and the Commission of the European Communities. Approximately 150 scientists of various nationalities worked under U.S. scientists' leadership for more than a year. The resulting study, *Atmospheric Ozone 1985*, was the most ambitious analysis of the stratosphere ever undertaken: three volumes containing nearly 1,100 pages of text and eighty-six pages of references.[10] This was followed by even more ambitions international studies.

The Montreal Protocol later institutionalized this concept by establishing independent international expert panels to periodically assess scientific, technological, economic, and environmental developments and thereby guide the negotiators in the implementation and revision of the treaty. Over the years, thousands of scientific and industry experts from dozens of countries participated in the effort to learn more about both the dangers and the possible technological solutions. This proved to be a central element in the protocol's success, facilitating agreement by negotiators on additional controls to protect the ozone layer. In effect, the protocol was deliberately designed to be a dynamic process of narrowing the ranges of uncertainties and adjusting the measures accordingly, rather than being a static one-time solution.

A major lesson from the ozone history is that Nature does not always provide policy makers with convenient early-warning signals of disaster, as exemplified in the case of the Antarctic "ozone hole." In 1985, British scientists published findings based on balloon measurements of ozone made at Halley Bay in Antarctica. It appeared that stratospheric ozone concentrations during the Antarctic early spring (September-October) were about 40 percent lower than during the 1960s. While the ozone layer recovered toward the end of each spring, the extent of the seasonal ozone collapse, or "ozone hole" (i.e., a portion of the stratosphere in which greatly diminished ozone levels were measured), had apparently accelerated beginning in 1979.

[10] See footnote 1.

Total chlorine concentrations over Antarctica, at a natural level of 0.6 parts per billion, had been slowly increasing for decades. However, no effect on the ozone layer was evident until the concentration exceeded two parts per billion, which apparently triggered the totally unexpected collapse. In other words, chlorine concentrations had *tripled* with no impact whatsoever on ozone until they crossed an unanticipated threshold. This nonlinear response has obvious implications for the potential dangers of other types of anthropogenic interference with the planet's natural cycles and resources.

The British group had actually initially hesitated to publish their findings because they were considered too fantastic.[11] Ironically, it was later discovered that U.S. and Japanese space satellites had not signaled the ozone collapse because, in order not to deluge scientists with unmanageable masses of data, satellite computers were programmed to automatically reject as anomalies any measurements so far below the "error" range of existing predictive models!

The role of scientists in the ozone history also provided some useful lessons for the climate change issue. During the 1980s, scientific assessments on climate change appeared regularly, under the aegis of WMO and UNEP, from a small group of largely self-selected scientists called the Advisory Group on Greenhouse Gases. In the summer of 1987, while preparing for the conclusive final negotiation in Montreal, I recommended that the U.S. propose establishing a formalized international assessment body on climate change, similar to what we were doing on the ozone issue. My belief was that findings would be more credible coming from a larger and more diverse group of scientists operating under intergovernmental auspices.

This idea attracted unexpected allies and opponents. Some traditionally anti-environmental officials within the Reagan administration endorsed the concept, anticipating that it would provide governments with more control over the science. In contrast, environmental groups feared that the process would become distorted by politics. My own feeling, grounded in the ozone experience, was that the great majority of scientists were unlikely to allow themselves to be influenced by political, ideological or commercial interests, and that governments for their part would have greater respect for the results of a comprehensive international process of investigation and peer review. The subsequent experience of the Intergovernmental Panel on Climate Change, founded in 1988, has largely confirmed this hope.

Lessons for the Private Sector

The history of the Montreal Protocol also underscored the importance of having sufficient funding for all levels of science, from curiosity-driven basic research to applied engineering solutions. Initially, most research funding came from government sources, in particular NASA and NOAA in connection with their space-related research.

[11] J. Farman, B.G. Gardiner, and J.D. Shanklin. "Large Losses of Total Ozone in Antarctica Reveal Seasonal Clx/NOx Interaction," *Nature, no. 315 (1985).*

But this was not always the case. In 1985, when the U.K. Government was still strongly opposed to meaningful controls over CFCs, it ceased financing, for obvious political motives, the British scientific mission in Antarctica that had uncovered the "ozone hole." Significantly, the financial gap was filled by the U.S. Chemical Manufacturers Association; the American chemical companies hoped that controls would not be necessary, but they wanted to resolve the uncertainties -- one way or the other.

In general, American industry throughout the ozone negotiations was more pragmatic than ideological. Recognizing the growing scientific consensus, the Alliance for Responsible CFC Policy, a coalition of about 500 producer and user companies, announced its acceptance of international controls in September 1986, three months before the formal negotiation process actually opened. Eight months later, American industry stayed conspicuously aloof from the campaign by anti-environmental elements within the administration to undermine a meaningful treaty, and subsequently fully endorsed President Reagan's strong position for the climactic September 1987 negotiation in Montreal.

The financial and intellectual resources of the private sector make its involvement and cooperation indispensable, since society ultimately depends primarily on industry to provide technological solutions. Technology is dynamic, and not, as often implied by those who resist change, a static element. If the market is left completely on its own, it may not necessarily bring forth the right technologies at the right time. Although the 1987 ozone protocol established targets that were initially beyond the reach of best-available technologies, the goals were in fact not unrealistic.

The Montreal Protocol was not, as some opponents charged, a "radical" treaty. On the contrary, it was an expression of faith in the market system. The treaty employed realistic market incentives to encourage technological innovation. The negotiators effectively signaled to the marketplace that research into solutions would now be profitable. Competitive -- and collaborative -- forces then took over, and solutions were developed much sooner, and at considerably lower cost, than had earlier been predicted.

The protocol in fact stimulated a virtual technological revolution in the international chemical, telecommunications, pharmaceutical, and numerous other industries. By providing CFC producers and users with the certainty that the CFC market was destined to decline, the treaty unleashed the creative energies and financial resources of the private sector to find alternatives. Following the protocol's signing, the chemical industry began the race for substitutes. Four months after Montreal, several hundred industry representatives participated in a CFC-substitutes trade fair in Washington.

Some user industries did not wait for the chemical companies to come up with substitutes; such companies as Nortel, IBM and Motorola re-examined their manufacturing processes and found ways to eliminate CFCs. In cooperation with a small Florida company, AT&T announced a replacement for CFC 113 derived from citrus fruit, for cleaning electronic circuit boards. Japanese and American importers of electronics parts from Thailand, including AT&T, Ford, Honda, and Toshiba, teamed up with EPA and Japan's Ministry of Trade and Industry to provide non-CFC technologies to their suppliers. More than 40 multinational companies from eight countries, including Asea Brown Boveri, British Petroleum, Hitachi, and Honeywell, joined to help Viet Nam phase out CFCs.

<u>Lessons for Credibility</u>

Another lesson from the Montreal Protocol's success was the importance of education: interpreting the continuously evolving and sometimes confusing data and communicating it intelligibly to the public, the media, and political and legislative leaders. This information flow mobilized public support for addressing the potential dangers of a diminishing ozone layer, and thereby promoted political consensus for both funding research and for policy actions. The role of the U.S. Congress was particularly critical in organizing many public hearings on the ozone issue over the years, and in commissioning several important studies by the National Academy of Sciences.

In the 1980s, environmental organizations that favored strong actions to protect the ozone layer generally avoided invoking apocalypse in order to capture media and public attention. As chief U.S. negotiator pressing the official American position for strong controls against the opposition of most of the other major producing and consuming countries, I insisted that our delegation in principle never exaggerate the scientific case: let the science speak for itself, even when it is not completely unambiguous. I wanted to preserve our integrity and not present the opposition with a gratuitous weapon against our position.

When some opponents of controlling CFCs within the U.S. administration tried late in the negotiations to reverse the strong American position (and, incidentally, to dismiss me as chief negotiator), they belittled the science and the dangers, claiming *inter alia* that the problem could be solved by wearing cowboy hats and sunglasses. The resultant ridicule and backlash from the Congress, scientists, media, public, and the White House itself eventually led to a personal decision by President Reagan reaffirming the U.S. position favoring strong controls.

Unfortunately, the lesson of scientific integrity appears to have been lost in the debate over climate change that began in the late 1980s. Some environmental groups became overly alarmist in exaggerating the case for global warming following the hot summer of 1988, and, later, by crusading for the Kyoto Protocol as the only conceivable solution. This only engendered a strong counter-reaction from some affected industrial sectors. In addition, when the predicted dire consequences of climate change did not emerge soon, the American public – which in any case is accustomed to natural seasonal weather extremes – became generally apathetic toward possible long-term dangers.

For their part, skeptics of climate change were also not immune to distortion. In an effort to discredit the climate science, opponents repeatedly cite the *"Heidelberg Appeal,"* released by a nongovernmental group at the United Nations Earth Summit in Johannesburg in 2002, as definitive evidence that most of the scientific community --

more than 4000 eminent international scientist signatories, including over 70 Nobel Laureates – rejects the idea that rising anthropogenic carbon dioxide emissions could cause dangerous global climatic consequences. In actuality, the one-page document is a general treatise on the importance of science and contains not a single reference to the climate problem.[12]

Lessons for Government

Some governments allowed commercial self-interest to influence their interpretations of the science: uncertainty was used as an excuse for delaying decisions. Some political leaders, particularly those in Europe with substantial chemical industries, were initially prepared to accept speculative long-term environmental risks rather than to impose the tangible near-term costs entailed in limiting products seen as important contributors to a modern standard of living. Short-range political and economic concerns were, therefore, formidable obstacles to cooperative international action based upon the theory of ozone-depletion.

Other political leaders, however, including President Reagan and the governments of Australia, Austria, Canada, Finland, Denmark, New Zealand, Norway, Sweden and Switzerland, decided to act even while there were still scientific ambiguities, based on a balancing of the risks and costs of delay.

As early as 1977, the U.S. Congress had authorized the Administrator of the Environmental Protection Agency (EPA) in the Clean Air Act to regulate "any substance … which in his judgment *may reasonably be anticipated* to affect the stratosphere, especially ozone in the stratosphere, if such effect *may reasonably be anticipated* to endanger public health or welfare" (emphasis added). This law attempted to balance the scientific uncertainties with the risks of inaction. And it opted for a low threshold to justify intervention: the government was not obligated to prove conclusively that a suspected substance could modify the stratosphere or endanger health and environment. All that was required was a standard of reasonable expectation. As Governor Russell Peterson, a senior advisor to President Nixon, had declared in reference to other potentially harmful chemicals, CFCs would not, like U.S. citizens, be considered innocent until proven guilty.

Unfortunately, current tools of economic analysis are not fully adequate for evaluating the costs and risks, and can be deceptive indicators; they are in urgent need of reform. The customary methods of measuring national income do not satisfactorily reflect societal and ecological costs -- especially those far in the future. Politicians should nevertheless resist the tendency to assign excessive credibility to self-serving economic interests that demand scientific certainty, and who insist that, simply because dangers are remote, they are therefore unlikely.

By the time the evidence on such issues as ozone layer depletion and climate change is beyond dispute, the damage could be irreversible and it may be too late to avoid serious

[12] See "Heidelberg Appeal" at www.sepp.org .

harm to human life and draconian future costs to society. The signatories at Montreal risked imposing substantial short-run economic dislocations even though the evidence was incomplete. The prudence of their decision was vindicated when the scientific models turned out to have actually underestimated prospective ozone depletion. And, thanks to the ingenuity of private entrepreneurs, the costs of action turned out to be much lower than originally predicted.

Conclusion: Acting Under Uncertainty

The Montreal Protocol was by no means inevitable. Knowledgeable observers had long believed it would be impossible to achieve. The ozone negotiators confronted formidable political, economic, and psychological obstacles. The dangers of ozone depletion could touch every nation and all life on earth over periods far beyond politicians' normal time horizons. But although the potential consequences were grave, they could neither be measured nor predicted with certitude when the diplomats began their work.

In the realm of international relations there will always be resistance to change, and there will always be uncertainties – scientific, political, economic, psychological. Faced with global environmental threats, governments may need to act while some major questions remain unresolved. In achieving the Montreal accord, consensus was forged and decisions were made on a balancing of probabilities -- and the risks of waiting for more complete evidence were finally deemed to be too great.

"Politics," stated Lord Kennet during early ozone debates in the House of Lords, "is the art of taking good decisions on insufficient evidence."[13] The success of the Montreal Protocol stands as a beacon of how science can help decision makers to overcome conflicting political and economic interests and reach solutions. The ozone history demonstrates that even in the real world of ambiguity and imperfect knowledge, the international community, with the assistance of science, is capable of undertaking difficult and far-reaching actions for the common good.

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