Pollution Prevention in Environmental Studies
NATIONAL POLLUTION PREVENTION CENTER FOR HIGHER EDUCATION

Bibliographic Teaching Outline

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Following the structure of the Resource List, this outline suggests a framework for integrating pollution prevention (P2) into environmental studies courses. Depending on the scope of your course, you may wish to use either the entire outline or only certain segments of it.

When a resource has relevancy in more than one section, the cite in the non-primary location notes the primary location in brackets. For example, Mitsch (1993) is mentioned in component III.A although the primary listing for this document is in component II.A. Therefore, a [II.A] appears with the Mitsch reference in III.A.

Acronyms Used in This Compendium

LCA	life cycle assessment (sometimes written as "life cycle analysis")
NPPC	National Pollution Prevention Center for Higher Education
OTA	Office of Technology Assessment (U.S. Congress)
P2	pollution prevention
UNEP	United Nations Environment Program
U.S. EPA	United States Environmental Protection Agency:
CERI	Center for Environmental Research Information
OCEP	Office of Communication, Education and Public Affairs
OPPE	Office of Policy, Planning, and Evaluation
OPP	Office of Pollution Prevention (pre-'92)
OPPT	Office of Pollution Prevention and Toxics (post-'92)
ORD	Office of Research and Development
OSW	Office of Solid Waste
PPIC	Pollution Prevention Information Clearinghouse
SAB	Science Advisory Board
U.S. GAO	U.S. General Accounting Office

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I. Introduction to Pollution Prevention

The topics in the first component give students the opportunity to become acquainted with the pollution prevention (P2) concept, and to understand its importance. The first section shows the connections that can be made between sustainability and P2, and the second section gives a historical overview. After this, the third section outlines issues and resources to examine the definition of P2, and it discusses evolution of national P2 policy as well as policy at the local, state and international levels. This component can be used in conjunction with the "Overview of Environmental Problems" and "Pollution Prevention Concepts" introductory documents.

I.A Preamble: Sustainability and P2

ECOLOGICAL SUSTAINABILITY AND POLLUTION

Why is pollution prevention important and how does it fit in with common environmental studies concepts? A variety of terms—sustainability, global change, human ecology, post-industrial society—can be related to P2, yet the relationship often is not clear. Therefore, the teacher's challenge in this section is to set the stage for P2 using familiar concepts from the rest of the course. A commonly used approach is the problem-solution model: unsustainability through excessive pollution is the problem, and P2 will help lead to sustainable human-environment interactions. This first section is a guide to help outline "the problem," with the possibility for many variations depending on the particular structure of the course and the length of time devoted to P2.

Perhaps the most appropriate place to start is with ecological sustainability. A number of environmental science textbooks, particularly Miller (1994 [key doc.]) provide excellent introductions to the chemical and biological concepts that underlie ecological functions. Likewise, an examination of underlying ecological concepts (Committee on the Applications. . ., 1986 [V.B]) may be a helpful resource to convey the practical aspects of ecological principles. For a more dire perspective, Meadows et al. (1992) provide an ominous update of their controversial book, *Limits to Growth*.

Many other authors (including Goodland, 1992; Gore, 1992; Hawken, 1993 [III.A]; Orr, 1992 [V.B]; Stern et al., 1992 [III.A]; Tolba and El-Kholy, 1992; World Conservation Union, 1991 [I.C]) examine the sustainability issue from a variety of perspectives. However, they share a common conclusion: a paradigmatic shift is needed in order to bring human systems in concordance with natural systems.

To be fair, not all authors share this conviction. For example, Larson et al. (1986), Schmidheiny (1992), and Wann (1990) give a more optimistic perspective that we are already moving towards sustainability. Cook's (1992) perspective is that the argument of such "gloom-and-doom" human incompatibility with the rest of nature is extreme and insupportable. Yet most sources will agree that sustainability is indeed a serious concern.

POLLUTION GENERATION

Some authors take a more specific approach to sustainability. Peet (1992) gives an accessible overview of energy use in natural systems. Piasecki and Asmus (1990 [III.B]) provide an introduction chronicling abuses to land, air, and water. A concise summary of environmental impacts is found in Keoleian and Menerey (1993 [II.B]). Hirschhorn and Oldenburg (1991 [key doc.]) offer detailed information about the generation of toxic and non-toxic pollutants. Indeed, it is important to stress that pollution can come in many forms—air, liquid, solid, energy, noise, odor; toxic and non-toxic. It is equally important to note that pollution, in the broad sense, can occur from both emitting substances *into* the environment as well as appropriating resources *from* the environment. An excellent source of resource usage (as well as pollution generation) is the biennial *World Resources* (World Resources Institute, 1994). Other sources documenting resource usage include (Durning, 1992 [III.C]; Gore, 1992; Lotter, 1993 [III.C]; and Ophuls and Boyan, 1992 [I.C])

Pollution occurs not only in a variety of forms, but it is also caused by a wide spectrum of sources. Industrial sources are an important but rarely salient because the pollution is typically disassociated with products. However, industrial emissions are a major source of pollution that are both well documented and well regulated (Hirschhorn and Oldenburg, 1991 [key doc.]; National Research Council, 1985 [I.C]; U.S. Congress, OTA, 1986 [I.C]; U.S. EPA, OPP, 1991b [III.A]).

Industry, however, is not the only source to blame. A short article by Kane (1993 [III.C]), for example, shows how individual actions contribute to carbon dioxide loading. In Durning (1992 [III.A]) environmental impacts take on a personal tone with the author's

critical look at consumption practices. Lotter (1993 [III.C]) takes this one step further with a personal environmental audit and action guide. An EPA video about non-point source water pollution shows how a variety of actors, from individuals to industries share in responsibility for pollution. In summary, having students grasp these different dimensions of pollution—how, who, what, and where—is instrumental in providing a basis for their understanding of both life-cycle impacts as well as pollution prevention management options.

SUSTAINABILITY AND POLLUTION PREVENTION

Several authors use sustainability concepts to discuss ameliorating environmental harm through P2 practices. For example, Hirschhorn and Oldenburg (1992 [key doc.]) provide a concise discussion of the link between sustainability and P2. Peet (1992) uses the more scientific language of feedbacks and externalities to justify the need to reduce pollution. The perspective of Stern et al. (1992 [III.C]) is social science, with a sweeping view of the forces and institutions needed to arrest global change. Vargish (1980 [III.C]) comes from a humanities perspective to explain why the concept of ecological limits is so frightening. Post (1991 [III.A]) takes a business approach, mentioning the need to reconcile economic activity with ecological viability. Smith et al. (1992) also come from a business perspective, examining sustainable development and the tradeoffs of growth vs. environment. Wann (1990 [II.A]) uses a novel but increasingly recognized perspective of achieving sustainability through patterning human processes after natural processes. Both problems and solutions are mentioned in Jamieson and VanderWerf's (1993 [key doc.]) report, which provides a helpful context for envisioning cultural forces that affect P2 programs. There are also numerous other authors and perspectives—engineering, public health, legal—that are also important. This range of perspectives illustrates why all academic disciplines share the responsibility for implementing a P2 strategy.

I.B History of P2

HISTORICAL ROOTS

One specific way to understand the context of pollution prevention is to examine its historical roots. Of course, the history of P2 is only one segment of environmental history. On the other hand, the history of P2 can provide an enriched understanding of the evolving human response to environmental impacts. Of the many documents that discuss the history of environmental protection, only a handful cover P2; this is probably due to the newness of the topic. Fortunately, a growing list of books and articles discuss the coming transition to a more ecologically oriented society.

The preventive ethic is commonly a central theme in these scenarios. Some of the authors who provide a helpful historical background to this shift in society include Ophuls (1992 [I.C]), Peet (1992 [I.A]), Meadows et al. (1992 [II.A]), and Commoner (1992 [I.C]). Taking a different perspective, Vargish (1980 [III.C]) discusses the public antipathy to such significant changes. The historical trend of de-materialization, one component of this new prevention-oriented society, is covered in Larson et al. (1986 [I.A]). Ophuls (1992 [I.C]) gives a particularly detailed account of the historical roots of our present environmental predicament, going back before the industrial revolution. It is more common to focus on developments in this century, such as Commoner's (1992 [I.C]) treatment of the post-World War II petrochemical boom. Likewise, Meadows et al. (1992 [II.A]) focus on the exponential rise in pollution levels during this century.

RECENT HISTORY

The bulk of United States pollution control policy was developed after the hallmark 1970 Earth Day. Some of the older works in this bibliography are included to show that P2 themes were present then, although the term "pollution prevention" was rarely used. Related topics include the interest in resource conservation and waste reduction in the early and mid-1970s (Conn, 1977), as well as the widespread attention to energy conservation in the middle and late 1970s (Conn, 1983 [III.C] and Hayes, 1992 [I.C]). The public health concerns of hazardous waste disposal that emerged as a significant concern in the early 1980s have continued to this day (Commoner, 1992 [I.C], and Montague in Miller, 1994 [key doc.])

The P2 theme has emerged from a brief but intense history of environmental protection efforts. Many authors introduce P2 by going back five or ten years to show the limitations of the pollution treatment mentality. The rallying call for prevention was sounded by several government-sponsored reports, such as those by the National Research Council (1985 [I.C]) and U. S. Congress Office of Technology Assessment (1986 [I.C]). Other accounts of the recent historical momentum behind P2 include Hirschhorn and

Oldenburg (1991 [key doc.]), U.S. EPA (1991 [I.C]), U.S. EPA, OPP (1991b [III]), and Freeman et al. (1992 [I.C]). A thorough international perspective can be found in Tolba and El-Kholy (1992 [I.A]). McMurray (1991 [III]) gives a historical account from the chemical industry's perspective. Perhaps it is appropriate to end by suggesting Wise (1993 [key doc.]), who discusses both the recent history of P2 as well as future trends.

I.C P2 Policy

This section includes the definition of P2, as well as approaches to P2 policy at the national, state and local, and international levels. (Section III covers government *implementation* of P2 programs.)

DEFINITION OF POLLUTION PREVENTION

The actual definition of pollution prevention is rather elusive. Many authors make the fundamental distinction between pollution prevention and pollution control. This is perhaps the most important point, but there are also other issues: the connection between pollution generation and resource use; the distinction between P2 and recycling; different types of pollution; and P2 opportunities at different stages in a product's life cycle (see Section II).

Hirschhorn and Oldenburg (1991 [key doc.]) provide a general definition and useful introduction to the concept of P2. Kenworthy and Schaeffer (1990 [III.B]) provides a clear explanation of the difference between pollution *control* and pollution *prevention* in an industrial context. Other sources that discuss the definition of P2 include Freeman et al. (1992); Pojasek (1991 [III.A]); and the U.S. EPA (1991). Although the Pollution Prevention Act (P.L. 101-508—Nov. 5, 1990) is the most widely referenced source for the definition of P2, it is somewhat confusing: it describes essentially identical terms—pollution prevention and source reduction, as well as further clarifying language—in different ways. More useful, however, is a short memo available from PPIC by EPA Assistant Administrator Hank Habicht (1992), which clarifies what P2 is and is not.

As adapted from the Habicht memo, here is one way of defining P2:

> Pollution prevention is any practice that reduces the amount or environmental and health impacts of any pollutant prior to recycling, treatment, and disposal. Pollution prevention includes equipment or technology modifications, reformulation or redesign of products, substitution of raw materials, and improvements in housekeeping, maintenance, training, or inventory control. The goal of any pollution prevention initiative is to reduce aggregate environmental impacts over the entire life cycle of a product system; therefore, resource and energy conservation are also forms of pollution prevention.

OVERALL POLICY ISSUES

Comparatively few documents discuss P2 policy in broad terms. Rather, most documents apply P2 within a particular political arena, such as U.S. government. Useful sources that deal with broader themes include a practical treatment of the progression in P2 policy by Pojasek (1991 [III.A]). Casler (1991) discusses how energy use and pollution impacts are reduced when the national budget priorities shift from defense to other categories. Hirschhorn and Oldenburg (1991 [key doc.]) also discuss general P2 policy issues.

UNITED STATES POLICY

A wide selection of documents touch on U.S. P2 policy. In fact, some of the suggested readings are by now already dated. Newsletters such as *Environment Reporter*, *Inside EPA*, and EPA's *Pollution Prevention News* and periodicals such as *EPA Journal, Chemical and Engineering (C&E) News,* and the *New York Times* are useful sources for current developments, as are electronic bibliographic information services such as Public Affairs Information Service (PAIS), Infotrac, and Nexis/Lexis.

Besides the documents listed in Subsection I.B, most documents about U.S. P2 Policy were written in this decade. In particular, OTA's *Serious Reduction of Hazardous Waste: For Pollution Prevention and Industrial Efficiency* is a seminal report that can be credited with starting the momentum for a national P2 policy. Another important early document is the National Research Council's report on reducing hazardous waste (1985). The EPA's Science Advisory Board also encouraged EPA to adopt a P2 approach to reducing environmental and health risks (1990).

The text of the Pollution Prevention Act of 1990 can be useful reading, particularly because it is only 10 pages long. Political science or policy students may wish to examine Congressional hearings that preceded the passage of this law. Following the P2 Act of 1990, EPA issued a lengthy "Pollution Prevention Policy Statement" in the *Federal Register* (U.S. EPA, 1991). It is a good place to start for a federal P2 policy primer. Although dated, Hirschhorn and Oldenburg's discussion of U.S. P2 policy (1991, pp. 24–28 [key doc.]) is short, illuminating, and somewhat critical in contrast to EPA sources. The entire July-September 1993 *EPA Journal* (1993 [key doc.]) is devoted to P2. Many of the articles in this issue discuss policy issues, from Congressional (Lieberman, 1993, and Baucus, 1993); EPA (Browner, 1993 [III.B]); and academic (Andrews, 1993) perspectives.

Commentaries about P2 policy can depend on the perspective of the author. For example, Sheridan (1992 [III.A]) gives a generally positive rating to U.S. P2 policy for the industrial sector, but warns of the potential for excessive regulation. Both Byers (1991) and Lis & Chilton (1993) take a more anti-regulatory view, with particular concern about what they consider EPA's artificial boundary between P2 and recycling. In contrast, authors such as Commoner (1992) take an extreme stance in the other direction—favoring strict government controls of private business in order to prevent pollution. Lieberman (1993) takes a more accommodative stance, supporting greater government involvement in encouraging businesses to prevent pollution. Likewise, then-Senator Albert Gore discusses his "Strategic Environment Initiative" —ideas about how government can work with businesses to encourage P2 and promote technological advancement (Gore, 1992 [I.A]).

For a more theoretical-academic approach, Roy's (1991) article combines social science and environmental policy perspectives. Freeman et al.'s (1992) review article, while not exclusively written for an academic audience, provides an almost exhaustive review of industrial P2 themes, including policy. However, Purcell (1992 [V.B]) notes the review includes neither non-industrial nor non-technical perspectives of P2.

If time permits, specific issues may be worth particular attention. For example, the Toxic Release Inventory (TRI) has been credited with leading to many P2 initiatives (Moos, 1992 [III.C]). A *Business Week* editorial ("How To. . .," 1993) suggests this type of information provision as a major direction in future U.S. P2 policy. Another example is the connection between P2 and energy efficiency policies, as discussed by Hayes (1991) and Lovins (1990).

STATE AND LOCAL POLICY

State and local pollution policies vary greatly. Some states have practically no P2 laws nor programs, while other states have extensive regulatory or assistance programs. Congress has, to date, decided against enacting sweeping P2 planning or regulatory legislation, leaving the door open for states to develop such programs on their own. As with many environmental issues, EPA's national P2 program is a backstop for the state programs, providing funding, information, and other resources. However, a General Accounting Office report faults EPA's state P2 assistance program for supporting non-P2 treatment and recycling programs (U.S. GAO, 1994 [III.B]).

Rather than attempt to provide representative documents from state and local programs, the reader is encouraged to contact nearby P2 offices for the most recent and relevant information. Contact information is provided in the *1993 Reference Guide to Pollution Prevention Resources* (U.S. EPA, February 1993 [key doc.]). However, there are a few documents that discuss state and local programs in broad terms. For an academic treatment, Rabe (1991) discusses the experiences of several states as a model for other states and the rest of the country. Geiser (1991 [III.A]) provides a more popular-audience discussion of state P2 and toxic-use reduction laws as related to "sustainable industry."

INTERNATIONAL P2 POLICY

Likewise, only a few accessible documents deal extensively with international P2 policy. Documents such as Hileman's (1992) cover the United Nation's "cleaner production" program. International P2 and sustainable development policy are the themes in a *Business Week* cover story (Smith et al., 1992 [I.A]) immediately preceding the 1992 United Nations Conference on the Environment and Development in Rio De Janiero. Portions of UNCED's *Agenda 21* (Agenda 21, 1993) and the World Conservation Union's *Strategy for Sustainable Living* (World Conservation Union, 1991) contain P2 themes. Tolba and El-Kholy (1992 [I.A]) provide general information about international environmental policy.

Congressional research reports with international policy themes include one discussing policy measures to reduce global greenhouse emissions (U.S. Congress, OTA, 1992a [III.B]); another on using trade and energy policies to reduce pollution (U.S. Congress, Senate, 1992); and a third on the design of products (U.S. Congress, OTA, 1992b [II.A]). This third report, *Green Products by Design*, includes an interesting discussion of different environmental policy models, indicating that the European approach is more focused at the end-product stage, while the U.S. model is more focused at the manufacturing stage. As shown in the next section, these two foci represent different stages of a product's life-cycle. Indeed, the theme of the next component is understanding P2 opportunities *throughout* a product's life cycle.

II. Understanding Pollution Prevention Through Life Cycle Assessment

Although there are many ways to understand the concept of pollution prevention, life cycle assessment (LCA) is used here to enable students to recognize the opportunities for reducing environmental impacts over the entire life of a product. All of a product's impacts, from initial resource extraction to ultimate disposal, can be included in a life cycle assessment. Thus the LCA approach is *synthetic*. LCA is also an *analytical* approach because it enables students to break down the entire system into components that can be more readily understood and analyzed.

While the mechanics of conducting an LCA are controversial, a more important theme for students to grasp is the "big picture" approach to environmental impact assessment. Life cycle assessment is one of several tools for understanding environmental impacts. Therefore, the first section surveys such themes across the broader landscape of human impacts on the environment. For those with little class time, the first section is not crucial. However, it is important to include key life-cycle assessment framework concepts from the second section. The third section will help develop student's critical thinking skills by pointing to LCA applications and controversies.

II.A The Big Picture: Holistic Analysis

Understanding P2 necessitates taking a "big picture" view. Although it may be easy to agree on the need for a comprehensive, critical perspective, it is much more difficult to agree on exactly what items such a perspective includes and excludes. This section is an introduction to some of the themes that may be included in such holistic analyses. It also provides a background and justification for taking a life-cycle approach. This section is most useful when there is sufficient time to examine this context for life-cycle assessment.

A "product system" is just one many interlinked systems, and systems analysis is, in itself, an area of study. There are numerous documents that unite a holistic, system-wide analysis with a P2 theme. For example, Peet (1992 [I.A]) provides a concise introduction to an environmental systems approach. An example of systems theory in practice (Meadows et al., 1992) uses a predictive systems model of global flows to argue for sustainable practices. Human systems are inextricably tied with natural systems, and a growing body of literature calls for human systems to mimic and thus mesh more closely with these natural systems. Authors such as Tibbs (1992), Mitsch and Jorgensen (1989), and Wann (1990) discuss this theme using a variety of terms: ecological engineering, industrial ecology, biologic design, etc.

As Orr (1992 [V.B]), Hawken (1993 [III.A]), Peet (1992 [I.A]), and others a point out, a greater challenge rests with fundamental knowledge structures. The traditional Western "linear thinking" model may have much utility, but it does not always complement the fundamental cyclical system of the ecological web. Education can provide the intellectual tools to promote a shift to more holistic thinking.

Life cycle assessment (LCA) is one such tool. Defined, LCA "consists of several techniques for identifying and evaluating the adverse environmental effects associated with a product system" (Keoleian & Menerey, 1994, p. 662 [II.B]). In a broad sense, LCA can be viewed as more than just a methodology; it offers students a *way of thinking* about the environmental impacts of products beyond what is readily apparent. Thus for a beverage container, the "big picture" is more than just the issues of disposability or recyclability: it is about the entire range of impacts throughout the "life story" of a container.

Particularly at this introductory level, getting students to think about life-cycle impacts is more important than overwhelming them with complex LCA methodology. However, giving an overview of the life cycle assessment framework can be a compelling approach for students to

understand the life-cycle concept. Therefore, the next section is an introduction to life-cycle assessment methodology, followed by an overview of controversial LCA issues. Following this "understanding" component, Section III examines different approaches for handling human impacts from a holistic, preventive perspective. As with ecological systems, both producers (businesses) and consumers (individuals) have roles to play, as do intermediaries (government).

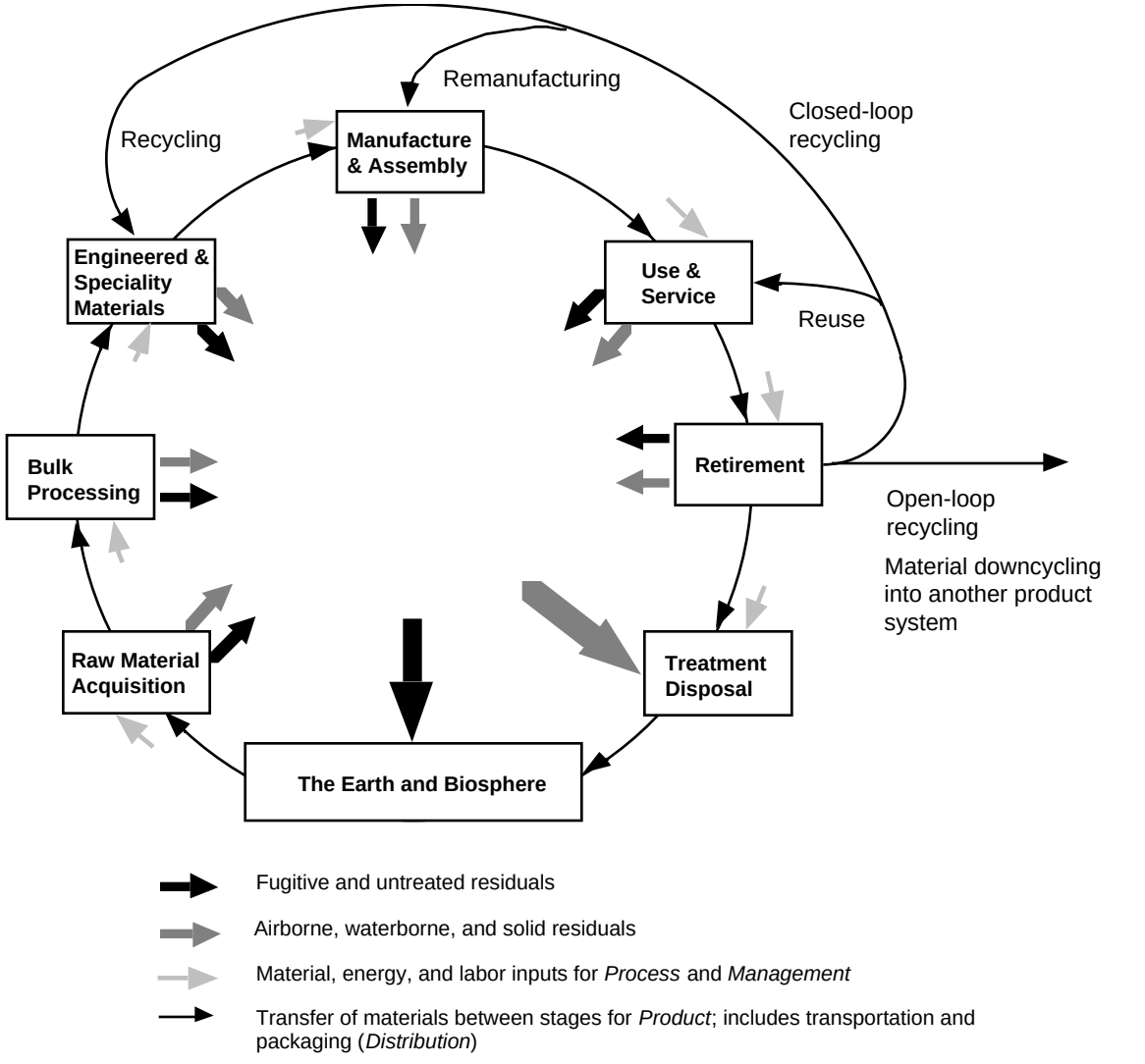
II.B Life Cycle Assessment Framework

The LCA framework is the "nuts and bolts" part of this section. Because there are relatively few sources of general information about the life cycle analysis framework, this section goes into greater explanatory detail than other sections in the outline. References to the bibliography are primarily clustered at the end of the section.

THE LIFE CYCLE SYSTEM

The life cycle system on which LCA is based is a "cradle-to-grave" set of stages that follow a product from its origins to its ultimate disposal. As shown on the diagram below, the life cycle system begins and ends with the earth and the biosphere. (This circular pattern is analogous with the ecological web of life as well as the Native American "circle of life.")

The life cycle system incorporates both sources and sinks. At each stage, energy and material "sources" may be needed, and likewise pollutants may be emitted to air, water, or land "sinks." Indeed, an innovative aspect of LCA P2 analysis is its capability to account for the transfers of pollutants and other material/energy flows across these different media (often called "cross-media transfers").



Raw material acquisition is the beginning stage of a product system. Activities such as mining, petroleum extraction, and forest harvesting are all examples of this stage. The raw materials must be transformed into usable materials and then manipulated through manufacturing processes. Although these stages may be less visible to the end-user, they can account for a significant portion of a product's life cycle impact.

Following manufacturing, product use is the next stage. Some products, such as food, are consumed in use while other products enter a post-use stage. Items that are reused or recycled are looped back into an earlier stage of the product life-cycle, although "open loop" recycling into different products sends the material into a different product system.

The open-loop recycling example illustrates an important factor in conducting LCAs: the boundary for any given product system. Even for the most basic product, there are many indirect impacts that could be included —such as the effect of using gasoline from imported oil to power a delivery truck that carries the product. At some point, an arbitrary boundary must be made and justified. Thus, in the case of most LCAs, once a product is recycled into a different product, it has crossed the product system boundary.

PRODUCT SYSTEM COMPONENTS

The term "product system" is preferable to "product" because of the non-product impacts associated with every product. In fact, there are four major product system components. In addition to (a) the product itself, there are also impacts from (b) processing, (c) distribution and (d) information / management components. Processing impacts encompass many of the impacts associated with transforming a raw material into a finished product, but there are also processing impacts during use and post-use stages. For example, cleaning reusable dishware is a significant use / post-use processing impact. Transportation impacts include getting the product to the end-user, as well as transporting raw materials, post-use detritus, etc. The management component is "the entire information network that supports decision making throughout the life cycle" (Keoleian & Menerey, 1994).

PRODUCT REQUIREMENTS

Product systems must satisfy other requirements in addition to minimizing environmental impacts, and LCAs can potentially be used to examine other impacts. Product life-cycle designers, in particular, may seek to minimize environmental impacts while still satisfying performance, cost, cultural preference, and legal requirements (Keoleian & Menerey, 1993). Likewise, consumers and others evaluating product systems may consider factors such as cost, performance, availability, social popularity, and aesthetic appeal as more important than environmental impacts.

To review, life cycle assessment includes three principal dimensions for analysis:

- Life Cycle Stages – raw materials acquisition, materials processing and manufacturing, product use, and post-use.
- Product System Components – product, process, transportation, and information / management
- Product Requirements – environmental, performance, cost, cultural preference, legal

As a three-dimensional matrix, this results in 80 unique combinations of factors! Students cannot be expected to take on such a mammoth LCA exercise, but LCA problems can be broken into more manageable components. For example, economics students could compare cost with environmental requirements by examining the incremental economic and environmental impact over the stages of a product's life cycle. Or psychology students could examine the product system impacts of differing personal and cultural preferences. There are many potential variations for using the LCA concept. Topic suggestions in Section IV are one place to turn for ideas on how to apply the LCA concept.

STAGES OF A LIFE CYCLE ASSESSMENT

As with other types of impact assessments, an LCA begins with goal-setting and scoping; this is particularly important in defining the product system boundaries, establishing a proper basis for comparing multiple products, and setting temporal and spatial boundaries. The final stage would involve analyzing and interpreting the results. In between the preliminary and final phases of the methodology are three major stages that distinguish an LCA from other types of assessments. As explained by the Society of Environmental Toxicology and Chemistry (SETAC, 1993), they are:

1. Life Cycle Inventory Analysis

2. Life Cycle Impact Assessment

3. Life Cycle Improvement Assessment

At the inventory analysis stage, the researcher identifies and quantifies materials and energy flows for a given product system. This stage of LCA is the most developed, with SETAC and other groups helping to set a standard methodological framework. However, such a life-cycle inventory is meaningless without an understanding of its environmental impact. Therefore, the researcher then procedes to an impact-assessment stage to "characterize and assess the effects of the environmental burdens identified in the Inventory component" (SETAC, 1993, p. 26).

These two stages are analogous to measuring quantity (inventory analysis) and quality (impact assessment). And the latter is much more difficult than the former! Environmental and human health impacts depend on many variables, with a tremendous number of potential interactions, not to mention value judgements. For example, one can accurately gauge the number of trees used to print a newspaper, but it's much more difficult to determine the resource-depletion, ecological, and human health impacts of using these trees. Therefore, it is not surprising that methodological standards for the life-cycle impact assessment stage are only partially defined. The cacophony of competing approaches leaves some doubt whether a standardized approach is even possible.

The third stage, life cycle improvement assessment, is the point of connection between *understanding* life-cycle impacts and *implementing* pollution prevention improvements. However, the results from this stage are dependent on the accuracy of the first two stages. Even if there is no defined methodology for life-cycle improvements, an improvement assessment can be used when the previous LCA components yield clear avenues for preventing pollution during a product's life-cycle.

REFERENCES TO THE LITERATURE

There is not copious literature, particularly introductory works, describing the framework of life-cycle impact assessments. The single most important reference is Keoleian and Menerey's *Life Cycle Design Guidance Manual* (1993). Although the entire document is too long for readings in most classes, portions of it are appropriate, particularly Chapters 2, 4, and 6. Another reading that covers these methodological issues in depth is the SETAC's *Guidelines for Life-Cycle Assessment* (1993). Another Keoleian and Menerey piece (1994) summarizes key points from their Manual, and adds further details in a critical review-style journal article.

Students may be more comfortable with brief, general readings about LCA. For example, Curran (1993 [key doc.]) provides a concise overview of LCA, mentioning some of the controversial issues. Two articles—by White and Shapiro (1993) and Wang (1993 [II.C])—are actually follow-ups to Curran's, responding to Curran and raising additional points. Nash and Stoughton (1994) may be considered a fourth article in this series, although it points out themes from a LCA conference. Nash and Stoughton mentions that a LCA approach may *not* agree with a less informed "conventional wisdom" approach to environmental impacts. For example, a recyclable product labelled as "environmentally friendly" may have a greater LCA impact than a less material-intensive but nonrecyclable product.

II.C LCA Applications and Issues

APPLICATIONS

Showcasing life-cycle applications can be a useful way to assist students with understanding life cycle impacts. An oft-cited example is Martin Hocking's short article (1991) comparing the life-cycle impacts of paper and plastic-foam beverage cups. Walley et al. (1992–93) presents a LCA for baking soda, which, even though it is a relatively simple product, illustrates the many variables associated with conducting LCAs. A set of two articles by Keoleian and Menerey (1991 [IV.16] and 1991–92 [IV.7]) analyze comparative life cycle impacts for five cases: disposable and reusable diapers, disposable and washable dishware, bulk and packaged product merchandising, office furniture manufacturing process improvements, and reuse of office paper as packing materials. Arthur D. Little (1991 [IV.6]) and Lehrburger (1989 [IV.6]) both examine life cycle impacts of disposable and reusable diapers. Their methodologies, however, differ, as do their conclusions.

At the industrial level, Geiser (1991 [III.A]) mentions the usefulness of the LCA framework as an important tool for promoting sustainable industry. Continuing with this theme, EPA's *Facility Pollution Prevention Guide* (U.S. EPA, ORD, 1992a [III.A]) encourages users investigating P2 opportunities to examine the impacts of a product's manufacture, use, and disposal. At a more fundamental level, the OTA's "Green Products by Design" (U.S. Congress, OTA, 1992b [II.A]) discusses policy and business opportunities to prevent pollution at the design stage. A video that illustrates thinking from a life-cycle perspective is *Where Our Food Comes From* (1989 [IV.9]). As the title suggests, it traces the sources of foods we commonly eat. Further examples and opportunities for examining LCA and P2 applications can be found in Section IV.

CONTROVERSIAL ISSUES

While life-cycle assessment can be a very useful tool for understanding pollution prevention, students should be encouraged to think critically about this and other analysis methodologies. This section introduces some of the critical literature surrounding LCAs This can be an important part of a complete introduction to LCA and P2, as well as an example of the nexus between science and environmental policy or management. However, this section may be omitted in briefer modules.

The most commonly voiced concerns about LCA are the quality of the data and nature of the methodology. Data limitations are universally mentioned, although authors describe a variety of specific concerns. Missing or incomplete information is one of the most basic concerns—even at the inventory level, since there is still much we do not know about effects of different substances on the environment (Curran, 1993 [key doc.]; Keoleian and Menerey, 1993 [II.B]; Lifset, 1991; Portney, 1993–94). Also, potentially useful proprietary information might not be verifiable or available (Curran, 1993 [key doc.]; Keoleian and Menerey, 1993 [II.B]; Portney, 1993–94, White and Shapiro, 1993 [II.B]). Curran (1993 [key doc.]) discusses the information gaps issue, although she does not treat this as a fatal flaw with the procedure. Crossen (1994), on the other hand, finds significant fault with LCA because the information gap invites a wide range of defensible assumptions.

Furthermore, the all-encompassing nature of LCA adds more uncertainty. At the highest level, the location of the system boundary affects what data is or is not collected (Keoleian and Menerey, 1994 [II.B]; Portney, 1993–94). At the impact assessment stage, Wang (1993) points out that the same pollutant levels at different points in the product life-cycle may need to be treated differently. Wang also mentions geographic uncertainty—the same pollutant levels may have varying impacts depending on the location of the emissions.

Measuring impacts often becomes an "apples vs. oranges" issue, with researchers facing the enormous challenge of reducing many different types of impacts (such as resource depletion, habitat change, atmospheric change, and human health effects) into one dimension (Crossen, 1994; Curran, 1993 [key doc.]; Keoleian and Menerey, 1993 [II.B]; Keoleian and Menerey, 1994 [II.B]; Portney, 1993–94). There is also the issue of what *types* of impacts will be examined. For example, Portney faults LCA for ignoring important non-environmental impacts, such as labor and capital usage.

With this litany of data concerns, the manner in which data is used—methodological concerns—seem relatively minor in comparison. The lack of a standardized LCA is a well-recognized problem (Crossen, 1994; Keoleian and Menerey, 1994 [II.B]; Lifset, 1991; Nash and Stoughton, 1994 [II.B]). There has been recent progress toward a more universally acceptable LCA inventory analysis procedure (SETAC, 1993 [II.B]). But there is little, if any, emerging consensus on conducting impact analyses and improvement assessments.

One way to help avert methodological squabbling is a third-party review process, although several authors (Crossen, 1994; Curran, 1993 [key doc.]; Keoleian and Menerey, 1993 [II.B]) note that there is often insufficient peer review of LCAs. Wang (1993) adds that all sectors—private, government and public interest—should participate in this review process. Related to this concern is Crossen's comment that research money is becoming increasingly dominated by private funding sources, which may be affecting how researchers approach their task.

Apart from specific data and methodological concerns, some authors raise broader concerns. For one, there is the practical concern that LCAs are lengthy and costly, limiting the potential LCA targets to those whose sponsors have the resources to undertake such projects (Keoleian and Menerey, 1993 and 1994 [II.B]; Portney, 1993–94). In practice, this limits LCAs to high-profile consumer items sponsored by a corporation, trade group, or the national government. And the results may soon become out of date (Portney, 1993–94).

Other concerns include the difficulty in comparing different products when the products do not provide identical services (Portney (1993–94). Disposable and cloth diapers, for example, provide similar infant protection but have quite different qualities. Comparability is also reflected in Crossen's (1994) comment that human behavior is considerably less predictable than the "rational actor" most modelers originally assumed. On the receiving end of LCA results, Portney notes the difficulty in conveying them in a succinct, understandable form. He also mentions a similar problem—the myriad factors that can potentially affect a product's life-cycle impact would stretch the decision-making capacities of those producing the product.

WHAT CAN BE DONE?

The critical literature addressing LCAs can be roughly divided into two groups. Critics feel the uncertainty surrounding LCA is so great that the procedure should be curtailed or significantly scaled back. Supporters recognize LCA's weaknesses but feel that it still provides useful results. Students may have differing opinions as well, and this could be a worthy topic for debate. Some of the authors who find fault with LCA advocate an alternative analysis system. For example, it is not surprising that economist Paul Portney's long list of problems with LCA is followed by his recommendation for greater use of the pricing mechanism (1993–94).

A number of authors recognize the limitations of LCAs and advocate streamlined methodologies which might not attempt to account for all variables but are still useful (Hocking, 1991; Portney, 1993–94; White and Shapiro, 1993 [II.B]). Some approaches use the LCA theme but are not strictly life-cycle assessments, such as the EnviroAccount personal environmental impact computer program and guidebook (Lotter, 1993 [III.C]).

To be legitimate, LCA methodology must strive for useful results. However, it is easy to "lose the forest for the trees." At its core, the life-cycle approach is not just a methodology: it is a *way of thinking* about environmental impacts. At this introductory level, understanding, for example, the precision of a dose-response relationship for a given variable is not as important as grasping the core concepts such as the stages of a product's life-cycle and the concept of a product system.

Thus, it is important that students grasp the life-cycle *approach* for understanding pollution prevention opportunities. Such an approach enables them to investigate opportunities for managing P2—in business, government, or across individuals and society—from a much richer perspective. Indeed, here at the midpoint of this outline, we move from a more passive "analysis / understanding" frame to a more active stance of "managing / doing." This may an appropriate time for reviewing what students have learned thus far.

III. Management of Pollution Prevention

Moving from understanding to doing, this section covers literature on managing pollution prevention practices in government and society as well as in business. The literature described here is a sampling of the more generalist management literature ("how to do P2"); the literature described in the next section mentions specific P2 opportunities for a number of products or sectors. As with other parts of this compendium, many more specialized pieces of the literature have not been included; this is especially the case for the burgeoning support for P2 in industry.

If you want to approach the management issue using a case study or problem-solving format, you may want to try using topics from Section IV, "Pollution Prevention in Practice," to illustrate themes outlined in Section III.

III.A Business Management

INTRODUCTION AND GENERAL LITERATURE

In the past decade, P2 has emerged as an important business topic. Accordingly, many of the numerous articles, books, and videos describing P2's role in business are quite recent. General treatments include articles by Freeman et al. (1992 [I.C]), Post (1991), Sheridan (1992), and Underwood (1993). Books include Gore (1992 [I.A]), Hirschhorn and Oldenburg (1991 [key doc.]), President's Commission (1993), Smart (1992), and the U.S. EPA's Office of Pollution Prevention (1991b). Videos, such as *Beyond Business as Usual* (unknown date) and *Less is More* (1990), are also available.

Another set of literature focuses on ecologically sustainable business development, often including P2 and life-cycle product stewardship as prominent themes. Representative works that mention P2 include a book by Schmidheiny (1992) and articles by Robins (1992) and Smith et al. (1992 [I.A]). Other pieces of literature emphasize the need for businesses to fit within an ecological framework. Terms used include "industrial ecology" (Tibbs, 1992 [II.A]), "biologic design" (Wann, 1990 [II.A]), and "ecological engineering" (Mitsch, 1993 [II.A]). Hawken (1993) also discusses the concept, under the rubric of dramatically changing the role of the corporate charter to be more ecologically sustainable.

A more management-oriented approach encourages "excellence" in business P2 management. For example, the report from the President's Commission on Environmental Quality (1993) discusses the connection between Total Quality Management (TQM) and P2, and includes many examples. Piasecki (1990) develops the "environmental excellence" concept for businesses as well as other sectors.

Other pieces of the literature do not fit neatly into any category, such as Lai's academic article looking at P2 from a green production and consumption perspective (1993 [III.C]) and Larson et al.'s discussion of society's move towards greater efficiency and reduced material-intensiveness (1986 [II.A]). One chapter in a P2 compilation for engineering students includes a number of engineering ethics creeds, making a connection between the P2 goal and professional ethics (Design for Recycling Team, 1992 [V.A]).

Not all the literature presents P2 in a positive light. For example, Cook (1992) notes that risk of human-induced ecological ruin, and thus the need for P2-oriented businesses, may not be as great as what some authors (particularly Meadows et al., 1992 [II.A]) claim. Taking another tack, Lis and Chilton (1993 [I.C]) note that the benefits of some P2 activities may be less than the implementation costs.

TECHNIQUES FOR IMPLEMENTING POLLUTION PREVENTION PROGRAMS

There is a great deal of literature describing how to design and run an industrial P2 program. Some of these documents can be obtained through libraries; many of them are available from state environmental agencies, the U.S. EPA (particularly PPIC), trade associations, and other sources. The literature mentioned here is sampling of more accessible pieces. Hirschhorn and Oldenburg (1991 [key doc.]) provide an excellent description of the stages of P2 programs, a theme also used by the National Research Council (1985 [I.C]) and Pojasek (1991b). Pojasek also describes 15 P2 program milestones and, in another article (1991a), covers the basic components of an industrial P2 program. Other authors, such as Kenworthy and Schaeffer (1990 [III.C]) and Conway et al. (1989), also describe the components of a successful P2 program. The U.S. EPA Office of Research and Development's *Pollution Prevention Benefits Manual* (1992a) is a one of best known P2 guidance manuals, although numerous others are available.

Much of the literature goes into more detail about particular technical requirements. Such detail is generally not appropriate at this introductory level, but authors such as Keoleian and Menerey (1993 [II.B]) incorporate life-cycle design as way to achieve P2. Dorfman et al. (1992) describe, for a lay reader, specific techniques that can be used to prevent organic chemical waste. Both Kidd (1991 [V.A]) and the Design for Recycling Team (1992 [V.A]) have produced course materials for engineering classes that are general enough to be used in an introductory environmental studies class.

OBSTACLES

Many of the sources thus far include only a brief discussion of the potential obstacles that can hinder a business P2 program. In some ways, this gives P2 a specious "everybody is joining the P2 bandwagon" image. While P2 enjoys the "win-win" prospect of environmental protection and economic benefit, many businesses are not rushing to implement P2 programs.

A number of pieces cover obstacles to P2 in depth, and each has a slightly different perspective. Cebon (1993), in a brief article, identifies three common "business culture" barriers—limited organizational vision, inadequate information flows, and organizational politics. Hirschhorn and Oldenburg (1991 [key doc.]), discussing their four stages of P2, touch on organizational and psychological obstacles in during the crucial Stage 1. Likewise, a pioneering National Research Council report (1985 [I.C]) discusses institutional factors that affect hazardous waste generation and reduction. Geiser (1991) describes why industry has been unwilling to invest in clean technology. In a real-life case study, McDonalds Corporation and the Environmental Defense Fund (1991) give a fascinating description of the challenges they faced in implementing a P2/recycling program. Taking a much broader perspective, Robins and Trisoglio (1992) mention problems facing businesses as they work toward global sustainable development.

INDUSTRIAL POLLUTION PREVENTION INITIATIVES

If the literature is any indication, pollution prevention activities are most likely to take place in an industrial setting, particularly in businesses involved in the manufacturing stage of a product's life cycle. This and the following subsection give references to broader P2 examples in industry as well as other business sectors. Look to Section IV for references to more specific topics.

The core of P2 interest lies in creation and assembly of products. Many of the largest U.S. manufacturers now recognize the benefits of P2, and they have the resources to research and implement changes in their factories. The pollution-intensive chemical industry is particularly noteworthy, as McMurray (1991) points out with P2 examples from many major chemical companies. Freeman et al. (1992 [I.C]) and Forester and Skinner (1992) also mention a variety of industrial P2 programs. Other more general articles, such as those noted in a previous section, invariably highlight manufacturing P2 cases.

Broader, consumer-industry P2 examples include a case study of the overall P2 program at Procter and Gamble (Maxwell et al., 1993) and a comprehensive study of consumer and industry response to source reduction and recycled-content products (U.S. EPA, OPE, 1989). Not all examples of P2 are positively received by industry, as Moberg (1993 [IV.14]) describes in industry's reaction to a proposed elimination of industrial chlorine compounds use.

POLLUTION PREVENTION IN OTHER BUSINESS SECTORS

In the agricultural sector, P2 activities such as organic farming and integrated pest management can dramatically decrease pollution impacts from pesticide manufacture and use. Assuming conservation of resources under the rubric of pollution prevention, such practices as conservation tillage and drip irrigation are also P2 examples; references that discuss them include Bernards (1991 [IV.16]), Hirschhorn and Oldenburg (1991 [key doc.]), Miller (1994 [key doc.]), Mitsch and Jorgensen (1989 [II.A]), and Tolba and El-Kholy (1992 [I.A]). (See also the discussion under Food and Agriculture in the Section IV.). A more controversial P2 approach is a shift from "animal agriculture" to less energy- and material-intensive plant-based agriculture, as described in Holmes (1992 [IV.9]) and Robbins (1992 [IV.9]).

Energy conservation is also a major P2 topic, but, aside from highly technical articles about energy-efficient process changes, governmental and individual actions are much better represented in the literature (see II.B and II.C). The Rocky Mountain Institute is well known for advocating energy efficiency, and its *Negawatts* video (1991 [IV.8]) illustrates how these efforts make sense in businesses. Other works, such as Hirschhorn and Oldenburg (1991 [key doc.]) and Geiser (1991) also touch on energy-efficiency programs in business.

P2 through architectural design is often aimed at achieving energy and other resource savings. The field of "green architecture" has grown significantly in recent years. Scholand (1993 [IV.1]) provides a general introduction to the topic. Environmentally appropriate design in architecture as well as other fields, is addressed in works such as U.S. Congress, OTA, (1992b [II.A]), Wann (1990 [II.A]), as well as in a course taught by Yust (1991 [V.A]). Again, architecture is one of the topics in the next component.

MARKETING POLLUTION PREVENTION

Businesses with successful P2 programs typically want the public to be aware of their efforts. Most marketing, however, is focused on end-products rather than earlier stages in a product's life-cycle. The literature reflects this tendency to focus on green products and marketing, by authors such as Carson and Moulden (1991); Dyllick (1989), and Goldstein (1990). However, some authors such as Garfield (1991) point to green overkill—using deceptive marketing to paint an environmental image.

Packaging is a case in point. For example, Holmes (1993 [IV.13]) discusses P2 packaging options and companies with innovative packaging systems. Other packaging examples include musical compact discs (Kleiner, 1991 [IV.13]) and fast-food containers (McDonald's & EDF, 1991). The latter example, however, offers an excellent example of perception versus reality. While McDonald's polystyrene clamshell hamburger containers have received the most attention, the report points out that greatest life-cycle impacts, and thus most promising P2 opportunities, lie behind the counter, invisible to consumers.

BUSINESS AND GOVERNMENT

This subsection is arranged under the assumption that business, government, and individuals / society are three distinct sectors that, nonetheless, overlap a great deal. A number of business-oriented writers mention the role of government intervention (and assistance) in business P2 programs. The literature here is in fact quite varied. Some authors claim that either government erects regulatory barriers to business P2 programs (Byers, 1991 [I.C]), or that mandated P2 requirements are an unnecessary expansion of government influence (Lis and Chilton, 1993 [I.C]). On the other hand, authors such as Commoner (1992 [I.C]) and Hawken (1993) claim that government is not being forceful enough in advocating P2 amongst businesses. Perhaps the perspective of Scholand (1993 [IV.1]) is most appropriate —that both the pull of voluntary initiatives and the push of regulatory forces increase the level of P2.

III.B Government Management

If there is a role for both business and government in achieving pollution prevention, then what are the mechanisms for government "management" of P2? While the previous section examined broad themes for governmental involvement in P2, this section takes a closer look at specific policies and programs. The focus of this discussion is the federal P2 role, although state, local, and international government programs are also included. Indeed, some state P2 programs are broader in scope than the federal program.

GOVERNMENT AS GUARDIAN

Government at all levels can play a number of roles in promoting P2. One role is that of a "guardian" that intervenes in the affairs or business, organizations, and individuals to prevent as much pollution as governmental bodies deem appropriate (Hawken, 1993 [III.A]). Commoner (1992 [I.A]), for example, calls for "command and control" governmental action to eliminate polluting processes.

Rather than a forceful intervener, government may act as a more passive gatekeeper. For example, government standards could be used to set acceptable boundaries for environmental marketing statements. There are also less severe mechanisms such as requiring businesses and other entities to develop P2 plans. For example, Geiser (1991 [III.A]) and Lieberman (1993 [I.C]) discuss the role of state and federal governments, respectively, in promoting P2 plans. For the most part, the U.S. EPA is working to make its current rule-making and enforcement activities more accommodating to P2 activities, rather than adding further regulatory burdens (Browner, 1993, and Kling & Schaeffer, 1993).

GOVERNMENT AS ASSISTANCE PROVIDER

Traditionally, environmental protection agencies are viewed primarily in the regulator or guardian role. Despite this image, EPA has many efforts underway to encourage rather than dictate P2. In this role, government acts, either directly or through an intermediary, as an assistance provider. Specific avenues include technical assistance to companies, informational assistance (e.g., PPIC), regulatory compliance assistance, and financial assistance (loans, grants and subsidies). Numerous examples of federal, state, and other P2 assistance programs are listed in EPA's annual *Reference Guide to Pollution Prevention Resources* (U.S. EPA, OPPTS, 1993 [key doc.]). Other references include Baucus (1993 [I.C]), who discusses a Senate proposal to encourage environmental technologies; Conn (1977 [I.B), who mentions subsidies and other assistance-type policy options; and the U.S. EPA OPPE (1989), which proposes a joint government / business program to encourage source-reduced and recyclable / recycled consumer products.

GOVERNMENT AS INFORMATION FACILITATOR

In between "government as regulator" and "government as assistance provider" is government's role in obtaining and communicating information about the P2 and other environmental attributes of a business, product, or other entity. In this role, government acts as a prod to facilitate the flow of information.

For instance, the Toxic Release Inventory (TRI) has been widely recognized as an important P2 tool, even though it only requires industries to report, not actually prevent, toxic releases. Making these releases known to the public as well as to the businesses themselves has proven to be significant inducement toward preventing pollution. Moos (1992 [III.C]) and Kenworthy and Schaeffer (1990 [III.C]) discuss how citizens can use TRI data; "How To..." (1993 [I.C]) reflects industry's preference for information disclosure over prescriptive regulations. EPA's 33/50 program to reduce toxic industrial emissions (1991 [I.C]) is one example of how governmental bodies can combine information facilitation with assistance programs to encourage voluntary P2 activities.

GOVERNMENT AS A POLLUTION GENERATOR

The models thus far assume government is taking actions on the affairs of other entities. Government *itself*, however, is a large generator of pollution. As such, it can set an example by implementing P2 measures.

Lewis and Weltman (1992) give 40 detailed suggestions for using the federal's significant purchasing power to promote energy efficiency, pollution prevention, and solid waste reduction. As a recognition of the federal government's tremendous potential as a P2 leader, President Clinton has signed three executive orders. The first requires federal compliance with the Toxic Release Inventory (TRI) and Pollution Prevention Act of 1990, and calls federal agencies to develop toxic chemical reduction goals (U. S. President, 1993a); the second calls for increased federal waste prevention, recycling, and purchases of "environmentally preferable products" (U. S. President, 1993b); the third calls on federal agencies to implement cost-effective energy-efficiency and water-conservation investments at federal facilities (U. S. President, 1994). Even before these executive orders, the U.S. EPA ORD published a guide on reducing the environmental impact of conferences and meetings (1991 [IV.16]). Another article contrasts two similar federal printing offices, one inefficient and the other efficient ("A Paper Tale," 1993).

U.S. EPA'S POLLUTION PREVENTION PROGRAMS

The U.S. Environmental Protection Agency is the lead federal agency not only in promoting P2 policy but also in implementing P2 programs. A useful place to start is Kling and Schaeffer's (1993) one- to two-paragraph descriptions of EPA's many P2 programs and initiatives. The EPA's *Reference Guide to Pollution Prevention Resources* (1993 [key doc.]) describes these programs in more detail. Many of these programs are also described in the NPPC's P2 slide show and accompanying script (1993). A video (*Beyond Business. . .*, [III.A]) introduces some of EPA's programs. Other general overviews of EPA's P2 programs are by Freeman et al. (1992 [I.C]) U.S. EPA (1991 [I.C]) and U.S. EPA OPP (1991a and 1991b [III.A]).

A convenient source for information on EPA's P2 programs is its Pollution Prevention Information Clearinghouse (PPIC), as described in the *Reference Guide,* U.S. EPA, OPPTS (1993 [key doc.]); for contact information, see this compendium's Resource List. PPIC can provide current descriptions of specific programs, such as the Source Reduction Review Project; the 33/50 program (see also U.S. EPA, 1991 [I.C]); the Energy Star initiative for computers (see also Betts, 1994 [IV.16]); Design for the Environment (DfE); and Water Alliances for Voluntary Efficiency (WAVE). Also, U.S. EPA ORD sponsored a compendium of case studies from other P2 programs (1992b).

OTHER NATIONAL PROGRAMS

There are numerous other federal offices with P2 programs. The White House and the Departments of Agriculture, Commerce, Defense, and Energy are particularly active. Many of these programs are partnerships between EPA and other federal agencies. Such partnerships include "Agriculture in Concert with the Environment" (ACE); "National Industrial Competitiveness through Efficiency: Energy, Environment and Economics (NICE^3)"; and "The Clean Technologies Program." Again, general information about these programs can also be found in the U.S. EPA's *Reference Guide to Pollution Prevention Resources* (1993 [key doc.]) and in the NPPC P2 slide show. Other sources of general information about national, non-EPA P2 programs include Freeman et al. (1992 [I.C]) and U.S. EPA OPP (1991a and 1991b [III.A]).

STATE AND LOCAL PROGRAMS

The degree of state and local involvement in pollution prevention programs covers the gamut. Some states have practically no P2 laws nor programs, while others have extensive regulatory and / or assistance programs. Likewise, there some outstanding county and city P2 programs, although many local governments defer P2 issues to state and federal programs. Many of the state programs receive financial assistance through the U.S. EPA's Pollution Prevention Incentives for the States program. The 10 regional EPA offices also provide organizational resources and financial assistance to state and local programs. Once again, the *Reference Guide to Pollution Prevention Resources* (U.S. EPA, OPPTS, 1993 [key doc.]) is an excellent resource for state program descriptions. Other general descriptions of state program and local programs are found in Freeman et al. (1992 [I.C]) and U.S. EPA, OPP (1991b [III.A]). The General Accounting Office (1994) gives a critical view of EPA-funded state P2 programs. Many of the programs, the GAO found, were inordinately involved in waste treatment and other non-P2 activities.

Geiser (1991 [I.C]) describes how state P2 laws have encouraged businesses to engage in more P2 activities. Likewise for energy conservation, Roodman (1993 [IV.8]) describes how state regulatory agencies, along with environmental groups, have been encouraging power utilities to invest in demand side management (DSM) programs to increase the efficiency of electricity use. Although not strictly a P2 initiative, Moore and Scott (1983 [IV.3]) give a balanced analysis of the effects from state beverage container deposit legislation. Jamieson and VanderWerf (1993 [key doc.]) give recommendations for integrating P2 into all of society through state programs. Besides one's own state, information about the more active P2 programs in such states as California, Massachusetts, Minnesota, Washington, North Carolina, and Oregon may be worth acquiring.

For local P2 programs, EPA has published a fact sheet describing P2 mechanisms, such as ordinances, that city or county governments can use (U.S. EPA, OPP, 1991a). Postel (1992 [IV]) gives several examples of cities that have used P2 principles to design water conservation programs. In Denver, a regional EPA staffer helped the city's airport authority integrate P2 features in the new Denver airport (McGraw, 1992 [IV]). Several of the case studies cited by the U.S. EPA ORD (1992b [III.A) take place in state or local government settings, such as state transportation garages or school districts.

INTERNATIONAL PROGRAMS

Governments around the world are developing P2 programs. The United Nations Environment Program (UNEP), in particular, has taken a lead role in promoting "clean production" at the industrial levels (Hileman, 1992 [I.C]). In fact, outside the U.S., P2 is not as common a term as "clean production" or "clean technologies." In addition to industrial P2 programs, many countries in Europe have government sponsored "eco-labels" or similar green-product programs (Lai, 1993 [III.C]; Rose, 1994 [IV.5]; U.S. Congress OTA, 1992b [II.A]).

Much of the literature that mentions non-U.S. governmental P2 programs is incorporated into a broader literature on global environmental sustainability. As the World Conservation Union shows (1991 [I.C]), government-sponsored P2 programs are one facet of a "world conservation strategy." Tolba and El-Kholy (1992 [I.A]) provide a useful reference of, among other topics, environmental management tools with an United Nations orientation. The World Resources reference series (World Resources Institute, 1994 [I.A]) is not only a useful reference, it also features reports on topical global resource and pollution issues

III.C The Role of Individuals and Society

This section has thus far discussed the role of businesses and governments in promoting pollution prevention. These sectors are instrumental, but P2 cannot expect to become a widely implemented environmental management theme without broader public support. This subsection discusses extending the management of P2 beyond the realm of businesspersons and governmental administrators.

"P2 and society" is a controversial topic because it potentially widens the P2 concept to a much wider range of actions. Few people would argue about the benefits of preventing pollution through more efficient industrial processes, while behavior changes such as reducing private automobile use may prevent pollution but are disagreeable to a wide segment of the population (Durning, 1992; Hirschhorn & Oldenburg, 1991 [key doc.]; Jamieson and VanderWerf, 1993 [key doc.]).

However, there are many "win-win" activities at the personal and societal level (see for example U.S. EPA OPPE, 1990, and U.S. EPA OSW, 1992 [III.B]). Activities such as conserving domestic energy and water, reducing household toxics, and buying efficiently packaged

products are seen as positive steps by most parties in the business, government, and household sectors. However, there are many shades of gray between socially acceptable P2 activities and unacceptable curtailment actions typified by the expression "freezing in the dark." For those promoting individual and societal P2, the challenge is to find the proper balance between preventing significant life-cycle environmental impacts and fitting within society's tolerance for change.

WHY EXTEND POLLUTION PREVENTION TO INDIVIDUALS AND SOCIETY?

Perhaps "pollution prevention" should remain a term used primarily in industry. Surely there would be less confusion about the concept if this were the case. However, excluding consumers from influencing what and how products are made is placing all P2 responsibility on producers and the governmental forces that affect them (see Selling Green, 1991). Yet in a free market, consumers, through the process of informed purchasing decisions, can have a significant impact on producers ("Are You . . .," 1992; Gore, 1992 [I.A]; Hirschhorn and Oldenburg, 1991 [key doc.]; Lai, 1993; Schwepker and Cornwell, 1991; U.S. EPA, OPPE, 1989 [III.B]). Furthermore, a variety of non-market activities—one's leisure activities, health choices, family planning decisions, etc.—can have a profound impact on an individual's environmental impact (De Young, 1990–91; Durning, 1992; Lotter, 1993).

INDIVIDUAL BEHAVIORS

As Durning (1992), Frankenfeld (1993 [II.A]), and others argue, one can make a moral argument to personally prevent pollution if the lives of future generations are valued. However, there is often a wide gap between feeling the tug of such an argument and actually engaging in conservation behaviors. The process of getting from concern to ongoing behaviors is an active area of psychological research (Conn, 1983; De Young, 1993a; Henion and Kinnear, 1979 [III.A]; Jamieson and VanderWerf, 1993 [key doc.]; Schwepker and Cornwell, 1991; Stern, 1992; and Winett, 1983). At a more applied level, this calls for personal involvement.

Other authors focus on supplying practical "how-to" information, as is seen with the plethora of "green living" guides (including Caplan, 1990; EarthWorks Group, 1989 and 1991; Elkington, Hailes and Makower, 1990; Harris, 1991; Hirschhorn and Oldenburg, 1991 [key doc.]; Seymour and Girardet, 1987; U.S. EPA OSW, 1992 [III.B]). At least one author, however, points out that green products can be a drain on the pocketbook (Wang, 1990). Nevertheless, there are many different ways in achieve personal P2 goals, and it is clear that such personal participation is a vital force for P2 (Bernards, 1991 [IV.16]; Gore, 1992 [I.A]; Hirschhorn and Oldenburg, 1991 [key doc.]; and Vargish, 1980).

SOCIAL FORCES

Encouraging P2 through personal involvement and behavior change is complemented by a broader social perspective. An EPA brochure that shows how individuals "can make a difference" also encourages them to set an example for others (U.S. EPA, OPPE, 1990). Many of the above-referenced sources that discuss personal actions also describe organizational and societal roles in bringing about P2 (Conn, 1983; Durning, 1992; Gore, 1992 [I.A]; Hirschhorn and Oldenburg, 1991 [key doc.]). The *Cultural Barriers to Behavioral Change* report (Jamieson and VanderWerf, 1993 [key doc.]) is notable in blending personal and societal P2 themes into a well-referenced summary and recommendations for state P2 programs. Other works touch on a variety of themes that can help society emphasize P2 (Peet, 1992 [I.A]; Piasecki, 1990 [III.A]; Stern et al., 1992; Uusitalo, 1986 [II.A]; World Conservation Union et al., 1991 [I.C]). Some authors make an appeal for more involvement in the democratic process (Gore, 1992 [I.A]); the economic system (Gore; Hawken, 1993 [III.A]); the environmental affairs of industry (Kenworthy & Schaeffer, 1990; Moos, 1992); and citizen groups and other non-governmental organizations (NGOs) (Bernards, 1990 [IV.16]; Caplan, 1990; EarthWorks , 1991; and Piasecki, 1990 [III.A]).

CONCLUSION

Altogether, the management of P2 does not break neatly into business, government and individual/society categories. There are other important forces that are outside or between these categories. Social forces, for example, encompass organizational behavior in both businesses as well as government. And government forces, often influencing businesses, are a rough proxy for the concerns of individuals. Perhaps the largest sector that has been excluded in this discussion is the "voice" of the non-human forms of life. Their voice may be louder than we realize, since natural processes can be models in efficiency and P2 (Wann, 1990 [II.A]). The next section gives examples of P2 activities that can help humans move toward nature's enviable model.

IV. Pollution Prevention in Practice

After students have been introduced to pollution prevention concepts, life-cycle impacts, and P2 management strategies, it is time for them to apply this knowledge to relevant topics. This section lists topic areas for students to explore for examples of P2. Under each topic is a brief description of potential issues plus references from the bibliography for further exploration. (Refer to the Annotated Bibliography for a complete citation and a lengthier description of each listed resource).

Topic areas were chosen for both the availability of resources and their appeal to introductory environmental studies students. A common theme throughout these topics is that P2 can have many facets—it can take place at the resource extraction, manufacturing, use, and post-use stages of a product's life-cycle; it can be initiated at farms, factories, households, and many other contexts; it can occur through the efficient use of resources as well as through reduction in pollutants; and it can be through any combination of reducing impacts to air, water, land, and energy.

Teachers can use this component as a basis for examining P2-related issues around a particular topic. You may wish to develop a discussion session, case study, or exercise around one or more of these topics. Likewise, students may want to use this section as a starting point for class projects or term papers. As with the other sections of this document, this section is far from comprehensive in listing relevant topics and resources. Consider this a starting place for further exploration, and keep in mind that there are often local examples and resources that can enrich students' learning experience. Topics are arranged alphabetically, with a collection of miscellaneous categories at the end.

■ Agriculture and Food Production

Food and agriculture may seem quite different from the typical industrial scenario for P2 programs, but there are many opportunities in this sector. At the resource extraction stage, issues of how food is grown —including tillage practices and soil conservation, water use, pest management / pesticide use, fertilizer use, and plant bio-engineering—are all areas with P2 opportunities. There are some manufacturing-stage P2 issues with how food products are processed and sometimes even "manufactured." A potential case study topic is a comparison of the life-cycle impacts of similar foods, one packaged and the other fresh. While the packaged foods may appear overpackaged, there can be hidden benefits such as decreased spoilage and lower transportation costs. For other foods, however, bulk merchandising can reduce life-cycle impacts. Clearly, consumers play a role here in their food product buying decisions. At the usage stage, students may want to examine the relationship between excessive food consumption and life-cycle impacts on both the ecosystem and humans. Post-use impacts in the food sector include both food and packaging waste management issues.

RESOURCES

Bernards, 1991—pro and con debate-style statements about the effect of low input agriculture

Durning, 1992 [III.C]—book chapter discussing global impacts from farming, the food system, and excessive food consumption, with suggestions for change

Elkington et al., 1990 [III.C]—chapter describing environmentally responsible personal actions for food products

Gore, 1992 [I.A]—book chapter addressing issue of food resources, and offering suggestions for change

Hirschhorn and Oldenburg, 1991 [key doc.]—book chapter about pollution prevention in agriculture

Holmes, 1992—article describing the environmental benefits of decreased meat consumption

Hume, 1991—article describing the environmental initiatives underway at the McDonalds fast-food chain

Keoleian and Menerey, 1991-92—article with case study of bulk grocery products merchandising

Lefferts and Blobaum, 1992—article about environmental aspects of food choices

McDonald's and EDF, 1991 [III.A]—report describing the waste reduction options and challenges for the McDonald's fast food chain

Orr, 1989 [II.A]—article describing a comprehensive ecological investigation of a college's food service

Robbins, 1992—article describing the environmental impacts of "animal agriculture"

Where Our Food Comes From, 1989—video showing the environmental implications of the food industry

World Resources Institute, 1994 [I.A]—reference book with data about worldwide food production and agriculture

Architecture

Connecting architecture with pollution prevention illustrates the power of the life-cycle impacts approach. An excellent opportunity for increasing energy efficiency, reducing indoor air pollution, and making best use of building space is at the design stage—preventing pollution through architectural design. Therefore, architects have a key role in promoting P2 through their practice. An entire resource compendium could be devoted to this broad topic, but specialized architectural knowledge is not necessary to explore this topic.

Potential topics include:

- Use the LCA framework to examine impact and P2 opportunities at each stage of a building's "life-cycle" (design, construction, use, demolition).
- Pick a building (home, dorm, school building, etc.) and note what changes could be made if building it again with P2 in mind.
- What opportunities are there for local, state, or federal government to encourage P2 in buildings? Possible answers include: building codes and inspections, property taxes, low-interest loans, building material standards, government purchasing, and regulated utility rates.
- How does a building's location and construction affect P2 opportunities? Transportation and solar energy are two possible impacts to consider.

RESOURCES

Hayes, 1992 [I.C]—text of a speech calling for increases in energy efficiency, particularly in architecture

Lewis & Weltman, 1992 [II.B]—book with suggestions for increasing energy efficiency and reducing pollution in federal government buildings

McGraw, 1992—article outlining efforts to incorporate P2 features in constructing the new Denver airport

Scholand, 1993—article describing new trends in energy efficient commercial and residential buildings

U.S. President, 1994 [III.B]—calls for increased fuel efficiency and water conservation in federal buildings

Wann, 1990 [II.A]—book giving examples of designing environmental protection in buildings

Batteries

Pollution prevention issues with batteries includes reducing the toxicity of materials found in batteries (including lead, cadmium, and mercury); increasing the life of batteries; designing battery-powered products to use less electricity; and, after all prevention options have been exhausted, recycling batteries in an environmentally sound manner. The resources below collectively provide a useful primer on the environmental impacts of batteries. Students may want to look at their own battery use or survey others, and examine opportunities to prevent battery-related pollution at the raw-material, manufacturing, use, and post-use stages of a battery product-system's life-cycle.

RESOURCES

Carpi, 1994—article about the impacts of battery disposal and new "green battery" technologies

Gasbarro, 1991—primer on batteries and how to minimize their environmental impact

Hirschhorn and Oldenburg, 1991 [key doc.]—portions of a book describing impacts and alternatives for household battery use

Beverage Containers

Beverage containers provide a good opportunity to look at comparative life-cycle impacts. Several beverage container product-systems can be compared: PET plastic bottles, glass bottles (reusable or "one-way"-recyclable), and aluminum cans. A comparative analysis is especially appropriate for illustrating the importance of life-cycle environmental impacts that are not readily apparent to the consumer. For example, many consumers may perceive recyclable glass bottles as environmentally superior to plastic ones. However, plastic bottles use significantly less material than glass, thereby reducing resource extraction, manufacturing, and transportation life-cycle impacts. Whether plastic is superior to recyclable glass depends on a host of other life-cycle impact factors. Reusable glass containers may have even fewer life-cycle impacts, but again key assumptions such the number of times the bottle is reused can significantly alter the conclusion. Unfortunately, much of the life-cycle impact information for beverage containers is either out of date or not easily accessible.

RESOURCES

Allen et al., 1992 [V.A]—one of a set of P2 engineering design problems examining the environmental impacts of soft drink containers

Durning, 1992 [III.C]—book with information about environmental impacts of packaged beverage consumption

Dyllick, 1989 [III.A]—case study examining a yogurt-maker's switch from plastic to reusable glass containers

Hirschhorn & Oldenburg, 1991 [key doc.]—book with a small amount of information about glass and plastic beverage bottles

Moore and Scott, 1983—article examining the environmental and other impacts of beverage container deposits

U.S. EPA, OPPE, 1989 [III.B]—report examining environmental marketing issues for consumer products, including beverage containers

■ Campus Initiatives

Students are becoming increasingly aware that pollution prevention opportunities exist under their noses! A diverse coalition of students, campus plant staff, environmental groups, and faculty members is appearing on campuses around the country. As with many other P2 efforts, typically these initiatives yield environmental benefits as well as cost savings for school administrators. Promising areas include energy conservation in heating, cooling, and lighting, water conservation, waste reduction, indoor air pollution, lab chemicals minimization, and transportation.

Institutions including the University of Kansas, the University of Wisconsin, Brown University, and Tufts University have innovative programs. The National Wildlife Federation (NWF) and Student Environmental Action Coalition (SEAC) also have "greening the campus" programs.

RESOURCES

EarthWorks Group, 1991 [III.C]—environmental action guide for students

Orr, 1989 [II.A]—article describing a comprehensive ecological investigation of a college's food service

■ Cleaning and Cleaning Products

Cleaning products and related cleaning issues are relevant to individuals, businesses, and industry alike. As the descriptions below indicate, there are a variety of perspectives on this issue. Most of the attention is on providing an environmentally appropriate product that is properly labeled. Looking further back in the product's life-cycle, impacts from manufacturing and resource extraction are also important. Specific issues that may be worth examining include: ingredient disclosure, by-products from manufacturing, toxic ingredient reduction, post-use impacts of cleaner use and packaging, efficient packaging, eco-marketing, business product stewardship, and the efficacy of "green" versus standard products.

RESOURCES

Harris, 1993 [III.C]—article about reducing environmental impacts from clothes washing

Hirschhorn & Oldenburg, 1991 [key doc.]—detailed book chapter on household toxics, including cleaning products

Maxwell et al., 1993 [III.A]—case study article mentioning Proctor and Gamble's cleaning products P2 efforts

Rose, 1994—article about the controversy with detergent eco-labels in Europe

Schmidheiny, 1992 [III.A]—book with case studies of environmental stewardship, including several cleaning product corporations

Walley et al., 1992 [II.B]—producer-sponsored article outlining a life cycle assessment of baking soda

■ Diapers

The debate between using disposable or reusable diapers is a classic environmental controversy. The issue is interesting enough to examine in both substance and form. On a substantive level, the seemingly abhorrent disposable diaper and the supposedly innocuous cotton diaper may neither be clear winners when all life-cycle impacts are considered. In form, the diaper debate epitomizes how the supposedly rational life cycle analysis process can be immersed in rhetoric and emotion. It also shows how varying assumptions can be used to reach different conclusions.

The debate itself makes for an interesting case study, partly because dueling LCAs are unable to produce a clear winner. Some relevant factors:

- Consider local conditions when deciding what type of diapers are locally superior. For example, a short-haul diaper service may allow economies of scale for transporting and washing reusable diapers. A community with very scarce landfill space is likely to be more concerned about the solid waste impacts of disposable diapers, while another community with scarce water supplies may be more concerned about water and sewage impacts associated with laundering cotton diapers.
- Cloth and disposable diapers are not completely comparable. Some experts argue that cloth is better next to a baby's skin, while others favor the wicking feature of disposable diapers.
- Direct diaper costs may not include hidden costs such as labor and transportation. Generally, cloth diapers are going to be less expensive to buy, but they typically require more labor—more frequent changes and washing time (if done at home). Disposable diapers trade reduced labor intensity for greater material intensity. For many people, this tradeoff is worthwhile.
- Most consumers do not directly pay for the solid waste costs of disposable diapers. Household solid waste disposal fees are often a set fee per month or part of a community's property taxes. However, communities with volume-based solid waste disposal fees may affect parents' diapering decisions.

RESOURCES

Arthur D. Little, 1990—disposable vs. cloth LCA (including environmental, health, and economic impacts) sponsored by a disposable diaper maker

Bernards, 1991—pro and con debate-style statements about the use of cloth diapers

Crossen, 1994 [II.C]—article describing the use of "tactical research" for disposable diapers and other products

Green Revolution, 1991—article mentioning the disposable diaper issue from an industry perspective

Holusha, 1990—article about the cloth-versus-disposable diaper debate

Keoleian and Menerey, 1991—case study of day-care center that switched from disposable to cotton diapers

Koshland, 1990 [II.C]—editorial welcoming the rationality of the LCA process in the diaper debate

Lehrburger, 1989—cotton diaper-industry supported report comparing cotton and disposable diapers

Poore, 1992—article presenting the cloth vs. disposable diaper debate as an example of environmental hyperbole; includes an inset comparing cloth and disposables

Proctor and Gamble, 1993 [V.A]—K-12 teaching materials, including an activity evaluating cloth and disposable diapers

Drinking Cups and Dishware

Martin Hocking in 1991 demonstrated the practicality of life-cycle assessments by showing, in two pages, the environmental superiority of polystyrene foam drinking cups over paper cups. Although his work has been criticized, and some of the manufacturing processes he analyzes are no longer dominant, it shows that a LCA need not be a magnum opus. Related issues to examine include reusable (plastic and / or porcelain) containers versus either polystyrene or paper cups and the environmental impacts of dishwashing.

RESOURCES

Allen et al., 1992 [V.A]—one of a set of P2 engineering design problems comparing polystyrene and paper drinking cups

Design for Recycling Team, 1992 [V.A]—set of engineering design problems including one comparing paper and polystyrene cups

Hocking, 1991 [II.B]—article with a short LCA of paper vs. polystyrene drinking cups

Keoleian and Menerey, 1991—article case study of a hospital cafeteria that switched from polystyrene to washable ceramic dishware

McDonald's Corporation, 1991 [III.A]—report with portions that discuss fast-food drinking cup and dishware options

Wells et al., 1991 [II.C]—comments criticizing or complementing Hocking's 1991 article

Energy Production and Conservation

Many activities can be ultimately reduced to energy and material flows. Energy use and conservation is an extensive area that has been widely investigated from both technical and socio-behavioral perspectives. Energy conservation is, in fact, often treated separately from P2. It is included here because, within the overall rubric of reducing life-cycle impacts, the potential of energy conservation programs are enormous. For instance, the references in the architecture and transportation sections are primarily about energy conservation.

Specific issues that could be addressed include: life-cycle impacts of different types of energy, connections between energy conservation and reduced air pollution, global change and energy use, demand-side energy management (DSM) programs, energy use by the federal government, energy conservation research, and energy efficient lighting. There are no doubt many more issues connecting energy and P2.

RESOURCES

Elkington et al., 1990 [III.C]—book chapter describing home energy conservation strategies

Gore, 1992 [I.A]—book chapter describing energy use and conservation strategies

Hayes, 1992 [I.C]—text of a speech calling for increases in energy efficiency, particularly in architecture

Hirschhorn & Oldenburg, 1991 [key doc.]—book with small section on energy conservation

Lovins, 1990 [I.C]—article about reducing air pollution through energy efficiency measures

Rocky Mountain Institute and U.S. EPA, 1991—video showing the economic and environmental benefits of energy efficiency

Roodman, 1993—article describing demand-side management programs for reducing electricity use

Tracey, 1992—article discussing the advent of energy efficient lighting products

U.S. Congress, OTA [III.B]—report examining mechanisms to reduce carbon dioxide emissions

U.S. President, 1994 [III.B]—executive order calling for energy efficiency in federal buildings

World Resources Institute, 1994 [I.A]—data about worldwide energy use and conservation

Industrial Pollution Prevention

Students in an introductory environmental studies course are less likely to be familiar with industrial settings than, say, engineering students. However, industry is at the forefront in advancing the P2 theme. Students may also find it useful to look at industrial P2 programs in order to gain a better grasp of life-cycle impacts and P2 opportunities at the manufacturing stage. Industry is also the major source for toxic pollutants, which are the focus of the federal Pollution Prevention Act of 1990 and similar state laws.

There is particularly good information about P2 in the following areas: chemicals, metalworking, solvent use and reduction, lubricating oil, oil refining, printing, and electroplating. The U.S. EPA's Pollution Prevention Information Center (PPIC) also distributes much topic-specific information on industrial P2.

RESOURCES

Allen, 1992 [V.A]—includes an engineering design problem for prioritizing P2 opportunities at a petroleum refinery

Conway et al., 1989 [III.A]—describes P2 and recycling practices and auditing; specific information about solvent and used oil recovery

Design for Recycling Team, 1992 [V.A]—includes first-year engineering unit on "design for disassembly"

Dorfman et al., 1992 [III.A]—book profiling 29 organic chemical plants' P2 efforts

Forester and Skinner, 1992 [III.A]—book describing examples of no- and low-waste technologies around the world

Kenworthy and Schaeffer, 1990 [III.C]—citizen's guide for using TRI and other data to encourage industrial plants to reduce pollution

Keoleian and Menerey, 1991–92—case study of process improvements at a office furniture manufacturer

Kidd, 1991 [V.A]—outline for a 15-week hazardous waste reduction course, including modules on used oil, solvents, and rinsing systems

McMurray, 1991 [III.A]—article describing the chemical industry's newfound enthusiasm for P2

Metal Industries . . ., 1993—compilation of fact sheets about P2 opportunities in the metal manufacturing and finishing industries

Moberg, 1993—article about the campaign to ban the industrial use of chlorine

Moos, 1992 [III.C]—article describing how Toxics Release Inventory (TRI) data can be used to encourage companies to reduce pollution

Schmidheiny, 1992 [III.A]—book with case studies of environmental stewardship with industrial corporations

Smart, 1992 [III.A]—compilation of company releases and other information illustrating businesses' efforts to reduce pollution and protect the environment

U.S. EPA, 1986 [II.C]—video highlighting industry P2 success stories

U.S. EPA, OPP, 1991a—comprehensive report describing government-sponsored industrial P2 programs

Shopping Bags

Grocery shoppers typically face a decision at the grocery check-out lane—"paper or plastic?" Actually, there are at least three grocery bag choices—kraft paper, polyethylene plastic, or reusable cloth bags. Paper may be perceived by many students to be the environmentally preferable choice, but on an environmental basis alone (not including factors such as performance, personal preference, litter, etc.) the evidence suggests that plastic bags are better. Unfortunately, most of the analysis to date has centered on paper vs. plastic, with little comparative analysis of cloth bags.

This issue is simple enough to encourage students to do an actual life cycle assessment in class; it could also be covered in lecture. Some of the important points of a shopping bag LCA include the following:

- Whether or not the bag is recyclable may be only the tip of the iceberg. Many of the impacts occur at the resource extraction and manufacturing stage but are sensitive to bag capacity, degree of reuse or recycling, and similar consumption factors.
- On a gram-for-gram basis, plastic resin may have more environmental impact. However, for a given amount of groceries, much more kraft paper is used, with accordingly greater impacts.
- Post-use impacts can be a major factor—if a household can reuse one type of bag while the other is thrown away, that may significantly change the total product-system impact.
- Paper vs. plastic is not the only LCA comparison that can be made. LCA may find both inferior to cloth sacks. A three-way comparison is difficult, particularly with the lack of data.
- There are a number of impacts, such as cultural preferences and ecological damage, that are not readily reducible to objective facts.

RESOURCES

Allen et al., 1992 [V.A]—one of a set of P2 engineering design problems comparing plastic and paper shopping bags

Hirschhorn & Oldenburg, 1991 [key doc.]—section in book on shopping bags and other grocery packaging

Transportation

Transportation is a many-faceted topic that lends itself to a P2 discussion session or problem-solving exercise. One can approach the issue from the perspecive of resource conservation (reducing the use of petroleum as well as roadway materials and space, automobile materials, airports, etc.) and/or emissions reduction (automobile exhaust, runoff from roads, groundwater contamination by petroleum products, etc.). P2 in the transportation sector goes far beyond mere technical concerns—transportation systems in the USA are intertwined with our culture.

Some points to consider include: life-cycle impacts of alternative fuels (natural gas, batteries/electricity, gasoline, ethanol); resource extraction and manufacturing impacts of car-making; air pollution impacts of different transportation systems (auto, train, plane, bicycle, etc.); other transportation system use-stage impacts (noise, land use, fuel consumption, etc.); cultural expectations, transportation systems and P2; eco-marketing of P2 transportation schemes; government forces and transportation systems; the 1990 Clean Air Act's trip-use reduction requirement; vehicle repair and maintenance and P2; and telecommuting and other transportation alternatives.

RESOURCES

Ayers, 1993—article describing the use of bicycles for basic transportation needs

Baldwin, 1993—article describing new environmental developments for automobiles

Bernards, 1991—pro and con debate style statements about alternative fuels

Durning, 1992 [III.C]—book chapter with data and description of transportation impacts worldwide; includes suggestions for change

Flavin, 1993—article describing innovations in energy efficient, low polluting automobiles

Holmes, 1993—article about the benefits and drawbacks of telecommuting

Lewis & Weltman, 1992 [II.B]—brief section on government procurement of efficient vehicles

Rocky Mountain Institute and U.S. EPA, 1991—video discussing different technologies for more efficient automobiles

Automotive Repair, Maintenance, Salvage Yards, Painting, Radiators, 1993—compilation of P2 fact sheets for automotive repair and maintenance shops

Water Pollution and Conservation

Preventing water pollution and conserving water use are both rich areas for exploration. The literature listed does not reflect the large number of issues that could be examined. Potential water pollution prevention issues include: protecting drinking-water watersheds, preventing non-point sources of water pollution (agriculture, roadways, etc.), and eliminating toxic discharges to sewers. A related group of issues include: efficient industrial use of water, xeriscaping (low water-use landscaping), more effective agricultural water usage, gray water reuse, domestic water conservation, and water transmission leakage reduction.

RESOURCES

Gore, 1992 [I.A]—book chapter on water use and conservation around the planet

Mitsch, 1989 [II.A]—book with numerous water-based examples of "ecological engineering"

Postel, 1993—article about increasing the efficiency of water use and case studies of water conservation programs

Seymour and Girardet, 1987 [III.C]—book chapter about conserving household water use

U.S. EPA, *Turning the Tide,* 1991—video showing the many actors involved in reducing non-point water pollution

U.S. EPA, OPP, 1991b [III.B]—fact sheet with a model local ordinance for reducing industrial pollutants discharged to sewers

U.S. President, 1994 [III.B]—executive order calling for water conservation in federal buildings

World Resources Institute, 1994 [I.A]—reference book with extensive data about water use and pollution

Miscellaneous Consumer Products

There are many more consumer-oriented products and other topics than are listed here. These listed resources can provide a starting place for further exploration. Other consumer products worth pursuing include: personal care products, medicines, lawn and garden products, pet supplies, gifts, compact disk packaging. Additional topics for discussion include "eco-marketing," consumer vs. producer P2 roles, environmental labeling, visible and behind the scenes pollution impacts of consumer products, household hazardous wastes, and the purposes of packaging. The resources below give some idea how wide the scope of this sector can be. Not included are resources that are specifically relevant for one of the specific topics.

RESOURCES

Carson and Moulden, 1991 [III.A]—book of green business strategies, especially for selling consumer products

Durning, 1992 [III.C]—book describing the impacts from consumer society and what to do about it

Elkington et al., 1990 [III.C]—guide to green consumer products and environmentally responsible individual actions

Holmes and Poore, 1993—article discussing current packaging issues from an environmental perspective

Kleiner, 1991—article describing efforts to reduce the amount of compact disk packaging

Maxwell et al., 1993 [III.A]—case study about Proctor and Gamble's efforts to reduce pollution associated with their consumer products

Schmidheiny, 1992 [III.A]—book with case studies of environmental stewardship of consumer product corporations

"Selling Green," 1991 [III.C]—critical article about

\eco-marketing from a consumer perspective

U.S. EPA, OPPE, 1989 [III.B]—report summarizing the literature about environmental marketing

U.S. EPA, OSW, 1992 [III.C]—consumer guidebook for reducing solid waste

Multi-Subject References and Miscellaneous Topics

Books that include a variety of P2 topics are listed here. Many of these resources are also listed under specific topics. These resources are a good place to start for finding additional P2 topics.

RESOURCES

Betts, 1994—article about "green computers"; includes a description of EPA's Energy Star program

Caplan, 1990 [III.C]—book with individual and political action strategies for a number of topics

EarthWorks Group, 1989 [III.C]—"50 Simple Things You Can Do to Save the Earth"

Elkington et al., 1990 [III.C]—book with advice for green consumers

Gore, 1992 [I.A]—book with chapters on tools for achieving environmental balance with the earth

Harris, 1991 [III.C]—book describing "choices for environmentally sound living"

Hirschhorn and Oldenburg, 1991 [key doc.]—data-rich book describing P2 opportunities for industry and consumers

Lotter, 1993 [III.C]—guidebook for determining one's personal "Earthscore" across a variety of pollution and resource use categories

Paper Tale, A, 1993 [III.B]—article describing inefficient and efficient federal government printing services

Schmidheiny, 1992 [III.A]—book describing models of corporate environmental stewardship

Seymour and Girardet, 1987 [III.C]—book with suggestions for individual actions to minimize pollution and reduce resource use

U.S. EPA, OPPE, 1990 [III.B]—pamphlet describing P2 actions individuals can take

U.S. EPA, ORD, 1991—report describing "how to run a conference as a clean product"

Wang, 1990 [III.C]—article profiling the finances of a family that strives to be "green"

Wann, 1990 [II.A]—book with numerous examples of the author's "biologic" concept—modeling processes after efficient natural designs

Other Potential Topics

There are countless other topics that can be used to apply pollution prevention concepts. A few additional topics include:

– Improving indoor air quality using P2

– Office paper waste prevention

– Reducing CFC production and use

– Eliminating chlorine bleaching in paper making

– Increasing the efficiency of direct mail campaigns

– Preserving greenspace and preventing pollution

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The mission of the NPPC is to promote sustainable development by educating students, faculty, and professionals about pollution prevention; create educational materials; provide tools and strategies for addressing relevant environmental problems; and establish a national network of pollution prevention educators.

In addition to developing educational materials and conducting research, the NPPC also offers an internship program, professional education and training, and conferences.

The NPPC provides educational materials through the World Wide Web at this URL: **http://www.umich.edu/~nppcpub/** Please contact us if you have comments about our online resources or suggestions for publicizing our educational materials through the Internet.