Industrial Ecology: A Coming-of-Age Story

by Jesse H. Ausubel

The Greek *oikos*, for "house," fathered the sibling terms economics and ecology. Economics, literally, is the house rules. Ecology is the branch of biology dealing with the mutual relations between organisms and their environment; it implies the webs of natural forces and organisms, their competition and cooperation, and how they live off one another.

Industry, according to the Oxford English Dictionary, is "intelligent or clever working" as well as the particular branches of productive labor. Reflecting in the late 1980s on the first two hundred years of the industrial revolution, several of us began to wonder whether it might be time for a new fusion of the old siblings, economics and ecology. (See J. H. Ausubel and H. E. Sladovich [eds.], *Technology and Environment*, National Academy Press, 1989.)

Industry had essentially solved the quantitative problem of production. Factories could readily and cheaply make

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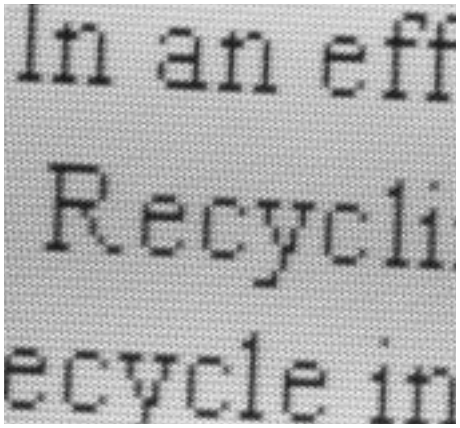

masses of shoes the world might want and stamp out masses of cars like tin ducks. But the massive production also generated massive byproduction. "Waste," a seemingly trivial offspring of early economies, now seemed prepared to impoverish or murder its parents.

Green nature appeared to have gone far in solving this problem. In nature, webs connect organisms living together and consuming each other and each other's waste. The webs have evolved so that communities of living organisms lose little or nothing that contains available energy or useful material. Industrial ecology asks whether nature can teach industry ways to go much further both in minimizing harmful waste and in maximizing the economical use of waste and also of products at the ends of their lives as inputs to other processes and industries.

A group of us, including Robert Frosch, Robert Ayres, and Braden Allenby, set off

Thinking about Environmental Federalism

by Wallace E. Oates

Environmental federalism is a complicated and contentious issue. And it is at the center of debates both in this country and in the European Union, where moves are afoot for the harmonization of environmental standards across the member nations. It is helpful in thinking about this issue to go back to some basic "principles." Doing so may not resolve the issue, but at least we can better understand the nature of the argument.

First, the issue is not a simple one of centralization versus decentralization of environmental management. Our governmental systems consist of several levels, and it is clear that there are important roles for nearly all levels of government in environmental protection. The issue is one of aligning specific responsibilities and regulatory instruments with the different levels of government so as best to achieve our environmental objectives.

Second, there exists a body of "principles" (or, perhaps better, "rough guidelines") for making this assignment. In brief (and with some simplification), the central idea emerging from the literature in public economics is that the responsibility for providing a particular public service should be assigned to the smallest jurisdiction whose geographical scope encompasses the relevant benefits and costs associated with the provision of the service.

The rationale for this principle is straightforward. Such decentralization of public decisionmaking allows outputs of public services to be tailored to the particular circumstances—the tastes of residents, the costs of production, and any other peculiar local features—of each jurisdiction. It is easy to show formally that such a decentralized outcome increases social well-being as compared with a centralized solution requiring more uniform levels of public services across all jurisdictions. In Europe, this is known as the "principle of subsidiarity," and it is enshrined in the Maastrict Treaty for the European Union. In the United States, we think of it more colloquially—as an aversion to the "one size fits all" approach.

Applying this general framework, we can envision a system of environmental management in which the central government sets standards and oversees measures for explicitly national pollution problems and intervenes where pollutants (like acid rain) flow across state and local boundaries; in addition, the central government would support research and the dissemination of knowledge on environmental issues, which benefit people everywhere. At the same time, the states and localities

under the banner of "industrial ecology" to explore whether we could massively reduce or do away with all waste. The banner captured attention in industry, government, and academia. The National Academy of Sciences and AT&T convened a colloquium on industrial ecology in 1991. Since then, workshops, many organized by the National Academy of Engineering, have addressed facets of industrial ecology, including its bearing in manufacturing and services industries, symbiotic co-location of industries, experiences in different nations, relationship to global environmental problems, and performance measures.

The welter of emerging ideas stimulated the Lawrence Livermore National Laboratory to invite the sorting out of directions for research. During 1995–97 a couple of dozen people participated in the process, which Iddo Wernick and I reported on. Our view is that the goal of industrial ecology is to lighten the environmental impact per person and per dollar of economic activity; the role of industrial ecology is to find leverage, the opportunities for considerable improvement from practical effort.

Industrial ecology searches for leverage wherever it may lie in the chain from extraction and primary production through "final" consumption, that is, "from cradle to rebirth." Mindful of the endless reincarnations of materials, the authors of the report refer to themselves as the "Vishnus," for the Hindu god known as the preserver.

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The report discusses several means for lessening impacts, including:

Zero emissions. Chances and ways to move from leaky to looped systems, and plausible scenarios for the transition from leaks to loops, especially for energy.

Materials substitution. Opportunities for changes in material properties to reduce environmental burdens and the time scales for improved or new materials to occupy markets.

Dematerialization. Trends in delivering equal or more services with less stuff.

Decarbonization. Evolution of the energy system for more service while burning less carbon, through more low-carbon fuel (natural gas) or no-carbon fuel (hydrogen) and through more efficient generation, distribution, and use.

Functionality economy. Reconception of industries as satisfying wants (such as floor coverings) rather than selling goods (carpets).

The report also explores methods for discovering and measuring progress, including:

Materials flow and balance analyses. Comprehensive accounting for industrial ecosystems at several levels (firm, sector, region) by elements (such as chlorine or cadmium) and by sectors (such as wood products or automobiles). This work was pioneered at

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would set their own standards and would manage environmental quality for matters that are contained within their own borders (such things, perhaps, as drinking water, refuse disposal, and air pollutants with solely local effects).

Is this, in fact, the way we do things? Not exactly (as they say in the Hertz ads). Under the Clean Air Act, for example, Congress has directed the Environmental Protection Agency to set uniform national standards for air quality—applicable to every point in the United States. Such standards apply irrespective of whether there is any transporting of pollution across jurisdictional lines. Curiously, under the Clean Water Act in contrast, Congress has given the states the responsibility (but subject to EPA approval) for setting their own standards for water quality. Environmental policy in the United States (and Europe as well) is characterized by a certain ambivalence on this matter.

What is the objection to decentralized environmental management? One objection (and this is where things get more

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complicated) is that state and local governments, in their eagerness to promote economic development through attracting new business investment and creating jobs, will set excessively lax environmental standards to keep down costs of pollution control. What results (so the argument goes) is a "race to the bottom" with states and localities competing with one another to reduce environmental standards. We thus need centralized standard setting and environmental management, as one author has put it, to "save the states from themselves."

But is this true? Note that this is really part of a more general and quite fundamental indictment of all state and local governance that says that economic com-

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RFF (see Allen Kneese's feature in this issue).

Life cycle analyses of products. Only a handful, such as Styrofoam cups and diapers, have been analyzed, and we need quick, reasonably accurate ways to sketch many products as well as skills to detail the most important or subtle.

Indicators. Intensity-of-use, waste-to-product ratios, and a suite of other metrics or compasses need to be developed and tested to guide the economy to get more out of material and leak less.

Finally, the report points to levers to achieve the goals of industrial ecology. Some levers relate to choosing materials, designing products, and recovering materials. Others relate to institutional barriers and incentives. For example, what are the prospects for waste markets and waste exchanges? Can accounting that better tracks materials improve both the environmental performance and profitability of firms? What leverage can be gained by changes in regulation of the recovery and transport of industrial wastes or by manufacturers taking back products?

The search for leverage is under way in the United States and around the world. The White House Council on Environmental Quality leads an industrial ecology interagency group soon to report on materials. The research scene is lively in Germany, the Netherlands, and a fast-growing list of other countries. The field now has a dedicated quarterly, *Journal of Industrial Ecology*. Lucent Technologies, AT&T, and the National Science Foundation award fellowships to industrial ecologists. The first Gordon Conference on industrial ecology will take place in June 1998. In this emerging field, the simple, powerful idea that society must balance its accounts of materials and energy, which RFF nurtured in the 1970s, is coming of age.

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The DOE report he coauthored with Iddo Wernick, "Industrial Ecology: Some Directions for Research," is available at *http://phe.rockefeller.edu/ie_agenda/*.

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petition will lead these governments to misbehave—to underprovide public services so as to keep taxes and expensive regulations at excessively low levels. This is curious in one respect. We generally applaud the work of competitive forces in the private sector, where Adam Smith's invisible hand guides self-interested decisions into socially beneficent outcomes. But here we are told that competition is socially harmful in the public sector.

The theory on this is not entirely clear. Certain economic models, for example, find that competition among governments (as in the private sector) encourages precisely the right kinds of decisions. There is no race to the bottom. Active competition for new economic activity in these models provides precisely the correct signals for decisions on public expenditures and taxation. At the same time, it is not difficult to introduce elements (and not unrealistic ones) into these models that generate distortions—in some instances in the form of excessively lax environmental standards. But the theory gives us no sense of the likely magnitude of the potential distortions. Unfortunately, at this juncture we cannot resolve this matter by an appeal to the evidence; existing studies of state and local competition, while of some interest, do not answer our question. At any rate, there exists little systematic evidence that supports the case for a race to the bottom.

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My own sense is that there remains a strong case for extensive decentralized environmental management encompassing the setting of standards as well as their enforcement. There has been an impressive growth in both the analytical and administrative capacities of state and local agencies. Moreover, it simply doesn't make economic sense to insist that all jurisdictions adopt the same set of centrally determined standards for environmental quality. Circumstances differ, and we should take advantage of the opportunities that this provides for a more flexible approach to environmental management. The problems of air and water quality management, for example, are very different between Southern California and Omaha (or Venice and Oslo, in the European setting) and these differences should manifest themselves in the stringency and the form of environmental regulations.

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