MASSACHUSETTS INSTITUTE OF TECHNOLOGY

PSTEP White Paper

The Program on Science, Technology and Environmental Policy: A Research Agenda for the Next Generation of Environmental Regulation

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ABSTRACT

In the view of many industry representatives there already exist technologies with improved environmental attributes for which it has not been possible to get regulatory approval or even concerted regulatory review. Is technology now "getting well ahead" of regulation? Can the regulatory approval process for new technologies keep up with the opportunities for innovation? There is a clear need for an objective, credible institutional base for evaluating technologies that are needed to address contemporary and long-term environmental problems. The Program in Science Technology and Environmental Policy (PSTEP) being launched at MIT seeks to be an important part of that institutional base. If the manufacturer's claims can be verified, and if the potential benefits of more rapid technological innovation are significant, then industry should aggressively support programs like PSTEP that present the ability to gain timely, credible and reliable technology assessments. In order to shape the regulatory process and hasten regulatory reviews, the research products created through PSTEP must be aggressively communicated to stakeholders, and we would like to solicit input and support from industry and government to move this initiative forward.

PSTEP is being designed as an academic initiative to allow graduate engineering students to do thesis work on specific environmental policy issues that are science and technology intensive. PSTEP students and faculty will work with the U.S. Environmental Protection Agency and Industry representatives to develop specific research topics and to collaborate on the decision making process. Students in the program will be jointly supervised by engineering and social science faculty, which represents a significant shift from traditional thesis work.

PSTEP may assist EPA in improving its capacity for technology assessment. So much of the criticism of EPA's analytic capabilities focus on risk assessment, but at least as important is its limited capacity to evaluate technologies for their risk mitigation potential. And risk mitigation assessments must go well beyond the typical focus on a particular technology's ability to mitigate a particular risk or only on the risk directly posed by that technology. At least five sets of issues, and the tradeoffs among them, must be addressed:

- Risk versus risk tradeoffs of new technologies
- Potential for production efficiency gains from new products and processes
- The environmental impacts of changes in supply chains due to product substitutions
- Monitoring and enforcement efficiencies arising from new product and process technologies
- Environmental performance incentives associated with technological innovation

This whitepaper, based on findings of a workshop held at MIT on November 1st, 2001, provides background for the issues that the program will explore and proposes ways in which the PSTEP initiative – working with partners in government and industry can address these issues.

INTRODUCTION AND BACKGROUND

More than 30 years of rigorous environmental regulation has produced many important gains in environmental protection. The development of new technology has been a key factor in realizing those gains. However, the demands for better environmental science and technology are greater than ever and the shortcomings of current regulatory approaches are increasingly apparent. In the early years of the United States Environmental Protection Agency (EPA), the emphasis was primarily on justifying regulations in terms of health risks. In that context, the role of science in the policy process focused on judgments about often uncertain data on human health effects of environmental pollution. Gradually the policy emphasis extended to risks to the natural environment and, more recently, the concept of "sustainability" has emerged to expand the notion of risk to include economic and social as well as environmental health dimensions. The more comprehensive conception of risk underlines the need for more systemic and integrated approaches to environmental regulation. The evolution in policy emphasis affects the scope of regulatory policy and the concomitant role that various actors within the policy process will play. It affects the role of science in the policy process, the range of political interests involved in environmental policymaking, and the responses of industry to demands for improved environmental performance.

Today there is broad agreement that holistic approaches to environmental regulation that promote behavior change and encourage innovation are necessary, but there has been limited success in efforts to "reinvent" regulation that provide such incentives. The next generation of environmental regulation not only must address unresolved problems of the past, it must also recognize the opportunities in technology development and the need for flexibility in the employment of technology such that neither innovation nor efficiency is limited. It is essential that regulatory policies be more sensitive to and directed at the need to encourage, not inhibit, innovative private sector activity. Policymaking processes must be made more responsive to new technological opportunities, their risks and costs, and the incentives necessary for their effective exploitation.

Furthermore, it is essential that innovative approaches to environmental protection not be sacrificed at the altar of irresolvable debates over scientific uncertainties. Instead, regulatory instruments should be designed to reduce uncertainty on an experimental, "learning by doing" basis. There is seldom a highly confident definition of the policy problem, of the most cost-effective regulatory instrument, or of the "best" response by the regulated sector. Science can seldom provide "certainty" and thereby remove the problem of political choice.

Often conflicting hypotheses exist and, because science is a necessary justification for regulations in the United States, uncertainty ensures that science in the regulatory process is prone to be highly contested. Industry has often relied on the courts as the last resort to alter regulations it finds unjustified or unacceptable. Now the use of the courts and public action programs by public interest groups serves to delay significantly the development and diffusion of new technology. Whose interests does delay ultimately serve? Does the continuing reliance on litigation to force change in regulations now serve to prevent effective

innovation? In any case, the courts have proven their limited capacity for evaluating science and technology effectively.

The adaptive "learning by doing" approach to policy making conceives of regulation as subject to routine review and reevaluation as new information appears and old solutions are tested against experience. Rather than viewing policy making as a one-shot exercise, in which the goal is to discover the optimum solution based on certain science, regulation setting should be conceived as a continuous process of learning and experimentation.[1] What is optimum may be less important than a strategy that involves developing new information about the problem. Recent studies by the National Research Council and a Presidential Commission have emphasized the need to view regulatory policy-making as an iterative process, with periodic evaluation and revision of decisions, which benefit from maximal information exchange and minimal institutional barriers between experts, publics, and decision-makers.[2] The intent to revisit problem framings and to measure the effectiveness of regulations has important implications for data gathering and establishing appropriate terms of reference for expert committees. [3]

Efforts to develop more efficient and effective approaches to environmental protection confront a number of fundamental theoretical and analytic shortcomings. Over the past thirty years, the focus of the environmental policy debate has been on coercive regulations that compel changes in behavior on the part of corporate entities. The debate over particular regulations has typically centered on specific environmental risks, particularly health risks, and on measures for mitigating individual risks. Government regulators, especially at the national level, have been viewed as the primary agents of change, and risk management – rather than risk prevention -- has been the principal policy concern. To the extent that corporate self-interest has been addressed as potentially serving environmental protection, the attention has focused on potential efficiency gains for business in altering particular production processes, reducing energy consumption, and so forth in a manner that promotes improved environmental performance. What has been overlooked is that corporate entities increasingly face incentives and competitive business opportunities that, if properly nurtured by regulatory policy, can inspire pro-environmental corporate strategies as a key instrument of corporate competition. In particular, there is growing evidence that multinational firms may have clear interests in employing aggressive, pro-environmental strategies as a means of gaining market advantage.

THE PROGRAM IN SCIENCE TECHNOLOGY AND ENVIRONMENTAL POLICY AT MIT

In light of these considerations, the Program on Science, Technology and Environmental Policy (PSTEP) is being developed within MIT to address the special problems of the next

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[1] D. A. Farber, *Environmental Protection as a Learning Experience*, **Loyola of L.A. Law Rev.,** Spring, 1994

[2] National Research Council, **Understanding Risk: Informing Decisions in a Democratic Society**, Washington, D.C.: National Academy Press. 1996
National Research Council, **Science and Judgment in Risk Assessment**, Washington, D.C.: National Academy Press, 1994

[3] Presidential/Congressional Commission on Risk Assessment and Risk Management, *Risk assessment and risk management in the regulatory decision-making process,* 1997.

generation of environmental regulation. Appendix A provides a complete description of the PSTEP initiative. The innovations necessary for the next generation of regulation to be successful include not only fundamental change in regulatory strategies but also strategies that promote innovative technological responses from industry. A broad-based multidisciplinary approach is required to identify and assess more flexible, robust and efficient regulations, and policies that promote technological innovation and industrial growth as well as social welfare. The PSTEP initiative is intended to bridge the existing gaps between engineering sciences and social and management sciences in addressing environmental issues, and thereby to contribute to improving environmental regulation and performance of manufacturing industries through research, education and outreach. PSTEP is being designed as a research initiative that will allow graduate students to perform thesis work on specific environmental problems that have a technical and/or scientific focus. A unique aspect of the program is that students will be jointly supervised by faculty from both the engineering and social sciences to create a more integrated research approach. This is a fundamental shift from traditional graduate thesis research. Institutions like MIT have both the special responsibility and the capability to bring these disparate academic disciplines together to develop a comprehensive and systematic approach to these important policy issues.

The most unique aspect of the PSTEP program is the intent to take an active part in the decision making process. MIT is in a position to offer objective and expert assessments of risk issues and technological opportunities for mitigating risks. It can play an important role in addressing the evident deficiencies in public understanding of the nature of increasingly complex environmental issues and the implications of alternative measures for addressing those issues. Many public officials and especially the public at large lack understanding of the role of technology in addressing environmental problems and are therefore suspicious of it. For PSTEP's research and education efforts to have policy significance, it will emphasize public outreach programs and develop new channels for communicating research results to the public and to regulatory stakeholders.

In sum, PSTEP intends to promote innovation at three levels:

- Development of improved analytic approaches and methods for risk assessment and regulatory instrument design;
- Development and diffusion of new risk mitigation technologies; and
- Communication methods for informing policy makers about the nature of environmental risks and cost-effective means for reducing them

PREPARING THE NEXT GENERATION OF LEADERS

Equally important is the need to prepare skilled and competent leaders for industry and government. New and innovative approaches to environmental protection require new approaches to education and training of those who will develop and employ technology. Traditional engineers receive inadequate training and exposure to policy issues, policy-making processes and the analytic approaches of the social sciences. Holistic approaches to environmental risks and mitigation technologies demand systematic training in the analytic

skills of the engineering, social, and management sciences in addressing environmental policy. The PSTEP program is organized as a joint education-research endeavor involving faculty and students from eight different departments within MIT having a commitment to multidisciplinary educational and research projects. It is intended to be a bold experiment in the integration not only of disciplines but in the use of focused research projects as a method of educating graduate students in the analytic methods of other disciplines.

As a first step in developing the research agenda for the PSTEP program a workshop was held in early November 2001 that involved representatives of regulatory agencies, industry, public interest groups and members of the academic community. This whitepaper is an effort to summarize the issues and ideas raised in that workshop as they inform the on-going development of a research agenda. Appendix B provides an overview of the workshop proceedings. Because the workshop involved only one day, it was not possible to deal in detail with any of the broad range of issues raised. Therefore, where appropriate, the issues raised at the workshop are discussed with reference to the treatment of those issues as revealed in the environmental policy literature.

By way of summary, there seemed to be general agreement on the following points with respect to the design of next generation regulations:

- The low-hanging fruit has been harvested. In many areas, incremental improvements may come at high costs.
- A new partnership between industry and government is needed that is less adversarial and more reliant on the initiatives of industry. However, industry initiatives require the support of regulators and the reduction of regulatory uncertainty.
- New approaches to pollution mitigation programs must take a total "systems approach" rather than a "fragmented," source-by-source approach.
- There is a great need for developing analytic capabilities and programs that account for the environmental impacts of the total production supply-chain.
- Industry's commitment to improved environmental performance will be a function of "fairness" in the sharing of the burdens of environmental improvements across industries, across firms within an industry, and across alternative sources of risk.
- Risk and cost shifting across sources of pollutants must be minimized; and risk shifting across industries or industry sectors must be minimized.

The paper is organized in three parts. The first entails a brief description of the issue context that explains the initial creation and organization of the PSTEP program. The second part considers the broad research themes that dominated the workshop discussion. The third part considers the particular research questions that were raised at the workshop or have been particularly evident in the policy debate.

POLICY AND TECHNOLOGY CONTEXT FOR DESIGNING PSTEP

Over the years there has been intensifying debate over the proper policy-making role of scientists and of scientific advice, as well as over effective procedures for gaining scientific advice. The US policy-making process reveals ambivalence about the role of expert advice

that has had important implications for regulatory policy. Where there is a prevailing belief in the rationality of science, policy debates are generally about who has the "right" science, not whether science should be the basis of policy. Even when broad policies are based on consensus science, the particular regulatory instruments selected to implement those broad policies often do not reflect sound scientific or technological knowledge nor do the methods used for monitoring, measuring and enforcing regulations reflect the best available technology. [4]

In the 1970s, environmental problems were rather simply defined, were generally conceived as local in origin and in resolution, and the policies employed were generally rather "blunt" instruments. Today, it might be said that the "easiest" problems have been addressed, and the "cheapest" and easiest solutions have been largely exhausted. Now, the problems are regional, national and global in their extent. Those issues have much greater scope, pose significantly more complex scientific questions, and confront policymakers with a much higher degree of uncertainty than prior issues, say, of solid waste disposal or individual industrial plant effluents to waterways. However large the scientific and other policy uncertainties may have been in the 1970s and 1980s, those uncertainties are magnified in the issues of concern today: ozone depletion, global warming, reduction of ambient air particulate matter, and so on.

While the demands on science in the regulatory context have grown over time, the definition of risk issues has remained narrowly construed. The focus of environmental regulation has been on particular polluting substances, from particular sources, to particular media. Technology assessments generally followed the stipulation of regulatory standards, rather than being a part of the standard-setting process, and were intended to provide "regulatory fixes" rather than to identify broader opportunities for improving overall industrial environmental performance. The consequences of this process were:

- Inefficiencies in command and control regulatory instruments
- Fragmented regulations that shift risks from one emitting source or medium to another
- Failure to focus public resources on highest priority risks.

During the first generation of environmental regulation the "role of science" in policy-making was played primarily by physical scientists and health scientists in synthesizing and evaluating available evidence that could justify the issuance of new rules and standards. The role of scientists seldom included risk assessment versus risk tradeoffs, or the assessment of alternative regulatory instruments. Instead, the role focused on identifying and assessing specific "risks" and on the uncertainties in the scientific evidence relative to those risks. Often it was only after such risks had been identified and deemed to demand regulatory action that engineers, economists, operations researchers and the like entered the process. Their role was generally narrowly confined to determining specific measures for mitigating

[4] Even the adoption of consensual procedures, as in negotiated rule making, apparently does not significantly reduce the probability of law suits. See C. Coglianese, *Litigating Within Relationships: Disputes and Disturbance in the Regulatory Process,* **Law & Society Review, 1996**

very particular, previously determined risks, not to consider how different definitions of the risk problem could minimize side effects of regulations, could allow more efficient regulatory instruments, or could better exploit available technologies. In identifying and evaluating alternative regulatory instruments the analysis typically focused on potential environmental benefits. The problems and uncertainties entailed in effective implementation and enforcement were usually overlooked.

The ultimate challenge to more effective use of science in regulatory policy-making, however, arises from the adversarial style of regulatory decision-making that highlights uncertainty, and polarises scientific opinion. The highly politicised US regulatory system, with its pluralist complexity, highlighted by separation of powers federalist political structures with divided jurisdictions, provides ample room for opportunistic challenges to scientific opinion as well as to final regulatory decisions. And the challenges typically take place in court.

The threat of litigation is a principal incentive for EPA and other regulatory agencies to develop convincing scientific justification for decisions. This issue also is at the heart of the purposes of PSTEP – to offer an objective and reliable source of scientific information along with a commitment to communicate actively that information to government decision makers and others with a stake in regulatory outcomes.

A final and important element in the PSTEP program involves the holistic framework within which environmental issues must be addressed in the future. The inefficiencies associated with regulations directed at single sources of emissions and narrow technology "fixes" have been noted. The next generation of regulations and industrial performance improvements will be most effective only if whole production processes are considered, from product design and raw material extraction through waste management and recycling. As one of the speakers noted at the PSTEP workshop:

> The desired result of new product and process technologies is to design them to emit only products. Design and co-locate systems such that the unavoidable wastes from one facility become the production inputs for another facility.

This statement and the commentary that followed are important in suggesting that the focus of environmental performance assessment should extend beyond "*product life cycle analysis*." Life cycle analysis of the polluting attributes of particular products is an important consideration; far more important is "supply chain analysis" that examines the total emissions and risks posed by all production inputs and outputs for all products moving through production, distribution, consumption and waste handling processes. As the representative from EPA challenged the organizers of the PSTEP program:

> MIT should consider an expanded vision of environmental protection. MIT should direct the engineers to where the most impact can be gained and encourage projects which examine environmental issues from the point of view of total supply chain and the full set of environmental impacts of the chain.

Figure 1 presents a schematic of the environmental impacts of the supply chain cycle:

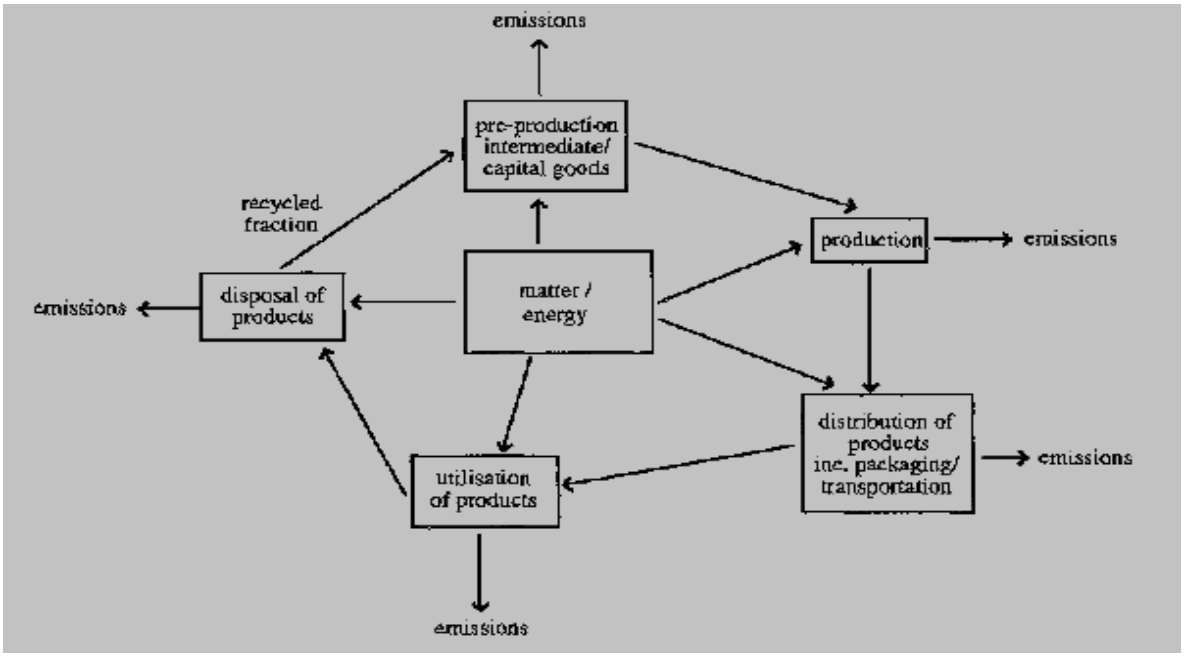

Figure 1: Environmental Impacts of Supply Chain Cycle

The complexity of the analysis of this cycle is suggested in Figure 2 describing the supply chain of the food processing industry.

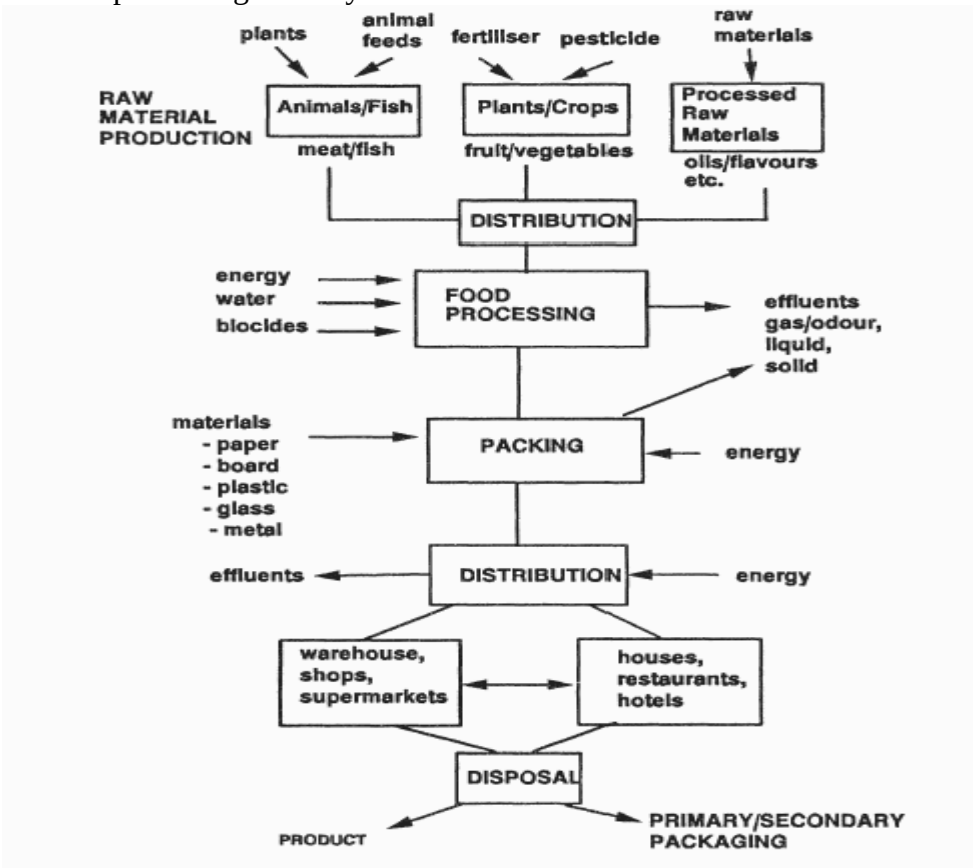

Figure 2: Supply Chain of the Food Processing Industry

This supply chain is particularly interesting because: (a) few of the environmental impacts associated with this chart have been effectively regulated; and (b) regulations that do exist tend to focus on a single element, thereby allowing "risk shifting" across polluting sources and across media. For example, restrictions on the use of particular pesticides have often simply led to the greater use of other pesticides that may pose risks at least as great or greater.

Given these issues and the supply chain framework, we can now characterize the overall PSTEP research agenda, and the agenda that emerged from the discussion at the PSTEP workshop. That framework locates specific research topics within four general issue categories: risk assessment; risk mitigation; risk and burden shifting; and risk education and policy adaptation. Specific research issues and areas are identified in Table 1 below:

Issue Areas	R&D and Product Design	New Materials & Components	Process Design & Management	Management Control Systems	Recycling & Reuse
Risk Assessment					
Risk Mitigation					
Risk Shifting and Burden Shifting					
Risk Education Regulatory Adaptation/Rigidity					

Table 1: Specific Research Areas for PSTEP

THE DOMINANT ISSUE THEMES OF THE PSTEP WORKSHOP

Discussions at the PSTEP workshop raised issues that can be usefully characterized as falling within two categories: issues relating to improvement in the regulatory policy-making process; and issues related to the development of new science and innovative technologies for mitigating environmental risks.

Improving Regulatory Policy-making: The comments from representatives of regulatory agencies were particularly useful and in no way in conflict with those offered by representatives of industry, public interest groups or academics in attendance. One regulator dramatically posed the compelling need for innovative regulatory strategies that are holistic by design and stimulate innovation:

> Considerable progress has been made over the last 30 years on environmental issues. The next 30 years is going to be different in the sense that the population will grow 50%, and the world economies may grow by 500% with an attendant 300% increase in potential emissions. These figures are daunting. In this light, EPA recognizes the growing need for innovative regulatory strategies.

That speaker went on to characterize the essential attributes of innovative regulatory strategies:

> The future requires a greater emphasis on environmental responsibility (meaning greater voluntary action by industry) as contrasted with just pollution control. The use of market based instruments and incentives are a key to achieving environmental goals. Innovation figures strongly in this strategy including new approaches to problem solving and a focus on high priority risk problems.

Though not disagreeing with the spirit of these comments, industry representatives and academic participants raised some important issues about the ability to achieve the conditions necessary for these innovative strategies to be employed. Of particular importance was a comment from an employee of a large industrial firm that is widely regarded as one of the most environmentally-conscious firms in the US. His comment clearly implied that simply asking firms to exhibit greater "environmental responsibility" would be ineffective without major advances in technology and especially in analytic capabilities.

> The low hanging fruit has pretty well been taken. Life cycle management has been adopted to get to the next level of advancement in environmental performance. During the R&D phase, the life cycle impacts are estimated but this turns out to be hard to do in practice. Audits reveal that the quality of such assessments is questionable at the early stages of development.

Even if industry seeks to be responsible, scientific uncertainty dominates. In short, uncertainty affects industry's efforts to project environmental impacts as much as it impacts regulatory agency's efforts to predict regulatory outcomes. In short, we need major advances in technology assessment and supply chain assessment methods. The spirit of this industry comment was seconded in the commentary of the representative of yet another firm committed to environmental responsibility. The implication of his views was that relying on industry initiative is likely to be inadequate.

> If environmental advances are desired, regulations are needed. Creating regulations that actually solve the problems is more difficult. As these issues get more complicated, there is greater need for the development of rigorous methodology and fundamental science by the academic community, and a greater need for effective political-technical interaction as well as better communication of results.

As an academic participant pointed out, in competitive markets the reliance on individual firms to take costly and uncertain initiatives is demanding a lot. Regulations are generally required to create a "level playing field" and regulators cannot avoid their responsibility either. Moreover, a proliferation of individual firm initiatives poses special problems in an area where regulatory agencies have been particularly weak: the area of monitoring and

evaluation of industry environmental performance. "While there are many problems in the design of regulations, too little systematic attention is given to monitoring and enforcement." Simple, end-of-pipe, best-available-technology regulations may be inefficient but at least they are easy to monitor and enforce. What education and training of regulatory enforcement personnel will be required to review the potentially very large range of innovative control measures undertaken by thousands of separate businesses?

In a similar vein, another industry representative commented that: "Environmental innovation follows regulatory certainty. Setting targets was the impetus for technical solutions. Mandating particular technology has not worked. It stifles innovation and the search for the best technologies." In other words, if the floodgates to individual firm initiatives are opened, what will be the incentive to innovate? Even if firms can accurately predict the cost-effectiveness of innovative control measures they undertake, how will they be assured that regulators will ultimately approve their initiatives?

The general case that was being emphasized was that uncertainty is a crucial concern well beyond issues of scientific uncertainty. Regulatory uncertainty was at least as great a problem. In this regard, a number of industry representatives commented on the range and degree of regulatory uncertainty. In particular, one industry representative mentioned the fact that his firm faces different and often conflicting regulations in different states. In many cases those divergent regulations are being challenged by industry and by public interest groups. How or when litigation may be resolved is highly uncertain. Moreover, the criteria on which final determination will be made are not at all clear.

The PSTEP program cannot, of course, resolve regulatory uncertainty. What it can do is address the issues of divergent and contingent regulations in terms of the scientific rationale for those divergences. It can serve to define appropriate criteria for evaluating regulations; it can provide the scientific evidence for assessing the merits of alternative regulations; and, most important, it can assist in the development of technologies that are robust across the range of concerns of all stakeholders demanding divergent regulations to meet their special concerns. Possibly the most telling comment regarding scientific uncertainty was offered by an MIT participant who urged that:

> While there are always lots of uncertainties in environmental decision-making, the key challenge is to identify and act on those components that contribute most to those uncertainties.

If uncertainties cannot be directly resolved, is it not possible to identify those issues that are the dominant contributors to uncertainty? Reduce uncertainty in a step-wise, recursive fashion and seek technological solutions that are robust across sources of uncertainty.

The Role of Science and Technology: The consideration of innovative regulatory strategies raises, of course, a range of technology issues. An MIT participant pointed out, the development of innovative regulatory strategies, especially market incentive programs, requires fundamental technological advances to be effective. The success of the SO_2 trading program, he pointed out, was premised on the ability to measure with reasonable accuracy the SO_2 emissions from particular stacks. It is not possible to trade pollution rights if the

pollution and its reduction cannot be measured. In the case of SO_2 the source of emissions was identified and the measurement technology was in hand. The problem in other areas is that either the sources cannot be distinguished or we lack the emission measurement technology. The development of such measurement technologies may be an important focus for the PSTEP and a crucial advance in the use of market incentive programs.

The ambivalence about the role of technology in regulatory rule-making was apparent in much of the discussion. Particularly intriguing was one comment:

> Often times the technology is moving faster than the regulatory bodies can react to it. But at least as important is when the regulations get ahead of the science. This especially applies to technology forcing regulations or regulations developed without a sound basis in science, such as the requirement for electric vehicles.

This comment would seem to endorse the need for routine regulatory review and adaptation. But it also reflects a deeper issue. Most agreed that regulation is an important if not necessary incentive for technological innovation that promotes environmental protection. On the other hand, explicitly technology-forcing regulations – like requirements for electric vehicles – are viewed with disdain. There was widespread agreement among the audience in favor of performance standards as opposed to technology standards, but the distinction at times seemed to get blurred. For example, the California regulation leading to research on electric vehicles was itself a performance standard. There was never an explicit requirement for electric vehicles, merely a requirement for "zero emission" vehicles. That is clearly a performance standard, but one that appeared to be approachable only by means of electric powered cars. On the one hand, the experience with technology standards is that they get "locked in" and prevent further innovation. What should be the basis of performance standards and to what categories of industrial facilities should they apply? What regulatory incentives can be provided for innovation beyond performance standards such that innovation is maximized?

As one speaker pointed out:

> Many industrial processes are over a hundred years old. They were definitely not developed with environmental protection in mind and they do not represent the latest technology developments. Environmental regulations may even be acting to prevent technological innovation where existing plants and processes are grand-fathered for preferential treatment and thereby old technologies get "locked in.

Clearly, preferential, grand-fathered treatment of old industrial plants inhibits innovation, not only by the owners of grand-fathered plants but also by their competitors. Older plants are likely to have a cost advantage due to preferential regulatory treatment. Why should their competitors place themselves at a further disadvantage by undertaking technological investments beyond those explicitly demanded by regulations?

A repeated theme during the workshop from many industry representatives was the view that many technologies are now available for which they cannot get regulatory approval or even concerted regulatory review. Cases were raised about mining technologies, engine

technologies, and process technologies. Strenuous arguments were posed that these technologies provide new major environmental benefits but were not being exploited. Though the implications of these arguments for PSTEP were not directly discussed, those implications seem clear. First, there is a need for an objective, credible institutional base for evaluating new technologies like those mentioned at the workshop. If the manufacturer's claims can be verified, then it should be the purpose of that institution not only to publish the results but also to communicate the results aggressively. Second, there is a need to evaluate existing regulatory standards in terms of their restrictions on useful technological innovations. The point is not to seek less demanding environmental standards but to seek standards that maximize incentives for technological advances.

Fundamental questions about the role of technology in environmental performance were explicitly raised or otherwise suggested by the workshop discussion:

- The most fundamental issues relate to the implications of the quickening pace of technology development since the 1970s. Whatever may have been the merits of technology standards in the past; such standards increasingly represent a barrier to innovation. Is technology now "getting well ahead" of regulation? Can the regulatory approval process for new technologies keep up with the opportunities for innovation? Does the continuing reliance on litigation to force change in regulations now serve to prevent effective innovation? Industry has often relied on the courts as the last resort to alter regulations it finds unjustified or unacceptable. Now the use of the courts and public action programs by public interest groups serves to delay significantly the development and diffusion of new technology. Are aggressive legal and political battles over genetically modified foods within the US and Europe and between the European Union and the US becoming the model of regulatory conflict in an age of rapid technological change? Whose interests does delay ultimately serve?

- How have rapid changes in technology affected perceptions of risk; and how have perceptions of risk affected technology development?

- What can EPA do to improve its capacity for *technology assessment*? So much of the criticism of EPA's analytic capabilities focus on risk assessment, but there appear to be at least an important issue in the capacity to evaluate technologies for their risk mitigation potential. Most importantly technology assessment must go well beyond the typical focus on a particular technology's ability to mitigate a particular risk or on the risks directly posed by that technology. At least five sets of issues, and the tradeoffs among them, must be addressed:

  1. *Risk versus risk tradeoffs:* new technologies may pose new risks but the issue is whether other, more significant, risks can be reduced and the new risks minimized. Environmental performance and particular risk mitigation measures should be assessed in terms of the impacts on the total production supply chain, and on the full range of environmental risks posed within that supply chain. Inevitably, in the choice of risk mitigation measures, there are risk tradeoffs and economic tradeoffs, the implications of which are often apparent only with a total systems approach.

2. *Production efficiency potential:* new technology may offer the potential for reduced production resource inputs; reduced use of particularly scarce resources; use of environmentally-friendly materials; reduced waste; and ease of recycling.

3. *Substitution of products:* new products may substitute for existing products that pose important health or environmental risks.

4. *Monitoring and enforcement efficiencies*: new technology can also provide significant new capacities for regulators to monitor, inspect, and evaluate environmental performance, by providing new points of regulatory leverage in the production process. These possibilities are demonstrated, for example, by the development of new HACCP (hazard analysis and critical control point) standards in the food processing industry. In this case, new and more efficient processing technologies also provide significantly improved regulatory monitoring and enforcement capabilities for enforcement agents. This example also reveals the conditions in which performance standards are clearly superior to particular technology standards.

5. *Environmental performance incentives*: to the extent that technology development provides either proprietary product or process technologies or technologies otherwise providing competitive advantage, firms have strong incentives for promoting regulatory and industry environmental performance standards that reinforce the preference for that firm's technology.

- What can industry do to assist EPA and other agencies in developing technology assessment capabilities? What are industry's opportunities and benefits in promoting more rapid technology approvals and diffusion? If those benefits are significant, then industry should aggressively support programs like PSTEP that present the ability to gain timely, credible and reliable technology assessments, and should support changes in regulatory rule-making procedures intended to hasten the pace of technology approval/disapproval decisions.

- How can new technologies create significantly improved capacities for supply chain environmental management? What technologies are needed for that purpose? Is there a role for product development networks to develop those technologies?

THE RESEARCH ISSUES FOR PSTEP

It was clear from the discussion at the PSTEP workshop as well as in the recent policy literature that the problems that have long plagued environmental risk assessment have changed only to the degree that the problems are more extensive and demanding. With respect to the assessment of health effects there have not been important advances in addressing the issues of:

- Limits of epidemiology in environmental analysis – the background noise problem
- Carcinogen identification
- Low dose exposures and the translation of high dose animal tests to human low dose exposures
- Threshold levels of toxic effects -- "how low is low" with respect to risks
- Lack of biomarkers
- Exposure effects on special populations – especially children, elderly and those with special health conditions
- Reproductive effects of exposures
- Cumulative exposure effects
- Compound effects of multiple exposures to different toxic substances

A major question remains unanswered: "Who gets to decide how much risk to take?" This question is increasingly being addressed to the courts for resolution but it is far from obvious that the courts have the capacity to resolve the question.

The expansion of the range and complexity of the risk assessment problems facing EPA is starkly illustrated by the recently passed Food Quality Production Act (FQPA) that replaced the Delaney Clause as a standard for assessing risks of pesticides. The Delaney Clause prohibited pesticide residues on food of substances that had proven carcinogenic in animal tests. Whatever its merits at the time of its passage in the late 1950s, by the late 1990s the advances of science and technology had made it obsolete at best. In the 1950s, substances might be measured in parts per hundreds or thousands; by the 1990s, substance residues could be measured in the parts per quadrillion. How could scientifically reliable assessments be made of the health effects of such tiny doses?

Whatever the limitations of the capacity to meet Delaney standards, however, the FQPA analytic requirements represent a virtual "revolution" in pesticide risk management. EPA had been struggling for more than twenty years to meet Congressional demands for pesticides that had been registered before 1974 to be reregistered. This meant issuing "tolerances" for acceptable levels of pesticide residues depending on toxicity. In that period a relatively small number of such pesticides had, in fact, been reregistered. Now all pesticides, whether registered before or after 1974, would have to be assessed for tolerances under a new and a much broader set of criteria. Rather than stipulate tolerance levels, EPA had routinely granted "emergency exemptions" to domestic farmers for use of otherwise restricted pesticides. Between 200 and 300 emergency exemptions from EPA's residue tolerances were granted each year to domestic pesticide users.[5]

The FQPA drastically increased the number and complexity of the technical criteria by which EPA now had to evaluate pesticide tolerances. And those new criteria went well beyond EPA's admittedly limited scientific knowledge in dealing even with the narrower criteria that had obtained previously. Now, new and existing pesticide tolerances for residues on both raw agricultural commodities and processed foods are governed by a "reasonable certainty of

[5] *FQPA Forestalls Possible International Action Against US Over Emergency Pesticide Use Exemptions,* **Food Chemical News,** December 23, 1996

no harm" safety standard. FQPA now demanded risk assessments based on a broad range of new risk standards.

Risk Mitigation: In considering risk mitigation issues, the workshop discussion focused on issues related to the characteristics and incentives of industry that may determine whether innovative technologies will be aggressively pursued. Environmental protection has traditionally been viewed as primarily the concern of government, and as embodying a set of particular environmental risks, science-based standards for determining acceptable risk, and primarily technology-based measures for mitigating those risks. However, it is increasingly clear that, if significant innovation is to occur, it will come from industry. The environmental policy debate has given ever-greater attention to alternatives to traditional regulatory mechanisms as means of motivating improved corporate environmental performance. What then are the incentives and capabilities of industry in pursuing innovation?

- What are the maturities of the industries and processes that pose environmental risks?
- What are the vulnerabilities in the technologies utilized by them?
- How do we get the “best and the brightest” to be involved in designing and developing new products and production processes?
- What are the necessary means for directing finance capital to major reconfigurations of industrial processes?
- What are the constraints posed by the major excess production capacity in many global manufacturing industries?

Apart from the general concern about technology innovation, the policy debate has increasingly focused on performance-enhancing market incentive instruments regulatory instruments. Yet the effectiveness of these mechanisms is poorly understood with respect both to their environmental impacts and their affects on corporate financial performance. The potential effectiveness of these measures is sensitive to assumptions made about the motivations for corporate environmental behavior, but there has been little systematic analysis of the motivations driving corporate environmental behavior.

- What explains differences in the environmental performance of different types of firms within or across industries in response to different types of regulatory and enforcement instruments? Why are incentives for improved environmental performance different across industries and product-markets, and across different types of firms?
- Changes in technology are a driver of changes in industry structure: how do the incentives for environmental performance change with dynamic changes in technologies and their effects on industrial structure?
- What firms, industry segments, or industry sectors would benefit most and who would be harmed by integrated regulatory standards directed at the performance of the total supply chain of firms?
- Can corporate promotion of more stringent environmental regulations or related industry standards form part of an overall corporate strategy for gaining competitive

advantage within an increasingly global marketplace characterized by rapid technological change, and increasing industry concentration?

- What are the implications of conflicts over the international harmonization of environmental regulations as they impact rates of technological diffusion changes in industrial structure, and environmental performance? Whose interests are served by promoting very stringent, internationally harmonized regulations, given that it is virtually inevitable that the costs and benefits will not be equally shared across firms within the industry, across the suppliers to those firms, or across industries that are in competition for the same buyer? How might large, multinational companies employ more stringent environmental standards as an instrument for gaining competitive advantage; and what strategic responses are available to smaller or more specialized firms within the same industry?
- How do different types of firms employ regulatory strategies – including self-regulation – to shift regulatory burdens across industries and firms, and to gain market share?

The combination of regulation, new technology and changing industry structure has fundamentally changed the competitive environment for many industries and serve to define the market attributes on which their competitive corporate strategies are determined. Because regulations affect the structure and practices of markets, they must affect overall corporate strategy, not simply short-term financial results; and a fundamental aspect of corporate strategy must be how to influence and exploit to the extent possible regulations affecting technology and business organization. Historically, there have been two approaches to corporate strategies that attempt to use environmental regulations to serve corporate interests. One that is increasingly apparent is the effort by firms to conduct very public campaigns to promote environmental protection, presumably in an effort to gain brand name approval. The second strategy and one more prominent historically, is the effort to gain preferential treatment within regulatory structures to gain cost and competitive advantage. This latter form of regulatory risk and burden-shifting across firms and industry segments is quite different from the risk-shifting generally treated in the literature as a problem of shifting risks from one source or medium to another due to narrow and fragmented, single-source regulatory standards.

Examples of preferential and discriminatory regulations are legion. Old industrial facilities are favored over new facilities; farms – major sources of air and water pollution – are the most preferentially treated; mobile sources of air pollution are more rigorously regulated than point sources; and, among mobile sources, new light duty vehicles carry the burden of air quality regulations relative to old or heavy duty vehicles. These discriminatory standards are not only a major source of regulatory inefficiency but also a major constraint to innovation in many industrial sectors.

There is, on the other hand, growing evidence of how technology and clever design of regulatory instruments – especially in creating what are effectively property rights – can create strong incentives for better environmental performance; and can do so without fighting direct political battles with politically powerful industry groups that have garnered preferential regulatory treatment. The classic example is that of organic food production. It

took many years of political effort on the part of interested small farmers to finally gain governmental regulations that stipulated the standards for so-called organic food. Without those regulations there was no way for those farmers to distinguish their product and prevent market entry by producers who failed to employ the costly procedures of high quality organic products. In effect organic food producers wanted a property right of special food product labels that indicated that very special production methods were used. With that label, organic farmers have been able to charge a significant price premium for their products. It also so happens that, in general, the production processes used by organic farmers also serve important environmental protection purposes.

In effect, organic farmers are exploiting the fact that most farmers engage in poor environmental practices – given limited regulatory oversight. By their own initiative, organic farmers sought product and process standards that effectively segmented the food markets to their advantage. Stringent regulations were essential to their cause. Are there not similar conditions in other product-markets?

IMPLICATIONS FOR THE PSTEP RESEARCH AGENDA

In the view of many industry representatives at the PSTEP workshop there already exist technologies with improved environmental attributes for which it has not been possible to get regulatory approval or even concerted regulatory review. Is technology now "getting well ahead" of regulation? Can the regulatory approval process for new technologies keep up with the opportunities for innovation? Industry has often relied on the courts as the last resort to alter regulations it finds unjustified or unacceptable. Now the use of the courts and public action programs by public interest groups serves to delay significantly the development and diffusion of new technology. Whose interests does delay ultimately serve? Does the continuing reliance on litigation to force change in regulations now serve to prevent effective innovation? In any case, the courts have proven their limited capacity for evaluating science and technology effectively. These considerations indicate a clear need for an objective, credible institutional base – like the MIT PSTEP Program -- for evaluating new technologies like those mentioned at the workshop. If the manufacturer's claims can be verified, and if the potential benefits of more rapid technological innovation are significant, then industry should aggressively support programs like PSTEP that present the ability to gain timely, credible and reliable technology assessments. In order to influence the regulatory process and hasten regulatory reviews, the research products of institutions like PSTEP must be aggressively communicated to stakeholders.

PSTEP can also assist EPA in improving its capacity for technology assessment. So much of the criticism of EPA's analytic capabilities focus on risk assessment, but at least as important is limited capacity to evaluate technologies for their risk mitigation potential. And risk mitigation assessments must go well beyond the typical focus on a particular technology's ability to mitigate a particular risk or on the risks directly posed by that technology. At least five sets of issues, and the tradeoffs among them, must be addressed:

- Risk versus risk tradeoffs of new technologies
- Potential for production efficiency gains from new products and processes

- The aggregate environmental impacts of changes in supply chains due to product substitutions
- Monitoring and enforcement efficiencies arising from new product and process technologies
- Environmental performance incentives associated with technological innovation

Appendix A:
Overview of the Program in Science Technology and Environmental Policy

The increase in environmental legislation since the early 1970s in the United States and other industrialized countries has produced significant benefits to environmental quality in these countries. At the same time, and with the wisdom of hindsight and experience, the same body of legislation has led to frustration and inefficiencies that reveal a remarkable absence of technological depth in the regulations and standards put in place to achieve environmental goals. This is due in part to a lack of input from the engineering sciences to decision making in public and private sectors and in the regulatory process. Many environmental regulations are by their nature science and technology-intensive, yet many public officials and the public at large lack understanding of the role that technology can and must play in solving environmental problems and, hence, are suspicious of it and reluctant to understand it. If these problems are going to be overcome in the future, it is crucial that institutions like MIT have a voice in the policy arena and that our students be prepared to address them. For students, this will mean better understanding of the gap between technology and policy that underscores much of environmental decision making and standard setting today. Traditional engineers receive inadequate training and exposure to policy, government and the social sciences, and because of this are under-represented in the process of formulating and promulgating regulations. Consequences for the environment and the manufacturer, obvious or discoverable to an engineer, too often are not even addressed in the decision making process. Unintended consequences are much more difficult and costly to redress after enactment of legislation.

Motivated by these concerns and by a desire to contribute to the preparation of new engineering and policy leaders, a research-based program that will bridge the gap between engineering and the social and management sciences with a focus on environmental policy has been formed.

The aims of the Program on Science, Technology and Environmental Policy (PSTEP) are:

1. To provide opportunities for masters and doctoral students to analyze specific regulatory standards through thesis work to determine:
    a. The role of the engineering sciences in determining the feasibility of the regulations or standards
    b. The development of efficient and effective technologies to address environmental issues
    c. The economic viability of alternative technologies (if appropriate) for meeting the standard or realizing the goals
2. To foster better understanding of the impact of environmental regulations on industrial development and its relationship to social progress.
3. To develop channels for educating government and business decision makers on the role of technology in meeting environmental goals and of how such knowledge can contribute to more effective policies and standards.

4. In concert with industrial and government sponsors of the program, propose alternative regulatory approaches that offer beneficial incentives and provide flexibility in technological responses to specific environmental problems.

Technology and the engineering sciences have much to contribute to the improvement of environmental policy and time is of the essence. Policy failure is frequently attributed to scientific uncertainty. Yet this is not often the case. More often it is due to poor understanding of the principles of technological feasibility, and this can be overcome by closing the gap between technology and public policy. PSTEP focuses on the engineering sciences and technology as the critical tools to address environmental policy and problem solve. PSTEP's charter is to educate future decision-makers in government and industry who are committed to engineering leadership beyond technical and physical challenges to better serve the interests of society, and who are trained to become those leaders through multi-disciplinary research and education that narrows the gap between engineering and the social and management sciences. MIT is one of the most effective places to bring together teams of engineers, medical specialists, economists and political scientists to address these problems.

Program graduates will converse equally well with technologists, consumers, and managers in both the industrial and government sectors. They will be uniquely prepared to contribute to the environmental debate and influence environmental decisions. PSTEP will bring together faculty and students from a variety of specialties, including the physical sciences, engineering, management and social sciences.

Appendix B:
PSTEP Workshop Overview and List of Participants

A workshop titled "Environmental Risk Management for the 21st Century" was held at the Massachusetts Institute of Technology (MIT) on November 1st, 2001. This workshop brought together leaders from industry, government, and academia interested in the discussing improvements in environmental regulations, primarily within the manufacturing industry. A list of participants and their affiliations follows at the end of this appendix. The workshop was co-sponsored by the Laboratory for Energy and the Environment and the Center for Technology, Policy and Industrial Development at MIT. The purpose of the workshop was to discuss the issue of environmental risk from a variety of perspectives in a structured, but open forum. The goals of the workshop were to solicit input from industry and government representatives to help identify appropriate issues for theses and advanced research, and develop means to ensure that results of this program are directed toward solving real problems. This was the first in a series of workshops that will be used to provide strategic direction for the Program in Science, Technology, and Environmental Policy (PSTEP) at MIT. Formal presentations on risk assessment, risk mitigation, risk shifting and risk education, and two panel discussions provided structure and the basis for discussion to the meeting. Contributions were off the record to promote open dialog and this appendix simply captures the main topics discussed.

Presentation on Risk Assessment, *Robert J. McCunney - Director of Clinical Research, MIT Center for Environmental Health Sciences, staff physician in the Pulmonary Unit of Massachusetts General Hospital and a faculty member of the Harvard Medical School*

Human health is one of the primary driving forces for the promulgation of environmental regulations. Environmental heath risks are generally measured by epidemiological studies and/or animal model studies. Decisions are often developed using incomplete, inadequate, and often contradictory data. Human disease frequently does not correlate well with animal exposure studies. Low dose exposure levels and threshold exposure levels are also controversial. Promulgated regulations on toxin exposure are difficult to relax even with reliable new data. Enhanced education in all spheres, public, business and government is the key mechanism for improvement. Increased use of new biomarker technology was offered as a hopeful prospect for addressing some of these issues.

Presentation on Risk Mitigation, *Donald R. Sadoway - John F. Elliott Professor of Materials Chemistry and Mac Vicar Faculty Fellow, Department of Materials Science and Engineering*

Many of the manufacturing processes in use today were developed decades ago when it was assumed that the earth was endowed with unlimited resources and disposal of "by-products" was a simple matter with minimal costs and risks. While end-of-pipe treatments work in some instances, in many others they are simply not economical or efficient. What is needed is a renaissance in processing science to help guide what amounts to a revolution in process design. Ultimately, we need processes that, in the words of Gordon Forward, "emit only product." This means that the by-products are either environmentally benign or useful as the resources for other processes. By adopting a systems approach to the problem some people have learned that wholesale process redesign, as opposed to substitution of reagents or unit operations, has led to

the discovery of efficiencies that result in higher profitability while meeting tightening environmental standards.

Presentation on Risk Education/Regulatory Adaptation, *Kenneth A. Oye - Director of Political Economy and Technology Policy Program, Center for International Studies and Associate Professor, Department of Political Science*

Public policies are necessarily imperfect experiments. Unanticipated collateral costs and benefits, technological change, and resistance make it difficult to get the policy right initially. Yet, once in place regulations are difficult to change and adapt to new scientific and technologic knowledge. This is a major source of inefficiency and lack of innovation. Cases studied in recent work suggest ways to enhance adaptation through learning within firms and among consumers. Policy and regulation can promote such learning--at the same time, firms through learning can gain competitive advantage through environmental regulation. Regulation is a source of business risk--but it can also be a method of containing and shifting business risks if companies recognize the competitive advantage to be gained.

It was suggested that adaptation is less dependent on government than on industry educating itself. The real issue is recognizing that stricter environmental standards can offer significant competitive advantages to businesses. Regulations can impact prices, conditions of market entry and terms of competition. Three different cases were used to illustrate this point. The first case involved the food safety and the meat packing industry. Deregulation in the 70's precipitated an increased incident rate of food poisoning (salmonella and botulism), public fear, and negatively impacted both small and large producers. Regulations enacted in response had the unexpected effect of favoring larger operations. Larger companies had access to capital, enabling them to adapt and comply. Small competitors could not respond and went out of business. This was a win-win situation for the large producers. They attained an enduring competitive advantage, and improved public perception of safety.

The second case focused on Dupont and ICI, two companies which dominated the CFC (chloro-fluoro carbon) chemical business. These companies invested in research on CFC alternative technologies well ahead of any market limiting legislation but found the alternatives too costly to effectively market. When the threat to the ozone layer was recognized, and caused CFC's to be phased out of production, these same companies were forced to abandon what was rapidly becoming a competitive commodity business. However, their prior research investment became valuable, as they started to market alternative patented chemicals, at higher monopolistic prices. Thus regulations banning CFCs significantly benefited Dupont and ICI.

The third case examined British Petroleum's (BP) strategy of acquiring and upgrading many small independent (dirty) petroleum refineries in Europe. They focused production on low sulfur fuels, while not required to. This altered the regulatory environment. When clean fuel was proven to be feasible, it became mandated by law. Environmental regulations increased the value of BP's investments. In effect, BP achieved de-facto exemption from anti-trust scrutiny by being clean.

Presentation on Risk Shifting, *James L. Foster - Research Scientist MIT Center for International Studies*

Several common perceptions suggesting that government policy and big business are the cause of regulatory imperfections were challenged. It was suggested that big companies are the cleanest companies and gain competitive advantages from stricter environmental regulation. Indeed large multinationals would prefer uniformly enforced regulations across geographical boundaries, rather then having to adapt to regional regulations. Risk shifting is really the practice of shifting environmental burdens and liabilities from one entity to another. Frequently this can be between industrial sectors. Companies act to minimize risk by divesting business segments with excessive environmental burdens or liabilities. Some times this is done with a product buy-back contract, so they dispose of a liability without loosing the benefits or continuity of supply.

Companies were divided into three categories for discussion purposes. The first group was called Rational Polluters. These firms require regulations and enforcement to deter behavior, and respond by doing as little as possible. Commodity producers tend to fall in this category. The second category is the Confused Polluter, which doesn't know which regulations apply or how to be in compliance. These are often, but not always small firms. The third group is the Lean/Green Competitor. This group gains process efficiency from clean practices, and tight controls. The incentive is both cost reduction and enhanced corporate reputation. The Lean/Green Competitor promotes preferential regulations and segments the market in its favor. Regulations become a barrier to potential competition. The concept of supply chain regulations to prevent risk/liability shifting was presented.

Morning Roundtable Discussion - Innovation and improving environmental performance--Issues, barriers and solutions

Moderator	*Gregory McRae -*	*Massachusetts Institute of Technology*
Panelists	*Gary C. Huber -*	*Vice President of Finance, Canyon Resources Corp*
	Bill Bunn -	*Medical Director and Vice President of Health, Safety and Productivity, Navistar International*
	James Antonini -	*Toxicologist, National Institutes of Occupational Safety and Health*

Gregory McRae introduced the panel and briefly spoke on barriers to reducing risks, unintended effects of regulations, and the need to bring more science to bear on recognized environmental problems.

Bill Bunn discussed problems associated with multiple regulatory regions, particularly with respect to mobile source air emission standards. He concentrated on diesel exhaust emission standards and regulation timing. He suggested that diesel exhaust can become clean, and diesels offer clear performance incentives.

Gary Huber presented the story of a small independent gold mining company with a substantial mineral deposit in Montana. While in the final stages of preparing an exhaustive and expensive

environmental impact statement required for production permits, the state passed a ballot initiative prohibiting the use of cyanide leaching technology in mining, essentially killing the project. The case is being fought in state and federal courts.

Larry Zobel discussed how his companies business is largely focused on new product development and marketing and that public perception is of paramount importance. Environmental fines are far more damaging for the impact on corporate image than for the financial cost of the fine. Profitable products have been withdrawn from the market because of the possibility of their being classified harmful in the future. Product environmental liabilities are hard to justify. Meeting all existing regulations is not necessarily an adequate metric for decision-making.

Afternoon Roundtable Discussion: Beyond Risk Management: the Next Generation of Environmental Regulation

Moderator	*Joanne Kauffman -*	*PSTEP Co-Director, Massachusetts Institute of Technology*
Panelists	*Chris L. Magee -*	*Professor of Practice, Engineering Systems Division, Vice President Ford Motor Co., Product Development*
	Timothy Johnson -	*Project Manager, New Products, Corning Glass, Diesel Particulates and Automotive*
	Derry Allen -	*Counselor, Office of Environmental Policy Innovation, US Environmental Protection Agency*

Joanne Kauffman challenged this panel to help identify how best MIT can contribute.

Timothy Johnson focused on vehicular emission control technology, which his company is intimately involved with. Emission control technology is a success story for the environment. The success of this specific technology is also linked with special fuel quality requirements, use profiles, engine design, and catalyst recycling. A critical distinction was made between government mandating environmental goals but not regulating the technology used.

Chris McGee spoke to the multifaceted nature of environmental issues and the need to examine combined or cumulative health or environmental risks. Frequently, well intentioned technologies introduced to benefit the environment pose unanticipated side effects. The case in point is the addition of oxygenates to gasoline formulations, which ultimately threatened ground water. The importance of keeping the fact (science) content of the decision process high was stressed.

The final panelist was Frederick (Derry) Allen. He pointed out that laws and environmental regulations are local and tend to ignore international concerns. A very vocal public has strong influence on the legislative process. This public functions with incomplete data and doesn't always comprehend technological limitations or capabilities. EPA reacts to criticism, but has little incentive to change the way it does business. Particular focus was devoted to the need for new regulatory approaches that focus on a "total systems" view of environmental problems. Innovative ideas and tools such as Life Cycle Analysis and Industrial Ecology need to be explored to integrate the traditionally fragmented environmental regulation.

Workshop Participants

Government (4 Participants)	
Frederick (Derry) Allen	U.S. EPA
Mike Hill	U.S. EPA Region 1
Robert Hillger	U.S. EPA Region 1
Chris Rascher	U.S. EPA Region 1
Industry (16 Participants)	
Brian Balukonis	Raytheon
Carl Bozzuto	Alstom Power
William Bunn	International Truck and Engine Corp.
Darnall Burks	Mitsubishi Materials
David Chock	Ford Motor Company
Robert Dean, Jr.	Synergy Innovations, Inc.
David Gobin	Synergy Innovations, Inc.,
Gary Huber	Canyon Resources Corp
Timothy Johnson	Corning, Inc.
James Key	American Welding Society
Willem Ledeboer	ITC
Christopher Magee	Ford Motor Company
Renee Olson	Agilent Technologies
Dennis Ramdahin	New York City Transit
Ajay Singh	New York City Transit
Larry Zobel	3M
Academia (22 Participants)	
Thomas Eagar	Massachusetts Institute of Technology
James Foster	Massachusetts Institute of Technology
Karen Gibson	Massachusetts Institute of Technology
Timothy Gutowski	Massachusetts Institute of Technology
Neil Jenkins	Massachusetts Institute of Technology
Joanne Kauffman	Massachusetts Institute of Technology
Omid Kassiri	Massachusetts Institute of Technology
Harold Larson	Massachusetts Institute of Technology
Claude Lupis	Massachusetts Institute of Technology
David Marks	Massachusetts Institute of Technology
Lewis McCulloch	Massachusetts Institute of Technology
Robert McCunney	Massachusetts Institute of Technology
Donald McGowan	Massachusetts Institute of Technology
Gregory McRae	Massachusetts Institute of Technology
Luisa Molina	Massachusetts Institute of Technology
Mario Molina	Massachusetts Institute of Technology
Ali Mostashari	Massachusetts Institute of Technology
Christine Ng	Massachusetts Institute of Technology
Kenneth Oye	Massachusetts Institute of Technology
Mikael Román	Massachusetts Institute of Technology
Donald Sadoway	Massachusetts Institute of Technology
Heather Seyfang	Massachusetts Institute of Technology
Nancy DuVergne Smith	Massachusetts Institute of Technology
Brian Zuckerman	Massachusetts Institute of Technology