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Barriers to Environmental Technology Innovation and Use

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BARRIERS TO ENVIRONMENTAL TECHNOLOGY INNOVATION AND USE

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Barriers to Environmental Technology Innovation and Use

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Principal Conclusions

I. Introduction and Summary

Technology innovation is critical to achieving higher environmental standards and cost-effective solutions to environmental problems. Yet there are concerns that innovative environmental technologies are not being developed at the same rate as in similar industries, and those which have been developed are not being used, resulting in lower environmental quality for the public and higher costs to industry.

The Environmental Law Institute (ELI), with support from the Joyce Foundation and the U.S. Environmental Protection Agency, has examined barriers to technology innovation in specific industries relevant to the Great Lakes region. The six industry case studies are presented in Chapters Two through Seven. These industries were chosen to reflect a mix of small and large manufacturing sectors, for which available data allowed a close examination of the barriers to innovation. For each, ELI research addressed the major pollution problem faced by the sector. The case studies attempt to distinguish between normal economic barriers to innovation and barriers specific to the environmental field.

These case studies show that innovative environmental technologies do face significantly higher barriers than are present in other fields. This difference is manifested in the decline of private venture capital for environmental technologies to virtually zero over the past decade, in an era of copious venture funding for technology in other fields.

The research shows that barriers specific to innovation in environmental technologies stem from the way our environmental regulations are designed and enforced, which in turn affects business decision-making. Fundamental reform of our regulatory emission and discharge rate-based standards is needed in order to remove the many barriers they create for innovation.

In addition, however, these case studies also show that typical business conditions such as industry's aversion to risk, lack of financing or lack of capital turnover can create major barriers to innovative environmental technologies. However, these barriers appear to be unrelated to the environmental nature of the technologies studied, and therefore do not entirely explain why innovative technologies are not being used in the environmental field to the same extent as in other fields.

In interpreting the following case studies, attention should be paid not only to the performance of technologies in relation to the specific pollutant at issue, but also to concepts of pollution prevention and industrial ecology.[1] In this context, the necessary innovation includes not only technologies which achieve greater control of a particular pollutant, but those which consume fewer resources and less energy, create less waste, and prevent pollution through cleaner processes instead of end-of-pipe treatment.

A summary of each case study follows.

Baking: Large bakers in urban areas are required to install reasonably available control technology (RACT) to control their emissions of ethanol, a volatile organic compound (VOC). EPA has defined RACT to require emission reductions of 80 to 95 percent, and has determined that catalytic oxidation is the only reasonably available technology which can achieve this level of reduction. There are some innovative technologies which can achieve slightly lower levels of VOC control and are cheaper, employ fewer resources and less energy, and do not use toxic metals. But they have been unable to receive permits under the RACT emissions rate standard. Such a standard creates several barriers to the use of innovative technologies: technologies not already "available" cannot be permitted; those which are close to but not achieving the 80 percent level cannot obtain the commercial testing, demonstration and refinement needed to improve their performance and become commercialized; and trading between sources cannot be allowed (absent special state programs) even though it would permit use of innovative technologies while achieving greater VOC reductions from other sources. In addition, EPA test methods for VOCs, which perform poorly in water-laden airstreams like those from bakeries, also create barriers to certain innovative VOC technologies which condense ethanol into a water medium. All these barriers are magnified by the permitting process, which requires vendors of innovative technology to overcome the barriers repeatedly in every state. These barriers combine to provide a monopoly position for the catalytic oxidation technology.

Dry Cleaning: Perchloroethylene (PERC), the main solvent used by the dry cleaning industry, is a hazardous air pollutant. As regulation of PERC has tightened, four generations of dry cleaning machines have added control technologies which have greatly reduced, but not eliminated, PERC emissions. Several innovative technologies would do away altogether with the need for PERC. Technologies using water, liquid CO_2 and ultrasound have all been shown to be as effective as PERC. Barriers to their use

arise from the small, fragmented nature of the industry, with 30,000 independent small businesses, and consequent lack of funds for research, experimentation, and risk-taking. Similar to other technology areas, external sources of funds such a private venture capital or government funding do not exist in sufficient amounts to fill this need. Another major barrier for the water technologies are "dry clean only" consumer labelling standards developed long before current technologies, and which impose a risk of liability on cleaners using innovative water technologies.

Electric Utilities/SO_2: Recent changes in regulatory standards to control SO_2 emissions from electric utilities allow a retrospective analysis of the effects of different regulatory approaches on technology use and innovation. SO_2 emission rate limits imposed in 1971 and 1977 prevented many utilities from adopting technologies and practices that could have effectively reduced SO_2 emissions. The 1977 new source standards mandated the use of scrubbers, a resource- and energy-intensive technology producing high levels of waste. Subsequently, the emissions cap and allowance trading system created by the Acid Rain Program of the 1990 Clean Air Act Amendments imposed an overall performance standard which now allows greater innovation and has resulted in a major shift towards cleaner process technologies. Barriers to trading in the utility sector remain, however, due in part to restrictive state utility laws. Economic estimates indicate the costs of achieving equivalent SO_2 reductions are halved in moving from the prescription for a particular technology (scrubbers) to a rate-based emissions standard, and halved again in moving from that standard to the 1990 emissions cap and allowance trading system.

Iron and Steel: This case study investigates technologies which address discharges of spent sulfuric, hydrochloric or mixed acids used to treat formed steel, a major pollution problem of the iron and steel industry. The most immediate barrier to lowering such discharges is the definition of solid waste in EPA's RCRA regulations, which requires that spent pickle liquor be treated as a RCRA waste if it is reclaimed and recycled. This requirement escalates the difficulty and cost of recycling so much that it becomes more economic for most firms to dispose of the liquor in landfills or inject the waste underground. RCRA in effect creates waste from material which would otherwise be reclaimed and reused. Other economic barriers to recycling include fluctuating economic variables, such as the prices paid for reclaimed ferric chloride, transport and other costs, as well as low prices for landfilling and underground injection. An integrated solution would be to remove the regulatory barriers to recycling while making it more expensive to dispose of these wastes through landfilling or underground injection. In addition, increasing customer acceptance of unfinished steel in certain applications could reduce pickle liquor creation. In the longer view, the principle barrier to eliminating the use of pickling acids altogether is the lack of funding and industry efforts to research and develop non-toxic alternatives to pickle liquor.

Pulp and Paper: Innovative technologies in the bleaching stage of papermaking can greatly reduce discharges of persistent organic chlorides, a major pollution problem. After a multi-year process, EPA recently adopted a Pulp and Paper Cluster Rule imposing significant new limits for water effluent discharges. Although the Cluster Rule sets numeric limits at a point that will force the adoption of cleaner chlorine dioxide technologies, it does not force adoption of even cleaner technologies and stops well short of requiring totally chlorine-free technology. Although cleaner technologies are competitive with older ones when building a new mill, the cost of retrofitting newer technologies onto the 300 existing mills is perhaps the major barrier to their use.

Wastewater Treatment: Innovation in wastewater treatment faces a mix of economic and regulatory barriers, many of which may be unique to publicly-owned utilities. Economic barriers include diminishing government funding for publicly owned treatment works, the conservative approach of municipal administrators, and the lack of privatization or alternative financing mechanisms which could help to overcome these conditions. Regulatory barriers to innovation include restrictive and outdated state and local codes which may establish technology-based standards based on traditional treatment methods, state procurement regulations which discriminate against new technologies, and inconsistent state standards which make it more difficult for new technologies to enter the market. Although regulation was a driving force to improve quality of surface water and develop treatment plants in the early decades of the Clean Water Act, technology vendors now view many regulations as out of date, and changed from being technology drivers to technology barriers.

In sum, the case studies here reveal both the strengths and weaknesses of our current environmental laws and policies in moving toward a new paradigm of sustainability. They show that, while our current environmental system has served us well, it has created significant barriers to innovation and has difficulty moving towards more integrated concepts of pollution prevention and industrial ecology. These case studies also show that normal economic and business conditions may cause significant barriers to innovation in environmental technologies. These conditions include the conservative nature of businesses in many sectors, the lack of capital turnover, and the small size of companies in sectors like dry cleaning. Although they create major barriers to innovation, these conditions are not unique to the environmental field and do not explain why innovative environmental technologies are not being used to the same extent as in other fields.

The barriers specific to environmental technologies stem from the way environmental regulations are designed and enforced, and how these in turn affect business decision-making. Perhaps most fundamentally, technology-based emission limits and discharge standards, which are embedded in most of our pollution laws, play a key role in discouraging innovation. Other regulatory barriers include state utility regulation which is slow to change and limits innovation and RCRA's definition of waste which creates strong disincentives to recycling and reclamation.

There are several independent reasons why technology-based limits and standards create these barriers. First, as shown best in the electric utility study, an emission limit may preclude the use of technologies that create equivalent pollution reductions but may not affect end-of-pipe concentrations. By limiting the technology choices available to firms, such standards create barriers whenever the objective of our pollution laws is to reduce overall pollutant loads.

Second, emission limits or discharge standards based on a single best technology create practical barriers to innovation by limiting permissible technologies to available ones that meet the standard. This requirement precludes the normal development and refinement process most technologies need to achieve their best performance and, in many cases, can limit permissible technologies to a single one. This situation was encountered in two of the case studies; it not only precludes innovation, but also leads to a monopoly position for the permitted traditional technology which discourages further improvements.

A third barrier is the permitting system. New technologies must overcome a two-step approval process, the first being acceptance by risk-averse business managers and the second approval by risk-averse government permit writers. These two steps greatly increase the cost and time required to innovate. In addition, the federal nature of our permitting system requires an innovator to gain separate approval in multiple states before a new technology can become generally recognized as effective.

Emission and discharge rate standards have other serious problems. They provide no incentives to go beyond the required reduction and, as such, they fail to develop a culture of continuous environmental improvement necessary to sustain research, development and investment in innovation. Finally, emission and discharge rate standards are one-dimensional, and while requiring a high level of control for one pollutant, may provide few incentives for overall cleaner production. Several case studies here show how current regulations favor end-of-the pipe technologies which consume significant resources and generate high wastes: flue gas scrubbing consumes huge amounts of lime and 2% of the power generated by a plant; catalytic oxidation for bakery VOCs requires platinum, a toxic metal; and RCRA requires disposal of millions of gallons of spent pickle liquor which would otherwise be recycled. In all these cases, innovative technologies could reduce pollution through process changes without such harmful side-effects.

These problems inherent in emission limits and discharge standards can be avoided whenever pollution needs to be addressed on a regional level. The electric utility case study shows how an SO_2 emissions cap is far more effective than an emissions rate limit in such a situation because it creates an enforceable standard without requiring technology review by a permitting agency. This emissions cap and allowance trading system could be used to address the many urgent regional pollution issues we now face, such as achieving reductions in urban ozone concentrations, particulate pollution and potentially also greenhouse gases.

The barriers inherent in emission limits and discharge standards appear deeply rooted, and not easily overcome by simple solutions like technology waivers, verification programs, or similar provisions. They appear to stem from the way traditional environmental standards -- such as RACT, BACT, LAER, BPT and BAT -- set maximum emission limits or discharge standards, and combine with the permitting structure which accompanies these standards.

Instead, potential solutions to overcome the barriers to innovative environmental technologies require fundamental reform. Our basic environmental laws need to be changed, where possible, away from technology-based rate standards which focus on end-of-pipe results and towards overall performance standards which focus on preventing pollution at the plant level, or regional level where feasible. This change will have the effect of removing the need for the review of compliance technology by permitting authorities, which is the root of so many of the barriers to innovation in the traditional environmental regulatory system.

Indeed, progress has been made in this regard in the emission cap approach created for SO_2 emissions, and under discussion for regional pollutants such as NO_x,[2] particulates and potentially greenhouse gases, and the advance technology incentives program created in the recent Pulp and Paper Cluster Rule. Applying overall performance standards to other areas may require consideration of programs such as emissions trading, information and audit-based systems and other ideas to complement our traditional end-of-pipe approach. Where possible, the standards should create continuous pressure on businesses to reduce discharges and achieve improvements in reducing all of their environmental impacts.

Improving the opportunities for innovation through these changes will effect greater pollution reductions while allowing businesses the flexibility in technology choice to harness costs as a driver to promote pollution prevention through reducing resource consumption, energy use and waste generation. The cost of basic inputs should then be changed to reflect social costs, with the effect that cost could become a truly integrated driver for pollution prevention, and could complement the driver created by environmental regulation focusing on a specific pollutant. Only then can environmental quality become integrated with business decision-making and we can move from an adequate environmental regulatory system to an excellent one.

II. Background

A. The Failure to Use Innovative Environmental Technologies

There is a widespread perception that innovative environmental technologies are not being adequately implemented and used to control pollution, resulting in lower environmental quality for the public and higher costs to industry. Federal activity to investigate the above question has been organized under the National Advisory Council for Environmental Policy and Technology (NACEPT), a public advisory committee advising the Administrator and staff of the U.S. Environmental Protection Agency (EPA). The NACEPT created the Technology Innovation and Economics (TIE) Committee specifically to address this issue.

The TIE Committee convened many multi-stakeholder meetings and issued three reports addressing the question of innovation. Their first report concluded that the disincentives to create innovative environmental technologies create a "market dysfunction symbolized by th[e] lagging rate of investment in environmental technology."[3] It describes how a number of policies, including government policies, can hinder technology innovation by making it difficult for companies to try something new. It concluded: "Permitting and compliance systems, as they function today, discourage all stakeholder groups from taking the risks necessary to develop innovative technologies" and that "changes to the environmental regulatory system will be needed to create incentives encouraging the environmental technology innovation process".[4]

The TIE Committee made a series of findings as to why innovative environmental technologies were not being implemented and used.[5] They concluded that fundamental changes would be needed to the environmental regulatory system and offered a series of recommendations. These stressed the need for modifying permitting and enforcement systems, providing incentives and flexibility for innovative technologies, improving testing and demonstration capacity, developing cross-media coordination, identifying and removing regulatory barriers, and developing EPA leadership.

The TIE Committee noted that, while environmental regulations create the market, they can also obstruct and slow innovation: "Regulatory and statutory requirements often limit the potential to introduce flexibility into implementing policies." They further concluded that "the emphasis in the environmental management system on single-medium pollution control strategies is rapidly reaching both technological and cost limits" and that "existing permitting and compliance authorities at all levels of government lack flexibility necessary to encourage technology innovation for environmental purposes."[6]

The Committee noted these hurdles facing industry can take many forms. For example, most environmental standards now in place were developed around a particular technology and can have the practical effect of "locking in" that technology's use. The permitting process can also discourage innovation by making the approval process for new technologies lengthier, more cumbersome, and less certain than for conventional approaches. Even when companies are allowed to use an innovative technology, they may be unwilling to risk non-compliance as they receive no reward for exceeding the minimum regulatory requirements and no protection against failure. Therefore, the same old technologies may be used year after year, freezing out newer and more effective alternatives.

The case studies in this report reinforce these conclusions. Standards such as BACT or even RACT can lead to one permissible technology. The environmental permitting process adds to these barriers by preventing normal development of new technologies and by creating extra regulatory hurdles. Finally, these permitting hurdles must be surmounted time after time in each state until a technology becomes generally acceptable.

B. The Decline in Venture Capital for Environmental Technologies

An independent way to verify the health of the environmental technology industry is to review the rate of financing available for new ideas. The TIE Committee of NACEPT concluded in 1990 "that for at least the past decade the rate of investment in environmental technology development and commercialization has lagged."[7] Since this statement, the level of venture capital financing for environmental innovation has gone from bad to disastrous: from $200 million in 1990 to only $30 million in 1996, in an era of unprecedented funding for technology in general.

Table 1. Venture Capital Available for Investment in Environmental Technologies ($ millions) Compared to Industry Size ($ billions)

Year	Environmental Industry Size ($billions)	Venture Capital ($ millions)
1988	125	120
1989	137	140
1990	149	200
1991	153	160
1992	159	110
1993	164	75
1994	172	60
1995	179	50
1996	181	30

Source: Environmental Business International

These data show that financing for environmental technologies is at an all-time low. This crisis severely constrains the development of innovative technologies. The lack of venture capital is especially problematic because it could be expected to fuel innovation by independent technology development companies. The decline in venture capital financing for environmental technologies reflects a similar trend in other private and public financing for environmental technology development. Between 1993 and 1996, environmental mutual funds have shrunk from $240 million to $80 million. The budget of the Department of Energy's Office of Technology Development has shrunk from $400 million to $290 million; and for the Department of Defense, from $180 to $150 million.[8]

Interviews with technology financiers reveal two key reasons why they no longer fund environmental technologies. First, even if a technology works and is commercially acceptable, it faces additional hurdles in the permitting process which may create time delays, lack of acceptance or other problems which prevent commercialization. This "double acceptance" barrier means fewer environmental technologies gain acceptance, and so fewer can become commercialized and profitable.

The second reason concerns market size, and is also related to the environmental regulatory system. The lack of a national permitting process means that the environmental market is fractioned into 50 state markets and hundreds of smaller ones, each one representing a permitting jurisdiction. Approval in one state or jurisdiction is no guarantee of approval in another, creating a balkanized market which creates a formidable barrier to entry of new environmental technologies. As a result, much private capital has virtually left the environmental field, as shown in the data above.

III. Principles

This section draws general principles from the six case studies in this report. It first discusses the barriers created by our regulatory system, which are the principal reason why innovative environmental technologies have a more difficult time being adopted and used than other technologies. It then discusses economic and business barriers which may also pose significant barriers to innovation, but do not affect environmental technologies in a different way than other technologies.

A. Emission Limits and Discharge Standards Create Barriers to Innovation

Technology-based emission limits and discharge standards which establish end-of-pipe rate standards are a major barrier to the creation and use of innovative environmental technology. As stated in the NACEPT report, "To a significant degree, these [fundamental] problems derive from the way the central approach to regulation in the United States -- 'best available technology'-based regulations -- is frequently used today. Reliance on 'best available technology'-based regulations impedes the development and introduction of innovative technologies."[9]

The Committee made the following recommendation:

> "Specifically, policy makers should reconsider the way 'best available technology'-based regulations are now developed and applied. Such regulations use agency established technology-based limits and use a technology to demonstrate that the limits are achievable. Even though these are performance-based requirements, they have a strong tendency to lock in the technology that is used to demonstrate achievability. To some extent, reliance on 'best available technology'-based regulations impede the development and introduction of innovative technologies."[10]

The case studies in this report reveal several problems with emission limits and discharge standards, which derive both from their inherent design and how they interrelate with our current system for approving permits.

1. Emission Limits and Discharge Rate Standards Restrict Choices

A major barrier to innovation created by emission limits and discharge rates arises when the permissible pollution standard is set so strictly that only one available technology exists which can meet it. This creates very high barriers to the development of any other technology because any new technology cannot be permitted commercially until it meets this standard. This requirement thus precludes the normal development and refinement process for most new technologies to achieve their best performance because it prevents the typical testing and demonstration process technologies need for commercialization.[11]

Of the four case studies which involve emission limits or discharge rates for specific pollutants, the problem of a single acceptable technology was found in two, the baking industry and utility industry before the change to a SO_2 cap and trade system in 1990. In the others, several technologies can still reduce discharges of chlorinated compounds in the pulp and paper industry and, in the dry cleaning industry, there has been little attempt to move beyond use of PERC. To judge from the case studies and the literature, therefore, the problem of technological "lock-in" under an emissions limit or discharge rate standard is common and has serious implications for innovation.

There are three reasons why emission limits and discharge rates may have this effect.

First, many statutes literally require the adoption of a single best technology by setting standards such as, "Lowest Achievable Emission Reduction (LAER)," "Best Available Control Technology (BACT)," or "Best Available Technology Economically Achievable (BAT)." However, as shown in the baking industry study, even with "Reasonably Available Control Technology (RACT); an emissions limit can lead to a situation where EPA has approved only one technology -- catalytic oxidation in this case -- which can meet the standard. This shows how an emissions limit actually becomes a technology standard if it is set at a level such that only one technology can comply. This problem becomes more serious as standards have become more strict over the past decades, because the stricter the standard, the greater the probability only one existing technology can achieve it.

Second, emission limits and discharge rates tend to dictate a single technology because they preclude the normal development and refinement process most new technologies require to achieve their greatest performance. As shown in the baking study, an emissions limit may prevent the typical testing and commercial demonstration process that technologies need for commercialization. Most technologies are developed, not invented, and require a period of research, bench-scale demonstration, commercial demonstration, and scale-up before full commercialization is possible. Setting a standard that only one existing technology can meet precludes this development process and may freeze innovation.

Third, emission limits and discharge rates may be poor performance standards because they measure achievement only by end-of-pipe concentrations. There are many technologies which reduce total pollutant loads through process changes, but may not reduce end-of-pipe concentrations. These could not be permitted under current emission limits and discharge rates even though they may achieve at least equivalent pollutant reductions and better pollution abatement through cleaner production. This was shown in the electric utility study, where many additional approaches to reducing SO_2 were able to be implemented once the emissions limit was changed to an overall performance standard through an emissions cap.

The electric utility case study provides an unusual retrospective view which allows comparison of actual performance under both a rate-based emissions limit and an emissions cap approach to curb SO_2 emissions. The case study shows that the former standard precluded the use of key technologies, and that innovation and use of those technologies has resulted in both cleaner production and considerable cost savings.

Table 2. Acid Rain Regulation - technologies permitted and estimated compliance cost by regulatory method:

	Emissions limits		Emissions cap	
Technology Prescription	% reduction	% concent	without trading	with trading
- scrubbers	- scrubbers	- scrubbers - limited use lo-sulfur coal	- scrubbers - major use lo-sulfur coal - fuel blending - no backup nec. - demand side mgt.	- scrubbers - major use lo-sulfur coal - fuel blending - no backup nec. - demand side mgt. - power shifting - trading
Cost in $billions/yr. to reach similar pollution reduction:				
7	4.5	--	2.5	1.2

The increased flexibility in the regulatory standard as one moves from left to right on Table 2 shows how more technologies can be used. The more flexible approaches allow innovation to occur in a greater number of technologies, which has resulted in significantly lower costs. Estimates by the USGAO allow a cost comparison and show that, in terms of cost, emission limits are almost 50% more efficient than strict technology prescriptions like mandated scrubbers and that an overall performance standard like an emission cap is again almost 50% more efficient than an emission limit. An additional 50% efficiency gain may be possible with trading, where feasible.

The problem with emission and discharge rate standards originates with the basic concepts and approach used in many environmental laws, which embody end-of-pipe pollution control and not pollution prevention, and provide for public accountability of pollution sources by authorizing citizen suits. The technology standards in many statutes use the term "control technolgy", and set specific emission limits and discharge rates, reflecting this end-of-pipe approach. As the TIE Committee commented: "The current system of single-medium permitting has achieved significant environmental gains primarily by stimulating a pollution control response, rather than by encouraging pollution prevention."[12] Nevertheless, the unintended effect of regulating through emission limits and discharge rates has been to preclude pollution prevention and to lock in existing control technologies.

Because emission limits and discharge rates restrict technology choices and preclude innovation, such standards only make sense when the objective is to reduce pollutant concentrations in the immediate vicinity of a pollution source. This was one of the original goals of environmental regulation in the 1970's and may be a reason why many of our chief environmental laws were structured this way. Indeed, there is still a need for the mandatory end-of-pipe concentration limit for SO_2 applicable to utilities that dates from the original Clean Air Act, but this has been superseded in importance by the need to achieve much greater reductions in SO_2 on a regional or national airshed level for ecosystem and human health. Increasingly stringent rate-based standards make little sense to address these problems because of their cost, tendency to consume large amounts of resources and their discouraging effect on innovation. An overall performance standard such as an emissions cap makes much more sense when pollution needs to be regulated at a regional level, such as SO_2, urban smog and particulate concentrations which are major pollution problems today.

2. Emission Limits and Discharge Rates Reduce Incentives for Improvement

In addition to their effect in limiting technology choices and innovation, emission and discharge limits also create no incentives to reduce pollution below the required

standard. "The way the regulatory system now operates, the incentive to innovate exists primarily with respect to the costs of performance and there is little, if any, incentive or opportunity to innovate for the better performance the nation will need."[13] The only way to create such broader incentives is to create regulatory systems with continuous drivers, which may include pollutant charges, disposal charges, emissions trading, and information-based systems like the Toxic Release Inventory.

Technology-based standards also discourage innovation for more fundamental reasons than the lack of incentives to find technologies which exceed the given standards. Compliance with technology-based standards produces a "stutter-step" approach to research and development, as new technologies are only needed at the infrequent intervals when a regulatory authority decides to tighten standards. Once the new standard is promulgated, firms must rapidly find and use a technology with the requisite performance. These characteristics do not encourage a culture of continuous research, development and improvement needed to foster innovation, and in particular they do not create any incentives for long-term, basic research to find wholly new approaches.

Without a continuing demand for better performance, there is no steady support for firms dedicated to researching and finding better ways of solving environmental problems. Recent investigation by ELI on this issue showed that research in the environmental field is at a very low level -- 3% of revenues for the firms which develop and sell environmental technologies -- and oriented almost exclusively to applied research with short-term time horizons.[14] This lack of research is evident in many of the case studies as described below in Part H, and is particularly evident in the dry cleaning, iron and steel and wastewater treatment case studies.

Finally, the electric utility case study reveals another interesting aspect of rate-based regulations which discourages improvement. Under the former SO_2 emission limits, scrubbers enjoyed a monopoly position for more than a decade, yet experienced relatively little improvement. There were, however, significant improvements in scrubbers soon after the 1990 Amendments exposed them to competition from low-sulfur coal under the emissions cap approach.

3. Permitting Systems Create Additional Barriers to Innovation

Another set of barriers for innovative environmental technologies derives from the current permitting system needed to implement technology-based emission and discharge rate limits. These permitting barriers are reviewed in the TIE reports and illustrated in several of the case studies here. They include the delays inherent in the permitting system, permit writers' lack of time, expertise and experience, the lack of rewards for implementing innovative technologies, and the cautious approach inherent in a government bureaucracy. Despite these problems, it is important to recognize that the current system has many benefits. It preserves state autonomy as long as federal pollution standards are enforced and allows state or local governments to adopt more stringent standards if necessary to protect public health from localized effects of pollution. It also may facilitate public participation by providing easily comprehensible standards which assist with citizen oversight and enforcement.

a) *Double Approval:* Innovative environmental technologies face two approval hurdles, compared to a single approval faced by technologies in other fields. Environmental technologies face an approval process by the regulatory authority as well as by potential users. This double approval process makes the use of innovative environmental technologies more difficult and drives financing away from environmental technologies because commercialization is easier in other fields.

The essential problem is that, when a permitting system requires a permit writer to review a firm's technology choices under standards such as BACT, RACT, LAER, and BAT, it consumes significant amounts of effort and time to gain permit approval. As shown in the baking industry study, due to the conservative nature of permitting agencies and the regulatory restrictions on acceptable technologies and test methods, it took much longer to convince the permitting authority than the using business of the merit of a viable new technology. Then, having surmounted these barriers at great effort in one state, the innovator faced them again in each new permitting jurisdiction.

b) *Time:* The time delays inherent in the permitting process also create barriers to innovative technologies. In the wastewater study, the General Accounting Office notes the time limits imposed by the state procurement process discourage innovation: "When EPA (or a state) directs a community to build a treatment facility within a tight time frame, the community and the consulting engineer may select a conventional system to avoid the additional time that may be required to design and receive approval for an alternative system."[15]

c) *Freezing Technology:* Setting standards in reference to a benchmark "best" technology also has the effect of locking in or freezing technology. In some situations, by definition, only one technology can achieve the required emission or discharge rate limit, and in others, documents like EPA Alternative Control Technology documents can dictate acceptance of a preferred technology. Subsequent technology developments then face high barriers in obtaining approval because of constraints on permit writers time and knowledge and the systematic bias against approving what has not been authorized before. This barrier is apparent in the case studies on baking and acid rain, where it has restricted the development and use of new technologies.

B. Other Regulatory Systems Create Significant Barriers

In several of the case studies, other kinds of regulatory barriers play important roles in precluding the application of innovative technologies. In both the electric utility and wastewater treatment studies, state laws have created environments which discourage innovation, and in the iron and steel case study, RCRA poses a significant barrier to reclamation and recycling.

1. State laws

In the wastewater technology sector, restrictive state and local codes and regulations create significant barriers to innovation. State procurement rules, based on the federal procurement rules used during the federal construction grants period, place narrow and strict procurement requirements on bidding processes which reduce the level of technology allowed to the lowest common denominator. In addition, state procurement laws requiring competition may discourage innovation by precluding bidding unless more than one firm proposes similar innovative technologies.

In addition, state and local wastewater codes and standards can restrict or actually prohibit the use of innovative technologies because many codes contain specifications that apply only to conventional technologies. These standards are engineering design specifications based on conventional technologies to meet secondary wastewater treatment, and may include parameters such as sizes of aeration tanks, retention times in flocculation basins, amount of chlorine for disinfection, etc. These standards are periodically updated, but for conventional treatment only; innovative technologies are not included.

Finally, in the wastewater arena, water quality standards vary from locale to locale. Because of this, developers and vendors of new technologies will always have to conduct many pilot tests in separate jurisdictions to demonstrate that their products can achieve various water quality standards, which is very costly and restricts new entrants.

In the electric utility study, state laws constrain trading of SO_2 allowances, precluding innovation as well as cost savings. Many state public utility commissions (PUCs) lack rules on treatment of allowance transactions, creating uncertainty and a significant barrier to risk-averse utilities. In addition, some state rules erode incentives to trade allowances, and technical aspects of standard state regulations for electric utilities tend to inhibit trading. In most states, the rules for the allowed rate of return, the depreciation rate, and risk that expenses may not be recoverable in electricity rates are all less favorable to allowance transactions. Furthermore, typical prohibitions against shareholder earnings on capital gains (but not capital losses) impose one-sided risk on utilities that purchase allowances.[16] A third problem has been explicit prohibitions by legislatures on trades that might undermine local economic activity, especially production of coal. These have all depressed demand for and willingness to purchase allowances.

2. Resources Conservation and Recovery Act (RCRA)

The iron and steel case study reveals a significant regulatory barrier in RCRA's definition of waste that precludes legitimate acid reclamation activities. As a consequence, hundreds of millions of gallons of waste acids which could be recycled are being injected underground or treated and disposed in landfills.

The recycling of spent pickle liquor is an existing technology with considerable pollution prevention potential, although only a small fraction of pickle liquor waste is currently recycled. A principal barrier to recycling is the definition of solid waste in RCRA, which requires RCRA treatment if wastes are reclaimed during the recycling process. Anecdotal evidence from several firms suggests this problem may be widespread because the application of RCRA makes recycling costs prohibitive.

Other barriers to recycling include fluctuating economic variables, such as the price paid for reclaimed ferric chloride, and transport and other costs. The impact of recycling on worker safety and transport accidents are other issues to be considered. A thorough assessment of the data on pickle liquor recycling and its potential could lead to a recommendation to revise the RCRA definition of waste to facilitate reclamation and recycling either on-site or off-site.

C. One-dimensional Environmental Standards Are Inconsistent with Pollution Prevention

The six case studies here also reveal the tendency of our traditional environmental laws to be one-dimensional in their application. By demanding technologies with the highest rate of control for one specific pollutant in one medium from one source category, our laws may dictate technology choices that have high overall material and energy costs or create other significant wastes, in a way that is inconsistent with current notions of pollution prevention.

In five of the six case studies in this report, current environmental requirements favor or require technologies with high materials consumption, energy use or wastes that must be treated or landfilled, rather than favoring innovative technologies with lower materials demand which might otherwise be used in these sectors. In these situations, business' desires to find less costly treatments are often more in alignment with overall or multi-dimensional environmental solutions and technology answers. This is because an approach that costs less typically, although not always, uses fewer materials and other resources. Barriers to innovation become particularly important, as business drivers to develop cheaper and cleaner technologies may be frustrated by one-dimensional standards.

In the baking and electric utility cases, this situation was created by traditional emission rate limits. In the baking study, the current RACT standard creates a monopoly for catalytic oxidation which achieves 96% control of VOCs, but with high energy and material use and which requires periodic replacement of the platinum catalyst, a toxic heavy metal. In the electric utility case, the pre-1990 SO_2 emission limits either encouraged or dictated the use of scrubbers, also a materials-intensive technology that consumes large quantities of lime and 2% of a utility's energy, as well as creating large amounts of sludge that must be landfilled.

In both cases, alternative technologies are much cleaner. In the baking study, alternative technologies have slightly lower VOC control, but have lower capital costs, much lower operating costs and energy use, and use no toxics. One technology even returns energy to the facility, and another does a superior job of cleaning up other wastes. In the electric utility case, the switch to an emissions cap and trading system for SO_2 in 1990 prompted an industry shift to cleaner coal and other processing methods which avoid both the high energy consumption and disposal of sludges created by scrubbing.

In the iron and steel study, the high material use arises from RCRA's definition of waste which produces restrictions on spent pickle liquor that would otherwise be reclaimed and recycled. RCRA defines material as a waste if it is reclaimed in a recycling process, imposing costs that cause most firms to instead discard spent pickle liquor through stabilization and landfilling or by underground injection, and purchase virgin materials.

The tendency for our laws to grandfather existing methods with high material demand is also evident in the wastewater treatment and dry cleaning case studies. In the former, state codes set technology-based prescriptions using traditional methods which are oriented towards mechanical and chemical treatment, compared to more modern technologies using ozone, ultraviolet radiation and other less material intensive methods. So also the regulation of the dry cleaning industry for many years has focused on requiring improved machinery and better disposal of toxic PERC wastes, whereas innovative technologies attempt to do away with PERC altogether.

The pulp and paper case study is the only one in which the innovative technologies are not significantly less material intensive than the more traditional technologies. Both the chlorine dioxide technology now required by EPA's Cluster Rule and more innovative chlorine-free technologies would significantly reduce emissions of the target pollutants, but both also use significant amounts of chemicals and energy to do so.

This review indicates that innovation is still an important need even in situations where an existing technology achieves a high rate of pollution control, as technologies are needed which achieve a similar result with less overall consumption of resources and energy and smaller amounts of waste. Regulations which require a single best technology with reference only to reductions in a particular target pollutant may thus preclude development of cleaner technology options.

In this regard, costs can become an important driver of clean production, as lower costs tend to reflect lower material and energy use and disposal costs. Business' motive to find less costly technologies becomes a driver for achieving more integrated resource reduction. Environmental regulations should therefore be designed to allow maximum flexibility for businesses to find cheaper technologies consistent with the need to reduce discharges of target pollutants. This means moving, where feasible, away from technology-based standards towards overall performance standards.

Two of the case studies here show progress in this regard. The barriers to innovation posed by the emission limits in the electric utility case study have been successfully addressed in the 1990 Acid Rain Program[17], which created an overall performance standard through an SO_2 emissions cap. Also, the recently announced Pulp and Paper Cluster Rule creates a Voluntary Advanced Technology Incentive Program which provides 5, 10 or 15 additional years for companies to comply if advanced and cleaner technologies are to be used.[18]

D. EPA Test Methods can Discourage Innovation

EPA standard test methods can also create significant barriers to the implementation of innovative technologies. In the bakery industry, there was no specific EPA-approved test method for ethanol, and the general approved method for organic gases, EPA's Method 25A,[19] performs poorly with a moisture-laden emissions stream such as those from bakery ovens. It is also not designed for methods, such as the innovative heat exchanger or the wet scrubber, which convert ethanol to a water medium.

Faced with the problem that this method creates a positive bias in testing ethanol emissions with high water vapor, innovative technology vendors have had to convince states to use another accurate test method in order to prove their technology could meet emission standards. Since acceptance of an alternative test method involves an exercise of discretion by the state regulatory authority, innovative technology vendors face an expensive and time-consuming process in fighting a battle for acceptance of the alternative test method in each state, in addition to gaining state-by-state approval of their technology.

E. Our Federalized Regulatory Structure Adds Hurdles

Many barriers to innovative technologies are reinforced by the potential need to achieve permit approval independently in each of the 50 states and more than 100 other permitting jurisdictions in the United States, each with a separate approval process. While our federal system does create problems for innovation, it has countervailing and strong political and policy justifications, including the federal system's role in preserving state autonomy, allowing for more stringent state or local standards where necessary, and allowing a ready forum for public participation in permit approvals.

The difficulty of obtaining permits in such a system is best illustrated in the bakery case study, where a lengthy effort to install the technology in Maryland simply laid the groundwork for repeated efforts in other states. The need to overcome repeatedly the same barriers restricts the ability of innovative technologies to successfully commercialize, and also reduces the interest of private capital markets in investing in environmental technologies.

In addition, our federalized system may create differing standards in many jurisdictions, and these variations disproportionally affect start-up and innovative technologies. In the wastewater study, a GAO study noted the barrier to innovation created because water quality parameters vary between jurisdictions. Because of this, developers and vendors of new technologies will always have to conduct many pilot tests in separate jurisdictions to demonstrate their products, which is very costly.

There are other, more political kinds of barriers to innovation created by the federal permitting system as well. In the electric utility study, several states in the past enacted laws to mandate SO_2 control technologies that might preserve in-state coal-mining jobs. Although these laws have been overturned as unconstitutional, more subtle ways could also be used to favor local political interests and prevent cleaner technologies.[20]

Finally, there is also variation in the way states have chosen to develop programs which attempt to lower the barriers to innovation created by the regulatory system. In the iron and steel case study some states are more aggressive than others in using the RCRA waiver provision which, although of limited usefulness, helps to redress the barrier created by RCRA's definition of waste. A variety of other programs are discussed in the next section.

F. Innovative Technology Waivers and Verification Programs have Limited Usefulness

One response to the barriers to innovation caused by the regulatory system has been to incorporate innovation waiver provisions into pollution control statutes. At the federal level, this has been done in the Clean Air Act[21], Clean Water Act[22], and RCRA[23]. These provisions allow for extended deadlines or other special procedures for innovative technologies, and are intended to encourage industry to develop new control or disposal technologies.[24]

In practice, they have not achieved their intended effect.[25] A study of the Clean Air Act waiver provision found that the high transaction costs, delay and uncertainty in gaining an exemption have greatly limited its usefulness. The study showed that, of the few companies which applied for a waiver, only one was approved in the initial three years, and companies that had applied were reluctant to do so again.[26] A similar result has been found for the Clean Water Act waiver provision.[27]

Generally, these waiver provisions suffer from the same defects as the regulations they are meant to redress. They are administratively complex, in some ways ambiguous in their definition of innovation, and depend on the timely consideration and approval by the same permitting body that administers other permits for conventional technologies. Many of the same barriers would apply, such as overburdened permit writers, time delays, and lack of appropriate expertise, so this system can do little to solve the permitting barriers identified above.

Technology verification programs may have greater potential for overcoming these barriers than technology waivers, but are also subject to many technical constraints. Such programs verify that a given technology passes a performance protocol administered and judged by an independent private party or the government. Although a popular idea with technology vendors and regulators, verification programs have been slow to be implemented, and those that have been developed suffer from many of same constraints as the regulatory programs they were meant to address.

Major problems with verification include the additional time delays and cost the programs require, and even after verification in many cases the findings may not be specific enough to a specific users' processes and facilities to be of great benefit. In a survey of environmental technology vendors and users,[28] user firms emphasize that regardless of the verification program, they usually need to conduct their own tests anyway to assure compatibility with their particular processes and equipment. Some also perceive that unless sufficiently rapid and effective, a verification process can itself become another barrier to commercializing an innovative technology.

In addition to permit waiver and verification programs, states have adopted a number of innovative technology programs that promote, fund or facilitate innovative technologies.[29] In some instances, these provide flexibility for regulatory standards under State Implementation Plans for ozone attainment and similar programs, but they cannot be more lenient than the federal provisions. As shown in the baking example, this limits their scope to technologies that meet or exceed regulatory standards, but may be less costly than traditional technologies, which does not address many of the fundamental barriers discussed above.

BUSINESS-RELATED BARRIERS

The case studies in this report have sought to ascertain whether there are particular barriers for innovative technologies in the environmental arena. They reveal that standard economic and business conditions often pose major barriers to innovative environmental technologies and play key roles in several of the case studies here. However, generally they are normal economic barriers confronted by all innovative technologies and do not present special barriers to environmental technologies.

G. Industry Conservativism and Risk-Aversion

Many innovative technology vendors point to institutional aversion to risk on the part of their client industries as a barrier to acceptance of innovative technologies. "Firms want to be first to be second" and "pioneers get arrows in their backs" are typical comments. However, there are many legitimate business reasons for firms to be cautious when accepting new technologies. An accurate business assessment of potential costs and benefits may dictate a cautious approach.

For the sectors studied in this report, industry's conservatism is mostly due to legitimate business appraisals of risk and benefit in accepting new technologies, which must shoulder a burden of proof that they will work in the specific context of an individual firm. The pulp and paper case study reveals how factors such as the individual and complex nature of facilities, as well as expense and days of production lost if a technology fails, create very real reasons for caution. In many industries, legitimate business risk aversion appears to be part of the burden of introducing any innovative technology and is not specific to the environmental industry.

In three of the case studies, however, the industries exhibit a genuine institutional aversion to risk-taking which appears to be greater than legitimate business caution and any regulatory barriers. In the dry cleaning industry, the lack of innovation appears to be due to the small, retail-oriented firms which comprise the industry and which lack the finance and capacity to experiment with new technological processes. The other industries which exhibited undue risk aversion are the electric utility and wastewater sectors. Both are heavily regulated by state laws which are slow to change, and both tend to be dominated by publicly-owned entities which have enjoyed virtual monopolies through most of their history. All these factors lead to an inability to act swiftly in embracing new technologies.

While such undue conservatism in these industries is a barrier to change and must be addressed in crafting public policy, it does not affect environmental technologies more than it would other technologies. Again, this aversion to risk appears to be a typical business barrier which any innovator must surmount.

To the extent industry's aversion to risk is greater for environmental technologies, this difference appears to be due primarily to the environmental permitting system which creates barriers to innovation that are absent in other technology fields. As noted above, innovative technologies must be accepted not only by user firms but also by permit writers; and the expense and effort to provide the needed demonstrations and tests are high barriers to marketing or using innovative technologies. A business may be unwilling to install an innovative environmental technology because, even if it is effective in reducing pollution, the permitting process may be longer and more costly than for a conventional technology, reinforcing a firm's inherent caution in innovating.

H. Funding for Innovative Environmental Technologies is Lacking

The lack of finance plays a major role as a barrier to the use of innovative environmental technologies. Finance is a complex issue, however, and its behavior as a barrier can be manifested in several different ways.

Of priority concern to environmental policy is the general lack of private finance available for environmental technology innovation, as show in the Table 1 above. Interviews with leading investors who have attempted to fund environmental technologies over the past decade make it clear they perceive two fundamental problems, both relating to the operation of the regulatory system. The first is that the permit process creates a second layer of review for any new application that not only adds time and cost, but often rejects viable technologies for reasons internal to the permitting system, such as lack of time, expertise, or risk-taking by government permit writers.

The second concern is that, while the overall U.S. market for environmental technologies is over $180 billion according to Environmental Business International,[30] in reality this is divided into hundreds of smaller markets defined by each permitting jurisdiction. In each one, innovative technologies must surmount the same barriers to industry acceptance and permitting approval. To contrast this situation to innovation in the field of medicine, it requires over $100 million and ten years to obtain Food and Drug Administration certification of a new pharmaceutical drug.[31] Once certified, however, a new drug obtains open access to 80% of the global market and, as a consequence, huge amounts of private capital are being invested to discover new products. In contrast, the lack of market size in the environmental field drastically escalates the costs of commercialization, and discourages innovation.

Absent changes to our federal system, the most practical way for environmental technologies to overcome this barrier is to move away from technology-based standards and towards overall performance standards like taxes or emissions caps. This shift would eliminate the case-by-case and state-by-state review of innovative technologies by permitting agencies and the balkanized system which creates such a barrier to financing. If this change were accomplished, arguably hundreds of millions of dollars in private capital would become available for investments in innovative environmental technologies.

A third funding issue is the lack of internal capital to finance innovation, also evident in the case studies here. This barrier is economic in nature and not restricted to the environmental field. The dry cleaning case study shows that the small to very small size of firms in an industry may create a near-total lack of finance for research and development. However, a lack of capital for research was also found in the iron and steel sector, although large firms predominate, due to increasing competitive pressures. The general lack of venture capital for environmental technologies becomes all the more important in these situations where there is no internal capital available for technology research and development.

A fourth economic barrier relates to capital flows and the expense of capital plant renewal, which is evident in the pulp and paper and wastewater studies. Here, major capital costs are required to install innovative technologies, which are easier to absorb when building a new plant. The slowness of capital turnover in these industries can be therefore be considered a barrier to innovation.

In the pulp and paper industry, an innovative technology would actually be cost-competitive with more traditional technologies if installed at a new facility. However, because very few new mills have been built in the U.S. this decade, innovative technology needs to be retrofitted in order to be used, which costs $10-20 million. Therefore, although innovative technologies have been developed which pollute less and are no more costly than traditional technologies, they are not being fully used due to lack of capital turnover in the industry. The only driver in this situation would be new regulatory requirements to achieve lower pollution levels.

The lack of capital for new treatment plants is also considered a barrier in the wastewater industry, where traditional federal funding sources have dried up. Although new wastewater treatment facilities are being built, EPA estimates that investment is only half of what is required. Again, innovative technologies are much more cost-competitive when installed in new facilities than when retrofitted, so this lower level of investment activity means a lower rate of investment in innovative water treatment technologies. However, because some new plants are being built, barriers in this industry may also have to do with other issues, such as institutional reluctance to change.

I. Research on New Technologies is Lacking

The lack of research and development (R&D) is an evident barrier in the case studies on dry cleaning, iron and steel and wastewater treatment, for differing reasons. As discussed above, there are virtually no funds available in the dry cleaning industry for R&D due to the small size of firms. The most significant initiative is being developed by a source outside the industry. In the iron and steel industry, while firms are large, their R&D departments have been slashed over the past 20 years as the industry has reduced costs to meet foreign competition. Today, there is relatively little capital within the industry for R&D. Wastewater treatment plants have traditionally relied on government funding for capital plants and research, both of which are in steady decline and have not been replaced by alternative funding sources.

The decline in research and development in many manufacturing industries is a national trend that is broader than the environmental arena.[32] However, it affects the environmental area significantly because so many technology improvements are required to meet our society's demand for increased environmental quality. In addition to what is happening in the manufacturing sector, an ELI study shows that most firms in the environmental technology vendor community are also devoting few funds (3% of revenues) to R&D, and spend virtually no funds on basic R&D.[33]

The need for improved strategies to fund research and development in environmental technologies is evident. There is a particularly compelling rationale for government support of R&D in the environmental area, because private capital markets do not place adequate value on the social benefits of improved environmental performance and thus will not provide adequate funding for innovative environmental technologies.

IV. Solutions

This section discusses potential solutions to the barriers for innovative environmental technologies described above. These solutions must take place on two different levels. The first fundamental reform is to change our basic environmental laws, where possible, away from technology-based standards which focus on end-of-pipe results towards overall performance standards. These include pollution taxes and emissions caps which focus on reducing pollution at the plant level or regional level, where feasible.

This first level of reform will have the effect of removing the need for the review of compliance technologies by permitting authorities, which is the root of so many of the barriers to innovation in the traditional environmental regulatory system. It should also allow businesses the flexibility to find least-cost solutions within a regulatory context, harnessing costs as a driver to promote pollution prevention through lower material use, energy use and waste creation. As noted above, it is also likely to remove the barriers which keep hundreds of millions of dollars in private capital from investing in environmental technologies.

However, more is needed. A second tier of improvement can only come by changing the fundamental nature of the supply and demand drivers which businesses face. On the supply side, the cost of resources, energy and waste disposal must be raised to reflect their true social cost. If so, costs could become a truly integrated driver for pollution prevention and complement the driver created by environmental regulations which focus on specific pollutants. Demand drivers also need to change so that increased demand for cleaner production creates the incentives for businesses to invest in the research and use of improved technologies. These solutions could lead us towards the more integrated solutions required for industrial ecology and pollution prevention.

A. Well-designed Environmental Regulations Can Drive Innovation

The role of environmental regulations as drivers of innovation is complex and easily misunderstood. Any environmental regulation, indeed any regulation, will create some change in behavior, and hence some innovation in the technologies applied. However, the extent, quality and duration of innovation can vary greatly depend on the kind of regulation passed.

The case studies here show that environmental regulations can be significant drivers of innovation, as in the pulp and paper industry, or can do the opposite and freeze technologies, as they did for decades with electric utilities. Their tendency to do the latter has led some commentators to label the environmental technology industry as an "old technology" industry, where only existing technologies are easily permitted.[34] The issue is not whether regulations drive innovation, but understanding of the extent and quality of innovation prompted by environmental regulations, and whether the regulations exert any pressure for continuous improvement.

The case studies in this report show that our traditional environmental laws and policies have usually avoided the pitfalls of imposing technology prescriptions, but have instead imposed emission limits and discharge rates which often have a similar practical effect. While they are better than strict technology prescriptions, these end-of-pipe standards are not as effective as overall performance standards and can significantly discourage innovation.

Discharge and emission rate limits on point sources of pollution can force only certain limited kinds of innovation, and our current permitting and compliance system developed around their use has had the effect of freezing the technologies at this level. The more environmental requirements can move away from rate standards regulating point sources towards overall performance standards and plant-wide or even industry-wide caps, the greater the number of technologies that may be used and the greater the potential for innovation to occur. A review of the case studies here sheds some light on the factors at work in determining the effect of regulations on promoting innovation.

The **dry cleaning** case study is a particularly interesting example of innovation-forcing regulation because this industry has lacked innovation for decades. Until environmental regulations began to restrict the use of perchloroethylene (PERC), the last significant change in the industry had come in the 1960's, when fire regulations required a shift from petroleum solvents to PERC. According to David Porter of Garment Care, Inc., these past decades have also corresponded to a decline in the garment cleaning industry as a whole, with a switch to home washing. Only with the pressure of environmental regulation have a few people starting to examine ways to provide cost, energy and environmentally-efficient cleaning services to a wider market.

To date, however, regulation of this industry has simply tightened discharge rates and emission limits, leading the industry to respond only by modifying its equipment to provide greater and greater end-of-pipe control and treatment of PERC emissions. Lack of finance, and perhaps of vision, in this small-business industry has generally precluded significant or well-funded investigation of alternative processes which avoid pollution altogether. However, an assortment of ad hoc efforts springing largely from individual initiatives, but also with government interest, has commenced experimentation with innovative technologies such as wet cleaning, ultrasound and liquid carbon dioxide. The latter effort is significant because it is the only integrated effort to launch a new product and originated outside the industry in a large technology company. It may soon cause another revolutionary change in dry cleaning technology.

Another case study where regulations have driven innovation is the **pulp and paper** industry, where regulation of hazardous effluents have driven a search for low or no-chlorine bleaching processes. The recent Cluster Rule passed in 1997 continues this process by essentially requiring the industry to shift from elemental chlorine bleaching to less polluting chlorine dioxide bleaching. However, this regulatory approach does not push the industry to seek further improvements, and a number of viable innovative technologies with much lower pollution levels are consequently not in demand.

The above examples show how regulations can force technological changes, although in both cases the response is restricted primarily to improved end-of-pipe technologies in one case and limited process changes in the other. Balancing these examples are others such as the **baking** study where environmental regulation has significantly restricted technology innovations. In particular, this study shows how emissions rate limits appear to exert particularly strong effects in freezing technology. These limits are designed so that only a single current technology can qualify and, given the great difficulty in obtaining approval of an alternative or innovative technology, this benchmark technology becomes the only one able to be permitted. In the regular course of events this technology would become obsolete and replaced by others, but the regulatory process "freezes" the process so the necessary testing, demonstration and improvement of alternative technologies are not undertaken.

The **electric utility** case study presents an especially vivid example of the failure of emissions rate limitations to drive significant potential technology innovations. Because the SO_2 emissions limit imposed in 1977 could only be met by end-of-pipe treatment with scrubbers, innovation in superior process change technologies was stalled until the law was amended in 1990. In retrospect, one can see how any source-specific emissions rate limit could not possibly have allowed for all the innovative technologies which became available after the SO_2 emissions cap and trade system was adopted in 1990.

While each of these examples shows how new regulations drive some kind of new behavior, the regulatory design also greatly affects the outcomes and implications for technology innovation and improvement. As shown in Table 2 for the electric utility case study, many different kinds of regulations can achieve the same level of environmental control, but have widely varying effects on cost and innovation. While each kind may have its appropriate applications, regulations which set performance goals with the greatest flexibility in compliance options succeed the best in terms of reducing costs and promoting technological innovation.

B. Emission Trading can Foster Innovative Technologies

In two case studies, emissions trading could promote significant gains in the use of innovative technologies. Since such gains should be weighed against the potential risk that trading can create localized concentrations of excess emissions, trading programs are implemented primarily for pollutant levels which cause regional, and not local, effects.

In the electric utility case study, the use of process technologies like low-sulphur coal was enabled by a combined SO_2 emissions cap and allowance trading program. Table 2 above shows that certain approaches, including power shifting and trading between utilities, were enabled specifically by the trading provisions of this program.

In the baking study, VOC emission trading through an open market system such as that proposed by EPA in 1995[35] and at work in a few states[36] could have assisted commercialization of the innovative heat exchanger technology, the leading competitor to the traditional and more expensive catalytic oxidizer. This technology could be shown even through traditional test methods to achieve 75% reduction of VOCs, whereas RACT standards require 80%. The bakers were willing to make up the difference and more through emission reductions in their own vehicle fleets, but were unable to obtain permits because emission trading is not allowed in most jurisdictions.

Trading opens the door to innovative technology in two ways. In the utility study, the closed method of emissions cap and trading can be shown to allow significantly more technologies to be applied to solving the acid rain problem. EPA's Acid Rain Program did this by fundamentally changing the regulatory system away from end-of-pipe standards to an overall performance standard. The baking study shows how open market trading, even without changing the regulatory system, can help to commercialize technologies which fail to achieve a standard by a small amount but are much cheaper or, conversely, technologies which can over-achieve a standard but are more expensive. Neither has a commercial life without a trading system. This is especially important for technologies which are in the beginning stages of development because allowing some initial uses through trading can lead to improvements which will enable them to compete directly with traditional technologies.

C. Increased Funding for Research and Development is Needed

Increasing the resources available for technology research and development is an important element in fostering innovation. However, as discussed in the introduction, most significant sources of funding for environmental R&D are in decline. Private venture capital for innovation in environmental technologies has declined precipitously and government funds, never plentiful, are shrinking. Furthermore, internal allocations for R&D by many businesses are also falling. Of particular concern is the finding that investment by firms that develop and market environmental technologies is also at low levels, around 3% of revenues for most firms.[37]

Commentators have pointed out that another failure of our traditional regulatory approach is that it lacks economic drivers for continuous environmental improvement.[38] Instead, businesses periodically must invest to meet a new regulatory standard, which then remains unchanged for a number of years. The failure of our regulatory approach to create a culture of continuous improvement is seen as a severe disincentive for research and development in technologies which improve environmental performance, and indeed very little research is being carried out by private environmental technology firms in the environmental area.[39]

This concern is especially important for environmental technologies, due to the considerable social benefits from improved environmental performance. Fundamental solutions to this problem are needed, such as increased government funding, tax policies favoring technology investments, or innovative approaches like Paul Samuelson's suggestion to require part of every mutual fund to devote a small portion of assets to basic research and development.

D. The Fundamentals of Demand and Supply Need to Change

1. Cost and Supply Drivers

Allowing firms greater flexibility in complying with enforceable environmental standards could not only drive innovation and reduce costs, but also produce other beneficial environmental results. Perhaps the major benefit of cost minimization is that what costs less tends to use fewer resources, less energy, or generate fewer overall wastes.

A second benefit of reducing the cost of environmental protection is that it can lead to greater demand for environmental quality, in the same way reduced prices lead to greater consumption of other goods. This process in environmental law however is slow and imperfect because it typically depends on legislation to achieve the more stringent standards. Occasionally, however, this process is discernable. The greatly reduced costs of SO_2 control created by the Acid Rain Program in the electric utility case study has, after only three years of implementation, resulted in a number of bills in Congress calling for significantly more stringent SO_2 standards.[40] Similarly, the current debate over greenhouse gas controls has centered on how much emissions reductions our society can "afford."[41] These examples reinforce the theory that lowering prices will trigger increased demand for improved environmental quality.

To maximize these benefits, society must harness this cost driver so that prices more accurately reflect the full social cost of goods and services. If the prices and costs of inputs are made to reflect full social costs and benefits, then businesses' economic motivation to reduce costs would then become an integrated driver of overall pollution prevention.

2. Demand Drivers

A focus on emissions and manufacturing behavior should not allow us to lose sight of the most fundamental driver of all -- consumer demand. In almost all of the case studies here, changes in consumer demand and behavior could result in significant environmental improvements and consequently enhanced use of innovative technologies.

This is perhaps most evident in the dry cleaning and pulp and paper case studies. Dry cleaning is a retail industry, and consumer acceptance is critical to acceptance of non-traditional technology alternatives to dry cleaning. This is particularly true of water-based technologies, which do not qualify as "dry" cleaning and therefore face consumer resistance, as well as barriers from consumer labelling regulations which impose liability if clothes are not "dry" cleaned. Changes in consumer demand could rapidly and dramatically increase the use of innovative technologies in this industry.

In the pulp and paper industry, consumer demand for bright paper underlies industry's use of chlorine-based technologies in the bleaching process and consequent discharges of AOX and other pollutants. Environmental technology in this country has been largely driven by regulations, with firms installing only the minimum technology needed to meet regulatory standards. Only a few firms have installed chlorine-free technologies to appeal to a greener market, and they have suffered when price premiums have disappeared due to lack of consumer demand for chlorine-free products.

Although consumer demand does not have as great a role in the other case studies, even with these it plays some role. In the iron and steel sector, the use of acid pickling technologies is driven by the demand for blemishless, finished steel products. Unfinished steel is used today only for car underparts and other hidden applications, and greater consumer acceptance of unfinished or partly finished steel in other applications would directly reduce the need for pickling acids. In the utility sector as well, enhanced consumer demand for "green" power from renewable sources could also play a significant role in reducing SO_2 emissions from coal-fired plants.

Endnotes

1. For a discussion of the concepts of industrial ecology, which includes closed-loop processes and materials reduction, see Graedel, T. & Allenby, B., INDUSTRIAL ECOLOGY (Prentice Hall, N.J., 1995).

2. See, *Utility Emissions Will be Limited Further if Federal Restructuring Bill Gains Approval*, 28 Envir. Reporter 1366 (Wash., D.C., Nov. 14, 1997) (creating a NOx cap of 785,000 tons for the 37 eastern states).

3. U.S. Environmental Protection Agency, PERMITTING AND COMPLIANCE POLICY: BARRIERS TO U.S. ENVIRONMENTAL TECHNOLOGY INNOVATION, at 4 (EPA 101 / N-91 / 001, January 1991).

4. *Id.* at 7, 15.

5. *Id.* at 26-40.

6. USEPA, REMOVING BARRIERS AND PROVIDING INCENTIVE TO FOSTER TECHNOLOGY INNOVATION, ECONOMIC PRODUCTIVITY AND ENVIRONMENTAL PROTECTION, EPA 100-R-93-004, p. iv, viii (April 1993).

7. USEPA, PERMITTING AND COMPLIANCE POLICY: BARRIERS TO U.S. ENVIRONMENTAL TECHNOLOGY INNOVATION, at 4 (EPA 101 / N-91 / 001, January 1991).

8. Unpublished data of Environmental Business International (San Diego, Ca, 1997).

9. USEPA, PERMITTING AND COMPLIANCE POLICY: BARRIERS TO U.S. TECHNOLOGY INNOVATION, *supra* note 3, at 15.

10. *Id.* at 39.

11. *See* Ashekov, N., *Understanding Technological Responses of Industrial Firms to Environmental Problems: Implications for Government Policy*, in ENVIRONMENTAL STRATEGIES FOR INDUSTRY: INTERNATIONAL PERSPECTIVES ON RESEARCH NEEDS AND POLICY IMPLICATIONS (Fischer, K. & Schot, J., eds., 1993)

12. USEPA, REMOVING BARRIERS AND PROVIDING INCENTIVE TO FOSTER TECHNOLOGY INNOVATION, ECONOMIC PRODUCTIVITY AND ENVIRONMENTAL PROTECTION, *supra* note 7, at vii.

13. *Id.* at 17.

14. ELI researched the research and development practices of the firms developing and selling environmental technology, and discovered the great majority of the industry, those concerned with air and water control technology, invest only 3% of their

revenues in research, and most report that 90-100% of all research is applied research with less than a two-year time horizon. Environmental Law Institute, RESEARCH AND DEVELOPMENT PRACTICES IN THE ENVIRONMENTAL TECHNOLOGY INDUSTRY (Washington, D.C., September, 1997).

15. See U. S. General Accounting Office, INFORMATION ON THE USE OF ALTERNATIVE WASTEWATER TREATMENT SYSTEMS, GAO / RCED-94-109 (Sept. 1994.)

16. Bohi, D. and Burtraw, D., *Utility Investment Behavior and the Emission Trading Market*, 14 Resources and Energy, 129-153 (1992); Solomon, B. D. *SO2 Allowance Trading: What Rules Apply?* (1994).

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37. Environmental Law Institute, supra, note 14.

38. Environmental Business Int'l, *The Challenge of Reinvention*, IX Environmental Business Journal, No. 4, p. 1 (1997).

39. The bulk of the environmental technology industry only invests 3% in research and development activities, and that 90% of this is applied. Environmental Law Institute, supra, note 14.

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Chapter Two:

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Technology Barriers in the Baking Industry

I. Introduction and Summary

The baking process produces ethanol, a non-toxic volatile organic compound (VOC), as a natural by-product of yeast fermentation. Bakers emit relatively small amounts of ethanol, with emissions reaching 100 tons annually in the largest bakeries. Although the baking industry has not traditionally been regulated by EPA, large bakers will be subject to regulation under the Clean Air Act Amendments of 1990 for releases of ethanol as a VOC. These are considered major sources in non-attainment areas and are required to install reasonably available control technology (RACT) to abate their emissions.

EPA has defined RACT to result in VOC emission reductions of 80 to 95 percent for large bakery operations. EPA's Alternative Control Document published in 1992 concludes that only combustion technologies can achieve these levels, with 96% control, and that only catalytic oxidation is available at reasonable cost. Since that determination, several innovative technologies have been developed which achieve roughly 80% levels of control, which are cheaper and cleaner, have lower capital costs, consumer fewer resources and less energy, and do not use the toxic metals required by catalytic oxidation.

Several aspects of RACT's rate-based standard present high barriers to introduction and use of the innovative technologies. First, because the RACT standard requires that technologies be "available," it precludes the use of innovative technologies which have not been demonstrated. Second, because the standard requires initial 80% control, technologies which are close to but cannot be shown to meet that level cannot obtain the commercial testing, demonstration and refinement needed to improve or to become commercialized. Third, because RACT standards are source- and media-specific, trading between sources cannot be used (absent special state programs), which might enable bakeries to use the innovative technologies while achieving greater pollution reductions in other areas.

There is a separate regulatory barrier created by the EPA test methods for VOCs, which perform poorly in water-laden airstreams and are not designed for technologies such as the heat exchanger or wet scrubber, which condense ethanol into a water medium. Even though more accurate tests specifically for ethanol are available, after much effort, technology innovators have only been able to convince EPA and state authorities in one state to allow this alternative test method to be used.

These regulatory barriers are magnified by the permitting process. After surmounting these regulatory barriers in one permitting jurisdiction, vendors of the innovative technologies must overcome the same hurdles again in other states. This combination of regulatory and permitting barriers provides a monopoly position for the traditional catalytic oxidation technology.

II. Background

The baking process produces ethanol, a non-toxic volatile organic compound (VOC), as a natural by-product of yeast fermentation. Bakers emit relatively small amounts of ethanol, with emissions reaching 100 tons annually in the largest bakeries. The baking process creates virtually no other significant air emissions.

Although the baking industry has not traditionally been regulated, large bakers will be subject to regulation under the Clean Air Act Amendments of 1990 for releases of ethanol as a VOC. Such releases will be addressed under State Implementation Plans (SIPs) and through Title V operating permits in ozone non-attainment areas.

The only practical treatment to destroy ethanol is to convert it to CO_2. Bacteria in air and water convert ethanol to CO_2 by natural means over time; treatment technologies can convert it rapidly into CO_2. Current control technology uses catalytic oxidation to convert the ethanol in the oven stack airstream into CO_2. Innovative technologies which would do the same thing at lower cost include heat exchangers and wet scrubbers, which extract the ethanol from the air into a water medium where it can be converted to CO_2 or safely discharged to municipal sewers.

There are 2500 bakeries in US with a potential CAA compliance issue due to their VOC emissions. This arises because bread is perishable, requiring major bakeries to locate in or near major population centers, which areas are often ozone non-attainment areas. Where large bakeries are major sources of VOC, they will be required to install Reasonably Available Control Technology (RACT) to curb their VOC emissions. Typically, the worst non-attainment areas require control of sources emitting more then 10 or 25 tons of VOCs, which would include most industrial bakeries.

The prospect of regulation for VOC emissions is a serious issue for the baking industry, because only 84 have installed control equipment as of late 1996. As baked goods typically carry only about a 2% profit margin, the cost and performance of VOC control technologies is a major issue for the industry. Some bakers are reportedly being put out of business, either by the need to borrow $500,000 for the conventional catalytic oxidation technology to reduce ethanol emissions or because they have old buildings which cannot support the 5-9 ton weight of the oxidizer.

III. Regulatory Framework

Large industrial bakers in non-attainment areas are major sources of VOCs and are subject to the RACT standard. This standard is contained in a section of the Clean Air Act for non-attainment areas which calls for states to develop compliance plans, "including such reductions in emissions from existing sources in the area as may be obtained through the adoption, at a minimum, of reasonably available control technology." CAA 172(c)(1). The RACT standard has been interpreted to require the consideration of the social, environmental and economic impact of the proposed controls and any alternative means of providing for attainment. 40 CFR 51.100 (o) (1996). To meet the RACT standard, a technology must therefore both be "available" or demonstrated, and achieve the desired environmental results at reasonable cost. 44 Fed. Reg. 53762 (1979).

The history of implementation of the Clean Air Act shows that EPA has generally implemented this provision by establishing emissions limits, such as described below for bakeries. This kind of performance standard is much better than a series of technology prescriptions, which might also have been an allowable regulatory option under the law. However, such a standard by definition restricts technology choices and, as shown below, may create unnecessary barriers to technology innovation when the goal is to reduce overall pollutants loads on a regional basis, such as VOCs.

EPA has defined the RACT standard for bakeries using an emissions rate limit. According to a memorandum from EPA's Office of Air Quality Planning and Standards in 1995, EPA "continues to believe that RACT should result in VOC emission reductions of 80 to 95 percent for large bakery operations." Where such reductions are not economically reasonable, EPA encourages states to propose specific alternative-RACT determinations in its bakery regulation as a less complex process than relying on source-specific SIP revisions. In addition, States can propose different requirements, and for example, California requires 90-95% emission reductions from large bakeries.

Because the RACT standard requires that technologies be "available," it precludes the use of innovative technologies which have not been demonstrated. Some states have special innovative technology waivers providing a special permitting process for such innovative technologies. But most state waivers require the achievement of 80% emissions reduction, and only Maryland has an innovative technology provision which can accommodate innovative technologies which are initially shown to achieve a 70% level of control. Code of Maryland Regulations, 26.11.19.21. This difference has proven critical for bakeries because standard test methods only show a 70% reduction of VOCs by the leading innovative technologies being considered today.

Interestingly, none of the states' innovative technology waivers appear to allow for creative solutions which consider issues beyond the source itself. Because alternative innovative technologies are much cheaper than conventional oxidizers, bakeries have been willing to offer additional voluntary VOC reductions to make up any shortfall from their bakery ovens, such as by converting their diesel trucks to natural gas. While a few states also have emissions trading programs that might cover this situation, no jurisdiction has accepted this offer so far.

IV. Alternative VOC Technologies

A. Traditional Technologies

EPA published the Alternative Control Technology (ACT) Document for Bakery Oven Emissions in 1992. It considered eight control technologies for reducing VOC emissions from commercial bakery ovens. Three of these were combustion technologies -- thermal oxidation, regenerative oxidation and catalytic oxidation -- and five were non-combustion technologies -- carbon adsorption, scrubbing, condensation, biofiltration, and process changes using alternatives for yeast. The document stated: "Devices under development or not demonstrated were not considered, although some show promise for the future."

EPA found all five of the non-combustion technologies to be ineffective or not currently feasible, whereas each of the combustion technologies were found to be able to achieve 98% reduction of VOCs. Of these combustion technologies, EPA found that catalytic oxidation was the only cost-effective compliance technology.

Capital costs of catalytic oxidation approximate $150,000 with operating costs ranging from $40,000 to 70,000, while capital costs for regenerative oxidation approximate $240,000 with operating costs in the range of $70-110,000 annually. Indeed, the one regenerative oxidizer actually installed in California did prove too costly at $1.3 million and still does not operate properly. Thermal oxidation was considered in the ACT document to be too expensive to warrant further evaluation.

This finding reinforced the practice at that time, as the document also found: "Of the approximately 23 ovens currently controlled, 21 use catalytic oxidizers, one uses a thermal oxidizer, and one uses a regenerative oxidizer." ACT Document at 4-5. Since development of the ACT document, almost all new installations have been of catalytic oxidizers. Of the 84 bakeries that currently have control equipment, 65 have catalytic oxidizers sold by CSM Environmental Systems, Inc. in Brooklyn.

B. Innovative Technologies

Since publication of the ACT document in 1992, several innovative technologies have been developed which were not analyzed by EPA and appear today to hold the best potential for reducing overall VOC emissions at lower costs to bakeries. To some extent, these involve multimedia approaches. Currently, the three most promising innovative technologies for control of VOCs in the baking industry are heat exchangers, bio-digestion, and wet scrubbers

1. Heat Exchangers

Heat exchangers extract ethanol from air by condensing it in water while returning heat to the bakery for other uses. This technology does not reduce ethanol to CO_2, but is a multi-media transfer into a water waste. Ethanol however does not create similar health problems as a water waste, as it is readily broken down by municipal waste systems like other organic matter. Most systems will accept the ethanol waste unless they are overloaded.

This technology is considerably cheaper than conventional catalytic oxidation in capital, maintenance and testing costs (see below). It may also become a net profit-maker if its function as a heat source can be made to reduce energy use (and energy-related pollutants) in heating the building or to pre-heat bakery oven intake air.

Giant Foods Bakery, Silver Spring, Maryland: A technology vendor, has made considerable efforts to sell its innovative heat exchanger technology to bakeries. Because the technology is innovative, it has encountered major barriers to sales due to the application of the RACT standards. State regulatory authorities have not accepted the technology as being "available" under RACT. That has limited sales to states with innovative technology waivers, and to date only the Maryland provision has been adequately flexible to allow use of this technology.

The heat exchanger technology was installed in the Giant Foods bakery in Silver Spring, Maryland in 1994, due to efforts by Giant and the Maryland Department of Environment to apply the innovative technology waiver in Maryland's air regulations. Generally, Maryland requires an 80% reduction of VOC emissions from bakery ovens. Maryland Air Regulations 26.11.19.21(D)(2). However, innovative control methods (other than thermal or catalytic oxidation) can be approved if they can be shown to achieve the 80% standard. If a new technology reaches 70% removal, it has an additional 24 months for modifications to be made in order to achieve the 80% standard, or possibly for the agency to propose a lowered limit to EPA. Maryland Air Regulations 26.11.19.21(E).

This flexibility in Maryland's innovative technology waiver was critical for the initial adoption of the heat exchanger by Giant because initial testing by traditional methods showed the technology was achieving only an approximately 70% ethanol removal rate. No other state's innovative technology program allows such flexibility. Although this technology was selected by a baker in Massachusetts, it was not able to be licensed under the Massachusetts STEP program for innovative technology because it could not be shown to reach at least 81% removal and because the state did not consider it sufficiently "innovative." It appears that state innovative technology waivers are generally ineffective at reaching the class of technologies which may be much cheaper than conventional ones but which cannot be shown initially to reach a comparable emission limit through traditional test methods.

A second major barrier to the installation of the heat exchanger technology proved to be the test procedure to verify ethanol emission reduction. EPA's approved test methodologies for VOCs, 18 and 25A, are designed for technologies like oxidizers which remove ethanol directly from an airstream. The heat exchanger instead converts ethanol into water-borne ethanol, where it is subsequently degraded. EPA's standard test methods have difficulty in testing the ethanol concentration in an airstream before treatment, and then in a waterstream after treatment.

The businesses involved had to finance many thousands of dollars in testing, observed by the Maryland Department of Environment, to show that alternative test methods and protocols could work accurately. A test method was agreed upon based on the blood alcohol test for ethanol levels used in the criminal court system, which the Department found more accurate than EPA methods. The lack of a standard test methodology to verify that this innovative technology achieves the necessary ethanol reduction, however, has continued to create a barrier to its acceptance in other states.

2. Bio-digestion

Bio-digestion uses microbes in a multimedia form (air and water) to convert ethanol as well as the fats and other baking by-products found in discharge water. A new bio-digester technology does not currently remove 95% of ethanol, but it does a superior job of extracting other material from water and greatly reduces BOD in water effluent well beyond current discharge limits. A firm employing a $1 million bio-digester could replace $1.5 million of less efficient equipment and reduce overall environmental discharges significantly. However, because the bio-digester is new technology, it cannot obtain permit approval. Bakeries apparently are not willing to take a $1 million chance that the bio-digester will achieve the required removal rate, or that they can convince EPA (or their state) to accept overall improved water discharge quality to compensate for not fully attaining the ethanol removal standard for air. To some extent, this situation highlights the lack of capacity for multi-media permitting in our present system.

3. Wet Scrubbing

Wet scrubbing technology is similar to the heat exchanger, but involves blowing the airstream containing VOCs through a water mist. The water absorbs the VOCs from the airstream, at a declining rate of efficiency over time. Wet scrubbing also costs significantly less than catalytic oxidation, with equipment costs around $100,000, plus lower operating and energy costs.

Holsum Bakery, Phoenix, Arizona: The Holsum Bakery in Arizona has proposed to use wet scrubbing in order to meet an Arizona regulation requiring 81% control of their ethanol emissions. Negotiations are still ongoing with the county, which has been delegated implementation authority by the state and EPA, with the primary issue concerning the test methods to evaluate the technology. EPA's standard air-to-air test methods perform poorly with a water-laden airstream and do not show that wet scrubbing attains the 81% level, while water testing methods do. The principal barriers experienced in this case study are again the inflexibility in the regulatory standard and EPA test methods.

4. Other Innovative VOC Technologies

Other innovative VOC technologies of a more theoretical nature have also been proposed but not yet installed by any bakeries. These include photo-oxidation which adsorbs ethanol onto titanium dioxide, photo-catalytic oxidation, bacterial fermentation, and genetic engineering of yeast. Preliminary testing of genetically engineered yeast however has not proven promising.

C. Technology comparisons

The following chart sketches out the differences in terms of costs and weight of the different technology options. It should be noted that, although there are clear advantages of the innovative technologies in terms of cost and weight, they also avoid some of the environmental problems associated with catalytic oxidation. A catalytic oxidizer requires considerable energy to operate and also requires replacement and disposal of the platinum catalyst, a toxic metal, every 5 years. Although this method achieves very high rates of VOC removal, these other problems make it a less than ideal technology and indicate the importance of developing new methods. Indeed, many of the alternatives involve more process-oriented pollution prevention approaches which save energy and landfill use.

Table 3. Abatement Technology Comparisons ($ figures in thousands)

Technology	Equipment	Installation	Wt.	Oper.
Catalytic oxidizer	$150-300	$120-300	8T	$20-125
Heat Exchanger (Giant)	100-200	50	1T	10
Wet scrubber	(100-200)			
Bio digestion	(100)			
Photo-oxidization	(100)			
Photocatalytic oxidization				
Bacterial fermentation				
Genetic engineering of yeast				

Sources: EPA ACT Document; Ira Dorfman, *Ten Years After: Clean Air regulations targeted oven emissions a decade ago. A front-line participant reports on current developments ... and progress.* Bakery and Snack, p. 106 (February 1996); Morris, Charles, *Bakery Trends: from Bagels to biodigesters - New Technologies Focus on Ethanol Abatement and Heat transfer*, Food Engineering Magazine (May 1996).

Although precise estimates cannot be made, a certain amount of the variability in the cost of alternative VOC technologies may derive from whether they can benefit from the current monopoly situation. Technology developers may want to price their technology at the current price of the oxidizer (around $250,000), and not at cost, which may be more like $100,000. Prices would be expected to fall to the latter figure if there is competition with other innovative technologies.

V. Barriers to Innovative Technologies

The chief regulatory obstacle is that the definition of RACT in the statute, as amplified by EPA's regulations, makes it nearly impossible to use any technology other than catalytic oxidation to control VOCs from bakery ovens. The standard for VOC removal is so high that only catalytic oxidation qualifies and has become the technology of choice for most permitting jurisdictions. A second barrier is the inflexibility of EPA's test methods, which work poorly with water-laden airstreams from bakery ovens. This result appears to be reinforced in several ways, as described below.

A. Definition and Application of RACT

The statutory definition of RACT requires EPA to set limits based on existing and available technologies. The definition requires essentially a backward looking standard based on available technologies. This automatically creates barriers to innovative technologies, which are by definition not available.

1. Availability

The RACT definition that a technology be "available" precludes the use of many innovative technologies. 44 Fed. Reg. 53762 (1979). This situation requires technology vendors to fight to convince permit writers in every jurisdiction that their technology can perform adequately. Such a struggle is very expensive and beyond the means of many innovators, as our federal system requires such efforts to be duplicated in every state. In addition, innovators are caught in a vicious cycle: their technology cannot get permitted because it is not available, and cannot become available because it cannot obtain the permits needed to become proven in a commercial setting.

In the case of the heat exchanger, no jurisdictions would accept an innovative technology such as the heat exchanger as conventional technology under RACT because they had never been demonstrated to reduce VOC emission from bakery ovens. Therefore, the technology was not judged "available" as required by RACT. This result freezes the development and testing of innovative technologies unless they can be show to have worked in another similar application or obtain permits under innovative technology waivers which entail special applications and lengthy procedures.

2. Inflexibility of a Point Source Standard

A second problem with the RACT definition is that it is premised on the application of an emissions limit to a single point source. This standard precludes common-sense solutions where very high cost abatement from one source could be compensated by cheaper and possibly greater abatement at other sources. Solutions, such as emissions trading, discussed below, or whole-plant emissions permitting, could address this problem.

3. Establishing RACT though Emissions Rates

EPA's traditional method of establishing a RACT standard through an emissions rate limit can create problems for innovation because it can dictate technological choices. In addition, choices made by EPA in applying the RACT standard have essentially created a monopoly position for the one technology judged the best when EPA considered alternative control technologies in 1992.

For bakeries, it appears that setting the regulatory standard at the highest point an existing technology can attain has precluded the use of other technologies. The RACT level of 80% reduction articulated by EPA cannot be met by any conventional technology except combustion, as shown by the ACT document, which favored the catalytic oxidation method. Although this result favoring a single technology might be expected with the Best Available Control Technology (BACT) or Maximum Achievable Control Technology (MACT) standards, it is surprising that RACT is set at a level so high that only one technology can qualify.

This standard thus creates an almost insuperable barrier to other technologies, such as the heat exchanger or wet scrubber, which can be demonstrated to reach 70% levels of compliance and could be reasonably expected to achieve an 80% compliance level with on-site refinements, the actual experience at the Giant Bakery. However, these technologies cannot obtain permits under RACT and thus never have a change to show they can achieve these improvements.

Without further on-site research and modifications and improvements, most technologies cannot reach a similar level in the near term. For example, it has taken several generations of oxidizers to reach a 98% efficiency level, and future improvements are likely to be very expensive. Reductions beyond this level, or methods which reach this level but at lower cost or overall pollution, will require different technology -- most likely the ones that cannot currently get approved. Arguably, the definition of RACT does not leave any room for new technologies to evolve.

4. Alternative Control Technology Documents

Another potential barrier is EPA's Alternative Control Technology document which may freeze technology at that point. Giving a regulatory stamp of approval to a single technology may tend to dictate the decisions of state permitting authorities in the future because they are justified in selecting the chosen technology, but must make a special case to justify the selection of any other technology. This has contributed to the dominance of catalytic oxidization for removal of VOCs from bakery ovens.

B. EPA Test Methods

The test methods used to measure VOC output from bakery ovens have been a significant problem in gaining approval of certain innovative technologies. There is no specific EPA-approved test method for ethanol, and the general approved method for organic gases, EPA's Method 25A, performs poorly with a moisture-laden effluent stream such as emitted by bakery ovens. In addition these methods are not designed for technologies like the heat exchanger or wet scrubber, which condense ethanol into a water medium.

Faced with the problem that this method creates a bias against testing ethanol emissions with high water vapor, innovative technology vendors have to convince states to use another test method in order to prove their technology could meet emission standards. In Maryland, based on a tests paid for by the industry, state regulators accepted a test based on the blood alcohol test for ethanol used forensically, which is highly accurate, but novel in its application to regulatory matters. This test has the added advantage of costing $27 per test instead of up to thousands of dollars required for other stack test methods. While Arizona is considering this approach, it still has not been accepted in other states. Because acceptance of an alternative test method involves an exercise of discretion by the state permitting authority, vendors must fight a battle for acceptance of the alternative test method in each state, an expensive and time-consuming process, and a major barrier to the deployment of innovative technologies.

VI. Potential Solutions to Barriers

A. Modify RACT

The barriers created by the RACT standard to innovative technologies in the baking industry are complex, and depend both on the statutory definition of RACT and on its application by EPA and regulatory agencies. The problems noted above in the definition likely cannot be addressed without a change by Congress in the statute which moves from the technology-based, point-source specific standards like RACT toward more overall performance standards such as an emissions cap. As shown in the SO_2 study as well, such a change can result in significant environmental gains at significantly less cost.

As this case study shows, EPA's application of RACT has resulted in some of the inflexibility that might be expected with higher standards such as BACT and MACT which explicitly restrict technology choices to one "best" type. Arguably, EPA should allow greater flexibility in RACT levels and greater opportunities for states to achieve common-sense tradeoffs in applying RACT.

B. Innovative Technology Waivers

Innovative technology waivers are one of the few methods available to vendors to break the vicious cycle preventing innovative technologies from being permitted and gain a performance track record so they can be considered "available." However, innovative technology permits are administered by the same agencies and tend to exhibit much of the same inflexibility as the permitting process.

Generally these programs will require that the new technology must surpass existing technology, greatly limiting their scope. These innovative technology programs are therefore generally ineffective at reaching the class of technologies which may be much cheaper than conventional ones, but which initially produce results just below existing standards. Even if these technologies are cleaner because they use less energy, produce less waste, or show great promise for the future, they cannot be approved even for innovative technology waivers because they do not exceed the performance of existing technologies.

C. Within-industry Trading

The American Bakers Association has offered to several states that bakeries be allowed to offset the needed marginal stack reduction in VOCs (usually a 10 to 20 ton / year reduction to meet BACT requirements) with larger reductions in VOCs from their delivery fleets. Bakers have the third largest private truck fleet in the US (130,000), behind UPS and FedEx, with significant opportunity for fleet conversion. No state has allowed such within-company, citing EPA regulatory and legislative restrictions. Such trading could be a big "win-win" since greater reductions in very toxic VOCs from vehicles (benzene, among others) would be traded for non-toxic ethanol emissions. Benefits would be local, sustainable, and achieved at a greatly reduced private and social cost.

The stringent regulation of bakery ovens, with high costs, can be contrasted to the relatively weak regulation of the more toxic VOCs emitted by bakery truck fleets, where reductions would cost much less. The situation is worsened by the fact that several cheaper innovative technologies only miss the bakery oven regulation by a few percent, but the existing standard precludes making this up by trading for less expensive VOC reductions from vehicles.

D. Inter-industry Trading

Costs of reducing ethanol emission from bakeries can be about $5,000 per ton. Many northeast U.S. bakeries would want to buy VOC emissions rights in an open market emissions trading program expected to be developed by EPA in 1995. 60 Fed. Reg. 39668. However, this program has now been delayed, so the only opportunities for inter-industry trading are the few states with existing emissions trading programs. See, *e.g.*, 310 Code of Massachusetts Rules 7.00 Appendix B, Michigan Administrative Code R.336.2208 *et seq.*, New Jersey Administrative Code 7:27-30. One baker in New Jersey has bought VOC credits under such a program for the past two years. Arguably, low-cost, effective and politically acceptable trading programs would do much to address pollution issues, achieve cost-effectiveness and promote innovation.

E. EPA Test Methods

Accurate test methods are essential to make our environmental laws work. However, as shown by this case study, they may need to be made more realistic and flexible, especially when there are known problems with certain methods. EPA should specifically address problems such as the poor performance of the VOC test methods in airstreams with high water content, and the lack of test methods that can deal with inter-media transfers.

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Chapter Three:

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Technology Barriers in the Dry Cleaning Industry

I. Introduction and Summary

This case study explores the central issues associated with the technologies to prevent, recycle or treat discharges of Perchloroethylene (PERC, PCE, or tetrachloroethylene), the principal pollutant emitted in the dry cleaning industry. It discusses the characteristics of the industry, its cleaning and emissions control technologies, and regulatory requirements. It then gives an overview of innovative technologies being developed for the industry including alternative approaches to garment cleaning, and any barriers to the development or adoption of these alternative technologies.

The dry cleaning case study is a particularly interesting example of innovation-forcing regulation because this industry has lacked innovation for decades. Until environmental regulations began to restrict the use of perchloroethylene (PERC), the last significant change in the industry had come in the 1960's, when fire regulations required a shift from petroleum solvents to PERC. Only with the pressure of environmental regulation have a few people starting to examine ways to provide cost, energy and environmentally-efficient cleaning services to a wider market.

Regulation of this industry has tightened discharge rates and emission limits, and has led the industry to respond only by modifying its equipment to provide greater and greater end-of-pipe control and treatment of PERC emissions. Four generations of dry cleaning machines have added additional control technologies which have greatly reduced, but not eliminated, PERC emissions.

The major barrier to innovation arises from the lack of finance, and perhaps of vision, in this small-business industry which has generally precluded significant or well-funded investigation of alternative processes which avoid pollution altogether. The small, fragmented nature of the industry, with 30,000 independent small businesses, lacks funds for research, experimentation, and risk-taking. Another major barrier for the water technologies are "dry clean only" consumer labelling standards developed long ago which impose a risk of liability on cleaners using innovative water technologies.

However, an assortment of efforts has commenced experimentation with innovative technologies that would do away altogether with the need for PERC. These technologies using water, liquid CO_2 and ultrasound have all been shown to be as effective as PERC. The latter effort is significant because it is the only integrated effort to launch a new product, originating outside the industry in a large technology company, and may soon cause another revolutionary change in dry cleaning technology.

II. Perchloroethylene: The Problem with Traditional Dry Cleaning

Perchloroethylene, or PERC, is the main solvent used within the dry cleaning industry, and is a chlorinated organic substance that persists in the environment. Breathing PERC can affect the human nervous system, cause liver and kidney damage, and irritate the skin, eyes, nose and throat. PERC is usually directly released into the air but can also penetrate soils, thus working its way into groundwater. Photochemical smog is formed when PERC reacts with other volatile organic compounds in air.

Concern regarding the impact of PERC on human health and the environment is increasing, and has led to the implementation of stricter federal and state regulations of the chemical. PERC has been declared toxic to the environment under the Canadian Environmental Protection Act (CEPA). It is considered a carcinogen according to the U.S. Environmental Protection Agency (EPA) and was recently designated a hazardous air pollutant (HAP) under the 1990 Clean Air Act Amendments. 58 Fed. Reg. 49354 (September 22, 1993). The Occupational Safety and Health Administration has also proposed a stringent permissible exposure level for PERC, which although not finalized at the federal level has been adopted by some states. Finally, several states have recently passed legislation that imposes taxes on purchases of PERC or the gross receipts of dry cleaners in order to cover the environmental costs of PERC disposal. These actions have resulted in the industry's search for alternative cleaning methods.

III. The Dry Cleaning Industry and Current Technologies

Dry cleaning is a mature service industry divided into commercial, industrial, and coin-operated sectors. Industry estimates indicate a zero growth rate for the commercial sector through 1996, and with both the industrial and coin-operated sectors anticipated to decline. The general decline of the industry can be attributed to more clothes being made of launderable fabrics, which reduces demand for dry cleaning.

The largest sector is commercial dry cleaning (SIC code 7216), with 30,000 facilities, generally located near densely populated areas and in shopping malls. Most commercial dry cleaners are single family operations with only two to three full-time employees, including the owner. Commercial dry cleaning is not a high-profit business. Typical start-up costs in 1993 were $113,000, and over 60% of dry cleaners had annual revenues below this amount. Only 6% have revenues over $500,000, and only ten companies had gross sales over $3 million.

There are an additional 3,044 coin-operated dry cleaners (SIC code 7215), which are being gradually phased out. Only 14% report revenues over $113,000 per year. EPA estimates there to be 325 industrial dry cleaners (SIC code 7218), which typically offer both dry cleaning and laundry services. Their average dry cleaning revenues are larger, approximately $1 million annually.

Table 1. Profile of the Dry Cleaning Industry

	Commercial	Industrial	Coin Op.	Total
Number of Facilities	30,494	325	3,044	33,863
Volume (T. clothes / yr.)	630,520	187,991	4,914	825,425
Sales ($ million)	4,300	385	29	5,200

Dry Cleaning Process: Dry cleaning is similar to conventional laundering, but uses organic solvents rather than water and detergent. The key steps are identical: garments are pre-treated for stains and loaded into the washing unit; solvent is drawn from the storage tank, and the garments agitated mechanically; after which they are drained and spun in a spin cycle to remove excess solvent. After the spin cycle, the solvent is filtered and distilled to remove impurities, and returned to the storage tank. The garments are then dried and pressed. During the dry cycle much of the solvent is recovered in a condenser and returned to the storage tank. The remaining solvent in the garments is recovered by venting ambient air through them.

Solvents: Traditionally, perchloroethylene (PERC), petroleum derivatives, chlorofluorocarbons, or 1, 1, 1 - trichloroethane have been used as solvents. The latter two were banned in 1995 under the 1990 Clean Air Act Amendments. PERC-based solvents now hold a dominant market share at 84%, due to effectiveness and non-flammability. Petroleum-based solvents had been the predominant solvents due to their wider applicability until fire regulations curtailed their use in the 1960s. This ban corresponded with a boom period in the dry cleaning industry when stores proliferated in shopping malls and urban settings.

Current Technologies: Four generations of dry cleaning machines are in use today. The first has separate washers and dryers, requiring the operator to transfer "wet" clothes between the two. The second generation machine combines the two components into a single machine. The third generation adds control technologies to reduce vapor emissions, and the fourth generation recycles air in the machine to reduce emissions further. Each successive generation reduces fugitive PERC emissions by reducing opportunities for vapor-atmosphere contact or by adding control technologies such as carbon adsorbers or refrigerated condensers.

First generation machines were the predominant type until the late 1960s. These so-called 'transfer machines' allow vapor to escape into the atmosphere and also expose the operator to the solvent during the transfer. Approximately 34% of dry cleaning machines in the U.S. are transfer machines. The National Emissions Standards for Hazardous Air Pollutants (NESHAP) for PCE dry cleaning machines will not allow new transfer machines to use PCE. Transfer machines can be retro-fitted with vapor control devices and with enclosures to capture fugitive emissions.

Second generation machines, together with third and fourth generation units, are called "dry-to-dry" machines because they integrate the washing and drying in the same unit, reducing the amount of solvent vapor that escapes. Residual vapors are vented into the atmosphere or sent to an external control device. Second generation machines comprise 21% of all units.

Third generation machines are dry-to-dry machines with refrigerated condensers. The principles of operation are the same as for the second generation machines that use refrigerated condensers except that the third generation is a closed-loop machine that does not vent air to the atmosphere. It recycles it continuously through the cleaning cycle, exchanging air with the atmosphere only during loading and unloading. Thirty-four percent of U.S. machines currently in use are third-generation units.

Fourth generation machines are non-vented, closed loop units with an additional internal vapor recovery device. The control technologies used in these machines are refrigerated condensers and carbon adsorbers.

Carbon adsorbers reduce emissions by using activated carbon to adsorb the organic solvent from the vapor streams generated during the aeration cycle. Adsorption allows a gas or liquid to retain molecules of gases or liquids which it contacts. A blower forces solvent-laden air from dry cleaning machines, through a bed of activated charcoal that adsorbs the solvent. The vaporized solvent is picked up by the steam, recovered downstream in a condenser, separated from the water, and then returned to the storage tank. Carbon adsorbers can be retro-fitted to both dry-to-dry and transfer machines.

In tests of carbon adsorbers, the removal efficiencies were above 95%. However, subsequent data from the California Air Resources Board led EPA to believe that in actual practice the removal efficiencies may be far lower. As a result, the NESHAP does not allow them as an option for primary control except in certain large facilities where carbon adsorbers were installed prior to the promulgation of the regulation in 1993.

Refrigerated condensers reduce emissions by capturing solvent-laden air generated during the aeration cycle and cooling it below its dew point. After the solvent condenses, it is separated from any condensed waste and fed into the storage tank. Most new machines have built-in refrigerated condensers, which can also be retrofitted to older machines. In dry-to-dry machines, refrigerated condensers achieve about 95% control of HAPs when compared to uncontrolled machines. The disadvantage of refrigerated condensers compared to carbon adsorbers is that they cannot be used to control low concentrations of emissions.

IV. Innovative Garment Cleaning Technologies

While improvements to traditional dry cleaning technologies have sought to reduce fugitive PERC emissions, the innovative technologies have sought process changes which eliminate the need for PERC altogether. Most of these innovative technologies would be cheaper to operate as well as cleaner than PERC-based dry cleaning, because inputs and ingredients are cheaper, or because they use more efficient methods such as continuous instead of batch cleaning, hydro-agitation or other means. The proponents of these technologies believe they may lead to considerable growth and rejuvenation in the industry.

Interestingly, the analysis of options for regulating PERC prepared for EPA in 1988 assumed that dry cleaners could not give up using PERC. It considered the alternative solvents to be petroleum, chlorofluorocarbon-113 and methylene chloride, and failed entirely to consider the alternative solvents and process changes available today.

Some developers of innovative technologies point out that the decline in the dry cleaning industry is not inevitable, but is due to the almost complete lack of research and innovation in the industry for decades. They believe that the pressure placed on the industry from the need to comply with environmental regulations has had the effect of galvanizing the industry to search for cleaner, cheaper and smarter ways to clean garments.

A. Wet Cleaning

Wet cleaning incorporates different types of alternative cleaning techniques and technologies which utilize water as the primary solvent rather than PERC. The detergents used are both pH neutral and biodegradable, and sizing agents are added to prevent dye bleed and give clothes body and shape. Wet cleaning can accommodate "Dry Clean Only" garments by reducing agitation during washing, increasing extraction of water prior to drying, and closely monitoring heat and moisture content during the drying process. Wet cleaning is labor intensive, however, and it is often necessary to increase the time spent in pressing each garment.

There are two types of wet cleaning in use: multi-process wet cleaning and machine wet cleaning. In multi-process wet cleaning, each garment is cleaned individually using a combination of steaming, spotting, gentle hand washing, scrubbing, tumbling, and / or hang drying. Machine wet cleaning allows the operator to program the machine according to the cleaning time, amount of mechanical action, temperature, and degree of water extraction specific to the type of garments being washed. The dryer prevents over drying with special moisture sensors. There are currently at least four organization operating wet cleaning projects.

1. The Center for Neighborhood Technology - *The Greener Cleaner*

The Center for Neighborhood Technology (CNT), a non-profit research and technical assistance organization, works with industries to find practical solutions to environmental problems. CNT became involved in the search for pollution-free alternatives to PERC in 1992. Its Alternative Clothes Cleaning Demonstration Project was launched in September of 1994 in order to test and demonstrate the wet cleaning process for all garments. CNT concluded that multi-process wet cleaning is at least as effective as dry cleaning with PERC.

On May 11, 1995, the *Greener Cleaner* opened in Chicago. It was designed by CNT as a 100% wet cleaning shop parallel to a dry cleaning operation in terms of volume and types of fabrics and garments cleaned. Garments were evaluated after six cleanings. During the first 29 weeks of operation, the *Greener Cleaner* wet cleaned 16,055 garments and of those garments, 61% were of fabrics that are typically labeled, "Dry Clean Only" such as wool, silk, rayon and linen. During this same period, 86% of the customers rated the shop's overall service as "excellent" or "good" and 85% said that they would recommend it to a friend. However, dimensional change (shrinkage / stretching) and grease spots posed some problems at the *Greener Cleaner*.

2. University of California at Los Angeles - *Cleaner by Nature*

Finding plausible alternatives to PERC is especially important in southern California, where over 10% of the nation's dry cleaners are located and 125 groundwater wells have been contaminated with PERC. The University of California at Los Angeles (UCLA) has developed a project which closely resembles CNT's *Greener Cleaner*. The UCLA-sponsored *Cleaner By Nature* opened as a demonstration shop on February 1, 1996 with a plant in Los Angeles and a drop shop in Santa Monica, and will participate in the UCLA study through January 31, 1997.

An Interim Progress report concludes that "the *Cleaner By Nature* demonstration site is cleaning the volume and range of garments typically encountered by a dry cleaner ... [at] significantly less expense than a PERC dry cleaning system." The report states that of the 12,068 garments cleaned, there were only 6 customer complaints and only 87 garments returned for more work.

3. Environment Canada - *The Green Clean Project*

Another similar project developed by Environment Canada is called the *Green Clean Project*. The project is a voluntary pollution prevention initiative designed to explore water-based cleaning as an alternative to the non-aqueous solvents (particularly PERC) used in the dry cleaning industry. Green Cleaning (a trade mark of Environment Canada) uses water and detergent in technologically-advanced washers and dryers to clean certain clothes which are normally dry cleaned. The project involves three phases: Phase One - *Green Clean Trial* (June - November 30, 1994) where the cleaning method was Green Clean only, without the option to dry clean; Phase Two - *Green Clean Extension* (December 1, 1994 - August 31, 1995) where the cleaning method was either Green Clean or dry clean items on site; and Phase Three - *Green Clean Facility* (August 1995 onwards) where the cleaning method is Green Clean or dry clean, with all dry cleaning sent off-site and returned for pressing on site.

Of many Canadian initiatives, *Langley-Parisian Cleaners*, located in Hamilton, Ontario, is Canada's first dry cleaning plant to replace equipment that uses PERC with wet cleaning equipment.

The Canadian Government is working with international Non-Governmental Organizations (NGOs) dealing with fabricare. The Fair Claims Guide (used by cleaners throughout North America), authored by the NGO International Fabricare Institute, was used to determine appropriate compensation for damaged garments. Once a claim was paid, the garment became the property of Environment Canada for training purposes and experimentation.

4. Orange Blossom Garment Care (ATECS, Inc.)

Ruth Wendenburg, owner of Orange Blossom Garment Care (ATECS, Inc.), a small garment cleaning shop in Miami, Florida, began wet cleaning two years ago when Val Clean (a freon-like fluorocarbon) was taken off the market. Ruth wet cleans silks, wool, cashmere, rayon, linen, cotton, etc., but not men's clothing. Most of the garments cleaned have a "Dry Clean Only" label. She believes that these care labels are out dated. Before wet cleaning existed, a "sour" chemical was used which was deadly to delicate fabrics. But with current technology, it is possible to wet clean with proper knowledge. Ruth believes that anyone can wet clean. She says, "It's just necessary to learn about fabrics and how to treat them...and to know and learn how to use wet cleaning." Possessing such knowledge, Ruth finds no barriers correlated with wet cleaning and believes a wet clean shop can be started with little money. At first, the wet cleaning process used home washers; the store now owns a wet clean machine.

5. Future developments and research with wet cleaning

Results from several independent studies indicate that wet cleaning may become a viable option for cleaners. Leather and suede that cannot be cleaned at a typical dry clean shop can be wet cleaned with a longer drying time. Other specialty items, such as wedding gowns, can also be wet cleaned. Special pressing equipment makes wet cleaning more efficient. Wet cleaning facilities have opened for business in the U.S., Canada, Europe (Austria, Denmark, Finland, England, Germany, Holland, Iceland, Ireland, Italy, Norway, Spain, Sweden and Switzerland), Japan, Australia, New Zealand, Argentina and Peru.

B. Liquid Carbon Dioxide/DryWash

Hughes Environmental Systems and its licensee Global Technologies are commercializing a liquid carbon dioxide technology called Drywash for the dry cleaning industry. Hughes representatives believe they have created an innovative technology that falls within the target price necessary for most owners of dry cleaning businesses. Hughes, through Global Technologies, has sublicensed this technology to five machine manufacturers around the world, including several of the largest dry cleaning equipment manufacturers, which have reportedly earmarked over $150 million to commercialize the product over the next five years.

On July 25, 1996, Hughes demonstrated the first full scale prototype, and the technology subsequently was awarded the number one technology prize for 1996 by Popular Science magazine. More recently, it was recognized as one of the top 100 technologies of 1997 by R&D magazine. Currently, pre-production units are being built and placed in select markets around the world for testing, with commercial production expected to begin in 1998. Global Technologies has also begun to develop financing mechanisms to assist dry cleaners to convert to their technology.

In addition to the Hughes technology, another liquid carbon dioxide dry cleaning technology has been developed by North Carolina State University in collaboration with Micell Technologies. Although this research team has also won awards for its technology, it has not yet advanced to the stage of developing an integrated hardware, technology and financing package that addresses the full range of commercial barriers to launching an innovative technology.

The Hughes/Global program represents perhaps the best organized and well-financed effort to establish an innovative technology in this field. Interestingly, this technology originated outside of the dry cleaning industry, from the use of supercritical CO_2 to clean aircraft parts in the defense industry by Hughes Aircraft in collaboration with the Los Alamos Laboratories. Hughes conducted research to identify potential commercial applications of this technology and chose to start with the dry cleaning industry. A large company like Hughes Environmental Technologies has been able to do the R&D necessary to develop this technology, which otherwise would have been very difficult for the smaller business entities within the dry cleaning industry.

C. Ultrasonic Aqueous Methods

Ultrasonic cleaning involves immersing clothing in a liquid medium, agitating the medium with a high frequency (18 kHz - 120 kHz) sound for a few minutes, rinsing with clean water, and drying, with no hazardous discharges. This process causes cavitation to occur where microscopic bubbles in the medium collapse and produce shock waves. Through friction, these waves loosen particulate matter from the surfaces of clothing.

Garment Care, Inc. located in North Kansas City, MO joined with Department of Energy's Kansas City facility (a partnership that was later to involve Amway

Corporation, Neo-Dyne Research and Crest Ultrasonics) to explore the possibility of using ultrasonic aqueous methods to clean garments. Funding was provided under an Small Business Initiate Cooperative research and Development Agreement from DOE.

The partnership postulates that cleaning could be made more efficient using an in-line, continuous-flow, clothes washing process with agitation provided by ultrasound. Garment Care contends that containers could be used to convey garments from beginning to end from an initial staging area, through a water-based wash trough, rinse section, drying chamber and into a packaging area. Throughout this process, the continuous application of ultrasound would allow for a critical increase in agitation which theoretically should decrease one or more of the other three factors (time, temperature and chemistry) necessary to clean clothes.

The team conducted aqueous cleaning tests on fabric swatches at three sites using different equipment and techniques. At the Garment Care site, a typical industrial 40 kHz ultrasonic cleaning system was used; Neo-Dyne Research used a higher powered, lower frequency ultrasonic cleaning system; and Amway Research used a Terg-O-Tometer to perform industry standard cleaning procedures. Results from these evaluations showed acceptable soil removal. However, due to a lack of funding, only Phase I of this project has been completed so far.

V. Barriers to Wet Cleaning and Other Innovative Technologies

A. Lack of Finance

The lack of financing and capacity for research and development appears to be one of the greatest barriers to the development and introduction of new dry cleaning technologies. This lack of funding appears to be characteristic of an industry dominated by very small businesses. Because only a very few dry cleaning firms have annual revenues of even as much as $1 million, none may have sufficient capital to launch serious research and development efforts.

This lack of financing is perhaps most apparent with the ultrasound technology, where a motivated entrepreneur spent several years negotiating to obtain a $100,000 SBIR grant to test this new technology. Even though the test was successful in demonstrating a possibly revolutionary new technology, another negotiation process is underway to obtain a follow-up grant which may become available to extend the testing further. The experiments with wet cleaning are also under-financed, with several small-scale demonstration efforts underway at scattered locations by independent universities and at cleaners supported by non-government organizations. There is no funding for full commercialization, promotion or marketing on a national level.

By contrast, the effort to develop, test and market the liquid CO_2 technology developed by Hughes Environmental Technologies in collaboration with the Los Alamos Laboratories and Global Technologies is a well-financed effort aiming to establish the technology on a global basis. This effort includes not only research and development, but also promotion and marketing as well as a financial component to help low-capital business invest in the technology. It is financed by investors contacted through Hughes and its partner organizations. Significantly, this technology and development program was realized by a firm outside of the dry cleaning industry, of a size able to mobilize the finance for an effort of this nature.

B. Industry Reluctance to Change

Although industry reluctance to change was mentioned as a barrier by some vendors of innovative dry cleaning technology, it is not considered a significant barrier by others because many dry cleaners are strongly motivated to move away from PERC solvents. This motivation is caused not only by the increasing stringency of environmental regulation imposed directly on dry cleaners, but also by the real estate industry which rents them space. Owners of shopping centers, malls and other establishments where dry cleaners traditionally locate are becoming reluctant to rent to dry cleaners because of their potential liability or loss of other customers due to the toxic nature of PERC emissions. Therefore, demand for new technologies is high if a technology can become affordable to this small business industry.

C. Care Labeling Rule

Care labeling poses a significant barrier to wet cleaning technologies. According to the Federal Trade Commission (FTC), its Care Labeling Rule only applies to manufacturers and clothing designers, and requires that they possess a legitimate reason to label a garment " *Dry Clean Only*." The Care Labeling Rule lays no restrictions upon the dry cleaner. However, if the cleaner chooses to disregard the garment's care label instructions, then they are cleaning it at their own risk. If damage occurs to the garment, the customer may sue the cleaner in small claims court.

The Care Labeling Rule does not act as a complete barrier to wet cleaning because cleaners will occasionally wet clean a garment based on fabricare knowledge rather than care label instructions. However, ignoring the care label instructions does expose dry cleaners to liability. Thus, different organizations are striving to amend the current regulations.

In Canada, many cleaners request the customer's permission (written or verbal) to deviate from care labeling instructions. Care labeling is a voluntary program for Canadian manufacturers, and there are no regulations that force cleaners to follow the care label. However, if a problem occurs after a cleaner ignores the care label instructions, the customer may be able to hold the cleaner liable for all damage. Given the advanced capabilities of new commercial wet cleaning and drying technologies, Environment Canada recommends that the care labeling criteria be changed to allow for more cleaning options when wet cleaning is possible.

In the United Kingdom, the Fabric Care Research Association (FCRA), a dry cleaning / laundry trade and research association, has completed a research project on wet cleaning, focusing on the effects of wet cleaning sensitive fabrics. They found that there is less shrinkage produced from wet cleaning than from gentle home washing; that tumble drying is the main cause of shrinkage in wool; and shrinkage in wool can be reduced by quick drying to 50% moisture retention and then air drying.

According to FCRA, both a wet cleaning test method and an accompanying care label need to exist. FCRA is working with other european institutions to develop these steps. FCRA hopes to change the current European Community regulation that absolutely requires cleaners to use dry cleaning methods on specifically marked garments even if wet cleaning is safe.

Domestically, organizations such as CNT and the Professional Wet Cleaning Partnership, which was formed by the dry cleaning industry, labor and environmental groups to encourage use of wet cleaning, are working with the FTC to modify its rule on Care Labeling of Textile Wearing Apparel to allow for a professional wet cleaning instruction where appropriate. Industry representatives have also gathered at the Hohenstein Institute in Germany to establish common criteria for designing a wet clean care label to be agreed upon internationally by all dry cleaning, equipment and supply associations. However, such regulations are still pending.

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Chapter Four:

Technology Barriers in the Iron and Steel Industry

I. Introduction and Summary

This case study examines innovative technologies for reducing the use of or treating spent pickle liquor in the iron and steel industry, and barriers to the use of such technologies. The study is based on research by ELI as well as a multi-stakeholder Workshop on Spent Pickle Liquor held in December of 1996 and co-sponsored by ELI and the Innovative Technology Working Group of the Iron and Steel Subcommittee of the EPA Common Sense Initiate. Proceedings of this workshop are available from ELI.

Pickle liquor consists of the sulfuric, hydrochloric or mixed acids used to treat formed steel. Spent pickle liquor is one of the major pollution problems of the iron and steel industry. Major pollution prevention efforts in the iron and steel industry have focused on these waste acids, as well as on reducing coke making emissions, and electric arc furnace dust.

The most immediate barrier to reducing pickle liquor waste is the definition of solid waste in RCRA regulations. Under EPA's interpretation, the regulations require that spent pickle liquor be treated as a RCRA waste if it is reclaimed and recycled. This interpretation of RCRA escalates the difficulty and cost of recycling so greatly that it has become more economic for most firms to landfill or inject the waste underground. RCRA in effect creates waste from material which would otherwise be reclaimed and reused.

Economic barriers to recycling pickle liquor include fluctuating economic variables, such as the prices paid for reclaimed ferric chloride, transport and other costs. If the recycling barrier under RCRA were lifted, other economic barriers to recycling might arise, such as further reducing prices for landfilling or underground injection. An integrated solution should be used to lower the regulatory barriers to recycling pickle liquor, while making it more expensive to dispose of these wastes through landfilling or underground injection. In the longer view, the principle barrier to completely eliminating the use of pickle liquor is the iron and steel industry's lack of funding and efforts to research and develop non-toxic alternatives.

II. Background

The steel pickling operation involves the immersion of oxidized steel in a heated solution of concentrated acid or acids (the pickling agent) to remove surface oxidation or to impart specific surface characteristics. After a certain concentration of metallic ions (mostly iron) build up in the pickling bath, the solution is considered spent and must be replaced. Spent pickle liquor is a listed hazardous waste (K062) due to its acidity and significant levels of the toxic metals lead and chromium.

According to EPA, pickle liquor is generated at 240 plants, approximately 70% of which are situated in Pennsylvania, Ohio, Illinois, Indiana and Michigan. EPA estimates these plants generate approximately 1,400 million gallons of spent pickle liquor annually: 500 million gallons of spent sulfuric acid, 800 million gallons of spent hydrochloric acid, and 74 million gallons of mixed pickling acids.

Various treatment options are feasible, but notably only 2% of pickle liquor is believed to be recycled plus a small amount reused in POTWs and other industries. EPA estimates that 40% of mills using sulfuric acid treat and then discharge the wastes to receiving bodies of water. Another 45% have the spent liquor hauled off-site by private contractors, who treat it (such as by lime stabilization) and dispose of the wastes in landfills or lagoons. The remaining 15% of mills use underground injection, discharge the waste to a POTW, or engage in acid recovery. Disposal practices for other pickling acids are believed to be similar.

III. Technology Choices

Pickling acids are currently the only method to remove the scale which forms when steel oxidizes in contact with oxygen. Removing the scale is necessary to create the look of finished steel. Consumer preferences are such that unpickled steel is only used for hidden applications such as car chassis parts where the rough nature of unpickled steel is acceptable. The following discussion considers the technology options for eliminating or minimizing the use of pickling acids, recycling acids, or reusing them in other industrial applications.

A. Eliminating or Minimizing the Use of Acids in Steel Finishing

The preferable pollution prevention alternative is to minimize or avoid the use of acids for the pickling process altogether. Environmentalists have stressed the need to "look outside the box" in attempting to find processes and methods which do this.

1. Acid Elimination

Relatively few technologies are available which could eliminate the use of acids in the pickling process. A few technologies are under experimental trials, which include mechanical scale removal and abrasion, now being used in conjunction with acid pickling so as to reduce acid use. Although experimentation is on-going, this method leaves a rough surface when used without acids which is not acceptable to most customers. More theoretical possibilities include ultrasound and the possibility of enveloping the steel in a nitrogen blanket or other oxygen-free environment, but they are generally considered impractical for large-scale application.

A barrier to the development of such innovative technologies is the lack of basic research being done in the steel industry. Industry representatives at the workshop commented that most large companies had as many as 300 people in their research division twenty years ago, but now had only a handful, and the focus was very product-oriented. Much research in the field is now left to technology vendors, but economic pressures have forced most of them to devote 90-100% of their research to short-term problems rather than such basic needs.

2. Acid Minimization

There is considerably more potential to adopt innovative technologies which significantly reduce or minimize the amount of acid used in the finishing process. J&L Specialty Steel has substantially reduced acid use both in an existing pickling process and in a new plant. In the existing plant, acid use was reduced through a series of over twenty technology or process changes identified by plant personnel. The driver of these changes was a highly motivated supervisor who believed the changes were profitable in avoiding the costs of energy, water, and acid disposal. In a new plant, the company invested in an innovative shallow bath pickling technology with continuous acid recovery from Ecotech of Canada which, though unproven, promises to reduce acid use greatly by comparison with traditional technology. Other new technologies include a process developed by Crown Technologies for hydrochloric acid that is available but has not had any commercial applications.

Potential barriers to the use of such equipment include the unproven nature of many technologies, which have not been shown to succeed in full-scale commercial applications, and the lack of capital to install new technologies. In many cases, the pay-back periods for acid minimizing technology are not as favorable as that of other investments open to steel companies. In the case of J&L, estimated payback period of 3 years for the acid minimizing technology, while favorable, was much longer than other investments with payback periods on the order of several months. They were able to overcome this barrier only when designing a new plant, where they wanted to adopt the best possible technology.

B. Acid Recovery and Regeneration

The second tier of the pollution prevention hierarchy includes the recycling or reuse of materials such as spent pickle liquor. While there is broad potential for the reclamation of spent pickle liquor, RCRA creates a major barrier to reclamation, as described below in the section on barriers. As a result, there is relatively little use of recycling in the United States, and recycling is practiced more in Europe and Japan.

Spent pickle liquor can be effectively recycled and reused in the steelmaking process, either on-site or off-site. Inland Steel has developed an off-site recycling program in Indiana and presented it at the workshop. Their facility now accepts spent pickle liquor from three plants, as well as non-Inland customers, and produces iron oxide for sale to the magnetics industry as well as hydrochloric acid for sale back to the pickling facilities.

Problems encountered by Inland include the initial financial barrier of needing to convert their pickling technology from steam sparging to the heat exchange method in order to be compatible with the recycling technology. Other significant problems were encountered in developing a greenfield site, and obtaining an air permit. Although most states now would apply RCRA to such a process, Inland was able to work out potential RCRA barriers with Indiana a decade ago by showing their system could use the exemption in 40 CFR 261.2(e)(i).

This application demonstrated the opportunities for avoiding disposal of pickle liquor as waste by using proven hydrochloric acid recycling technology. It also illustrates the difficulty of getting improvements through the regulatory system, and the lack of provisions for a learning curve in environmental regulations. Inland representatives also noted that economic drivers, such as low prices for iron chloride, can become a barrier by making disposal a cheaper option than recycling.

1. Acid Reuse

Reuse of spent pickling acids is feasible in other industrial applications such as sewage treatment and tanning. These applications use pickle liquor because of its high iron content. Sewage treatment plants may use pickle liquor under a specific RCRA exemption; it is a substitute for ferric chloride to precipitate out phosphorus from waste sludge.

The Metro Milwaukee Sewage District uses five million gallons of pickle liquor a year, delivered free from various sources, to reduce phosphorus. One problem they have encountered is that the supply of pickle liquor depends on steel production, and they have had to buy ferric chloride at market prices during a couple of short-term periods when supplies of spent pickle liquor were inadequate. Milwaukee has used a system of controls to screen incoming pickle liquor from various sources to ensure adequately high iron content and sufficiently low amounts of heavy metals. They had rejected the participation of one source producing pickle liquor with too high a zinc content. Pickle liquor has been a relatively low source of heavy metals at this plant, and the pollutant levels in the bio-solids produced there are well below applicable limits. The opportunities for such use could expand in the future with more areas imposing tight controls for phosphorus which leads to eutrophication of water bodies. The alternatives to the use of pickle liquor for phosphorus control are using virgin ferric chloride, or biotreatment, the latter requiring major renovation of existing sewage treatment plants.

Spent pickle liquor is also used in the tanning process. Prime Tanning Corp. uses ferrous sulfate to treat their wastes and adds pickle liquor to tie up sulfides which would otherwise be created and result in emissions of H_2S. They used 1.3 million gallons of pickle liquor produced by five local plants in 1995. The city monitors their wastes, which tends to have pollutant levels equal to or lower than municipal sewage. The resulting biosolids are applied as soil conditioner and fertilizer on neighboring lands. This firm has complied with all applicable limits for pollutant levels for land application.

Future research could focus on the environmental acceptability as well as the opportunity for industrial reuse of spent pickle liquor. The data presented at the workshop showed the facilities reusing the liquor were in compliance with all pollution standards. While there are significant benefits of reuse options, which avoid landfilling or underground injection, environmental groups may be concerned about trace levels of toxic metals and the opportunity for increased transportation-related spills from off-site recycling facilities. However, the transport and use of rejuvenated pickle liquor may be less dangerous than the alternative transport of the more concentrated virgin acids.

IV. Worker Safety Issues

Major worker exposure issues in steel pickling include acid mists, heavy metals, and accidental releases. Study is needed to considered whether pollution prevention technology increases or reduces such risks, and appropriate abatement practices. Current exposure to acid mists created by the hot process can reach 1-4mg / m3. Levels of sulfuric acid mist far below these have been linked to cancer. Proper ventilation, such as push-pull ventilation, is needed to control mists. Lower acid tank levels during recycling may eliminate the effectiveness of push-pull ventilation, but this problem can be solved through design changes and proper maintenance scheduling.

Benefits in reduced worker exposure levels due to acid recovery technology may include reductions in acid mist generation and in reductions in accident potential due to fewer entries to the acid tank for cleaning, and in lower raw materials needs. However, potential increases in workers' exposure to heavy metals due to recycling is of concern if the liquor contains hexavalent chromium, although pickle liquor generally is believed to contain only the less toxic trivalent chromium. Electro-winning is recommended to remove chromium in pickling tanks before the acid is regenerated.

Recommended actions to promote pollution prevention included the reporting under TRI of metals released in spent pickle liquor, such as chromium and lead, and reinstating sulfuric and hydrochloric acid on the TRI. These changes would help track pollution prevention success. More data on pickle liquor treatment and fate is also needed.

V. Barriers to Innovative Technologies

1. RCRA Barriers

Regulatory barriers created by RCRA have proven to be a major disincentive to the reclamation and recycling of spent pickle liquor. Arguably, million of gallons of spent pickle liquor are being injected underground or landfilled because RCRA precludes it from being reclaimed and recycled. Material presented by EPA at the Pickle Liquor Workshop summarizes these barriers:

1) RCRA's definition of waste results in significant permitting requirements if pickle liquor is reclaimed (primarily storage permits in the context of recycling);

2) EPA's derived-from rule states that a solid waste residue generated from the treatment of a listed hazardous waste continues to be a hazardous waste and carries the cost of the pre-treated material; and

3) Hazardous waste transportation for off-site recycling has added costs.

These barriers derive from the definition of waste in EPA's regulations: "(c) Materials are solid wastes if they are recycled or accumulated, stored, or treated before recycling...." There is an exemption to the RCRA definition for recycled material which is returned to an industrial process, but it does not apply whenever the material is reclaimed during this process. 40 CFR 261.2(e) (1996). Spent materials, such as pickle liquor, are specifically stated to be solid wastes when reclaimed. 40 CFR 261.2(c)(3).

Although there are limited exceptions to this rule, such as when the material is to used as a substitute for a commercial product, these are subject to a legitimacy test. 53 Fed. Reg. 522 (January 8, 1988). According to EPA's presentation at the Workshop, the result is that "Acid regeneration and ferrous chloride or ferrous sulfate recovery of spent pickle liquor are types of recycling considered to be reclamation and cause the liquor to be considered a solid waste that is also a K062/hazardous waste."
As a result, RCRA storage permits are required for on-site or off-site reclamation of spent pickle liquor, and they are extremely expensive and difficult to obtain. The application of RCRA in this manner creates waste through a perverse environmental incentive, and results in tens of millions of gallons of pickle liquor being landfilled or injected underground rather than being recycled.

Although RCRA provides some relief through a variance process for materials that are reclaimed, this can only be used when the materials are reused in the original production process in which they were generated; and it is subject to obtaining a state permit. 40 CFR 260.30(b) & 260.31(b). Representatives of two state environmental agencies and EPA explained the issue of the applicability of RCRA to the recycling of pickle liquor at the Workshop on spent pickle liquor.

Ohio EPA has begun discussions with Ohio steel producers who are attempting to recycle pickle liquor. Because Ohio statutes implementing RCRA consider spent pickle liquor (SPL) to be a waste, recycling is not being done. In a letter to the industry, the Ohio EPA has stated "the reclamation of SPL ... is a very desirable alternative to deep well injection and other methods of disposal." In a search for alternatives to this environmentally detrimental result, Ohio EPA has offered to the industry in a letter of September 11, 1996, to use the limited waiver provisions under RCRA and Ohio law to allow a variance from the waste classification for SPL that is reclaimed, which is under discussion. In late 1997, Ohio was considering granting the first such variance to allow SPL on-site reclamation.

The Indiana Department of Environmental Management presented an example under Indiana law where an off-site pickle liquor recycling facility had been permitted in the past. The department had authorized the recycling by using the exemption to RCRA for material shown to be recycled for use as a manufacturing ingredient under 40 CFR 261.2(e).

The definition of waste in RCRA poses a significant barrier to the recycling of pickle liquor, by creating significant paperwork and permitting burdens. The "cradle-to-grave" approach of RCRA in essence precludes the "cradle-to-cradle" approach of recycling. EPA, in order to facilitate materials recycling, is considering amending the definition of waste in RCRA, which affects many industries as well as the steel industry. Although the revised regulation may not be finalized for a couple of years, EPA is currently considering definitions which would exclude on-site but not off-site reclamation, and those which would allow both on-site and off-site reclamation.

2. Economic Barriers

In addition to the RCRA barriers, economic factors can contribute to discourage recycling and lead to a low recovery rate for spent pickle liquor. Because reclamation of SPL produces such commercially saleable products as ferric chloride or ferric sulfide, a low metal content in SPL or low price for these substances could become a barriers to recycling. So too could the economics of using regenerated acid compared with virgin acid. Because there is a greater free acid content in spent sulfuric acid liquors than in hydrochloric acid, the economics may favor only recycling the former. Finally, economic issues such as the distance to potential metals recovery facilities may be also determine whether recycling is feasible.

More fundamentally, the economics of reclamation may be determined by the prices charged for alternatives such as treatment and release to water sources, underground injection and landfilling. These prices are determined in part by regulations, and in this sense greater restrictions or stronger enforcement of existing rules for landfilling or underground injection by regulatory authorities may promote SPL recycling. Stricter restrictions on landfilling in many European countries have encouraged their higher SPL recycling rates.

3. Lack of R&D on Acid Avoidance and Minimization Technologies

Several potential technologies could avoid the use of acids in the pickling process, but adequate research is lacking to evaluate their full potential. These included pickling in an oxygen-free environment, mechanical scale removal and abrasion techniques, and ultrasound. A significant barrier to development of these technologies is the low level of R&D spending in the iron and steel industry, which has declined dramatically in the past two decades and focused more on applied instead of basic research.

More developed technologies are available to minimize acid use, and there may be considerable opportunity to implement them. Barriers included the lack of a track record for many innovative technologies and the financing barriers for construction of new plants, as well as the even higher costs of retrofitting existing plants to use these technologies.

One suggestion for overcoming the research barrier is to increase R&D collaboration with universities and national labs. Another is to convene meetings between technology vendors, users and knowledgeable consultants in order to overcome constraints to using innovative technologies.

4. Barriers to Reusing Pickle Liquor in Other Industries

Another option is to reuse spent pickle liquor in industrial applications such as municipal solid waste and the tanning industry. This option is limited by the number of industries which can use pickle liquor. For instance, sewage treatment plants only use it if they need to remove phosphorus and if the use will not make them exceed effluent standards on waste metals.

Presentations by members of both industries showed this reuse is feasible in well-managed programs, while meeting all pollution limits and saving money. The principal barrier to the increased reuse of pickle liquor is transportation cost, so users such as POTWs must be sufficiently close to steel mills to have the option make economic sense in relation to the use of virgin ferric chloride. This reuse of spent pickle liquor could be promoted by credits for transportation costs where net public benefits from reuse could be expected and revising EPA's draft 1981 guidelines that promote the use of pickle liquor in federally operated sewage treatment works.

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Chapter Five:

Technology Barriers in the Pulp and Paper Industry

I. Introduction and Summary

According to EPA, "the pulp and paper industry is the largest industrial process water user in the United States." Although BOD, COD, suspended solids, and color present serious threats to receiving waters, the pollutants of greatest concern from the pulp and paper industry are adsorbable organic halides (AOX). The best known of the AOX family are chlorinated compounds such as dioxin and furans. Both persist in the environment, can bioaccumulate, and are toxic to human and ecosystem health.

There has been considerable progress in developing and installing pollution prevention processes and technologies in the pulp and paper industry. These technologies include improvements in the early stages of the papermaking process which reduce the need for chemical bleaching compounds at the bleaching stage and less toxic methods of bleaching. This case study focuses on bleaching technologies because this stage produces AOX.

The major new technology options today are Elemental Chlorine Free (ECF) bleaching, which substitute chlorine dioxide for elemental chlorine and may also include oxygen delignification, extended cooking or ozone bleaching. The second type of bleaching -- Totally Chlorine Free (TCF) -- requires technologies that would not use any form of chlorine.

After a multi-year process, EPA recently adopted a Pulp and Paper Cluster Rule imposing significant new limits for water effluent discharges. During this process, EPA considered two options and chose Option A, which allows for continued use of conventional pulping and bleaching processes but requires a complete substitution of chlorine dioxide for elemental chlorine. Option B would have set lower AOX limits and would have required the addition of oxygen delignification or a closed-loop process. Option B is also an ECF technology, but would have promoted greater progress toward achieving the eventual goal of totally chlorine free (TCF) operations.

There are technologies on the market or currently in development that can significantly reduce or eliminate the production and release of AOX. However, there are barriers to the purchase and implementation of these technologies. The most common barrier is cost, especially the high capital cost of retrofitting existing mills to use these technologies. Others include the economic conditions of the industry, lack of profitability and a lack of investment in research and development.

The role of EPA's regulations has been recently clarified by the choice of Option A for the Cluster Rule which requires companies to switch to ECF technology, at a minimum. Many representatives of companies marketing TCF technologies said that, if EPA had chosen Option B, the Cluster Rule could have helped to remove the barriers to using TCF technologies. TCF technology manufacturers seem hopeful that, despite the Cluster Rule, some companies will choose to install TCF bleaching. There are several reasons for this hope. Mills in certain states, for example North Carolina and Maine, may soon be required to comply with even stricter AOX limits than those set nationally. Some other mills also see the benefits of a closed-loop system because of the money saved by recycling process chemicals, and closed-loop simply cannot be achieved using chlorine dioxide due to the corrosivity of that chemical. Prices of TCF chemicals, such as ozone and hydrogen peroxide, are also decreasing, thereby making TCF processes more economically competitive.

Another important barrier identified by many technology manufacturers and developers is the conservatism of the industry. Pulp and paper manufacturers are wary of new technologies and may be unwilling to allow demonstrations of technologies due to the high cost of testing runs. This industry attitude makes it difficult for technology manufacturers to convince firms of the efficacy of proven technologies.

Finally, the lack of consumer demand for chlorine-free paper is another reason that firms have little economic incentive to switch to TCF processes.

Thus, it appears that barriers to innovative technology in the pulp and paper industry are primarily economic. In such a context, drivers for chlorine-free technologies must come externally, from regulatory or demand-based drivers. Although the recently announced Cluster Rule requires the elimination of elemental chlorine, the most polluting technology, it does not call for chlorine-free technologies and, consequently, does not create maximum incentives for innovative technology.

II. Background

According to EPA's 1995 Profile, there are 565 pulp, paper, and paperboard mills in the U.S. The typical pulp mill uses 16,000-17,000 gallons of water per ton of pulp produced, taking in 10 million gallons of water per day and subsequently generating the same volume of effluent water. In 1992, pulp and paper mills generated over one and one half trillion gallons of wastewater. The pulping and bleaching stages of paper manufacture are the major sources of pollutant releases.

Because wood is the most common fibrous material used to make pulp (called "furnish"), pulp mills are near to areas where pulp-grade trees are grown. Therefore, areas in the Southeast, Northeast, Northwest and North Central United States, including areas around the Great Lakes, face significant pollution from the pulp and paper industry.

Paper making is most often a four-step process. First, pulp is made; second, pulp is processed; third, pulp is bleached; and fourth, paper and / or paperboard is produced. Occasionally, the third step is eliminated for certain types of paper or paper products, which are then considered to be unbleached. In addition, prior to the first step, furnish is manipulated to be usable in pulp production, such as debarking logs and chipping them to a uniform size (20mm x 4mm), and screened.

1. Pulping. Furnish can be converted to pulp chemically, semi-chemically, or mechanically. In 1993, approximately 84% of all U.S. pulp tonnage was produced using chemical pulping, 6% by semi-chemical pulping, and 10% by mechanical pulping. Chemical processes produce pulps for high-quality papers, whereas semi-chemical and mechanical processes yield pulps for use in corrugated containers, newsprint, and non-permanent paper products.

There are two widely recognized chemical pulping processes in the United States. Kraft (also called sulfate) pulping is the highest-producing process, while sulfite pulping is used to produce only a small percentage of pulp, most of it from softwood furnish, and creates pulp that is easier to bleach than kraft pulp but not as strong. Semi-chemical pulping, which generally uses hardwood furnish, is a two-step process which begins with partial chemical digestion of furnish and is completed when furnish is mechanically refined to separate the fiber. Mechanical pulping uses physical pressure instead of chemicals to separate furnish fibers.

2. Pulp Processing. To obtain clean pulp for bleaching and paper processing, pulp facilities remove impurities, such as uncooked chips, and recycle any residual cooking liquor via the washing process. Some pulp processing steps that remove pulp impurities include screening, defibering, and deknotting. Pulp processing may also include thickening, blending, and drying for storage. At this stage, left-over cooking liquor from chemical pulping is removed from pulp by washers and recovered to be reused. This step is economically and environmentally important because, the more liquor removed from the pulp, the less bleach needs to be used in the bleaching stage, reducing the need to purchase new chemicals and resulting in fewer environmental releases.

3. Bleaching. Bleaching is any process that chemically alters pulp to increase its brightness. There is high consumer demand for papers that have been bleached; in 1993, 50% of pulp used in U.S. paper production had been bleached. Chemical bleaching is accomplished in several stages, the number of which depends on the whiteness desired, the brightness of initial stock pulp, and plant design. The more stages, the more bleach that is used. The bleaching process is highly dependent on how much lignin remains in pulp; the higher the lignin concentration, the more chemical bleaching agents must be used.

The bleaching process requires chemical inputs and has traditionally required elemental chlorine (Cl_2). However, due to scientific evidence that elemental chlorine yields chlorinated organic compounds (dioxin and furans) and chloroform, industry has begun to substitute other chemicals such as chlorine dioxide (ClO_2), ozone (O_3), oxygen (O_2), polyoxometalates (POMs), and peroxide (H_2O_2). In addition, industry has begun to use pollution prevention processes before, during, and after the pulping stage to delignify pulp to even higher degrees so that the use of bleaching chemicals will be minimized.

Mills that use total substitution of chlorine dioxide for chlorine are said to be Elemental Chlorine Free (ECF) mills, while those that use no chlorine products whatsoever are called Totally Chlorine Free (TCF). TCF mills use oxygen and hydrogen peroxide as the basic bleaching options, but may also use ozone, sodium hydrosulfite, or peroxyacids. Oxygen delignification is a prerequisite for TCF mills. A "closed-loop" mill -- one that recycles all process chemicals and releases no effluent -- is called Totally Effluent Free (TEF). Currently, an economic, environmental, and political debate surrounds ECF, TCF, and TEF.

4. Stock Preparation. In the stock preparation stage, pulp is converted into paper stock. Specific "wet additives," such as resins, waxes, fillers, dyes, and other chemicals to enhance texture, quality, opacity and brightness, are blended with pulp to create specialty products. The pulp goes through a series of processes to dry and press it into paper, after which coatings may be applied.

III. Regulatory Framework

Although BOD, COD, suspended solids, and color present serious threats to receiving waters, the pollutants of greatest concern from the pulp and paper industry are the AOX family of chlorinated compounds like dioxin and furans. Dioxin has been shown to cause cancer and other problems in humans and wildlife. Chloroform is another chlorinated organic compound that makes its way into the wastewater. These compounds are found in the waste stream of pulp and paper mills after the chlorination/extraction phase and, according to one theory, dioxin and furans are formed when contaminants from defoaming agents used to remove chemicals from pulp reach with chlorine during the bleaching stage.

A. Traditional Pollutants Regulated under the Clean Water Act

Under the Clean Water Act, any existing point source in the pulp and paper industry must comply with effluent limitations representing the degree of efficient reduction attainable by best practicable control technology currently available (BPT). The Clean Water Act requires EPA to assess BPT by comparing the total cost of the application of the technology, which must be developed based on the latest scientific knowledge, to its effluent reduction benefits. CWA §304(a) and(b)(1)(B).

EPA's regulations are designed specifically to reduce emissions of conventional pollutants -- BOD, TSS and pH -- from pulp and paper mills. EPA sets overall effluent limitations for mills (see Table 1) and also additional limitations for mills that use specific operations such as wet barking, log washing or chip washing, and log flumes or log ponds. The BPT regulations are subdivided into specific limitations on maximum discharges for any one day and average daily values for 30 consecutive days for the pollutants BOD, TSS and pH. 40 CFR 430.72.

The Clean Water Act imposes new source performance standards (NSPS) on sources that are "constructed" after the passage of the Act in 1972. CWA §306(a)(2). This standard represents the largest degree of effluent reduction that the EPA finds achievable through the "best available demonstrated control technology, processes, operating methods, or other alternatives, including a standard permitting no discharge of pollutants." CWA §306(a)(1) Under the NSPS, facilities must comply with maximum one day effluent limitations for BOD, TSS, and pH, and lower average daily values for 30 consecutive days for the same three pollutants. There are also limitations for the priority pollutants of pentachlorophenol and trichlorophenol.

Table 4: Overall effluent limitations for mills

	One day maximum	
	Existing mills	**NSPS**
BOD	15.45 kg / kkg	10.3 kg / kkg
TSS	30.4 kg / kkg	18.2 kg / kkg
pH	Within range of 5.0-9.0 kg / kkg at all times	
Pentachlorophenol	0.0019 kg / kkg	
Trichlorophenol	0.012 kg / kkg	

B. Toxic Effluents and the Pulp and Paper Cluster Rule

Recognizing a need for more stringent effluent limitation guidelines in the pulp and paper industry, the EPA has recently promulgated the Cluster Rule designed to reduce significantly the toxic effluents from the nation's pulp and paper mills, approximately 100 of which still use chlorine. The Cluster Rule addresses simultaneously air and water emissions from mills in order to prevent them from transferring pollution from one medium to another. The regulatory framework of the integrated air and water rule, which is the first of its kind, is focused on reducing and eliminating the discharge of the toxic pollutants of dioxins and furans from pulp and paper mills. 61 FR 36836 (1997).

EPA's Cluster Rules set numerical effluent limitations, guidelines, and standards regulating the concentrations of the toxic pollutants of TCDD (2,3,7,8-tetrachlorodibenzo-p-dioxin) and TCDF (2,3,7,8-tetrachlorodibenzofuran) in wastewater. The effluent limitations also require reduced amounts of adsorbable organic halogens (AOX) and chemical oxygen demand (COD) in the wastewater. AOX is an index which gives a quick indication of the total chlorinated organic matter in the wastewater. 58 FR 66079. The COD measures the amount of oxygen consumed by organic and inorganic matter in water or wastewater. 58 FR 66080 (1994).

On November 14, 1997, EPA announced that the agency had chosen Option A, requiring complete substitution of chlorine dioxide, but not the further addition of oxygen delignification or a closed-loop process which would have been required by Option B. Table 2 represents the projected effluent limitations under Options A and B. The limitations are separated into daily and monthly average discharges. Table 2 also includes the proposed effluent limitations for end-of-pipe AOX and end-of-pipe COD effluent limitations for pulp and integrated mills.

Table 5: Proposed effluent limitations under Options A and B

	Daily Max		Monthly avg. limitation	
	Option A	Option B	Option A	Option B
TCDD	ND*	ND	N/A	N/A
TCDF	24.1 pg/l	24.1 pg/l	N/A	N/A
Chlorinated Phenolics	ND	ND	N/A	N/A
Chloroform	5.06g/kkg	5.33 g/kkg	2.80 g/kkg	2.80 g/kkg
AOX (end-of-pipe)	0.769 kg/kkg	0.236 kg/kkg	0.448 kg/kkg	0.162 kg/kkg
COD (end-of-pipe)	64.0 kg/kkg	42.7 kg/kkg	45.6 kg/kkg	30.4 kg/kkg

* Non-detect (ND). The EPA has set ND limitations only when the pollutants were all non-detected below the minimum level of the EPA's analytical method.

The Cluster Rule as proposed identified two technology options for consideration in final effluent limitations based on BAT. Option A, which EPA adopted, requires elemental chlorine-free (ECF) technology. It allows for the continued use of conventional pulping processes, but requires mills to employ a complete (100%) substitution of chlorine dioxide for elemental chlorine as the key process technology for paper bleaching. Option B would have set lower levels for AOX, requiring the adoption of oxygen delignification or extended cooking in addition to complete (100%) substitution of chlorine dioxide for elemental chlorine as the key process technology for paper bleaching. Although Option B is an ECF technology, it would have promoted greater progress toward achieving the goal of eventually achieving nationwide TCF operations. A third regulatory option would have been to require TCF technologies, which are in use in approximately 60 mills around the world but have few applications in the United States.

There is considerable debate about the need to go beyond chlorine dioxide substitution in the bleaching process. Some researchers, as well as pulp and paper industry representatives, believe chlorine dioxide substitution is a solution which will reduce the emissions of harmful dioxins and furans to acceptable levels. According to the American Forest and Paper Association, 9 out of 10 operating pulp and paper mills have non-detectable levels of dioxin in effluents, which has been achieved primarily by substituting chlorine dioxide for elemental chlorine.

Although elemental chlorine consumption in U.S. pulp and paper companies continues to decline, chlorine releases are still a problem. Some sources claim that the chlorinated organics resulting from chlorine dioxide bleaching are completely biodegradable and non-bio-accumulative. Other scientists and experts disagree, however, citing studies which have shown the presence of dioxins in Elemental Chlorine Free (ECF) mill effluents. Because dioxin can be harmful at levels below those detectable by EPA measurement protocols, many scientists have expressed concern that even non-detectable levels may still be too high. In their view, chlorine dioxide substitution is not the best method and it should at least be used with oxygen delignification, ozone, or extended cooking. These disagreements lead to questions about which technology achieves the highest effluent reduction and whether the latest, most effective technology can be practicably applied considering the costs involved in retrofitting mills to adopt new technological processes.

According to the EPA, the Cluster Rule's success is contingent upon commitment by the pulp and paper industry to research, experiment with, and implement new technologies and pilot projects that will reduce, and eventually eliminate, the discharge of pollutants from new and existing sources. A key ingredient in achieving these goals is an "industry committed to continuous environmental improvement." 61 FR 36836.

IV. Technology Choices in the Pulp and Paper Industry

A. Conventional Technologies

Currently, there has been progress in developing and installing pollution prevention processes and technologies in the pulp and paper industry, and the trend is to rely on such technologies rather than to continue using conventional end-of-the-pipe treatment to reduce the release of pollutants. Major pollution prevention technologies have included the substitution of chlorine dioxide for elemental chlorine bleaching, as well as oxygen delignification, extended cooking, and such complementary technologies as techniques for producing uniform chip thickness in the woodyard which will assure that extended delignification leads to pulp with low lignin contents.

1. Elemental Chlorine

In most of the common bleaching sequences, the first stage is either chlorine or chlorine dioxide. Elemental chlorine is a very strong, non-specific oxidant and is often used without damage to pulp in the first stage, when lignin content is high. However, elemental chlorine reacts to produce the AOX toxic pollutants that are released in mill wastewater effluents. Therefore, many mills have converted to the substitution of chlorine dioxide, an even stronger oxidant, to decrease pollution levels.

2. Chlorine Dioxide Substitution

Currently, conventional chlorine dioxide substitution technology in the U.S. replaces up to 50-70% of chlorine with chlorine dioxide in the first bleaching stage. Studies have found that, at specific substitution rates, chlorine dioxide can be as or more effective than chlorine bleaching, especially with regard to strength, brightness, and lignin removal. However, pulp yields can decrease as substitution rates near 100%.

The literature indicates that with "high" (i.e., 50-70% or higher) rates of substitution, AOX production is low. This is because, whereas chlorine reacts substitutively, additively, and oxidatively with lignin, chlorine dioxide is a stronger oxidant. Because substitution and addition are the reactions that produce AOX, the use of chlorine dioxide increases the proportion of oxidative reactions and reduces the formation of chlorinated organic compounds.

However, chlorine dioxide is also associated with certain negative aspects, such as the formation of chloroform, a toxic volatile organic air pollutant. In addition, the byproducts of chlorine dioxide manufacture, such as chlorine gas and hypochlorite, can be environmentally detrimental. It is also potentially dangerous to produce and use chlorine dioxide, and employee safety must be carefully monitored. Finally, concerns have been raised about ensuring proper treatment of byproducts, such as chlorates, sodium sulfate, and sulfuric acid, which occur at high percentage levels of substitution.

3. Oxygen and Peroxide Extraction

The removal of chlorinated and oxidized lignin during the first alkaline extraction stage can be increased with the addition of either oxygen, hydrogen peroxide, or both. Oxygen, a strong oxidant, is also a strong bleaching agent. The use of oxygen in extraction limits the amount of chlorine needed in later bleaching stages, with a reduction in approximately 2 kilograms of chlorine per kilogram of oxygen charged, and a 25-30% reduction in pollution load. Hydrogen peroxide (H_2O_2), also a strong oxidant, acts much like oxygen to remove lignin and bleach pulp, and has other advantages. Besides reducing the potential for AOX production, hydrogen peroxide can be recycled from solution and sold on the market. It also has beneficial uses in the final extraction stage, by permitting reductions in chlorine dioxide use without sacrificing pulp brightness.

In addition to the current pollution prevention technologies described above, there are many technologies in development that may eventually be incorporated into pulp mill processes in the future. According to the U.S. EPA, "a number of additional technologies capable of reducing pollution generation in the pulping area are available and have been discussed to varying lengths in the literature... the additional methods have in some cases been discussed for several years without making it into full-scale mill operation, or have seen only limited full-scale operations." EPA, August 1993. Examples of emerging pulping technologies include: the Alcell process; steam explosion (a waterless method for creating pulp from recycled paper); the Lignox Process; solvent pulping; Organocell Pulping; Alkaline Sulfite Anthraquinone Methanol (ASAM); Polysulfide cooking; enzymes; and demethylation.

Emerging technologies for pre-bleaching and bleaching stages include: the SLC extraction process; POZONE (a less expensive method for producing ozone for use in oxygen delignification); and the Rapson-Reeve closed cycle. Researchers are currently investigating the use of laccase, an oxidative, lignin-degrading enzyme that could be used for pretreatment. Also, new chlorine-free bleaching chemicals, such as peracetic acid (CH_3CO_3H) and peroxymonosulphuric acid (Caro's acid, H_2SO_5) are being explored as alternatives to ozone in combination with alkaline peroxide. Another promising bleaching technology uses polyoxometalates (POMs) to oxidize lignin.

B. Innovative Technologies

The following technologies could prevent the creation of AOX in the bleaching process. They are the principal technologies which can go beyond chlorine dioxide substitution and create a TCF pulping process.

1. Hydrogen Peroxide

Hydrogen peroxide (H_2O_2) can be used as a substitute for chlorine and other chemicals that form chlorinated organic compounds in the bleaching stages. A major manufacturer and distributor of hydrogen peroxide was asked to outline the regulatory and business barriers to innovation in the pulp and paper industry and to identify barriers faced in selling the technology to the pulp and paper industry. In response, the manufacturer identified EPA's choice of Option A for the Cluster Rule, capital costs to retrofit technologies, and the conservative nature of the pulp and paper industry as present or potential barriers to marketability of H_2O_2 technologies. There are successful demonstrations of the compatibility of using chlorine dioxide and hydrogen peroxide, and this combination (or chlorine dioxide with some other peroxygen chemical) can be used in alternate bleaching stages to meet the .448 effluent limit for AOX under Option A.

Although it is possible to do ECF bleaching using only chlorine dioxide, this requires significant expertise on the part of bleaching engineers and would require sophisticated secondary treatment. Except in the case of a mill with full capacity to use only chlorine dioxide, Option A of the Cluster Rule will neither prevent nor promote the use of hydrogen peroxide. However, if EPA had chosen Option B, this technology would have been promoted because some form of technology using peroxygen chemicals, oxygen, or ozone would have been necessary.

Cost is also a barrier. The estimated capital cost to convert an existing mill using this technology to TCF is between $20 and $30 million, falling to $10 million in plants that already use oxygen delignification. Although the operating costs for using TCF could be comparable to those of using ECF, industry is reluctant to make the investment up-front to convert to TCF. Although no new kraft mill have been built in the last decade, a new TCF plant could be quite economically competitive because the "conversion cost" would be absorbed in up-front construction costs.

Technology vendors also cite the conservative nature of the pulp and paper industry as another barrier to innovative technology, saying the industry "moves at a snail's pace unless something is proven beyond the shadow of a doubt." The principal driving forces are environmental or economic and, if a mill is currently able to meet environmental standards, economics become the limiting factor. A technology vendor can show mills how to save money using H_2O_2 but, because pulp costs $500/t and mills produce 1,000t/day of pulp, this demonstration could cost a mill $1/2 million/day. This is an expensive test run, and many mills are reluctant to do so because the cost of a failure is so high.

2. Polyoxometalates (POMs)

A team at the University of Wisconsin's Department of Chemical Engineering is developing the use of polyoxometalate (POM) bleaching processes for pulp. This process is "pre-competitive," which means it has yet to reach the open market but is expected to be in pilot stage in the next 18 months. POM technology is currently to be tested in a pilot run by the equipment manufacturer at a commercial mill within 18 months. It is funded by a consortium of 6 manufacturers, the state government, and the University of Wisconsin.

Polyoxometalates (POMs) are a class of discrete polymeric metal-oxide anions. They are water soluble, highly resistant to oxidative degeneration, and easily built from common mineral ores such as Mn, Fe, Co, Ni, Cu, and Zn, which are known to act as "shuttles" in nature. Whereas chlorine removes lignin through an oxidative process that yields chloride, POMs oxidize in such a way that only CO_2 is released. Furthermore, the POM process is necessarily a closed-loop cycle that has been engineered to reuse process chemicals with no extra burden to a mill's recovery boiler.

A principal advantage of POM technology is that it produces no additional burden for recovery boilers. An average Tomlinson recovery boiler can be likened to a building burning from the inside out. A mill producing 1,000t/day is likely to have 3-5 of these boilers, and some modern mills have just one enormous boiler. Each boiler costs approximately $100M, about half of the cost of the mill. Companies typically size the rest of the mill to match this most expensive piece of equipment, and run all of the other mill processes accordingly. Therefore, the recovery boilers become a limiting factor in the mill efficiency equation.

The reoxidation reactor in the POM process eliminates organics that build up in the water and regenerates POM in a process called wet oxidation. Because this process does not burden the recovery boiler system, the POM process is more productive than other ECF and TCF processes for a particular boiler size. There are also capital cost advantages to POM over chlorine, ECF, ozone and oxygen processes because mills do not have to buy bleaching chemicals, which are all recovered through wet oxidation.

POM technology, like other TCF technologies, is predicted to cost on the order of $40 million to install for a mill with 500t/day production. If one were to build a new mill using POM, it would be very competitive, but it is estimated to cost nearly $1 billion to build a large new mill today.

3. C Free Ozone Bleaching

Another innovative technology produces "C Free" technology, an ozone bleaching technology using high consistency (38-42% consistency) ozone. This technology utilizes a patented reactor to apply ozone to pulp, and the process allows a mill to apply as much or as little ozone as desired, which means that the process is quite flexible. The process also uses smaller than usual concentrations of ozone, consumes very little water, and occurs at atmospheric pressure, which produces marked safety benefits. The application of ozone to pulp is the second step in a process that starts with oxygen delignification. After ozone is applied, there is an alkaline extraction stage followed by brightening with either chlorine dioxide or hydrogen peroxide. Therefore, C Free can be a part of either an ECF or a TCF bleaching cycle.

The C Free technology has been marketed since 1991. One of the systems is in use at Consolidated in Wisconsin Rapids, WI, where an ECF cycle is being used on hardwood pulp. FCA Graphics in Sweden uses C Free in their TCF line, and SAPPI in South Africa uses C Free in an ECF line. Despite the use of C Free in various mills around the world, there are barriers to marketing this technology. Cost is the main issue today that discourages the use of C Free technology. Mills also have concerns about specific quality issues, such as pulp brightness and strength, when replacing a system with ozone.

Cost is a complex issue for C Free. Because every mill is unique, it is difficult to make general estimates about costs; but for retrofits, it is often cheaper to use chlorine dioxide than ozone, especially if there is already chlorine dioxide production capacity at a mill. But if a mill has used only chlorine and does not have a lot of extra capacity to switch to 100% chlorine dioxide, the difference in capital cost becomes closer to about 20-25% higher for ozone. When this is amortized, and the savings in operating costs is added, it is almost equivalent to chlorine dioxide. Furthermore, there would be a bleach chemical savings of as much as $5 per ton, and most of the filtrate can be recycled when a mill is using ozone.

It is possible to avoid paying for ozone as a capital cost. Some mills, such as SAPPI in South Africa, have leased C Free in "over the fence" transactions. In this way, mills can turn ozone expenses into operating, rather than capital, costs. Additionally, recent technological developments have made it less expensive to produce ozone. Ozone can now cost about as much pound for pound as chlorine dioxide. One process, called dielectric technology, sends an electrical spark across a gap containing oxygen, which is converted to ozone. The glass tubes once used as the dielectrics have now been replaced with ceramic ones, making the technology less expensive. In addition, producers have the capability to use a more efficient power supply, which reduces specific energy costs. Since 80-85% of the cost of producing ozone is spent to power the process (the rest is the cost of oxygen), such increases in energy efficiency have dramatically reduced the costs of producing ozone.

Overall, the vendor sees a bright future for C Free, even though the Cluster Rule as adopted does not require ozone technology. Future demand may be driven by the need to conserve fresh water. Certain mills may also look to TCF as a way to close the loop. Although use of chlorine dioxide and external treatment of filtrates is a possibility for closed loop processes, it is not a proven solution, whereas TCF is a lot easier; all of the TCF chemicals are more compatible with the environment than chlorine dioxide, and using TCF is much easier in terms of maintenance, especially due to reduced corrosion.

4. Bleach Filtrate Recycle (BFR) case study

Champion International Corporation's pulp and paper mill in Canton, North Carolina has begun to use the Bleach Filtrate Recycle (BFR) process to reduce the emissions of color and AOX in its effluent stream. The process has two major components: the mineral removal process; and the chloride removal process. BFR is not a TCF technology per se. It is a technology that makes it possible to run a mill using ECF bleaching with sharp reductions in AOX and other effluent releases.

Although BFR is not an actual TCF technology, it would enable a TCF mill to close the loop by effectively removing metals and chloride from furnish and caustic. However, it is expensive to install, with capital costs at a 1,000t / day ECF mill of $12-16 million, and at a TCF mill of the same size, $10-14 million.

V. Barriers to Technology Implementation

Currently, the technologies used by the pulp and paper industry are being improved or replaced with machines and processes that prevent or reduce the creation and release of pollution. Although there has been progress in developing and installing pollution prevention processes and technologies, this has been primarily the substitution chlorine dioxide for chlorine and not TCF technologies.

A principal barrier to adopting TCF technologies appears to be the high capital cost of retrofitting existing mills to use these technologies. Other barriers include the economic conditions of the industry, a lack of investment in research and development, and industry conservatism and reluctance to implement new technologies. Many of these barriers would affect any technology innovation in the industry and do not appear to be specific to environmental technologies. In such as situation, drivers to force improvements in environmental standards must be created externally through more stringent regulations or by increased consumer demand for chlorine-free paper.

A. Economic barriers

1. Cost to retrofit

Although the cost of constructing a new mill with TCF technology may be equivalent to other options, the cost of retrofiting an existing mill with a TCF technology is very expensive. Retrofit costs were found to range from $12-16 million for BFR, to $10-30 million for hydrogen peroxide to $40 million for POM technology at a mill with 500t/day production. Existing plants have little incentive to switch to ozone systems either, because their capital costs are greater than those of chlorine dioxide. Because no new kraft pulp mills have been built in the past decade, the innovative technologies must be retrofitted, and the cost to retrofit becomes a significant barrier to their use.

One of the reasons for the high cost of retrofitting pollution prevention technology is the limit imposed by the recovery boiler system, a major piece of equipment which determines the capacity of the whole plant. Anything that is installed in the mill after initial construction that will increase the load to the recovery system leaves a mill with three options: decrease production, install a new boiler at a very high cost, or ship liquor out of the mill to be reprocessed elsewhere. All of these options represent a loss of efficiency, money, energy, and/or chemicals. The POM technology has an advantage here, as the POM effluent is recycled and contributes no extra burden to the recovery cycle and boiler.

In general, this barrier deals with capital costs, since TCF technologies can be equivalent (hydrogen peroxide) or cheaper (POM) to operate than traditional processes. However, despite all of the advances in making cheaper ozone, it still costs at least 20% more to use ozone than chlorine dioxide in most mills.

2. High Costs of Testing

The costs of a commercial test of an innovative technology are high, due to the large size of most mills and the complex, and the individual nature of each mill. Because pulp costs $500/t and mills produce 1,000t/day of pulp, an innovative technology demonstration could cost a mill $1/2 million/day, which is a very expensive test run. The risks are also high, as due to the complex and individual nature of each mill's process, testing or use at one mill may not indicate a technology will work at another mill. Innovative technology vendors point to these high costs and risks as a reason mills are conservative and reluctant to test innovative technologies. Such conservatism may be nothing more than an accurate assessment of the costs and benefits of using a new technology, but it is nonetheless a barrier.

There are unique testing barriers in the case of the POM technology, as there are many potential POMs. Companies involved want to be absolutely sure they are piloting the right POM, and not make a major investment and test only to find that a better POM is discovered in the future.

3. Additional Economic Barriers

The barriers created by the cost to retrofit and test are exacerbated by other economic considerations affecting the pulp and paper industry.

Lack of profitability: The major barrier one technology vendor encounters in trying to market their innovative technology is that the industry is making little profit at this point. The vendor notes that pollution prevention is done only when required and that the industry has reached the point where mills are only spending money on replacement parts. Mills will not even pay for proven technologies, such as expansion of black liquor evaporates, to help their bottom line.

Market instability: The cyclical nature of the industry has already presented barriers to implementing other pollution prevention technologies in the industry. For example, oxygen delignification saves chemicals, is cost-effective and, if installed, would lower operating costs. However, the instability of the market leads the industry to not invest capital, and therefore companies have not installed oxygen delignification.

Demand for paper is sporadic and follows closely the demand cycles in other sectors. According to a recent report by the International Institute for Environment and Development (IIED), "the effects of these cycles on prices within the [pulp and paper] sector tends to be exacerbated by a `capacity cycle,' with `lumpy' additions to supply (due to the large scale of modern mills) occasionally getting ahead of market demand." Such "lumpy" additions lead to depression of product prices, which in turn reduces a mill's cash flow and access to credit through equity or loans. The IIED report goes on to explain that

> Investment in new capacity is largely curtailed, just as the sector begins to recover. When prices respond, there tends to be a surge of new capital investment. Because of the lead time in bringing new capacity on-stream (three to four years for a greenfield mill), the resultant surge in capacity often coincides with the next business cycle downturn. The prices of basic commodity grades fall sharply in the face of over-capacity, cash resources are strained and balance sheets suffer. IIED, p.24.

Mill complexity and lack of uniformity: Both these factors are a function of the unique engineering of pulp and paper mills. The water circuits in pulp and paper mills are very complex, and no two mills are identical. This complexity is a barrier to bringing new products and technologies into the industry because it raises the costs of retrofits and testing. In addition, it fosters an attitude among mill owners of lack of trust in tests or results achieved at other mills because they may not apply at other mills.

B. Regulatory Drivers

1. The Cluster Rule does not Force TCF technology

The Cluster Rule, described above, set forth two options for end of the pipe effluent limitations on AOX. EPA adopted Option A with an effluent limit of .448 AOX, strict enough to preclude use of elemental chlorine as a bleaching agent but permitting either the use of chlorine dioxide or the combined use of chlorine dioxide and hydrogen peroxide. EPA did not adopt Option B, which would have mandated stricter limits and provide greater incentives for the use of TCF technology.

The Cluster Rule also adopts a three-tier Advanced Technology Incentive Plan for facilities to go beyond the requirements of Option A. In exchange, the facilities will be given more time to come into compliance based on the technology particular to that tier. Tier I technologies would have 5 years to meet the requirements; Tier II, 10 years; and Tier III, 15 years. Examples of technologies are best management practices which eliminate leakage and spills, capturing and recycling fiber line disruptions through detailed planning of maintenance outages and unexpected disruptions.

For the innovative technologies described here, except in the case of a mill with full capacity to use only chlorine dioxide, Option A of the Cluster Rule will neither prevent nor promote the use of hydrogen peroxide. There are successful demonstrations of the compatibility of the use of chlorine dioxide and hydrogen peroxide, which can be used in alternate bleaching stages to meet the effluent limit. The Cluster Rule will not force ozone technology, and so will not promote C Free or other ozone technologies. At the state level, however, North Carolina and Maine are proposing legislation that would be stricter than federal regulations it will most likely force TCF processes. As for BFR, unless there is a regulatory change that forces all U.S. mills to go to closed loop bleaching cycles, BFR will be a technology that will be marketable to mills with unique permitting problems. The process will help these mills to meet tight color discharge limits, or reduce AOX effluents.

The Cluster Rule demonstrates both the positive and negative aspects of traditional effluent standards. The Cluster Rule tightens the standards for toxic effluents from the pulp and paper industry and can be expected to lead to significant public health benefits. It also dictates technology in a way typical of effluent standards.

Because the effluent limit is high enough to eliminate the use of elemental chlorine technologies, it will only result in the broad adoption of chlorine dioxide technology, the cheapest way to meet the effluent limits. On the negative side, it gives no incentive for mills to go beyond the regulatory standard or to use TCF technologies.

While the Cluster Rule was pending, it also created a waiting period of several years when firms were reluctant to upgrade their plants or invest in new technologies because of the uncertainty of the outcome of the rulemaking. Such a regulatory driver does not create a stable situation with a continuous demand for environmental improvements, which would provide the conditions for long-term research and development of innovative technologies. Instead, it creates a step progression in which demand is only created sporadically when regulations become stricter.

Many have pointed out that a consistent economic consequence must be attached to pollutant discharges to lead to continuous environmental improvement. Demand drivers for pulp and paper, as noted above, have been weak in exerting such continuous pressure for less pollution. Ultimately, the regulatory environment needs to be changed to focus less on specific limits than on an overall context to reduce effluents towards the goal of closed loop or effluent free processes. Tools such as pollution charges, emissions trading and even zero discharge limits may eventually contribute better results.

C. Industry Aversion to Risk

The conservatism of the pulp and paper industry is noted by some of the innovative technology vendors as a major barrier to innovative technology. They believe the only driving forces at a mill are environmental or economic and, if a mill is currently able to meet environmental standards established by the regulations, economics become the sole driver. Another view is that the conservatism of the industry comes from the high cost of test runs and retrofitting TCF equipment, which puts so much at stake in converting to a new technology.

The industry's conservatism is also reflected in the lack of new technology research and development. Although some progressive companies are investing in research and development, many mills are content to wait for innovators to develop and market products and then consider buying. For example, while Union Camp tested and installed an ozone technology, other companies waited and bought the technology only after it was proven. Companies such as Consolidated, Potlatch and Weyerhauser and others are also investing in new methods, but many in the industry do not.

D. Consumer Demand

Another barrier to the use of TCF technologies is the absence of a price premium for an environmentally superior product. The lack of consumer demand for unbleached products and leads to weak economic drivers or incentives for mills to switch to TCF. Arguably, if demand were greater, a price premium could be charged for unbleached products, and there would be more experimentation and adoption of innovative technologies.

Some mills installed TCF because there was formerly a premium for TCF pulp; but that premium has now almost evaporated, leaving the mills competing with TCF pulp at ECF prices. Unless technology innovation lowers the price of TCF technologies and the cost of retrofitting them onto existing facilities, current demand does not appear able to provide an incentive for using TCF processes.

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Chapter Six:

Technology Innovations for Controlling So_2 Emissions from Utilities

I. Introduction and Summary

Electric utilities produce significant proportion of our nation's air pollution, including most of the emissions of sulphur dioxide (SO_2). This pollutant has been regulated since the initial Clean Air Act was passed in 1970, but different SO_2 emission limits have been used. Changes in the Clean Air Act in 1977 and 1990 allow the comparison of different approached to regulating air pollution and provide a unique look at how various standards may create barriers and affect industry's technological choices.

The initial approach to regulating SO_2 in 1970 created emissions limits to protect local health, which are still in effect. One perverse consequence of these local standards was utilities' construction of tall stacks in order to disperse SO_2 emissions from their powerplants more broadly, but the stacks simply worsened both acid rain and regional health effects.

To address these regional concerns, further reductions were imposed on new powerplants under the Clean Air Act Amendments of 1977, which mandated significant end-of-pipe reductions in SO_2 emissions from utilities. This standard did not allow for compliance through the use of process changes or demand reduction but required the use of scrubbers. The high cost of scrubbing led to a new approach when action became necessary to further reduce emissions of sulphur dioxide (SO_2) once acid rain problems were identified.

The Acid Rain Program in Title IV of the 1990 Clean Air Act Amendments establishes a new overall performance standard -- an emissions cap -- for SO_2 emissions, departing from the former system of emission limits. Data available from the first two years of this program's implementation in 1995 and 1996 show it has been highly successful. Utilities have over-complied and reduced their SO_2 emissions by 40% less than the cap, and their costs have been less than half the projection of $4 billion. The program appears to have other desirable features as well, as it has achieved 100%

compliance in its first year, fostered innovation, reduced litigation, and requires very few regulatory staff to manage.

A review of these statutory changes helps to explain how the different SO_2 standards have dictated different technological options and have produced different compliance behavior by utilities. This review reveals increasing efficiency in achieving positive environmental and economic results as the regulatory system moved in two directions: away from point-source standards and towards plant-wide or industry-wide caps, and away from effluent limits towards measures of overall performance. The results with SO_2 indicates that an emissions cap and allowance trading approach is preferable to end-of-pipe restrictions when it is can be used for regulating pollutants with regional or national effects.

The success of the Acid Rain Program in reducing SO_2 emissions demonstrates that greater consideration of the costs of environmental regulation need not undermine the goal of improved environmental quality. To the extent cost reductions can be traded for increased environmental quality, the conversion of technology-based emission limits to overall industry or facility-based performance standards may be the simplest as well as the cheapest way to improve our approach to environmental regulation.

II. The Acid Rain Problem

Acid precipitation, together with dry deposition of acidic particulate matter, is caused primarily by emissions of sulphur dioxide (SO_2), but also in part by nitrous oxides (NO_x). When these substances rise into the atmosphere, they combine with water to form, respectively, sulfuric acid and nitric acid particulates, which contribute to acid deposition when the water particles fall to earth.

The principal source of SO_2 emissions are fossil-fueled powerplants. Utilities contribute approximately 70% of SO_2 emissions, with a remaining 11% from industrial boilers, 11% from industrial processes, and 8% from other sources.

Acid rain precursors as well as their secondary pollutants have impacts on both ecosystems and human health. A recent EPA estimate of potential human health benefits from the Acid Rain Program was $3 billion for Phase I, and up to $40 billion after Phase II is implemented. Visibility benefits from the Acid Rain Program have been estimated to be worth $1.6 billion per year in the next decade in residential areas, and $700 million or more in recreational areas. In addition, there are substantial environmental benefits to ecological systems that are more difficult to quantify in monetary terms, as acid rain creates significant ecological damage to water bodies and land through acidification.

Although acid rain is a national problem, it is most severe in the eastern United States because most high-sulphur coal is found in the Appalachians and Midwestern coal fields. Western coal fields, such as those in the Powder River Basin, are mostly low-sulphur coal. As the cost of transportation is a significant part of the cost of coal, utilities have tended to burn local coal, so high sulphur emission have been associated with eastern and midwestern power plants. The impact on the east is reinforced by political forces, as some states have attempted to require their local utilities to burn high sulphur coal to protect in-state coal mining jobs, and by weather patterns which blow SO_2 emissions largely from west to east.

III. History of SO_2 Regulatory Standards

A. Standards before 1990

The earliest versions of the Clean Air Act imposed point-source-specific emissions limits for SO_2 based on National Ambient Air Quality Standards. These were initially adopted in 1971 and established an emission rate per million British thermal units (mmBtu). 36 Fed. Reg. 8186. The primary standard still applies and limits SO_2 emissions to 365 ug/m^3 (0.14 ppm), averaged over a period of 24 hours and not to be exceeded more than once per year. 40 CFR Part 50. This standard is intended to protect human health based on ambient air quality within the vicinity of a powerplant.

This standard led to the concept of "compliance coal," or coal with sulphur content which was equal or less than this standard. Compared to the later New Source Performance Standard passed in 1977, this early standard afforded greater flexibly to sources in selecting different abatement technologies, including some use of low-sulphur coal.

The Clean Air Act Amendments of 1977 then imposed a rate-based standard on sulfur emissions from newly constructed facilities that required a 90 percent reduction in smokestack SO_2 emissions, or 70 percent if the facility used low-sulfur coal. 44 Fed. Reg. 33580 (June 11, 1979). This approach required scrubbers, as confirmed in Sierra Club v. Costle, 11 ELR 20455, 657 F.2d 298 (1981), where the court noted that scrubbing was the only available technology which could achieve such stack reductions. As a result, the 1977 SO_2 standard essentially eliminated compliance through the use of process changes, fuel-switching or demand reduction.

Although these emission limits were nominally performance standards, they provided little room for utilities to deviate from the technology that could achieve the 70-90% reduction rate, and thus little incentive for innovation. Utilities were limited in their choice of fuels, and the only technology available to meet the 1977 standard was scrubbing, which costs $300 per ton of SO_2 removed and consumes 2.1% of a powerplant's electric generating capacity. In retrospect, we can see how this rate-based standard became, in practice, a technology standard.

B. The 1990 Acid Rain Program

Utilities' complaints about the expense of installing scrubbers and increasing awareness of the damage cause by acid rain led to a national debate and search for an alterative approach to regulating SO_2. Over seventy bills were introduced in Congress in the 1980s aimed at acid rain control. One approach would have prescribed certain technologies -- the Waxman-Sikorski bill of the 98th Congress (H.R. 3400) was cosponsored by over 80 House members and would have required scrubbers on the 50 largest utilities. This debate culminated in the passage of Title IV of the Clean Air Act Amendments of 1990. Title IV embodies a historic "cap and trade" compromise between environmental interests, who sought a 10 or 12 million ton reduction in annual SO_2 emissions, and industry groups who claimed such reductions would be prohibitively expensive.

The Emissions Cap: Under Title IV, total national emissions of SO_2 from electric utility powerplants are capped at 8.95 million tons, approximately 10 million tons less than the amount emitted by such facilities in 1980. Reductions are to take place in two phases. Phase I began in 1995 and affects the 110 dirtiest plants, mostly coal-fired facilities. Starting in the year 2000, Phase II covers all other plants with more than 25 megawatts of capacity, smaller ones with a sulphur content of fuel greater than 0.05 percent, and all new plants.

Title IV assigns a number of allowances to each affected powerplant, which in total equal the overall emissions cap. Each plant's allocation is based on their historic base period (1985-1987) emission rates, scaled down so that aggregated emissions equal the cap. One SO_2 allowance entitles its holder to emit one ton of SO_2. Other industrial sources of SO_2 are excluded from the mandatory program, but they may voluntarily subscribe after establishing a historic emission profile.

An emission cap is an overall performance standard and differs in important ways from traditional emissions rate limits which prescribe allowable levels of pollution from each source. Although this new performance standard is mandatory with high penalties for no-compliance, utilities can choose among competing technologies for reducing SO_2, which include scrubbing, fuel blending, fuel switching, clean coal technology, or energy conservation and reducing demand for electricity. Another desirable feature of an emissions cap is that the reductions of pollution are permanent even if economic activity increases, whereas conventional emissions limits for specific sources could still allow increased pollution when more sources are built.

Allowance Trading: The second significant innovation in Title IV is the provision for trading of allowances. If a utility reduces its emissions below its allocated amount, it can switch them to another of its units, bank them for future use, or sell them. This provision promotes innovation and allows even greater cost savings by creating incentives for the powerplants with the lowest costs of SO_2 reduction to make their reductions and switch or sell their allowances to other plants or utilities with higher costs. Trading thus minimizes overall compliance costs.

IV. Effects on Technology Choices

The cap and trade performance standard adopted in Title IV freed electric utilities in two important ways: it enabled utilities to determine both how and where to reduce SO_2 emissions. The emission cap allows them to choose among competing technologies, and the trading system allows them to choose where to make the necessary reductions. These changes have led to major cost savings and a dramatic shift to process changes instead of end-of-the-pipe pollution treatment.

The following chart illustrates how the different regulatory approaches for SO_2 have affected utilities' technology options for achieving compliance. Column A represents the Waxman bill which would have mandated scrubbers at major utilities; column B is the 1997 NSPS rate-based emissions limit; column C is the 1970 emissions limit; and columns D and E are the 1990 Acid Rain Program, both with and without active trading. These methods are arranged from the most restrictive on the left (a technology prescription) to the most flexible to the right, which allow increasingly more technology choices.

Table 6. Acid Rain Program - Technologies and Estimated Costs by Regulatory Method:

<table>
<tr><td>Technology</td><td colspan="2">Effluent limits</td><td colspan="2">Emissions cap</td></tr>
<tr><td>Prescription</td><td>% reduction</td><td>% concent.</td><td>w/o trading</td><td>with trading</td></tr>
<tr><td>A</td><td>B</td><td>C</td><td>D</td><td>E</td></tr>
<tr><td>- scrubbers</td><td>- scrubbers</td><td>- scrubbers
- limited use
- lo-sulfur coal</td><td>- scrubbers
- major use of lo-sulfur coal
- fuel blending
- no backup nec.
- demand side mgt.</td><td>- scrubbers
- major use of lo-sulfur coal
- fuel blending
- no backup nec.
- demand side mgt.
- power shifting
- trading</td></tr>
<tr><td colspan="5">GAO estimates of cost in $ billions/yr. to reach standard:</td></tr>
<tr><td>7</td><td>4.5</td><td>--</td><td>2.5</td><td>1.2</td></tr>
</table>

As this chart shows, each approach to regulating SO_2 allows different technologies to be considered. Utilities' ability to choose among an increasing number of technology options as one moves to the right has led to dramatically reduced costs of compliance. A GAO report estimates the cost of abating SO_2 emissions under the Acid Rain Program at $1.2 billion in 1997, and $2.2 billion in 2002 when Phase II is operational. The report concludes that this is less than half of the cost which would have been incurred under more traditional end-of-pipe or smokestack approach.

The increasing availability of various technologies moving from left to right on the chart determines, for the most part, the different costs associated with achieving a similar environmental result. Because innovation occurs in a greater number of technologies as well and compliance becomes cheaper due to competition among various technologies, there are also increased opportunities for enhanced environmental results when the regulatory system allows for more technology options.

A. Effects of Implementation of Acid Rain Program

Data are now available from implementation of Title IV in 1995 and 1996. They allow us to evaluate the program and identify how the cap and trade system has achieved different results. These data show that utilities reduced emissions 40% below the emissions cap, at a cost to industry less than half that predicted under more traditional emission limits. In addition, there was 100% utility compliance without any enforcement actions, significant innovation, and the program required very few government employees to manage. The shift from scrubbing to process changes has also reduced the significant resource use, energy consumption and landfill discharges associated with scrubbers, which were the traditional end-of-pipe technology.

A review of the changes that took place under Title IV allows us to identify the compliance technologies which allowed industry to halve the costs of achieving the same control through emission limits. The evidence below suggests that the emissions cap has been the most important element in reducing costs, given the dramatic differences among the costs of the various technologies allowed to meet this overall SO_2 performance standard. However, the trading provisions of Title IV also contributed and may play a greater role in future reductions and cost savings.

1. Increased Ability to Use Low-sulfur Coal

The primary reason for utilities' declining costs in controlling SO_2 emissions has been their dramatic increase in using low-sulfur coal which, in turn, has been driven by technological changes and a reduction in the delivered cost of low-sulfur coal. The lower coal prices have been primarily due to a reduction in costs of rail transportation of low-sulfur western coal, which has been driven by investment and innovation in the rail industry. Many observers in the Clean Air Act debates conjectured that rail transport bottlenecks would arise and preclude western coal from playing a big role in compliance plans of eastern utilities. Hence utilities' price forecasts were based on prices for low-sulfur Appalachian coal locally available to eastern utilities. However, these potential rail bottlenecks never materialized.

Rail transportation constitutes about 50% of the total cost for low sulfur coal from the west delivered to the east, as western coal is considerably cheaper to mine than eastern coal. Transport costs have decreased because, following passage of Title IV, the rail industry has implemented a number of innovations and improvements to meet increased demand for western coal. These include double- and triple-tracking, increasing size of coal car fleets, using new and more powerful locomotives, improving car design such as aluminum cars, and developing coal tipping technology which increases car dump speed.

A second explanation for increased use of low-sulfur coal is that the expected capital costs to using low-sulfur coal have failed to materialize due to the flexibility offered by Title IV. Utilities originally thought their boilers would have to undergo extensive modifications to accept high-ash low-sulfur coal from the Powder River Basin. However, fuel blending has been one of the major compliance strategies of utilities because it allows them to take advantage of the low sulfur fuels while avoiding capital investments that would be necessary if they had to rely exclusively on low sulfur fuels.

2. No Need for an Extra Scrubber

A major economic cost of the past SO_2 emission limits was their requirement that utilities comply with the limits continuously. As a result, the 1977 NSPS not only required scrubbers, it required two scrubbers so the second could be used during emergencies or scheduled maintenance of the first scrubber. Although utilities with several units were able to reduce the economic impact of this requirement by building a back-up scrubber which could serve two or three units, the economic cost of the second scrubber was still high.

Although a continuous emission limit standard which requires a backup scrubber would be needed to reduce local pollution concentrations, it should not be necessary for controlling regional pollution. The reductions of SO_2 needed to address long-range SO_2 transport and the acid rain issue are regional, not local, and so it makes little sense to require the second scrubber when there are much cheaper ways to achieve the overall SO_2 reduction. Under the 1990 SO_2 emissions cap, utilities can now achieve the necessary pollution reductions without an extra scrubber and by any other means they can find, including emissions averaging, power shifting, or allowance trading.

3. Allowance Trading

With traditional emission limits, or even an emission cap at individual facilities, these facilities would be faced with two capital intensive and expensive options: install scrubbers or switch fuels entirely with the associated capital investments in handling facilities. The allowance trading program allows facilities to capture their own low-cost emission reductions through internal power shifting among units or by selling and trading in the allowance market, thereby reducing costs significantly.

As a result, the most recent study on the costs of Title IV by the Massachusetts Institute of Technology shows that the overall cost of compliance in Phase I is only $720 million, and that many plants not relying on scrubbers are arguably complying with Title IV at virtually no cost or at a savings, due principally to the low cost and availability of low-sulfur coal.

In summary, Title IV's new regulatory approach has significantly changed utilities' compliance behavior in abating SO_2 emissions. Formerly, scrubbers were installed in all new utility units to reduce SO_2 emissions. Since passage of Title IV, only 17 utilities have installed scrubbers, about half of previous expectations for Phase I, and no new scrubber has been purchased since the early days of the Acid Rain Program. Instead, utilities have chosen cheaper compliance options, particularly fuel blending and switching to low-sulfur coal. In doing so, they have significantly reduced the energy loss and wastes associated with scrubbing, and have allowed firms to avoid capital intensive, irreversible investments during a period of major change in the industry's economic regulation.

B. Innovation and Investments Prompted by the Acid Rain Program

There has also been notable innovation in utilities' uses of existing powerplants and equipment. Coal-fired powerplants are designed for a particular type of coal, and deviations in any of several important properties may impair plant performance or harm equipment. Conventional thought had assumed that combustion of low-sulfur sub-bituminous western coal in eastern utility cyclone boilers would be most troublesome because it does not share the characteristics of commonly used bituminous coal, including moisture content, heat content and ash properties. Utilities' experimentation prompted by the Title IV allowance trading program has led to an improved understanding of the ability to blend fuels. The detrimental effects of blending have been found to be fewer than originally supposed.

The technology of scrubbing has also evolved considerably in recent years. Prior to Title IV, scrubbers usually included a spare absorber module to maintain low emission rates when any one module was inoperative. An important innovation in scrubber technology is the reduced need for spare modules. As long as emission allowances can achieve compliance, utilities can save considerable capital costs by eliminating the spare modules and averaging their SO_2 emissions or using their own or purchased allowances during periods of maintenance or unplanned outage.

Another significant technical implication of Title IV is the incentive for improved efficiency in scrubbing. New scrubbers exhibit increased efficiency and reliability. Improvements in scrubber design and materials have also reduced utilities' maintenance costs and increased their utilization rates, increasing SO_2 removal from 90% to 95%. With these improvements, scrubbing may be cost effective compared to the overall cost of SO_2 reduction and the opportunity cost of allowances. The incentives are such that utilities may be likely to upgrade existing scrubbers through improvements including larger modules and elimination of reheat.

Title IV has had a significant positive effect on innovation and investment related to SO_2 compliance. Any type of environmental regulation which tightens standards stimulates innovation in the technologies to achieve the emission reductions, but there is a big difference in how innovation performs under different types of regulation. Title IV appears to have stimulated innovation and investment in the least-cost compliance options. By contrast, the prior SO_2 emission limits only promoted innovation in scrubber technology because they along could achieve the required end-of-pipe emission reductions.

Instead, Title IV creates an overall performance standard, which has promoted competition between different compliance options and has forced innovation and investment in a number of areas. Newly faced with competition from other approaches, scrubber technology has improved and the price per ton of scrubbing has declined 50% since 1990. However, the principal innovation has been in rail transport of coal, which would have been impossible to predict or stimulate under the old approach. Approximately half the delivered cost of low-sulfur coal is rail transport and, faced with a substantial new market due to Title IV, rail companies have competed strongly to win contracts. Meanwhile, cost-reducing innovations have cut transport costs for coal in half.

Investment has also been prompted by the shift in approach to regulating SO_2. A study by Clean Air Capital Markets identified $12 billion in investment associated with Title IV:

$6 billion	Development of low-sulphur coal fields
3 billion	Scrubbers and modifications
2 billion	Coal-related rail investment
1 billion	Allowance purchases
12 billion	

Unlike the previous standard, Title IV appears to have promoted innovation in least-cost compliance options. Utilities adopted least-cost solutions instead of paying for mandated technology.

V. Remaining Barriers to Inter-utility Trading

The above-mentioned cost reductions have been achieved despite the lack of significant inter-utility trading of allowances until very recently. This lack of inter-utility trading has been noted by some as a failure of the Acid Rain Program. Many of these comments fundamentally confuse the two kinds of trading programs. The closed system, or emission cap and allowance trading programs like Title IV, fundamentally changes the regulatory structure, and benefits come from the emission cap system itself, as well as the trading. Major benefits can come without a single trade. In contrast, an open market trading system typically does not alter the command-and-control regulatory system but allows trades to be made to improve efficiency. Their only benefit comes if trading is substantial.

The Acid Rain Program has been very successful due to the freedom given industry under the overall performance standard to choose the "**how**" or the method of compliance. The trading provisions allow for further cost reductions based on the "**where,**" or the differences in costs of SO_2 reduction to different utilities. The opportunity for trading benefits are strong, as the GAO report identifies 41 utilities in Phase I with costs higher, and sometimes significantly higher, than current allowance prices and potential buyers of allowances.

However, in the first years of the Acid Rain Program, there was a significant lack of inter-utility allowance trading. The GAO estimated in 1994 that only two of the utilities that would benefit from trading were doing so. Another source estimated that, as of March 1995, only 1 to 3.5 % of allowances allocated for Phase I were involved in "real" inter-utility trades. Trading activity has picked up significantly in 1996, with 4 million allowances traded, but is still well below the levels indicated by the significant differences in compliance costs between firms.

There are several important obstacles that have impeded allowance trading. Most significant have been institutional obstacles created by the actions (or lack thereof) of state public utility commissions (PUCs). The lack of firm rules in many states has create uncertainty, and several aspects of standard regulation of electric utilities tend to inhibit trading. Arguably, these have depressed demand and willingness to pay for allowances.

First, many states lack rules on treatment of allowance transactions, creating a significant barrier to risk-averse utilities. Second, the rules that have been developed generally erode the incentive to trade. In most states, the rules for the allowed rate of return, the depreciation rate, and risk that expenses may not be recoverable in electricity rates are all less favorable to allowance transactions. Furthermore, states typically prohibit shareholder earnings on capital gains (but not capital losses) thereby imposing a one-sided risk on utilities that purchase allowances.

A third problem has been explicit prohibitions by state legislatures on trades that might undermine local economic activity, especially production of coal. Nearly every state with substantial Phase I compliance obligations enacted legislation to promote the use of coal mined within the state. Perhaps the most aggressive attempt was an Illinois law subsequently struck down by the courts as unconstitutional that would have encouraged electric utilities to burn coal mined in Illinois by requiring installation of scrubbers as part of their Clean Air Act compliance. Other laws have aimed at the same goal in more subtle ways, for instance, by offering pre-approval for cost recovery of investments in scrubbers.

In addition to these problems at the state level, the public has responded in unfriendly ways to announcements of trades, criticizing both the sellers and buyers of allowances. Also, some analysts have criticized EPA's allowance auction as a poorly designed institution that generates prices below those emerging from bilateral trades between utilities. As a consequence, there are ample hurdles to allowance trading and ample explanations why trading has been slow to develop.

VI. Conclusion

The Acid Rain Program enacted in Title IV of the 1990 Clean Air Act Amendments was created to reduce emissions of sulphur dioxide which cause acid rain. Following its first years of implementing in 1995 and 1996, Title IV appears to be very successful. It has resulted in utilities over-complying by reducing their emissions to 40% less SO_2 than the standard allows, at a cost of less than half the projected $4 billion expense. The program appears to have other desirable features as well. It has achieved 100% compliance in its first year, fostered innovation, reduced litigation, and requires very few regulatory staff to manage.

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Chapter Seven:

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Technology Barriers for Wastewater Treatment

I. Introduction and Summary

The Clean Water Act (CWA) requires cities and towns to build and maintain wastewater treatment plants that meet national standards for discharging water pollution. Most major metropolitan areas and large communities use conventional systems with large sewers and well-proven mechanized techniques to treat wastewater. These systems in general consist of activated sludge systems with chlorination to meet secondary wastewater treatment requirements.

More innovative treatment technologies such as ozone, ultraviolet (UV), biological nutrient removal, enzyme technology and oxidation are experiencing increased acceptance and application. Alternative technologies, those that are relatively more proven than innovative technologies, also offer potential for cost savings.

More widespread adoption of alternative and innovative technologies by wastewater treatment plants faces a number of barriers: (a) diminishing government funding which reduces the opportunities for expanding, upgrading and efficiently operating treatment plants; (b) municipal and state agency managers who are conservative about approving new technologies; © a general failure to make information about new technologies available to government and industry decisionmakers; (d) restrictive state and local regulations, especially those which are technology-based, require competitive bidding, or establish inconsistent treatment standards; and (e) the need to adjust training and management to the requirements of new technologies which the actors involved may also view as an impediment.

II. Background

Each day, billions of gallons of wastewater from domestic, commercial, and industrial sites pass through sewers to publicly owned treatment works (POTWs) to remove pollutants before discharging the treated water (effluent) to rivers, lakes, and other water bodies. Residuals from the treatment process, such as sludge, are incinerated, landfilled or composted.

POTWs are public utilities owned by a municipality or regional government authority such as a water and sewer district. Operation and maintenance of POTWs may be performed by private companies. In 1992, there were approximately 15,500 POTWs in the US, with about 3,000 classified as "major" plants serving 10,000 or more customers or processing 1 million gallons or more daily and 12,500 "minor" plants processing less than 1 million gallons daily. Funding for wastewater collection and treatment services is generally provided by local governments through bonds, state revolving loans and through service fees and taxes. POTWs are regulated entities and must adhere to federal, state and local regulations. Unlike water utilities which must meet drinking water standards that tend to be uniform nationwide, POTWs must meet permit limits which vary from state to state.

Wastewater treatment technologies used by POTWs can be classified as conventional, alternative, or innovative. Conventional treatment technologies clean wastewater centrally using well proven or established mechanical techniques and discharge directly into surface water. Innovative technologies are considered cutting edge and not fully proven, whereas alternative technologies are considered relatively more proven and have been used or demonstrated. This case study examines barriers to the use of alternative and innovative technologies for treatment of wastewater. Disposal and treatment of residuals, such as sludge, is a separate issue not addressed here.

EPA has reported that, since 1972, considerable progress has been made in controlling water pollution. According to EPA, the number of people served by improved levels of wastewater treatment has risen significantly, and the health of many rivers has been restored after sewage and industrial wastewater treatment facilities have been constructed or upgraded.

Despite these improvements, some waters are still not suitable for swimming or fishing. EPA's 1988 National Water Quality Inventory states that persistent pollution problems remain. For example, out of 519,412 river miles that were assessed, 158,081 miles (30%) did not fully meet state water quality standards. These standards are still being violated because effluent discharges, plant operation malfunctions, and combined sewer overflow bypasses from POTWs have contributed to the deterioration of many surface waters. Many treatment plants built in the 1970s are reaching their design capacity in the 1990s and will soon require major rehabilitation or replacement. In a 1990 report on the status of state revolving fund programs, EPA estimated that 4,689 wastewater treatment facilities in the 50 states and Puerto Rico were in significant non-compliance -- those with serious and/or repeated violations of effluent limits and compliance schedule milestones -- and will require major construction to correct these problems.

At the same time that POTWS are finding it difficult to meet permit requirements -- such as more stringent limits on nutrients and toxins -- the federal share in construction costs and research of innovative and alternative technologies has decreased. In the 1987 Amendments to the CWA, Congress dramatically changed the federal role in financing wastewater treatment by shifting the responsibility for financing more than $83.5 billion in wastewater needs to the states and, in exchange, authorizing the federal government to provide $8.4 billion in capitalization grants for state revolving funds (SRFs) over six years. The 1987 Amendments also called for the termination of the Innovative and Alternative Wastewater Treatment Technology (I&A) Program after fiscal year 1990. Some say the lack of federal funding has adversely affected the operation and maintenance of POTWs and therefore improvements to treatment processes. According to EPA, the cost of municipalities' unmet needs for wastewater treatment facilities rose about $17.7 billion from 1988 to 1992 and totaled $108 billion in 1992.

III. Regulatory Framework

The Clean Water Act requires EPA and the states to set limits on the discharge of pollutants into rivers, lakes and other water bodies. In addition to placing controls on industry, the CWA requires cities and towns to build and maintain wastewater treatment plants that meet national standards for discharge pollutants.

The baseline level of treatment by POTWs is secondary treatment which should produce effluent quality of 30 mg/l (milligrams per liter) biological oxygen demand (BOD) and 30 mg/l suspended solids, or the equivalent of 85 percent removal of these conventional pollutants. These standards are technology-based insofar as they are based on what conventional technology could achieve at that time or because these specifications apply conventional technologies. If these treatment requirements are not sufficient, more stringent controls -- such as advanced levels of wastewater treatment -- are required in order to meet water-quality-based standards.

Each POTW is issued a discharge permit that establishes its effluent discharge rates in order to meet water quality standards, as determined by the uses of receiving water bodies, which may vary from state to state. Therefore, states have primary responsibility for designating stream segment uses, which lead to water quality standards and thus dictate discharge rates. Section 402 of the CWA provides the framework for issuing and enforcing permits for POTWs to ensure that pollutant discharges do not result in a violation of water quality standards.

In most cases, POTWs do not have difficulty meeting the baseline secondary treatment requirements, as treatment technologies for secondary treatment are well established. However, local water quality standards may be higher and more difficult to meet. Water quality standards that require stricter limits on BOD, suspended solids, nitrogen, phosphorus, copper, ammonia, chlorine residuals or toxic discharges are becoming very expensive for POTWS to meet due to the cost of installing additional treatment technologies to reach those stricter limits.

IV. Wastewater Treatment Technologies

Domestic wastewater is the spent water originating from all aspects of human sanitary water usage. Untreated domestic wastewater is typically composed of dissolved and suspended solids, biodegradable organics including pathogens (measured by BOD), nitrogen, phosphorus, oil and grease. BOD is commonly used to define the "strength" of wastewater by indicating the presence of bacteria, other microorganisms, and protozoa. These organisms are important because they play a fundamental role in the decomposition and stabilization of the organic waste in wastewater treatment plants.

Regardless of the technology used, wastewater treatment processes can be divided into five main categories:

- **Aerobic biological treatment** (with oxygen) such as activated sludge, rotating biological contactor, trickling filters, aerobic ponds or lagoons;

- **Anaerobic treatment** (without oxygen) such as suspended and fixed growth systems;

- **Land treatment** such as slow-rate systems, constructed wetlands, overland flow, or rapid infiltration where wastewater is land applied after some level of pretreatment;

- **Physical and chemical treatment** such as flocculation, sedimentation, heavy metal removal through precipitation and pH adjustment, chlorination, dechlorination, ozonation and ultraviolet radiation; and

- **Advanced treatment** such as nitrification and denitrification for nitrogen control, air stripping, ion exchange, phosphorus control, granular media filtration (sand, coal), carbon adsorption, activated carbon, reverse osmosis.

A. Conventional Treatment Technologies

Most major metropolitan areas and large communities use conventional systems with large sewers and well proven or established mechanized techniques to treat domestic wastewater. These technologies have been established for many years. According to one former professor of water engineering, "I was always astounded there was nothing new in our field. The stuff I was looking at in the 70's was just improving on what the Egyptians did 5,000 years ago. But that's changing now."

Conventional systems in general consist of activated sludge systems with chlorination to meet secondary wastewater treatment requirements. These systems employ a combination of physical (removal of solids), biological (killing microbes), and chemical processes (chlorination for final disinfection). These mechanical systems are highly engineered, treat relatively large quantities of wastewater in a small amount of space, and are advantageous in urban areas where land is costly and / or unavailable. Conventional treatment processes usually require substantial attention from operators, consume considerable amounts of energy, and produce residuals such as sludge that must be treated and disposed, especially in comparison to the demands of alternative technologies' natural systems.

B. Alternative and Innovative Technologies

According to an Environmental Business Journal (EBJ) report, "innovation in water / wastewater treatment technology has been held at bay by a market that is regulatory and cost-driven rather than technology driven." However, as the water / wastewater industry becomes increasingly price-sensitive, as shown by rising water and sewage treatment costs, the article predicts that "efficient water resources management, especially water reclamation, will drive more technically efficient solutions." EBJ ranked the relative innovation need for tertiary filtration of domestic wastewater as medium and for biological treatment technology of domestic wastewater as high. This reflects the gap in current research and development for these increasingly important technologies.

In general, an innovative wastewater treatment technology should meet two conditions. First, the technology or its application must include an inherent risk which is outweighed by benefit, thereby making the risk acceptable. Second, the technology should meet one or more of a series of criteria which measure its advancement over the state of the art in the wastewater treatment industry: 1) cost reduction, 2) reduction in use of energy, 3) improved removal or destruction of a pollutant, 4) improved operational reliability, 5) improved environmental benefits, and 6) potential for joint treatment of industrial and municipal waste. In the wastewater industry, innovation tends to be new applications of, or new improvements to, existing technologies that have not been fully proven for the proposed application, rather than completely new technologies per se.

The following gives the distribution of innovative technologies installed in the last 10 to 15 years. This data may lend perspective to the application of innovation in wastewater treatment technologies.

Innovative technology	Percent installed
aeration	11.4%
clarifiers	10.9%
sludge technologies	10.7%
disinfection	9.4%
lagoons	7.8%
nutrient removal	7.7%
oxidation ditches	7.0%
filtration	5.3%
energy conservation and recovery	5.0%
land application of effluent	4.4%
other	20.4%
Total	100%

Treatment technologies such as ozone, UV, biological nutrient removal, and oxidation are examples of innovative techniques experiencing increased acceptance and application. The following section describes these wastewater treatment technologies currently in use at a few POTWs.

1. Ozonation

Ozone (O_3) may be used for disinfection and oxidation of organics in both water and wastewater treatment plants. As a disinfectant at typical dosages of 3 to 10 mg/l, ozone is an effective agent for deactivating common forms of bacteria and bacterial spores, as well as eliminating harmful viruses. Additionally, ozone acts as a chemical oxidizer, and can reduce BOD and odor. Ozone has also been found to be a good oxidant for the removal of cyanide, phenol, and other dissolved toxic organic materials. The combination of ozonation and activated carbon treatment can achieve 95% removal of chloroform and other trihalomethanes. Effective pesticide destruction has been demonstrated when ozone is used in conjunction with UV radiation.

Ozone injection into the wastewater flow is accomplished by mechanical mixing devices, countercurrent or co-current flow columns, porous diffusers, or jet injectors. Ozone acts quickly and consequently requires a relatively short contact time. Limitations to the use of ozone are the high cost, especially compared with chlorination, and the complex series of mechanical and electrical units requiring substantial maintenance.

Ozone has been used in the water industry since the early 1900s, particularly in France, and it has been fully demonstrated but not widely used in the United States because of the high costs compared to chlorine treatment. One vendor of ozone technology stated that lack of information on the performance of the technology was the main barrier three or four years ago to ozone acceptance in the United States. However, recent developments in ozone generation technology have lowered costs and made it more competitive with other methods.

2. Ultraviolet Disinfection

Ultraviolet (UV) radiation is being used to disinfect drinking water as well as wastewater more frequently as reliable equipment has become more available. UV technology is about 50 years old and initially was used in industrial applications and later installed in small wastewater treatment systems. In the beginning, UV was not widely accepted because the equipment used at that time was difficult to operate. Over the years and after many demonstrations, technical improvements have been made to the process equipment. UV is a success story in the acceptance of an innovative technology as an alternative to chlorination.

UV light for disinfection is generated by special low pressure mercury-vapor lamps, which require regular cleaning. UV may also be laser generated although this method is less common. The inactivation of microorganisms by UV radiation is based on photochemical reactions in the DNA molecule that produce reproductive system errors. Advantages to use of UV include: no chemical consumption, low contact time, no harmful by-products, a minimum of or no moving parts, and low energy requirements.

Vendors of UV technology, however, point out that the technical improvements are not the only driving factors in UV acceptance for municipal wastewater treatment. UV has become more accepted as regulations are passed concerning the effects of toxins, especially residual chlorine, on receiving waters. As a result, POTWs have had to both chlorinate and then de-chlorinate their effluent before discharging, which is a costly procedure. There has also been growing concern about worker safety handling hazardous chlorine chemicals. UV achieves the same disinfection without chemicals and UV-treated effluent does not carry residual toxic compounds.

One major vendor of water and wastewater treatment technology, has provided UV systems for water treatment to a variety of industries, such as electronics manufacturers, pharmaceutical, food and beverage, power generation, and cosmetics companies, for more than 40 years. Only recently, through a joint venture with a German company, has this company applied the technology to domestic wastewater at municipalities and POTWs. According to a firm representative, POTWs are interested in UV because of toxic effluent discharge requirements. However, the POTWs are requiring on-site pilot tests first. The firm is willing to carry out these tests and bear the expense as a way to overcome the barrier of lack of knowledge and trust about UV technology.

3. Biological Nutrient Removal

Biological nutrient removal (BNR) is defined as any biological process that removes nitrogen, phosphorus, or both beyond that typically obtained by conventional secondary treatment. Since phosphorus and nitrogen are the key nutrients leading to growth of algae and aquatic plants associated with eutrophication, controlling these nutrients is very important to maintaining water quality standards. In addition, ammonia nitrogen, the most common form of nitrogen from POTW effluent, is toxic to fish at relatively low concentrations and can exert a significant oxygen demand on the receiving waters.

Some of the earlier technologies included air stripping and ion exchange to remove ammonia (South Lake Tahoe plant in 1969), nitrifying trickling filters to control nitrogen (Huntington Village Plant in 1973), and chemical precipitation (addition of lime, aluminum and iron salts) to control phosphorus (Lower Potomac Pollution Control Plant in 1969).

With BNR, the control of nitrogen in wastewater begins with nitrification for oxidization of ammonia-nitrogen and, if required, ends with denitrification to reduce nitrates and nitrites into nitrogen gas. Phosphorus is removed through biological uptake by microbes and careful control of oxygen content, pH, and temperature of the waste stream.

BNR processes have proven successful and are commonly being used in municipal wastewater treatment plants nationwide. The first treatment process combining both biological phosphorus and nitrogen removal was in Palmetto and Largo, Florida in 1979 using a modified "Bardenpho" process. Under this process, nitrogen removal is accomplished by biological denitrification, and phosphorus removal by microbial uptake into the waste activated sludge. In the nearly 20 years since the first application, BNR has become well established. The number of operating facilities has increased from two or three in the early 1980s to nearly 300 today.

New regulations from EPA and ecological studies on the effects of toxins and nutrients have caused a shift in focus on water quality initiatives away from conventional pollutants which are controlled by secondary treatment, towards control of nutrients, toxins, pathogens and contaminated sediments. This has changed water quality standards that establish the type and configuration of treatment methods.

Many large urban cities in the northeast and midwest are now facing the need to provide nutrient removal. However, there are some obstacles to nutrient control implementation through BNR. First, POTWs in these urban areas are often located in fully-developed areas with limited room for additional tanks and facilities. To retrofit these plants for nitrogen removal can be expensive. Second, characteristics of the wastewater, such as the seasonal cold temperatures, may not be suitable for BNR. Also most owners and designers of POTWs prefer to select established wastewater treatment methods, not the less proven nutrient control innovations. This is usually because of the great risks associated with a failed technology, such as permit violations, possible enforcement actions, and public health problems. However, wastewater plants are beginning to face a combination of demands in terms of cost, performance and physical restrictions, that cannot be easily met with existing technologies.

Thus there is a new incentive to look closely at technologies that potentially require less land area, provide better control of aesthetic impacts, and may be less expensive. Some of these methods include improvements to multiple pass step-feed aeration basins, fixed film enhancement in suspended growth reactors, membrane technology to enhance solids-liquids separation, and biological filters (submerged filter media).

The Mason Farm Plant in Carrboro, North Carolina and the Little Patuxent Water Reclamation Plant in Savage, Maryland are examples of wastewater treatment plants that are currently using innovative BNR processes. Mason Farm uses a single stage "nitrification" process for BNR and chlorine for disinfection. The "nitrification" process was developed by its operator, the Orange Water and Sewerage Authority. It achieves denitrification and phosphorus removal without adding chemicals by using primary solids fermentation and side stream treatment to denitrify the return activated sludge and induce biological phosphorus removal. Through these methods, Mason Farm is achieving an effluent quality conventionally considered unattainable without adding a tertiary process.

Howard County in Maryland selected an anaerobic-anoxic-oxic configuration for nitrogen and phosphorus removal to meet the requirements of the 1988 Chesapeake Bay Basin Wide Nutrient Reduction Strategy. The existing plant was retrofitted to implement the BNR process. Usually advanced nutrient removal upgrades are expensive. In this case, Howard County's costs were kept down by participating in the Maryland Department of the Environment (MDE) biological nutrient removal grants program that funds up to 50% of the capital cost of BNR projects. The Maryland program provides incentives to help communities achieve nutrient removal goals and encourage municipalities to consider innovative BNR technologies.

4. Enzyme Technology

Enzyme technology has been in existence for more than 15 years, but only recently has this technology been applied to treat municipal wastewater. Enzymes are biological products isolated from their host organisms that act as catalysts for biological processes to break down or remove pollutants by increasing the rate of the desired reaction. Enzymes have been applied in industrial laundry operations to eliminate harmful bacteria and in soil remediation to break down hydrocarbons. Enzymes have also been used for pest control and to prevent algal buildup in drip irrigation systems. Enzymes can be applied to both specific or broad applications.

As discussed earlier, bacteria and other organisms are the basis for biological secondary treatment for wastewater, such as activated sludge and biological nutrient removal processes. With enzyme technology, enzymes added to the wastewater carry out the same biological operation as these organisms. The benefit of using enzymes is the reduction of waste sludge (cell material) from wasted and killed bacteria that is normally generated by employing the other methods.

A relatively new company just two years old, has started to market their enzyme technology to municipalities and POTWs. The first application of their product was at a food processing plant which discharged its wastewater to a POTW. The POTW at the time was in the process of increasing its industrial user fees based on the influent quality (BOD and total suspended solids) from their industrial users. The company conducted a full-scale demonstration at the food processing plant and reduced the BOD load by 50% and the total suspended solids by 45% using enzymes. As a result, the total surcharge fee from the POTW decreased.

Interest in enzyme technology for wastewater treatment applications is growing, but mainly internationally. This particular firms has linkages with engineering design firms in Brazil and India. A demonstration project is planned in Poland, financed through the United Nations and the World Bank. Breaking into the U.S. domestic POTW market, however, is difficult. A company representative stated that they face several barriers with POTWs. Municipalities and their consulting engineers are conservative and not anxious to change; it is difficult to convince municipalities to examine the economic benefit of using their product; and information and education about enzyme technology is lacking on the part of design engineers, state regulators and municipalities. The firm plans to reduce these barriers by stepping up an educational campaign and by conducting demonstration pilots.

5. Land Treatment Systems

Natural treatment and collection systems are designed to treat municipal wastewater to meet secondary treatment standards and are best suited for areas of low-density development and small communities. They require large amounts of land so as to utilize soil, vegetation, and aquatic environments as treatment or disposal media. They employ few mechanical parts, use little energy, and have lower construction, operation, and maintenance costs than conventional treatment systems. In addition, they operate on a more simple model, demand fewer and less-skilled staff to operate, and produce less sludge. Large communities can use these systems by themselves or in combination with mechanical systems. Their land requirements, of course, reduce their advantages in densely developed areas. Several such alternative, natural-based treatment systems are described below.

Constructed wetlands, aquaculture, or marsh systems treat raw or partially treated sewage. They also can reduce further pollutant levels from effluent of other treatment processes such as a lagoon. In a constructed wetland, wastewater flows through beds of marsh plants grown in soil or gravel. This low cost system requires little attention and may be operated year-round. It requires relatively little land in comparison to other land treatment systems.

Overland Flow Systems apply wastewater at the top of a gently sloping hill and collect it at the bottom of the hill. During its downhill journey, evapotranspiration and limited percolation treat the wastewater. Upon collection, the wastewater is disinfected and discharged. These systems can treat wastewater from a lagoon. The system needs limited attention; the operator periodically should move and remove grass, which may be marketed as hay. Rural areas with large amounts of pasture or meadow lands and tight soils can use this type of system to their benefit.

Slow-Rate Land Application, also called spray irrigation, consists of soil-based treatment that applies effluent at a controlled rate to a vegetated soil surface of moderate to slow permeability. The wastewater is used as a component of irrigation. It is applied by spraying or flooding furrows, for example sprinklers apply wastewater to cropland, woodland, golf courses or other vegetated areas. Generally this process does not discharge effluent into surface water. This system can be used with lagoon effluent, also.

Lagoon technology refers to a stabilization pond or aerated (oxygenated) lagoon. It consists of a shallow impoundment in which wastewater is treated by natural processes without the aid of mechanical equipment or chemical additives. The aerated lagoon operates in the same manner except it uses mechanical equipment to enhance the aeration process. Stabilization ponds require about 1 acre for every 200 people served, and aerated lagoons require 1/3 to 1/10 as much land.

V. Barriers to Innovative Technologies

Inventors, manufacturers, and vendors of any new and innovative environmental technology must overcome typical market barriers of product acceptance, brand recognition and consolidation. However, in the POTW market there are a number of additional barriers that impede the use of innovative wastewater treatment technologies that are specific to the regulatory framework and nature of how POTWs operate. Summarized below are the five main categories of barriers identified by ELI from our research and discussions with representatives from trade organizations, EPA and technology vendor companies.

A. Lack of Funding

The estimated cost of constructing the municipal wastewater treatment facilities needed to comply with CWA standards (e.g., limits for conventional pollutants such as BOD and pH, toxins, nutrients, and pretreatment programs for industrial discharges) is rising. According to the Water Environment Federation, EPA's latest assessment of national wastewater treatment needs shows that almost $150 billion will be necessary to meet current program requirements for municipalities. Major funding needs include secondary treatment facilities, minimum combined sewer overflow controls, and water quality permitting.

Although there are major unmet needs in water treatment infrastructure, traditional sources of finance are declining. User fees are increasing at a rate 2.6 time that of inflation and now account for 60% of POTW revenues (up from 52% in 1992), but they have not made up for the decline in federal funds and bond proceeds. The resulting lack of funding has led many cities and counties to postpone both the rehabilitation of old plants and the construction of new ones. Therefore very few POTWs are investing in the purchase of innovative technologies.

In the past, federal funding has been the cornerstone for financing compliance with regulatory standards and construction of wastewater treatment plants mandated by the CWA. Billions of dollars have been invested to help state and local governments meet national clean water goals. However, the 1987 Amendments to the CWA shifted major responsibility for financing wastewater needs to the states and provided only limited federal funding.

EPA funding for research has also dropped since 1979, and other public sector funding of wastewater treatment research and development is limited. GAO reported in 1994 that "EPA officials said that current funding levels have prevented the agency from keeping abreast of emerging technologies." During the 1970s and 1980s, EPA vigorously promoted the wider use of alternative systems through its I&A Program and technical transfer activities authorized under CWA. Since the discontinuation of this program, "information that is critical to the use of alternative wastewater systems has not been developed or disseminated to those who could use it."

Of special note is the I&A Program's modification and replacement provision which made allowances for the flaws and failures inherent in new technologies (often cited as a barrier). Many assert that the loss of EPA's technology transfer activities hinders the wider use of alternative technologies. In the past, critical components for promoting them were EPA's independent evaluation of alternative technologies, publication of technical manuals reflecting these evaluations, and dissemination of this information through workshops and training seminars.

GAO recognized the need to increase resources for state and local governments which operate POTWs. Aside from federal funding, alternative financing mechanisms include taxes and fees for wastewater treatment. Other suggestions for augmenting funds are a national or state trust fund to be capitalized by a charge added to sewer bills, tax incentives for private investment in wastewater treatment plants, and development of regional authorities or cooperative agreements between rural authorities to help small local governments meet wastewater treatment needs more efficiently.

Thus, while increasing demands are being placed on POTWS to meet more stringent limits on nutrients and toxins, federal support for construction costs and research of innovative and alternative technology projects has decreased. Although POTWs ar developing new revenue sources, the history of state control of POTWs and dependence on federal funds has meant that alternative sources are slow in developing, delaying capital investments.

B. Conservatism of Municipal and State Administrators

Municipal and state managers of wastewater treatment plants are reluctant to approve or purchase anything that has not been well-proven. They tend to be conservative because their mandate is to protect public health and the environment. One technology vendor observed that "municipalities are the real challenge. There is a fundamental difference between new technology for the [micro]chip business and new technology for the water business. The municipal customer is by his very nature conservative. He's reluctant to risk the public with some new fangled device, so getting the first few installations always takes a long time."

This hesitancy about using new technology in turn discourages private investment in future advanced or cost-effective technology. Reinforcing this tendency are financial disincentives within the private sector to design or construct facilities that employ alternative systems. Consulting engineers are concerned about financial liability and reputation if a system fails, and may also earn higher compensation on more expensive traditional projects, which may also take less time to design than newer alternative systems. This may bias them against selection of innovative technologies.

The lack of comprehensive and current information on innovative wastewater technologies' applicability, performance, and cost further reinforces resistance to their greater use. Engineers, plant operators, and municipal officials may be largely unfamiliar with innovative and alternative wastewater treatment technologies, and also state regulators who are unfamiliar with innovative or alternative technologies are less likely to approve their use.

Others believe that municipalities' conservative approach is due to their monopoly position and the lack of privatization. Information from Environmental Business International shows that currently less than 5% of the $24 billion wastewater treatment industry is privately owned, significantly less than even in other utility sectors. Some see the lack of competition as a reason that municipalities do not make an effort to improve plant performance and perhaps are not willing to take risks with new or innovative technologies.

Research has been conducted on the slow growth of the private market, identifying the barriers to privatization. Obstacles to private ownership include the restrictive federal subsidy program under CWA, which precludes private ownership of wastewater facilities built with federal grant money, unless the grant is fully repaid. Although a 1992 Executive Order liberalized this requirement, sources say provisions have not lived up to their promise. In addition, the CWA regulates private municipal facilities as industrial, not municipal, sources.

C. Restrictive State and Local Codes and Regulations

1. Procurement Requirements

State procurement laws that require competitive bidding or awards to the lowest cost bidder may discourage the purchase of innovative technologies. Many of the current state procurement rules were based on the federal procurement rules used during the federal construction grants period. When that program ended and SRFs began, the states adopted their own codes, and many placed very narrow and strict procurement requirements on bidding processes which reduce the level of technology allowed to the lowest common denominator.

A significant barrier is created by laws in many states which specify that there must be at least two competitors in order to bid on a state contract. If a vendor has a unique technology or is other only firm to present the innovative technology, it can't be considered. There must be someone else with the same new technology. For example, California's rule has a three brand name or equal rule, while North Carolina's procurement statute states that, if the specifications are not submitted for open bidding, the engineer can lose his or her license. Currently, the Water and Wastewater Equipment Manufacturers Association, Inc. is conducting a detailed study of state procurement rules.

One example in California involved a fine bubble diffuser with a proprietary membrane for aeration that was proposed for a POTW. This equipment required less electricity than the conventional bubble diffuser, which led the local electric utility to promise to contribute $100,000 to help the POTW purchase the equipment. However the proprietary membrane had no competitor. According to the vendor, California's regulations for the state revolving fund prohibit the use of a sole source for water treatment and wastewater treatment equipment. In the end, the more efficient aeration equipment was not purchased.

Others maintain that procurement regulations are not a major barrier. According to Richard Kuhlman, Branch Chief for the State Revolving Fund Program at EPA, the federal regulations for these funds do not require nor forbid states to consider innovative wastewater treatment technologies. Evaluation and selection of treatment technologies is at the discretion of state authorities. In fact, some states offer incentives for the use of innovative technologies, such as low interest rates on loans through the SRFs. Some states require performance bonds and pilot tests of new technology to reduce the risks involved. The key issue is not the procurement rules, but the state engineers' approval processes for expenditures from SFRs because they tend to be conservative and approve only conventional technologies.

State procurement laws also generally require awarding state contracts to the lowest bidder. Often the bids do not include operation and maintenance (O&M), but only the up-front capital expenditures. Innovative technologies with higher up-front costs but with lower operation and maintenance costs would therefore be eliminated from lowest bidder competitions.

The GAO has noted another limitation which discourages innovation are the time limits imposed by the state procurement process: "When EPA (or a state) directs a community to build a treatment facility within a tight time frame, the community and the consulting engineer may select a conventional system to avoid the additional time that may be required to design and receive approval for an alternative system."

2. Performance Specifications Based on Older Technologies

State and local codes and regulations can restrict or actually prohibit the use of innovative wastewater treatment technologies because many codes contain performance specifications that apply only to conventional technologies. For example, some states have standards for retention times in flocculation basins or clarifiers that are now out of date with currently available technology which reduces the amount of retention time required.

Also there is a compilation of water and wastewater design standards known as the Ten State Standards, first written in the 1960s for the states in the Ohio River Basin, to which many engineers and state authorities continue to refer. These standards are engineering design specifications based on conventional technologies to meet secondary treatment. This guidebook delineates sizes of aeration tanks, amount of chlorine for disinfection, etc. These standards are periodically updated, but for conventional treatment only. Innovative technologies are not included.

D. Variations in State Effluent Standards

It is very difficult to invent one technology that will apply to all wastewater and meet all effluent criteria because these parameters vary from location to location. What works in one state does not guarantee success in another or even just down the road. Because of these variations, developers and vendors of new technologies will always have to conduct many pilot tests to demonstrate their products, which is very costly.

V. Conclusion

Selection of wastewater treatment technology depends on the physical characteristics of the treatment site, the configuration of the community, the level of necessary treatment, and the characteristics of the wastewater to be treated. Innovations tend to be improvements to existing treatment methods, some of which are centuries old. But still there is resistance to the use of these innovative technologies.

POTWs are public agencies which, unlike private sector entities, do not compete with each other and do not fear being closed down for permit violations. POTWs provide a public service that a town or municipality cannot do without. Although these conditions should make POTWs more open to trying new treatment techniques, POTW plant managers, design engineers, state regulators and municipalities are considered to be extremely conservative and typically do not embrace new technologies.

Two of the barriers identified through this research may came as no surprise: the lack of funding and the conservative nature of POTW operators, designers and regulators. According to a GAO report on alternative wastewater treatment systems, EPA plans to address the conservative nature and lack of knowledge barriers by gathering and disseminating information on various technologies. Also EPA plans to analyze and disseminate information about the performance of technologies from the I&A program discussed above which still have not been seriously reviewed, considering that the I&A program ended in 1990.

Some say privatization is the answer and privatization is a current, if slow, trend for POTWs. Some hope that this will increase the acceptance of innovative technologies for cheaper, better, faster wastewater treatment. In the larger context, cities and municipalities are beginning to be compete with each to attract businesses, jobs and more residents. Assets of a municipality include its water quality and natural environment. POTWs discharging into waterways play a significant role in quality of municipalities natural environment. Perhaps this competition will serve as push towards finding better and cheaper ways for treating wastewater.

In addition, attention needs to be focused on regulatory barriers such as state procurement practices and special state programs that may also be used either to inhibit or promote the use of these innovative wastewater treatment technologies.

Although regulation has been a driving force to improve quality of surface water and develop basic waste-waster treatment plants and standards in the early decades of the Clean Water Act, in the eyes of many vendors these regulatory specifications are now out of date. They have gone from being drivers to becoming barriers. Vendors encourage the elimination of technology-based specifications and standards a move towards performance measures to meet water quality based standards.

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Chapter Eight:

Conclusion

These case studies reveal many types of both regulatory and business barriers to innovation. Key regulatory barriers appear to stem from the fundamental precepts embedded in our pollution laws oriented toward pollution control and disposal. Many laws explicitly require control technologies through standards such as BACT and RACT, and RCRA's "cradle to grave" system may preclude "cradle to cradle" recycling. Other regulatory barriers not specific to environmental laws include procurement requirements and consumer labelling laws.

While the current regulatory system has served us well, it creates barriers to more integrated approaches that implement pollution prevention concepts and promote industrial ecology. Perhaps our regulatory system should emulate the only complex system that has endured over time -- millions of years -- which is our ecosystem. In nature, all energy is renewable, and complex and elegant systems of recycling blur the distinction between wastes and inputs. This difference may indicate our environmental regulatory system is not paying adequate attention to the fundamental nature of energy sources, nor placing adequate emphasis on recycling and reuse.

The case studies also reveal many significant business-related barriers to innovation. While not specific to environmental technologies, these barriers must nonetheless be addressed. Key barriers like the lack of private funding for research on innovative technologies, especially basic research, need to be overcome through creative policy mechanisms. We need to also address fundamental issues like the nature of supply drivers through tools such as pollution taxes and other incentives, as well as by redirecting consumer demand and eliminating inappropriate subsidies. Only then can our currently adequate environmental system move to become an excellent one.

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