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Colloquium Paper

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Industrial ecology: An emerging management science

(management sciences/environmental institutions/corporate change)

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ABSTRACT **Pollution is a complex equation, compounded by population, rate of consumption, and toxic emissions per unit of resource consumed. This article defines industrial ecology as a management science that focuses a corporation's expertise on the third variable. Thus, industrial ecology is involved with changing the efficiency of machines, not just changing the law or a firm's compliance strategy. This article also explores how this emphasis allows a profoundly different orientation than the end-of-the-pipe regulatory approach of the last 20 yr.**

What follows addresses each of the five stated purposes of this meeting, articulated so clearly by Lynn Jelinski in her invitation letter. To be brief, I comment directly on each of these purposes.

Purpose 1: To Define the Field of Industrial Ecology

Pollution is a complex equation: pollution = population × rate of consumption × toxic emissions per unit of resource used. For me, then, industrial ecology is the management science of focusing a corporation's expertise on this third variable—toxic emissions per unit of resource used. Thus, industrial ecology is involved with changing the efficiency of machines, not just changing the law or the firm's compliance strategy. This is a profoundly different orientation than the end-of-the-pipe regulatory compliance approach of the last 20 yr.

The new emphasis is on the efficiency of the manufacturing process, not just the marketability of the products. I'd like for you to think of it as a design triangle, whereby the desires to reduce waste, save materials, and conserve energy are linked in a shared dynamic. Two observations can be made about this triangle: (*i*) This design triangle meshes economic motives with environmental goals. It is a vital mix with the potential to break down long-standing logjams that exist between business, government, and citizens. It helps industrialized cultures move beyond blame. (*ii*) The triangle represents a systematic process orientation, instead of a production orientation.

Because I have filled my last two books (1, 2) with examples of these pursuits of industrial efficiency, let me offer here three brief examples of what I mean.

Hundreds of industrial firms in Europe have implemented this conceptual triangle to reduce waste and improve profits. One of the outstanding success stories from France is an innovative thermoreactor, a paint-drying technique developed by Sunkiss. This technique has been installed at metal-finishing operations for products ranging from small metal products to cars and locomotives. The use of this technique by France's Alstholm Atlantic on two of its metal-painting lines has yielded the following promising environmental and economic benefits: (*i*) a 99% reduction in emissions of evaporated solvents, which are destroyed in the thermoreactor's catalytic heating/drying process; (*ii*) the elimination of the explosion risks usually associated with drying operations because of solvent fumes; (*iii*) a 99% reduction in drying time, which increases production and expedites automation on the painting lines; and (*iv*) an 80% savings in the energy requirements for the drying operations, which yields annual savings of 1.1 million francs. The cost to Sunkiss for the purchase and installation of the thermoreactors was earned back in the form of savings in only 2 mo.

Industry–government alliances here in the United States have already yielded some impressive results with very little start-up capital. For instance, a partnership effort among the California Department of Health Services, entrepreneurs at Toxics Recovery Systems International, and the Anaheim-based AeroScientific Corporation, a manufacturer of printed-circuit boards, has resulted in an ingenious method for the treatment of heavy-metal waste. This method transforms formerly discarded wastes from the production of circuit boards into solid metallic sheets that can be sold as scrap. The system can save a firm upward of $100,000 in the costs of the Resource Conservation and Recovery Act (RCRA) permitting alone and can speed up business operations by eliminating the need for lengthy state or federal regulatory review. "The biggest advantage is that we'll be free from the enormous liability that companies face every time they ship something out of the plant for off-site disposal," comments Mark Kowalski, director of facilities at AeroScientific. The heavy-metal discharges from the old process were reduced to zero.

A 3M electronics plant in Columbia, Missouri, altered its cleaning of copper sheeting. The change also helped the company's bottom line. Rather than spraying the metal with ammonium persulfate, phosphoric acid, and sulfuric acid, the plant now scrubs the copper in a rotating brush pumice. The plant's generation of liquid hazardous wastes has been reduced by 40,000 pounds per year. In 1985, 3M saved $15,000 in raw materials, disposal, and labor costs. The $59,000 investment paid for itself in 3 yr.

The key to these successes is not just technology but *institutional innovations in management*. An organizational structure that clearly places these environmental initiatives into the corporate strategy group is needed in many firms today.

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Purpose 2: To Delineate Important Issues and Problems that Need to be Addressed

For me, then, industrial ecology is the strategic insistence of managers to resist three dominant industrial myths concerning the environment. These three popular fallacies distort and misinform many decision makers, especially technical-staff and science-based planners working within narrow regulatory directives.

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Abbreviations: PVUSA, photovoltaics for utility scale applications; RCRA, Resource Conservation and Recovery Act, the chief hazardous waste management law of the U.S. Congress.

I want to pause to address each of these myths because I feel that unless corporate scientists and managers become conversant on these issues, industrial ecology will remain an oxymoron for the public at large.

If recent research and development budgets are any indication, our budget chieftains ignore the necessities of industrial ecology. Although $6 trillion was afforded Star Wars as recently as 1989, only $500 million was earmarked for energy research and development. What's worse, >90% of these energy dollars was funneled into old options, financing massive clean-coal and enhanced oil-recovery efforts. Energy efficiency, the most utilitarian investment and the logical first step in any industrial revitalization, accounted for ≈5% of the total energy budget.

How long can we afford such disproportionate investments? If America is to move beyond environmental gridlock in the next decades, three dangerously entrenched fallacies must first be overcome. These are the following:

(*i*) Things do not change rapidly. This notion, more than any other attitude, has hindered the search for environmental excellence over the last 40 yr. Endless litigation over flawed regulations, which even when improved can still be circumvented, is clearly not the most practical way to pursue environmental excellence. Nations can speed up environmental progress tremendously by harnessing market forces and through the use of private capital.

(*ii*) Government and industry are natural enemies when it comes to the environment. This peculiar cultural quirk makes Americans spend a great deal of energy spinning their wheels. We have to stop pretending that the best deal in business is to scam government and vice versa. Instead we need to realize that industrial challenges often require joint ventures. Public–private partnerships in Japan and Europe offer useful examples, some worthy of adaptation. Recent agreements on ozone protection, involving U.S. leadership and U.S.-based industry, provide other examples.

(*iii*) The economy and the environment are in direct and vicious conflict. Impaired economic thinking has for too long short-changed the earth. To believe we can have a sound economy only by incurring severe environmental costs is unsophisticated, but this false dualism is deeply ingrained in American institutions. New challenges, however, such as the need to compete with more efficient foreign manufacturing capacity, demonstrate that the answers to economic and environmental problems are often the same.

Besides these conceptual issues, I believe the number 1 problem facing the field of industrial ecology in the 1990s will be securing safe, clean, abundant alternatives to fossil fuels.

Back in the early 1980s, the big issue was limiting industrial use of land disposal. After RCRA was amended in 1985, the question became not if but how: How can industrial America secure safe alternatives to pits, ponds, and industrial lagoons? I suspect that a similar shift will occur, in the middle of the 1990s, in the debates over global warming. The question will be how much and how frequently can we step off the petrochemical treadmill.

One early example lies on an abandoned industrial site on the outskirts of Davis, California, and is known in the energy trade as PVUSA. PVUSA, which stands for photovoltaics for utility scale applications, is a world-class "solar supermarket," where inventive arrays of solar cells are being tested to find out which approaches will be the most competitive in tomorrow's world market. Photovoltaics (PVs), as you know, is but one of the many new energy technologies that combine the world's new environmental standards with the practical needs of industry.

A few forward-looking U.S. utility executives, manufacturers, and government officials, however, understand America's need to coordinate its energy expertise more effectively to prepare for the future—hence, PVUSA. The research effort is a joint venture among the California Energy Commission, the federal Department of Energy, Pacific Gas and Electric (the largest investor-owned utility in the world), and other utilities from across the country. Eventually between 15 and 30 competing 20-kW arrays will be plugged into a computer analysis system that will provide the information base for America's mission to secure markets for tomorrow's clean-energy technologies. The project is slated to cost only $40 million, a tiny blip compared with the towering expenditures on fossil-fuel and nuclear research.

The work of PVUSA displays the value of American efforts to assemble world-class researchers for results outside of defense, medicine, or agriculture. It also represents an important counterpart to Japan's Rokko Island, a location where 100 different 2-kW solar systems, designed by approximately a half dozen Japanese manufacturers, are lined up side by side for vigorous head-to-head competition to determine which photovoltaic product Japan will use to try to dominate the world market. We may be witnessing a major energy revolution in the 1990s; if American manufacturers don't want to see the photovoltaic market go the route of cars, electronics, and other current imported technologies, then research and development efforts, such as PVUSA, need to be expanded to include the whole range of alternative energy paths. Industrial ecologists, working within the resourceful confines of their corporation, must be prepared to stress and to institutionalize these alternatives to fossil fuels wherever possible.

Purpose 3: To Identify Leaders and to Coalesce Thinking in the Field

This event is a reassuring first step, and because it is the most accomplished of our five purposes, I will say no more about it. The published proceedings go far in documenting the nature of this network.

Purpose 4: To Understand the Disciplines Encompassed by this Field

Here I will make an unpopular point. The key to most successes in waste reduction and energy conservation is not really breakthrough science or high technology, but institutional innovations in management. That's why I think of industrial ecology as a management science.

Today, what is most needed are corporate structures that elevate the role of environmental managers within the firm, individuals who are given the time and resources to coordinate technical, legal, and public relation needs. The chief executive officer can't do this.

Let's call this new professional an environmental manager. From my vantage point, these individuals need three primary skills besides the technical disciplines: (*i*) a sense of history—sensitive to the weight of past mistakes, (*ii*) analytical abilities—to sort out the present legal and technical predicaments, and (*iii*) the managerial tact to insist on a process orientation and the means to justify its successes, rather than the long-standing production orientation (3).

Purpose 5: To Determine What Further Action Is Warranted by Academia and Industry to Ensure that this Field Prospers

The top priority is to locate an institutional home in most corporations that allows the professional growth of industrial ecologists. We are now engaged in a survey of 300 firms itemizing changes in staff, title, and function regarding corporations. If you would like your firm to participate in this research effort, please call or write me directly at Rensse-

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laer's School of Management and ask for "The Corporate Change and the Environment" questionnaire.

A second function would be to fund the following kinds of research: (*i*) research focused on more efficient uses of fossil fuels, (*ii*) research on private energy efficiency in homes and appliances, (*iii*) research to strengthen motor vehicle fuel-efficiency standards, (*iv*) research to increase energy efficiency through comprehensive least-cost bidding at electric utilities, and (*v*) enhanced research on alternatives to fossil fuels.

The choices are clear. Industrial ecologists in the 1990s must mobilize affordable alternatives to fossil fuels. Just as nations shifted the burdens of waste management in the 1980s from pits, ponds, and industrial lagoons to on-site reduction, reuse, and treatment, this next decade will require the employment of tens of thousands of industrial ecologists who can help their firms shift to safer energy strategies. This is only one part of the mission of industrial ecology, but in my estimate it is a central part worthy of sustained emphasis.

1. Piasecki, B., ed. (1984) *Beyond Dumping: New Strategies to Arrest Toxic Contamination* (Greenwood, Westport, CT).
2. Piasecki, B. & Davis, G. (1988) *America's Future in Hazardous Waste Management: Lessons from Europe* (Greenwood, Westport, CT).
3. Piasecki, B. & Asmus, P. (1990) *In Search of Environmental Excellence: Moving Beyond Blame* (Simon and Schuster, New York).

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