U.S. Department of Energy
Office of Policy and International Affairs and
Office of Energy Efficiency and Renewable Energy

TECHNICAL REPORT FIVE

**THE INTERRELATIONSHIP
BETWEEN
ENVIRONMENTAL
GOALS, PRODUCTIVITY
IMPROVEMENT, AND
INCREASED ENERGY
EFFICIENCY IN
INTEGRATED PAPER AND
STEEL PLANTS**

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EXECUTIVE SUMMARY

This report presents the results of an investigation into the interrelationships between plant-level productivity, energy efficiency, and environmental improvements for integrated pulp and paper mills and integrated steel mills in the United States. Integrated paper and steel plants are defined as those facilities that use some form of onsite raw material to produce final products (for example, paper and paperboard or finished steel). Fully integrated pulp and paper mills produce onsite the pulp used to manufacture paper from virgin wood fiber, secondary fiber, or nonwood fiber. Fully integrated steel mills process steel from coal, iron ore, and scrap inputs and have onsite coke oven facilities.

Purpose

The purposes of this study are the following:

- To obtain the opinion of selected companies on apparent tensions between productivity, energy efficiency, and environmental improvements associated with conventional environmental regulation
- To assess the extent to which “win-win” environmental/productivity improvement opportunities are possible
- To examine decisionmaking practices that have influenced past investment practices
- To examine the extent to which different environmental and energy policy approaches by the Federal Government may encourage win-win outcomes

Research Method

The study uses a case study approach that combines data analysis, company site visits, and a literature review of the interrelationships between environmental regulation and productivity. Historical plant-level data for integrated paper and steel plants are used to quantify the magnitude of productivity, energy intensity, and environmental performance. To carry out the data analysis, the most recent techniques in productivity measurement are used so that pollution, technology innovation, and technology adoption could all be simultaneously

incorporated into the measurements. The company site visits involved interviewing environmental and energy managers at two integrated paper and two integrated steel facilities to discuss their opinions on issues that pertain to their situation. The examples of sources of tensions were collected from discussions with industry representatives, so they represent an industry point of view on these issues.

Principal Findings

In this summary, the main findings from this investigation are presented in four broad areas: (1) evidence of tensions associated with conventional environmental regulation (that is, the command-and-control approach); (2) productivity, energy efficiency, and environmental impacts; (3) decision-making factors that influence plants' environmental and energy-efficiency investments; and (4) strategies to help industry address their diverse performance goals.

Evidence of Tensions Between Environmental Performance, Productivity, and Energy-Efficiency Goals Associated With Conventional Environmental Regulation

Two categories of tensions were identified from the interviews with companies: tensions between environmental goals and productivity goals, and tensions between environmental goals and energy-efficiency goals.

Conventional Environmental Regulation and Productivity

- Companies report that the current permitting process is a source of tension between environmental regulation and productivity. For example, all companies felt that the permitting process associated with the Prevention of Significant Deterioration (PSD) program of the Clean Air Act hurts productivity because of the added administrative costs (\$100,000 to \$200,000). The permitting process can also be detrimental to industrial expansion because of the associated delays, which often last 1 to 2 years.
- Several companies reported that tensions concerning their diverse performance goals have resulted from regulators encouraging a facility to adopt a

control technology that may not be fully proven to work or completely transferrable to different operating environments.

Conventional Environmental Regulation and Energy Use

- The issue most commonly reported by companies was that the operation of emission-control devices consumes a great deal of energy. For example, many emissions are controlled by air capture, which requires a high amount of energy.
- Conventional regulations may not allow for certain types of energy-efficiency projects. Several companies cited the example that, although in certain cases it would be preferable for a company to burn waste liquid fuels onsite as an energy source that could be substituted for fossil fuels, many companies sell their waste liquid fuels to brokers who incinerate them without any energy recovery. This is because the Resource Conservation and Recovery Act (RCRA) may inhibit the use of waste products as fuel.
- Two companies expressed the view that the top-down approach to determine the best available control technology (BACT) under the PSD program of the Clean Air Act can nullify the cost-reduction advantages of an energy-efficiency project by adding to project costs.
- Conventional regulations often do not provide an incentive to pursue innovative technologies. Companies perceive that (1) if they pursue innovative technologies, direct costs will almost always increase, and (2) if they demonstrate an ability to operate at a lower emission level, new regulations will require other facilities to operate at a lower level even if their local situation is inconsistent with the lower emission limit, and the original facility will be forced to operate always at a lower level regardless of cost penalties.

These observations drawn from company interviews are generally well-known industry viewpoints that have been reported elsewhere. All of the companies interviewed felt that these tensions among environmental performance, productivity, and energy are associated with conventional environmental regulations.

Productivity, Energy Efficiency, and Environmental Impacts

For both the integrated paper and steel industries, long-term trends in productivity and energy intensity show that technical change is the dominant component of growth, and recent declines in production efficiency have offset increases in technical change.

Analyses of long-term trends in productivity for the integrated paper and steel industries, respectively, that decompose productivity growth into technical change and production efficiency components,¹ have revealed that technology improvements have accounted for the bulk of productivity growth (Table ES-1). From 1988 onward in the integrated paper and steel industries, declines and slowdowns in overall productivity have been mainly caused by declines in production efficiency. This sometimes dramatic drop in production efficiency in 1988–1991 was mirrored by an increase in technical change.

¹*Technical change* is the productivity improvement that results from improvements in best practice over time through, for example, plants adopting newly developed, state-of-the-art technologies. Failure to adopt new best-practice technologies results in inefficiencies that reduce plants' realized productivity gain—that is, plants begin to fall behind and have lower productivity growth than feasible. On the other hand, *production efficiency* includes more aggressive and widespread adoption of existing best-practice technologies and practices by plants.

Table ES-1. Summary of Long-Term Productivity Trends for the Integrated Paper and Steel Industries^a

Productivity	Integrated Paper Industry (percent per year)	Integrated Steel Industry (percent per year)
Average Overall Productivity Growth	2.2	2.5 (only 1.7 during 1973–85)
Technical Change Component	1.8 (has been steady and robust)	3.0 (has not been steady and robust)
Production Efficiency Component	0.4	0.6

^aThe time period covered is 1972–1991 for the steel industry and 1974–1991 for the paper industry. Difficulties with the paper industry sample in the first 2 years of available data for the paper industry prevented including them in the study.

The study finds a common trend in fossil-fuel and electricity intensity for both the integrated paper and integrated steel industries. Fossil-fuel intensity declined at an average rate of 4 percent and 3 percent per year for the paper and steel industries, respectively, with much of the decline occurring in the 1970s. Purchased-electricity intensity has risen at about 1.2 percent and 4 percent per year for the paper and steel industries, respectively, although these trends have been highly volatile. In both industries, technical changes may be closely tied to electricity use—for example, the use of process controls.

Results for the Integrated Paper Industry

Best-practice paper plants have obtained a distinct production advantage over non-best-practice paper plants in their fossil-fuel intensity, conservation of electric power, and use of cogenerated power.

- In 1979, best-practice paper plants had 7 percent lower fossil-fuel intensity than plants that were not best practice; by 1992, these plants had 12 percent lower fossil-fuel intensity.
- Although by 1992 both best-practice and non-best-practice paper plants had lowered fossil-fuel intensity by more than 50 percent, best-practice plants made more improvements, which widened the gap.
- In 1979, best-practice plants used only 4 percent less purchased electricity than plants that were not best practice, but by 1992 the best-practice plants used 80 percent less purchased electricity.
- Best-practice paper plants became more electricity efficient (or self-sufficient), while the intensity of purchased electricity of other plants actually rose.

Win-win opportunities are observed between the average and best-practice plants.

The study found that 42 percent of the plants in the data sample had clear win-win opportunities—that is, they exhibited the potential to reduce *all inputs* (energy, labor, materials, and capital) and *all four criteria air and water pollutants* (sulfur dioxide, nitrogen oxides, total suspended solids, and biochemical oxygen demand) while *simultaneously* increasing production.

- By doing so, declines in the paper industry's average energy intensities have been approximately 7 and 8 percent for fuels and electricity, respectively.
- The decline in average air and water pollution intensities, defined as tons of pollutant per dollar value of shipments, has been 5.5 to 6.5 percent.

- Similarly, the decline in energy and toxic chemical (sulfuric acid, chlorine, and methane) release intensity are estimated to have been 6 to 9 percent.

The similarity in the results for toxic releases and for air and water pollution suggests that production efficiencies that give rise to these win-win opportunities may not be tied to specific pollution activities, but are a general issue of plant-level productivity—that is, production inefficiency adversely affects both business and environmental goals.

Conventional environmental regulations impose losses in productivity, but improved production efficiency could offset some of these losses.

If observed air and water emissions are constrained by conventional regulations, and if we compare the difference between best-practice plants with best-practice plants that do not have such emission constraints, then the average productivity loss to best-practice paper mills is about 9.5 percent of total industry output. This represents productivity loss due to environmental regulatory constraints, and it includes both direct and indirect effects. For an average integrated paper mill, this loss is about \$20 million in lost production. The study further estimates that if all plants were operating efficiently, production efficiency improvement could reduce productivity loss to about \$7 million, on average.

“Capital rationing” is a source of environmentally related productivity losses but is a small contributor to overall production efficiency.

The requirement that capital be allocated to abatement expenditures (possibly causing capital rationing) is one type of indirect environmental effect. This study estimates that in 1990 the overall productivity loss due to production inefficiency was 17 percent; productivity loss due to historical pollution requirements was 9.5 percent; and the pollution abatement capital constraint (that is, capital rationing) lowered productivity by 3.3 percent. These estimates suggest that although the abatement capital constraint itself may play a small role in reducing overall production efficiency, it may be an important source (about one-third) of environmentally related productivity losses.

Results for the Integrated Steel Industry

Improved efficiency provides win-win opportunities to reduce losses in productivity imposed by sulfur dioxide emission constraints.

The analysis of the 17 integrated steel plants found that in 1990, the average productivity loss due to sulfur dioxide emission constraints was about 11.2 percent, or \$90 million, for a typical steel plant; it could be cut in half if

best-industry practices were used. There could be a roughly 5.7-percent decline in energy and air pollution intensity, if all plants could operate at best practice.

The losses due to the abatement capital constraint reduce productivity by a modest amount, although the reduction is a higher share than was found for the integrated paper industry.

In 1990, the overall productivity loss due to production inefficiency was 14 percent; productivity loss due to historical pollution requirements was 11.2 percent; and the pollution abatement capital constraint lowered productivity by 4 percent. These estimates are very similar to the integrated paper industry results, suggesting that the indirect effect of the abatement capital constraint may be an important source of environmentally related productivity losses.

Decision Factors That Influence Plants' Environmental and Energy Investments

The commonly known factors shaping the direction and size of capital investments by industry are basic economic forces such as prices, taxes, economic growth, and cost of capital. The study identified the following several additional drivers that influence environmental and energy investments:

(1) environmental compliance is a top priority for the companies interviewed; (2) the appearance of being a good corporate citizen is also a reason why companies seek to make environmental improvements, including discretionary improvements that go beyond compliance; (3) competitiveness and long-term business development goals may also necessitate discretionary investments; and (4) regulatory uncertainty can put productivity-enhancing plans on hold (for example, when wrestling with a permitting issue).

In addition, the study identified three key aspects of organizational behavior that appear to influence investment practices regarding environmental and energy-efficiency technologies.

First, different cultures exist within the companies' upper management and plant-level management. The level of decisionmaking varies over the companies, ranging from highly decentralized practices (where each facility in a company makes its own decisions) to a very centralized system (where corporate management and the board control the majority of capital and determine which investments are appropriate for each facility, and where local authority for investment is very limited).

Second, all of the companies interviewed indicated that in their hierarchy of investment priorities, compliance comes first; productivity or capacity expansion, second. Energy efficiency is generally a lower tier consideration unless it has a high return on investment or will lead to a substantial cost reduction. However, several companies noted that the installation of new production equipment and new capacity normally incorporates the latest energy-efficient processes and equipment.

Third, several company viewpoints were expressed about energy-efficiency and environmental investments themselves and how they influence overall investment practices:

- Capital rationing is practiced, and investments in energy efficiency are dictated by the availability of capital. All companies interviewed practiced capital rationing, whereby only a finite amount of capital is available for investment each year. From this finite pool of capital, projects to comply with regulations are funded first. All other investments, including energy efficiency, come from the remaining funds.
- Companies treat energy-efficiency and environmental investments separately. The four companies indicated that energy efficiency is simply viewed as a cost issue and that energy-efficiency improvements play a secondary role when assessing the merits of an investment.
- New facilities provide the best opportunities for making energy-efficiency improvements. The greatest gains are likely to occur during times of production growth with installation of new production capacity. Improvements at existing facilities can be more costly by comparison because of inadequate support facilities and lost production.

Strategies for Addressing Diverse Goals

In recent years, the Federal Government has engaged in efforts to reinvent the way it promotes energy efficiency and regulates environmental protection. There is remarkable commonality in the new directions the Department of Energy (DOE) and the Environmental Protection Agency (EPA) are taking in their efforts to help industry improve energy and environmental performance. For example, common themes guiding reinvention of programs at DOE and the regulatory approach at EPA include (1) greater emphasis on pollution prevention; (2) application of more holistic approaches, such as EPA's new multimedia emphasis or DOE's emphasis on integration of energy efficiency,

pollution prevention, and productivity principles; (3) industry-by-industry dialog to build on shared values and better establish policy that fits the way businesses work; and (4) encouragement of flexible means for industry to achieve performance goals. The similarities in the way DOE and EPA are carrying out their missions suggest clear opportunities for the two organizations to combine their strengths and coordinate efforts toward developing more consistent environmental and energy-efficiency policies.

The study offers a number of observations that are relevant to the recent paradigm shifts at DOE and EPA:

1. Removing existing production inefficiencies is a key element for achieving productivity growth in integrated paper and steel plants.
2. Environment-related productivity losses and losses due to the need to shift capital for abatement are small compared to overall production inefficiencies.
3. Well-managed plants appear to be better environmental performers (in the integrated paper industry).
4. Companies place mandatory environmental investments at the top of their investment priorities.
5. Capital rationing is practiced at least in the companies interviewed and possibly in most companies in their industry.
6. Win-win opportunities are observed where the outputs of pollutants can be reduced while simultaneously increasing production and reducing other inputs.

These findings of the study, among others, support two key conclusions:

- *To the extent new environmental and energy policy approaches provide industry with greater flexibility to direct investments at addressing the significant production inefficiencies, the recent paradigm shifts at DOE and EPA may be a better way for Government to encourage win-win outcomes.*
- *To the extent environmental and energy policies focus more broadly on increasing production efficiency and achieving more win-win solutions, then the capital constraints associated with pollution abatement and capital rationing may be less important.*

Several strategies for the Federal Government can be identified and supported by the empirical findings of this study. Most of the strategies identified are already being implemented in various ways by DOE and EPA as part of

their reinventing government initiatives. These strategies are more fully presented in Chapter 4.

Strategy 1. EPA, with DOE support, encourages alternative compliance strategies

Strategy 2. DOE fosters technological growth through continued support of research and development on energy-efficient, pollution prevention technologies

Strategy 3. DOE, EPA, and trade associations continue efforts to develop and disseminate information on best practices and pollution prevention opportunities

Strategy 4. EPA and DOE work together to give greater consideration to secondary energy and productivity impacts when evaluating environmental technologies

Strategy 5. Energy-efficiency programs target efforts to encourage use of best practice by the potentially large population of non-best-practice plants

Finally, to the extent that the opportunities measured in this study reflect constraints of the conventional regulatory system on options for companies to achieve higher levels of environmental, productivity, and energy performance, the new EPA initiatives (such as Project XL, the Environmental Leadership Program, the Common Sense Initiative, and the proposed voluntary incentive program of the paper industry Cluster Rule) and recent industry-DOE partnerships (such as the Industries of the Future initiative) may represent better ways for Government and industry to achieve mutual goals.

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1. INTRODUCTION

The paper and steel industries are two of the largest and most important industries in the United States. Together they make up more than 6 percent of the value added by U.S. industry and consume more than 20 percent of the energy used in the manufacturing sector (EIA, 1994; Bureau of the Census, 1991). From 1980 to 1991, capital expenditures on pollution abatement were between 5.5 percent and 17 percent of the total capital expenditures for the paper industry, SIC codes 2621 and 2631, and between 4 percent and 20 percent for the steel industry, SIC code 3312 (Bureau of the Census, 1991).

Both the paper and steelmaking processes have pollutant sources that are subject to a basic group of Federal statutes and regulations (EPA, 1995a and 1995b): the Clean Air Act (CAA), the Clean Water Act (CWA), the Solid Waste Disposal Act (SWDA), and the Resource Conservation and Recovery Act (RCRA). Under these laws, specific regulations have been established for the industries in general, and for many of the ancillary activities that occur at production facilities. Regulations under other laws, such as the Toxic Substances Control Act (TSCA), the Emergency Preparedness and Community Right to Know Act (EPCRA), or the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) also contribute to the environmental compliance landscape at many paper and steelmaking facilities.

This study examines the interrelationships between plant-level productivity, energy efficiency, and environmental improvements, focusing on integrated pulp and paper and integrated steel plants in the United States.¹ Integrated paper and steel mills are defined as those facilities that use some form of onsite raw material to produce final products, for example, paper and paperboard or finished steel. Fully integrated pulp and paper mills produce onsite the pulp used to manufacture paper from virgin wood fiber, secondary fiber, or nonwood fiber. There are approximately 200 integrated pulp and paper mills in the United States (EIA, 1995a).² Fully integrated steel mills process steel from coal, iron ore, and scrap inputs, and have onsite coke oven facilities. In 1987,

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¹A paper or steel plant or mill, for example, is a single physical entity with a unique location that includes one or more production lines. Throughout this report, plants, mills, facilities, and establishments are used synonymously. A company or firm may comprise a single plant or multiple plants. Company and firm are used synonymously in this report.

²For the data analysis portion of this study, the pulp and paper sample used is restricted to mills with chemical pulping. See Appendix A (Selection of Case Studies Industries) for more details.

there were approximately 20 fully integrated steel plants in the United States (EIA, 1995b). Nonintegrated paper and steel mills purchase material inputs in processed form.

The integrated subindustries of the paper and steel plants are the focus of this study in part because integrated plants tend to have higher energy use and rates of pollution compared to nonintegrated plants. Integrated plants are also establishments where tensions between environmental, productivity, and energy-efficiency goals are most apparent.

U.S. industry operates in the face of two potentially conflicting forces: increasing needs for compliance with environmental regulations, and heightened pressure for improved productivity to remain competitive. Companies report that this situation has often led to investment problems, which has forced them to make tradeoffs between various productivity or regulatory compliance goals. For instance, sometimes protecting one environmental medium has resulted in damage to another, or, in other cases, controlling environmental emissions has had negative impacts on productivity. Companies' efforts to address these tradeoffs may be exacerbated when energy efficiency is added to the equation; for example, sometimes protecting the environment can cause an increase in energy consumption, or environmental compliance requirements may inhibit investments in energy-efficient technologies.

At the same time, however, interest in technologies for "green" products, pollution prevention, waste minimization, zero discharge processes and aspects of industrial ecology on the part of U.S. industry and government research and development (R&D) agencies has increased significantly. Win-win investment situations are being reported where investments can reduce production inefficiency through simultaneous increases in output, decreases in pollution, and decreases in the level of input resources used.

In recent years, the Federal Government has engaged in efforts to reinvent the way it promotes energy efficiency and regulates environmental protection. There is remarkable commonality in the new directions the Department of Energy (DOE) and the Environmental Protection Agency (EPA) are pursuing in their efforts to help industry improve energy and environmental performance. For example, common themes guiding reinvention of DOE and EPA include the following:

- Greater emphasis on pollution prevention

- Application of more holistic approaches, such as EPA's new multimedia emphasis or DOE's emphasis on integration of energy-efficiency, pollution-prevention, and productivity principles
- Industry-by-industry dialog to build on shared values and better establish policy that fits the way businesses work
- Encouragement of flexible means for industry to achieve performance goals

The common ground in the way DOE and EPA are carrying out their missions suggests clear opportunities for the two organizations to combine their strengths and coordinate efforts toward developing more consistent environmental and energy-efficiency policies.

Purpose

The purposes of this study are the following:

- To obtain the opinion of selected companies on apparent tensions between productivity, energy efficiency, and environmental improvements associated with conventional environmental regulation
- To assess the extent to which win-win environmental/productivity improvement opportunities are possible
- To examine decisionmaking practices that have influenced past investment practices
- To examine the extent to which different environmental and energy policy approaches by the Federal Government may encourage win-win outcomes

This study supports the goals and objectives of the strategic plans of DOE's Office of Policy and International Affairs and Office of Energy Efficiency and Renewable Energy by providing input to the energy and environmental policy development process. The findings are expected to aid government in its effort to develop innovative regulatory and nonregulatory approaches that are holistic and systemic, are effectively implemented, and create opportunities for industry to undertake energy-efficiency, environmental, and productivity investments that are both cost-effective for them and in the best interest of the Nation.

Issues Addressed

The study examines the following four broad issues:

- Conventional environmental regulation may directly affect plant-level energy use and productivity. To the extent that some plants have “better” ways to meet environmental goals, the failure to use “best-practice” methods represents lost business investment opportunities in meeting these goals for plants using less efficient methods. The extent of these lost opportunities is an issue that the study seeks to clarify.
- Environmental regulation may also influence investment and other resources in a manner that is flexible or nonflexible. For example, a nonflexible influence associated with the conventional environmental regulatory approach may be to create constraints on decisions that have an indirect impact on productivity. The size and prevalence of this effect in the industry is one issue the study seeks to clarify.
- Energy-efficiency goals can highlight narrowly focused energy-conservation activities or process changes that improve energy savings, reduce costs, and enhance productivity. How these types of investment projects rank and interact with environmental projects is an issue the study addresses.
- The role of investment strategies as a possible factor in the energy, environmental, and productivity picture is a central issue that this study seeks to clarify. Whether or not environmental investments reduce the investment in discretionary categories and whether energy investments interact with environmental and general investment projects depends on company investment decisionmaking practices.

Research Method

The study uses a case study approach that combines plant-level data analysis, company site visits, and a review of recent literature.

The data analysis uses historical plant-level data for the steel and paper industries and the data envelopment analysis method to quantify the magnitude of productivity, energy intensity, and environmental performance trends. Estimates of trends in industry productivity and energy intensity over the period 1972–1991 for the steel industry and 1974–1991 for the paper industry are produced. The analysis estimates compliance-driven production efficiency

losses and the corresponding potential to make win-win environmental/productivity improvements. The extent to which pollution abatement capital expenditures constrain other investments for improving productivity and energy efficiency is also estimated.

The company site visits involved interviewing environmental and energy managers at four integrated paper and steel companies to discuss their views on the extent to which the tradeoffs between the three performance goals (productivity, environmental, and energy-efficiency improvement) affect their plants. Company interviews were conducted over the period from May 1996 to May 1997. Additional topics are covered, such as company decisionmaking practices pertaining to how diverse goals are addressed. Companies were identified with the assistance of the American Forest and Paper Association (AFPA) and the American Iron and Steel Institute (AISI).

The study focuses specifically on fully integrated chemical pulp plants in SIC 2621 and 2631 (pulp and paper mills) and fully integrated plants in SIC 3312 (blast furnace and steel mills). It therefore does not presume that the magnitude, source, and scope of impacts found for these sectors could be generalized to all paper mills or steel mills or to the entire U.S. manufacturing industry.

It is also noted that the study only focuses on the cost and productivity side of the environmental mitigation issue. A more complete assessment of costs and benefits associated with conventional environmental regulation was not performed. A benefits analysis was beyond this project's scope.

Organization of the Report

The report is divided into four chapters. Chapter 2 provides a brief overview of initial observations from a review of the literature. Chapter 3 presents the study's major findings. These findings include estimates of trends in industry productivity and energy intensity; estimates of the sources of productivity losses, including the extent to which pollution abatement capital expenditures constrain other investments for improving production and energy efficiency; and estimates of the potential for win-win opportunities to simultaneously increase output, decrease pollution, and decrease the level of inputs used (labor, energy, materials, and capital). Company opinions regarding the relative magnitude and source of tension associated with conventional environmental regulation, and aspects of company investment decisionmaking

THE INTERRELATIONSHIP BETWEEN ENVIRONMENTAL GOALS, PRODUCTIVITY IMPROVEMENT, AND INCREASED ENERGY EFFICIENCY IN INTEGRATED PAPER AND STEEL PLANTS

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practices are also reported. Chapter 4 identifies strategies involving DOE and EPA that can help integrated paper and steel plants acquire win-win solutions for achieving their diverse goals. Several appendices provide more detailed technical information.

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2. REVIEW OF RECENT LITERATURE

This chapter summarizes key observations from a review of recent literature.¹ Environmental regulations and energy-efficiency programs play a large role in the interrelationships between energy, environment, and productivity in industry. The major issues associated with these factors, which were identified in the initial review of the literature, are summarized below.

Regulatory Compliance

Historically, environmental regulations were seen to be in conflict with business goals of producing the most goods and services at the greatest profit. This is because the impacts of environmental regulations were characterized as constraints that placed additional direct costs on the production process, such as increased operating cost outlays.

Michael Porter argues the position that environmental regulations can be a route to improved competitiveness (Porter, 1991). Porter and van der Linde (1995a and 1995b) advocate the notion of resource productivity to illustrate the potential positive value of environmental regulations. Their thesis is that properly designed environmental standards can serve as a motivator for innovations by industry that will go well beyond traditional approaches of just meeting environmental requirements and will actually lower the total cost of a product or improve its overall value to customers. The idea is that these types of innovations permit companies to use their entire range of process inputs—capital, materials, labor, and energy—more productively at the same time that environmental emissions are reduced. These gains often are sufficient to offset the costs of the improvements, which is just the sort of win-win situation sought by industry and regulators. Porter and van der Linde argue that, ultimately, this basic productivity improvement provides these companies with broad-based business advantages, sometimes placing them years ahead of their competition.

Porter and van der Linde place strong emphasis on the use of carefully designed regulations to meet environmental goals by creating opportunities for industries to innovate and solve environmental problems in their own ways.

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¹Although much of the information summarized in this chapter refers to U.S. industry as a whole, it also applies to the pulp and paper and the steel industries.

To illustrate these situations in relation to the regulatory climate faced by industrial companies, Porter and van der Linde describe experiences in Sweden where a supportive regulatory environment helped the domestic pulp and paper industry to establish a global leadership position in advanced clean process technology. To implement their environmental regulations, Sweden started with relatively loose guidelines for the industry, allowing greater flexibility in compliance, with a clear indication that tougher standards would be implemented later. This approach is contrasted with the conventional approach of U.S. regulators where more traditional strict emissions controls were mandated, environmental laws passed, and very tight compliance deadlines set.

Swedish firms reacted to the tougher standards expected in the future and continually incorporated innovative process changes in their normal business plans of capacity replacement and expansion. Pulp and paper emission reduction took longer in Sweden, but in the end, its industry had a stronger competitive position. Because of their early lead in clean processing due to regulatory requirements, Scandinavian companies were able to take advantage of growing public concern for environmentally superior products and establish valuable niche markets. These firms were the first ones in the world to introduce totally chlorine-free paper processing. This and other examples have led the authors to place a strong emphasis on the use of carefully designed regulations to meet environmental goals by creating opportunities for the industry to innovate and solve these problems in its own way.

However, not everyone agrees with the Porter hypothesis that environmental regulations are not only benign in their impact on international competitiveness, but can serve as a net positive force for innovation by driving private firms to become more competitive. For example, Walley and Whitehead (1994) argue that "talk is cheap, environmental initiatives are not," pointing out that, overall, compliance with environmental regulations is still an expensive proposition for most companies, even after particular cases of efficiency gains resulting from regulation are taken into account. Walley and Whitehead illustrate this apparent discrepancy with an example of a chemical company that had a 55-percent internal rate of return (IRR) on employee-generated environmental initiatives that generated environmental and cost reduction benefits not driven by regulatory mandates. However, the IRR on all corporate environmental projects (averaged together), including capital investments to meet mandated environmental requirements, was negative 16 percent.

The Porter hypothesis has been criticized in the literature as lacking significant evidence (Jaffe et al., 1995). After reviewing the relevant literature

through 1994, Jaffe et al. find that, overall, the Porter hypothesis is largely based on anecdote and speculation and lacks a base of systematic empirical evidence. This careful kind of support for the Porter arguments is just beginning to be collected, and Jaffe et al. believe it is too early to tell if this positive aspect of regulation is present in other than isolated, special cases.

Much of the difference between these two positions is methodological, that is, analysis of anecdotal evidence of profitable waste reduction verses statistical analysis of costs. Neither method reveals whether many pollution reduction goals would be met at low (or negative) cost with well-designed regulations. Even if meeting environmental goals will continue to be costly on average, it is important to find out if it can be made substantially less costly through improved regulations and support for process innovations.

Compliance Costs

Several analysts have estimated expenditures for regulatory compliance and found the cost impacts to be substantial (OTA, 1994). Process industries such as pulp and paper and primary metals have greater pollution control expenditures as a percentage of their capital and operating expenditures, compared with nonprocess industries.

In addition to the direct costs of compliance with environmental regulations, there are indirect costs as well, including two important categories: unmeasured costs of pollution abatement, and "lost opportunities." Unmeasured costs include productivity losses, product quality, fees and taxes, regulatory delays, and research and development costs. Additional costs include administrative costs, management and engineering staff time, environmental training, and the environmental portion of costs embedded in capital equipment.

Lost opportunities are potential investments that could provide highly innovative or multiple (productivity-environmental and energy-enhancing) benefits to plants, but which are not permitted because investment funds must go to meet mandated environmental requirements in a less efficient way. They may be directly associated with investment constraints and/or to the required use of a control technology process that does not encourage innovation (Ellsworth, 1983).

Studies that examine the impact of pollution abatement have traditionally focused on reported expenditure data. To the extent that expenditures

underreport the "actual" cost, two recent studies find the cost impacts of pollution abatement on productivity to be greater than the direct reported costs (Barbera and McConnell, 1990; Gray and Shadbegian, 1993). They find that the impacts on productivity associated with indirect costs can be either as much as 3 to 4 times the impact of direct costs in the paper and steel industries (Gray and Shadbegian, 1993), or as low as zero (that is, an estimate of a "no effect" impact) (Barbera and McConnell, 1990) for paper.

It is important to note that indirect effects need not be negative. Barbera and McConnell find some positive indirect effects for some industries in their study. For example, the product quality impact may be positive or accelerated retirement may induce a newer, state-of-the-art vintage of equipment. However, these potential positive effects are driven by the existence of the lost opportunities discussed above. A more recent study of the Swedish paper industry does account for potential lost opportunities (Brannlund et al., 1995). They find that loss in profits due to regulation (which include both direct and indirect effects) range from 4 to 17 percent.

Evidence From Previous Studies of Tensions Between Energy-Efficiency, Environmental, and Productivity Goals

A major challenge facing industry involves optimizing investments in pollution abatement so that the negative impacts on productivity and energy efficiency are minimized. Examples of the difficulties in achieving this are often illustrative of the unintended consequences of conventional environmental regulation. The three sources of apparent tension most often reported in the literature concern (1) conventional environmental regulations and energy efficiency, (2) environmental regulation and productivity, and (3) multimedia issues.

Environmental Energy-Efficiency Paradoxes

Investments in environmental projects often increase energy consumption and costs. In the steel industry, for instance, environmental requirements, such as waste water treatment facilities and air pollution control systems, add to the energy requirements. These systems require the use of pumps, fans, and

compressors and the operation of other equipment that increases energy use. Indirectly, environmental requirements also may reduce energy efficiency by lowering the amount of capital available for investment in newer, more energy-efficient technologies.

In the paper industry, regenerative thermal oxidation, a process used to control volatile organic compounds (VOCs), exemplifies the apparent tensions. In regenerative thermal oxidation, gases are gathered together and pumped into a device that is heated with natural gas. The VOCs are burned off, and carbon dioxide and water remain. This technology comes from the paint drying industry, where concentrations of VOCs are high enough to support combustion; however, in the paper industry, VOC concentrations are too low to sustain the flame necessary for burning, so fuel needs to be added.

Notwithstanding the adverse effects environmental controls may have on energy use, recycling in the paper industry can present a paradox of a different kind. While recycling has clear environmental benefits, it can result in increased energy use. For example, increased use of chemically pulped recycled paper products increases nonrenewable energy consumption in the paper industry because much of the energy required to make paper from virgin chemical pulp is normally supplied by waste products generated in the process (Gaines and Stodolsky, 1993). These wastes are not present with recycled materials; therefore, more energy must instead be supplied by purchases of conventional fuels from offsite.

Adverse Productivity Impacts Due to Environmental Regulation

In general, requirements to purchase abatement equipment influence productivity in two ways: directly by adding to total costs, and indirectly by changing the way conventional inputs are used to produce the manufactured good. While the direct effect reduces productivity by increasing costs with no commensurate increase in manufactured output, the indirect effect could be positive, negative, or zero. The indirect abatement effect varies substantially by industry. Some industries have been capable of ameliorating part of the productivity costs of environmental regulation through changes in other inputs.

Productivity can also be adversely affected any time a plant has to install an extra abatement device to operate when the main one is not on line (for example, during device malfunction or for cleaning). This may add considerably to the direct cost of abatement.

Multimedia Issues

One problem with the conventional regulatory scheme is cross-media transfer where it is possible to inadvertently have an adverse effect on one environmental medium as a result of trying to protect another. Multimedia issues fall beyond the scope of this study and are currently being addressed by the EPA in several of its new initiatives, such as the Common Sense Initiative, that, among other things, aim to reform single-media regulation policies (Browner, 1994).

Relative Importance of Energy Efficiency

Although environmental compliance is very important for many industries, energy efficiency by itself usually is not a high priority. Because of competitive pressures both in the United States and abroad, most plant managers and company officials focus on improving the overall economic productivity of all their inputs, not just energy efficiency per se. Generally, those industries with high energy intensity (that is, energy use per unit of output) and high energy-related costs have had the most extensive efficiency programs.

Win-Win Opportunities

The existence of win-win opportunities in industry, whereby process or equipment changes in manufacturing plants can simultaneously increase productivity performance and reduce environmental emissions (often including energy savings as well), is beginning to be documented in the open literature.² Specific cases of simultaneous improvement in productivity, environmental emissions, and energy use have been reported in a number of the materials processing industries such as chemicals, pulp and paper, and steel. Many of these situations have been labeled illustrations of improved "resource productivity," a term that indicates that companies can better themselves by investing to change the total picture of how they use all re-

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²Several examples have received attention from Michael Porter. See, for example, Porter and van der Linde, 1995a and 1995b, and Porter, 1991. Other instances of win-win process investments by industry are presented in Romm, 1995.

sources, or inputs, to their production process (as opposed to just focusing on cutting labor, materials, or scrap costs alone). The resource productivity concept is based on the premise that when harmful pollutants and other process wastes are discharged into the environment, this is a sign that overall resources have been used incompletely, inefficiently, or ineffectively. Data compiled by the authors show that, in some cases, the costs of meeting environmental standards can be minimized, if not eliminated, through innovations that simultaneously produce other competitive benefits.

Opportunities may exist where production inefficiencies could be rectified and both environmental and business goals could be achieved simultaneously. Where current production inefficiencies do exist, regulation can sometimes produce positive competitive benefits for industries beyond improving the environment. For instance, beneficial investments have occurred in pulp and paper where press drying increases paper strength and reduces energy use by 20 percent, thereby cutting several pollutants. Other examples are in steelmaking where basic oxygen and electric arc furnaces have cut open hearth furnace pollutants, and coke-free steelmaking, which offers further pollutant-reduction potential (OTA, 1994). Generic improvements, such as use of computerized process controls to restrict environmental releases, have also led to increased process throughput and reduced scrap and rework in many industries.

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3. PRINCIPAL FINDINGS

This chapter describes the principal findings drawn from the study. The first part of the chapter provides further evidence of tensions between environmental, energy, and productivity goals based on discussions with environmental and energy managers at several companies visited. The examples of sources of tensions were collected from discussions with industry representatives, so they represent an industry point of view on these issues. The second part of the chapter describes the findings developed from the data analysis concerning the analysis of long-term productivity trends and production input intensity changes, estimation of environmental/productivity win-win opportunities, and analysis of pollution abatement capital constraint. The third part of this chapter describes motivations and factors influencing investment decisions. A description of the research methodology and the detailed findings from the plant-level data analysis can be found in Appendices A and B, respectively.

Company Views Concerning Tensions Between Environmental Performance, Productivity, and Energy-Efficiency Improvement Associated With Conventional Environmental Regulation

Based on interviews with company officials from two integrated pulp and paper facilities and two integrated steel facilities, the following results are presented to illustrate the nature of the tensions plants face.¹ Two categories of tensions were identified from discussions: (1) between environmental goals and productivity goals, and (2) between environmental goals and energy-efficiency goals.

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¹The companies participating in the study represent major U.S. interests with integrated mills:

- Company 1 is one of North America's largest producers of forest products. It is an integrated company that grows and harvests timber and manufacturers, distributes, and sells forest products, including logs, wood chips, building products, and pulp and paper. The company is also a recycler of wastepaper, newspaper, and corrugated boxes.
- Company 2 is one of the top five paper companies in the United States. Its major areas are in pulp and paper.
- Company 3 is a prominent integrated steel company in the United States that has interests in coal and iron ore mining, and operates onsite coke facilities.
- Company 4 is one of the top five integrated steel companies in the United States.

Conventional Environmental Regulation and Productivity

Company views concerning tensions can be organized into four areas: general, permitting, control technologies may not be demonstrated to work in all plant environments, and lack of consideration of the variation in facility situation.

General

All of the companies felt that their foreign competitors were not subject to the same regulatory pressures as companies in the United States. Therefore, they believe regulations pose additional costs and make them less competitive because increased capital costs are necessary to be in environmental compliance. They reported that these costs consume a significant part of corporate capital and leave less money available for other productivity-improving investments.

In general, the companies feel that the regulatory process does not take diminishing returns into account, that is, for each unit of pollution prevented from being released into the environment, it becomes more expensive to prevent the next unit. Representatives from three companies made this point. As a result, they believe the costs for cleaning the environment have become unrealistic, especially based on the amount of risk involved. The effort in time and money to remove the last trace of a pollutant is not worth the negligible risk posed by the release.

Permitting

The companies felt that the permitting process was a source of tension between environmental and productivity goals. Companies 1, 2, and 3 reported that the permitting process associated with the Prevention of Significant Deterioration (PSD) program of the Clean Air Act hurts productivity because of the added administrative costs and the associated delays. Company 1 said that it takes between \$100,000 and \$150,000 to prepare an application for a permit, assuming that existing information is used. However, at a large mill, it may cost as much as \$300,000 to \$500,000 to collect the data, analyze them, and prepare the application. The permitting process takes a minimum of a year, and that is only if a project doesn't exceed the new source performance standards. Under certain circumstances, the process can take as long as 2 years.

The companies believe that PSD permitting is detrimental to industrial expansion because of the time lags involved. Any activity that results in a new

source or a modification of a source that causes a significant increase in emissions for criteria pollutants needs to be permitted.² This means that process changes as well as expansions are often delayed as a result of permitting.

Company 2 believes that these delays, in general, prevent U.S. industry from moving quickly to meet market demand. For example, this company takes 1.5 to 2 years to complete the permitting for a major expansion, plus the time it takes for construction. That means that company officials must make expansion decisions 3.5 to 4 years before new production can come on line. The company believes that this puts American industry at a strong disadvantage to foreign competition, which can react more quickly to increased demand and capture the market before U.S. capacity can be built. International rivals can install new technologies and open new facilities more quickly.

Three companies felt that delays associated with permitting can cause losses in market share. Because of these delays, companies often adjust their behavior to avoid the permitting process altogether. For example, Company 3 said its strategy is to stay below the levels that trigger PSD, which may mean modifying other facilities to keep the net emissions below the level. The company also stated that all this juggling may result in overall production efficiency losses.

Control Technologies May Not Be Demonstrated To Work in All Plant Environments

In addition to permitting, according to several companies interviewed, other tensions can result from the desire on the part of the regulator to encourage a facility to adopt a control technology that may not be transferable or fully proven to work in different operating environments. Company 1 believes that

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²The PSD rules are as follows:

For a new source: There are two categories of polluters (based on when the regulations for the industry were passed). If a facility is in one category (which includes steel, paper, chemicals, utility boilers, and so forth), and has a new source with emissions of certain pollutants over 100 tons, the facility must get a PSD permit. If a facility is in the other category (regulated more recently) then it must have 250 tons before the PSD is required.

For modification of existing sources: If a facility is already regulated under PSD at 100 tons or 250 tons (depending on what category the facility falls under), then the facility will need a new PSD permit if the change results in a significant net *increase* in emissions. The specific amounts for each pollutant are given in the regulations. However, even if the facility does not need a PSD permit, other permits, like construction permits, may be necessary, even for minor changes or changes with net decreases.

this can cause decreases in productivity because of money wasted on unproven environmental investments. For example, Company 1 spent 2–3 years developing a control strategy for VOCs from wood products plants. Approval was received from the States and construction began. The company is in the process of installing \$50 million of equipment at seven plants. However, according to Company 1, results from subsequent air quality modeling have indicated that installation of the equipment may in fact hurt the environment more than not installing it.

Lack of Consideration of the Variation in Facility Situation

Company 3 reported that the regulations oftentimes do not reflect variations in their facility or supply market situations. For example, the ozone requirements make using oil difficult because of the nitrogen oxide (NO_x) emissions associated with its use. Natural gas is a good substitute for oil. However, this poses a problem for Company 3 in the winter because natural gas is more costly and may not be available when needed on the East Coast at that time of year. Fortunately, research has shown that ozone is more of a problem in the summer. However, the regulations limiting NO_x emissions are year-round. Company 3 feels it would improve competitiveness if the regulations captured this seasonal aspect to the problem.

Conventional Environment Regulation and Energy Use

The companies visited have suggested tensions between compliance with conventional environmental regulation and energy use in four areas: emission controls requires energy use; the regulations may make investments in energy efficiency projects prohibitive; the regulations may not allow for certain types of energy-efficiency projects; and the regulations do not provide an incentive to pursue innovative technologies.

Emissions Control Requires Energy Use

One of the most common conflicts reported by the companies was that operating emissions-control devices consumes a great deal of energy. For example, Company 3 noted that in the steel industry, in general, many of the emissions are controlled by air capture. This means that there is total enclosure of the air surrounding a process, which is then evacuated from the area,

collected, and put through a baghouse. This requires a high amount of energy. Company 3 roughly estimated that each scrubber costs \$1 million per year to operate and that much of these operating costs are energy costs.

In addition to the energy used by control equipment, sometimes combustion (which requires energy) is used as a control method. For example, the Cluster Rule proposal put forth by EPA in 1996 advocated steam stripping of high methanol sources as a maximum achievable control technology (MACT). Steam stripping is a process that removes methanol from liquid. Under the proposed Cluster Rule, the methanol is incinerated. This technology would require the use of a distillation tower, air to perform the incineration, and natural gas to supplement the steam. All of these factors would contribute to an increase in energy use. Most mills would need to increase their energy consumption to generate the additional amount of steam needed to perform steam stripping.

Company 1 provided an example to illustrate its desire to use the minimum amount of energy to achieve compliance. Company 1 invested in power controls on an electrostatic precipitator (ESP) to control power so that power use and costs were minimized while still meeting opacity and particulate matter (PM) emission requirements. This project took advantage of the mill's normal variability. Normally, the ESP was operated at such a power that it could capture the highest rate of particulate emissions and keep the mill in compliance. When the mill operation (boiler) had normal or lower than normal PM, the ESP took out more than necessary, and the emissions were below allowable. With the controls, the ESP power was reduced during low emission periods, allowing PM releases to go up (but still below limits).

The Regulations May Make Investments in Energy-Efficiency Projects Prohibitive

As discussed previously, many of the companies interviewed have expressed the view that the permitting process can adversely affect productivity by adding to administrative costs and introducing delays. In addition, several companies felt that the top-down approach to determine the best available control technology (BACT) under the PSD program of the Clean Air Act can make process changes prohibitively expensive. A BACT analysis is required for any

new, modified, or reconstructed emissions source for pollutants whose potential emission rates exceed emission limits established by EPA.³

Companies 1 and 2 stated that energy-efficiency projects usually (but not always) change the emissions profile of the facility and hence require a permit update and BACT review. They noted that if BACT reveals that a technology exists that has a higher total removal efficiency for the pollutant in question, they are required to install the technology. Even if the lower BACT technology could also achieve compliance, these added costs could end up causing the energy-efficiency project to be canceled.

Company 2 provided an example of this. It is now technically feasible to add higher liquor solids to the boiler. The benefits are better energy efficiency in the boiler and less purchased fuel. However, changing the boiler will change the emission profile. Whether the emissions are more adverse or less, the regulations require that any significant change in the profile be accompanied by a BACT analysis. As a result, the cost incentive of the energy-efficiency project was nullified.

The Regulations May Not Allow For Certain Types of Energy-Efficiency Projects

Company 2 identified a problem associated with RCRA. The interpretation of the "waste" guidelines could inhibit energy-efficiency projects. The RCRA rule determines whether a material is a solid or hazardous waste. The Boilers and Industrial Fuel (BIF) rule applies if a facility burns a material that is characterized as a hazardous waste. Materials that are normal fuels or fuel components burned for energy recovery by definition are *not* hazardous wastes. There exist many opportunities for varying interpretations of a "normal fuel or fuel product." As a consequence, many facilities shy away from efficient energy

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³A BACT analysis must be performed for each new, modified, or reconstructed emissions source. BACT can be viewed as a five-step process that requires companies to rate technologies in order by removal efficiencies. Step one requires companies to list all available options for air-pollution control that can be implemented practically at the source. This includes technologies that may have never been implemented in these industries; if the technology exists, it must be listed. Step two requires that companies explain which technologies are not feasible and why. Step three requires companies to rank the feasible controls by their effectiveness at removing the pollutant of concern. The ranking is by the "top" highest pollutant removal efficiency down. Step four allows the companies to consider the energy, environmental, and economic impact of each technology. Companies must document why particular technologies may not make sense. In the fifth step, the companies propose a BACT technology to the regulator who has authority to grant the permit. The BACT analysis and resultant control technology recommendations are documented in the PSD application.

recovery practices due to the overwhelming consequences of RCRA and the BIF programs. Sending high-Btu (clean fuel) materials off-site results in high transportation and handling costs. Generally, the material is sent to an incineration device that has no energy recovery. This mode of disposal is simply an inefficient use of a clean fuel. The utilization of these alternate fuels on-site would promote the use of fossil fuel substitutes.

As another example, Company 2 describes an approach for deriving energy value from its processing of odorous gases stripped from its condensate stream. It then concentrates methanol from the condensate and uses the methanol as fuel to burn the odorous gases. Current RCRA regulations discourage this efficient practice due to the jeopardy of inadvertently invoking hazardous waste rules and other associated RCRA requirements.

Conventional Environmental Regulations Often Do Not Provide an Incentive To Pursue Innovative Technologies

There was agreement among the companies interviewed that conventional environmental regulation has a built-in disincentive for pursuing innovative technologies that may help achieve or go beyond compliance requirements. Companies perceive that direct costs will almost always increase, and that if they demonstrate an ability to operate at lower emissions (that is, to exceed compliance), new regulations will make this lower emissions limit a requirement for the industry. This means other facilities will be required to operate lower even if their local situation is inconsistent with the lower emission limit and the original facility will be forced to always operate lower regardless of cost penalties.

For example, Company 3 believes that if it were to operate below limits in one area, because it would improve local air quality, for example, then EPA would take this information and modify the standard to require less pollutant emission everywhere. This penalizes success because imposing a more stringent emission standard could result in violations down the road if the company is not able to meet the new standard. Therefore, under conventional regulation there is no advantage to a company to go beyond what is required to meet a standard.

Productivity, Energy Efficiency, and Environmental Impacts

The results for the analysis of plant-level productivity, energy efficiency, and environmental performance are presented in this section. Detailed findings can be found in Appendix B. This analysis uses data on historical plant performance to determine if there is empirical evidence that—

- Production efficiency improvements have been a source of productivity growth in the integrated paper and steel industries
- There are production efficiency improvements that are a source of simultaneous increases in productivity, energy efficiency, and environmental performance
- Requirements for environmental capital expenditures “squeeze out” other productivity improvements

The analysis approach looks at the production process in a holistic, systems manner, by examining the overall relationship between inputs and outputs, rather than focusing narrowly on individual process stages, energy conservation, or pollution control. The analysis is performance based, that is, it looks at what has been done in real facilities under real operating conditions. Similarly, it does not analyze permits and compliance to determine environmental performance. Instead, it looks at actual emissions, relative to the overall production output of the plant.

This analysis does not address the innovation aspects, such as the possible role of environmental and energy-related production changes in inducing the advance of best-practice technology. This type of analysis was beyond the project’s scope.

This section summarizes three types of analysis results that are more fully presented in Appendix B.

- Long-term trends in productivity, technical changes, production efficiency, electricity intensity, and fossil-fuel intensity (over the period 1972–91)
- Estimates of environmental/productivity “win-win” opportunities (that is, the differences between an average plant and the best-practice plants that results in the opportunity to simultaneously increase production output, decrease pollution, and decrease the level of inputs used (labor, energy, materials, and capital))

- The loss of productivity due to capital expenditures being diverted to pollution abatement

Results are presented for each of the case study sectors, integrated paper and steel, respectively. To help the reader interpret the results presented in this section, it is instructive to briefly summarize several key aspects of the data analysis that are described in detail on pages A-5 through A-23.

The productivity index used in this report is decomposed into technical change and production efficiency components.⁴ *Technical change* is the productivity improvement that results from improvements in best practice through, for example, plants adopting new best-practice technologies. Advances in best practice can only increase the opportunities for improved plant-level productivity. Failure to do so results in inefficiencies that reduce plants' realized productivity gain, that is, plants begin to fall behind and have lower productivity growth than feasible. On the other hand, *production efficiency* includes more aggressive and widespread adoption of existing, best-practice technologies and practices by plants that can result in plant-level productivity growth that is higher than the average plant. By decomposing the plant-level productivity into these technical change and production efficiency effects, the extent to which improvements in production efficiency have a net positive contribution to industry productivity growth can be assessed.

Traditional productivity growth measures, such as the one presented in this study, compare the growth in input usage (for example, labor, energy, and materials) with the growth in output. They do not consider the reduction of pollution as an output with a measurable value. There are approaches that attempt to do so by adding the social value of pollution reduction, based on marginal damage estimates, to the value of output (for example, see Repetto, et al., 1996). This report does examine the role of pollution as an undesirable output, but not in the productivity growth estimates.

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⁴The index is measured at the plant level by the Malmquist efficiency decomposition method described in Appendix A (pages A-19 through A-20). Industry average productivity, reported in this section, is the average of this index over the plants included in the respective industry samples. Growth rates are based on a regression trend line for an exponential growth equation. The results reported here are not for the entire industry, only those included in the analysis. These plants are felt to be representative of the industry as it exists today and cover most of the integrated portions of the paper and steel industries.

Over the same time period that productivity growth is examined, fossil-fuel and electricity intensity indicators are constructed as plant-level ratios of fossil-fuel and electricity expenditures divided by plant-level total value of shipments, all measured in constant 1987 dollars.⁵ Since the numerator and denominator of the intensities are both expressed in dollars, the intensity is also a cost share.

This section also presents estimates of the extent of opportunities to reduce selected emissions of air, water, and toxic pollutants, while simultaneously increasing productivity. These opportunities are so-called win-win, since they would allow a plant to increase output, while at the same time decrease pollution as well as inputs of labor, energy, and so forth. This is a very strong definition of win-win opportunities, since it requires simultaneous reductions in all pollutants and all production inputs. Other more narrowly defined opportunities may also exist, for example, reductions in fossil-fuel combustion and corresponding air emissions.

These estimates of win-win opportunities are compared to estimates of productivity losses due to differences in the stringency of conventional emissions regulation. This is done by estimating how much more industry output could be produced if all pollutants were allowed to be emitted at the highest rate observed in the data set, under the assumption that resources for abatement purposes could be used in production instead.

One hypothesis regarding the adverse effects of conventional regulation concerns the practice of "capital rationing."⁶ For situations where regulations

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⁵Only electricity and fossil-fuel purchases are analyzed, not total electricity or total Btu energy use.

⁶Capital rationing means there is not enough capital available for investments. A few studies have examined the capital rationing and budgeting practices of large manufacturers (Ross, 1986). Capital rationing is present when the overall plant-level investment budget is set at some arbitrary level without considering the number of profitable investments available to the plant. Ideally, any investment with a high enough rate-of-return (that is, profitable investments) would be funded if sufficient capital resources could be economically acquired. However, if the plant's or company's investment strategies do not set total investment budgets based on all investments that satisfy a hurdle rate (that is, a threshold IRR, a minimum for a project to be implemented), but instead arbitrarily set plant-level capital budgets from year to year, profitable projects can go unimplemented. Capital rationing may be a policy that is only practiced in some plants or for some classes of projects. For example, a new plant or product line may be evaluated by a hurdle rate, but energy-efficiency (or other productivity enhancing/cost cutting) projects for an existing plant or product line may be subject to rationing. Often, even less money is "available" for discretionary projects under capital rationing. If capital rationing creates an investment situation where investing to meet environmental requirements "crowds out" other discretionary investments, then certain opportunities to enhance productivity and lower costs are lost.

require capital expenditures to be made for (presumably nonproductive) pollution abatement equipment, then capital may not be available for other (presumably productive) purposes. The data analysis estimates of the impact of allocating capital expenditures to pollution abatement by computing the productivity that results from assuming that all pollution abatement expenditures were treated as nonabatement capital. Each plant was then compared to the best-practice plant that had similar levels of nonabatement new capital expenditures. These plant-level estimates of the potential increases in productivity are discussed in terms of the lost opportunities to reduce energy use and to increase production efficiency.

Results for Integrated Pulp and Paper Plants

The four main findings are (1) efficiency improvements enhance productivity growth; (2) win-win opportunities are observed between the average and best-practice plants; (3) conventional environmental regulations impose losses in productivity, but improved production efficiency could offset some of these losses; (4) capital rationing is a source of environmentally related productivity losses, but is a small contributor to overall production inefficiency.

Efficiency Improvements Enhance Productivity Growth

More rapid and widespread adoption of new technology can allow less productive plants to more quickly “catch up” with their best practice counterparts. This increase in production efficiency contributes to higher rates of productivity growth in the paper industry. While improvements in best-practice technology (technical change) account for the majority of total factor productivity (TFP)⁷ growth from 1974–1991, production efficiency improvement increases industry average TFP growth by an additional 22 percent (that is, 1.8 to 2.2 percent per year), as shown in Figure 3–1.⁸

Fossil-fuel intensity declines at an average rate of 4 percent per year, but primarily during the 1974–1987 period. The rate of decline in the early period is nearly twice the rate of overall productivity growth. This is presumably because of plants’ increased self-sufficiency, that is, their use of biomass

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⁷Total factor productivity is constructed as a ratio of an index of the productive output of a plant divided by an index of all plant inputs. See Appendix A for details.

⁸Growth rates are based on a regression trend line for an exponential growth equation.

THE INTERRELATIONSHIP BETWEEN ENVIRONMENTAL GOALS, PRODUCTIVITY IMPROVEMENT, AND INCREASED ENERGY EFFICIENCY IN INTEGRATED PAPER AND STEEL PLANTS

Figure 3-1. Long-Term Productivity Growth and Energy Intensity Trends for Integrated Pulp and Paper Plants

byproducts as fuels, along with improved end-use efficiency. Changes in fossil-fuel intensity are mirrored by changes in productivity growth. For example, the decline in fossil-fuel intensity stops in 1988, as do overall productivity improvements. However, there is no hint that the rate of technical change improvement was affected, so the cause and effect between fossil-fuel intensity and productivity is not clear.

Purchased-electricity intensity is rising at about 1.2 percent per year, although this trend is highly volatile and follows the business cycle, as do production efficiency improvements. Best-practice plants, that is, those with the highest production efficiency, have obtained a distinct production advantage in their conservation of electric power or their use of cogenerated power.

Win-Win Opportunities Are Observed Between the Average and Best-Practice Plants

Relative to observed best practice, 42 percent of plants in the data sample had opportunities (that is, exhibited the potential) to reduce *all* inputs (energy,

labor, materials, and capital) and *all four criteria air and water pollutants* (SO₂, total suspended particulants, total suspended solids, and biochemical oxygen demand) while *simultaneously* increasing production.⁹

- By doing so, declines in average energy intensities for the integrated paper industry are approximately 7 and 8 percent for fuels and electricity, respectively.
- Declines in average air and water pollution intensities, defined as tons of pollutant per dollar value of shipments, are 5.5 to 6.5 percent.
- Similar results showing 6 to 9 percent reduction in energy and toxic chemical release (sulfuric acid, chlorine, and methane) intensity were estimated.

These estimates do not include the potential of achieving further reductions in a smaller subset of energy and pollution variables, nor do they include further reductions that could result from optimizing costs between energy, capital, labor, and so forth.

The similarity in the results for toxic releases and for air and water pollutant emissions suggests that production efficiencies that give rise to these win-win opportunities may not be tied to specific pollution activities, but are a general issue of plant-level productivity, that is, production inefficiency adversely affects both business and environmental goals. Put differently, well-managed plants appear to be better environmental performers.

Conventional Environmental Regulations Impose Losses in Productivity, But Improved Production Efficiency Could Offset Some of These Losses

If observed air and water emissions are constrained by conventional regulation and we compare best-practice plants with best-practice plants that do not have

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⁹It is important to note that this result is derived from very a strict criterion for identifying win-win opportunities. The analysis measures the amount by which inputs and environmental "bad" outputs could be reduced, while simultaneously increasing output by the same proportion. This means that one type of improvement is not considered more valuable than another. Instead, any production efficiency opportunities that would lower inputs of energy, labor, and materials, and lower pollution levels, and increase output levels is estimated. This gives a very conservative estimate of win-win opportunities, because a plant that is unable to reduce any single input or pollutant while increasing output is not considered win-win. Only those plants that can "do it all" are included in the estimate of environmental/productivity win-win opportunities. One should also note that the percentage of plants on the frontier is related to the ratio of the number of observations to the number of constraints in the LP used to calculate the results. The inclusion of a wide range of pollutants, as has been done here, increases the number of constraints. (See Appendix A for details on the analysis method, and Appendix B for detailed analysis results.)

such emission constraints, then the average productivity loss to best-practice paper mills is about 9.5 percent of total industry output.¹⁰ For an average integrated paper mill, this loss is about \$20 million annually in lost production. However, not all plants are best practice. If all plants were operating efficiently, then this production efficiency improvement would reduce the productivity loss to about \$7 million, on average. In addition, this production efficiency improvement would also reduce air and water pollutant emissions.

Capital Rationing Is a Source of Environmentally Related Productivity Losses, but Is a Small Contributor to Overall Production Inefficiency

The aforementioned productivity loss due to environmental regulatory constraints includes both direct and indirect environmental effects, while the requirement that capital be allocated to abatement expenditures (possibly causing capital rationing) is one type of indirect effect. This study estimates that in 1990—

- The overall productivity loss due to production inefficiency was 17 percent.
- Productivity loss due to historical pollution requirements was 9.5 percent of total industry output (as noted earlier).
- The pollution abatement capital constraint (that is, capital rationing) lowered productivity by 3.3 percent; this corresponds to about one-fifth of overall production inefficiency.

This suggests that the abatement capital constraint may be an important source (about one-third) of environmentally related productivity losses.

While the approach used to estimate overall productivity loss and the approach for estimating productivity loss due to pollution abatement constraint are not strictly comparable, taken together they suggest that the indirect effect of capital spending on abatement is an important part of the productivity impact of environmental regulations. While the abatement capital constraint may play a small role in reducing overall production efficiency, its indirect effect on productivity may be viewed as a substantial component of environmentally related productivity losses.

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¹⁰This is lower bound based on comparison of the highest currently emitting plant(s). It does not consider what the potential productivity loss of those highest emitting plants would be if they were completely uncontrolled.

The implication is that if society has been willing to accept the direct costs of regulations to attain environmental goals and policy concerns itself with minimizing the indirect effect, then the capital abatement constraint does appear to be an important category of indirect effect. If policy focuses more broadly on increasing production efficiency and achieving more win-win solutions, then the capital constraint may be less important.

Results for Integrated Steel Plants

The three main findings are (1) productivity and energy intensity reflect the turbulent history of the steel industry; (2) improved efficiency provides win-win opportunities to reduce losses in productivity imposed by SO₂ emission constraints; and (3) the losses due to the abatement capital constraint reduces productivity by a modest amount, although the reduction is a higher share than was found for paper.

Productivity and Energy Intensity Reflect the Turbulent History of the Steel Industry

Over the period 1972–1991, industry average productivity grew about 2.5 percent per year, as shown in Figure 3–2.¹¹ However, this is largely weighted by the last 6 years of the data, that is, productivity growth is only 1.7 percent per year during the 1973–1985 period. Technical change is the main component, growing at about 3.0 percent per year. The rate is much lower, at 2.6 percent, for the period 1973–1985. Technical change has not been robust and steady growth as with the paper industry. During 1981–1986 and right after the first oil price shock, technical change was stagnant. On the other hand, large increases in technical change occurred in the 1988–1991 time period.

Like the paper industry, production efficiency follows closely the business cycles of the steel industry, but, unlike the paper industry, it shows a modest decline over the period, about 0.6 percent per year. The dramatic decline in production efficiency offsets increases in technical change, yielding “no net increase” in total productivity.

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¹¹Growth rates are based on a regression trend line for an exponential growth equation.

THE INTERRELATIONSHIP BETWEEN ENVIRONMENTAL GOALS, PRODUCTIVITY IMPROVEMENT,
AND INCREASED ENERGY EFFICIENCY IN INTEGRATED PAPER AND STEEL PLANTS

Figure 3-2. Long-Term Productivity Growth and Energy Intensity Trends for Integrated Steel Plants

Purchased-electricity intensity is rising at about 4 percent per year, although this trend is highly volatile. At the plant level there is a high degree of variation, presumably due to some plants adding electric intensive technology, while other plants have not. Fossil-fuel intensity declines at a rate of 3 percent per year, with very little of this decline occurring in the 1970s. Changes in fossil-fuel intensity are mirrored with changes in productivity growth. Fossil-fuel intensity drops when productivity rises. However, the cause and effect are not clear.

Improved Efficiency Provides Win-Win Opportunities To Reduce Losses in Productivity Imposed by SO₂ Emission Constraints

The analysis of the 17 integrated steel plants found that in 1990 the average productivity loss due to SO₂ emission constraints was about 11.2 percent or \$90 million for a typical steel plant. This could be cut in half if best industry

practice were used.¹² This would result in an average of roughly 5.7 percent decline in energy and air pollution intensity, if all plants could operate at best practice.¹³

***The Losses Due to the Abatement Capital Constraint
Reduce Productivity by a Modest Amount, Although the Reduction
Is a Higher Share Than Was Found for Paper***

In 1990, the loss in productivity due to abatement capital expenditures was 4 percent of total industry output, compared with the overall production efficiency loss of 14 percent. This corresponds to more than one-fourth of overall production inefficiency. The loss due to the abatement capital constraint is more than one-third of the estimated 11.2 percent loss due to air emissions regulation. If the abatement capital effect is more sensitive to the financial status of a firm (or industry), then it is not surprising that this effect is more pronounced for steel than for the relatively healthier paper industry.

Decision Practices That Influence Plants' Environmental and Energy Investments

Up to this point, this chapter has focused on reported conflicts and on productivity trends and estimated inefficiencies. Both of these kinds of results relate to the outcomes or consequences of investment choices made by plants. This section examines decisionmaking factors and investment practices that

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¹²Water emission data were not complete enough for the steel data set to warrant their inclusion, and, because of the small sample of integrated steel plants (and the subsequent requirements of confidentiality by the Census Bureau), the results for the steel industry are more limited than what is presented for the paper industry. The data only had usable observations for 17 fully integrated plants with coke oven batteries operating in the United States in 1992. This is in contrast to well over 100 fully integrated, chemical pulp paper plants. It was not feasible to produce as detailed statistics for subsets of these 17 plants as is produced for the paper industry analysis.

¹³This decline represents a composite reduction of the improved inputs and environmental productivity that the plants in our sample could achieve. The small number of facilities, 17, and an even smaller number of companies who own these plants prevented more detailed results from being presented. This is due to the aforementioned Census confidentiality rules. The composite index is based on the efficiency measure, which is an index of both the input and pollution reductions. The weights for the index are determined for each plant in the sample, based on the corresponding best-practice plants, and so is not a fixed weight index.

influence plants' environmental and energy-efficiency investments, as determined from company interviews.

Figure 3-3 illustrates conceptually the key elements underlying investment behavior. This figure serves as an organizing framework for the findings presented in this section. First, the factors that shape the direction and size of investments are discussed. Second, investment practices pertaining to the three measures of industrial performance are discussed.

Factors Shaping the Direction and Size of Investments

Both environmental goals and energy-efficiency policies shape the focus of investment. Mandatory environmental requirements or voluntary environmental programs (for example, EPA's 33/50 Toxic Releases Inventory Reduction Program) in one way or another steer the direction of business investments toward reduced adverse environmental impacts. Similarly, energy-efficiency policies and programs can lead to energy savings and cost reductions for a company.

Figure 3-3. Framework for Understanding Investment Decisionmaking

The commonly known factors shaping the direction and size of investments are the basic economic forces like prices, taxes, economic growth, and cost of capital. The company interviews revealed several additional factors—compliance, image, competitiveness and long-term business development goals, and regulatory uncertainty.

Compliance

Compliance with environmental regulations is the main reason why companies make environmental investments. All four companies viewed compliance with regulations as their top priority. Without the regulations, it is probable that most companies would not make the same level of environmental investments, unless there were strong business reason to do so. A representative from Company 4, for example, indicated that most environmental investments are driven strictly by regulations. However, there are other reasons why companies make environmental investments. Although these reasons probably stimulate fewer investments relative to regulations, it is important to understand these rationales.

Image

Today, being a good corporate citizen is also a reason why companies seek to make environmental improvements. Company 2, for example, regards its relationship with the communities in which its facilities are located as very important. For this reason, the company was willing to go beyond what was required by regulations to make one of its newer facilities virtually odor-free so that it would not be offensive to the people who lived nearby. This was done to promote a positive relationship with the community and is seen by the company as part of its long-term strategy. Company 2 feels that this investment pays for itself in the sense that it does not have an antagonistic relationship with the community and when it seeks to expand or make changes, it will probably not be met with opposition on the local level. In addition, the company wants to develop a reputation for being a good corporate citizen.

Competitiveness and Long-Term Business Development

Business strategies to remain competitive may also necessitate discretionary environmental investments. Company 1 indicated that the market for green products can drive discretionary environmental investments. The company is making investments in totally chlorine-free pulp because its customers are

beginning to demand it. Similarly, Company 1 also produces cardboard boxes for one of its customers from recycled paper, even though it would be cheaper to make the boxes with virgin material. The customer demands the recycled product because it wants to enhance its public image by packaging its product in a recycled box. In addition, this customer is unwilling to pay more for the recycled box. Therefore, to maintain its customer base, Company 1 has had to absorb the costs associated with the production of cardboard boxes from recycled fiber.

Long-term business goals are also a driver. Company 1 stated that its primary business goal is to maximize shareholder value. However, the company believes in the concept of "sustainable" shareholder value, whereby the emphasis is on the long-term nature of their thinking and the fact that environmental goals, as well as other issues, such as employee satisfaction, are wrapped into the equation. The company views environmental investments in the long term and does not simply see them as short-term, unrecoverable costs. Therefore, Company 1 seeks to anticipate future compliance requirements, minimize the impact on its installations, and keep the company in line with ever tightening environmental regulations.

Company 2 also emphasized the long-term perspective. The company tries to look ahead 5 to 10 years and plan for it. For example, the company installed oxygen bleaching at one of its mills before it was required. It has now initiated some projects that are not currently required, but that could become issues in the future, such as odor control and biochemical oxygen demand (BOD) reduction. It is starting to work on achieving the minimum impact mill. Company 2 seeks to differentiate itself by examining innovative technology and doing things its competitors are not likely to do. Philosophically, the company seeks to look beyond immediate issues. Its goal is to make capital investments because the company wants to, not because it has to.

Regulatory Uncertainty

A fourth factor shaping companies' investment decisions has to do with regulatory uncertainty. Company 1 said that oftentimes, when there is regulatory uncertainty, productivity-enhancing plans are put on hold. For example, the company was planning a mill expansion, but put this project on hold while it was wrestling with a VOC permitting issue. Company 4, a steel company, also expressed concerns about unexpected regulatory changes, indicating they

and other steelmakers appear always to be chasing a standard that periodically gets revised.

Regulatory uncertainty can also stimulate a company to act. For example, Company 3 has made discretionary investments in a waste management system because it fears being subject to future liabilities regarding landfills. The company looked at the landfill situation in terms of cost and the potential for future problems and decided it would be better to reduce the total amount of waste generated to protect the company from future liabilities regarding landfill remediation.

Investment Practices

Two key aspects of organizational behavior that seem to influence investment practices regarding environmental and energy-efficiency technologies are the level of decisionmaking authority, and how investments are prioritized.

Level of Decisionmaking Authority

Different cultures exist within companies' upper management and plant-level management.¹⁴ For example, plant managers may have increased responsibility for energy and environmental compliance at facilities. In these cases, investment outcomes reflect the plant manager's perspective because the upper management may not be making the decisions at the facility level. There are also cases where most change is originated in a top-down fashion, with headquarters initiating environmental and energy-efficiency projects.

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¹⁴For U.S. manufacturing companies in general, the level of decisionmaking authority comes into play because usually individual facilities control their expense budget, but it is the corporate office that oversees capital investment. Usually new facilities and other large expenditures are capitalized, and retrofits (depending on their size) are expensed. Since expense dollars come out of the current year's budget, site managers have an incentive to favor expenses that pay for themselves in 1 year. Higher expenses reflect poorly on site managers because the cost of the project usually exceeds the energy costs saved during the first year. A capital investment, on the other hand, can be amortized over the life of the project and can meet investment hurdle rates more easily. However, corporate managers prefer to expense projects because tax laws allow those expenses to be subtracted from earnings in that tax year. In addition, corporate managers, whose perspective is companywide, also look at all the other projects competing for available capital. Therefore, if the project is thrown down to the plant level, it may not be implemented for the reasons stated above. Similarly, a project identified at the plant level may not be implemented when thrown up to corporate.

The company visits showed that at different companies decisionmaking rests at different levels. Companies 1 and 2 (both paper companies) have decentralized decisionmaking, whereas Company 3 (a steel company) has a centralized decisionmaking system. A representative from Company 4 noted that although many economic studies are done, the "gut feeling" of senior executives is a key determinant of business investment. Because only a few companies were interviewed, it is not possible to make generalizations about the location of decisionmaking authority in the integrated paper and steel industries in general. The initial impression from the company visits was that paper companies vary in terms of centralization, but that, in general, steel companies are more likely to be centralized.

Representatives from Company 1 explained that each of its facilities makes its own decisions and that it is the responsibility of corporate management to keep abreast of what is going on at the mills. Each facility takes ownership for its energy and environmental issues. Corporate management makes sure that none of the facilities moves too far from the corporate goals. The facilities all share the same overall goals of the corporation, but they may choose to do things differently. Some mills may choose to assign project engineers to work on problems; others will develop a high-performance team. Help is available from corporate headquarters for facilities that request it. Within the company, large mills are knowledgeable and have opinions about energy, environment, and productivity while the smaller mills may not have as much information. As a result, the large mills are more likely to take on projects themselves, whereas the small ones are more likely to go to corporate management for help.

At Company 1, each mill gets its own limit on how much it can emit, and the mill seeks to achieve this target in the most economical way. Although there are cross functional teams and ways of sharing information across mills, each mill has autonomy. To comply with environmental laws, facilities are given the funds they need by corporate management or they are shut down. In terms of other discretionary investments, each facility considers return on investment (ROI) as the primary criterion for investment.

Similarly, at Company 2 each division is a separate entity. Many resources are available at the facility level to handle the major environmental, energy, and productivity issues. The company has found that corporate edicts are less effective. Each facility controls its capital budget, and economics drive projects. If a pollution prevention or energy-efficiency investment has a good

ROI, the facility will implement it. There are only basic boundaries to which the facilities must adhere. Each facility is responsible for finding ways to achieve environmental compliance and profitability. This includes responsibility in terms of finances, energy, environment, health, and safety. Decisions are specific to each mill, because each mill has a different situation. For example, it is reasonable to expect one mill to have no offsite odor because of its configuration, but it may not be reasonable to expect this from another facility.

At Company 3, decisionmaking is centralized. Corporate management and the Board control the majority of capital and determine which investments are appropriate for each facility. Representatives from the company indicated that the reason for this is because the industry is capital-intensive and capital-short. For these reasons, investments need to be carefully managed by senior managers who can look at the company overall. Local authority for investment is limited.

How Investments Are Prioritized

According to the company interviews, the two factors that most influence investment behavior are environmental regulations and ROI. All four of the companies interviewed indicated that in the hierarchy of investment priorities, regulatory compliance comes first, productivity second. The rationale is that if a facility cannot operate within the bounds of the regulations, it will be shut down. The hierarchy of investment priorities described by each of the companies is shown in Table 3-1.

Company 3 emphasized that investments depend on the company's hurdle rate, or the minimum payback required to make the investment worthwhile. This company noted that while many win-win projects, that is, projects that have both environmental and economic benefits, sound good, they often have lower rates of return compared with straight productivity-enhancing projects. Even though the projects' ROI may be positive, the company feels it cannot afford to invest in these projects, because it must pay interest on the capital it uses; the company wants to use its capital in the way that is likely to generate the highest possible ROI. Since it has to pay to borrow money, its investments need to make the cost of borrowing worthwhile.

Company 4 indicated that investments consist of discretionary and nondiscretionary categories. Nondiscretionary investments are those used to meet regulations or maintain the basic operating ability of the plant. The company representative interviewed believed that for his company and the

Table 3-1. Hierarchy of Investment Priorities

Company 1. Integrated Pulp and Paper Company

- Environmental Goals and Regulatory Compliance
- Investments with Highest Rates of Return
- Value to Shareholders (that is, stockholder value)
- Value to Customers

Company 2. Integrated Pulp and Paper Company

- Environmental Goals and Safety Regulations
- Productivity Enhancements
- Cost Reductions
- Value to Customers

Company 3. Integrated Steel Company

- Environmental Goals and Regulatory Compliance
- Maintenance of Operations
- Future Expansions
- Facility Enhancements

Company 4. Integrated Steel Company

- Environmental Goals and Regulatory Compliance
  - Improve Product Quality
  - Cost Reductions
-

integrated steel industry in general, discretionary investments made from the 1950s to 1970s could be justified if they could increase sales. But post-1975, few discretionary investments could meet required hurdle rates.

Company Views About Energy-Efficiency Investments

The comments made by representatives from the paper and steel companies suggest four main observations regarding energy-efficiency investments.

- Capital rationing is practiced, and investments in energy efficiency are dictated by the availability of capital.
- Energy is not treated differently from any other production input.

- Companies treat energy-efficiency and environmental investments separately.
- New facilities provide an opportunity for energy-efficiency improvements to be made.

Capital Rationing Is Practiced, and Investments in Energy Efficiency Are Dictated by the Availability of Capital

Three companies interviewed indicated they practiced capital rationing. They explained that each year there is only a finite amount of capital available for investment. From this finite pool of capital, money required to remain in compliance with regulations is taken from the top. All other investments, including energy-efficiency investments, come from the remaining capital. Energy-efficiency projects compete with other customer-driven quality and productivity improvement projects, modernization programs, and nondiscretionary environmental expenditures.

Since environmental costs consume a significant part of corporate capital, there is less money available for other, productivity-improving investments. Given many companies' large total operations budgets, a single investment can be a large percent of the total. For example, Company 1 said that, on average, a mill with capital costs of \$100 million would spend \$15 million on capital for environmental controls. After the mill is built, operating costs for the facilities were likely to total more than \$15 million over the lifetime of the plant. This means that if significant environmental improvements need to be made to 10 of the company's mills, the cost is equivalent to the cost of building a new mill. Company 2 also reported that environmental costs are 15 to 20 percent of the capital cost of building a new mill. At one of its newer mills, which is very large, this cost was about \$200 million.

Energy Is Not Treated Differently From Any Other Production Inputs

All four companies indicated that energy is treated no differently than any other production input. Energy costs are seen simply as a component of operating costs. Energy consumed per ton of production is not as much a driving force for energy reduction as is overall production cost. Investments in energy efficiency are not given special treatment by any of the companies interviewed; these investments are held to the ROI requirements to which all other discretionary and productivity-improving investments are held. For example, Company 2 reported that energy is a cost of doing business, of no higher or lower

intrinsic value than the cost of wood, chemicals, and labor. The company seeks to conserve energy wherever possible, but since energy is just another raw material, there are no specific energy-related goals. A representative from Company 4 also noted that energy-efficiency investments are almost exclusively cost-driven.

Although some investments may not be counted as "energy projects" *per se*, energy-related improvements frequently accompany process improvements. In the paper industry, for example, boiler audits, which are usually billed as addressing safety and environmental concerns, also cover energy efficiency. Similarly, high-efficiency motors, lighting, and insulation improvements are usually listed under capital improvement projects even though they affect energy efficiency. Company 3 stated that energy-efficiency improvements are usually rolled into their capital improvement program and are likely to occur when other major processes are being revamped.

Companies Treat Energy-Efficiency and Environmental Investments Separately

All four companies indicated that energy efficiency is viewed as a cost issue and that energy-efficiency improvements *per se* play a secondary role when assessing the merits of an investment. Company 2 described energy as primarily an economic issue that has environmental implications. For example, the products of combustion, such as fly ash, are environmental issues, but, for the most part, energy-efficiency investments are decided on the basis of cost.

Several company representatives expressed the viewpoint that energy and environmental issues are treated as completely separate issues, not only by their companies, but by EPA as well. Company 1 reported that when evaluating environmental technologies, both the company and the regulator are supposed to consider the energy implications of the technologies, but, in practice, increases in energy use do not provide a rationale for arguing against a particular technology.

Still, some processes have energy benefits, even though they were not designed with those in mind as a primary purpose. Company 2 provided an example of this phenomenon. Recovery boilers recover energy, but this is secondary to their main function, which is to recover chemicals.

New Facilities Provide an Opportunity for Energy-Efficiency Improvements To Be Made

Comments from the companies interviewed reveal that the best time to install new technologies, whether they be for energy-efficiency or environmental improvement, is during new plant construction. This is because retrofitting existing facilities costs more and has less attractive payback periods than investing in new facilities. In addition, companies are reluctant to invest in plant improvements when they are uncertain how long the facility will remain open. Several energy-efficient technologies may be appropriate in new plants, but not economically feasible at existing plants. In the steel industry, for example, technologies such as top pressure recovery turbines, basic oxygen furnace off-gas recovery, programmed heating of coke ovens, hot mill table covers, and evaporative skid cooling, have good paybacks in terms of purchased energy saved versus capital invested. However, they may not have good paybacks when retrofitted to existing plants. Therefore, the greatest opportunities for making energy-efficiency improvements occur during times of production growth and installation of new production capacity. Investment in new facilities allows installation of state-of-the-art equipment and processes with minimal additional investment that is specifically attributable to environment or energy efficiency.

As noted in the previous discussion of capital rationing, if a requirement for significant environmental improvements at multiple facilities of a company results in a decision by the company to not build a new mill, then an opportunity for joint environmental, productivity, and energy-efficiency improvement is lost.

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4. FEDERAL STRATEGIES FOR ADDRESSING DIVERSE GOALS

Recent Paradigm Shifts in Environmental Protection and in the Promotion of Energy Efficiency

Recent trends in reinventing environmental protection, along with consistent parallel changes in the way energy efficiency is promoted, may be a better way than the conventional regulatory approach for aiding industry to obtain win-win solutions. Table 4-1 describes the nature of paradigm shifts occurring at both EPA and DOE.

EPA is currently working with industry and the public to reform its system of regulation, which, in the past, relied on pollution-by-pollution regulations, adversarial and entrenched solutions, rigid means, end-of-pipe controls, and the one-size-fits-all approach (Browner, 1994). Reinvention efforts began in earnest in 1993 and involve efforts by EPA to—

- Promote pollution-prevention principles that encourage industry to reach further into the manufacturing process to reduce pollution rather than rely on end-of-pipe controls¹
- Shift from regulation by incident to regulation by strategic initiative
- Integrate flexibility into its enforcement approaches
- Build cooperative partnerships.

The recent environmental regulatory developments are exemplified by new EPA initiatives, such as the Common Sense Initiative, Project XL, and the Environmental Leadership Program.

On the energy side, DOE is reinventing the way it promotes and supports industrial energy efficiency. This effort began in 1993 with a shift in the way

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¹The Pollution Prevention Act defines pollution prevention as the use of materials, processes, or practices that reduce or eliminate the creation of pollutants or wastes at the source. It includes practices that reduce the use of hazardous materials, energy, water, or other resources, and practices that protect natural resources through conservation or more efficient use.

DOE's Office of Industrial Technologies does business with its industrial clients. The key elements of this paradigm shift include the following:

- Cooperative partnerships instead of independent (and sometimes conflicting) government and industry actions
- An emphasis on technology commercialization as well as technology development
- Encouragement of shared values and voluntary actions instead of legislated regulation
- A holistic approach integrating energy, productivity, and environment instead of a narrow energy efficiency and waste reduction focus (Swink, 1994)

Two DOE initiatives that illustrate this new paradigm are the Industries of the Future and the National Industrial Competitiveness Through Energy, Environment, and Economics (NICE³).

Table 4-1. Recent Energy and Environmental Paradigm Shifts of Government Agents

Theme	Energy Efficiency	Environmental
Pollution Prevention	Emphasis on pollution prevention and resource recovery in addition to energy-efficiency technologies	Greater emphasis on pollution prevention
Holistic Approach	Programs and policies reflect greater emphasis on integration of energy efficiency, pollution prevention, and productivity principles	Multimedia emphasis
Industry-by-Industry Dialog; Fits the Way Businesses Work	Promotes shared values and cooperative partnerships with industry	Actively encourages dialog among government, industry, and environmental groups
Flexible Means	Promotes voluntary initiatives	Introducing flexibility into enforcement and compliance procedures

What the Study Tells Us About These Paradigm Shifts

The study offers a number of observations that are relevant to the paradigm shifts at DOE and EPA.

The study offers a number of observations that are relevant to the recent paradigm shifts at DOE and EPA:

1. Removing existing production inefficiencies is a key element for achieving productivity growth in integrated paper and steel plants.
2. Environment-related productivity losses and losses due to the need to shift capital for abatement are small compared to overall production inefficiencies.
3. Well-managed plants appear to be better environmental performers (in the integrated paper industry).
4. Companies place mandatory environmental investments at the top of their investment priorities.
5. Capital rationing is practiced at least in the companies interviewed and possibly in most companies in their industry.
6. Win-win opportunities are observed where the outputs of pollutants can be reduced while simultaneously increasing production and reducing other inputs.

These findings of the study, among others, support two key conclusions:

- *To the extent new environmental and energy policy approaches provide industry with greater flexibility to direct investments at addressing the significant production inefficiencies, the recent paradigm shifts at DOE and EPA may be a better way for Government to encourage win-win outcomes.*
- *To the extent environmental and energy policies focus more broadly on increasing production efficiency and achieving more win-win solutions, then the capital constraints associated with pollution abatement and capital rationing may be less important.*

Strategies

The study has shown that improvements in production efficiency make an important contribution to productivity growth in both the integrated paper and steel industries. In addition, the historical importance of technical change in productivity growth suggests that future policies to encourage the development and commercialization of new best-practice technologies can contribute significantly to productivity growth.

Five strategies are identified from the data analysis and company interviews. Most of these strategies are already being implemented in various ways by the Department of Energy and the Environmental Protection Agency, as part of their initiatives to reinvent government.

Strategy 1. EPA, With DOE Support, Encourages Alternative Compliance Strategies

The study has noted several barriers that conventional regulation, particularly the permitting process, can have on productivity and on energy efficiency. According to the company interviews, it appears that some regulations and the permitting process can stifle the innovation that continued technical change requires.

Based on company comments, a strategy to encourage alternative compliance approaches that incorporate some consideration of industry preferences for how to meet environmental compliance requirements is desirable. One specific approach on the permitting side could be to streamline the PSD process, especially for source modifications that are done to improve energy efficiency or environmental quality. For example, BACT analysis could be skipped in cases where the ambient air-quality testing still needs to be done.

Also, according to the comments from several company representatives, the preferred compliance strategy is one based on a holistic approach, looking across media and pollutants as well as considering all the implications of a particular technology. Several of the companies who participated in the study prefer a more flexible approach that would allow them to comply and reduce risk in the most cost-effective manner and does not force use of technologies that are unproven or that have a small marginal benefit at a high marginal cost.

Several elements of this strategy are already being implemented by EPA as part of its Common Sense Initiative, Project XL activities, and the proposed voluntary incentive program of the paper industry Cluster Rule.

Strategy 2. DOE Fosters Technological Growth Through Continued Support of R&D on Energy-Efficient, Pollution-Prevention Technologies

This study identifies best practice based on the best technology in use, but this best practice is constantly changing, as measured by the technical change indices. Research and development (R&D) is an important driver to technical change, and government-funded R&D has been an important component. Industry-government R&D partnerships, such as those supported by the Department of Energy's Office of Industrial Technologies, have increasingly emphasized productivity (for example, product yield and throughput) improvement and waste minimization as effective methods to reduce energy use per unit of salable product. To the extent these projects focus on productivity, with corresponding energy and environmental benefits, they represent a better way of government doing the business of R&D. Working in partnership with the private sector on innovative technology R&D projects is one important way of ensuring that historical technological change is sustained.

The integrated paper companies visited identified a number of R&D interests:

- Developing the minimum impact mill
- Finding economical and environmentally friendly bleaching processes
- Developing improved drying techniques, like infrared, impulse drying, or microwave
- Improving the brightness of chemomechanical pulps that impede market acceptance
- Exploiting energy-efficiency opportunities in the areas of black liquor gasification and higher liquid solids
- Improving the cost-effectiveness of water conservation for improved energy efficiency and environmental performance
- Developing improved fiber recovery with win-win benefits for energy, environment, and production

One steel company representative suggested a role of government as a stimulus to industry R&D funding aimed at supporting certain kinds of precompetitive research, namely (1) conducting technical feasibility studies that help industry eliminate unattractive technology options or identify preferred technical approaches, and (2) sponsoring long-term research in the areas of process control and process advances that would be helpful in reducing production and environmental costs and increasing environmental benefits.

Strategy 2 is already being implemented by DOE's Office of Industrial Technologies, in partnership with AFPA and AISI, where several R&D projects are being developed or are under way, including some in areas above.

Strategy 3. DOE, EPA, and Trade Associations Continue Efforts To Develop and Disseminate Information on Best Practices and Pollution-Prevention Opportunities

This study found evidence of a trend in the integrated paper industry toward increased production efficiency and pollution prevention improvements. This trend was less evident in the integrated steel industry. To support this positive trend in the paper industry and to encourage a turnaround in the steel industry, EPA, DOE, and industry trade associations could work jointly to develop and disseminate more information on pollution prevention opportunities and best practices. This could include constructing realistic performance benchmarks that focus on production efficiency improvements in the best-practice plants. Existing delivery mechanisms could be employed, such as DOE, EPA, AFPA, and AISI programs already established for delivering information to industry.

Strategy 4. EPA and DOE Work Together To Give Greater Consideration to Secondary Energy and Productivity Impacts When Evaluating Environmental Technologies

Another strategy could be for EPA and DOE to work together to give stronger consideration to secondary energy and productivity impacts in the BACT analysis. At least one company reported that when it evaluates environmental technologies, both the company and the regulator are supposed to consider the energy implications of the technologies, but, in practice, increases in energy use do not provide a rationale for arguing against a particular technology.

Because the BACT process intends to introduce the best available controls into the production process, a properly implemented BACT analysis may encourage rather than discourage adoption of best-practice production and energy-efficient technologies. It is not certain how prevalent this issue is for paper and steel plants. However, efforts by DOE and EPA to work together to ensure secondary energy and productivity impacts are given adequate attention would be consistent with companies' desire to pursue win-win solutions.

Strategy 5. Energy-Efficiency Programs Target Efforts To Encourage Use of Best Practice by the Potentially Large Population of Non-Best-Practice Plants

The analysis has shown a potential for win-win opportunities in about 42 percent of the integrated paper plants. This means that the largest potential for emission reduction and production efficiency improvement comes from less than half of the paper plants. Fossil-fuel use has dropped in the paper industry, but it has dropped much more in best-practice plants. Electricity purchases have risen in paper plants, on average, but have fallen significantly in the best-practice plants. There appear to be more than 40 percent of paper plants that can benefit from targeted strategies by DOE to identify and encourage the potential in these plants for simultaneous environmental, productivity, and energy-efficiency improvements.

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APPENDIX A. RESEARCH METHODOLOGY

The general research approach is a modified case study method. Each industry case is analyzed using two related components: (1) historical plant-level productivity, energy, and pollution data and (2) field interviews made at companies. These two component approaches, when combined, produce an attractive integrated set of findings. Analysis of historical plant-level data for the steel and paper industries was used to quantify the magnitude of productivity, energy intensity, and environmental performance. On the other hand, company site visits with environmental and energy managers provided a realistic picture of "industry's" perceptions and concerns.

Selection of Case Study Industries

The first step in conducting this study was to select case study industries.

The selection of case study industries began with a list of energy- and pollution-intensive industries. The following industries were included in the selection process:

- Pulp and Paper Mills (SICs 2621 & 2631)
- Flat Glass (SIC 3211)
- Hydraulic Cement (SIC 3241)
- Organic Chemicals (SIC 2869)
- Agricultural Chemicals (SIC 2873)
- Blast Furnaces and Steel Mills (SIC 3312)
- Primary Aluminum (SIC 3334)
- Vehicle Assembly, Parts and Suppliers (SIC 371)

A set of criteria was established to choose the industries for the case studies. These criteria were judgmentally ranked for each of the eight industries, and an overall index was created. Table A-1 describes the criteria used.¹ The indus-

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¹Table A-2 uses Btu per dollar value of shipments as the measure of energy intensity when applying criteria for the selection of the case study industries. On the other hand, the plant-level data analysis portion of this study uses electricity and fossil-fuel intensities expressed as expenditures in 1987 dollars divided by plant-level total value of shipments as measures of energy intensity.

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Table A-1. Industry Selection Criteria

Industry Selection Criteria	Explanation
Availability of data for the empirical analysis	Prepared Census data sets, trade association data, and including ease of implementation
Focus on production cost and productivity	The degree to which cost and productivity are major business strategies, rather than new products or markets
Energy consumption	Amount of consumption and level of energy intensity
Long-term role in the U.S. economy	Prospects for continued growth or decline, import or export position of the domestic industry, overall size (percent of GNP), and so forth
Homogeneity of industry or the presence of well-defined subindustries	The degree to which the industry produces a narrowly defined product range or the presence of well-defined subindustries
Potential for engagement in voluntary action	Including technical potential, proactive trade groups, and competitive business pressure
Participation in DOE programs	The degree to which DOE has been active in the sector.
Potential for cooperative industry consultations	Past cooperation and industry contacts
Potential future (near-term) regulatory change	Whether new regulations are being considered that may affect the sector and could influence industry productivity
Size of environmental regulatory burden/impacts	Cost share of capital expenditure and operating costs
Availability of technology data	1991 MECS data, adoption of DOE technology data, trade association and other data
Other	Any additional information not covered above

tries with the highest ranks were chosen for case study. Table A-2 gives the results. The pulp and paper industry and the steel industry obtained the highest ranking.

To further focus the analysis, it was decided to examine specific subindustries of the paper and steel industries. The study focuses on the integrated industry subindustries (that is, those that convert raw materials like pulp wood or iron ore into finished and semifinished goods), because this part of each industry covers the entire range of process, environmental, energy, and business issues that the industries each face. Paper and steel integrated plants also tend to have higher energy use and rates of pollution compared to their nonintegrated counterparts.

Table A-2. Industry Selection Criteria Ranking

Scoring the Industries in Each Category ^a	2621 and 2631, Pulp and Paper	3211, Flat Glass	3241, Hydraulic Cement	2869, Organic Chemicals	2873, Agricultural Chemical	3312, Steel Mills	3334, Primary Aluminum	371, Vehicle Assembly
Availability of data for the empirical analysis	2	2	4	0	1	4	2	2
Focus on production cost and productivity	2	3	2	1	3	3	4	2
Energy issues:	4	2	3	3	3	3	3	1
Energy consumption, Trillion BTU	1.3	0.05	0.3	0.9	0.27	0.8	0.04	0.002
Energy intensity (thous. BTU/\$ val ship)	45	20	100	21	110	55	30	1
Opportunities for conservation	4	2	2	3	2	2	1	3
Long-term role in the U.S. economy	4	2	3	4	3	2	0	4
Homogeneity of industry	2	3	4	0	2	3	4	3
Well-defined subsectors	3	3	4	0	4	4	4	3
Potential for engagement in voluntary action	2	1	1	4	2	2	2	3
Participation in DOE programs	3	1	1	4	2	4	3	0
Potential for cooperative industry consultations	4	2	2	2	2	3	2	3
Potential future (near-term) regulatory change	4	1	3	3	3	3	1	1
Size of environmental regulatory burden/impacts	4	1	2	4	1	3	1	2
Energy related	4	1	1	2	1	3	1	1
Non-energy related	3	1	3	4	1	3	1	3
Availability of technology data	3	1	3	1	1	2	1	1
Median	3	2	3	2.5	2	3	2	2
Mean	3.1	1.8	2.7	2.2	2.3	3.0	2.3	2.1

Source: Qualitative ranking performed by Gale Boyd (Argonne National Laboratory) and Marc Ross (University of Michigan).

^aAll scoring based on scale from 0 (lowest) to 4 (highest) with exception of ranking for energy consumption and intensity indicators.

Therefore, paper and steel plants are further broken down according to whether or not they are fully integrated facilities. This narrows the scope of the study, but also makes the conclusions more realistic. To make performance comparisons between plants, the data analysis portion of the study requires that the plants share a common production technology and operating history. Hence, the data analysis only examines the performance of fully integrated plants that have continuously operated from 1974–1991 for paper plants and 1972–1991 for steel plants.² Fully integrated paper plants are defined as those that use primarily virgin raw materials, for example, wood fiber or coal and iron ore, to produce final products, for example, paper and paperboard or finished steel. To make performance comparisons across plants, the production technology must also be similar across plants. This is done by restricting the data analysis to paper mills (in the data sample) that are fully integrated, chemical pulp mills. This means that groundwood and recycled feedstock plants are excluded from the data analysis portion of the study. For the steel industry, only continuously operating plants with all of the primary steel production stages are considered in the data analysis, that is, plants with onsite coke ovens, blast furnace, and basic oxygen furnaces as well as rolling and finishing. Steel plants whose primary business is specialty steel (for example, stainless and so forth) are excluded.

The selected industries represent industries where tensions between environment, energy, and productivity might be most apparent. The integrated mills in the paper and steel industries also share some common characteristics that led to their selection. Thus, where common themes in the data and company interviews for the two selected industries emerged, this study provides a signpost from which to get guidance on possible future strategies to consider for integrated mills in paper and steel industries.

However, the study does not presume that the magnitude, source, and scope of impacts found for these sectors would generalize to all SIC 2621 and 2631 (pulp and paper mills) and 3312 (blast furnaces and steel mills) or to the entire U.S. manufacturing industry.

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²The time period covered is 1972–1991 for the steel industry and 1974–1991 for the paper industry. Difficulties with the paper industry sample in the first 2 years of available data for the paper industry prevented including these years in the study.

Plant-Level Data

The primary data source for this report was plant-level data from the U.S. Bureau of the Census (hereafter, Bureau). Access to the data is provided by the Bureau's Center for Economic Studies (CES) through its program of Census Fellows and Special Sworn Employees (SSEs). SSEs have complete access to confidential plant-level data collected by the Bureau but are required to execute a statement that they will not disclose these data. Yet, by its very existence, the CES encourages research on economic and modeling issues that may involve plant-level data. Thus, the results of any analysis (including those presented in this report) based on CES-compiled plant-level data are reviewed by the CES for confidentiality disclosure. This type of review generally requires that any aggregate statistics compiled by researchers at the CES for publication or outside release cover at least four to six plants. Other types of behavioral (statistical) relationships are reviewed by CES as well to ensure they do not violate confidentiality.

The plant-level economic data used for this project come primarily from three sources:

- The Census of Manufacturing (CM)
- The Annual Survey of Manufacturing (ASM)
- The Pollution Abatement Capital Expenditure Survey (PACE)

These data have been collected by the Bureau for the purpose of constructing industrywide and economywide aggregate figures on activity in the manufacturing sector for release to the public in a variety of reports.

The CM obtains various measures of economic activity for every manufacturing plant in the Nation with one employee or more. For example, there were 367,998 plants operating in the United States in 1987, with one employee or more. The CM is conducted at 5-year intervals, covering years ending in "2" and "7." For every manufacturing plant with one employee or more, the CM collects data on the plant's inputs of labor, materials, and capital; its output of products and services; its location; and the legal form of organization of the owning company. Associated with each plant record is a permanent identification number and location. Both of these items stay with the plant from its start until it shuts down. In addition, each plant is linked to a parent company, and detailed status codes allow one to trace ownership changes over time as well as construct firm-level data.

The ASM is a national sample survey of manufacturing plants, conducted each year the CM is not conducted; the ASM obtains various measures of economic activity. In census years, the ASM data are also collected by the CM for those plants in the ASM panel. The 1988 ASM included about 14 percent (53,106) of the 367,998 plants that reported in the previous CM year. The ASM collects the same basic measures of economic activity as the CM, but in survey years, less detailed information on materials consumption and each plant's product outputs is collected. For example, in survey years, the value of products shipped is recorded only in terms of approximately 1,500 product classes instead of the roughly 11,000 individual products used in census years. Given the number of variables collected in the ASM and CM, it is possible to generate data extracts from the Longitudinal Research Database (LRD) using a variety of selection keys, such as geographic location, industry, size, and plant. The ASM sample is drawn from the plants in the CM. The sample is selected during the year following each census year and is used for data collection for each of the years. After 5 years, a new sample is drawn from the most recent CM. In each year of the CM, the number of plants in the LRD jumps to a number that is 5 to 6 times larger than it is in non-CM years as a result of the fact that the ASM sample is a subset of the universe of plants in the CM.

Other plant-level data are used in the data analysis portion of this study. These data are plant-level estimates of pollution output that are reported to the EPA. The following are primary sources of the pollution data:

- Aerometric Information Retrieval System (AIRS)
- Permit Compliance System (PCS)
- Toxic Release Inventory (TRI)

AIRS is the primary source of criteria air pollution data, while the PCS is the primary source of criteria water pollution. Another important source of plant-level pollution data is the TRI. Difficulty in combining all three of these data sources with the above LRD prevented toxic air and water emissions from being considered simultaneously with other air and water pollutants in the study. This is something that should be addressed in followup studies.

The value of shipments is the measure of output, since the output of integrated steel and paper plants can vary in the composition of products, for example, integrated plants that produce both paper and paperboard products are included in the paper industry analysis. The data for energy are also measured in dollars, so the computed energy use trends are similar to cost shares. Moreover, only purchased energy is analyzed and byproduct fuels or

cogenerated power are not accounted for. This means that byproduct energy utilization as well as direct energy conservation contributes to lower energy intensity. In the context of productivity, this makes some sense since a plant that replaces fuel purchases with some internally generated source does so because of a cost benefit. Other inputs of capital, materials, and so forth are employed to make use of the byproduct energy which lowers purchased energy costs per dollar of output and yields a net savings to the plant.

Analysis of Plant-Level Data

The data analysis focuses on computing various plant-level indices for productivity measures and relating capital investment constraints implied by environmental regulations to the observed productivity or energy-efficiency measures. This permits an assessment of the extent of tensions between these factors that gives rise to different levels of production efficiency at integrated paper and steel plants.

Three types of analytic results are developed and discussed for the integrated paper and steel industries:

- **Long-Term Productivity Trends.** Estimates of trends in industry productivity and energy intensity.
- **Environmental/Productivity “Win-Win” Opportunities.** Estimates of compliance-driven production efficiency losses and the corresponding potential to make win-win environmental and productivity improvements; win-win opportunities are defined as a reduction of production inefficiency that would allow a plant to simultaneously increase output, decrease pollution, and decrease the level of inputs used (labor, energy, and so forth).
- **Abatement Expenditure Constraints.** Estimates of the extent to which abatement capital expenditures constrain other investments for improving production and energy efficiency.

The long-term trends, environmental and productivity opportunities, and the abatement capital expenditure analysis are presented for the integrated paper and steel industries, respectively.

Following a brief discussion of productivity measurement and the basic analysis method, the analytic approaches used to estimate long-term productivity trends, environmental and productivity opportunities, and the abatement capital expenditure impacts are each discussed.

Productivity Measurement and Best-Practice Analysis

The data analysis uses a modeling framework for computing alternative productivity indices using measures of pollution output, rather than reported data on abatement expenditures (Fare et al., 1989b). This framework also explicitly recognizes the potential for relative inefficiency in plant-level production and pollution control decisions.

Plant Productivity Measures

The analysis of productivity is performed using a total factor productivity (TFP) measure. Total factor productivity is constructed as a ratio of an index of the productive output of a plant divided by an index of all plant inputs. Commonly used productivity measures are expressed as the relative use of labor or energy to produce some unit of output, expressed either in physical or monetary units. These measures, like staff-hours per ton of paper or kilowatthours per ton of steel, are simple to calculate and focus on specific inputs and issues that relate to those inputs. Because many inputs are used to produce paper and steel, a measure of productivity that accounts for all inputs in the production process (that is, growth accounting or TFP) is a better alternative.

Two basic types of plant productivity comparisons are developed in this research: a productivity cross section comparison, which is made across entities (companies or plants); and a productivity growth comparison, which is made over time to measure the rate of productivity changes for a particular entity. Previous studies focus on productivity growth (Barbera and McConnell, 1990; Gray and Shadbegian, 1993).

Best-Practice Analysis

To measure productivity using multiple inputs (and outputs), one must define "how much" a plant could produce with some prescribed level and mix of inputs.³ The analytic method for doing this is "best-practice" analysis (also referred to as "frontier" analysis).⁴ The best-practice plants are those that have

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³Of course, the different production technologies are an important source of the difference in inputs used and outputs produced. We measure the inputs in economic terms, that is, dollars spent on wages, capital stock, and so forth. Therefore, one might interpret the efficiency discussion in terms of input budgets.

⁴These techniques also are referred to as Data Envelopment Analysis (DEA) and may be derived from activity analysis use in linear programming (LP) models of production systems.

minimum inputs per unit of output for any mix of inputs, that is, they are the most efficient in their use of inputs among all similar plants in the industry being studied.

The terms “best-practice plant” and “most efficient plant” are used synonymously in this report. One of the strengths of this analysis is that the individual situation of each plant is approximately taken into account. The focus of the analysis is not how far a plant is from a national-average “minimum-cost plant” or an idealized engineering model of a plant; rather it is how far each plant is from the best “observed practice” of other similar plants. Huntington (1995) discusses the relationship between best-practice analysis and traditional engineering analysis. The best-practice production frontier is defined as those plants that use production methods and technology that have minimum inputs requirements per unit of output, for the given mix (relative amounts) of inputs. Over time, production methods and technology will change. *Technical change*, the most basic component of productivity growth, is defined as the measure of how much the best-practice “frontier” has changed. Not all plants use best practice, and a measure of how close or how far a plant is from best practice is defined as *production efficiency*. Figures A-1 and A-2, showing the concepts of best-practice production frontier, technical change, and production efficiency, are useful for understanding these productivity concepts.

Technical Change

The mechanisms of technical change can be embodied in new technology or capital, for example, a new machine or process. However, best-practice technical change can also include nontechnology improvements, such as new managerial methods, shop floor practices, just-in-time inventories, or anything that increases the output of a facility with the same or less inputs of labor, materials, energy, and capital. Because best-practice plants are already operating with minimum inputs, it is likely that new technology adoption has an important role in changing the best-practice production methods.

Figure A-1 shows the levels of two types of production inputs, variable and fixed, that could be used to produce some desired level of production at two points in time, say years 1 and 2. The data analysis in this report uses more than two inputs, but the exposition is easier if only two are shown. The curved lines are defined by the most efficient production entities, referred to as the best-practice production frontier. One can interpret fixed inputs as capital, and variable inputs as labor, energy, and so forth. Considering, for the moment, only desirable, or “good” outputs, all points along the line year 1 “production

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Figure A-1. Measuring Best-Practice Technical Change

Figure A-2. Measuring Best-Practice Production Efficiency Change

frontier” produce the same level of marketable output and represent best-practice input combinations.⁵ All points to the right of and above the frontier produce the same level of output as the best-practice plants, but are “inefficient” in their use of inputs relative to best practice. Production points to the left and below the frontier are not technically feasible in year 1.

The year 2 production frontier illustrates what might happen as plants improve over time after year 1. In an effort to catch up with the competition during year 2, suppose the plant in question has moved from point A to point E (which was not technically feasible in year 1). This is a productivity gain since the plant at point E is more efficient than the plant at point A; moreover, the plant at E is superior even relative to last year’s efficient point B, since point E uses fewer variable inputs than B as well as less capital than point A.

However, in year 2, production technology has improved for the best-practice plants as well, as indicated by the shift in the best-practice frontier to the position for year 2. This means that point E is still less efficient relative to point F, although it represents a total productivity gain over point A. This can be seen by comparing the distance from A to B and from E to F, which shows that at E, the plant is closer to the frontier, having improved its overall production inefficiency. Moving closer to the frontier is the production efficiency change.

To visualize technical change, note that E was not technically feasible based on best practice in year 1. The best-practice technology in year 2 had improved and may be measured by either the distance from B to C or from D to F, shown.⁶ These shifts in the best-practice frontier represent the reductions that were made possible by improvements in technology, which is called technical change.

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⁵A single configuration is not judged as best practice. The single combination that would be optimal would also depend on specific energy prices, capital costs, and so forth. These prices might vary in regions and under different conditions. Best practice here is defined as technical potential.

⁶If the technology improves in such a way that all inputs are all equally more productive, then the distance from B to C or from D to F would always be the same. However, not all technical changes are neutral—some technical advances benefit energy, some may benefit labor. To construct a single, well defined index that is consistent with economic theory for the Malmquist index of TFP growth, the geometric average of these shifts is used.

Production Efficiency

Productivity growth over time, that is, the change in the amount or number of inputs that will produce some output, implies that plants can improve their production efficiency and make overall productivity gains. Production efficiency change is the second major component of productivity growth. The mechanisms for production efficiency improvement are the same as those for technical change; the mechanisms simply apply to productivity gains in the less efficient (that is, non-best-practice) plants.

Figure A-2 illustrates the production efficiency concept. To illustrate production efficiency measurement, consider the example of a specific plant producing the same output level as the best-practice plants (that is, plants on the production frontier), but with the input combination at point A. This less efficient operation consumes more inputs than plants on the frontier for the same output. The production inefficiency of A is measured by simply assuming that all inputs are reduced by the same proportion relative to the frontier point B. Thus, the distance from A to B represents the production inefficiency in point A, and movement of a plant from A to B would represent a production efficiency increase.

The analogy of a race is useful in understanding the two productivity concepts. Technical change is how fast the industry leader is running, while production efficiency change describes whether the rest of the pack is catching up or falling behind. This kind of framework allows insights into the dynamics of an industry while also permitting a decomposition of productivity changes at the plant level.

Measuring Long-Term Productivity Trends

The first phase of plant data analysis is to determine the long-term industry productivity trends. This is done using the TFP index at the plant level for all plants and then averaging these results for the industry level. The long-term trends are also decomposed into the two productivity components, technical change and production efficiency. Finally, long-term trends in the energy inputs (that is, electricity and fossil fuels) are also investigated.

To compute productivity changes for the steel and paper industry data in this research, an easily computable form of a TFP calculation, based on the Malmquist productivity index, is used (Caves, Christensen, and Diewert, 1982). This approach allows a comparison of the relative growth (decline) in output relative to the amount of inputs required to produce the observed

output level. Fare et al. (1989b) show that the Malmquist productivity index can be decomposed into the production efficiency and technical change components. For each plant, the TFP productivity change index, OP, between two periods, t and $t + 1$, is defined and computed as follows:

$$\text{Production Efficiency Change} = PE = F_{t+1, t+1} / F_{t, t}.$$

$$\text{Technical Change} = TC = \left[\left(F_{t, t+1} \times F_{t, t} \right) / \left(F_{t+1, t+1} \times F_{t+1, t} \right) \right]^{1/2}.$$

$$\text{Overall Productivity Change} = OP = TC \times PE.$$

The term $F_{t, t+1}$ is the distance function which measures the amount of production efficiency improvement necessary for each plant to move from its current position of inefficient use of inputs to the closest hypothetical best-practice plant with the same output on the frontier, that is, the corresponding plant with minimum use of inputs. In the Malmquist decomposition analysis, the plants that define the best-practice production frontier are determined by solving a linear programming problem which determines $F_{t, t+1}$ for each plant (Fare et al., 1989). A description of the Malmquist index and the linear programming used to compute $F_{t, t+1}$ is given in the section A.4.⁷

Once the individual OP, PE and TC plant calculations are made, industry average productivity is determined as the average of this index over the plants included. Trends in the energy inputs are also calculated to examine long-term industry trends. Fossil-fuel and electricity intensity are two simple measures of energy inputs. They are plant-level ratios of fossil-fuel and electricity expenditures,⁸ measured in constant 1987 dollars, divided by plant-level total value of shipments. Because the numerator and denominator of the intensities are both expressed in dollars, the intensity is also a cost share. Reported industry average

⁷The linear programming problem determines which plants define the lower envelope of the observed data to approximate the underlying production isoquants. In the linear programming analysis, the production efficiency of all plants is measured relative to the best practice plants in that the efficiency measure of a plant is the ratio by which inputs (and therefore costs) could be reduced by making that plant comparable to the best practice plants. To measure this, all plants operating on the frontier have an efficiency rating of 1.00 (or 100%), whereas all other plants operate inside the envelope and have an efficiency rating of less than 1.

⁸Only electricity and fossil-fuel purchases are analyzed, not total electricity or total Btu energy use. Therefore, byproduct fuels or cogenerated power are not accounted for. This means that byproduct energy utilization as well as direct energy conservation contributes to lower energy intensity. In the context of productivity, this makes some sense, because a plant that replaces fuel purchases with some internally generated source does so because of a cost benefit. Other inputs of capital, materials, and so forth are employed to make use of the byproduct energy, which lowers purchased energy costs per dollar of output and yields a net savings to the plant.

growth rates are based on exponential trend regressions. The plant-level data used are described in pages A-5 through A-7.

Estimating Environmental and Productivity Win-Win Opportunities

It is typically assumed that plants suffer a loss in potential output as a result of restrictions placed on their emission of pollutants. This output loss is one measure of environmental "costs." This section discusses the output loss due to pollution-control investments using the best-practice framework introduced earlier with a slight modification to consider two kinds of outputs: a desirable, or "good," output (marketable products) and undesirable, or "bad," outputs (pollutants). The use of the best-practice framework is important because not all plants are efficient in their production of "goods" and control of "bads."

The presence of win-win opportunities requires the presence of production inefficiency. In their article, "Green and Competitive," Porter and van der Linde also equate pollution with inefficiency. Pollution often is a form of economic waste—a sign that resources have been used incompletely, inefficiently, or ineffectively.

Whether pollution and energy are signposts for inefficiency is not an issue that this study examines, but it is clear that a win-win opportunity implies some type of production inefficiency. The chemical plant example mentioned in Chapter 2 (Whalley and Whitehead, 1994) can be used to illustrate the concept of inefficiency in the use of production inputs in the two-output case. The company in the example was able to uncover, through their employee program, some inefficiencies whose elimination created net benefits to both the environmental and business goals, leading to a 55-percent internal rate of return. These win-win investments were associated with some form of production inefficiency, since the productivity benefit existed even in the absence of the desire to improve the environment.

When considering possible productivity losses related to environmental goals, it is important to separate two effects: the production inefficiency, which can generate a beneficial linkage between pollution reduction and productivity increase; and the production losses that arise because of regulation of pollution in best-practice plants. The method to make this distinction is discussed below.

Environmental aspects of plant productivity can be measured using the "output" version of best-practice analysis. In the previous section, it is assumed that lowering the inputs and producing the same output is being done by the plant. For the purposes of this discussion, consider the case where inputs are fixed, but the plant seeks to produce more output. Both approaches can be used to measure technical change and production efficiency. Use of best practice analysis here does not mean that other economically viable environmental and productivity opportunities do not exist, but rather that only the opportunities actually used in plants are measured in this report.

The solid line in Figure A-3 shows the economic tradeoff that occurs when producing a mix of two types of economic output, if both were desirable or at least unregulated, with some fixed total amount of economic resources. When the amount of all outputs produced is constrained by the levels of inputs, labor, energy, and capital, then producing more of one output will require that some amount of the other output must be given up. The curve is defined by the most efficient production entities. If an entity is using resources inefficiently as for point A, then more output can be obtained, as indicated by the arrow from A to A'.

Figure A-3. Production Efficiency Losses Related to Desirable and Undesirable Outputs

However, the approach changes where some outputs are desirable ("goods") and some are not ("bads"). If "bads" are constrained so that they are not freely disposable (that is, they cannot be produced and then thrown away somewhere), then the economic tradeoff is the dotted line rather than the bold line as shown in Figure A-3 (see Fare et al., 1989b). Any plant that is less efficient than a best-practice plant can move from point B to point A, producing more goods and less bads. The increase in production and decline in pollution comes from the more efficient use of the resources, based on observed best practice.

Regulation constrains the disposal of "bads" so that some "goods" are given up to reduce "bads." This regulatory effect is illustrated by moving from A to A'. Point A is the best practice, relative to the conventional regulations that require certain levels of pollution control. If regulations were not imposed, then more goods would be able to be produced (as represented by A'). Any additional "bads" are simply disposed of. One measure of the cost of regulation is the amount of desirable outputs that are "lost," represented by the difference A to A'. Using this conceptual framework, estimates of the potential for simultaneous (that is, so-called win-win) productivity, energy, and environmental improvements are measured.

The computational procedure used to estimate environmental and productivity opportunities involves solving a "hyperbolic graph efficiency measure," a linear programming problem (Fare, 1989b). The details of this procedure are in the section beginning on page A-19. This procedure is somewhat different from the discussion of reducing inputs with outputs fixed, or reducing bads and increasing "goods" with inputs fixed. Although based on the same concepts as the above discussion, the procedure optimizes inputs and outputs simultaneously.

The estimates are based on an analysis of five production inputs: capital, labor, material, fossil fuel, and electricity and, as described above, two types of outputs: "good" outputs, measured as the dollar value of shipments, and a set of "bad" outputs, namely the quantity of criteria air and water pollutants or toxic releases. The calculation procedure estimates the amount that plants could reduce production inputs and all "bad" outputs, while increasing "good" output at the same time. The estimates do not take into account any constraints implied by technology in place. It is assumed that the less efficient plants can take advantage of the technologies available in the best-practice plant with similar mix of inputs and outputs. The analysis is limited to 1990, the only

year that had sufficient data on both air and water pollution to conduct a multimedia productivity analysis.

It is important to note that this analysis uses a very strict criterion for identifying production inefficiency, that is, win-win improvements. The analysis measures the amount by which inputs and environmental "bad" outputs could be reduced, while simultaneously increasing output by the same proportion. This means that one type of improvement is not considered more valuable than another. Instead, any production efficiency opportunities that would lower inputs of energy, labor, and materials; lower pollution levels; and increase output levels is estimated. This gives a very conservative estimate of win-win opportunities, since a plant that is unable to reduce any single input or pollutant while increasing output is not considered win-win. Only those plants that can "do it all" are included in the estimate of environmental and productivity win-win opportunities.

As discussed above, the regulation of pollution is represented by the assumption that the pollutants are not "freely disposable," that is, reduction in pollutant requires some reduction in output (for an efficient plant). To measure output loss due to regulation, the disposability assumption is imposed in the calculation of best practice, so that some "goods" are given up to reduce "bads." This productivity loss due to regulation is estimated by analyzing best practice with the disposability constraint and without disposability, and comparing the two results. The difference between the two productivity measures gives an estimate of the overall costs, as represented by productivity due to regulation. These implied costs include direct costs, labor, capital, and materials diverted to abatement activities, as well as indirect costs, plant down time, and so forth.

Estimating the Effect of Pollution Abatement Expenditure Constraints

One source of production inefficiency driven by implementing environmental controls is in the company allocation of investment capital to pollution abatement instead of production efficiency improvements. As discussed in Chapter 2, mandatory environmental investments may reduce the money that is put into other more productive areas of a plant. This loss of productive capital due to capital expenditures on pollution abatement is referred to as the abatement capital constraint. This potential effect is examined in this third

segment of plant data analysis by modifying the framework used to measure the production efficiency component of productivity.

In the basic production efficiency framework discussed previously, capital stock is measured as a perpetual inventory of past investments and depreciation of existing stock. To estimate the effect of pollution abatement expenditure constraints, the following three kinds of capital inputs are considered: existing stock, new plant and equipment, and new abatement capital.

It is possible to infer the magnitude of production efficiency loss at a plant due to the requirement that a fixed share of new investment be spent on abatement technology rather than on production improvements. This is done by comparing the level of plant production efficiency (that is, how far from best practice a plant is positioned) under two alternative assumptions about the composition of capital expenditures made each year:

- *Both productivity and abatement expenditures are made*—New plant and equipment and abatement capital must be spent in the observed quantities.
- *Only productivity expenditures are made*—All new investment expenditures were hypothetically made in the new plant and equipment category with no abatement expenditures.

The difference in the production efficiency in these two cases is an estimate of the production efficiency loss due to the abatement capital constraint.

As with the productivity trends analysis and the environmental/productivity opportunities analysis, a series of linear programming problems are evaluated to measure the productivity loss due to the environmental constraint on capital expenditures. (See pages A-20 through A-23.) Each linear programming problem measures the productivity of a plant, relative to best practice, under the two alternative assumptions about the composition of new capital, or current period investment. These plant-level estimates are presented in terms of "lost opportunities" to reduce energy use and to increase production efficiency due to the required pollution abatement expenditures.

Productivity Measurement Calculations

Malmquist Efficiency Decomposition

The Malmquist decomposition (Fare et al., 1989b) is used to construct the long-term productivity measure.

This is done via solving a series of linear programming problems:

$$F_{t, t+1} = \text{Min } \lambda,$$

subject to

$$z \times G_t \geq g_{t+1},$$

$$z \times X_t \leq \lambda x_{t+1},$$

for

$$z \geq 0,$$

$$\lambda \geq 0,$$

where

x_t = observed inputs for a single plant,

g_t = observed "good" outputs for a single plant,

X_t = matrices of inputs for the entire sample, for all years earlier than t ,

G_t = matrices of outputs for the entire sample, for all years earlier than t , and

z = an activity vector.

The decomposition is computed as follows:

$$\text{Production Efficiency Change} = PE = F_{t+1, t+1} / F_{t, t}.$$

$$\text{Technical Change} = TC = \left[\left(F_{t, t+1} \times F_{t, t} \right) / \left(F_{t+1, t+1} \times F_{t+1, t} \right) \right]^{1/2}.$$

$$\text{Overall Productivity Change} = OP = TC \times PE.$$

This linear programming problem is run four times to obtain the measures; $F_{t, t+1}$, $F_{t, t}$, $F_{t+1, t+1}$, and $F_{t+1, t}$, for each plant in the sample.

Hyperbolic Graph Efficiency Measure

Hyperbolic graph efficiency measure is used to compute output loss and multicriteria production efficiency with pollution outputs. The basic linear programming problem is as follows:

$$\begin{array}{ll} \text{subject to} & \begin{array}{l} \text{Min } \Gamma, \\ z \times G_t \geq g_t, \\ z \times B_t = \Gamma b_t, \\ z \times X_t \leq \Gamma x_t, \end{array} \end{array}$$

for

$$\begin{array}{l} z \geq 0, \\ \lambda \geq 0; \end{array}$$

$$\text{Efficiency} = \lambda = \Gamma^{-1/2},$$

where

- x_t = observed inputs for a single plant,
- g_t = observed "good" outputs for a single plant,
- b_t = observed "bad" outputs for a single plant,
- X_t = matrices of inputs for the entire sample, for all years earlier than t ,⁹
- G_t = matrices of outputs for the entire sample, for all years earlier than t , and
- z = an activity vector.

⁹This is the no-technical regress assumption. It implies that technical change is never negative, but can be constant, that is, no change. This is a reasonable assumption because technology does not revert to an earlier stage of development, but at least stays constant.

To compute the pollution control output loss a modified linear programming problem is run, replacing the equality constraint for the undesirable output, B , with an inequality.

$$\begin{array}{ll}
 & \text{Min } \Gamma, \\
 \text{subject to} & z \times G_t \geq g_t, \\
 & z \times B_t = \Gamma b_t, \\
 \text{for} & z \times X_t \leq \Gamma x_t, \\
 & z \geq 0, \\
 & \lambda \geq 0;
 \end{array}$$

$$\text{Efficiency} = \lambda = \Gamma^{-1/2}.$$

The ratio of the two efficiency measures, λ , obtained in each problem give the percentage output loss. These two LP problems are each run for every plant in the data set for each year in the sample.

Capital Constraint Efficiency Measures

To measure the productivity loss due the constraint on capital expenditures, a series of LP problems are evaluated. They each measure the productivity of a plant, relative to best practice, under alternative assumptions about the composition of new capital, such as the current period investment.

$$\begin{array}{ll}
 & \text{Min } \lambda, \\
 \text{subject to} & z \times U_t \geq u_o \\
 & z \times X_t \leq \lambda x_t^o \\
 & z \times K_t^1 \leq \lambda k_t^{1o} \\
 & z \times K_t^2 \leq \lambda k_t^{2o} \\
 & z \times K_t^3 \leq \lambda k_t^{3o} \\
 \text{for} & z \geq 0, \\
 & \lambda \geq 0,
 \end{array}$$

where

- x_t^o = observed variable inputs for a single plant,
- k_t^{io} = observed capital for a single plant,
- u_t^o = observed outputs for a single plant,
- X_t = matrices of variable inputs for the entire sample,
- K_t = matrices of variable inputs for the entire sample,
- V_t = matrices outputs for the entire sample, and
- z = an activity vector.

K is partitioned into three components $K = (K^1, K^2, K^3)$, where

- K_t^1 = previous period capital stock (perpetual inventory method),
- K_t^2 = current period investment less current period pollution abatement capital expenditures, and
- K_t^3 = current period pollution abatement capital expenditures.

The above linear program is the most restrictive, because it requires capital expenditures on abatement in the current period. We successively relax the definition of the production technology to obtain a less restrictive efficiency measure. The ratio of the resulting efficiency scores is the loss due to capital rationing or other capital constraints.

Min λ ,

subject to

$$\begin{aligned} Z \times U_t &\geq u^o, \\ Z \times X_t &\leq \lambda x_t^o, \\ Z \times K_t^1 &\leq \lambda k_t^{1o}, \end{aligned}$$

and

$$Z \times (K_t^2, K_t^3) \leq \lambda (K_t^{2o} + K_t^{3o}),$$

for

$$\begin{aligned} z &\geq 0, \\ \lambda &\geq 0. \end{aligned}$$

Finally we apply the least restrictive definition, where no pollution abatement is in the technology, but current period spending on nonabatement capital K_t^2 is allowed to be equal to the total k_t^{2o}, k_t^{3o} .

$$\begin{aligned}
& \text{subject to} && \text{Min } \lambda, \\
& && Z \times U_t \geq u^0, \\
& && Z \times X_t \leq \lambda x_t^0, \\
& && Z \times K_t^1 \leq \lambda k_t^1, \\
& \text{and} \\
& \text{for} && Z \times (K_t^2) \leq \lambda (K_t^{2o} + K_t^{3o}), \\
& && z \geq 0, \\
& && \lambda \geq 0.
\end{aligned}$$

Field Interviews

Approach

Face to face discussions with environmental and energy managers were conducted from May 1995 through May 1996 to identify regulatory, technology, and decisionmaking factors that contribute to current or future conflicts between the three diverse goals that are the subject of this study. It should be noted that the results derived from this field research represent the opinions of the environmental and energy managers at corporate and mill levels that were interviewed.

The companies participating in the study represent major U.S. interests with integrated mills. Emphasis was placed on choosing large, integrated companies that face environmental regulations and that represent geographical diversity. Companies were identified with the assistance of the American Forest and Paper Association (AFPA) and the American Iron and Steel Institute (AISI). Meetings with participants were held at their facilities. The interviews were conducted in a conversational manner and participants were free to speak about issues that they saw as most important. The study team guided the discussion and followed up with questions for the purpose of clarification.

Discussion Topics

Topics discussed during plant site visit meetings focused on the decisionmaking practices of these companies pertaining to their environmental, energy-efficiency, and productivity-improvement investments. Table A-3 lists the general discussion topics. The discussions were tailored to touch upon several general topics rather than to use specific questions. The topics served as a guide to move the discussion toward the information items sought. These topics and information items are presented below.

Business Goals/Nature of Business

Before ways in which environmental regulations put constraints on or provide opportunities for the companies were discussed, it was important to understand

Table A-3. Field Interview Discussion Topics

Business Goals/Nature of Business: This area of discussion focused on learning about their markets, technology, competitive pressures, and long-term business strategies.

Environmental Drivers/Goals: The specific environmental concerns and regulations most important to the companies were of interest, especially the problems and costs that these issues and regulations placed on the companies. Information regarding direct and indirect costs was sought.

Investment Practices and Factors That Influence Decisions: It was also important to identify the factors that influenced company decisions to invest in various technologies. The nature of the investment decisionmaking process and whether the process for environmental compliance technologies is the same as the one used for productivity-enhancing or energy-efficient technologies was discussed.

Conflict or Common Ground: Information on the costs that environmental compliance place on the companies and the ways in which these costs influence the capital available for other projects, particularly energy-efficiency projects was also of interest. Special emphasis was placed on learning about win-win situations, which are changes in technology and business practices that can result in multiple gains—in energy efficiency, productivity, and environmental performance.

Opportunities and Suggestions for Improvement: Finally, companies' views on what could be done to promote better integration of environment, energy and productivity improvement goals were obtained. Companies' thoughts on roles for DOE and other Federal agencies and areas where they saw opportunities for collaboration and cooperation between their industry and government were discussed.

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more about each company's business. This discussion focused on learning about their markets, technology, competitive pressures, and long-term business strategies.

- Current issues/events in industry
- Level of discretionary investments
- Characteristics of key markets
  - Major product areas
  - Size of market/potential growth/reduction of market
  - Degree of competitive pressure
  - Type of competition (domestic/international)
- Primary business goals
  - Market share
  - Cost reduction
  - New products
  - Product quality
- Fuel mix

Environmental Drivers/Goals

Information was gathered on the specific environmental concerns and regulations that were most important to the companies, especially the problems and costs that these issues and regulations place on the companies. Information regarding direct and indirect costs was sought.

- Major pollutants of concern
- Sources of pollutant emissions
- Major regulations of concern
- Primary compliance strategy
- Preferred compliance strategy
- Role of energy efficiency in compliance strategies
- Cost associated with environmental compliance

- Voluntary activities to improve environmental quality (that is, internal or external standards, programs, and so forth)
- Cost associated with voluntary activities
- Obstacles and incentives to implementing pollution prevention (internal and external)
- Degree to which energy efficiency and environment are viewed as separate issues

Investment Practices and Factors That Influence Decisions

It was also important to identify the factors that influenced company decisions to invest in various technologies. The nature of the investment decisionmaking process and whether the process for environmental compliance technologies is the same as the one used for productivity-enhancing technologies was discussed.

- Financial issues that shape investment
  - Distinction between mandatory investments (those made because of regulations) and discretionary investments (those made by choice)
  - Availability of capital (for example, external financing versus retained earnings, and so forth)
  - Criteria for investment (rate of return/other)
  - Capital versus operating expenditures
- Company practices/modes of operation
  - Level/location of decisionmaking authority
  - Dependence on size of project
  - Dependence on type of project
  - Differences in rate-of-return criteria for environmental projects and other investments
  - Location of charging for environmental costs—to environmental management division or production unit?
- Other Factors
  - Influence of long-term business goals and concerns of stockholders on decisions

- Effects of business cycle
- Capacity issues

Conflict or Common Ground

Information on the costs that environmental compliance place on the companies and the ways in which these costs influence the capital available for other projects, particularly energy-efficiency projects, was also of interest. Special emphasis was placed on learning about win-win situations, which are changes in technology and business practices that can result in multiple gains—in energy efficiency, productivity, and environmental performance.

- Examples of tensions and degree of prevalence
  - Environmental compliance projects that lower productivity or increase energy use
  - Environmental costs that decrease capital available for other projects
  - Projects that would be funded if environmental expenditures were not necessary
  - Other (negative/positive) impacts of regulations on ways of doing business
  - Accumulation of company funds in anticipation of new requirements
  - Projects that could meet environmental goals at lower cost than regulation-driven projects
  - Projects that could achieve lower overall emissions than required at similar cost to projects that meet just regulated pollutant levels
- Examples of common ground
  - Example of win-win investments that have been made at your company
  - Example of win-win investment not exploited because of some constraint
  - Whether your company's environmental compliance strategies provide opportunities for review/update/change in business practices
  - Regulatory incentives that encouraged long-term thinking

- Ways that technology affects the degree of conflict between environmental and productivity investments
  - Technologies currently used
  - Areas where improved technology is needed
  - Extent of use for end-of-pipe or process change technology to meet environmental goals
  - Examples where process changes could be made in lieu of end-of-pipe controls

Opportunities and Suggestions for Improvement

Finally, company views on what could be done to promote better integration of environment, energy, and productivity improvements were obtained. Company thoughts on the best role for the Department of Energy (DOE) and other Federal agencies and where it saw opportunities for collaboration and cooperation between its industry and government were obtained.

- Changes in the regulatory process that would improve the system
- Technical opportunities where energy use and emissions overlap
- Innovative technologies for environmental compliance
- Changes in decisionmaking practices that could improve investment
- Opportunities to more effectively integrate energy efficiency and environmental compliance investment decisionmaking
- The role of energy efficiency as an environmental compliance strategy
- Opportunities where environment/energy/productivity goals can be mutually achieved
- What can DOE or other Federal agencies do?
- What can industry do?

Limitations of the Research Approach

The research approach used in this study has several limitations that are worth noting.

Limitations of the Data Analysis

While one could argue that using actual data from plants, rather than a hypothetical plant from an engineering drawing board, is one of the strengths of the best-practice approach, one drawback is that the best practice of plants in a particular year is used to define what is feasible for all years. This ignores some important distinctions. While something may be technically feasible, in a static sense, it may not be economic in a dynamic sense.

Some equipment or process may be less productively efficient relative to the current best practice, but may still have a useful lifetime to the plant. As long as the plant or process covers something more than its cost of operation, it may be worth running, even if it is not best practice. This implies that some of the estimated production efficiency may be due to the sunk nature of the capital stock and would not change until the normal replacement of capital equipment or without some additional external force, such as energy price changes that raise the cost of production higher than the price of the product. Some authors have argued that environmental regulations may serve as such an external force (Myers and Nakamura, 1980). If regulations encourage capital turnover in productively less efficient industrial processes, then they can have an offsetting productivity benefit. Myers and Nakamura cite the improved energy efficiency of paper plants, after the imposition of waste water regulation, as one important example.

Also, the analysis assumes that products are relatively homogeneous, and that price differences adequately reflect any product differences.

Another potential problem with using observed best practice as the yardstick for measuring productivity is that it is backward-looking, rather than forward-looking. It cannot compare today's best-practice technology with a technology that is not yet in widespread commercial use. At best, one can only measure the magnitude and direction of the technical change that has occurred.

The data analysis performed for this study only generated results for a panel of plants that have been in the industry since the early 1970s and are still operating. This means that impacts that lead to plant closure or best practice represented by greenfield plants are not included. The former is of some concern, but would require analysis beyond the project scope. The issue of greenfield plants in the steel industry is not relevant because there are none. Very few greenfield integrated paper mills have been built. Capacity expansion at existing sites is the major source of paper industry growth.

The three analyses performed (productivity and energy-intensity trends analysis, analysis of win-win environmental/productivity opportunities, and analysis of pollution abatement constraint) are conceptually similar but not strictly comparable. One area of conceptual difference is that the set of plants used to compute the long-term productivity trends is not exactly the same set of plants used for pollution impacts and pollution abatement expenditure data because of constraints on data availability.

The second source of difference is conceptual. The estimates of production efficiency in the long-term trends do not account for pollution. In other words, differences in regulation and effectiveness in pollution control may contribute to the estimates of production (in)efficiency. The estimates of productivity loss due to pollution regulations are based on observed differences in emissions and emission rates. If some level of control is common to all plants, then the production loss estimates do not account for that common level of control, only the incremental differences in control. In other words, if all plants had identical controls (and no inefficiencies) then it would not be possible to estimate the productivity losses. In that sense, the estimate of productivity loss due to controls is a lower bound.

The third source of conceptual difference is between the abatement capital constraint analysis and the analysis of overall productivity loss due to pollution requirements. The abatement capital constraint analysis uses reported PACE data and does not use reported emissions data. This was done to increase the available sample size of the data. Too many observations would have been lost if a single sample that included complete data for pollution abatement expenditures and emission level were constructed. Because the productivity estimates from the abatement capital constraint only implicitly account for losses due to environmental regulations (both direct and indirect impacts), then the inferences about the pollution capital constraint (an indirect effect) are not strictly comparable. However, useful inferences can be made.

Finally, this approach to exploring the capital rationing constraint issue does not identify the specific indirect impact mechanism of capital rationing of abatement spending. To do so, one would have to compute the plant-level cost of capital from financial data. While this is technically feasible, it is very difficult. There is some evidence on how working capital affects investment based on financial data constructed from publicly traded manufacturing companies (Fazzari and Petersen, 1993). This type of data could be matched to the Census data in this study to support similar analysis. A simple alternative

would be to compute a measure of payments to capital, that is, value of shipments less variable costs and compare that to the book value of capital stock. A low value could suggest a more financially strapped plant. One would expect this to be correlated with capital rationing and large indirect abatement effects.

Limitations of Site Visits

The site interviews produce a mixture of both fact- and opinion-type information. The facts include a rich source of anecdotes and examples of company or plant-level technical problems and suggested solutions. The opinions include the perceptions of the company personnel regarding the relative magnitude and source of the tensions addressed in this study. These perceptions may be very accurate or they could be slightly exaggerated. Some attempt to weigh the validity of the claims of conflict must be made before policy is formed on their basis. However, good policy includes careful consideration of both "fact" and "opinion," since both are subject to interpretation.

APPENDIX B. DETAILED FINDINGS

FROM THE PLANT-LEVEL DATA ANALYSIS

This appendix presents the detailed results for the three types of analyses:

- Long-term trends (in productivity growth, technical change, production efficiency change, and electricity and fossil-fuel intensities)
- Estimates of environmental/productivity “win-win” opportunities (that is, the differences between an average plant and the best-practice plants that result in the opportunity to reduce pollution and increase productivity simultaneously)
- The loss of productive capital due to capital expenditures for pollution abatement

It should be noted that because of the small sample of integrated steel plants (and the subsequent requirements of confidentiality by the Census Bureau), the results for the steel industry are more limited than what is presented for the paper industry. The data only had usable observations for 17 fully integrated plants with coke oven batteries operating in the United States in 1992. This is in contrast to more than 100 fully integrated, chemical pulp paper plants. It was not feasible to produce as detailed statistics for subsets of these 17 integrated steel plants as is produced for the integrated paper industry analysis.

The long-term trends, environmental/productivity win-win opportunities, and the abatement capital expenditure analysis are presented for each of the case study sectors in turn.

Integrated Pulp and Paper Results

Long-Term Trends

During the period 1974–1991, industry average productivity grew about 2.2 percent per year, although this growth is somewhat volatile, as shown in Figure B–1. Technical change is the main component, with robust and steady growth of about 1.8 percent per year. There are no periods of boom or bust in the technical change component of industry’s productivity. Production efficiency shows slight improvement during the period—about 0.4 percent per year. This component is very volatile and follows closely the business cycles of the industry.

Figure B-1. Long-Term Productivity Trends for Integrated Paper Plants

Production efficiency and electricity intensity are quite sensitive to business cycles. From 1988 onward, declines and slowdowns in overall productivity are caused by declines in production efficiency, because technical change contributes to steady increases over the entire 1974–1991 period. There are additional productivity losses, ranging from 5 to 10 percent, due to declines in production efficiency during recession years. This is because rates of input usage are not proportional to the level of output. Inputs like labor, capital, and electricity may be idled while production levels fall. Electricity intensity is particularly sensitive to recession, presumably because machines keep running even when material throughput is lower, as shown in Figure B-2.

Fossil-fuel intensity declines at an average rate of 4 percent per year, but primarily during the 1974–1987 period. This rate of decline is nearly twice the rate of overall productivity growth. This is presumably because of industry's increased self-sufficiency, that is, the use of biomass byproducts as fuels, as well as improved end-use efficiency. Changes in fossil-fuel intensity are mirrored by changes in productivity growth. For example, fossil-fuel intensity declines stop in 1988, as do overall productivity improvements. However, there is no hint that the rate of technical change improvement was affected by the dramatic

Figure B-2. Long-Term Energy Intensity Trends for Integrated Paper Plants

decline in fossil-fuel intensity, so the cause and effect between fossil-fuel intensity and productivity is not clear. In 1979, best-practice plants (that is, those with the highest production efficiency) had 7 percent lower fossil-fuel intensity than plants that were not best practice. By 1992, fossil-fuel intensity for best-practice plants was 12 percent lower than for non-best-practice plants. Although by 1992 both best practice and non-best-practice plants had lowered fossil-fuel intensity by more than 50 percent, best-practice plants made somewhat more improvements, which widened the gap.

Purchased-electricity intensity is rising at about 1.2 percent per year, although this trend is highly volatile. Technical changes may be closely tied to electricity use, for example, process controls. Best-practice plants, have obtained a distinct production advantage in their conservation of electric power or their use of cogenerated power. In 1979, these plants used only 4 percent less purchased electricity than plants that were not best practice. By 1992, the best-practice plants used 80 percent less purchased electricity. These best-practice plants became more electricity-efficient (or self-sufficient), while the intensity of purchased electricity of other plants actually rose.

Environmental/Productivity Win-Win Opportunities

Most plants (58 percent) were considered to be efficient in their production and pollution abatement, because they could not further reduce at least one input or pollution output.¹ In other words, some plants are considered “efficient,” since they could not improve their performance in some single emission or energy category but could improve in the others. About one-third of the plants could reduce all of their emissions and increase productivity by 10 percent or less. Relative to the observed 58 percent efficient, best-practice plants, 42 percent of plants in the data sample had opportunities (that is, exhibited a “potential”) to reduce all inputs—energy, labor, materials, and capital—and all four criteria air and water pollutants—sulfur dioxide (SO₂), total suspended particulants (TSP), total suspended solids (TSS), and biochemical oxygen demand (BOD)—while simultaneously increasing production.²

Although win-win opportunities exist to improve all dimensions of performance (productivity, energy, and environmental), there appear to be further, targeted opportunities in the energy area. Figure B-3 presents the reductions in average industry energy and air and water pollution intensities,³ if all plants were operating at best practice. If all plants were operating at best practice, industry average energy intensities would decline by 7.3 and 8.1 percent, for fuels and electricity, respectively. Other inputs’ intensities decline as well. The decline by 7.7 percent in labor intensity (defined as production and nonproduction person hours per dollar value of shipments) is shown for reference purposes to illustrate that all inputs in production are included in these productivity changes. Declines in air and water pollution intensities are

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¹If opportunities are the result of technology in place, that is, sunk capital, then the potential improvements are viewed as modest, because it would require capital turnover to achieve the improvements. If, however, opportunities are the result of poor management or plant practices, then opportunities may be viewed as more substantial, because they might occur without substantial physical changes or investments.

²Recall that in the section beginning on page A-13, it is noted that this result is derived from a strict criterion for identifying win-win opportunities associated with production inefficiency. One should also note that the percentage of plants on the frontier is related to the ratio of the number of observations to the number of constraints in the LP used to calculate the results. The inclusion of a wide range of pollutants, as has been done here, increases the number of constraints.

³Air and water pollution intensities are defined as tons of pollutant per dollar value of shipments.

Figure B-3. Projected Change in Average Industry Input and Pollution Intensity if All Integrated Paper Plants Were Operating at Best Practice

somewhat less, ranging from 5.5 to 6.5 percent reductions. The air pollutants show somewhat larger potential reductions, perhaps because of the close link between air pollution and energy use.

Similar effects, although slightly higher, are found when toxic releases (sulfuric acid, chlorine, and methane) are analyzed.⁴ If all plants could operate at best practice, industry average intensities for energy and toxic release pollution would decline by 8.7 percent and 10.1 percent for fossil fuels and purchased electricity, respectively, and 6 to 9 percent for toxic releases (depending on the kind of toxic, 8.8 percent for chlorine releases, 6.7 percent for methane releases, and 8.4 percent for sulfuric acid releases).

The similarity in the results for toxic releases and for air or water pollution emissions suggest that production efficiencies that give rise to these win-win opportunities may not be tied to specific pollution activities, but are a general

⁴Only the top three most common toxic releases were included in the analysis. Many other toxic releases occur in paper mills.

issue of plant-level productivity, that is, production inefficiency adversely affects both business and environmental goals. Put differently, well managed plants tend to be better environmental performers as well.

From 1987 to 1991 there is a drop in production efficiency that was seen in the long-term trends. This decline in production efficiency appears to carry over to the pollution opportunities as well. Since many plants exhibit no win-win opportunities, this means that the estimated changes in overall industry average pollution and energy intensities come from a small number of plants that have much-larger-than-average reductions. For example, if half of the plants do not have win-win opportunities that also reduce electricity use, but the overall industry average reduction in electricity intensity reduction is 8.1 percent, then the remaining plants must have about twice the potential reductions. These plants with the larger-than-average reduction potential represent the "low hanging fruit."

If one compares best-practice plants, assuming that regulations limit the disposability of air and water emissions, with best practice without such restrictions, then the average productivity loss to best-practice paper mills due to the requirements to abate air and water pollutants is about 9.5 percent of total industry output. This estimate of loss includes both direct and indirect effects. Conceptually, this estimate is based on comparing best-practice plants to a hypothetical situation where those plants would be allowed to emit air and water pollutants at the highest rate observed in the plant-level data. For an average integrated paper mill, this loss is almost \$20 million in lost production.

Plants with large losses (more than 20 percent productivity loss) appear to be smaller, more energy-intensive, and considerably less pollution-intensive than other plants. Several hypotheses that are consistent with these observations can be suggested.

- Based on the observed lower rates of pollution (measured by pollution intensity, that is, tons per dollar value of shipments) these plants may simply produce a higher-value paper product. Since the productivity effect of an environmental requirement is measured in terms of lost output, then the impact is higher for plants with more highly valued products.
- Tighter regulations, due to the location of a plant in important watersheds or in nonattainment areas, would tend to create larger losses.

- The inability of small plants to utilize economies of scale in pollution abatement, which is a capital-intensive activity, may also account for why smaller plants exhibit greater output losses.
- Small plants may also be older vintage. Older vintage technology would tend to be more energy-intensive as well.

While we have no direct evidence to support these possible explanations, they are consistent with patterns in the paper industry.

Analysis of Abatement Expenditure Constraints

The loss of productive capital due to capital expenditures on pollution abatement (hereafter referred to as abatement capital constraint) is estimated at about 3 to 5 percent over the period 1979–1982 and 1989–1992 (periods in which data were available). That is, production efficiency could be increased by 3 to 5 percent if some share of new capital expenditures were not required to be spent on pollution abatement. This loss of productive capital to pollution abatement capital expenditures accounts for about one-fifth of the difference between production efficiency of an average plant and a best-practice plant. This means that the abatement capital constraint is only a relatively small source of overall production inefficiency. The analysis also found that the abatement capital constraint has a marginal effect on plant-level energy use, as measured by comparing the industry average energy bill of a plant with the abatement capital constraint with the energy bill on an average plant without the abatement capital constraint.

Figure B-4 shows that the loss due to the abatement capital constraint is stable over the two time periods 1979–1982 and 1989–1992, even though the level of production efficiency is higher and environmental expenditures are lower during the earlier (1979–1982) period. The requirement to spend capital on abatement therefore does not appear to have been important historically as a factor influencing overall productivity.

In 1990, the overall productivity loss due to general inefficiency was 17 percent, and the pollution abatement capital constraint lowered productivity by 3.3 percent. As discussed in the previous section, the productivity loss due to pollution requirements has been estimated to be approximately 9.5 percent. This suggests that the abatement capital constraint may be an important source (about one-third) of environmentally related productivity

Figure B-4. Productivity Loss Due to Abatement Constraint in the Paper Industry

losses. The overall productivity loss includes both direct and indirect effects. The abatement capital constraint is only one type of indirect effect.

While the approach used to estimate overall productivity loss and the approach for estimating productivity loss due to pollution abatement constraint are not strictly comparable, taken together they suggest that the indirect effect of capital spending on abatement is an important part of the productivity impact of environmental regulations. While the abatement capital constraint may play a small role in reducing overall production efficiency, its indirect effect on productivity may be viewed as a substantial component of environmentally related productivity losses. The implication is that if society is willing to accept the direct costs of attaining environmental goals and that policy concerns itself with minimizing the indirect effect, then the capital abatement constraint does appear to be an important category of indirect effect. If policy focuses more broadly on increasing production efficiency, then the capital constraint is less important.

Integrated Steel Results

Long-Term Trends

Over the period 1972–1991, industry average productivity grew about 2.5 percent per year, as shown in Figure B–5. However, this is largely weighted by the last 6 years of the data; productivity growth is only 1.7 percent per year during the 1973–1985 period.

Technical change is the main component, growing at about 3.0 percent per year. The rate is much lower, at 2.6 percent, for the period 1973–1985.

Technical change has not experienced robust and steady growth as with the paper industry. During 1981–1986 and right after the first oil price shock, technical change was stagnant. On the other hand, large increases in technical change occurred in the 1988–1991 time period. This increase is mirrored by dramatic decline in production efficiency yielding “no net increase” in total productivity.

Figure B–5. Long-Term Productivity Trends for Integrated Steel Plants

Like the integrated paper industry, production efficiency in the integrated steel industry follows closely the business cycles of the industry; but unlike the paper industry, average production efficiency in the steel industry shows a modest decline over the period: about 0.6 percent per year. The major declines occurred during the recessions in 1975, 1982, and 1988, and the rebound is slower when compared to the paper industry, with the notable exception in 1975. As was found in the paper sector analysis, there was a dramatic drop in production efficiency in 1988–1991, which is mirrored by a dramatic increase in technical change.

Purchased-electricity intensity is rising at about 4 percent per year, although the trend is highly volatile, as shown in Figure B-6. The high degree of variation in electricity intensity may reflect the practice of some plants adding electric arc furnaces and other electricity-intensive technology, while other plants do not.

Fossil-fuel intensity declines at a rate of 3 percent per year, with very little of this decline occurring in the 1970s. Changes in fossil-fuel intensity are mirrored by changes in productivity growth; fossil-fuel intensity drops when productivity rises; however, the cause and effect are not clear.

Figure B-6. Long-Term Energy Intensity Trends for Integrated Steel Plants

This is not the productivity of the entire industry from this period, but the productivity of the plants that are remaining in the industry. Many of the plants with very low productivity are likely to have been closed in the 1970s. The data used in this analysis are for the plants that remained in the industry and do not include those that were closed. This study does not examine their productivity prior to closure. This would provide an interesting avenue of future study. The trends for those plants may contrast with the trends for the aggregate industry, which had greatly lowered the fossil energy intensity over the same period. Presumably some of the improvement in the energy intensity of the overall industry was driven by plant closure and shift in the industry to minimills, not large changes in energy use at the remaining facilities.

Environmental/Productivity Win-Win Opportunities

If all plants could operate at best practice, potential win-win opportunities would result in a decline of roughly 5.7 percent in energy and air pollution intensities. This decline represents a composite reduction of the improved inputs and environmental “productivity” that the plants in our sample could achieve.⁵

By comparing the best-practice productivity of plants in the sample to the productivity that would result if disposability of emissions (that is, regulations) were relaxed, the estimated average productivity loss to steel mills due to air pollution regulation is valued at about 11.2 percent of total industry output. This is almost \$90 million in lost production for an average integrated steel plant.

Analysis of Abatement Expenditure Constraints

The productivity loss due to abatement capital expenditure ranges from 2 to 7 percent of industry output, as shown in Figure B-7. The 7-percent productivity loss occurs in an outlier year, coming at a low point in overall

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⁵The small number of facilities, 17, and an even smaller number of companies that own these plants prevented more detailed results from being presented. This is due to the aforementioned Census confidentiality rules. The composite index is based on the efficiency measure, which is an index of both the input and pollution reductions. The weights for the index are determined for each plant in the sample, based on the corresponding best-practice plants, and so it is not a fixed weight index.

Figure B-7. Productivity Loss Due to Abatement Constraint in the Steel Industry

industry productivity. More typical production efficiency loss due to the abatement capital constraint is 2 to 4 percent. Unlike for paper, the loss is not stable over time; it follows the overall trend in production efficiency.

The losses due to the abatement capital constraint reduce production efficiency by a modest amount, although the reduction is a somewhat higher fraction than was found for paper. For example, in 1990 the loss due to the abatement capital constraint is 4 percent, while overall production efficiency loss is 14 percent. This corresponds to more than one-quarter of the overall production efficiency loss and is more than one-third of the estimated loss due to air emissions regulation.⁶ This is very similar to the paper industry results, suggesting that the indirect effect of the abatement capital constraint may be an important source of environmentally related productivity losses.

⁶Water emission data were not complete enough for the steel data set to warrant its inclusion. Air pollution emissions are a much more common environmental issue in integrated steel plants. Also, the capital expenditures are not separated into the components of air, water, and so forth. Total capital expenditures on abatement are used.