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Searching for the Profit in Pollution Prevention:

Case Studies in the Corporate Evaluation of Environmental Opportunities

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EPA initiated this research to more fully illuminate the challenges facing industry in the adoption of pollution prevention (P2) opportunities, and to identify issue areas that can be studied and addressed by policy-makers and industry. *The case studies in this paper describe three P2 projects that were chosen for analysis precisely because they were in some way unsuccessful.* This analysis, based on a small and non-random sampling, is not necessarily representative of the experiences of all companies or all P2 investment possibilities.

Searching for the Profit in Pollution Prevention: Case Studies in the Corporate Evaluation of Environmental Opportunities*

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Resources for the Future

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The concept of pollution prevention, or "P2," is emblematic of a new, proactive environmental mindset that promises more sustainable industrial management. By targeting the causes, rather than the consequences, of polluting activity, P2 seeks to eliminate pollutants at their source and thereby avoid the need to treat or dispose of those pollutants later. The P2 concept has given rise to talk of win-win opportunities in which innovation and new ways of thinking will lead to waste reduction and, at the same time, make firms money by reducing costs or stimulating new products. Unfortunately, the vision of pollution prevention as a set of win-win opportunities is somewhat at odds with actual corporate experience. While anecdotal evidence from a number of studies suggests that such opportunities exist and that many firms have pursued them, proponents say the pace of P2 is too slow and that the private sector is somehow failing to see opportunities in front of it.

Very little is actually known about how and why, in the real world, firms pursue or do not pursue pollution prevention. To address this deficit, this report presents case studies of P2-related decisions made at three different firms, all global chemical manufacturers headquartered in the United States. A particular type of business activity was sought for analysis.

First, the investment or product marketing effort had to involve a pollution prevention opportunity. Pollution prevention was defined as a new product or process that allowed for pollutant source reductions or that involved in-process recycling. Second, the investment or marketing opportunity had to be promising enough to be technically and financially evaluated by the firms themselves. Third, the investments or product had to be in some way "unsuccessful." That is, the firms chose to not invest in the product or process changes, or investment was significantly delayed, pending the resolution of market, technical, or regulatory uncertainties. For the purposes of this project, unsuccessful P2 opportunities are of greatest interest because they allow us to focus on the corporate rationale for *not* making P2 investments. Fourth, the study sought projects with a capital, technical, or marketing "scale" sufficient to ensure a certain degree of complexity to the decision. Finally, the analysis required the participating firms to provide detailed, often proprietary, data on the projects considered.

The cases open a window onto business decision-making generally, and environmental decision-making specifically. They allow for a deeper understanding of the relationship between pollution prevention and corporate profitability. It should be noted, of course, that three, non-randomly selected cases cannot be used to draw broad policy or empirical conclusions. Instead, they should be viewed as a lesson on the practical challenges facing private sector managers. Regulators, policymakers, and other corporate managers can presumably benefit from a better practical understanding of corporate P2 decision-making.

The cases shed light on the following types of questions: Are firms really passing up P2 opportunities that could save them money? Do firms' current financial and accounting practices treat environmental investments differently from other investments? What hurdles must P2 investments clear? Do firms evaluate P2 opportunities in a defensible manner, or are there persistent organizational biases against P2, perhaps due to inappropriate accounting procedures or incentive schemes? Are there unambiguous financial benchmarks that can be used as a guide to which P2 projects should go forward?

The cases reveal the kinds of technical, regulatory, and informational issues that are likely to face any firm contemplating P2 innovations. While based on a very limited sample, the evidence contradicts the view that firms suffer from an inability to appreciate profitable P2 investments. Using concepts from business and financial theory to analyze the decisions that were made, the study concludes that the investments were financially unattractive because of significant unresolved technical difficulties, uncertain market conditions, and, in some cases, regulatory barriers or insufficient emissions enforcement. In many cases, the mystery of why a P2 opportunity was not successful can be resolved simply by taking a closer look at the costs, benefits, and risks involved.

Principles Illustrated by the Cases

The cases concretely illustrate a set of more general principles relating to the technical, regulatory, and financial challenges facing P2 project evaluation and implementation.

1. Technical issues

P2 projects will often present complex technical challenges that have important implications for financial analysis.

> *In complex manufacturing operations, even a relatively small pollution prevention process change may require changes in a whole set of interrelated processes. If so, the pollution prevention option cannot be analyzed financially without a technical, financial, and regulatory analysis of these other required process changes.*

Moreover, firms must often bear costs in order to estimate the costs of potential new projects.

> *Formal financial analysis may in some cases be moot, if technical uncertainties associated with the project cannot themselves be resolved at reasonable cost.*

Before financial analysis can occur, the firm must be able to identify the new technologies and processes that will be required by the project. In order to come to that specification, however, numerous questions must be answered.

2. The implications of uncertainty

Uncertainties, whether market-related, technical or regulatory, can fundamentally alter the economics of a project decision. For instance, uncertainty can in some cases create an incentive to delay action.

> *With some investments, there is value in the delay of a project decision. Delay allows for resolution of uncertainties and the avoidance of irreversible, and potentially wasted, investments.*

In economic parlance, there may be a significant "option value" to delayed investment arising from unresolved uncertainties.

3. Regulatory pressure and regulatory barriers

Effective regulatory enforcement may be important to the development and marketing of P2 products. Meaningful monitoring and compliance efforts, particularly those directed at under-regulated firms, increase the financial value of new products that provide P2 solutions.

> *Existing effluent standards can act as a powerful motivator for pollution prevention by creating markets for technologies that can address firms' compliance issues.*

While effective regulatory enforcement is in some cases central to the creation of markets for P2, some forms of regulation can stand in the way of P2.

> *In some cases, regulatory rules can raise the costs of supplying and using pollution prevention technologies. This can have the unintended consequence of inhibiting the diffusion of technologies with desirable environmental characteristics.*

The desire to experiment with P2 innovation is often thwarted by rigid media- and technology-specific regulations.

4. The (unsuccessful) search for clear financial benchmarks of P2 profitability

Financial analysis of any investment is as much an art as it is a science. The complexity of factors employed in a sound investment analysis and incomplete information regarding future market, regulatory, and technical conditions mean that calculations of financial return need to be viewed with caution and sophistication. For instance,

> *Accounting techniques must be evaluated in order to determine whether reported benchmark figures (such as rate of return) are viewed by management insiders as complete and unbiased. Managers are likely to better understand the ways in which their own analyses are biased. If so, benchmark figures must be interpreted with care, particularly by outside analysts.*

While the “rate of return” to P2 projects seems a natural metric of desirability, even that measure must be weighed against a larger set of factors.

> *Rate of return is relevant only as it compares to a project’s cost of capital. Moreover, the cost of capital is not typically easy to measure, since it is intimately related to project risk. Thus, the implication of a particular rate of return figure for decision-making requires detailed knowledge of factors contributing to risk.*

No single rate of return “hurdle” can be used as a benchmark for judging an investment’s profitability.

Conclusions and Implications for Public Policy

Rather than organizational barriers or myopia, the cases reveal a set of complex but ultimately rational motivations for the decisions made by managers. Appreciation of those motivations is important because it can help guide public- and private-sector efforts to improve corporate America’s pollution prevention performance.

This analysis’ conclusions should not be taken as either a defense or condemnation of the firms’ environmental performance. The “right” level of pollution prevention to be undertaken by the corporate sector is a question left to a different study (though it is worth emphasizing that regulations, and the avoidance of regulatory costs, were in all the cases a “driver” that motivated the firms’ search for pollution prevention). Still, without a detailed accounting of social benefits and costs, little can be said about whether more or less stringent regulation was appropriate in these cases. Instead, the cases say much more about *the way* in which firms are regulated.

The report advocates more extensive experimentation with flexible, “performance-based” regulations. P2 increasingly calls for firms to engage in the redesign of complex products and processes in ever-changing product markets. Performance-based regulations, which allow greater latitude for technological experimentation via product and process reconfiguration, will enhance the expected financial value of truly innovative approaches to pollution prevention.

1. Introduction

For the last 25 years environmental regulation and private sector environmental management have focused on end-of-pipe emission reductions and remediation of existing soil, air, and water pollution problems. This "compliance-driven" approach to regulation was largely dictated by the scope of environmental problems left by decades of relatively unhindered industrial production and the urgency of legal and institutional reforms needed to foster improvements. With significant environmental improvements, however, has come a greater emphasis on more forward-looking and flexible environmental strategies. Instead of reacting to pollution that is about to be (or already is) released to the environment, regulators and the private sector are turning to environmental strategies that target the causes, rather than the consequences, of polluting activity. "Pollution prevention" (P2) is at the heart of this new prospective mindset. Pollution prevention seeks the most direct resolution of environmental problems -- the elimination of pollutants via source reduction or recycling before treatment or disposal become issues.

Pollution prevention is a challenge for the private sector because it requires diverse forms of innovation. Pollution prevention can require the redesign of products, the reconfiguration of manufacturing processes, and the realignment of supplier and customer relationships. Because innovation is difficult, often costly, and inherently uncertain, firms must also find new ways of integrating environmental concerns into the corporate planning process. This paper seeks to illuminate the way in which firms are confronting these challenges. Through the use of case studies, the paper provides a window into the corporate evaluation of opportunities for P2 innovation.

The way in which the private sector approaches pollution prevention is pertinent to a large set of ongoing environmental policy debates. Calls for pollution prevention are at the center of a broad regulatory and corporate movement. Information-based programs such as the Toxics Release Inventory and experiments with flexible regulation, such as those associated with the Common Sense Initiative and Project XL, are united by their ultimate goal of pollution prevention.[1] Within the private sector, there is talk of "sustainable corporate environmental management," which inevitably centers on firms' ability to prevent, rather than

[1] The Pollution Prevention Act of 1990 was the first federal legislation geared toward fostering this new way of thinking. It has been accompanied by state-led legislation and programs and calls for further federal legislation. These statutory approaches are diverse, but they all attempt to motivate pollution prevention via a combination of information disclosure, mandatory prevention planning, and voluntary commitments. For an overview of the history and current status of the pollution prevention movement, see EPA (1997). Another good summary document is Freeman, *et al* (1992).

treat or dispose of waste.[2] A commonly expressed belief within this movement is that pollution prevention is a "win-win" corporate strategy. In this view, innovation and new ways of thinking will lead to waste reduction, and at the same time, make firms money by reducing costs or stimulating new products.[3]

Pollution prevention, cast as both a corporate and an environmental benefit, has ignited hope in less adversarial environmental regulation. It has also created optimism in the private sector's ability to come up with low-cost solutions to their environmental problems. Unfortunately, the vision of pollution prevention as a set of win-win opportunities is somewhat at odds with perceptions of actual corporate behavior. While anecdotal evidence suggests that win-win opportunities exist, and have been pursued by many firms, there is some frustration that the pace of change is inadequate.

The idea that pollution prevention can save firms money, but that they nevertheless neglect these opportunities, colors debate over regulatory reforms geared toward pollution prevention. For some, it calls into question the desirability of regulatory reforms often associated with pollution prevention, such as regulatory flexibility. If firms cannot be counted on to make environmental improvements that save them money, the argument goes, then only the blunt instrument of command and control regulation can be counted on to get the job done.[4] Others undoubtedly consider failures to invest in profit-making pollution prevention a further example of corporate environmental intransigence.

Another line of thinking holds that "organizational barriers" account for firms' failure to be aware of and pursue win-win investments. Organizational barriers may arise, for example, due to information barriers, accounting-based distortions, or inappropriate

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[2] DuPont claims that over the last 10 years the company has shifted its environmental technology effort from 85 percent investment in pollution control to 60-70 percent investment in "green" products and pollution prevention (Pelley, 1997, 138).

[3] Barry Commoner expresses the view as follows: "The strategy of prevention cures the conflict between environmental quality and economic development that is inherent in the control strategy ... Properly designed, the productive investments engendered by the strategy of prevention could trigger a much-needed economic renaissance" (Commoner, 1994, 217).

[4] One analysis of waste reduction at chemical plants concluded that waste reduction was brought about in some cases only when required by regulation to do so, but that the plants found the measure to be "cost-effective once in practice" (Sarokin *et al*, 1985). This type of result suggests that command and control regulations, in some cases, lead to both lower private sector costs and improved environmental quality and that private sector managers were unable to identify the opportunity themselves.

For a recent study with a similar overall perspective, see the NRDC study referred to in section 3 of this paper (Greer and van Loben Sels, 1997).

managerial incentive schemes.[5] The policy implications of this perspective point toward regulatory assistance or requirements focused on internal management and accounting processes.

For their part, corporate environmental managers tend to be more skeptical of pollution prevention's profitability.[6] They point to regulatory barriers that reduce the financial incentive to change production processes or introduce new products with uncertain regulatory mandates.

Much of this debate hinges on whether pollution prevention can actually be counted on to save firms money. Consider the implications of evidence that companies fail to pursue pollution prevention opportunities that would profit them. First, this evidence would lend credence to the argument that regulations should mandate pollution prevention.[7] Second, it would point toward the need to reform private sector capital budgeting, accounting, and environmental management techniques to overcome organizational barriers to P2. If, on the other hand, pollution prevention's economic benefits are overstated, a different set of issues arises for regulators and firms. If firms do not pursue pollution prevention because it is simply not profitable to do so, attention should be focused on factors that contribute to the difficulty, cost, and benefit of implementing P2 innovations. Perhaps environmental costs are not being adequately imposed on the firms creating them. Perhaps technical assistance and government R&D could be used to lower technical barriers. Or perhaps regulatory reforms should be used to lower regulatory barriers to P2 product and process changes.

These issues are of central importance to the future of environmental regulation. Unfortunately, very little is known about why -- in the real world -- firms pursue or do not

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[5] As an example, Porter (1995, 131) suggests that assignment of environmental issues to corporate departments without full profit responsibility leads to excessively narrow and incremental decisions. He also suggests that firms use inappropriately high hurdle rates to screen environmental investments.

[6] Evidence on the profitability of P2 opportunities is decidedly mixed. For instance, an Environmental Protection Agency study (EPA, 1992) evaluated a broad set of source reduction options at a large-scale petroleum refinery. Most of the options were found to have negative rates of return and only one had a rate of return higher than the historical rate of return for projects at the refinery. This type of evidence runs counter to the hope that there are plentiful, undiscovered, win-win P2 opportunities. However, the EPA also has been able to develop an extensive set of case studies depicting P2 successes. For examples see the Environmental Accounting Project's web site (www.epa.gov/opptintr/acctg).

[7] The state of New Jersey has pioneered mandatory P2 planning. A study of New Jersey's experience suggests that mandatory planning leads to more ambitious corporate P2 goals and can help reveal opportunities for cost savings (Natan, *et al*, 1996).

pursue pollution prevention opportunities. The case studies presented in this paper seek to fill that void by analyzing real-life pollution prevention investment decisions. The first two cases deal with investments that did not survive their firms' capital budgeting process. The third involves difficulties associated with a pollution prevention product being marketed to a large group of commercial customers (who themselves are deciding whether to invest in pollution prevention). With the cases, the study hopes to shed light on private sector environmental decision-making. In turn, this will shed light on the ways in which public policy can best promote pollution prevention.

2. Design of the Study

The study centers on pollution prevention initiatives at three different firms, all global chemical manufacturers headquartered in the United States. A particular type of business activity was sought for analysis.

First, the investment or product marketing effort had to involve a pollution prevention opportunity. Pollution prevention was defined as a new product or process that allowed for pollutant source reductions or that involved in-process recycling. Environmental benefits had to come from these types of innovations, not from new disposal or treatment methods.

Second, the investment or marketing opportunity had to be promising enough to be evaluated by the firms themselves. More specifically, the opportunity had to involve not only technical, but also financial, analysis. The financial analysis is critical. Even if a pollution prevention technology passes muster in engineering labs or environmental health and safety meetings, it will not succeed in a practical sense unless it survives a firm's strategic analysis and capital budgeting process. Strategic and financial analysis is the key corporate decision-making nexus. It is the decision-making activity during which the widest variety of internal corporate expertise is brought to bear to evaluate costs, rewards, and risks. What types of information are collected? How is the information used? Since investment analysis is the principal information-processing function of a corporation, firms' investment analyses are the best place to look for answers.

Third, the investments or product had to be in some way "unsuccessful." That is, the firms chose to not invest in the product or process changes, or investment was significantly delayed, pending the resolution of market, technical, or regulatory uncertainties. For the purposes of this project, unsuccessful P2 opportunities are of greatest interest because they allow us to focus on the corporate rationale for *not* making P2 investments.

Fourth, the study sought projects with a capital, technical, or marketing "scale" sufficient to ensure a certain degree of complexity to the decision. P2 opportunities on a smaller scale (e.g., equipment purchases, certain chemical substitutions, general shop-floor housekeeping) are important, and may be easier to achieve, but lack the complex range of factors that impact large-scale business decisions.

Finally, the analysis required the participating firms to provide detailed, often proprietary, data on the investments considered. Only with this level of detail was a full portrayal of the decisions possible.

The cases open a window onto business decision-making generally, and environmental decision-making specifically. They allow for a deeper understanding of the relationship between pollution prevention and corporate profitability. It should be noted, of course, that three, non-randomly selected cases cannot be used to draw broad policy or empirical conclusions. Instead, they should be viewed as a lesson on the practical challenges facing private sector managers. Regulators, policymakers, and other corporate managers can presumably benefit from a better practical understanding of corporate P2 decision-making. The cases shed light on the following types of questions. Are firms really passing up opportunities that save them money? Do firms' current financial and accounting practices treat environmental investments differently from other investments? What hurdles must P2 investments clear? Do firms evaluate P2 opportunities in a defensible manner, or are there persistent organizational biases against P2, perhaps due to inappropriate accounting procedures or incentive schemes? The cases reveal the kinds of technical, regulatory, and informational issues that are likely to face any firm contemplating P2 innovations.

The paper is organized as follows. The next section presents the three case studies. Section 4 draws more general lessons from the cases, and in particular focuses on the effect of information constraints on P2 decision-making. Section 5 concludes and addresses the question of how regulation and public policy can best promote private sector pollution prevention.

3. The Cases

This section presents three case studies of pollution prevention decision-making. The three firms whose P2 initiatives were analyzed are, in order of presentation, Dow Chemical, Monsanto, and DuPont.

Dow

The Facility

The Dow facility, part of its polyurethane business, is a chemicals manufacturing plant located in La Porte, Texas, with annual revenues that exceed $350 million per year. The facility manufactures methylene diamine diisocyanate (MDI), the primary input to polyurethane foam and thermoplastic products. Based on TRI reporting data, the plant's emissions are primarily to the air, with smaller amounts being released to water.

The plant releases roughly 300,000 pounds of waste and incinerates, in a thermal oxydizing unit (TOX), roughly 2.5 million pounds of TRI-reported waste annually. The principal constituents of the incinerated waste stream are phosgene, methanol, and monochlorobenzene (MCB).

The Pollution Prevention Opportunity

In 1995 and 1996 Dow participated in a collaborative study with the Natural Resources Defense Council to identify pollution prevention opportunities at the La Porte plant. Assisted by an expert in the identification of P2 opportunities, the Dow-NRDC project identified an opportunity for in-process recycling of MCB. MCB recycling is environmentally beneficial since the incineration of MCB creates "products of incomplete combustion." Recycling would eliminate these emissions. The quantity of emissions avoided was not quantified by the study, but was assumed to be environmentally significant.

This environmental "win" is accompanied by a potential economic "win" for Dow. The ability to recycle -- rather than incinerate -- MCB creates the possibility that the facility's incinerator can either be shut down or removed from its status as a RCRA-regulated boiler.[8] Retirement of the incinerator would eliminate some operating costs. However, the primary benefit derives from avoidance of incinerator retrofitting costs associated with new MACT

[8] Note that there is an "extreme" TOX option -- total shutdown -- and an "intermediate" option -- conversion to non-RCRA status. The intermediate option creates a broader set of technical options for the firm. Specifically, the TOX could remain a viable disposal alternative for wastes that do not have a RCRA designation.

and particulate standards expected to be issued in 1999 or 2000. Shut-down, or the incinerator's conversion to a non-RCRA unit, would allow Dow to avoid millions in incinerator upgrade costs associated with these new, tougher standards.

Process Changes Associated with TOX Elimination

The recycling of MCB is a necessary, but not sufficient, condition for the elimination of the La Porte incinerator. A complicating factor is that a variety of waste streams are incinerated in the TOX.[9] TOX shutdown requires new forms of disposal for the non-MCB wastes otherwise sent to the TOX. In other words, the economic benefit of recycled MCB -- TOX retirement -- is contingent on the technical feasibility and cost of a host of other process changes. As an example, consider the phosgene waste stream. If not incinerated in the TOX, phosgene must be source-reduced, treated via scrubber, or recycled. Each of these options presents unique technical challenges, has uncertain costs, and may create regulatory issues. All of these must be evaluated in order to determine the costs and feasibility of diverting that single waste stream from the TOX.

The Dow-NRDC group realized that TOX elimination was the primary, but not the only, potential source of financial benefit.[10] While recycled MCB was the pollution prevention opportunity, TOX elimination was the economic driver. The study group therefore targeted a "TOX elimination project" for analysis. This project was mirrored by a Business Opportunity Plan (BOP) initiated by Dow to evaluate the project's technical, economic, and regulatory feasibility.

From a business standpoint, recycled MCB alone is not a win-win opportunity. A win-win investment is possible only if MCB is recycled *and* the other TOX waste streams are source-reduced, recycled, or diverted to other modes of disposal. It is this "bundle" of process changes that Dow must evaluate financially. The MCB recycling option cannot be analyzed financially without a technical, financial, and regulatory analysis of the other waste streams diverted from the TOX. This may seem obvious, but it is a point worth emphasizing.

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[9] In addition to MCB, the TOX incinerates, in measurable quantities, methanol, phenyl isocyanate, phosgene, carbon monoxide, carbon tetrachloride, and chloroform.

[10] Note the following terminological convention used in this analysis. "Environmental benefits" denote beneficial changes in environmental quality brought about by a process or product change, or other decision. "Financial benefits" relate to the dollar value of those changes to the firm itself. For example, environmental benefits can create financial benefits by reducing a firm's expected liability costs.

In complex manufacturing operations, even a relatively small pollution prevention process change may require changes in a whole set of interrelated processes. If so, the pollution prevention option cannot be analyzed financially without a technical, financial, and regulatory analysis of these other required process changes.

Financial analysis of the TOX elimination project requires estimation of the aggregate costs of all waste stream process changes.

The Preliminary Financial Analysis

In 1996 Dow's polyurethane business was presented with a financial analysis associated with the P2 project. Cash flows were estimated for several options, including continued use of the TOX for all existing waste streams, continued use of the TOX but with removal of RCRA waste streams, and total TOX elimination.[11] Sound managerial accounting techniques were employed: The accounting exercise featured standard discounting methods, a 10-year time horizon, an estimated dollar benefit associated with avoided repermitting costs, and the inclusion of a relatively rich set of capital items associated with process reconfiguration.

The results of the financial analysis were encouraging in at least one respect. Depending on assumptions, rates of return for the MCB-recycle and TOX elimination option were estimated to be as high as 70%. Even more encouraging from a financial standpoint was the RCRA declassification option. This option had an estimated 135% rate of return, though keeping the TOX in non-RCRA operation was acknowledged as an environmental negative. While the recommendation of the La Porte site's management team was to pursue RCRA declassification, headquarters management never considered this to be a serious option due to its questionable environmental implications.

When presented with the options, more senior management opted to delay a decision on the project. The reasoning behind this decision is explored in greater depth below. Before doing so, however, it deserves emphasis that the cash flow estimates in the existing financial analysis are very preliminary. While sound accounting techniques were employed, the cost estimates are highly speculative. Thus, the principal value of the firm's preliminary financial analysis is that it identifies technical and regulatory issues that the firm must still resolve. Its value as an accurate prediction of the project's expected value is much smaller.

Why Has the TOX Elimination Project Not Been Pursued?

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[11] These cash flow estimates were derived using the expertise of engineers at La Porte, as well as regulatory and engineering personnel at Dow headquarters.

Dow's polyurethane business group has considered and rejected the investment proposal twice. Why? Given the strongly positive rate of return estimate from Dow's internal financial analysis, the decision to not move forward is initially puzzling. It is less puzzling when the speculative nature of the analysis is considered. The economic and technical data available to Dow suggests that the project's profitability remains highly uncertain. Given its underlying technical and financial characteristics, the project's delay is not particularly surprising. The case highlights a relatively prosaic reason for the investment's lack of success: P2 innovation can be costly and create a set of complex technical challenges.

To explore the project's profitability, it is natural to organize the analysis on the basis of the project's costs and its financial benefits. Costs arise from the need to divert waste streams from the TOX. Benefits arise from the ability to retire the TOX itself, at least as a RCRA-permitted unit. Analysis of the case indicates that technical and regulatory challenges present uncertain and potentially significant capital and human resource costs. At the same time, the project's financial benefit is uncertain.

Technical Uncertainties. This section provides a more detailed description of the non-MCB waste streams that would have to be diverted, were the TOX retired. For each waste stream there is typically a set of options for reduction, disposal, recycling, or sale. While somewhat technical, the discussion should also give a flavor for the technical and economic complexity of the project's evaluation.

*Methanol*Methanol at the La Porte facility, due to its ignitability characteristics, is a RCRA-regulated waste stream. Options for this stream include (1) out-of-process recycling (i.e., sale to another plant or firm); (2) burning off-site; or (3) in a different 'clean fuel' boiler on-site.[12]

The recycling option has attractive economic and environmental characteristics. However, the La Porte manufacturing process contaminates the methanol with impurities that render it unsuitable for most other commercial uses. This creates an as-yet unresolved technical problem. How and at what cost can the methanol be decontaminated? Also, a customer for the methanol must be found. The off-site burn options require the identification of an alternative incinerator and, like the recycling option, require transportation off-site. Also, off-site incineration is typically much more expensive than on-site incineration.[13] The

[12] The team also considered the possibility that methanol could be eliminated from the process entirely. This was ultimately determined to be technically infeasible.

[13] Off-site incineration costs can exceed on-site costs by a factor of ten. See "Combustors Said to Face Uncertain Future with MACT Standards, Market Overcapacity," *Environment Reporter*, Vol 28, no. 7, June 13, 1997, p. 307-308.

use of methanol as a fuel in an on-site boiler was not evaluated extensively enough to resolve whether or not this was a viable option.

Liquids collected from absorption units. Much of the MCB to be recycled at La Porte is originally collected in “pressure swing adsorption units” (PSAs). For the MCB to be recycled, however, it must first be decontaminated. Decontamination creates a host of technical issues relating to how and when the stream becomes contaminated. The MCB is contaminated with water and chlorinated impurities in undetermined concentration.

Resolution of these issues has important consequences for the process’ redesign. If the chlorinated impurities are present in low enough concentration, then the water can be removed and the MCB reused. This is the most desirable outcome financially, since it simply requires the installation of a molecular sieve for water removal. If chlorinated impurities are present in sufficient quantity, however, they must be removed since their buildup significantly affects the efficiency of the production process.

If removal of chlorinated impurities is required there are three basic options. At a cost of $1 million a new distillation column, dedicated to impurity removal, can be constructed. It is clearly desirable to avoid this cost. There are two possible ways to do so, but each with their own technical uncertainties. If contamination arises during one particular stage of the process, then an existing column could be used for decontamination. Process analysis is required for this issue to be resolved. If contamination is introduced elsewhere, a different column could possibly be used. The technical question in this case is whether that column could be used to do “double-duty” distillation.

Phenyl isocyanate. Phenyl isocyanate (phenco) is a stream with some source reduction potential (an option currently being pursued at LaPorte). However, total elimination via source reduction is not expected to be possible. Recycling has also been considered, though the nature and removability of contaminants in the phenco stream is an unresolved issue. The most viable option is transport off-site for sale or incineration. The primary technical issue in this case is how to lower transportation risks. Phenco has “reactive” properties that make it unstable for transportation. A possible, but untested technical fix is to react the phenco with waste polyols, to form an inert foam. If successful, this technique would render phenco safer for transport.

Carbon tetrachloride and chloroform. Carbon tetrachloride and chloroform are contaminants in the MCB stream. In order for MCB to be recycled, they must be distilled and burned off-site. (As contaminants in the MCB stream they are currently incinerated in the TOX). Removal via distillation column is the only alternative. Treatment of this stream is not problematic technically, though investment in a distillation column is an expense. And off-site incineration creates transportation risks and increases disposal costs.

Products from an organic recovery system. La Porte has an organic compounds recovery system (ORS) to treat groundwater contamination caused by a previous owner of the site. MCB is a prime constituent of this waste stream. Recycling requires this MCB to be captured via a PSA unit. There are three possible PSA solutions. First, there is an existing PSA unit used to backup the TOX. This unit is relatively old, however, and its remaining life is uncertain. Second, there is another existing PSA on-site that could possibly be used. Use of this unit is uncertain because of questions regarding whether or not it can handle the air volume created by the ORS. Also, there is a significant capital cost associated with connecting this PSA to the organic recovery system. Third, a new, dedicated PSA for ORS vapors could be constructed. There is also a non-PSA solution. ORS vapors could potentially be burned in the TOX if it were converted to non-RCRA status (though see discussion of regulatory issues below).

Phosgene. Phosgene is produced on-site and used as a reactant in the production process. There are two removal options. First, use of an existing scrubber unit, currently used as a safety backup. Technical upgrade of this unit to a primary mitigation device would be required. Second, phosgene could be incinerated in the TOX if it is converted to non-RCRA status (phosgene is not a RCRA waste stream). Also, the possibility that phosgene could be recycled was considered. The technology for doing so is largely undefined.

Waste water treatment plant salinity. La Porte has a waste water treatment plant (WWTP) that relies partially on the TOX as a source of water. If the TOX is eliminated, the TOX water stream may no longer be available to the WWTP, an issue discussed below. Without this water, the salinity of the WWTP increases. This is problematic since the plant's biological treatment system is calibrated to a particular level of salinity. Without that balance, its effectiveness as an organic removal system is reduced, which creates a possible compliance problem. Thus, a technical solution would be required that allows for salt reduction. Alternatively, the plant would require increased freshwater use, which creates regulatory issues of its own (see below).

Regulatory Uncertainties. Regulation raises often complex technical and financial questions, questions that must be resolved before the financial implications of a process change can be clear. Several of the process changes required for TOX elimination raised regulatory issues.

The capture of MCB. MCB vapor from the ORS system is currently being burned in the TOX. Because it is introduced to the TOX as a vapor, it is not RCRA-regulated. However, if MCB from the ORS is to be recycled, it would be captured as a liquid. If this MCB contained any impurities subject to RCRA regulation, these impurities in liquid form could prohibit their incineration in a non-RCRA TOX.

Phenco stabilization. Regulatory approval may have to be sought if phenco is to be combined with waste polyols. The rationale for this combination is to increase the stability of phenco, making it safer for transport. It is not clear, however, that this stabilization approach would be permissible. Regulatory approval is not guaranteed, and in any case would have to be requested. The combination of two different forms of hazardous waste creates a regulatory issue that would have to be resolved.

Phosgene treatment. For phosgene, the TOX has a higher "treatment efficiency" than would the phosgene scrubber alternative. Because Texas has an "anti-backsliding" rule, TOX shutdown would require testing, monitoring, and re-permitting of a scrubber-based phosgene treatment system.

Waste water treatment plant salinity. The TOX's regulatory permit currently requires combustion gases to be cooled and cleaned by water that is acquired from a freshwater source. This water does double-duty, however, since it is then sent to the facility's wastewater treatment plant. Plant managers are concerned that if the TOX is eliminated they may not be granted regulatory approval to draw this same freshwater stream. While TOX elimination requires no net increase in freshwater use, the WWTP alone may not be viewed as a justifiable use of the water.

Issues arising from transportation. Several of the options associated with TOX elimination involve the transportation off-site of non-MCB waste streams -- specifically methanol and phenco. Taking waste streams off-site for sale or incineration by another firm's facilities raises liability concerns. Use or disposal of wastes by other firms can potentially tie Dow legally, via liability, to environmental problems caused by those other firms. Firms that generate waste can be liable for damages due to use or disposal at other firms' sites. This is true even if the primary generator takes all possible precautions in transportation and has no control over the care taken by the firm to whom the waste is transported. Transportation therefore exposes Dow to a set of risks over which it has relatively less control.

The pollution prevention opportunity at La Porte presents numerous technical and regulatory challenges.[14] This has a number of implications for the project's financial analysis. What should be clear is that *the firm must bear costs to estimate costs.* Specifically, the firm must devote human resources to the solution of technical, market and regulatory issues. Before financial analysis of the TOX elimination project can occur, the firm must be able to identify the new technologies and processes that will be required by the project. In order to come to that specification, however, numerous questions must be answered. Can existing

[14] The challenge was described by one participant as "managing 50 speculations at once."

purification systems be used to treat different waste streams? Is there another firm in close geographic proximity that is willing to purchase (or be given) waste methanol? Will regulators allow the use of freshwater for a wastewater treatment plant in the absence of the TOX, or must the firm "innovate around the problem." These and other questions must be answered in order to define the technical specifications of the TOX elimination project.

> *Formal financial analysis may in some cases be moot, if technical uncertainties associated with the project cannot themselves be resolved at reasonable cost.*

These uncertainties have not all been resolved at the La Porte facility. One explanation for the project's lack of success is that it involved a set of process changes that presented significant technical and regulatory challenges.

The Option Value of Continued TOX Operation. Consider now the potential benefits of the TOX elimination project. The recycling of MCB would allow for some raw materials reductions (thus reducing certain input costs). TOX shutdown would also eliminate certain energy and labor costs associated with its operation.[15] The principal benefit, however, arises from the ability to avoid re-engineering, testing, and capital costs associated with new RCRA permit requirements. The La Porte TOX will be subject to new RCRA rules that promise more stringent particulate and new "maximum available control technology" (MACT) standards.

Dow estimated a $4 million cost for the upgrades necessary to remain in compliance. Thus, the economic benefit of TOX elimination is the avoidance of a potentially significant upgrade bill. Several uncertainties cloud this estimate, however.

First, the date at which compliance will be required is uncertain. Currently, the Environmental Protection Agency has until November, 2000 to promulgate the new regulations. Following the rules announcement, an unspecified amount of time is allowed for testing and upgrade. From a financial analysis standpoint, the timing of the requirements is significant. The further in the future the requirements are put in effect, the less motivation Dow has to eliminate the TOX today.[16] This is due to the effects of *discounting*. As is explained elsewhere in this report, discounting implies a reduction in the value of benefits (or costs) that arise in the future. Specifically, a $4 million benefit in 3 or 4 years is worth substantially less than a $4 million benefit today. Delayed regulatory rulemaking thus reduces

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[15] Of course, as noted above, there will be potentially off-setting labor, energy, materials, and technical costs associated with the diversion from the TOX of non-MCB waste streams.

[16] Complicating the issue of timing, is EPA Region 6's "combustion initiative," which may allow for accelerated permitting. This is currently only a possibility for the La Porte facility, however.

the value of TOX elimination. Due to the effects of discounting, regulatory delay in the case acts as a disincentive to invest in process change.

More importantly, the technical requirements are not known as of yet. This means that, until the new standards are announced, the $4 million estimate is subject to upward or downward revision. This uncertainty creates an economic incentive to delay action on the TOX elimination proposal. In economic parlance, there is an "option value" to delayed investment. When investment decisions are not easily reversed there is an incentive to avoid committing resources until uncertainties are resolved.

As noted earlier, there are numerous technical and capital costs associated with the diversion of the non-MCB waste streams. Many, if not most, of these costs are irreversible in the sense that they could not be recovered if Dow decided in the future to re-open the incinerator.[17] Another way of putting this is that the commitment to TOX elimination imposes "sunk" costs. When an investment has uncertain benefits and involves irreversible investments, the use of conventional investment rules such as Net Present Value (NPV) can be inappropriate. In these situations, NPV fails to capture the value of delaying the decision (the "option value") until uncertainties can be resolved. The TOX elimination project is an example of an investment situation in which the option value is likely to be large. It involves significant, irreversible costs and its benefits (the avoided upgrade cost) hinge on an uncertainty that will be resolved in the not-too-distant future.

> *With some investments, there is value in the delay of a project decision. Delay allows for resolution of uncertainties and the avoidance of irreversible, and potentially wasted investments.*

Finally, TOX elimination could lead to another lost option with potential value. In the longer term, the La Porte plant may be used to produce different products with as-yet unseen process characteristics. While a wholesale process reinvention is relatively unlikely for the plant, it is worth noting that the TOX could be useful or necessary as part of such a process re-configuration and that de-commissioning now could make re-configuration impractical.

Consider the following example. By deriving the option value of a delayed decision, the example demonstrates that a positive NPV is not sufficient motivation for managers to go ahead with a project.[18] Assume the following: that for an investment of $2.1 million the firm

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[17] Actually, Dow management expresses a concern, based on their perception of current regulatory attitudes toward incineration, that once closed, the TOX could never be re-opened.

[18] The example is meant to be illustrative, rather than a numerically accurate depiction of the Dow investment decision.

could invest in new process technology, human resources, and testing and achieve environmental benefits due to recycling. The financial benefit would be due to avoided retrofitting costs that are currently uncertain. Two outcomes are possible, with equal probability. Either the avoided costs are $2 million or they are $6 million, depending on regulatory requirements. Assume that the new compliance standard is announced in 3 years and must be immediately implemented by the firm.

Assuming the investment is made today, and discounting cash flows at a 10 percent interest rate, the project's NPV is calculated as follows.[19]

$$NPV = -2.1 + \frac{[(.5)2 + (.5)6]}{(1+.1)^3} = .904 = \$904{,}000$$

The positive net present value would ordinarily suggest that the firm move forward with the project. However, we now calculate the present value of waiting to make the investment decision until the regulatory standard is announced. By waiting, the firm can avoid making the $2.1 million investment if the standard requires retrofitting changes that cost only $2 million. (The firm will not invest in this situation since it is clearly not in the firm's financial interest to spend more to avoid a cost than the cost itself.) Therefore, the firm will move forward with the investment only if the regulatory standard implies the larger retrofitting cost. The NPV of delaying and making the investment only if avoided upgrade costs are large is

$$NPV = (.5)[-\frac{2.1}{(1+.1)^3} + \frac{6}{(1+.1)^3}] = 1.464 = \$1{,}464{,}000$$

The value of waiting is greater than the value of investing immediately.[20] This is true for two reasons. First, the firm can avoid the investment if the benefits turn out to be small. Second, the three year delay reduces the present value of the investment's cost. As a result, the option value of the delayed decision is $560,000, or the difference between the two NPVs.

In addition to the unresolved technical issues described earlier, this example illustrates another reason for the Dow investment's failure to be approved. Given uncertain regulatory

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[19] The fractional term is the expected, and discounted, benefit of being able to avoid the upgrade cost in 3 years.

[20] To help understand the equation, note that with probability .5 the firm does not make the investment and therefore bears no cost and receives no benefit.

standards and the irreversible nature of the investments necessary to move to alternatives to TOX-based disposal, a delayed decision is likely to be optimal.

Other Organizational and Strategic Issues

Capital and human resource constraints have also played a role in the decision to put off the TOX project. Resolution of technical issues and regulatory uncertainties and relative confidence in positive rate of return estimates is not sufficient to guarantee project success. Typically, firms also prioritize their investment activities, pursuing those that offer the highest rates of return on capital and human resources. As is described elsewhere in this report, capital rationing is a mechanism that helps firms prioritize.

Capital rationing has been a concrete issue for the La Porte investment. In 1996 Dow's polyurethane business had an 86% hurdle rate for new capital projects. This rate can be explained by (1) a fixed (rationed) amount of new capital made available to the polyurethane business by senior Dow management and (2) the existence of a competing capital project within the business that offered a particularly high expected return. Dow has 15 global business units, each with a limited amount of capital to be allocated in a given year. The competing project involved a plant in Freeport, LA. The Freeport project was financially competitive relative to La Porte, as well as competitive in terms of the environmental benefits it promised. The Freeport plant promised to eliminate 50 million pounds of chlorinated organics by harnessing a new process chemistry, a P2 investment with environmental benefits an order of magnitude greater than that proposed at La Porte.[21] Given capital rationing, the La Porte investment was a relatively unappealing investment target.[22]

The same can be said of investments in human capital. Given the relative merits of the Freeport investment, it is not surprising that human resources, particularly technical expertise, were focused on that investment. This had decidedly negative implications for the La Porte investment. Given the complexity of the technical issues that had to be resolved, sustained problem-solving activity -- which was dependent on the active involvement of scarce personnel -- was a prerequisite to moving forward with the TOX elimination project.

[21] This figure is speculative. Nevertheless, the magnitude of possible reductions is clearly significant.

[22] The question of why firms ration capital at all is explored in section 4.

Monsanto

The Product

The Monsanto case involves a process that, at the time, was associated with its Rubber Chemicals business unit. The firm was producing aminodiphenylamine (4-ADPA), an intermediate product for the production of anti-oxidants, at plants in the U.S., Belgium, and the United Kingdom. The final anti-oxidant product has a wide range of uses, but its primary market is the world tire industry where anti-oxidants are used to improve tire durability and safety. The market for this product is large and represented a significant fraction of the Rubber Chemical unit's annual revenues.

The existing process chemistry for 4-ADPA production used benzene, nitric acid, and chlorine to produce nitrocholorobenzene (NCB). NCB was then converted to 4-NDPA by reaction with aniline. The 4-NDPA was in turn reacted with hydrogen to get the desired 4-ADPA. The many process steps leading to creation of the 4-ADPA intermediate product required the disposal and handling of large quantities of chlorine. In addition, the process created carbon monoxide, xylene air releases, and an aqueous waste stream contaminated with inorganic salts. The process was the second-highest generator of waste in Monsanto's Chemical Group. These environmental characteristics made the process a prime target for process reinvention.

The Pollution Prevention Opportunity

Beginning in the mid-80s, the Rubber Chemicals unit and Monsanto Corporate Research began to explore alternatives to the process chemistry. In 1991, chemists and chemical engineers achieved a technical breakthrough with real promise: the possibility of a process with virtually zero waste generation. The innovation, dubbed ADPA, is a "direct coupling" technology that eliminates the use of chlorine and several process steps in the production of the 4-ADPA intermediate product.

The project was granted a budget in excess of $10 million for development costs, including the construction and operation of a fully-integrated pilot plant. By mid-1993 the pilot plant had demonstrated the technical efficacy, environmental benefits and potential economic value of the new process. The environmental benefits of the new process were significant and included

- a 91% reduction in organic wastes
- the virtual elimination of inorganic wastes, with total elimination of chlorine
- waste water generation only 3% of its former total
- greater chemical stability (significantly reduced risk of "runaway reactions")
- the elimination of xylene emissions.[23]

Another significant driver for the firm, however, were cost savings associated with the process change. The ADPA process required less than 50% of the old raw material inputs and required fewer process steps. For these reasons, ADPA was projected to reduce production costs by a magnitude virtually guaranteed to have a positive impact on profits and market share. The firm had discovered a true "win-win" investment opportunity. In fact, the technology's qualities were so obvious that commercial development was considered a "no-brainer" by Rubber Chemicals management. Many of the process' benefits were never quantified, simply because they were so large. At least on a stand-alone basis, ADPA was predicted to be a sure-fire success. In light of this, it is noteworthy that Monsanto did not choose to develop ADPA as part of its Rubber Chemicals business, due to major impacts on integrated business units. While ADPA was ultimately developed, its transition from prototype process to the commercial market was not immediate nor particularly smooth.

ADPA Today

Today, the ADPA technology is owned and used in the production of anti-oxidants by Flexsys, an independent, global rubber chemicals company, formed as a joint venture between Monsanto and the Dutch firm Akzo Nobel. The formation of this new company was central to ADPA's implementation and hints at the complexities surrounding the technology's commercial development. As we will see, issues well beyond the technology and product itself complicated its implementation. Changes in Monsanto's strategic goals, interrelationships between the 4-ADPA product line and other business units, and a set of issues relating to divestiture and ownership of assets ultimately determined when and how the technology would be brought into commercial use. Particularly because ADPA had such clear benefits, the case underscores the complex tradeoffs that must be faced by managers responsible for the evaluation and implementation of pollution prevention, or any other, investment opportunities.

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[23] Aggregate reductions were predicted to be significant. For a single plant, the numbers translated into a 56 million pounds per year reduction in chemical waste generation and a 1 billion pound per year reduction in waste water requiring treatment.

Changing Markets and the Corporation's Strategic Goals

The ADPA story illustrates the way in which even a clear win-win process improvement can be influenced by global market changes and the shifting strategic goals of a multi-national firm. The fate of ADPA was largely determined, not by the financial or environmental benefits of the project itself, but by the fate of the larger rubber chemicals business in which it was embedded and the other Monsanto businesses with which it was integrated.

A shift in strategic goals. In the early 1990s, CEO Richard Mahoney was looking for a way to improve Monsanto's stock performance and position the firm to take advantage of changes in world chemical markets. One of his strategies was to announce a new corporate financial goal: specifically, a 20 percent return on equity (ROE).[24] Mahoney's financial advisors had studied the broader market and determined that firms in the top quartile of stock performance (measured by the price-earnings ratio) were those which consistently met a 20 percent ROE.[25] In effect, then, a 20 percent ROE was chosen as a proxy for "improved stock performance." A likely reason is that ROE provides a relatively concrete target for managerial decision-making. ROE is a standard accounting measure, and thus a convenient yardstick with which to compare business lines and judge capital investments.[26] Thus, the 20 percent ROE target was designed to motivate a shift in Monsanto's businesses toward markets and products that offered greater promise for growth.

At the time of Mahoney's announcement in 1992 Monsanto's ROE was 12 percent, well below the target. One broad strategic implication of the new goal was for the firm to start moving into so-called "specialty" chemicals and out of commodity-type chemicals. Specialty chemicals tend to be innovative and targeted at markets where the product will enjoy a significant competitive advantage. Competitive advantages arise when the product fills a new market niche or when it significantly outperforms existing, competing products.[27] In contrast, commodity products tend to be high-volume, established products that are -- by

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[24] Return on equity is defined as the a firm's net income divided by average stockholder's equity.

[25] A high price/earnings ratio can usually be taken as evidence that market sees good growth opportunities for the firm.

[26] Note that while ROE is a standard accounting measure, it is not a theoretically sound metric by which to judge the desirability of alternative investments. ROE calculation does not require knowledge of cash flows and does not involve discounting, making it a highly suspect measure of profitability.

[27] Monsanto's shift toward "life sciences" products, such as genetically engineered fertilizers, is an example of their move toward specialty chemicals.

definition -- very competitively supplied. Anti-oxidants, such as 4-ADPA derivatives, are examples of the latter. The entire rubber chemicals business, in fact, was beginning to be seen as a product line incompatible with the 20 percent ROE goal. Note that this shift in strategic thinking was occurring simultaneous to the ADPA development program.

The Rubber Chemicals Business. The company's shifting strategic goals spelled trouble for the Rubber Chemicals (RC) business. International rubber chemicals markets are highly competitive and subject to cyclical worldwide demand fluctuations. Most of Monsanto's competitors had comparable production processes and excess capacity. In addition, a set of other market changes threatened the firm's strategic position. First, the collapse of the Soviet Union resulted in a significant loss of sales in the region as Eastern European suppliers flooded the market and created significant downward pressure on prices. Second, Monsanto's customers were consolidating. In the 1980s there were 20 or more major tire manufacturers. By 1992, however, after a wave of failures, mergers, and acquisitions 5 major tire producers were supplying the bulk of the world market. This consolidation allowed tire manufacturers to exercise buying power and bargain for steep price reductions from suppliers such as Monsanto. Finally, changes in tire manufacture itself (increased production of radial tires) were leading to long-lasting products. Increased tire durability meant reduced rubber demand. Rubber consumption was growing worldwide by only 2 percent per year.

Taken together, these strategic factors suggested that rubber chemicals was a business where growth potential was limited, particularly in relation to other markets Monsanto might enter. The numbers underscored the strategic analyses. Rubber Chemicals dropped from a business with a 16 percent ROE in 1989 to a business with an 8-fold reduction in net income (and a roughly 2 to 3 percent ROE) in 1992. While some of this was due to unavoidable cyclicality, the accounting returns calculated in 1992 fell far short of corporate goals.

Capital Rationing and ADPA's Impact on the Business Unit

Monsanto at the time was composed of 15 distinct business units that competed amongst themselves for shares of a limited yearly capital budget. Once granted, the budget could not be exceeded without the approval of corporate headquarters. Also, any project over a particular size had to be approved by headquarters. The capital investments necessary to get ADPA operating commercially placed it in this category (in particular, plant construction costs were large). This meant that the Rubber Chemicals business was not the sole decision-maker. Capital rationing and a parent business line with relatively poor performance meant that ADPA's financing was not assured.

ADPA's impact on the Rubber Chemicals business was strongly positive. The question was, was its impact going to be positive enough to turn around the business as a whole? Management was looking at the following options and projections for the RC business. Independent of ADPA, the business had secured internal financing to conduct a large-scale business reorganization. Monsanto had granted RC a capital budget to aggressively reduce costs anywhere savings were available. The restructuring plan involved facility closures and "debottlenecking" innovations to capture economies of scale at core plants. Even with these efforts, and the cost and competitive advantages they would create, the projection was for an 8 percent return on capital.[28] Given the firm's new strategic targets, this was only marginally acceptable.

Development of ADPA would improve the Rubber Chemicals business' financial performance. Expectations were that ADPA would add roughly 3 percentage points to the business' return on capital. This is significant, particularly given the dilution of its benefit across the entire business line. Nevertheless, a 10 or 11 percent ROC remained well below Monsanto's strategic financial targets.

What's Wrong With a 10 percent Return on Capital?

While a 10 percent return fell short of the CEO's strategic goal, it is still natural to ask why a firm would pass up a 10 percent return. The short answer is that a firm can make a 10 percent return and still lose money. The more detailed answer requires a brief review of financial principles.

Before turning to that review, however, we temporarily set aside two important issues. First, the Rubber Chemicals unit's 10 percent ROC is not necessarily relevant to the ADPA decision. What is relevant are the returns specific to ADPA. Second, ROC is not a theoretically sound measure of financial value.[29] Nevertheless, ROC, while analytically dangerous, is not an entirely worthless measure of value. For now, we can infer -- as did managers at Monsanto -- that a discounted cash flow analysis would produce a theoretically sound, and qualitatively identical conclusion: the Rubber Chemicals unit was generating positive, but lackluster, returns.

The Opportunity Cost of Capital. A business that makes a 10 percent return on its capital can lose money because the capital itself has a cost. For instance, if the capital would have earned 15 percent if used to finance a new agricultural product, then 15 percent is the cost of capital. (In economic parlance, 15 percent is the *opportunity cost* of capital). Note

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[28] Note that some of the figures cited in the case refer to return on capital (ROC), while others refer to return on equity (ROE). Both are measures of investment return, though return on capital is the more comprehensive measure since it accounts for the return on capital financed via both equity and debt.

[29] For reasons similar to those mentioned in footnote 26.

that a firm loses money if it takes capital away from a project that earns a 15 percent return and puts it in a project that earns only 10 percent.

A firm will lose *money if it directs capital from a project that offers a higher return to a project that offers a lower return. While seemingly simple, this truism has a direct corollary that is often not understood: investing in a project with a positive rate of return can* reduce *a firm's profits.*

In other words, evidence that a pollution prevention investment has a positive rate of return is not the same as evidence that it is an economically desirable project.

This economic reasoning can also shed light on CEO Mahoney's 20 percent ROC target. Given new technological and market opportunities opening to Monsanto, the direction of capital toward Rubber Chemicals had a high opportunity cost. In fact, this cost may have been so high that investment in assets promising a 10 percent return would have reduced the value of the firm. This was particularly true given the financial risks presented by the Rubber Chemicals business, an issue to which we now turn.

Risk, Return, and the Cost of Capital. The opportunity cost of capital is a function of more than the returns offered by alternative investments. It is also a function of those investments' risk.

Given a choice between a risky investment and a safe one, an investor will always prefer the safer of the two. The implication is that, in order to acquire capital from an investor, the riskier firm will have to promise a higher return than the safer firm.[30] In turn, this means that the opportunity cost of an investor's capital is higher for riskier firms. Thus, a firm's cost of capital is related to the way in which capital markets assess its risk. These ideas are the basis of understanding the so-called capital asset pricing model (CAPM). CAPM says that an asset's expected risk premium varies in direct proportion to an index of risk, called beta.[31] Because riskier firms must offer a higher return, capital is more expensive for them to acquire.

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[30] This explains why so-called prime lending rates, with which most consumers are familiar, are always well below the corporate cost of capital (hurdle rate). To compensate for the greater risk relative to treasury bills, the market provides an average risk premium well above the return provided by safe treasury bills.

[31] Statistically speaking, beta is the ratio of (1) the covariance between an asset's return and the return of a broader portfolio, and (2) the variance of the broader portfolio. Typically, the broad portfolio is a diversified portfolio of publicly traded stocks. Beta therefore measures the sensitivity of an asset's value to changes in the market generally.

Risk and the Rubber Chemicals Business. Not all risks affect capital costs. For instance, because of the ability to diversify, investors can significantly reduce risks by holding a portfolio of investments whose uncertain price movements "cancel out" on average. A risky investment can have a "low beta," and in turn relatively low capital costs, as long as the risks it presents are diversifiable. Only non-diversifiable risks affect capital costs.

Non-diversifiable risks are a function of several factors. Perhaps the most important factor is the sensitivity of a firm's earnings to the economy's overall business cycle. It is noteworthy that the Rubber Chemicals business is highly cyclical, and so would be expected to have a high beta. Also, a project's operating leverage -- the proportion of its costs that are fixed and that therefore must be borne regardless of whether the asset is ultimately productive or idle -- influences the project's risk. All else equal, projects with higher fixed costs will have higher betas.[32] On this score, too, Rubber Chemicals is likely to have a high beta. The fixed costs associated with chemicals manufacture tend to imply high project-specific betas. This would also hold true for the ADPA investment itself.

Because of the non-diversifiable risks associated with the RC business, and ADPA specifically, the cost of capital for this business could be higher than 10 percent, perhaps significantly so. High risk, low return businesses are not desirable targets for capital investment. For these reasons it is not surprising that some within Monsanto were resisting any continued investment in the RC business.

Disentangling ADPA from the Rubber Chemicals Business

Strictly speaking, the firm's concern with returns in the RC business should not have been relevant to the ADPA investment decision. An inviolable principle of financial project evaluation is that a new investment should be evaluated "incrementally," not on the basis of its impact on average returns across a larger business. Financial theory holds that, when evaluating a new capital investment, only the new, appropriately discounted, cash inflows and outflows created by the project are relevant. Taking this view, ADPA was a much better investment than indicated by calculations such as "ADPA will improve the RC business' ROC by 3 percentage points." In fact, a preliminary estimate suggested that, on its own, ADPA promised a 45 percent return on capital, a return well above the firm's strategic target. Given that projects should be evaluated incrementally, and given the high ROC estimate, why didn't the firm simply move ahead with ADPA as a stand-alone project?

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[32] For more detail on how to estimate a project's beta see Foster (1978).

Monsanto analysts sought to view ADPA independently, but in the end "couldn't divorce" ADPA from the RC business. To understand why, it is necessary to highlight a key technical interdependence associated with the 4-ADPA process. This technical relationship, in turn, had financial and accounting implications that tied the ADPA decision to the RC business and other integrated Monsanto businesses.

4-ADPA and Chlorobenzenes. The old 4-ADPA production process required large quantities of a product called PNCB (paranitrochlorobenzene). This product, along with a co-product, ONCB (orthonitrochlorobenzene), was produced by another Monsanto division. The innovative ADPA process eliminated the bulk of Monsanto's PNCB needs and would severely limit the availability of ONCB. In fact, this is a primary source of ADPA's economic benefit. Process steps and raw inputs used to make chlorobenzenes are eliminated by ADPA. This change, however, meant that the financial impact of ADPA could not be isolated. Costs associated with chlorobenzenes had to be considered. These costs can be separated into two categories. First, ADPA created cash outflows by reducing efficiencies in chlorobenzene production and requiring plant decommissioning expenditures. Second, ADPA raised accounting issues within Monsanto related to the recovery of fixed costs associated with now-redundant chlorobenzene units.

Negative Cash Flows Created by the Switch to ADPA. While reduced chlorobenzenes was a benefit of ADPA, there were also some off-setting costs associated with reduced chlorobenzenes production. First, closure of one or more chlorobenzene units was a possibility. In many ways this was considered a desirable outcome (the chlorobenzenes business, like Rubber Chemicals, was relatively lackluster). Nevertheless, there were costs associated with closure. Some of these costs were tangible, such as the cost of decontaminating and disposing of redundant, non-salvageable capital equipment. Others were less tangible, such as the impact on the workforce of plant closures. Second, Monsanto still required PNCB and ONCB for other products, though in limited quantities. This meant that the elimination of all the firm's PNCB plants was not possible. The elimination of chlorobenzenes from 4-ADPA production meant that these plants would be significantly under-utilized, and thus be less efficient to operate. Because plants were optimized for pre-ADPA production volumes, ADPA would have the effect of increasing operating costs at the PNCB plants remaining on-line. These costs, because they were cash outflows and the direct result of a shift to ADPA, were relevant to the financial analysis of ADPA.

Accounting Charges Associated with ADPA. Looming even larger were a set of large fixed costs associated with the now-obsolescent chlorobenzene facilities. With PNCB no longer being used by Rubber Chemicals, the chlorobenzenes business would have a much harder time recovering the fixed costs associated with its production. As a result, financial projections for the ADPA project and the RC business as a whole included "charges" corresponding to these unrecovered fixed costs. This had a clear, negative impact on the ADPA project's economics.

From the standpoint of financial theory, these costs should not have been assigned to ADPA or Rubber Chemicals. Unrecovered fixed costs from the chlorobenzenes business were, technically speaking, sunk costs and therefore should have been irrelevant.[33] The cost of building the chlorobenzene plants was a cash outflow that occurred many years before the ADPA decision was made. Whether or not ADPA went forward, Monsanto had already borne this cost.

It is common to confuse sunk costs and cash flows. One reason is that accounting procedures take a fixed cost and "depreciate," or spread, it over a period of years. But depreciation does not mean that the firm is paying a fraction of a fixed cost in yearly installments. Rather, depreciation is a technique required by the tax system to calculate a firm's yearly profits (and thus its tax liability). While for tax purposes the method spreads a cost over a number of years, there is not a yearly cash outflow. The actual cash outflow typically occurs earlier, at the time the capital is installed -- for instance, when contractors and equipment suppliers are paid.

Also, large fixed costs create complicated issues for diversified firms such as Monsanto. In order to compare the value and performance of individual business units, firms will typically make those units into distinct "profit centers." Profit centers allow each business unit (such as Rubber Chemicals) to be evaluated on its own terms. This leads to better investment decisions and, with performance monitoring, allows the firm to create managerial incentives tied to an individual unit's successes and failures. An issue arises, however, when one internal business requires an input from another internal business: namely, how is that input to be priced? While not purchased on the open market, the input must have a "price" that can be assigned to the appropriate profit center. The simple answer is that the internal price should be equal to the cost of producing the input. This becomes complicated, however, when the cost involves fixed costs that must be shared between businesses.

Rubber Chemicals was being "charged" just such an internal price for the PNCB used to make 4-ADPA. This is a completely sound financial practice, and one that is necessary for firms using distinct profit centers as an internal accounting strategy. With ADPA, Rubber Chemicals no longer needed PNCB. This threatened the chlorobenzene business' ability to recover its fixed costs via Rubber Chemicals charges. The accounting solution was to charge Rubber Chemicals obsolescence costs (the unrecovered chlorobenzene costs). Again, this is

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[33] The so-called "sunk cost fallacy" is a common and time-worn error in financial analysis. For examples see Brealey and Meyers (1991), pp. 96-98.

a sound financial practice, if it is used simply to assign costs for internal accounting purposes. What was unsound was the assignment of obsolescence costs to ADPA during the project's financial evaluation. The assignment was inappropriate because the unrecovered, fixed chlorobenzene costs were sunk costs. As cash flows, they had been paid out years earlier. The confusion was natural enough. After all, the Rubber Chemicals business had been seeing chlorobenzene charges as annual cash outflows. From the larger corporate perspective, though, the unrecovered chlorobenzene costs should have been identified as sunk and thus irrelevant to the ADPA decision.

Failure to appropriately distinguish between financial measures such as cash flows, accounting charges, and sunk costs can bias analysis of new investments.

These financial evaluation issues ultimately did not hinder the development of ADPA. The innovation's benefits were so obviously positive that development went forward. But the case provides a lesson in the complexities and challenges that confront financial evaluation. Financial analysis techniques are an area where many firms continue to innovate and improve quality. In this regard, it is instructive to note that current internal guidelines at Monsanto stress the importance of incremental analysis to sound capital budgeting evaluations. A similar change has occurred with regard to discounted cash flow techniques. As we have seen, in the early 90s Monsanto used non-discounted cashflow benchmarks (e.g., return on capital) to compare projects. The firm's current capital appropriation procedures require discounted cash flow measures of expected profitability.

ADPA's Commercial Development

ADPA was a technology with significant economic value. Unfortunately, the product it produced was embedded in an under-performing business. The strategic solution, and what ultimately guaranteed ADPA's development, was Monsanto's divestiture of the Rubber Chemicals business. In 1995, Monsanto formed a joint venture, Flexsys America, with Akzo Nobel. The venture provided a desirable solution to several of the strategic and financial issues raised by ADPA and the rubber chemicals market.

Under the firms' agreement, Monsanto would transfer to Flexsys the bulk of its rubber chemicals capital base, including a number of plants worldwide, as well as rights to the proprietary ADPA technology. Akzo Nobel would transfer several of its own rubber chemicals products and businesses to Flexsys. Ownership of the joint venture was evenly divided between the two firms and the resulting business was able to finance the development of an ADPA production facility in Belgium.

The joint venture promised several benefits. It permitted consolidation in the European rubber chemicals market. In particular, the firms would be able to capture scale economies in production and staffing. Also, the joint venture implied significantly greater market share. This promised a competitive advantage that could be used to counter tire manufacturers' increased buying power in the rubber chemicals market.

While Monsanto had to share its new technology, the joint venture allowed them to shed the RC business' under-performing capital assets and get another firm to underwrite the ADPA's commercial development costs. ADPA's implementation ultimately hinged on a major business restructuring, brought on by worldwide market changes and shifting strategic goals.

Environmental Accounting

ADPA's entanglement with complex production and strategic issues should not obscure the fact that a primary driver for its development was pollution prevention. Pollution prevention motivated the R&D effort which spawned the new process chemistry. Given this, and given the significant environmental benefits associated with ADPA, how was the value of this improvement expressed in the firm's financial decision-making process?

The environmental benefits were not translated into financial terms that had a direct impact on the decision analysis. There are several reasons for this. First, the financial analysis of all costs and benefits -- not just environmental costs and benefits -- was relatively rudimentary. As indicated earlier, year-by-year cash flows were only estimated. A detailed line-item cost and benefit analysis was not conducted. While the firm failed to quantitatively account for financial benefits arising from changed environmental conditions, it also failed to quantitatively account for many other benefits and costs. Second, it could be argued that detailed financial analysis of environmental changes was unnecessary because the waste reductions were so obviously large that there was no need to estimate their precise financial value.

The goal of environmental cost accounting is to ensure that environmental costs (and savings from reduced costs) are given weight in decision-making equal to the weight given to non-environmental costs and benefits. We should ask, then, whether ADPA's environment-related financial benefits -- though not quantified -- got equal qualitative weight in the firm's decision-making. There is evidence that ADPA environmental benefits were prominently valued in the firm's decision-making. A good guide to this is the prominence of environmental considerations in business summaries presented to top management. Internal documents show that waste reduction was listed as a key driver in favor of ADPA in every summary of the investment's pros and cons presented to financial staff. In a "Corporate Finance Staff Review" ADPA's environmental benefits are presented on equal footing with financial and strategic considerations. Or consider a decision brief presented to CEO Mahoney that included a small list of key considerations, two of which were related to the project's environmental benefits. These summaries invariably included statements such as "reduces waste by 95%." Environmental problems associated with chlorobenzene production were also typically listed as reasons to get out of that business.[34] While state of the art risk analysis and financial estimation of these environmental benefits was not in evidence during the ADPA decision, there is no evidence that environmental benefits were being given insufficient weight in the business' decision calculus.

[34] These problems included the production of hydrochloric acid salts. While not a regulated substance, elimination of this waste stream was nevertheless seen as having a significant (if unquantified) value.

DuPont

The Product

The DuPont case relates to a product called the "DuCare" photochemical processing system. The DuCare system is a package of four integrated products designed for sale to customers in the graphic arts (printing and publishing) industry. The industry, in the process of developing 1.5 billion square feet of silver halide photographic film annually, generates a huge amount of photochemical waste. The DuCare system was designed to reduce photochemical consumption and the industry's pressing disposal needs. In lieu of traditional fixer and developer chemistries, DuCare uses proprietary process chemistries that allow for recycling. The four integrated products that make up the DuCare system include (1) a proprietary, recyclable "developer," (2) a recyclable "fixer," previously commercialized by DuPont, (3) a transportation system that collects and returns the developer and fixer to a DuPont processing facility for recycling, and (4) technical assistance in the choice and installation of washwater treatment technologies. Note that the chemicals are not recyclable on site. Instead, the chemicals require transport to a central facility where the recycling chemistry takes place, followed by re-distribution to the graphic arts customer. The goal of the system is a "zero effluent" photochemical process.[35] The target customer base is composed of medium- and large-scale commercial printers and publishers with environmental compliance, stewardship, and cost concerns.

The Pollution Prevention Opportunity

The environmental benefits of the DuCare system are, by design, significant. Traditional methods for dealing with photochemical waste include direct release to the drain for subsequent treatment at a POTW (publicly owned treatment works), transport of wastes for off-site TSDF disposal, or illegal dumping. DuCare, by recycling the photochemicals, eliminates releases to the environment, whether those releases are destined for the drain, a treatment works, or a disposal facility.

A variety of wastes are eliminated by a recyclable chemical process. With respect to photographic developer, the standard process creates an environmentally problematic chemical oxygen demand (COD). A typical developer has a high COD of roughly 100,000 ppm. As a point of reference, the EPA limit is a COD of 2,000 ppm. Again, spent developer is either is hauled away for disposal at a licensed toxic substance disposal facility, is dumped

[35] While the product must be transported off-site, it is technically a form of "in-process" recycling.

illegally, or is sent legally to a POTW where treatment charges may be levied. The DuCare developer, by being fully recyclable, eliminates all of these releases.

There are significant environmental gains associated with the fixer and washwater treatment, as well. The standard photographic fixer, if untreated, contains 2,000 to 6,000 ppm of silver (EPA limit, .7 ppm), 40,000 ppm of ammonia (900), 180,000 ppm total sulfates (5,000), and has a COD of 120,000. Most photoprocessing labs use some method to reduce silver concentrations, but all of the other undesirable effluents generally remain untreated. Again, because it is totally recyclable, the DuCare fixer completely eliminates these releases. The DuCare washwater treatments reduce freshwater consumption, which is significant in photochemical processing. These kinds of benefits arise each time a graphic arts customer employs the product. Calculated on a base of 500 customers, DuPont estimates that the DuCare system results, annually, in a 10 ton reduction in silver emissions and a 375,000 ton reduction in other chemical wastes.[36]

From a private financial perspective, DuPont saw a commercial opportunity in its ability to sell this kind of pollution prevention. This is in contrast to the two cases we have previously analyzed. In the previous cases, the analysis related to decisions regarding a firm's own investment in pollution prevention. The DuPont case is somewhat different. The DuPont case features financial and marketing analysis relating to a pollution prevention technology that it wishes to sell to other firms. To a great extent, then, the case's focus will be on the demand of DuPont's *customers* for pollution prevention.

Customer demand for pollution prevention was a primary motivator for DuPont's development of the product. The DuCare system was envisioned as a way to reduce environmental compliance costs for its film and photochemical customers. While being associated with environmental leadership is mentioned in company documents as a desirable aspect of the product, the primary motivation was financial. DuPont expected to make money by selling pollution prevention to its customers. The market opportunity became possible via the reality (and perception) of increasingly stringent environmental regulation.[37] As product planning proposals spelled out clearly, "customers want to minimize environmental risk and

[36] DuPont estimates that, industry-wide, 30 million gallons of used fixer and developer are created annually. On the assumption that each square meter of processed film creates 800 ml of waste fixer and developer, this annual effluent contains approximately 1,000 tons of hydroquinone, 1,000 tons of sodium sulfite, 2,000 tons of ammonia, and 75 tons of silver. Currently, the vast majority of this waste either is released to POTWs or is dumped illegally.

[37] DuCare strategy documents highlighted changing patterns and stringency of regulation. "Public concern about the environment has led to more regulations and increasing enforcement. As a result, photochemical effluents are coming under greater scrutiny and more stringent control across North America."

liability and want help in managing these issues." By eliminating emissions, DuCare would help its customers' regulatory compliance issues disappear. There was the possibility that the DuCare system might be viewed by regulators as a best available control technology status. Moreover, full recyclability meant that customers who used third-party disposal would eliminate any "cradle to grave" liability exposures associated with that transaction.

The regulatory and legal environment in which graphic arts photo-processors exist was expected to give rise to a demand for pollution prevention. This demand could be satisfied via DuPont's technology, service, and transportation system, presumably at some profit to DuPont. Also, there was a generally accepted belief among managers that an environmental processing technology would lead, not only to increased photochemical sales, but to increased film sales, as well. This was a significant financial driver for DuPont since film sales create the bulk of its graphic arts revenues and profits.[38]

DuCare Today

The DuCare system was introduced commercially by DuPont in 1994. Since then, the product has been successful, when viewed from a technical perspective. From a chemistry and product design standpoint, all elements of the system have performed as projected. Unfortunately, the product has failed, by a significant margin, to live up to its initial financial promise. Development-stage projections were quite promising. A 1993 financial analysis predicted that the product would have a 10-year net present value of $2.78 million, not including film sales attributed to customer use of DuCare. Film sales generated by DuCare were estimated to have an additional $6.5 million 10-year NPV. Currently, however, the product has failed to turn any profit. Excluding the uncertain value of stimulated film sales, the product has to date been unable to earn revenues sufficient to recover operating and startup costs.

The most direct explanation for this failure to meet expectations is that consumer demand for the product has been much weaker than predicted. A 1992 business plan offered a "conservative" estimate that DuCare would lead to a 10 percent -- and continuously increasing -- market share in the graphic arts film and photochemicals business. Today, that market share is less than 5 percent. Out of an estimated universe of more than 16,000 potential customers, DuCare is currently used by fewer than 600.

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[38] This synergy was quantitatively estimated in firm analyses. Each gallon of recycled developer was expected to generate demand for 50 to 100 square feet of DuPont film.

The DuPont graphic arts business unit -- the business unit that developed and commercialized DuCare -- is being sold to Agfa, a competitor in the graphic arts business. The sale comes on the heels of relatively poor financial performance from the graphic arts business unit generally. DuPont's inability to motivate significant sales of the DuCare system contributed to these financial difficulties. We now turn to the question of why demand for the DuCare product fell so far short of expectations.

Why Has Demand for the DuCare System Been Relatively Weak?

DuCare is a pollution prevention technology embedded in a photo-processing system. DuPont's customers, while potentially drawn to pollution prevention, are primarily purchasing a photo-processing system. The photo-processing market itself is quite competitive. DuPont's direct competitors include Kodak, Agfa, Anitec, Fuji, and 3M. Thus, a direct, but incomplete, explanation for DuCare's financial under-performance is that other firms have out-competed DuPont. To understand why this may be, note that a customer is essentially choosing a process technology with two primary features: price and environmental performance. DuCare has failed to sell up to expectations because it is at the high end of the price spectrum and because customers (apparently) do not feel that its environmental characteristics are sufficiently valuable to outweigh the price premium. At this point it is useful to turn to a more detailed analysis of DuCare's costs and environmental benefits, relative to other options available to DuPont's customers. We will compare DuCare to (1) DuPont's existing (and more "standard") photochemical process and (2) a competing, photoprocessing technology with pollution prevention features.

A non-environmental cost comparison. First, consider the non-environmental costs associated with the alternatives. These include up-front capital, chemical input, chemical processing, and transport costs.

DuCare vs. the standard process. Excluding environmental considerations, the standard photochemical process is cheap, relative to DuCare. The chemicals employed are cheaper to produce and more competitively supplied. The recyclability of the DuCare chemicals means that there is less of a need to purchase "fresh" chemicals, but the transportation and chemical recycling costs mean that even recycled batches of the chemicals are more expensive than DuPont's standard chemicals. For example, the standard developer costs $1.79 per gallon. The DuCare developer is more than twice as expensive, costing $4.65 per gallon. This is a single up-front cost differential, however, since it relates only to the cost of the initial batch of developer. Subsequent , recycled batches cost $1.38 per gallon. Does this mean that the DuCare developer is cheaper in the long run? No, since the $1.38 cost does not include the cost of *transporting* the developer as part of the recycling process. Transportation costs add an additional $.81 per gallon.

As for the recyclable fixer, it is more expensive than standard fixer, but is also of higher concentration. The greater concentration implies a lower replenishment rate, so that customers ultimately need to purchase less fixer. So despite its higher price per gallon, the recyclable fixer's effective cost is roughly equivalent to the costs of a non-recyclable fixer. Again, though, transportation adds further to the overall cost. Because fixer has a "hazardous" regulatory classification, its transportation costs are even higher than they are for developer. With a hazardous classification, licensed transport and storage is required. This translates into fixer transportation costs of $1.42 per gallon, on average. (A set of additional problems associated with fixer's hazardous classification is discussed below).

Up-front capital costs associated with the standard DuPont and DuCare systems are comparable.

DuCare vs. a competing environmental process. A competing technology, called On Line Recirculating Electrolysis (ORE) allows for effluent reductions and reduces the fixer replenishment rate. From a non-environmental standpoint, the ORE technology requires a much higher up-front capital cost ($10,000 versus $3,000) than does the DuCare system. However, it has lower on-going chemical costs and, because it is not a recycling technology, does not have the costs associated with chemical transportation to a recycling facility. Excluding environmental considerations, the ORE technology is a cheaper long-run alternative to DuCare. And because of its desirable impact on fixer replenishment, its long-run cost may be even less than the cost of the more standard photochemical process.

Note that this cost analysis highlights a fact with significant competitive implications. Quite simply, unless compliance costs are considered to be a relevant concern, the DuCare system is more expensive than other options available to DuPont's customers.

The environmental comparison. From an environmental perspective, the existing DuPont process and the ORE process cannot compete with DuCare. The full recyclability of the DuCare chemicals means that effluent wastes are essentially eliminated. As noted earlier, photochemical processing creates significant silver, COD, ammonia, and sulfates emissions. The ORE process allows for on-site silver removal. The ORE system does not address the non-silver effluent streams, however.

With the ORE and standard method, therefore, photo shops can dispose of non-silver waste by sending it to the drain or by shipping the waste to a third-party site for disposal. The latter is the environmentally preferable disposal method. This "hauling" and disposal option is costly, however. In fact, if a photo shop is going to haul waste for disposal, these hauling costs imply a net process cost greater than that associated with the DuCare system.

	Standard process	ORE system	DuCare

Operating cost (¢/sq.ft. film) without hauling	7.6	6.0	8.4
with hauling	26.6	23.4	8.9
Silver to drain (ppm) without hauling	130	. 5	< 1
COD to drain (ppm) without hauling	5200	2700	100
Initial capital cost ($)	2,900	10,000	3,000

Table 1

Table 1 presents a simplified summary of the characteristics of DuCare, relative to the other two methods.[39] It is likely that a customer would use the kind of data contained in this table when making the decision of which photo-chemical process to use. The table highlights the fact that none of the processes is cheapest in all circumstances. In particular, note how the desirability of the DuCare system is a function of whether or not the customer hauls its waste for off-site disposal. If the customer hauls waste, DuCare is by far the cheapest method (8.9 cents per square foot of film developed), in addition to being environmentally superior. However, if the customer does not haul its waste, DuCare is the most expensive option (8.4 cents).

Based on this analysis, it would be natural to conclude that demand for the DuCare P2 technology is a direct function of whether or not customers are hauling their waste for disposal, instead of releasing effluents directly to the drain. The gamble DuPont took with DuCare hinged on whether or not hauling waste would be a *de facto* regulatory requirement due to stricter effluent standards and greater enforcement. According to one document, "in areas with strict regulations where hauling waste is becoming the norm, the Zero Effluent

[39] The data is based on DuPont financial analysis. The DuCare product always requires transport. The DuCare "without hauling" option, the less than 1 ppm silver release, and the 100 COD release to the drain, arise from wash water, not fixer or developer, disposal.

offering will have a significant cost advantage." The fact that demand for DuCare has not been as strong as envisioned may be explained by relatively lax enforcement of photochemical waste regulations.

Regulatory Pressure and the Market for P2

From the beginning, the project's financial and strategic analyses identified regulatory pressure as the primary driver of the market for DuCare. Much of DuPont's optimistic financial and marketing analyses was predicated on the assumption that regulatory compliance and standards would continuously tighten and affect larger and larger numbers of graphic arts facilities. Because of the perceived trend in regulatory stringency, the firm felt that "the financial advantage of competitive offerings is already gone in some areas and is expected to be short-lived in many more." As part of its analysis, DuCare financial projections and business plans included an "environmental pressure map" of the United States. This map ranked different areas (down to the zip-code level) in terms of regulatory stringency -- stringency being measured by allowable silver concentrations and the perceived likelihood of enforcement. Three categories were differentiated: "strict," "transitioning," and "lax."[40] Customer concentrations were then laid on top of this map to create an overall estimate of the number of potential customers in stringent or transitioning areas. These firms were DuPont's target customer group.

The importance of regulatory pressure is further highlighted by the degree to which lax regulatory enforcement was viewed by project managers as an unlikely risk, but one of the key assumptions on which marketing projections were based. As one document, labeled "Key Business Risks and Assumptions" put it, there was a risk that "customers may be unwilling to pay for [DuCare] services in environmentally lax or transitioning areas."

> *Existing effluent standards can act as a powerful motivator for pollution prevention by creating markets for technologies that can address firms' compliance issues. It is important to emphasize, however, that standards must be monitored and enforced if they are to have the maximum impact.*

It is difficult to definitively establish that insufficiently aggressive effluent monitoring and enforcement is the root cause of DuCare's difficulties. The financial analysis presented above, however, points to enforcement issues as at least a partial cause of DuPont's marketing problems.

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[40] "Strict" areas were defined as those in which there was an enforced silver standard below 1 part per million. A "lax" area was one in which the standard was greater than 5 ppm or one in which standards were "not enforced" at all.

It is not entirely surprising that monitoring and enforcement would be problematic. Photochemical drain discharge occurs in relatively small amounts and by numerous, geographically diffuse, and shallow-pocketed firms. Monitoring difficulties are particularly significant in jurisdictions that face budgetary and technical enforcement constraints.[41]

Moreover, marketing surveys conducted by DuPont lend weight to the overall conclusion that the threat of regulation is the key driver for DuCare's customers. The firm surveyed all DuCare customers in 1995, asking them to indicate the importance of a range of factors that contributed to their decision to adopt the DuCare pollution prevention technology. The following is the percent of those responding who ranked the factor as extremely or very important (only the top six factors are reproduced below):

Factors considered central to adoption	% saying yes
The ability to meet future regulatory requirements	96
The ability to meet existing regulatory requirements	94
The ability to reduce chemistry consumption	72
Elimination of the need to measure and mix chemistry	66
Ability to market environmental leadership to customers and employees	61
The automated collection and distribution system	61

Clearly, regulation-related concerns are the most prominent motivator. The survey also revealed that 90 percent of DuCare's customers described their firms as existing in an "extremely, very, or somewhat strict" regulatory climate. At the very least, this analysis suggests that perceptions of regulatory stringency are central to the firms' demands for the DuCare product.

A Regulatory Barrier

DuCare can help customers achieve regulatory compliance and reduce expected liability costs, but only if regulation and liability are perceived to be problems worthy of consideration by customers. In this way, the above discussion highlights the sensitivity of demand for DuCare to regulatory enforcement. An appropriate conclusion to draw is that stronger regulation is good for pollution prevention.

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[41] A common means of monitoring is to monitor "downstream," or aggregated effluent currents. Given the dilution that occurs by the time downstream measurements can be taken, however, it can be very difficult to establish responsibility or standards violations unless the release is particularly large.

Interestingly, the DuCare case also highlights the way in which regulation can be bad for pollution prevention. In particular, the spent fixer's regulatory classification raises the costs of providing and using DuCare. In this instance, regulatory interventions are inhibiting the diffusion of pollution prevention.

Used fixer, even if part of a recycling-based system, is given a "spent material" RCRA classification. An unfortunate consequence of this rule is that, simply by using the product, DuCare customers become hazardous waste generators. According to several people interviewed for the case, regulatory burdens associated with this rule create a powerful motivation to simply discharge used fixer to the drain and POTW. The RCRA classification issue is the largest source of DuCare customer complaints. Its costs are difficult to quantify but are related to several factors. From a customer's standpoint, the spent fixer distribution system requires them to administer special handling and storage, labeling, training, and reporting procedures.[42] Many small printers have never had experience with this sort of regulatory program. For firms that generate other hazardous waste streams, the spent fixer classification -- and use of DuCare-- may "bump" them from small-quantity to large-quantity generator status. This would imply a set of additional regulatory burdens associated with that type of classification. Again, it is difficult to quantify the impact of these requirements on demand for DuCare. It is safe to say, however, that the hazardous classification has not helped DuPont in its efforts to market the product.

The classification also increases the costs of providing the recycling system. As noted earlier, the "reverse distribution" system that sends the fixer back for recycling is a major cost component. The hazardous classification means that the developer and fixer must be shipped separately. The inability to consolidate shipments increases costs, since there are scale economies associated with the transport of loads to the central processing facilities. The licensed transport required for the fixer is approximately twice as expensive as the transport used for the spent developer (spent developer has a less onerous "corrosive" Department of Transportation classification).

> *In some cases, regulatory rules can raise the costs of supplying and using pollution prevention technologies. This can have the unintended consequence of inhibiting the diffusion of technologies with desirable environmental characteristics.*

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[42] For example, recycled shipments must be "manifested." This involves an EPA number for shipment and documentation of goods to be shipped, quantities, transporters, and destination. And requirements differ widely across states, requiring state-specific compliance expertise on the part of DuPont's customers.

The spent fixer classification is a concrete example of a regulatory barrier to pollution prevention.[43] By raising the DuCare product's direct cost (via transport and storage charges) and creating administrative burdens for customers, the rule may be creating a negative environmental impact. Drain disposal is the predominate alternative to DuCare. It is therefore reasonable to assume that the rule's burdens have created some shift toward drain disposal, a decidedly less desirable means of dealing with photochemical waste.

[43] DuPont has raised the fixer classification issue with the EPA, which is currently considering a change in the classification of silver-bearing waste. In the past, the official position has been that no special exemption is available and that, in any event, precious metal reclamation exemptions may apply to DuCare materials. There is a significant lack of clarity in that rule's interpretation, however. Moreover, many states do not have precious metal exemptions.

4. Information and the Financial Evaluation of Pollution Prevention Opportunities

The case studies provide a window into firms' concrete strategic, technical, and financial thinking. In particular, they provide insight into the ways in which firms collect, process, and act on information when making investment decisions. We now return to some of the broader questions that motivated the study. Is information relating to environment-related financial benefits appropriately reflected in corporate decision-making? Are the firms coming to financially sound conclusions? Are there straightforward financial benchmarks that can be relied on to indicate the profitability of pollution prevention? Based on what was learned in the cases, we offer some tentative conclusions.

Are environment-related financial benefits being captured appropriately by the decision-making process?

One of the primary challenges to pollution prevention is the need to define and quantify the benefits of such investments. An emerging literature emphasizes the desirability of methods such as environmental cost accounting as a means to improve corporate decision-making. With the identification and quantification of environment-related financial benefits, firms can be expected to make better private, and environmental, decisions.[44] For instance, environmental accounting can highlight the way in which changes in a production process reduce future environmental compliance costs. This reveals a benefit to investment from a process change, a benefit that may not otherwise have been captured in a capital budgeting decision. The quality of environmental accounting is of clear importance, and not least to firms themselves. Are financial benefits being captured adequately?

As we evaluate firms' accounting of environment-related financial benefits and costs, it is important to distinguish between two types of questions. First, to what extent are financial benefits and costs *quantified*? Second, are environment-related financial benefits and costs, even if not quantified, being given sufficient *weight* relative to non-environmental benefits and costs? Note that the first question deals with the detail and numerical sophistication of quantitative estimation techniques -- the way in which the firm determines the bottom-line impact of activities that affect the environment. The second question deals with the impact of accounting techniques on the firm's decisions. Failure to accurately quantify benefits and costs could bias investment decisions against pollution prevention.

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[44] See White, Becker, and Goldstein (1992) and White, et al. (1995).

The quantification of environment-related financial benefits

Consider first the issue of quantification. The financial analyses associated with the above cases show relatively little economic quantification of environment-related financial benefits and costs. In almost none of the documentation reviewed were dollar values attached to savings from reduced emissions or liabilities. (There are a couple of exceptions worth noting. The first is the dollar value of savings associated with avoided incinerator upgrade costs in the Dow case. The second is DuPont's analysis of benefits associated with not having to haul and treat spent photographic fixer and developer wastes.[45]) In fact, one of the cases revealed an example of management spelling out its desire to explicitly *avoid* the use of certain quantified environmental benefits during economic evaluation. An internal Dow document states that "savings from enhanced environmental protection and avoidance of liability will not be considered in economic evaluation. These issues will be a factor in the leadership decision-making process..." In other words, describe the enhanced environmental protection, but don't give us a dollar estimate of its value.

How is this lack (or explicit avoidance) of environmental accounting data to be interpreted? First, it should be pointed out that, while economic values are not quantified, there is extensive technical quantification of environmental benefits (e.g., pounds of a pollutant eliminated annually). In all of the cases, for instance, emissions reductions are analyzed and quantified in a variety of ways. The only step that is missing is the translation of these technical environmental benefits into financial benefits. Why is this step not taken? The best explanation is that it is simply too difficult to arrive at economic values with any precision. When a firm is estimating conventional costs, such as the cost of a new piece of capital equipment, something as simple and available as the market price of the item can be used. There is no analogous list of prices, or costs, that can be used to translate reduced environmental emissions into a dollar value. Methodologies chosen to do so may be somewhat *ad hoc*, and thus of questionable accuracy.

Methods for environment-related financial benefit estimation are being improved. For instance, depending on the type of financial benefit being estimated, historical data can be used as a guide to avoided future costs (the benefit). As technologies, consumer tastes, and regulatory standards change, however, the ability to quantify these benefits and costs accurately becomes more difficult. It may be reasonable for upper management to discourage the use of quantification techniques that are untested and aimed at the estimation of values that are so inherently uncertain.

[45] The more pertinent question in the DuPont case is whether or not DuPont's customers go through a similar calculation. While DuCare is marketed in a way that conveys compliance-related savings, it is not clear that compliance is considered a relevant issue by many of its potential customers.

The evidence suggests that better forms of environmental accounting are needed. However, it also suggests that there are significant challenges to the collection and analysis of this type of data. For instance, when dealing with new products and processes, where can data on their environmental risks be found? To illuminate this problem, consider the distinction between cost *estimation* and cost *accounting*. Historical cost accounting data (i.e., data that is certain) can be used for cost estimation, but only if past costs are a good guide to future costs. This may not always be so. Historical, actuarial environmental accounting data is not useful if it provides data on environmental risks, technologies, and legal situations that firms are not likely to encounter in the future. For instance, a firm's expected future liability costs should probably not be estimated by looking at its past Superfund liability costs. Because of Superfund, firms dispose of wastes very differently than they did 20 and 30 years ago. Because of its highly uncertain technical and legal nature, environmental cost estimation may inherently be more speculative than we, or firms themselves, would hope.

The effect of uncertain financial benefits on decision-making

Given the lack of quantified financial benefits, do the cases suggest that potential environmental improvements are given inadequate weight by corporate decision-makers? The answer is no. While un-quantified, environmental benefits are given significant qualitative value in the decision-making process. Evidence for qualitative weighting includes the inclusion of environmental benefits as key "drivers" in the decision-making process. Environmental benefits, such as physical data on quantities of emissions reduced, are routinely featured in summary documents presented to upper management at the time of decision-making. The "paper trail" (agendas, strategic analyses, and decision-making summaries) followed to re-construct these cases are permeated with a qualitative understanding of environmental benefits. The cases suggest, therefore, that non-quantified environmental benefits do not necessarily imply an inadequate weighting of environmental benefits in the decision-making process. Instead, lack of quantification may simply indicate the inherent difficulty of establishing precise financial values. In light of this, it also deserves mention that many types of accounting data (i.e., not just environmental accounting data) are often incomplete and surprisingly imprecise. Thus, evidence of poor environmental accounting data and procedures can be viewed as a symptom of poor accounting techniques generally, rather than as evidence of a specific environmental accounting problem.[46]

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[46] There is a justifiable concern that environmental benefits may not be captured adequately by accounting procedures based on short time horizons. However, in the cases (Dow and DuPont) where yearly cash flows were estimated, the time horizon used was ten years. (Current corporate guidelines at Monsanto require evaluation over a 10 year horizon). Particularly given the effects of discounting, a 10 year horizon is methodologically sound and should capture the lion's share of net present environmental benefits.

Are firms missing win-win pollution prevention opportunities?

Some observers believe that companies fail to pursue their own economic self-interest when it comes to pollution prevention. For instance, Porter (1995, 132) claims that companies exaggerate the risk of environmental investments, use inappropriate rate of return hurdles, and thus "leave ten-dollar bills on the ground." This type of assertion, while thought-provoking, is difficult to prove or refute without evidence related to actual corporate investment decisions. Even when an investment is explored in detail, as in the NRDC study of the same Dow LaPorte investment described in this paper (Greer and van Loben Sels, 1997), conclusions about an investment's economic desirability are often made without adequate analysis of business and financial considerations.[47]

The case studies in this paper were motivated in large part by the desire to better understand the corporate rationale for rejecting, or delaying, identifiable pollution prevention opportunities. As the cases show, basic concepts from business and financial theory suggest that the firms' investment decisions were financially rational. This is contrary to the view that firms suffer from a myopic inability to appreciate cost-saving P2 investments. Instead, significant unresolved technical difficulties, uncertain market conditions, and, in some cases, regulatory barriers or insufficient emissions enforcement, rendered the investments financially unattractive. In many cases, the mystery of why firms do not pursue P2 opportunities can be resolved by simply having a deeper understanding of the costs, benefits, and risks associated with those investments.

This conclusion implies nothing about the social desirability of the firms' decisions. Reasonable persons can -- and do -- differ regarding how much pollution prevention is the right amount of pollution prevention. But it does imply that there may be fewer high-return P2 opportunities than many believe. Those who favor mandated, command and control-style, regulations may wish to claim that many high-return, win-win opportunities exist, but that firms ignore those opportunities. After all, if this were true, command and control regulations could be viewed as forcing firms to do what is in their own economic self-interest anyway. This line of thinking should be viewed with skepticism. The investments analyzed here were

[47] This paper's description of the La Porte investment decision owes a great deal to the NRDC's excellent technical study of pollution prevention opportunities at the plant. It disagrees with the study's conclusions regarding the financial desirability of TOX retirement, however. Dow's failure to approve the investment is taken as evidence that "cost savings are not enough to convince industry to adopt prevention actions" (p. 418). This conclusion is based on the authors' belief that TOX retirement would reduce costs for Dow. But conclusions about cost savings require business and financial analysis that is as detailed as NRDC's technical analysis. When detailed financial analysis is brought to bear on the question of cost savings, those savings are far from certain.

by no means clear-cut financial winners. The cases suggest that firms are quite capable of identifying the actions that are in their greatest financial self-interest.

Information barriers and the search for clear financial benchmarks of P2 profitability

The cases challenge the belief that organizational barriers are to blame for missed or delayed P2 opportunities. Nevertheless, it should also be clear that firms face significant informational problems when they evaluate new investment opportunities. Managers never have perfect information regarding the costs and benefits of a new investment. In fact, imperfect information explains a great deal about the way in which firms analyze and make investments. It is important, however, to distinguish between a firm's imperfect methods for dealing with imperfect information and evidence of organizational failures.

The term "organization failure" connotes the existence of a correctable management strategy, accounting procedure, or financial methodology. For instance, if the benefits of an environmental investment were analyzed only over a 3-year horizon, this could easily be labeled an organizational failure. The failure to account for benefits beyond three years could easily be corrected by a longer-horizon investment analysis. And better, more profitable decisions would be expected. Similarly, if financial managers rarely spoke with environmental managers or infrequently integrated regulatory expertise into business analysis, this could be easily, and profitably, corrected. The cases, however, exhibit little in the way of these correctable types of failure. Instead, the cases depict managers struggling with much more formidable challenges to investment decision-making -- challenges that are pervasive and not limited to the analysis of environmental investments.

Consider the concept of a "hurdle rate" for new investments. Most firms define a rate of return that new projects must exceed before capital is directed toward the investment. In general, firms will not make investments that fall short of the hurdle rate, even if the investments have a positive rate of return. This can be a source of frustration to advocates of pollution prevention, who see a positive rate of return as evidence of profitability. A positive rate of return seems to be a clear benchmark. When firms ignore that benchmark and focus on some higher hurdle rate it is natural to suspect the firm's "decision rule." But is a hurdle rate decision rule a correctable organizational failure? The answer is no. Hurdle rates and the rationing of capital serve an important, inescapable corporate function. They are means by which firms account for the risks of investment and inherent imperfection of information at their disposal.

The rate of return

In order to explore these concepts in more detail, consider a hypothetical P2 investment opportunity that has been estimated to have a 30 percent rate of return. How can we explain why a firm would not make an investment that offers such an apparently positive return on investment?

In a capital budgeting context, the "internal rate of return" (IRR) on a proposed project is a function of the timing and size of "cash flows" associated with the project. Cash flows include the initial cost of a project (the outlay) and its subsequent inflows (such as sales revenues). While rate of return is a concept that seems intuitive, it is actually quite subtle. Consider the technical definition of IRR: a project's internal rate of return is the discount rate at which the project's net present value is zero. While the technical definition is somewhat obscure, for simplicity, it is possible to think of rate of return as a measure that accounts for a project's benefits and costs, year-by-year.

The first point to make about IRR calculations is that in the capital budgeting stage rates of return are always estimates, and thus are inescapably uncertain. An IRR estimate is only as good as the analysis on which it is based. Techniques such as environmental cost accounting are methods to improve the accuracy of these estimates. Environmental cost accounting allows for a more complete accounting of the cash flows that form the basis of the IRR calculation. A problem with rate of return calculations may be that they fail to incorporate "soft" (harder to quantify) costs and benefits. If this is true, a 30 percent rate of return estimate may be "adjusted" qualitatively by managers. For instance, if a project has a calculated rate of return of 30 percent, but will result in employee layoffs, the cost of which has not been quantified, managers should view the 30 percent figure as being too high. Alternatively, if the project analysis does not include environmental cost savings, managers would, appropriately, view the 30 percent figure as too low.

> *Accounting techniques must be evaluated in order to determine whether reported benchmark figures (such as rate of return) are viewed by management insiders as complete and unbiased. Managers are likely to better understand the ways in which their own analyses are biased. If so, benchmark figures must be interpreted with care, particularly by outside analysts.*

Assuming the IRR is an unbiased, accurate estimate, the financially sound IRR investment rule is as follows: proceed with the investment if the IRR exceeds the cost of capital. Technically speaking, this rule ensures that the investment has a positive Net Present Value, a measure of profitability. Projects are desirable (profit-maximizing) only if they have positive NPVs. Thus, the IRR figure is by itself not a guide to an investment's desirability. It is the *comparison* of IRR and cost of capital that is relevant.

Risk and the cost of capital

What is meant by the "cost of capital?" First, note that the cost of capital has little to do with what we normally think of as a "cost." In particular, it is distinct from the cash outlays necessary to buy equipment or change a production process. These conventional costs are, in financial parlance, "negative cash flows." The cost of capital is not a cash flow. Instead, a project's cost of capital is defined as the "opportunity cost of using the capital for the project versus using it for some other equivalent project." In other words, if a project requires a $100 cash outlay, the cost of capital is *not* the $100. The cost of capital is the cost of not spending the $100 on something else.

Returning to the definition, the cost of capital is the opportunity cost of using the capital for this project versus using it for some other equivalent projects. What are equivalent projects? Equivalent projects are those that pose equivalent risks. The relationship between risk and the cost of capital is central to the analysis of capital budgeting decisions. When someone loans or invests their money they are concerned with both the expected return on and the risk associated with the loan or investment. Investors have varying "tastes" for risk and return. Some prefer safer investments. Those willing to accept risk can do so, and because they take on these risks, command a higher expected return.

When a firm seeks money for a risky project it must raise the capital from investors who are attracted to the level of risk and return presented by the project. But note that these investors could just as easily invest their money in other firms' risky projects. The opportunity cost of investing $100 in the project is thus the cost of giving up the opportunity to invest $100 in other projects with similar risk profiles. What is the "opportunity" that is being given up? The opportunity is the ability to earn the rate of return associated with the other projects. If a 30 percent return can be earned on other investments, a firm needs to show investors that their risk-equivalent project can yield a return of at least 30 percent.

Determining the cost of capital therefore requires an understanding of other opportunities available in the market. Financial tools such as the Capital Asset Pricing Model (CAPM) account for the importance of risk and are designed to value investment opportunities. Capital cost estimation requires knowledge of the broader market's "risk free interest rate" and "market risk premium." These terms, respectively, relate to the returns offered by a perfectly safe investment and a diversified stock or bond portfolio. Then, the firm must estimate its equity and debt "betas." Roughly, these betas measure the contribution of an investment in the firm to the riskiness of a diversified portfolio. With these estimates a firm's cost of capital can be estimated. The technical, mathematical nature of these concepts should not obscure the fact that the process of estimating them is as much an art-form as it is a science.

Rate of return is relevant only as it compares to a project's cost of capital. Moreover, the cost of capital is not typically easy to measure, since it is intimately related to project risk. Thus, the implication of a particular rate of return figure for decision-making requires detailed knowledge of factors contributing to risk. No single rate of return "hurdle" can be used as a benchmark for judging an investment's profitability.

Finally, it should be noted that a firm's cost of capital will not in general be the same as the cost of capital for a specific project. Because the cost of capital is a function of risk, capital costs will differ in different divisions, for different product lines, and across individual projects. If the project in question is riskier than the firm's business generally, the cost of capital will be higher -- because riskier investments demand a higher return. Ideally, then, it is desirable to estimate the equity and debt betas associated with investments that are equivalent to the contemplated project. This usually involves the estimation of betas associated with other firms' investments. The difficulty in determining investments that are "risk-equivalent" is one of the things that makes the task subjective.

Capital rationing

Now assume that a firm has calculated a project's cost of capital at 25 percent. If the IRR is 30 percent, should the firm make the investment? In general, yes, since these numbers indicate a positive net present value (the rate of return exceeds the opportunity cost of capital). In practice, however, businesses commonly depart from a pure "positive net present value" decision rule. In other words, firms do not generally move forward with projects simply because they have positive NPVs. Instead, firms often set limits on the capital available to individual business units. This places a ceiling on funds available for new investment and forces managers to prioritize across projects, all of which may have positive NPVs. This financial management technique is termed "capital rationing" and is used commonly in the private sector.

Capital rationing is in evidence in the Monsanto and Dow cases. The P2 projects had positive rates of return, rates that may in fact have exceeded the firms' costs of capital. Nevertheless, the supply of investment capital to the business decision-making units was limited by corporate headquarters. Thus, the capital constraint can be viewed as a culprit in the failure of the firms to move forward with the investments. After all, if the businesses had no such constraint any investment with a positive NPV would presumably be financed. Given this, is capital rationing an organizational barrier to pollution prevention? In other words, is the rationing of capital an irrational, correctable corporate decision-making procedure?

To answer these questions, it is necessary to explore firms' rationale for limiting the availability of capital to their business units. The principal rationale is that capital rationing is necessary for internal financial control. In this view, rationing counters the tendency of managers to overstate the benefits of investment opportunities with which they are involved. In general, it is very difficult to align the personal incentives of managers with the incentives of the firm as a whole. For instance, compensation and prestige are invariably related to the scope of projects under a manager's control. This creates a tendency to propose and seek acceptance of a large number of investment projects. One way to seek acceptance for projects is to make capital budgeting estimates that are over-optimistic. That is, managers may be led to bias their forecasts of cash flows associated with a new investment (e.g., over-state expected benefits or under-state expected costs). Again, this emphasizes the inherently uncertain, and subjective, nature of financial data. Capital rationing, therefore, is a means to correct largely unavoidable problems associated with imperfect information, managerial monitoring, and investment incentives.[48] It should not be viewed as an easily correctable organizational failure.

When capital is rationed, investments are not judged on the basis of whether the rate of return exceeds the cost of capital (the positive NPV rule). Instead, projects are typically ranked, with capital invested in those promising the highest net return. In practice, this can mean that the most rational investments need not be those that promise the highest rates of return or net present value. Instead, the most desirable projects are those that provide the highest NPV *per dollar invested*.[49]

The implication is that capital rationing leads firms to prioritize their investments. While this may mean that certain P2 opportunities are passed over, it does not in general mean that environmental investments are disadvantaged. The Dow La Porte investment is illustrative. One reason the TOX elimination project has not moved forward is that the project has failed to meet the polyurethane business' current hurdle rate. The hurdle rate was high -- roughly 86 percent. The hurdle rate was this high, however, because an alternative use of the business' funds promised an 86 percent return. Given capital rationing, money used at La Porte would have taken away from this other project. In effect, the "bar was raised" on the La Porte investment because of the need to prioritize expenditures and the existence of higher-priority investments.[50] Also, it is worthy of note that the higher-priority

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[48] For analyses that explore the theoretical justification for capital rationing see Holmstrom and Costa (1986) and Antle and Eppen (1985). They show how the private concerns of managers, combined with private information, can create managerial incentives to over-invest. Capital rationing is shown to be an effective corporate strategy to counter these incentives.

[49] See Brealey and Meyers (1991) who give examples of the way in which investment rules under capital rationing can violate the idealized NPV rule.

[50] The rationing issue was addressed by internal corporate decision-making documents in the following way: "The polyurethane business is global and makes capital environment decisions based on global priorities. The cost and return of the TOX elimination project was not as favorable as other projects the business is funding. These other projects include as much as a hundred million dollars in capital and two new source reduction technologies

investment was also more environmentally beneficial than the La Porte P2 investment would have been. Source reductions associated with the rival investment exceeded reductions at La Porte by an order of magnitude. Thus, prioritized capital budgeting should not be viewed as a barrier to pollution prevention. In fact, financially prioritized investment is also likely to lead to prioritized environmental innovation.

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which will eliminate 30-60 million pounds per year of material from incineration by increasing the yield of processes in the polyurethane business."

5. Conclusion: Pollution Prevention and Public Policy

The cases presented in this analysis were explored in order to shed light on the organizational and economic issues that shape pollution prevention decision-making. For those concerned about environmental quality, it is natural to be frustrated with decisions that reject or delay investments that could improve a corporation's environmental performance. Much of that frustration may be alleviated, however, via a better understanding of the strategic and financial factors that affect the profitability of pollution prevention investments.

This analysis' conclusions should not be taken as either a defense or condemnation of the firms' environmental performance. The "right" level of pollution prevention to be undertaken by the corporate sector is a question left to a different study (though it is worth emphasizing that regulations, and the avoidance of regulatory costs, were in all the cases a "driver" that motivated the firms' search for pollution prevention). Still, without a detailed accounting of social benefits and costs, little can be said about whether more or less stringent regulation was appropriate in these cases. Instead, the cases say much more about *the way* in which firms are regulated.

The results of this analysis can be viewed largely as a defense of the soundness with which managers weighed the private benefits, costs, and risks of the pollution prevention investments they were evaluating. Instead of revealing evidence of corporate organizational barriers or myopic decision-making, the cases demonstrate a set of complex, but ultimately prosaic motivations for the decisions that were made. Appreciation of those motivations is important because it can help guide public- and private-sector efforts to improve corporate pollution prevention performance.

The findings here run counter to the perception that firms are somehow failing to pursue win-win opportunities. Instead, failure to pursue P2 is usually best explained by a project's lack of expected profitability. Surely some profitable P2 opportunities have gone undetected by the private sector. But once unearthed, firms have both the motive and ability to evaluate profit opportunities. Convincing firms of the profitability of investments they are uniquely capable of evaluating themselves is likely to be a relatively unconstructive approach to P2 promotion. Instead, a more fruitful approach is to focus on barriers to P2's profitability.

What policy changes are likely to enhance P2's profitability? First, the cases reveal regulatory barriers of varying significance. The desire to experiment with P2 innovation is often thwarted by rigid media- and technology-specific regulations. The rigidity of many regulations is understandable given the difficulties of environmental enforcement. Nevertheless, efforts to promote regulatory flexibility and innovations should be embraced as a means to foster the corporate sector's ability to develop environmental innovations. The

DuPont case featured a regulatory barrier associated with a material classification issue. While there are sound reasons for the material classification system in general, removal of that barrier would be a desirable example of "seeing the regulatory forest for the trees." In specific cases, rules act at cross purposes with the environmental goal. Flexibility is the only way to avoid that kind of problem. Of course, the DuPont case also highlighted a way in which lax regulatory enforcement can weaken the demand for P2 technologies.

Second, performance-based (as opposed to technology-forcing) regulation is likely to be a better way to promote private sector P2 innovations.[51] P2 increasingly calls for firms to engage in the redesign of complex products and processes in ever-changing product markets. Performance-based regulations, which allow greater latitude for technological experimentation and longer time-horizons for compliance, allow firms to meet targets in the largest variety of ways.[52] In contrast, existing regulations feature substantial regulatory influence over the technologies used by firms. Not only are specific technologies often mandated, but technical constraints also arise because emission standards are applied to individual substances rather than broader categories of effluent. Because of this, limits on the output of a single substance can significantly constrain the design (or redesign) of a production process.[53] Moreover, because of an emphasis on specific abatement procedures for specific effluent streams, firms must continually re-permit as their production processes change. This re-permitting is a costly and time-consuming exercise in and of itself --

[51] Instead of judging environmental compliance on the basis of specific technological inputs or narrowly-defined emissions standards, performance-based regulation relies on more holistic measures of a facility's environmental performance. For instance, compliance with aggregate limits (on a larger "bundle" of chemicals), rather than chemical-specific limits, is consistent with a performance-based approach. The EPA's "Project XL" -- a voluntary industry-regulator initiative to promote innovative forms of environmental regulation -- is currently fostering experimentation with performance-based permitting.

[52] Care must be taken not to confuse "flexibility" with a lack of regulatory stringency. Flexible permitting, at the aggregate level, can be very stringent. But flexible permitting allows firms to meet even stringent aggregate targets in the way they best see fit.

Performance-based regulation is not without limitations of its own. Monitoring and enforcement issues, in particular, loom large. The uniformity (inflexibility) of standard command and control regulations is a virtue, since it is easier to monitor technology or emissions standards that are fixed and common to many firms. However, given the unique characteristics of most firms, the constraints imposed by uniform standards should be viewed as a potentially significant barrier to P2 innovation.

[53] Emission standards may not explicitly dictate a technology choice. However, they often carry an implicit incentive to employ a standard technology. This is because standards are usually developed based upon the emission characteristics of specific technologies. Firms can minimize their likelihood of being found in violation of standards by employing the technologies on which the standards were based. Innovative approaches run a higher risk of generating permit violations, or triggering permitting delays.

particularly for firms whose production processes must change frequently. Performance-based environmental permitting should be explored as a means to lower these barriers and constraints.

Flexible, performance-based regulation has another important consequence: namely, it enhances the private sector's demand for improved environmental accounting information. Rigid regulations do a particularly poor job of fostering the private sector's demand for, and development of, better environmental accounting information and methods. After all, end-of-pipe, single-media, and technology-forcing regulations leave firms with little reason to innovate, and therefore even less reason to collect information that would reveal environment-driven financial opportunities. Better information helps firms only if they have the flexibility to act on --and benefit from-- better information. Regulatory flexibility, by expanding the technological options open to firms, increases the value of information relating to those options. In the end, regulation that allows for a wide variety of innovative solutions is likely to be the best way to induce firms to invest in better environmental information and decision-making.

The analysis of financial evaluation procedures has highlighted significant information barriers faced by firms. This underscores the continued importance of improved environmental cost accounting methods to better estimate environment-related financial benefits. Improved data collection, estimation, and evaluation techniques can only improve corporate decision-making. The important, and open, question for future research is: what forms of environment-related information are likely to be most valuable to the private sector? This study has suggested that firms can be expected to do a relatively good job of evaluating the environmental and financial characteristics of P2 opportunities, once those opportunities are identified. Perhaps the greatest challenge for firms, however, is the initial identification of those opportunities. The technical identification of P2 opportunities may be well served by greater efforts at basic R&D and firm-specific "materials accounting."[54] Mandated accounting requirements are of questionable value, given the idiosyncratic needs of specific firms and facilities. And confidential business information issues undermine the practicality of mandatory and publicly-disclosed P2 planning. However, government promotion of state of the art accounting practices, including materials accounting, is likely to concretely benefit firms that are increasingly concerned with environment-related costs and opportunities.

[54] Materials accounting denotes efforts to track the physical flow of materials into, through, and out of a given facility.

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