EDWARD A. PARSON

The Technology Assessment Approach to Climate Change

We should apply the lessons of the Montreal Protocol: Enlist industry expertise and focus on manageable goals for reducing greenhouse gas emissions.

Policy debate on global climate change is deadlocked. Why? One major reason is that assessment of options for reducing greenhouse gases has been strikingly ineffective. The Intergovernmental Panel on Climate Change (IPCC), which produces respected and successful assessments of atmospheric science, has applied the same approach to the fundamentally different problem of assessing technological and managerial options to reduce emissions. The predictable result has been options assessments that are broad, vague, and disconnected from practical problems. One reason is that IPCC has, crucially, failed to draw on private-sector expertise. Yet such expertise could inform policy and promote emission reductions directly, as one prominent recent success demonstrates. That notable success is the assessment of technological options to reduce ozone-depleting chemicals under the Montreal Protocol. An assessment process similar to that used for ozone-depleting chemicals can be applied to problems of mitigating greenhouse gas emissions and may represent the best near-term opportunity to ease the present policy deadlock.

The sharpest debate over climate change has concerned how to respond to uncertainties in climate science, such as the significance of recent climate trends, their attribution to human influences, and climate model projections of future changes and their impacts. But these are not the only uncertainties that matter. Equally important are uncertainties over future greenhouse gas emissions and their control. How fast will emissions grow if unchecked? How much can they be reduced, by what means, at what cost? The deadlock persists, and climate science uncertainties matter, because of widespread concern that emission cuts will generate serious economic and social costs. If it became clear that cutting emissions was cheap and easy, the present deadlock would yield readily to agreement on large precautionary cuts, despite uncertainties in climate projections.

But future emissions and the ease with which they can be reduced are much more uncertain than the present debate would suggest. Under plausible assumptions about socioeconomic and technological change, global emissions in 2100 could range from

Edward A. Parson (ted_parson@harvard.edu) is at Harvard University's John F. Kennedy School of Government.

half to 10 times present levels. This uncertainty stems from imperfectly understood demographic, behavioral, and economic processes. Technological change is an important component of the equation, too. Even leaving aside the possibility of fundamental technological advances, there are many incremental innovations that can reduce future emissions substantially. These include measures to increase the efficiency of energy use, reduce the carbon content of primary energy, decouple atmospheric emissions from fossil energy use, and target non-CO2 greenhouse gases from industrial and agricultural activities. Expert assessments of such options can reduce uncertainty about the cost of limiting emissions and provide useful input to policy decisions. Yet several assessments of greenhouse gas reduction options have achieved little, either in reducing uncertainties or in providing useful policy advice.

This failure reflects no special discredit on the IPCC. Many attempts to assess options for managing other environmental issues have similarly failed because of a basic structural problem that all such attempts face. Successful assessment requires the energetic and honest efforts of first-rank experts from the industries that are potential targets of regulatory controls. But these people's time and attention are among their companies' most valuable competitive assets. Releasing them to help advise public policy is costly under any conditions. Releasing them to help formulate regulatory restrictions on their own companies is even less attractive. No company or industry has an interest in helping regulators to impose burdens on them.

The record attests to the force of this obstacle: Options assessments are attempted infrequently, and succeed even less frequently at engaging industry expertise. When private interests do get involved—typically when an issue's political salience makes it risky for firms not to participate—their recommendations usually follow one of two patterns. Most often they are so vague, abstract, and qualified that they provide no useful policy guidance. In other cases, they provide a forceful defense of the status quo, arguing that changes in current products or practices would be costly, difficult, or futile, or would lead to health and environmental costs as bad as those they avoid.

One striking exception to this pattern is the assessment of technological options to reduce ozone-depleting chemicals under the Montreal Protocol. This treaty, the centerpiece of the ozone-layer regime, is the most conspicuous success yet in managing any international environmental issue. The ozone regime enjoys nearly universal participation and has reduced ozone-depleting chemicals by 95 percent (and still growing) in 15 years. This success was not achieved by the control measures in the original treaty. Instead, it was achieved by the rapid adaptation of the controls and the flood of innovations that followed. The protocol's novel process of assessing alternatives to ozone-depleting chemicals was central to this adaptation. Where so many prior attempts had failed, it consistently drew in industry experts who provided high-quality technical advice and spurred development and adoption of measures to reduce chemical use. These linked processes of assessment, innovation, and diffusion were so powerful they almost made the regulations appear superfluous, as private reduction efforts stayed consistently ahead of regulatory requirements.

Keys to success

This success was not due to uniquely benign characteristics of the ozone issue. Indeed, the Montreal Protocol was achieved only after 10 years of policy deadlock that included several unsuccessful attempts to assess technological options. The most serious efforts were two 1979 studies, one by the Rand Corporation and one by a National Academy of Sciences (NAS) committee. These studies included industry surveys and interviews and, in the NAS study, a few industry experts as participants. Expert views at the time diverged widely, yet both studies reinforced the industry position that chlorofluorocarbon (CFC) cuts would be difficult, costly, and dangerous. They concluded that the maximum reduction in U.S. CFC use achievable at any price was 25 percent (Rand) to 50 percent (NAS). Proponents of CFC reductions could not demonstrate that extensive reductions were feasible, because they lacked the authoritative technical knowledge to rebut industry claims.

The ozone regime overcame this blockage, providing a powerful example of effective assessment of technological options. Yet, for climate change and other issues, this example has been ignored. A technology assessment panel was one of four independent expert panels (on atmospheric science, the effects of ozone loss, technology, and economics) established by the 1987 Montreal Protocol to review new results and advise the parties' periodic reviews of control measures. Because they were organized in some haste late in 1988 in response to pressure for tightening the protocol, the panels had a lot of freedom. They were permitted to choose participants, carry out their work, and prepare reports to the parties with little political oversight—independence that greatly enhanced their effectiveness.

Organizers of the technology panel decided quickly that the expertise needed to do their job resided principally with the private sector, so they adopted an organization and procedures substantially different from those of the other panels to make it easy for private-sector experts to participate. They organized in separate workgroups for each major type of ozone-depleting chemical, such as refrigerants, solvents, foams, and aerosols. Teams of experts evaluated the potential of specific technologies and operational changes that might reduce chemical use in specific applications. Participants came mostly from companies using the chemicals, but also from industry associations, governments, universities, and nongovernmental organizations (NGOs). Experts from companies producing CFCs were at first excluded, a contentious decision that reflected negotiators' mistrust of these firms for their long history of obstruction. This decision was reversed in 1990, after the first assessment was completed.

Motivating private-sector participation is one basic challenge of technology assessment. Keeping the process credible is the other.

The Technology Panel, which after 1990 became the Technology and Economics Assessment Panel (TEAP), was strikingly successful. In four full assessments and many smaller tasks, it presented a huge number of specific technical judgments that were, with few exceptions, persuasive, technically supported, and consensual. It frequently reported that reductions could be made further and faster than previously believed, judgments that usually proved to be accurate or even somewhat conservative. TEAP carefully avoided usurping the parties' authority, but its specific, carefully delimited statements of feasible reductions repeatedly exercised strong influence over the rate and direction of parties' decisions. Even when parties did not precisely follow TEAP's judgments of maximum feasible reductions, policy actors disputed or criticized TEAP's conclusions only rarely and accused them about as often of being too timid as too bold. One measure of the parties' approval was their repeated requests for TEAP to take on additional jobs.

Just as the normal failures of technology assessment reflect inadequate private-sector expertise, TEAP's effectiveness reflected its success at eliciting the serious, honest, and energetic participation of first-rank industry experts in the service of the regime's environmental goals. Many factors helped attract these participants, including managerial initiatives to keep the process efficient and goal-directed. But the fundamental reason why private-sector experts came and their employers agreed to send them, was that the process provided private benefits to participating companies and individuals.

These private benefits were of several types. The first was help in meeting the companies' urgent need to reduce ozone-depleting chemicals to comply with current and anticipated regulatory targets. It was crucial for TEAP's success that it started work shortly after the 1987 protocol had adopted 50 percent cuts in CFC use. These cuts posed a serious threat to users in those countries, including the United States, that no longer used CFCs in aerosol sprays, the one large use that was easy to replace. Widespread calls to further tighten targets sharpened this threat, making users want to reduce dependence on all ozone-depleting chemicals as rapidly as possible. TEAP's working groups assembled critical masses of experts, with antitrust protection, to evaluate reduction options in each specific usage area, a problem-solving capacity greater than even the largest firms could deploy by themselves.

This help in managing the business risk of regulations was the most important private benefit to participants, particularly for the firms most dependent on CFCs and particularly in the early years of the regime. But it was not the only benefit. Participants also gained current detailed information about the transition from ozone-depleting chemicals, about which chemicals and uses posed greater and lesser challenges, and about the contributions of various types of technology and expertise. This information had substantial commercial value. It helped participants project market trends and identify new opportunities to sell products and services related to the transition. Individual participants also benefited from the professional challenge and prestige of the process. This was a self-reinforcing benefit, since the success and reputation of the process depended in turn on the stature of the experts participating. Because the first-rank experts on many topics worked for competing firms, TEAP gave them an opportunity to work intensively with and gain the respect of an elite group of peers that their normal professional lives did not offer.

The work of TEAP and its sectoral sub-bodies provided these private benefits while fulfilling a mandate to provide high-quality technical advice to the parties about feasible reductions. Moreover, although providing this advice was TEAP's official job, the same activities provided other benefits to the regime as well. The processes of solving problems, refining known options, and evaluating new ones that occurred in and around TEAP's bodies repeatedly identified opportunities to reduce chemical use beyond existing regulatory targets. Moreover, participants' growing enthusiasm about the success of the process and their stature in their industries made them willing and able to act as missionaries, instructing their peers about reduction options and exhorting them to join the effort. These processes helped advance the margins of what reductions were feasible, and of what reductions were actually achieved—contributions of a fundamentally different character from TEAP's official job of advising the parties. These contributions reflect a basic distinction between assessments of technological options and of scientific knowledge: Technology assessments have much greater capability to alter the reality they are assessing. Indeed, their effectiveness in doing so should be one major criterion of their success.

Motivating private-sector participation is one basic challenge of technology assessment. Keeping the process credible is the other. Any attempt to harness private interests for a public purpose runs the risk that private interests will distort or impair the pursuit of public ends to serve their own. TEAP avoided capture by status-quo interests, which so often causes technology assessments to deadlock. But it still had to manage the subtler risk of biased judgments favoring particular technologies, firms, or industries. Professional norms, explicit ground rules, and the personal integrity of participants provided some protection against this, but stronger controls were also needed. TEAP managed this risk through the mandates, membership, and operations of its working groups. Each group's participants were chosen not only for their overlapping expertise but also for their divergent material interests. Some participants had interests in particular technical options but were balanced by advocates of other approaches. Moreover, although all producers of alternatives shared a general interest in a rapid transition from CFCs, their interests were balanced by those of the user firms that would bear the cost if the transition was too fast. Participants with high levels of closely overlapping expertise subjected all technical claims to vigorous questioning and criticism, thereby disciplining and restraining any attempts to advance claims that were weakly supported, exaggerated, or biased.

In sum, the success of technology assessment in the ozone regime depended on three conditions. First, the problems to be solved were difficult enough and focused enough that technical workgroups assembled from multiple organizations provided a crucial boost to the capacity to solve them. Second, it was possible to assemble workgroups with enough overlapping technical expertise to provide this incremental capability, but with material interests divergent enough that their discussions would reveal and restrain partisan claims. Finally, participants had private interests that could be advanced through the process, interests that were strong enough to motivate them to participate but not so strong and competitive that they were preoccupied with maneuvering for individual advantage. The principal private interest was a need for help in meeting present and anticipated regulatory controls. Another was commercial opportunities that would emerge from the assessment process or the transition it was supporting. The relative success of TEAP's many activities shows these private interests to be crucial, in that participants had to be willing to share their knowledge and expertise not only with government officials, but also with each other. When private interests in the success of the process were not strong enough because participants believed they could block further controls, the assessment failed to attract serious participation and produced reports that were technically weak and more likely to be challenged. When individual, rival private interests were too strong (for example, when participants thought the panels' judgments were likely to confer large gains or losses on particular firms) those interests obstructed participants' willingness to share information and ideas openly.

The most important requirement is that industry participants have strong enough private interest in the assessment group's success.

Climate change

In contrast to the ozone issue, assessment of technological options to mitigate climate change has thus far been ineffective. This job falls within the mandate of the IPCC's Working Group 3, which has used the same organization and procedures as the rest of the IPCC. Comprehensive assessments of mitigation are conducted by large chapter teams of independent scientists, drawn principally from universities, research institutions, governments, and NGOs. Chapter groups are organized around broad issues in mitigation, not specific problems of reducing emissions in particular industries or uses. Collectively authored chapters and their summaries go through lengthy rounds of scientific and government review, with all comments and authors' responses documented, while separate summaries for policymakers are negotiated line-by-line by government representatives. This process pursues the legitimate aims of rigorous peer review, transparency, and democratic accountability, but it is unwieldy and time-consuming and gives control over the most prominent assessment output to an intergovernmental body. Unsurprisingly, participation by private-sector experts has been minimal. IPCC assessments of atmospheric science have been prominent and high in quality, but its assessments of mitigation options have been broad, diffuse, and technically uneven. They have provided neither useful guidance to policymakers nor practical contributions to emission reductions such as those TEAP provided for ozone.

This is an important missed opportunity. A more effective process could advance policy debate on climate change and directly reduce greenhouse gas emissions. There are large structural differences between the climate and ozone issues, of course. The scale, diversity, and importance of the human activities causing environmental burden are much greater for climate. That makes the wholesale application of ozone policies (in particular, the radically simplifying approach of cutting the offending activities to zero) deeply suspect, if not impossible. But these differences need not preclude the application of the model of technology assessment developed for ozone, so long as the corresponding conditions for success are present.

These conditions can be present for the greenhouse gas problem if the problem is carved into manageable pieces. No body has the expertise to assess the entire greenhouse gas mitigation problem with specificity, detail, and authority. But such assessments can be done for many separate subcomponents of the problem. In fact, although the diversity of emitting activities obstructs both comprehensive assessment of mitigation and development of comprehensive policies to control emissions, the same diversity represents an advantage in separating and assessing manageable subproblems. The activities or technologies whose conditions are most favorable for this model of assessment—the low-hanging fruit—can be pursued first.

The conditions that identify promising pieces of the mitigation problem correspond to those that facilitated TEAP's success. First, the technological questions addressed must be such that individual organizations find them too hard or not sufficiently rewarding to solve by themselves, so that multiorganizational technical teams are necessary. This will likely be the case for problems that require inputs from several complementary areas of expertise unlikely to be found within one company but focused enough so that relevant domains of expertise can be identified with reasonable confidence. Second, it must be possible to limit the risk of capture by one point of view through appropriate assembly and management of workgroups. To the extent that participants' interests in the group's outputs diverge from the public interest, they must also diverge from each other. Participants thus would be motivated to police each other's claims, yet have enough overlapping expertise to do this policing effectively. There is tension between these two conditions, which must be balanced appropriately for each problem and workgroup. Increasing the overlap of participants' expertise can increase the group's ability to restrain partisan claims, but expanding expertise in a broader set of relevant technologies can increase the workgroup's capability. An additional condition is that participating companies must not perceive strong competitive advantages (for example, the fate of specific proprietary technologies) turning on the assessment's outputs, lest they withhold or selectively reveal information for individual advantage.

> *The strongest motivation for companies and industries to participate in technical assessments comes from existing and anticipated regulatory restrictions.*

The most important requirement is that participants have strong enough private interest in the group's success. A firm deciding whether to join an assessment must consider not only the direct consequences of the technical deliberations but also the consequences of regulation or other policy likely to follow from the assessment. The simplest case in which firms might perceive enough benefit to participate would be when they judge the assessment likely to advance the development of true "no regrets" reduction options: those that are advantageous to adopt even when the implicit price of emissions is zero. Firms might benefit from adopting such options through cost reductions, improved yields, or improved products. The amount of reduction available from such options is controversial; engineering cost analyses consistently show that many such existing opportunities are not pursued, presumably because of unmeasured costs or other obstacles. But even if the pool of such options across the economy is modest, sectors or technologies where they appeared particularly abundant would be promising areas to concentrate the initial work of technology assessment bodies.

A second class of opportunities would arise from reduction options with modest costs in relatively cartelized industries: those with substantial concentration of production, barriers to entry, and inelastic output markets. In such industries, the largest barrier to adopting costly environmental technology is that the first firm doing so risks a large penalty from losing business to the others. But all could move together with no competitive effects and small overall cost. In these situations, the assessment process would serve not just to identify and develop options to reduce emissions but also to coordinate their adoption by competing companies so that none is uniquely penalized.

The strongest motivation for companies and industries to participate in such technical assessments, however, comes from existing and anticipated regulatory restrictions. Many firms participating in TEAP received and recognized other benefits as the assessment process continued. But it was the need for help in meeting impending regulatory restrictions that got them in the door initially, and this motivation remained important through 10 years of assessments. Any significant regulatory controls on greenhouse gases would immediately create similar incentives for industry to pursue mitigation options and participate in collaborative assessment to help identify them. But the greenhouse-gas policies in place at present are few and weak. The effective cost of emitting remains zero in most of the industrialized world, and will remain zero in the United States under current policy. (Speculative emission trades are now taking place at prices above zero, but these reflect bets on future policies, not the effect of present ones.) Those countries that implement the Kyoto targets might face a substantial emissions price, depending on how liberally they grant credit for buying fictitious cuts from Russia or Eastern Europe. Even without U.S. participation, the financial and technological resources of firms facing high emission prices in these countries may be sufficient to initiate a positive feedback between emission-reducing innovations and regime tightening. This suggests that an ozone-style technology assessment process may bring significant benefits even with the United States outside the regime. If U.S.-based multinationals with operations in those countries also choose to participate, the feedback could spread to the United States. That would weaken political opposition to emission cuts and create a powerful economic constituency favoring them, even while U.S. policy continues to lag the rest of the world and to maintain an emission price of zero.

Although policies putting a price on emissions must pass some minimal threshold to attract managers' attention, their stringency can be modest initially. Even a price of a few dollars per ton of carbon will bear heavily on some businesses. That will make some further emission-reduction technologies cost-effective or worth pursuing in the expectation that they soon will be. Small initial steps can initiate positive feedback such as operated in ozone, particularly if there are spillovers from the sectors or technologies most affected by early policies to other technologies or sectors.

Moreover, sophisticated firms respond not just to regulations and policies in place but also to their expectations of future ones. Regulations already enacted create the strongest interest in pursuing emission-reduction options, but similar interests arise from developing the capacity to meet anticipated controls or forestalling threatened ones, if the threat is sufficiently salient and credible. Strong public and political concern may suffice to create a perceived medium-term risk of emission restrictions. This risk may be particularly salient for businesses that are most vulnerable to the threat of regulations: those with large, highly concentrated emissions sources or those that expect to have disproportionate burdens from abatement. Even firms that do not perceive the risk strongly enough to invest in developing alternatives themselves may be willing to participate in collaborative processes to do so in order to gather information, develop expertise, and identify specific risks and opportunities from potential regulations.

Identifying specific pieces of the greenhouse-gas problem that appear most promising would likely require separate preliminary consultation and assessment, updated periodically in response to changing technological, economic, and policy conditions. Even before such a systematic search, however, plausible candidates for near-term attention can be identified. These might include, for example:

- Process efficiency improvements in major energy-consuming industrial sectors such as steel, smelting, chemicals, and pulp and paper
- Fuel efficiency of vehicles, particularly automobiles and light trucks
- Energy efficiency of major household appliances
- Separation and sequestration of carbon from fossil fuels, either at the point of combustion or upstream
- Industrial emissions of gases with high global warming potential such as perfluorocarbons, hydrofluorocarbons, and sulfur hexafluoride

Note that this list includes various consumer products for which it has long been suggested that purchasers do not adequately value efficiency. But it excludes energy-converting capital equipment for which efficiency advances can confer decisive competitive advantages, such as gas turbines, industrial furnaces and boilers, or photovoltaic cells.

For these assessments to succeed, their institutional setting must also meet certain conditions. To attract the participants and achieve the working conditions needed for success, workgroups will require substantial independence from external oversight so that they can maintain efficient, flexible, and confidential proceedings and retain full control over their outputs. But achieving salience and credibility in policy arenas will require some official standing with governmental or intergovernmental bodies. Government sponsorship and participation will probably be required to provide antitrust approval and institutional continuity between specific task groups and to help ease bureaucratic or policy obstacles to attractive mitigation options.

The IPCC is the single official source of authoritative scientific and technical information on climate change, but its design and procedures make it incapable of conducting assessments of the type proposed. Modifying or suspending the IPCC's principles and procedures to let such assessments operate within it is an unlikely prospect, so these assessments will most likely have to operate outside it. Various specific institutional arrangements could be considered. Separate ad hoc assessment bodies for particular problems could operate as consultants to an intergovernmental body, either to the IPCC (as with one group contributing to the 2001 assessment) or to some body under the Climate Convention. Such an advisory relationship would provide the official status helpful in gaining policy attention and administrative continuity, while the group's independence can be protected by publishing its reports directly in addition to providing them to the sponsoring body. Alternatively, assessment bodies could be established as independent NGOs, which could seek joint sponsorship of each assessment by multiple governmental and intergovernmental organizations and make their reports and briefings available to officials and negotiators. A higher-level process will be needed to identify tasks ripe for assessment and provide institutional memory. Unlike the assessments themselves, this task could fall to an IPCC body or to informal consultations involving IPCC and Climate Convention officials, industry representatives, and independent experts.

Whatever institutional setting is chosen, a technology assessment process similar to that used for ozone-depleting chemicals holds the most promise of harnessing the creativity and energy of private industry toward substantial reductions of greenhouse-gas emissions. Such assessments can create a mutually reinforcing feedback with sensible mitigation policies. Any mitigation policy will promote effective technical assessment of mitigation, while successful assessments will clarify and facilitate sensible mitigation policy. Even if the initial steps are small—assessments for a few targeted sectors or technologies that represent low-hanging fruit, and modest (but real) mitigation policies in several Organization for Economic Cooperation and Development countries—setting these interactions in motion may be the most effective step that can be taken now to chip away at the present policy deadlock.

Recommended reading

William C. Clark et al., "Option Assessment in the Management of Global Environmental Risks," in *Social Learning Group, Learning to Manage Global Environmental Risks* (Cambridge: MIT Press, 2001).

Intergovernmental Panel on Climate Change, *Climate Change 2001: Mitigation. Report of Working Group 3* (Cambridge: Cambridge University Press, 2001).

Intergovernmental Panel on Climate Change, *Emissions Scenarios. Special Report of Working Group 3* (Cambridge: Cambridge University Press, 2000).

Edward A. Parson, *Protecting the Ozone Layer: Science and Strategy* (New York: Oxford University Press, in press).

United Nations Environment Programme, *Report of the Technology and Economic Assessment Panel*, April 2001. Available at www.teap.org.