

## Books

*Green Chemistry: Theory and Practice*, by Paul T. Anastas and John C. Warner. Oxford, UK: Oxford University Press, 1998, 135+xi pages, ISBN 0-19-850234-6, \$75.00.

*Green Chemistry: Frontiers in Benign Chemical Synthesis and Processes*, ed. by Paul T. Anastas and Tracy C. Williamson. Oxford, UK: Oxford University Press, 1998, 364+xvii pages, ISBN 0-19-850170-6, \$120.00.

*Green Chemistry: Designing Chemistry for the Environment*, ed. by Paul T. Anastas and Tracy C. Williamson. Oxford, UK: Oxford University Press, 1996, 251+xii pages, ISBN 0-8412-3399-3, \$95.00.

In recent years, there has been an increasing level of concern about the effects of toxic chemicals in the environment. This concern began in the 1960's with the publication of Rachel Carson's *Silent Spring*, which drew the public's attention to the negative effects of the widely used pesticide DDT on bird populations. Since then, the effect of such chemicals on human health has become a controversial and contentious issue, as detailed in the popular courtroom drama *A Civil Action*, which describes the litigation surrounding the claims that chlorinated hydrocarbons and heavy metal residues released by industrial operations in the Woburn, Mass. area caused an "epidemic" of children's cancers in that community. Other scientists have claimed that a whole class of chemicals, known as "endocrine disruptors," when released into the environment can lead to deformed offspring and reproductive failure for generations to come.

In response to this public concern, regulatory pressure, and the increasing threat of litigation, there is a growing impetus to develop chemical manufacturing processes which "reduce or elimi-

nate the use or generation of hazardous substances in the design, manufacture, and application of chemical products." This statement is the definition of "green chemistry" which is quoted in the opening chapter of the Anastas and Warner text. Green chemistry is a pollution prevention approach which involves the reduction or elimination of hazardous substances as feedstocks, reagents, solvents, products, and by-products from chemical processes.<sup>1</sup> Specifically, green chemistry is the design of chemical products and processes that are environmentally benign relative to preexisting processes. By reducing or eliminating the use or generation of hazardous substances associated with chemical design, manufacture, and use, chemists can greatly reduce the risks to human health and the environment. This approach actually represents a major paradigm shift at the U.S. Environmental Protection Agency. It replaces the usual command-and-control approach to treatment and abatement of toxic waste (by federal or state regulation) with the first of the Twelve Principles of Green Chemistry (Anastas and Warner, p. 30), namely, "It is better to prevent waste than to treat or clean up waste after it is formed." Green chemistry strategies and technologies encompass the use of alternative, non-polluting synthetic pathways; the use of alternative reaction conditions; the design of chemicals that are less toxic than current alternatives or inherently safer with regard to potential accidents; increasing energy efficiency in chemical processing; substitution of depleting resources by renewable ones; and identifying functional substitutes for chemical products and processes which involve reuse or recycling rather than requiring disposal.

Green chemistry is based on concepts that are surely familiar to readers of this journal, such as life-cycle analysis, ecoefficiency, atom economy, and design for the environment. A number of illustrations of how these principles are applied in specific processes are included in

the books being reviewed. A few examples are given below.

Adipic acid [ $\text{HOOC}-(\text{CH}_2)_4-\text{COOH}$ ] is a key intermediate in the manufacture of nylon. The usual route to adipic acid starts with benzene, a carcinogenic molecule derived from fossil fuels, and involves several hydrogenation and oxidation steps over heavy-metal catalysts at elevated temperature and pressure. One of the unwanted byproducts is nitrous oxide, which may be released to the atmosphere as a greenhouse gas. A new process for adipic acid synthesis that eliminates all of the environmental problems associated with the current industrial process<sup>2</sup> involves a biosynthetic reaction starting with glucose (a renewable biomass product). The reaction takes place in water solution at room temperature, generates no nitrous oxide, and requires only a single hydrogenation step at moderate pressure.

Another example involves disodium iminodiacetate [ $\text{NaOOCCH}_2\text{NHCH}_2\text{COONa}$ ], used in the manufacture of Monsanto's Roundup<sup>®</sup> herbicide. The traditional Strecker process for manufacturing this substance uses four highly toxic chemicals—ammonia, formaldehyde, hydrogen cyanide, and hydrochloric acid—and generates 1 kg of waste for every 7 kg of product. An alternative process that relies on copper-catalyzed dehydrogenation of diethanolamine<sup>3</sup> is inherently safer, produces a higher overall yield, and eliminates the need for subsequent purification steps; and the  $\text{H}_2$  byproduct can be immediately utilized either for industrial hydrogenation processes or as a non-polluting fuel source. These two examples well illustrate one of the key features of green chemistry, namely, that seeking to eliminate pollution at the source can often lead to processes which are more efficient and eliminate the need for separation and purification steps, thereby providing a significant economic advantage.

One would expect green chemistry to have had a much wider impact in chemical research, technology, and curricula than has been the case so far. The chemistry community needs to be better educated about industrial ecology concepts, so that these ideas can be incorporated into educational programs and research strategies. The three books reviewed here, written or edited by some of the leading U.S. proponents of

green chemistry, will help both the chemistry and industrial-ecology communities gain familiarity with this field.

*Green Chemistry: Theory and Practice*, by Paul Anastas (Office of Pollution Prevention and Toxics, U.S. EPA) and John Warner (now on the faculty of the University of Massachusetts, Boston) provides an introduction to this field at a fairly general and qualitative level. It includes numerous examples, including those cited above, but no detailed analyses of specific cases. The authors have included four pages of short-answer questions, but do not provide substantive problem sets or exam questions. We have heard that Oxford University Press is planning to make this book available in a low-cost paperback edition; in this form, it would serve quite well as an introductory-level text for this topic.

*Green Chemistry: Designing Chemistry for the Environment* is an American Chemical Society Symposium Series volume developed from an ACS Division of Environmental Chemistry symposium held in August 1994. The 17 papers cover the now-standard areas of alternative feedstocks, reagents, and starting materials; alternative syntheses and reaction conditions; alternative solvents, including supercritical fluids; and biotechnology and bioprocessing. *Green Chemistry: Frontiers in Benign Chemical Synthesis and Processes* is an edited volume of 20 individually authored chapters, covering many of these same areas. The latter volume provides more up-to-date information and includes extensive references. Both of these collections have been co-edited by Dr. Anastas and Dr. Tracy Williamson, also at the U.S. EPA.

While these volumes make a valuable contribution to a better understanding of this approach to chemistry, there are still some unmet needs for books yet to be written, particularly for educational purposes. There is still no real textbook on green chemistry, as noted above. The *Theory and Practice* book is a useful introduction and does include a list of short-answer questions, but does not work through detailed case studies in which the linked issues of chemistry, regulatory compliance, scale-up, and economic considerations are analyzed in depth. The Symposium proceedings and edited-chapter volumes provide in-depth coverage of a number of specific topics, but are not suitable for use as a

textbook since they lack a uniform treatment or pedagogical focus. Fortunately, the American Chemical Society and the Green Chemistry Institute are actively engaged in developing educational and curriculum materials on this topic.

A recent review of these books in a major scientific periodical<sup>4</sup> began, "The 'green' vogue has hit chemistry!" Although this review is in fact quite positive, the introductory sentence does a disservice to green chemistry. There is already a significant level of activity in this field, as demonstrated by annual conferences on this topic in the U.S., China, and Europe; a related Gordon Research Conference on "Environmentally Benign Chemical Synthesis"; a "Green Chemistry Journal" published by the Royal Society of Chemistry; a series of Presidential Green Chemistry Challenge Awards presented at an annual ceremony in Washington; and an advocacy group, the Green Chemistry Institute, which was led by Dr. Joseph Breen before his untimely death in the summer of 1999. Green chemistry is not just a current fad or this year's "hot topic." Green chemistry is *the* chemistry of a sustainable future.

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## Notes

1. U.S. Environmental Protection Agency, *Green Chemistry Program Fact Sheet*, EPA 742-F-99-019 (April 1999).
2. *Green Chemistry: Frontiers in Benign Chemical Synthesis and Processes*, p. 158.
3. *Green Chemistry: Theory and Practice*, p. 99.
4. W. Leitner, *Science* 284, 1780 (11 June 1999).



*Eco-Efficiency—The Business Link to Sustainable Development*, by Livio D. DeSimone and Frank Popoff. Cambridge, MA: MIT Press, 1997, 292 pp. ISBN 0-262-04162-6, \$27.50.

Thoughtful, practical and upbeat, *Eco-Efficiency* offers a management philosophy that persuasively links environmental to economic

performance, and provides practical management tools for the implementation of this philosophy. The definition is as follows:

Eco-Efficiency is reached by the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing environmental impacts and resource intensity throughout the life cycle, to a level at least in line with the earth's estimated carrying capacity (World Business Council for Sustainable Development 1997).

*Eco-Efficiency* is an excellent reference for decision makers at all levels in business and, as a primer in environmental literacy, should be required reading for MBA students. A good overview and introduction to the major concepts and challenges of sustainable development, the book also offers concrete tools directly applicable to business. The issues covered are equally relevant for functional managers and executives. Coverage of many business initiatives, including the World Business Council for Sustainable Development (WBCSD) and its goals, put the book into the broader, and historical, context of current business efforts. Barriers to becoming eco-efficient are addressed squarely. Many examples of specific applications, illustrative success stories and company case studies from several continents suggest that eco-efficiency is attractive and feasible for business. They also inspire. Overall, the book is very applied, very useful, but sometimes tiring in its propensity for lists. It does make a handy and accessible reference book and is highly recommended reading.

The title, *Eco-Efficiency—The Business Link to Sustainable Development*, promises much. Logical persuasion, to be successful, must be close to familiar concepts and premises, and the book does deliver that close linking beautifully. The premises of the basic concepts constituting eco-efficiency, and the conceptual framework operationalizing those concepts, are firmly rooted in business logic, in opportunity and profit seeking, and in the pursuit of competitive advantage. This makes the concepts relevant and appealing to business. This effort is coming a long way in tackling sticky and challenging issues, and convincingly brushes aside falsely dichotomized issues of business and environment.

In the foreword, Maurice Strong, well-known business thinker on sustainability, suggests that eco-efficiency can help individuals, governments *and* business to achieve “responsible attitudes.” The book is written “by business for business,” or more specifically, by the heads of two multinational companies (DeSimone is Chair and CEO of 3M Company; Frank Popoff is Chairman of WBCSD. Such high-profile authorship is more than symbolic. It is an example of the business leadership called for, and indicates considerable public commitment to the principles advocated in the book. Perspectives and biases are stated carefully, such as the “belief” that more efficiency and productivity in the use of resources helps move toward sustainability. They become the premise for the book’s tenor: that no change can be achieved unless business is able to make a profit, finds win/win situations, and can be opportunity seeking.

What is not addressed is the question of whether squeezing more use out of resources and generating less waste in the process will be sufficient to attain sustainability. Eco-efficiency helps to reduce the negative impact of production on the environment; less negative impact per unit of production is the result and the stated goal is to get industrial production closer to the carrying capacity (“eco-capacity”) of the earth. Whether eco-efficiency, in the face of a rapidly growing population and increasing consumption per person, has the potential to bring production and consumption in line with eco-capacity, or whether it will only help to reduce the negative environmental impact to lower levels than today, is not discussed. Perhaps that is not the role of this book. Perhaps the focus needs to be on the opportunities opened up through widespread application of eco-efficiency: on their potential to assist in the transformation of the way of doing business and to initiate a new search for more fundamental solutions.

The seven guidelines of eco-efficiency, discussed and illustrated in the book, are worth repeating in full:

- reduce the material intensity of goods and services
- reduce the energy intensity of goods and services

- reduce toxic dispersion
- enhance material recyclability
- maximize sustainable use of renewable resources
- extend product durability
- increase the service intensity of products

The latter two seem innocuous enough, but carry in them an invitation to fundamentally re-evaluate what business has, or has not, traditionally viewed as its responsibility. Looking at product durability, a list of considerable barriers is outlined, from financial models in use to product design characteristics, from the customer’s image of “used” products to the need for effective networks of repair, maintenance and remanufacturing services. Perhaps the most promising suggestion, to increase “service intensity,” is also the least developed. Service intensity is defined as increasing value to the consumer while keeping environmental impact constant; examples are “shared use” (e.g., phone message services by phone companies which replace individual answering machines; public libraries), “multifunctionality” (e.g., reducing trips by utilizing every leg in transportation), and “upgrading” (e.g., using modular design to increase durability and broaden function). Redefining a business from selling products to leasing them, and thereby redefining ownership of products, can generate incentives to lengthen the useful life, and thus build more longevity into those products. In this example, the strategic focus shifts from the product and its production to the service the product provides.

The suggestions for increased durability and service intensity also hint at potentially fundamental changes in the way consumers use and value products, and the services and benefits they receive from them. If education about durability or usability over time, for example, becomes part of the role of business, then the quality of products might draw attention from the quantity to the quality of consumption. This is perhaps the area where the development of “patterns of sustainable production” interconnects most with “patterns of sustainable consumption.”

Which sector, business, government, individual consumer, or business consumer, will take on the responsibility to develop that difficult

link, is as yet undecided. Moreover, this discussion hints at a sensitive issue: does business cater to fundamental needs of consumers, or can it actually shape wants? The distinction is critical for the assignment of responsibilities. To date, these two have been treated as separate, and consumers are considered responsible for their wants, choices, and resulting collective consumption patterns. Eco-Efficiency suggests a more active role for business in educating (industrial or end-) users of its products on issues of durability or service intensity, in order to affect usage patterns such that environmental impact is reduced. To take this role, business will need to accept—publicly—its ability to shape and direct consumption. And consumers will need to accept responsibility for their choices. Education will be an essential component.

These considerations highlight just how closely production and consumption are interconnected; a greater appreciation of that relationship will be an important step toward generating new questions, and new solutions.

The core themes of the book serve as an excellent summary. They are: emphasis on service, focus on needs and quality of life, consideration of the full product life cycle, recognition of limits to eco-capacity, and a perspective recognizing the process of moving toward sustainability as much as the destination. Fully consistent with the last of these, *Eco-Efficiency—The Business Link to Sustainable Development* is offered as an encouraging invitation for business to act; as a response to the wake-up call from the Rio Earth Summit in 1992; and, in light of the work left to be done, “as a work in progress.”

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*In the Company of Partners: Business, Environmental Groups, and Sustainable Development post-Rio*, by David F. Murphy and Jem Bendell. Bristol: The Policy Press, 1997, 283 pp., ISBN 1-86134-017-6, £15.95, \$28.95 (paperback).

Partnerships between companies and environmental organizations represent a slippery slope for all involved. Companies risk opening their

doors to organizations that might otherwise be (and, in some cases, simultaneously are) organizing protests, lodging lawsuits, or lobbying for tougher regulations. Activist groups risk undermining their credibility and currency with members, funders, and the general public by garnering a reputation of being in bed with the enemy.

And yet there is much potential value for both companies and activists. Business-environmentalist partnerships can help polarized parties find middle ground on contentious issues; allow both parties to share expertise and insight that can supplement each other's sometimes narrow perspectives; and, somewhat more cynically, engender a kinder and gentler image of both organizations that might help them win the support of customers, members, and the general public.

*In the Company of Partners* attempts to map the art and social science of these partnerships, in this case producing a map that describes the lay of the land without necessarily giving directions on how to reach a destination called “partnership.” It is a utilitarian work, thorough and authoritative, if not a bit uninspiring.

The authors—Murphy, a research fellow with the New Academy of Business in London; and Bendell, a researcher, writer, and consultant on social and environmental responsibility to The Body Shop and other firms—begin their tour with the 1992 Earth Summit in Rio de Janeiro, although they give a nod to earlier efforts to merge business and activist interests. But it was the Earth Summit, they maintain, that “proved to be a watershed in business relations with nongovernmental organizations working on environment, development, and human rights issues.” That event provided the impetus for companies and environmentalists to think beyond such superficial alliances as corporate sponsorships and cause-related marketing to work together on “strategic and operational policy issues which have a direct impact upon core business practices.”

Murphy and Bendell define business-environmental group partnerships as “collaborations where environmental groups assist participating businesses primarily with internal operational issues.” This limited definition illuminates one of the book's principal shortcomings: While many of today's business-environmentalist part-

nerships focus on helping companies develop greener products, policies, and processes, some partnerships provide other forms of value. For example, while environmental groups are willing to provide research or consulting services to companies, they also may facilitate dialogues between companies and communities or other stakeholders, or participate in joint education or lobbying campaigns.

In other partnerships, companies lend expertise to environmentalists, helping them develop or enhance capabilities, or provide market research, communications strategies, materials distribution, or other vital services. And, of course, there are marketing partnerships—perhaps the most controversial and risky of all—in which companies and activists jointly promote products, services, or causes in a way that attempts to provide credibility, exposure, or increased revenue to either or both parties.

Murphy and Bendell give short shrift to many of these opportunities, despite the demonstrated value they often have in helping companies or nonprofits further their respective missions, visions, and goals, not to mention their ability to foster dialogue and reduce friction simply by having the two groups working cooperatively.

Where the book does illuminate is in telling stories, though they remain relatively few and far between. Perhaps most enlightening is the tale of McDonald's, which has boldly gone where few companies have gone, partnership-wise, while simultaneously bearing the brunt of environmental activists' most vigorous efforts to villainize the fast-food giant.

McDonald's helped engineer the era of business-environmentalist partnerships in 1990, when it joined forces with the Environmental Defense Fund (EDF)—an activist group founded in 1967 with the motto "Sue the bastards"—to seek ways McDonald's could dramatically reduce its operations' solid waste. That partnership is credited with making McDonald's an environmental leader in its industry. Inspired by the tangible results it derived, the company subsequently launched additional partnerships with EDF and other nonprofits. Meanwhile, the McDonald's-EDF alliance became a model of how companies and nonprofits could partner effectively.

At the same time the EDF-McDonald's part-

nership was launched, McDonald's filed a libel suit against five Greenpeace activists in response to a leaflet they had distributed about the company. Three of the activists apologized and agreed not to repeat the alleged actions. But two decided to fight the case in what came to be known as the McLibel lawsuit. In addition to being one of the planet's longest-running libel suits, McLibel also became a catalyst for international protests using the World Wide Web and other technologies.

Murphy and Bendell don't proffer any lessons to be learned from McDonald's trials and tribulations with environmental partnerships. Does the company's experience prove that such partnerships don't really provide the reputational benefits that might have been envisioned? Would its P.R. battles have been worse had the company not previously engaged environmentalists? Should the company have done things differently, or did it do the best it could under the circumstances? The authors never say.

The book concludes with a checklist "for successful management of partnerships"—a series of bulleted tips for both companies and activists detailing a partnership's initiation, implementation, and evolution. Its wisdom is sound, the tips comprehensive, the advice solid. But the five-page appendix is not enough to redeem the 270-odd other pages of this book.

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*Technology and Global Change*, by Arnulf Grübler. Cambridge, England: Cambridge University Press, 1998, 452 pp., ISBN 0 521 59109 0, \$49.95 hardcover.

*Technological Trajectories and the Human Environment*, ed. by Jesse Ausubel and H. Dale Langford, National Academy of Engineering. Washington, D.C.: National Academy Press, 1997, 224 pp., ISBN 0 309 05133 9, \$44.95 hardcover.

It was not uncommon for early environmental partisans, some thirty years ago, to cast technol-

ogy as the root cause of environmental degradation. A critique thus arose—with nuclear power, chemical pesticides, and automobiles offering good targets—that pitted a perceived independent technological momentum against the larger interests of “society.” By the mid-1980s, this society-technology “debate” had come to be viewed as naive and obsolete, and it gave way to focus on a “paradox”: that technology was both a source of and a solution to environmental problems. The two books reviewed here, both of which draw deeply on the ideas and individuals dominant in the discussion of technology and the environment over this period, take us to the next stage. At bottom, they are extremely optimistic, envisioning a steady path of progress in which technology can ultimately “liberate” the environment.

Beneath a wealth of highly specific sectoral analyses, the books address recurring, fundamental questions: what is technology, and whence is its direction set? Grübler answers directly: “all technological change is induced; [it] is not exogenous to the economy or society at large.” This position—surely correct—sets the stage for environmentally optimistic technological outcomes, so long as the proper societal “inducement mechanisms” are put in place. The NAE volume is somewhat more ambivalent. Its central organizing concept, technological trajectories, underscores the force that established pathways of technological change possess, as well as the extreme difficulty of rerouting them in the short run. This realistic position—also surely correct—still gives way to optimism in most of the component essays, which tend to see the likely technological trajectories as departing from the high rates of population growth, unsustainable agriculture, and excessive carbon and materials dependency that have characterized the twentieth century.

The two books make an excellently complementary pair. Grübler’s provides a much closer, deeper look at the phenomenon of technological change, and offers a more coherent whole—the virtues of single authorship. The NAE collection of essays by different authors—all well-recognized authorities, Grübler among them—offers by far a wider range of views as well as a more pointed discussion of sector-specific trends. Neither book is by any means an “easy read.” On the

contrary, both are obviously the product of the scholar-technologist mentality, which focuses on concepts, long-term trends, and the “big picture,” rather than on immediate problems, management solutions, or policy prescriptions.

Grübler’s book spends over a hundred pages in Part I considering “What is Technology?” Well-spent, these pages deal in detail with concepts and theoretical models of technological change, as well as a summary history of transformative technologies over the last hundred years. A criticism that should be made of this analysis, however, is its excessive rooting in models from economics and science that now lag management and systems scholarship. Today, the most compelling work puts forward the concept of an “innovation system” and focuses on how its components interrelate. Only touching on this vein, Grübler’s review seems slightly obsolete. Part II attacks the details of the relationship between agriculture, industry, and services, on the one hand, and the natural and human environment, on the other. More than 200 pages, this review could well serve as a text on the subject. Perhaps the most interesting part of the book is its conclusion, in which the author waxes expansive and reflective, even endorsing the broad “manifesto” to “liberate” the environment offered by Jesse Ausubel in the NAE volume. After this, a postscript and appendix add discussion of data and models that could easily have been left out.

The NAE book is a well-chosen set of essays that explore long-term trends (“trajectories”) in population dynamics, agriculture, energy, electricity, materials usage, industrial waste, and consumer life styles. Given the breadth and diversity of these topics, the editors have wisely chosen not to offer the typically superficial “overview” or “synthesis” chapters that often mar such volumes. Instead, Ausubel’s introductory essay on the “liberation” of the environment from human degradation, and Klaus Michael Meyer-Abich and Chauncey Starr’s two conclusory pieces on the history and future of humans and their environment offer provocative contrasts to the data-intensity that characterizes the other essays. Starr’s bottom-line conclusion is particularly worth noting: getting rich is the ultimate answer. By this, he means that higher levels of societal wealth provide the

means to preserve the environment, while at the same time revealing to people the importance of doing so. This, it should be noted—though the volume never does—is precisely the position motivating the most progressive environmental and economic policies in the developing world today: that societal, economic, and environmental well-being go hand-in-hand. The tone of the essays and choice of authors do give the volume the feeling of the work of a “club” product—which it is, in the sense of being a part of an ongoing NAE project and a community that is devoted to a particular approach to environmental and science and technology policy issues.

Valuable as they are, these two volumes by no means present the whole story on the connection between technology and the environment. In the technical realm, the most stunning omission is any discussion of the ongoing revolution of biotechnology, which will certainly transform industry, agriculture, and human health. The trajectory of biotechnology also holds the potential for major environmental benefit, although its realization is far from secure, and there are many down-side worries.

Since private firms are overwhelmingly the generators of new technology, the volumes' failure to consider their role in detail can easily leave a false impression. From thirty years' exposure to environmentalism, the values and management practices of corporations worldwide have been sweepingly revamped. Their best managers and engineers see environmental goals as a valid, routine aspect of business. Even the creation of environmental technology is an established business—absorbing hundreds of billions of dollars yearly—with a thriving component of innovators and entrepreneurs. Without an appreciation of this milieu, one's understanding of the sources of change is incomplete.

Lastly, there is the world of public policy. Although neither of the volumes seems to have been intended to engage this context (most of the “policy” paragraphs are thin indeed), they—or better still, another volume—could well have. It is worth remembering that it has been public policy—not technology scholarship—that has transformed the environmental consequences of the technologies in current use. And it is worth recognizing that public policy today is struggling

to move its relationship to technology beyond the early legal mandates that were intended to “control” technology (many of which are dysfunctional today) to a posture of stimulating beneficial technological change. The wisdom contained in these two volumes—refocused and extended—could offer much to the public policy debate. Such a connection has yet to be made.

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### Relationships Are Important

*Accounting for Resources, 1: Economy-Wide Applications of Mass Balance Principles to Materials and Waste*, by Robert U. Ayres and Leslie W. Ayres. Cheltenham, UK: Edward Elgar Publishing, 1998, 264 pp., ISBN 1858986400, \$90.

*Accounting for Resources, 2: The Life Cycles of Materials*, by Robert U. Ayres and Leslie W. Ayres. Cheltenham, UK: Edward Elgar Publishing, 1999, 400 pp., ISBN 185898923X, \$120.

We shudder and think there can be no more important task for contemporary science than to better understand the natural environment and man's relation to it. (Kneese et al. 1970)

The two-volume set, *Accounting for Resources, 1 and 2*, is the latest work by two people who have spent almost three decades pursuing a better understanding of the relationship between human industrial society and the environment. This detailed and comprehensive presentation of years of research and thought by the authors demonstrates that they have made substantial progress towards their goal. This is an important and impressive publication. Important, because it provides the most comprehensive examination of the physical workings of the industrial economy of the United States known to exist. Impressive, because it represents the efforts of only two individuals whose span of technical competence makes them truly unique. The book, which contains both general overview and detailed techni-

cal chapters, has something for everyone with an interest in this subject.

The more general chapters offer the reader insights into a lifetime of thinking about the relationship of humans to their environment. Chapter 1 provides an introduction to the concept of industrial metabolism and materials flow analysis. The term industrial metabolism is used by the authors to describe the material stocks and flows and the physical and biological relationships that must be added to economic models in order to understand man-nature interactions. Approaching the physical world in this manner leads to the basic view that each industrial sector is a transformation process where raw materials and free goods from the environment are converted into products and wastes. Although the authors prefer the term industrial metabolism to encompass this new body of theory, the chapter is as good a statement of the principles of industrial ecology (IE) as can be found in the literature.

Eleven technical chapters are devoted to analyzing the material flows associated with major industrial sectors, and specific problem materials. These chapters explain, in physical terms, how these important components of an industrial society function. An amazing, sometimes overwhelming, amount of detailed information on production and use, production processes, and waste flows is provided to explain in detail how things work. The mass-flow diagrams presented for each of the industrial sectors provide clear, and extremely useful, IE overviews of these activities. I have found these, and previous presentations, useful on a number of occasions as an aid in defining system boundaries, and as a check for independently derived data. In all the cases where I had an opportunity to compare data, the publication was found to be reliable.

The text which accompanies the flow diagrams contains an incredible wealth of detail which will be of interest to workers in these specific areas. Unfortunately, the reader's task is not an easy one owing to insufficient organization of detailed information. In many places specific data on materials, formulas, and measures are enclosed in long sentences making the extraction of useful information arduous. This difficulty is offset to a degree by the material flow diagrams that serve as road maps for the detailed data.

Although not particularly user-friendly, these chapters will be read and reread for many years, and will provide guideposts for future researchers working in these areas. Depending on the readers' interest, the following chapters will be read selectively:

#### **Industrial sectors**

- Agricultural industries
- Forest industries
- Extractive industries: Fuels
- Extractive industries: minerals and metals
- Inorganic chemical industry
- Organic chemical industry

#### **Specific material flows**

- Chlorine life cycle, 2 chapters
- Mercury
- Arsenic, and cadmium
- Copper, lead, and zinc

The chapter entitled "The Problem of Measurement" addresses one of the vexing problems of IE. How do we deal with material flows and outputs, which vary significantly in quality? All material flows alter the environment in some fashion, but the unit impacts are drastically different. A pound of arsenic is different from a pound of lead. We in the IE community, however, do not have a convenient measure for quantitatively expressing these differences. In the context of life-cycle assessment, the authors introduce the concept of "exergy" as an objectively measurable unit which can be plausibly related to environmental damage. Exergy, defined as "a measure of the distance from ultimate thermodynamic equilibrium with the environment," is intended for use in life-cycle assessment (LCA) studies. To this end, several detailed examples of how the concept may be applied are included. Exergy values for a considerable number of selected chemical compounds, exemplary materials, and exemplary metal production processes are given in Appendices B, C, and D.

Exergy is not an easy notion to understand. This is not helped by the authors, who in the process of introducing this novel concept, create some confusion about its overall utility. In Chapter 1 they state that "... while exergy is not

necessarily a good measure of environmental harm in any specific case, it is a very good basis for comparing inputs and outputs." In a later chapter, they state that "... the exergy content of a waste stream can equally well be interpreted as a general measure of its potential harmfulness..." and "... we seek a standard unit of account for measuring environmental impacts of economic activities." While I don't know if this concept is being studied by others, a consistent, reproducible method of evaluating output flows in an LCA would be an important contribution to industrial ecology.

I liked the unusual chapter that is devoted to the historical reconstruction of pollutant emissions in the Hudson-Raritan Basin. While it is one of the shorter chapters in the book, the authors felt it was important because it demonstrates that "... even in the absence of direct measurements, quite a lot can be inferred indirectly by making imaginative use of the economic data, process data, and the mass-balance principle." In this chapter, the authors are detectives, seeking out bits and pieces of information from diverse sources to recreate a picture of what historically took place. This chapter may serve as a wake-up call for some researchers who are waiting for detailed data before tackling important issues. In many cases a good answer is good enough; we don't need the precise one. This chapter will be of interest, and useful to those engaged in regional IE studies, either current or historical.

In a more general vein, the authors devote a chapter to "Environmental Issues and Measures of Sustainability." This chapter deserves to be read because the overview pronouncements are the result of years of technical study and effort. The authors present the argument that man-made capital and natural capital, which are substitutes for each other in some cases, can only be complements in others. The underlying reason is that there are several specific physical criteria which must be satisfied for sustainability. In addition to the obvious need to stabilize populations, the authors list a half-dozen conditions that essentially define the "strong sustainability" position. This chapter provides general, clearly stated principles of use to the nontechnical reader, but frustratingly evolves into detailed

data and equations that dilute the strength of the compelling arguments. Although the general evolves from the detailed, the trip from the general to the detailed and back is one that most of us cannot make as easily as the authors can.

Also included as an Appendix is a computer-assisted simulation for balancing LCA's. The authors point out that published data on unit processes are often unbalanced and outline a procedure for using off-the-shelf computer models to create a database of standard industrial processes that are balanced in terms of individual chemical components.

The scholarship, originality, thought, extensive notes and references, and sheer hard work that has gone into this book far outweigh any defects in organization and presentation. This work represents a large step on the road to knowledge. By breaking down the problem into manageable pieces and analyzing these in detail, the authors have created a body of work that will come to be seen as seminal for the field of industrial ecology. Anyone working in the field of industrial ecology should have a copy. General audiences, concerned with macro-environmental issues, will benefit from having this book in their library as a valuable reference, and IE researchers will value the work for the conceptual data-rich models which suggest, and provide a context for, many areas of future work. How beneficial it would be if the concepts and analyses embodied in this technical publication could also be condensed and interpreted for a broader policy audience.

This book is a major contribution towards understanding what is required to bring our industrial economy into harmony with our environment. To accomplish this, the authors, by their own admission, were required to do considerable detective work. In doing this hard work, they have made the task of those who follow considerably easier.

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## Greening the University

*Ecodemia: Campus Environmental Stewardship at the Turn of the 21<sup>st</sup> Century: Lessons in Smart Management from Administrators, Staff, and Students*, by Julian Keniry. Washington, DC: National Wildlife Federation, 1995, 222 pp., ISBN 0945051573, \$14.95.

*Green Investment, Green Return: How Practical Conservation Projects Save Millions on America's Campuses* by David J. Eagan and Julian Keniry. Washington, DC: National Wildlife Federation, 1998, 77 pp., ISBN 0945051654, \$14.95.

*Greening of the Ivory Tower* by Sarah Hammond Creighton. Cambridge, MA: MIT Press, 1998, 372 pp., ISBN 0-262-53151-8, \$27.50 (paper).

*Implementing Sustainable Development at University Level: A Manual of Good Practice* edited by Walter Leal Filho, Frances MacDermott, and Jenny Padgham. Bradford, UK: Centre on Environmental Education, 1996, 200 pp., ISBN 1 85143 149 7, \$16.00.

Progressive and well-managed institutions of higher education, like progressive and profitable industries, are beginning to rethink materials flows, prevent pollution, and conserve energy. The dominant rationale for doing so is much the same as that for industry, which is to say that resource conservation generally pays. Moreover, such measures coincide with public expectations regarding the environment and can be regarded as a kind of damage control. This is, for the most part, good news. But closer examination reveals that the efforts to date, more often than not, have been driven by outsiders who challenged institutional operations. Their motivations generally have had less to do with the potential to save money than with the embarrassing discrep-

ancy evident in institutions purporting to induct the young into responsible adulthood themselves acting irresponsibly—a gap often noted by alert students. The movement toward green campuses throughout the U.S., nonetheless, has now acquired a fair momentum.

In 1988, ten graduate students at UCLA, led by April Smith, published a report (“In Our Backyard”) on the environmental impacts of UCLA in the Los Angeles area. It was not a pretty picture and the university, unsurprisingly, initially denied or excused most of the findings. At the same time, others were beginning to examine alternative means to provision campuses beginning with locally grown food. Throughout the late 1980s and early 1990s a number of “campus ecology” reports on food, energy, materials, and waste were generated by campus activists. Perhaps the most notable efforts were those by a former philosophy student, Walter Simpson, at the State University of New York-Buffalo. Simpson’s work has resulted in substantial energy savings to the university amounting now to ~\$9million/year over what otherwise would have been spent. At Tufts University, Tony Cortese helped to galvanize efforts to implement both better environmental practices and ecological literacy through annual faculty seminars. At Rutgers University, Kevin Lyons has substantially changed the rules for institutional purchasing.

In the 1990s these initial efforts grew into a larger and more sophisticated movement. Notable in this process was the leadership of Ms. Julian Keniry at the National Wildlife Federation. Ms. Keniry helped to originate the program at NWF and to organize efforts on campuses throughout the country. *Ecodemia: Campus Environmental Stewardship at the Turn of the 21<sup>st</sup> Century : Lessons in Smart Management from Administrators, Staff, and Students* (1995) is a description of the first phase of that work. It is generally upbeat, focused on success stories and opportunities to reduce environmental impacts through improvements in landscaping, transportation, energy, dining services, hazardous waste minimization, and waste management. She reports on a wide range of activities, indeed success stories, at dozens of institutions. More importantly, *Ecodemia* is a kind of “how-to” manual

based on the experiences of practitioners from large and small institutions alike. This is the best overview of greening efforts on U.S. campuses now available. A later, and shorter, publication *Green Investment, Green Return: How Practical Conservation Projects Save Millions on America's Campuses* documents financial savings from initiatives ranging from efforts to reduce the use of automobiles at Cornell University to a composting program at Dartmouth. The single feature that ties these initiatives together is the fact that they saved money. Of course, they did a great deal more. Success stories also instruct by example and they stretch students' sense of what it is possible to do with imagination, careful analysis, and determination. Taken together, these two publications by the National Wildlife Federation provide a useful overview of efforts by U.S. colleges and universities to promote efficiency, reduce waste, and use their buying power to support the emergence of better and more sustainable communities.

Sarah Creighton's *Greening the Ivory Tower* (1998) is a more detailed and systematic analysis of how to green campus operations. The great virtue of her work lies in the dispassionate level of common sense based to a large degree on efforts to green Tufts University. The book should become a standard reference for efforts to reduce campus resource flows and integrate these with larger management issues. It is aimed, not so much at activists, as at administrators and facilities managers who need practical advice and reassurance that these things make sense. Both Creighton and Keniry stress the importance of cooperative strategies that engage students with administrators and campus managers. Equally important, both emphasize the importance of seeing institutions linked by thousands of small decisions to natural systems. Analysis of those seemingly small actions requires a high level of competence and institutional commitment. The goal, as Creighton argues, is a university that "uses resources with care, considers the environmental impact of all its decisions, and makes these decisions with an eye toward waste reduction, energy efficiency, and reducing life-cycle impacts . . . to guide teaching, research, and operations." [286]

Walter Leal Filho and colleagues in *Implementing Sustainable Development at University Level: A*

*Manual of Good Practice* (1996), describe efforts underway to green European universities. Until recently, there has been relatively little cross-fertilization between U.S. and European campus environmental efforts. As a result, the activities described in *Implementing* have to do, mostly, with curriculum matters, not those of resource flows. Perhaps this is a predictable difference between Europeans and Americans. If so, each could learn something from the other. For most U.S. colleges and universities, the effort to "green" the curriculum lags behind efforts to promote energy efficiency and recycle waste. For Europeans, the reverse is apparently true. In any case, it is essential that both occur in tandem in the clear recognition that greening operations are a means to the larger end of improving how we think. Readers of this journal should regard efforts to eliminate waste, improve energy efficiency, reduce or eliminate the use of toxic and hazardous materials, reduce materials flows, use renewable energy, and reform the curriculum with great sympathy and interest. These are parts of a common movement to reduce environmental impacts and establish the foundation for a more sustainable culture. Both stem from the drive to calibrate the behavior of organizations and institutions with ecological realities for reasons that are both morally right and economically smart. Both will require a dramatic change in perception of how the world is stitched together. The best way to initiate the changes in both perception and practice is to create examples that mimic the way natural systems work and that can be seen, studied, and improved upon. And both face a common challenge inherent in the glacial pace of change due to administrative lethargy, institutional barriers, and old habits which die hard.

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*Business Management and the Natural Environment: Cases and Text* by Forest Reinhardt and Richard Vietor. Cincinnati, OH: South-Western College Publishing, 1996, 700 pp., ISBN 0-538-84328-4, \$93.95.

*Environmental Management: Readings and Cases* by Michael Russo. Boston, MA: Houghton Mifflin Company, 1999, 431 pp., ISBN 0-395-87817-9, \$43.75.

For those in search of a text to use in teaching courses on business, environment, and sustainable development, there are two relatively new books that should help fill the void. Reinhardt and Vietor's *Business and the Natural Environment*, and Russo's *Environmental Management* might appear, on the surface, to be competitors. In point of fact, however, these two collections of readings and cases are largely complementary. Although both books feature an excerpt from Aldo Leopold's *Sand County Almanac* and share the case "Acid Rain: Southern Company" in common, the overlap ends there.

*Business and the Natural Environment* represents the "Harvard" perspective on business and the environment. Because Reinhardt and Vietor wrote the lion's share of the teaching cases on this topic through the early to mid-1990s, this book provides an excellent collection of all their classics, including favorites such as Laidlaw Environmental Services, Starkist, Xerox: Design for Environment, Aracruz Cellulose, and Global Climate Change. These cases, and others, have been staples for those of us who have been teaching in this area for the past several years. In all, the book includes 26 cases and notes, divided into five sections: Introduction, Market failures and regulatory pressures, Market opportunities and competitive pressures, International institutions, and Environmental values. The organization of the book reflects, at least in part, the organization of Reinhardt's class on this subject at Harvard. Excellent teaching notes are also available for most, if not all of these cases.

The book does, however, suffer from some shortcomings. First, because it was published in 1996, most of the material in the book dates back to 1995 or before. Given the pace at which these issues are developing in corporations, the mate-

rial is, unavoidably, now somewhat dated. There is little treatment, for example, of emerging issues or opportunities for corporate sustainability, fundamental innovation, or market reinvention. Most of the firm-level content relates to response to regulation, pollution prevention, or design for environment. To their credit, however, Reinhardt and Vietor have developed a number of cases at the national or global level dealing with different aspects of sustainable development. These include Renewable Energy in the U.S., Forest Policy in Malaysia, Environment and International Trade, Global Climate Change, and China (C): Energy and the Environment.

A second shortcoming relates to the readings included in the book. While the subtitle is "Cases and Text," the book is, in fact, heavy on cases but quite light on text. Indeed, there are only five readings in the entire collection. Most of these are either historical context setters (e.g., Pinchot's "The fight for conservation" and Leopold's excerpts from *A Sand County Almanac*) or classic pieces from the economics literature (e.g., Coase's "The problem of social cost" and Solow's "The economics of resources or the resources of economics"). While the author's framework piece "Environmental management: A framework for business strategy" is useful, it does not provide adequate conceptual background or analytical tools for students to tackle the cases with. In short, the book lacks the "software" needed to stand alone. Interestingly, some of this material has recently appeared in article and book form by Forest Reinhardt. His 1999 article in the *Harvard Business Review* entitled "Bringing the environment down to earth" and his new book *Down to Earth* provide much of the conceptual and analytical footing that is missing from the volume being reviewed here.

In contrast to Reinhardt and Vietor's book, Russo's *Environmental Management* provides a more recent collection of cases and readings drawn from a range of sources (I must confess a slight bias here because this book contains two readings and three cases either authored or supervised by me). The book is divided into five parts. Part I provides "perspectives on the environmental challenge" in the form of two think pieces: one by Lester Brown and Jennifer Mitchell and one by me. Part II contains nine

readings on the “institutional setting of environmental issues,” including classics from the earlier part of this century (e.g., Aldo Leopold and Garrett Hardin) and more recent selections on regulation and environmental economics by authors such as Portney, Cairncross, Vernon, and Esty). Part III houses five readings on “managing to be environmentally responsive,” including pieces by Ed and Jean Stead, Peter Cebon, Matt Arnold, and Jacquelin Ottman. Part IV consists of a set of five readings on “principles of corporate ecology.” This section provides background on necessary tools and techniques including life-cycle analysis, environmental accounting, design for environment, ISO 14000, and the Natural Step. Finally, Part V contains 15 cases or simulations from a variety of sources and covering a wide range of topics. These cases are supported by a companion volume of detailed teaching notes and associated materials.

While Russo’s book contains more recent material and draws from a wide range of sources, it still focuses, as the title suggests, on environmental management and not the larger construct of corporate sustainability. Most of the material in this book is also decidedly American. Indeed,

most of the readings deal with environmental management from the perspective of the U.S. or at most the developed world. The problems and challenges of emerging economies and the developing world are left largely unaddressed. A few of the cases (e.g., Solar Electric Light Fund, International Climate Change Partnership, and Oil in the Ecuadorean Rainforest) do address issues of developing country concerns but there is not adequate reading material in the collection to prepare students to effectively address these cases.

Overall, however, I think these two books make an important contribution to the growing literature on corporate environmental management and sustainable development. While neither represents the “perfect” textbook for a class on this emerging topic, I’m not sure it is possible to produce such a product at this point in history: The issues and challenges are simply moving too quickly to be captured for any length of time by a single textbook.

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