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ABSTRACT

This learning module aims to engage students in problem solving, critical thinking, scientific inquiry, and cooperative learning. The module is appropriate for use in any introductory or intermediate undergraduate course that focuses on human-environment relationships. The module stresses the key principals, concepts, and problems in the emerging field of industrial ecology. It focuses on three broad themes: the linkages among technological change, industrial change, and global environmental change; the utility of a systems approach to analyzing industrial activity; and the opportunities and constraints involved in making industries more closely resemble ecosystems in their productive and consumptive processes. Activities in the module are designed to address these themes through more specific scenarios, such as product life cycle analyses and the examination of local businesses. The module contains 6 figures, a guide, a summary, an overview, a glossary, references for all units, supporting materials, and suggested readings. It is divided into thematically coherent units, each of which consists of background information, teaching suggestions, student worksheets, and the answers expected for each activity. (BT)

HANDS-ON!

Industry in Concert with the Environment: Technological Change and Industrial Ecology

An Active Learning Module
on the
Human Dimensions of Global Change

HANDS-ON!

DEVELOPING ACTIVE
LEARNING MODULES ON THE
HUMAN DIMENSIONS OF GLOBAL CHANGE

Industry in Concert with the Environment: Technological Change and Industrial Ecology

Module developed for the AAG/CCG2 Project
"Developing Active Learning Modules on the Human Dimensions of Global Change"

by

James Eflin
Department of Natural Resources and Environmental Management
Ball State University
Muncie, IN 47306
e-mail: jeflin1@wp.bsu.edu

Significant revisions contributed by CCG2 Summer 1996 workshop participants Sarah Bednarz (Texas A&M University), Michael Coles (Clark University), Susan Cutter (University of South Carolina), Lisa Graumlich (University of Arizona), Paul Laris (Clark University), Tom Lewis (Manchester Community Technical College), Susi Moser (Clark University), Shannon O'Lear (Syracuse University), Bimal Paul (Kansas State University), and Frances Slater (University of London), and by Jeremy Holman (Clark University), Project Staff.

Developing Active Learning Modules on the Human Dimensions of Global Change
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1710 Sixteenth Street NW
Washington, DC 20009-3198
Phone: (202) 234-1450
Fax: (202) 234-2744
Internet: gaia@aag.org

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Editor's Note

A major goal of this project "Developing Active Learning Modules on the Human Dimensions of Global Change," is to disseminate instructional materials that actively engage students in problem solving, challenge them to think critically, invite students to participate in the process if scientific inquiry, and involve them in cooperative learning. The materials are appropriate for use in any introductory and intermediate undergraduate course that focuses on human-environment relationships.

We have designed this module so that instructors can adapt it to a wide range of student abilities and institutional settings. Because the module includes more student activities and more suggested readings than most instructors will have time to cover in their courses, instructors will need to select those readings and activities best suited to the local teaching conditions.

Many people in addition to the principle author have contributed to the development of this module. In addition to the project staff at Clark University, the participants in the 1996 summer workshop helped to make these materials accessible to students and faculty in a variety of settings. Their important contributions are recognized on the title page. This module is the result of a truly collaborative process, one that we hope will enable the widespread use of these materials in diverse undergraduate classrooms. We have already incorporated the feedback we have received from the instructors and students who have used this module, and we intend to continue revising and updating the materials.

I invite you to become part of this collaborative venture by sending your comments, reactions, and suggested revisions to us at Clark. To communicate with other instructors using hands-on modules, we invite you to join the Hands-on listserve we have established. We look forward to hearing from you and hope that you will enjoy using this module.

Susan Hanson
Project Director

School of Geography
Clark University
950 Main St.
Worcester, MA 01610-1477
ccg2@vax.clarku.edu

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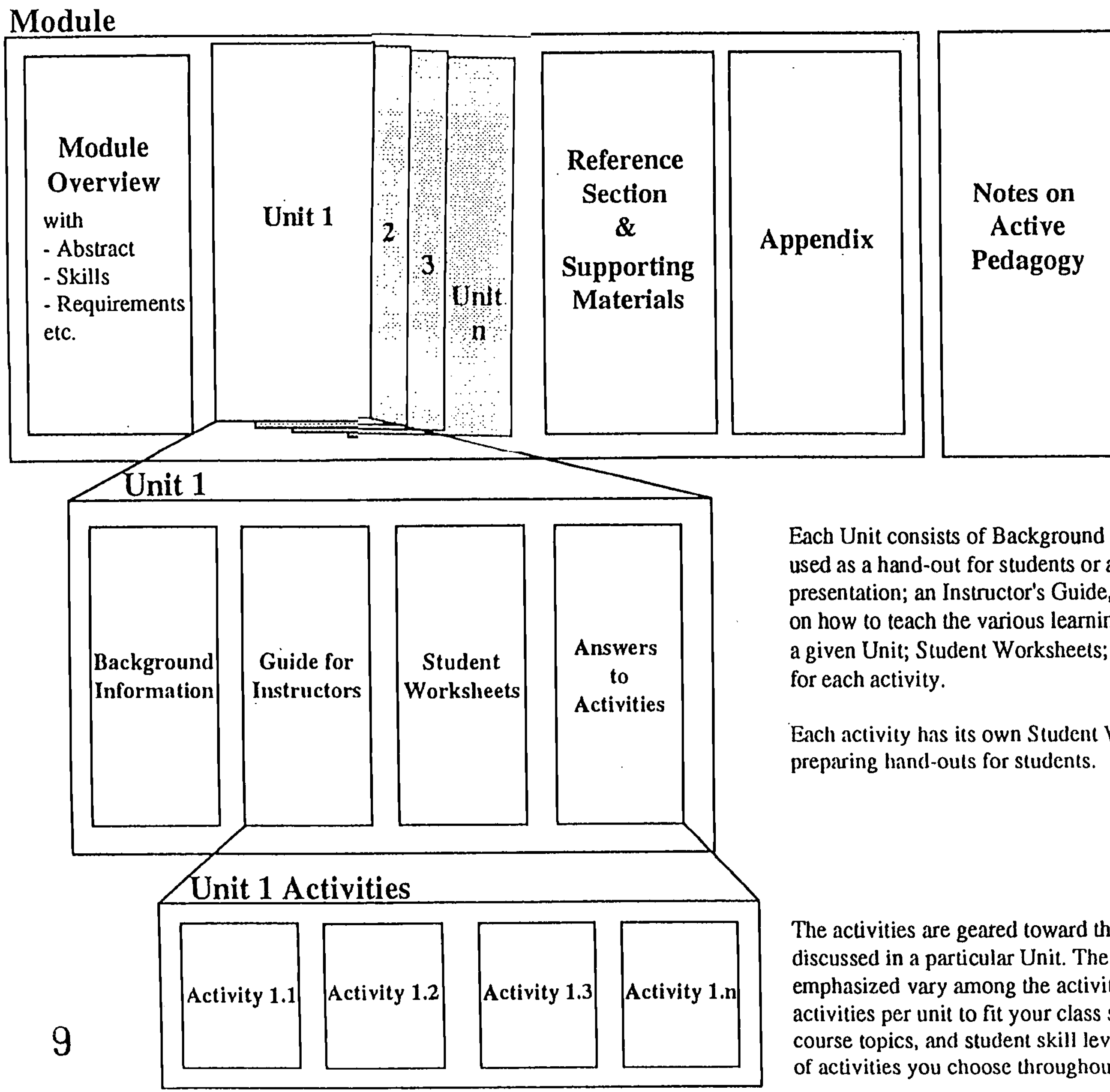
Guide to this Module

This guide is meant to help you navigate this module.



The module is divided into Units, i.e., sections that are thematically coherent and that could, if necessary, stand alone. In addition, the module contains a Reference Section, Supporting Materials and an Appendix. The Supporting Materials can be used to facilitate the teaching of this module or simply to augment it with interesting ideas and information. Additional sections with further information may or may not be present, e.g., a list of accronyms, or a glossary. A separate section on Active Pedagogy comes with every module purchase.

Each Unit consists of Background Information that can be used as a hand-out for students or as the basis for an in-class presentation; an Instructor's Guide, consisting of suggestions on how to teach the various learning activities associated with a given Unit; Student Worksheets; and the Answers expected for each activity.

Each activity has its own Student Worksheet for ease of preparing hand-outs for students.

The activities are geared toward the theme(s) and concepts discussed in a particular Unit. The particular skills and themes emphasized vary among the activities. Choose one or more activities per unit to fit your class size, time, resources, overall course topics, and student skill levels. Be sure to vary the types of activities you choose throughout the module.

Summary: Industry in Concert With the Environment: Technological Change and Industrial Ecology

Abstract

This module stresses the key principles, concepts, and problems in the newly emerging field of industrial ecology. The focus is on three broad themes: the linkages among technological change, industrial change, and global environmental change; the utility of a systems approach to analyzing industrial activity; and the opportunities and constraints involved in making industries more closely resemble ecosystems in their productive and consumptive processes. The activities are designed to address these themes through more specific scenarios, such as product life cycle analyses and the examination of local businesses.

Module Objectives

The module has four major objectives:

- to demonstrate the linkages between industrial processes and the environmental and human aspects of global change at a variety of scales.
- to involve students in using a systems approach to understand industrial processes and draw analogies to ecological processes.
- to enable students to make generalizations about technological innovations and change.
- to demonstrate the opportunities, constraints, and values involved in the industrial ecology approach to building industrial systems in tune with the environment.

Skills

- ✓ data gathering (field work), presentation, analysis, and interpretation
- ✓ interviewing
- ✓ map reading and interpretation
- ✓ critical reading and writing
- ✓ role playing
- ✓ creative writing
- ✓ library/Internet research
- ✓ debating
- ✓ oral presentation
- ✓ team collaboration
- ✓ issue analysis and position formation

Activities

Activities are designed for individuals, small groups, and/or the entire class:

- ✓ group discussions
- ✓ map/collage presentation
- ✓ quantitative data gathering and interpretation
- ✓ film review and interpretation
- ✓ debate
- ✓ field work (local industry and the
- ✓ home)
- ✓ critical reading and writing

Material Requirements

- ✓ Student Worksheets (provided)
- ✓ Suggested readings (some provided)
- ✓ World map
- ✓ Colored markers or thumb-tacks
- ✓ Access to World Wide Web (optional, but very helpful)
- ✓ Film *Koyaanisqatsi* (optional)

Human Dimensions of Global Change Concepts

- ✓ technological change
- ✓ systems, feedbacks, inputs, and outputs
- ✓ thermodynamics, entropy
- ✓ Type I, II, and III ecologies
- ✓ industrial ecology
- ✓ industrial metabolism

- ✓ driving forces
- ✓ impacts

Geography Concepts
- ✓ scale (local-global)
- ✓ core-periphery relationships
- ✓ nature-society relations

Time Requirements
2-3 weeks (i.e., 2 sessions per unit)

Difficulty
Intermediate to challenging. Students learn to apply system, ecology, and thermodynamics terminology to industrial systems at the local (firm) to global (North-South) scales through critical readings, field research, and discussions.

Module Overview

The word ***industry*** often conjures up images of dirty gray buildings with smokestacks that soil the air and drainpipes that pollute rivers. This module takes a much broader view of industry, proposing that industrial systems are analogous to ecosystems: both consist of producers and consumers interacting with one another in the input, output, and internal exchange of material and energy. In industry, however, rapid technological advance has increased the speed at which society converts raw material into products and accompanying waste.

This module seeks to provide students with an understanding of the key principles, concepts, and problems in the emerging field of industrial ecology. We ask students to decide for themselves whether industry can become "greener": can it be made to replicate ecological systems in the way ecosystems reuse all the organic material they produce?

The module explores three broad themes:

- the linkages among technological change, industrialization, and global change;
- the utility of a systems approach to analyzing industrial activity; and
- the opportunities and constraints involved in making industries more closely resemble ecosystems in their productive and consumptive processes.

Unit 1 examines how technological change has enabled industry to transform nature in ever more powerful ways. As industrial production has been empowered with increasingly sophisticated technology, society's ability to effect global change has increased dramatically. The activities seek to develop the student's sense of connection to the global industrial complex and an appreciation of industry's ability to affect its local and global environments.

In Unit 2, students use a systems approach to analyze industrial processes; students are asked to pay particular attention to material and energy "inputs," their internal processing, and their "outputs" of products and waste. The activities engage students in systems analysis by having them critique their own homes, their local industrial sites, and popular case studies of their own choosing.

The third unit examines the problems and possibilities involved in industrial ecology study and practice. In the activities, students grapple with the socioeconomic, technical, informational, and other constraints to making society's industrial activities sustainable. Students also identify instances where elements of industrial ecology are being practiced or where the potential exists to do so.

1 How Does Industry Alter the Global Environment? Understanding the Problem

Background Information

Setting the Stage

In the popular 1984 movie *The Gods Must be Crazy*,[1] American audiences were introduced to a concept we now might call the human dimensions of global change; at that time, perhaps we were less reflective on the *global* implications and simply watched the film for its humor. But in fact, this film illustrates the concept of technological change as a **driving force**,[2] broadly conceived, for *environmental change*.

Set in the Kalahari Desert, *The Gods Must be Crazy* opens with a band of Bushmen going about their everyday lives in their traditional encampment. One day, from high above, a Coca-Cola bottle is tossed out of the cabin window of a plane by its careless bush-pilot. The bottle falls out of the sky and into the lives of the Bushmen. The Bushmen become greatly disturbed, thinking that the bottle fell from their "gods" in the sky. Turmoil ensues among the band; they have never encountered an object like this before. Lacking previous experience of glass bottles, the Bushmen can only muse about the object's significance. What does it represent? How did it come to be in their world? Is it good or is it evil? Does it have an inner power? What did the gods intend by giving it to the Bushmen? Were they being careless? Everything has a purpose, but is it possible that their gods were actually being wasteful?

Inevitably, squabbles break out among the clan over what to do with the bottle and who should hold it. After several disruptions to their way of life, the bottle's presence ultimately forces the Bushmen to reconsider their basic beliefs about power and equality in their society and to question their cosmological beliefs. Another society's waste quickly becomes an agent of permanent change in the Bushmen's way of living. At first, the Bushmen reject the new object; they try throwing it back to the gods in the sky. After this proves futile, the camp leader accepts the responsibility to carry it to the "end of earth," and to throw it out of their lives forever. In this

[1] *The Gods Must be Crazy* was first released as a motion picture in 1984 as a C.A.T. Film, written, produced, directed, filmed, and edited by Jamie Uys. It was re-released in VHS format in 1990 by CBS/Fox Video. Length: 109 minutes.

[2] Words in bold face appear in the *Glossary*.

way, they feel that they can banish the evil that accompanied the bottle; once the bottle is gone, they believe their life will return to normal.

We can see in the Coke bottle an image of industrialized society which, as depicted in the movie, exists on the margins of the Bushmen's realm. The bottle demonstrates the contradictions in modern society and that society's inability to recognize its influence on the rest of the world. The bottle, of course, is a metaphor for technology; its introduction to the Bushmen's life is a metaphor for technological change.

In this module we look at technology and technological change in terms of how they affect societies and the natural environment. Technology and its changes are, of course, created by humans and affect them and the environment. This mutual relationship is important to understand as a driving force of global societal and environmental changes and as a means of mitigating some of the impacts of these changes. The module concentrates on the crucial roles of technology, industry, and technological change in the context of global environmental change. It highlights the conceptual frameworks of industrial ecology, which serve as a guide for thinking about the linkages between nature and society. Maybe it is safe to say that rather than the gods, "the people must be crazy," if we don't think about these linkages.

The Trends and Consequences of Technological Change

Let's begin by examining technology and technological change over time. Our industrial society and the technology that helped create it did not fall out of the sky like the coke bottle. Technological changes evolve over long periods of time and have always had significant consequences for humans and the environment. By **technology**, we refer to the means by which people consciously modify the material nature of their world; technology mediates the interactions between people and their environment. It is a resource like any other, except that unlike natural resources that exist whether humans recognize them or not, technology is intentionally created by humans to structure the life-chances of people in society, to manipulate social and political power, and to alter the environment according to their wishes.

Over time, technological changes have lead to mechanization, industrialization, and many associated social changes. Lewis Mumford (1934) divided modern history into a series of three technological complexes, representing the rise of civilizations and economies based on mechanical technologies. The first phase was characterized by the use of technical skills to harness water and wind power and by the use of wooden implements. The second phase coincided with what we now call the **Industrial Revolution** and relied heavily on coal and iron resources. The third and current phase is characterized by an increasing reliance on electricity and metal alloys.

According to Headrick (1990), the most important technological achievements in modern times have had at least two major objectives. First, each innovation has been designed to solve a particular problem, e.g., irrigating a piece of land where water is scarce or immunizing people to social commentators worry that such technologies will create a cadre of "socially maladjusted" people who feel more comfortable with personal computers than interacting with each other face to face. For some, this represents a shift from a modern to a postmodern society (Castells 1989; Harvey 1989; Cloke et al. 1991; Soja 1989).

Technological changes also affect our relationship to the environment. Technology is the tool by which we preserve, conserve, and exploit natural resources (Evernden 1992; Jenseth and Lotto 1996; Cutter 1994). Increasingly sophisticated and powerful technology enables us to control or condition more and more aspects of the environment; it also allows us to protect and distance ourselves from nature. Ultimately, the ways that we use technology for such purposes and its role as a driving force for environmental change are very much influenced by our individual and collective views of the environment.[3]

Technological Change and the Human Dimensions of Global Change

The first known air pollution disaster in the US occurred in 1948 in Donora, Pennsylvania when fog, laden with sulfur dioxide vapor and suspended particles, stagnated in the Monongahela Valley for five days. Thousands of people became ill and about twenty died (Miller 1990). The killer fog resulted from a combination of conditions including the mountainous terrain surrounding the valley, a stable weather pattern, and a spatial concentration of industries that emitted deadly pollutants. To prevent future disasters of this kind, many industrial facilities began to construct taller smokestacks to force harmful emissions out of the local environment. While this technological mitigation resolved a local pollution problem, it created another. By the 1970s, emissions from industries like coal-burning power plants were producing acid rain (deposition) that damaged forests, lakes, and buildings thousands of miles away from the source. Today, 75 percent of the acid rain that falls in Canada originates from emissions in the US. This example illustrates not only how one technological solution can produce another problem, but also how the environmental impacts of the technologies of the modern era have become *regional* or *global* rather than local in scale.

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[3] These world views (or paradigms) help explain how people relate to the biotic and abiotic worlds. Some scholars (e.g., O'Riordan 1989) place them on a continuum with the ends of the scale representing two extremes: at one end of the scale are "ecocentric" views, which hold that humans are part of the biotic and abiotic worlds and thus have no primacy over other species or elements that are part of planetary systems. This world view is most often held by radical environmentalists and deep ecologists. At the other end of the continuum is the "technocentric" world view, which holds that humans hold primacy over other organisms and that nature simply provides opportunities (through its abundance of natural resources) for societies to use it and thus may manipulate elements in the biotic and abiotic world to improve human welfare and society at all cost. The ecocentric view suggests preservation of resources over everything else, while the technocentric views tends toward exploitation of the environment.

Most people fall somewhere between these two positions. They hold a pragmatic view that combines some elements of ecocentric and technocentric views. Many of the environmental managers of today hold such a mixed world view, and believe that resources can be utilized in a sustained way to meet larger societal goals. This is the view inherent in the concept of industrial ecology adopted in this module.

Technological changes can have global impacts in two distinctly different ways. Some types of global changes are systemic in nature. **Systemic change** occurs when activities in one place directly affect a globally functioning system (Turner et al. 1990a). For example, industrial emissions of greenhouse gases like CO_2, methane, or chlorofluorocarbons directly alter the chemical composition of the earth's atmosphere and may lead to changes in the global climate. A second type of global change is cumulative. **Cumulative change** results from local activities that are widely replicated in many places and together produce a change in the global environment (Turner et al. 1990a). For example, many industrial processes affect local water sources. As these industries are replicated globally, they can have a cumulative impact on the hydrosphere and/or biosphere.

Global environmental change results from the cumulative and systemic effects of countless individual and collective actions at the local level. Local changes are often (but not always) immediately obvious -- they can be smelled, seen, or felt. The factors causing these changes are reasonably well understood and the means to improve local environmental conditions and to prevent further environmental degradation are relatively well known. But when there are no perceptible local effects, many individuals assume that they will have no global consequences. As the above discussion of systemic and cumulative global changes indicates, however, a time lag and geographic distance between cause and effect are rather common in an age of large technologies.

Such transboundary and globally pervasive environmental problems create new challenges for policy makers and governments because they require international cooperation and negotiation. For example, at the 1992 Earth Summit in Rio de Janeiro, 167 nations signed the Framework Convention on Climate Change intended to reduce greenhouse gas emissions and the risk of global warming. Further, global environmental issues also involve a variety of complex issues such as equity and fairness, responsibility, and trust. Waste disposal (which has become a regional or global problem as regulations, rising costs, and public opposition have forced industries and government officials to search for more distant places to dispose of wastes) is just one example of an issue involving these complexities. In some areas in the US, poorer communities often agree to accept wastes for disposal in their community (along with the associated health and environmental risks) because of the increased revenues it will produce. Likewise, the poorer countries of the world have become not only suppliers of raw materials to the rest of the world but also the recipients of wastes produced in wealthier countries.

Industrial Ecology and Global Change

So where does focusing on the negative consequences of technological change leave us? Should we try to throw the "coke bottle" back to the Gods and reject technology as the Bushmen did? Or are we irrevocably committed to a world view that accepts technology despite the problems it has created? Is the only solution to our problems more technology? If so, how do we alter our "linear perspective" of technological development (which sees all new technology as promising progress) and begin to take a more complex, holistic, and global perspective? The answers to these questions depend in part on the world view that each of us holds.

Global changes are the ultimate consequence of a short-term perspective that focuses on solving local and immediate problems without consideration of the global and long-term consequences. In addition, the predominant paradigm in society is that technology can overcome environmental problems and continue to improve the lives of human beings as long as we take measures to mediate technology's harmful effects. Some people argue that every technology will have its unexpected consequences. But "technological fixes" or "tailpipe" solutions to environmental problems are at best temporary expedients and often they create as many new problems as they solve (e.g., Lynn 1989).

Throughout history, human productive activity has occurred in what can be called an open system. People have taken natural materials, transformed them into products for use, and discarded worn-out products and left-over materials. This practice often forced early societies to change locations as the build-up of wastes and the depletion of locally available resources rendered existing settlements uninhabitable or production processes unprofitable. This was fairly reasonable behavior as long as uncontaminated places were easy to find. Today, however, the situation is entirely different. It is no longer possible to avoid the wastes that we create; their disposal is a burden and, as we've seen, can contribute to global changes.

The current global situation suggests that our open industrial system cannot be sustained indefinitely. We consume too many natural resources to produce the things we want or need while generating too many by-products (toxic substances, emissions, solid waste etc.) that harm us and the environment. These changes threaten to upset the global environmental conditions we have adapted to and come to depend on, and they have the potential to threaten the survival of many species on earth (including humans). For these reasons, we need to reconceptualize and redesign the ways that industrial systems operate to place more control over the flow of materials. It is here that industrial ecology can contribute.

The basic definition of the term "industrial ecology" connotes an industrial system that operates much like a natural ecosystem:

> In natural ecosystems, materials and energy circulate continuously in a complex web of interactions: Microorganisms turn animal wastes into food for plants: the plants, in turn, are either eaten by animals or enter the cycle through death and decay. While ecosystems produce some actual wastes (by-products that are not recycled, such as fossil fuels), on the whole they are self-contained and self-sustaining. In a similar fashion, industrial ecology involves focusing less on the impacts of each industrial activity and more on the overall impact of all such activities (Frosch 1995b:19).

Robert Frosch's notion of industrial ecology offers a useful metaphor for reconceptualizing industrial systems while addressing issues of global change. Exactly how our current open industrial systems will be transformed into closed industrial ecology systems remains, however, an unanswered question; it also remains to be accomplished.

In next unit, we will examine industrial ecology in more detail and will develop the systems approach that forms the basis of the concept. In Unit 3, we will examine the opportunities and constraints to industrial ecology and explore some of the analytical tools it provides for analysis.

1 How Does Industry Alter the Global Environment? Understanding the Problem

Instructor's Guide to Activities

Goal
The activities in Unit 1 (1) heighten the student's sense of place and sense of connection to both local and global industrial activity, (2) emphasize how industrial activity brings about local and global environmental and social change, and (3) encourage students to interpret the changes that technological advancement has produced throughout the world.

Learning Outcomes
After completing the activities associated with this unit, students should:
- understand how local industries can have regional and global environmental impacts;
- recognize their connections to global industry by virtue of the everyday products they use;
- develop a sense of place within the global community; and
- recognize the ways that technology has transformed the life chances of society and social culture.

Choice of Activities
It is neither necessary nor feasible in most cases to complete all activities in each unit. Select those that are most appropriate for your classroom setting and that cover a range of activity types, skills, genres of reading materials, writing assignments, and other activity outcomes. This unit contains the following activities:

1.1 They Don't All Have Smokestacks -- In-class discussion
1.2 Shirts, Shoes, and Watches -- Mapping exercise
1.3 Between Utopia and Dystopia -- Film review and interpretation

Suggested Readings
The following readings accompany the activities for this unit. Choose those readings most appropriate for the activities you select and those most adequate for the skill level of your students.
- Background Information to Unit 1 (all students should read)
- Stern, Paul C., Oran R. Young, and Daniel Druckman. 1992. Human causes of global change. In C. Stern, O. Young, and D. Druckman, eds. *Global environmental change*. Washington, D.C.: National Academy Press, pp. 44-69.

- Lynn, Walter R. 1989. Engineering our way out of endless environmental crises. In *Technology and Environment*. Washington, D.C.: National Academy Press, pp. 182-191.
- Ausubel, Jesse H., et al. 1989. Technology and environment: An overview. In *Technology and Environment*. Washington, D.C.: National Academy Press, pp. 1-20.

Activity 1.1 They Don't All Have Smokestacks

Goals

This activity facilitates discussion on the linkages among technology, industry, and global change. Students consider industry in a broad sense in a brainstorming session, identify the important local industries in the community, and discuss how the local industry might have links to global change.

Skills

✓ identifying linkages between local and global scales
✓ brainstorming

Material Requirements

- Flip chart, notepad, or overhead projector to record information for use in a later activity (optional)

Time Requirements

25 minutes

Tasks

This is a starter activity intended to get students thinking about how industry in general is connected to global change and, more specifically, how the businesses in your town or community are linked to global change. Begin the activity by asking students the following questions:

1. What sorts of resources and what sorts of wastes are associated with the following industries?

tourism	agriculture	military/defense
film/entertainment	construction (e.g., homes)	fast food chains

2. Can you name some industries with strong global impacts that have the following characteristics:
   - High carbon or other trace gas emissions;
   - Large imports of resources from outside the region. (Be sure to note the impacts of extraction. Are there any limitations to sustainable extraction of resources? What are the implications for land degradation or biodiversity?); and
   - Large exports of waste, hazards or other impacts?

After you have considered these questions briefly, ask the class to select a local industry, preferably one that is important to the community and/or to the families of the students in the classroom. Important industries may the largest regional employer, a growth industry, a highly visible industry because of a recent event, or an industry with a good reputation. Ask students to brainstorm for a few minutes about the potential impacts that the local industry has on the environment. Encourage them also to think about the industry's activities in a global context. Does the local industry affect the global environment? Where do the various resources used in the industry come from? Where do the wastes go?

Note: You may want to record the information from the brainstorming session on an overhead transparency, a chalkboard, or flip chart for use in Activity 2.2.

Activity 1.2 Shirts, Shoes, and Watches

Goals

Students examine local-to-global relationships by locating on a map where various items they own have been produced. This map can be further developed by adding the social and environmental conditions associated with industries in various places (see Activity 2.5).

Skills

- ✓ map reading
- ✓ group collaboration

Material Requirements

- a world map (a copy for an overhead transparency is provided in *Supporting Material 1.2*)
- colored thumb-tacks or markers

Time Requirements

20-25 minutes

Tasks

Place a world map at the front of the classroom. (Use the map in *Supporting Material 1.2* to create an overhead transparency or enlarge it to create a poster-sized map.) Ask students to examine the label on the shirt of the student sitting next to them as well as the label on their own shoes and watches to determine where the items were made. Ask each student (in a large class, select a few students) to use a color marker or thumbtack to indicate the origin of each item, on the map. Use a different color for each product (i.e., red for watches, blue for shoes, green for shirts). Since many countries will be marked more than once with the same color, the class should be able to see a distribution of the origin of each item. Discuss the patterns visible on the map and ask students to consider the relationship between their present location and the place where the items were produced. Use the following questions to guide the brief discussion:

1. What major regions of the world are not represented?

2. Why are watches made in the Philippines or shoes in southeast Asia?
3. What are the environmental, economic, and/or social consequences of global markets?
4. Are you accountable for the environmental impacts resulting from the production of items in other countries?

Alternative version

Instead of focusing on shirts, shoes, and watches, ask students to determine where the food they eat in one day comes from. Students will need to keep track of everything they eat during one day and investigate where the products originate. Remind students that many packaged foods list only the site of distribution on their labels -- not where the products were actually made. You can ask students to prepare their own maps to bring to class (provide *Supporting Material 1.2* as a hand-out) or use 15 minutes or more in class to map the locations as suggested above.

Activity 1.3 Between Utopia and Dystopia

Goals

Students evaluate and respond to a film that graphically portrays the environmental and social impacts of the modern, global, industrial culture.

Skills

✓ qualitative data interpretation
✓ film interpretation

Material Requirements

- *Student Worksheet 1.3* (provided)
- The film *Koyaanisqatsi*. Although this film is now out of print, copies can still be obtained from university media collections or at local video rental stores. The complete citation is *Koyaanisqatsi: Life Out of Balance*, an IRE presentation produced and directed by Godfrey Reggio (Carmel, CA: Pacific Arts Video Records), 1983; 87 minutes.

Time Requirements

2 class periods (100 minutes); 87 minutes for the film and additional time (10-15 minutes) for discussion

Tasks

A thought-provoking conclusion to this unit is to watch the popular underground film, *Koyaanisqatsi* by Godfrey Reggio. Depicting a view of modern American society from the perspective of Native American ideals, the film explores the largesse and imbalances of technologically driven lifestyles to reveal the chaos and disorder that come from the mechanical world view. Viewers will find the film to be intense with penetrating minimalist music by Philip

Glass; only one word is uttered throughout the entire film -- a chanting of the film's title "koyaanisqatsi."

Beginning and ending with a slow motion observation of a rocket launch, *Koyaanisqatsi* takes viewers on a ride across the sacred landscape of the Hopi people in the American Southwest. The starkness and serenity of an untouched land is then shattered with image after image of industrial and urban settings. People are reduced to the scale of ants, their buildings to piles of rubble. Flows of people, cars, and products quicken and quicken with the tempo of the music reaching a crescendo when, like the line by Marx, "all that is solid melts into air."[4] From utopia to dystopia, the film provides a prophetic image a possible future.

At the film's conclusion, we are presented with five definitions of the Hopi word koyaanisqatsi, including:

- crazy life
- life in turmoil
- life out of balance
- life disintegrating
- a way of life that calls for another way of living.

The message of *Koyaanisqatsi* is clear: if we continue to let technology overwhelm human-environment interactions, global change will occur in a manner that is detrimental to all living things. The sacredness of the land will be destroyed; settlements will outsize human scale; and our lives will take place at a dizzying pace. It is clearly a crazy life that calls for another way of living. Take at least two class periods (50 minutes each) to show the film to the class. Instruct students to pay particular attention to film's main themes and to contemplate how other groups of people unlike themselves might respond to the film's message.

After the film is over, use the remaining time to ask the class the following questions:

1. What is the meaning of the Hopi word "koyaanisqatsi"? (Five definitions are provided near the end of the film.) Which definition do you think has the most power or meaning in terms of this film? Why?
2. What is the film's primary message? Do you agree or disagree with it? Why?

[4] Attributed to Karl Marx, from the *Communist Manifesto*; quoted in Berman (1982: 21).

3. Briefly speculate on responses to the preceding questions that might be given by persons from several cultures or social groups. Examples of these groups include the following:[5]

Libertarian party	Buddhists
Greenpeace	Republicans or Democrats
Christians	United Auto Workers

4. Discuss the environmental images portrayed in the film in terms of three or more of the following concepts:

embodied energy	entropy (see Unit 2)	technological change
environmentalism	modernity	sustainable development

[5] References to various cultures, social groups, ethical positions, ideologies, or world views may be selected for comparison, depending on other aims and goals of the class. The author of this module has found it useful to ask students to provide interpretations from the standpoints of various writers whose materials have been read by the class; these include Abbey (1968), Evernden (1992), Leopold (1966), McHarg (1971), and D. Smith (1993). Sometimes it is interesting to ask the students to provide an interpretation from the standpoint of their instructor, as well! It is equally useful to ask students to provide interpretations from the standpoint of the four schools of "environmentalism" (as discussed by O'Riordan 1981, 1989).

1 How Does Industry Alter the Global Environment? Understanding the Problem

Student Worksheet 1.3

Activity 1.3 Between Utopia and Dystopia

You will watch a popular underground film, *Koyaanisqatsi*, which depicts a view of modern American society from the vantage point of Native American ideals. The film explores the largesse and imbalances of technologically driven lifestyles to reveal the chaos and disorder that come from the mechanical world view. The film is quite intense with penetrating, minimalist music by Philip Glass. Only one word is uttered throughout the entire film -- a chanting of the film's title "koyaanisqatsi."

Pay particular attention to the key themes about technology and industrialization that permeate the film. Also, try to imagine how other groups of people unlike yourself might respond to those themes. After the film is over, you will discuss the film and several questions related to the central message of *Koyaanisqatsi*. Use the space below to take notes while you watch.

1 How Does Industry Alter the Global Environment? Understanding the Problem

Answers to Activities

Activity 1.1 They Don't All Have Smokestacks

Because this activity is primarily an in-class discussion, there are no specific answers. See *Notes on Active Pedagogy* for suggestions on leading a small group discussion.

Activity 1.2 Shirts, Shoes, and Watches

The maps created in this activity will vary depending on the items that students own. In general, the maps will show a high concentration of products that originate outside the US in areas such as southeast Asia. Use the map and the patterns that develop to explore the links among consumption, global markets, and global environmental change.

Activity 1.3 Between Utopia and Dystopia

There are no specific answers to this activity. Use the film to encourage debate and a lively class discussion.

2 Industrial Ecology as a System: A Conceptual Framework

Background Information

In Unit 1, we mentioned that the predominant world view of our society today holds that technology can overcome environmental problems and continue to improve the lives of human beings as long as we take measures to mediate technology's harmful effects. There are those, however, who are less optimistic about science and technology. In this unit, we will look at perspectives that are critical of this dominant paradigm, and how they can inform a different, more environmentally sound approach to industrial production and consumption. One such approach is known as industrial ecology and is rooted in studies of both thermodynamics and systems. Before we examine industrial ecology in more detail, let's begin by exploring relevant concepts from these two areas.

"Entropy Isn't What it Used to Be"[6]

In 1980, Jeremy Rifkin, a critic of the dominant techno-managerial world view, published a controversial book entitled *Entropy* that provided a compelling conception of the interplay among world views, technology, and global environmental change. Rifkin used the **second law of thermodynamics** as the basis for a critique of modern society and its material economy. In a nutshell, the second law holds that energy is degraded through its use; it becomes less and less useful to do work. **Entropy** is a measure of the state of usefulness of energy. The lower the entropy of a system, the more work that energy can do.

An easy way to understand entropy is to think of a home that is heated by a gas furnace. The gas in the pipe leading to the furnace has low entropy (high energy content). Once burned, the entropy of the gas increases as the energy from the gas is dispersed into the home in the form of heat. Eventually the heat dissipates into the surrounding environment as it escapes through the doors and windows. The more the heat dissipates, the greater the increase in entropy. Once the energy has escaped the house and entered into the surroundings, it is no longer in a useful state. In other words, the energy has dissipated and is no longer useful for the purpose it was intended. Thus "entropy is never what is used to be" -- it increases all the time.

[6] Graffiti inscribed on the ceiling of a room in the Jet Propulsion Laboratory in Pasadena, California.

In Rifkin's view, entropy plays a key role in explaining the environmental problems of today. By applying the second law of thermodynamics to energy and materials consumption in modern society, Rifkin argued that technology speeds up the use of both energy and materials. In his view, the modern industrial system is a transformer of materials and energy, increasing entropy and reducing the usefulness of materials and energy.

What concerns Rifkin and others is the **sustainability** of natural resource use. They see technology as a tool that has locked society into an non-sustainable future. A characteristic of the modern era is the use of technology and natural resources in a profligate way, one that continues to transform the earth, speed up the use of nonrenewable energy, and accelerate material entropy in the process. Material waste and waste heat are inevitable outcomes of this process. Waste heat is produced in the process of fuel combustion and is a measure of the inefficiency of energy transformation. Solid waste, produced as by-products of material fabrication or mineral extractions, is a measure of the inefficiency of a material manufacturing system. Effluent discharged from a factory or processing plant is a measure of the inefficiency of chemical transformations. Each case illustrates an industrial system that is operating within the greater complex of the global environmental system and that is generating a dissipative loss (i.e., irreversible loss through the simple dispersion of energy and materials). Such losses represent tangible evidence of the inefficiency of production systems, as the wastes are no longer recycled or reused in the production processes. Once lost from the system through dissipative loss, these wastes must be disposed of -- stored in a landfill or a containment pond or discharged into the air, soil, or water (where they become diffused).

From this cursory look at the second law of thermodynamics, entropy, and dissipation we can see one major requirement for an alternatively designed industry -- to limit every opportunity within the production and consumption processes for energy and materials to get lost. This requirement produces several possible strategies:

- to increase energy and material efficiency -- something that can actually be achieved through technological innovation;
- to make the process of resource extraction, production, consumption, and waste disposal/emission/pollution into a closed loop cycle; in other words reuse and recycle materials wherever possible; and
- to reduce the need for new/fresh natural resources and the release of wasteful and potentially harmful by-products (both of which can be facilitated by the first two strategies). This is particularly necessary for **nonrenewable resources** (those that are not replaced after use through natural regrowth) and waste repositories that are finite (either literally or in a practical economic sense).

Another implication of Rifkin's work is that we should increase our reliance on renewable forms of resources. Coupled with reduced depletion of nonrenewables, this would be a way to reduce the consumption of energy and resources. It may not be possible to shift entirely from the use of nonrenewable resources, but it makes sense to devise and implement strategies for minimizing the use of nonrenewable materials and energy sources.

The Concept of a System

If technology is in fact, as Rifkin would have it, simply a transformer of energy and matter into waste, then it is virtually inevitable that its use will lead to continued degradation of the environment. Increasingly, this journey toward degradation is global in scope, cumulative in impact, and uncertain in effect. But while technology introduces negative forces of change in the world, it also benefits society. It provides returns from the stock of natural resources that are necessary (or desired) for maintaining the ways of life to which humans have become accustomed. A hallmark of the modern world view is that technologies make progress (at times synonymous with economic growth) possible. Yet, if the ultimate outcome of "progress" is a degraded environment, we might ask (like the Bushmen did of their new-found Coke bottle) if technology is good or evil. More pragmatically, we might consider what role technology ought to play in a redesign of industrial systems such that we can live sustainably and within the limits of the natural environment.

For centuries, humans have considered themselves somehow outside of nature, seemingly able to live less and less by the laws of ecology and thermodynamics. The increasing scale of technologies and the growing human population on earth that use them make it paramount that we rethink human-nature relationships as integrated. What is commonly known as the *systems approach* is one useful framework to reconceive this mutual relationship.

A **system** can be defined as a group of interacting, interrelated, or interdependent elements forming a complex entity. Each element has specific properties that enable the system to function. This entity cannot continue to exist unless it has a continual input of materials to maintain itself; the entity will also have a constant output of waste materials to dispose of. An entity that has inputs and outputs and interacts with the external environment is called an **open system**. An entity that has minimal interaction with the external environment is called a **closed system**.

Let's look at some examples of systems. A biologist might view the human body and its inner workings as a system. The body itself is the entity; it has a well-defined boundary, generally perceived to be the surface of the skin. The body is composed of many interacting, interdependent elements (e.g., the heart, lungs, stomach). Each element has a specific function that enables it to help the system function: the heart pumps blood, the lungs transfer oxygen, and the stomach digests food. In order for the body to survive, it needs inputs such as oxygen, water, food, and other nutrients. The body also produces outputs of waste materials such as heat, carbon dioxide, feces, and so on. The body must in fact interact with its external environment in order to exist. On a larger scale (and one more relevant to the subject of industrial ecology), we frequently use the term **ecosystem** to refer to the relationships and interactions between living things (plants, animals) and their environment (earth, air, water).

To summarize, a system can be defined as an entity that has the following properties:

- elements -- a set of objects within the entity having specific attributes and functions within the system
- internal relationships -- a set of relationships among the elements (i.e., inside the entity)

- external relationships -- a set of relationships between the system and its environment involving the exchange of inputs and outputs.

Figure 1 summarizes these relationships in a simple model, and Figure 2 illustrates the difference between closed and open systems. Keep in mind that these figures are simplifications of reality in which we define the elements and boundaries. For example, we could also define the elements of a human body not at the level of organs (the heart, lung, and stomach) but at the level of the circulatory, respiratory, and digestive systems. Our model could also have omitted some elements (e.g., the human soul which some believe is as essential as a heart). We could have even forgotten to consider an essential venue of output such as the release of energy from the human body from stress. In sum, it is not as easy as it may seem to identify all the components and relationships of a system.

Figure 1: A Simple System Model

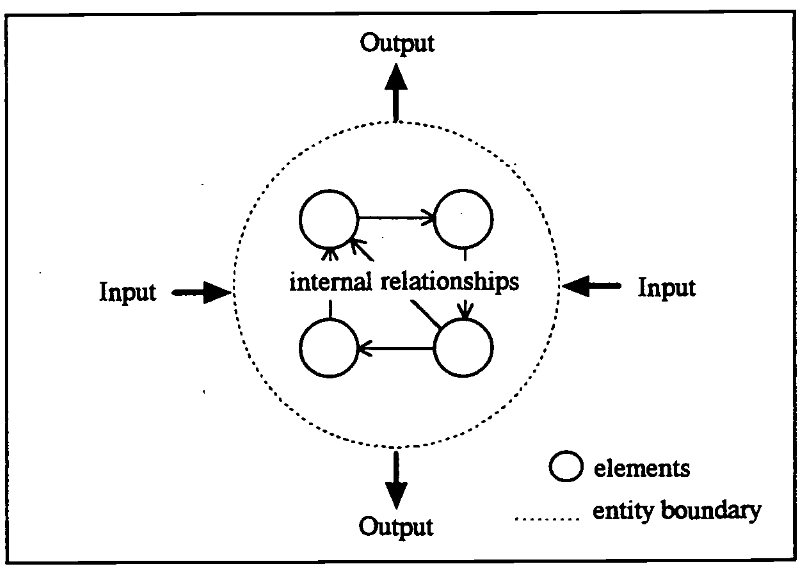
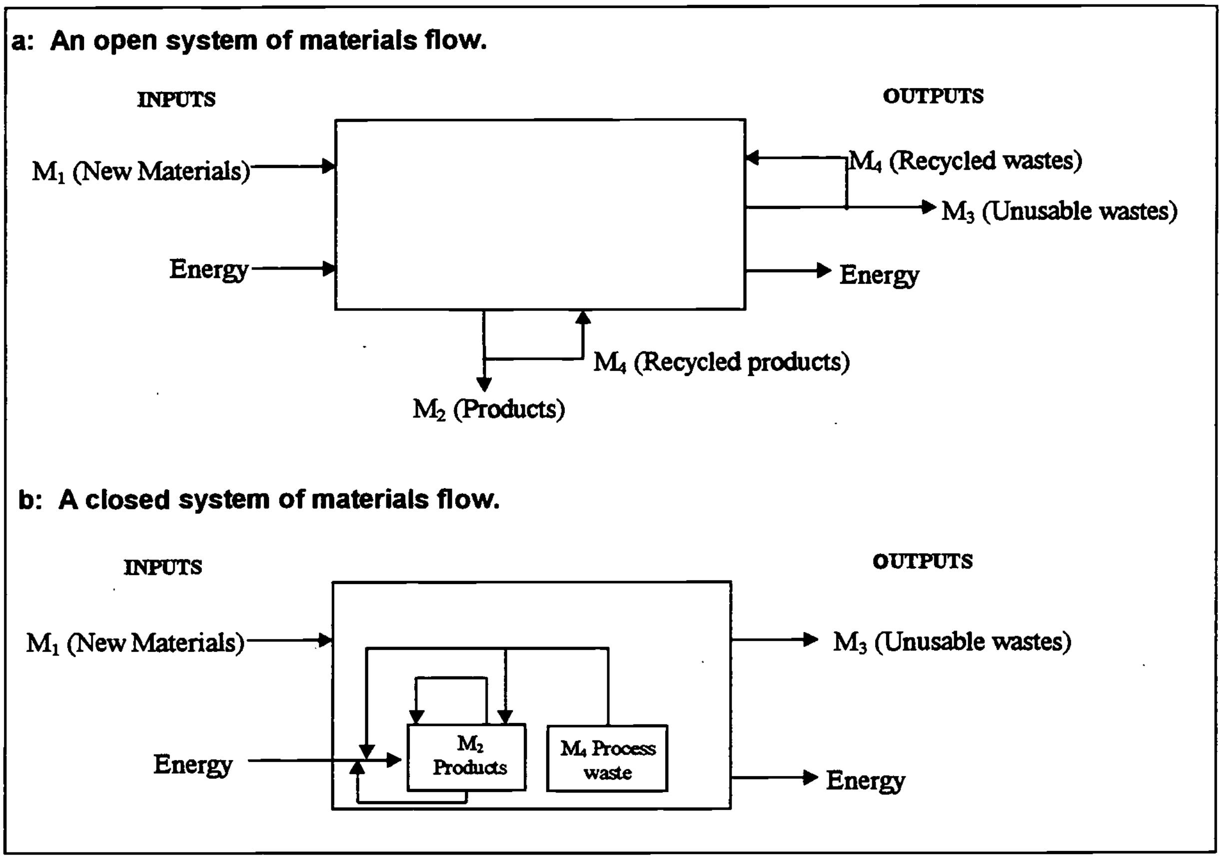


Figure 2: Open and Closed Systems of Materials Flow



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Now let's take the system idea to a higher level. Human society as a whole can be thought of as a system standing in constant input/output relations with the natural environment. This societal system is made up of subsystems or related sets of elements that are functionally linked to each other and to the external environment (again, the definition of system boundaries and elements makes all the difference). One type of a subsystem or subset of elements is an industrial system, which we will explore in more detail below.

Industrial Systems

Industrial society uses technology, both mechanical and industrial, to transform raw and manufactured materials to create goods with utility for society. Traditional technologies were based on handicrafts, manual labor, and extensive agriculture. The products of traditional social labors were constructed with tools made directly, or nearly directly, by human hands (e.g., knives, hoes, and plows). Industrial technologies, by contrast, include automated production, mechanical processes, and mechanized agriculture. In these industries, most tools are produced by other tools, that are in turn produced and managed by other tools and so on through secondary and tertiary levels of economic activity.

It is not only the types of technologies that distinguish industrial from pre-industrial societies. Industrial systems are often equated with processes that developed under the larger framework of modernity (Berman 1988; Toulmin 1990), within a mechanical world view (Rifkin 1980), and in urban, centralized systems of modern western society (Dicken and Lloyd 1981). But the most important indicators of industrial activity are the *scale* and *intensity* of the transformations. Agriculture that uses automated or mechanical processes, sophisticated information transfers, and intensive management practices to create high yields from the land is really *industrial* agriculture. Similarly, modern raw materials extraction is also characterized by intensive applications of mechanical and automated technologies, as well as by increasingly sophisticated uses of information, making it appropriate to refer to these practices as *industrial* mining, *industrial* forestry, or *industrial* fisheries. By extension, it may be appropriate to regard some tertiary activities as *industrial* services, since they are similarly involved in the intensive transformation of materials.

Now that we understand what makes systems industrial, what is it that makes them systems? Based on the definition of a system from the last section, industrial systems:

- are entities comprised of elements (plants or sites where goods are produced or where supporting functions occur),
- are linked together through internal relationships (transfers of goods and flows of information), and
- interact with the broader social and physical environments through external relationships.

Think of the extraction and processing of raw materials such as oil and metal ores (input), and the emission of wastes (output) such as CFC's or landfill-bound trash. Individual industries can be seen as only one element (related to other elements) in a much larger system. Much of classical economic geography and industrial location theory emphasized the internal relationships of industrial systems. These schools neglected to focus on the relations of industries with the broader physical environment except to see it as a source of raw materials (inputs) or a sink for residuals (outputs) in a standard input-output analysis.

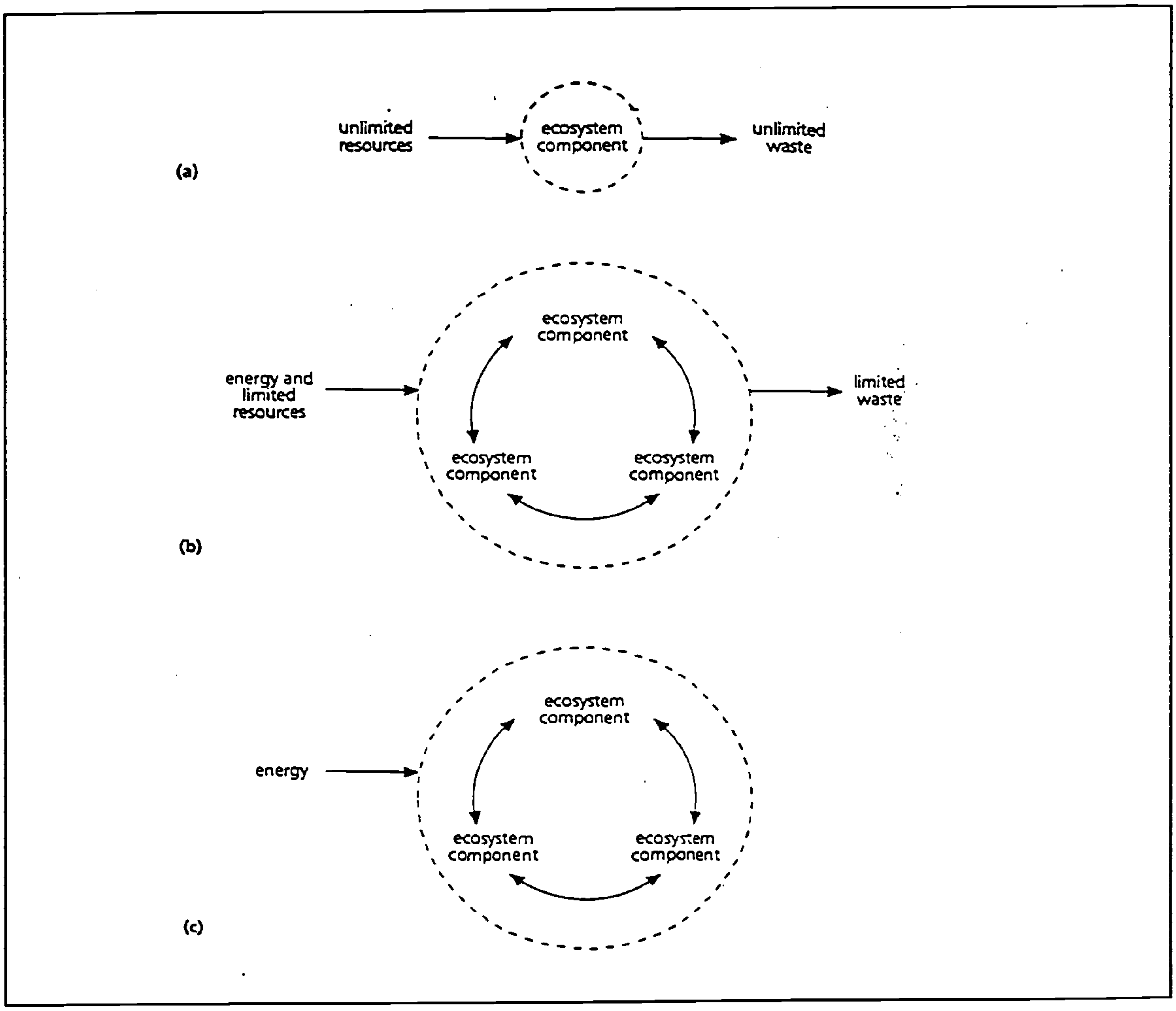
When we consider the human dimensions of global change, i.e., which human activities drive and mitigate major global changes, our focus must shift from the exclusive concentration on internal relationships to the external relationships between industrial systems and the natural environment. Thinking about technology as a transformer of the environment, as Jeremy Rifkin did, enables us to make choices that might reduce the effects of the inevitable entropy within systems. The pace or speed of material throughputs and energy flows within an industrial system can be thought of as the *metabolism* of industry. From this organic analogy, we can make a natural extension -- industrial systems are like natural ecosystems in that they are made up of sets of producers and consumers (elements) that interact with one another (internal relationships) and

A **Type I ecology** is characterized by a linear flow of material throughputs and corresponds to the earth's very early life forms that were largely unconstrained by resource limitations. Essentially, food comes in and wastes goes out, with a seemingly unlimited supply of both. Picture the massive world ocean providing H_2O for the ancient microscopic protozoan and bacteria and the atmosphere serving as a sink for their CO_2 waste. There was not much internal recycling of waste occurring, but there didn't have to be. As Graedel puts it, "at that time, the potentially usable resources were so large and the amount of life so small, that the existence of life forms had essentially no impact on available resources" (Graedel 1994: 24). This parallels what we could call "hyper-waste" in human systems in which a "frontier mentality" prevails. This mentality, common during the westward expansion of the United States, lead to viewing resources as unlimited, production and consumption as goals, and prolifigate waste generation as a necessary (and unproblematic) consequence of human activity. From our privileged present-day vantage point, the frontier mentality appears counter to the principle of sustainability. After the American Civil War, however, this perspective more closely represented "manifest destiny" and was used (in part) as a justification for resource exploitation (Petulla 1977).

A **Type II ecology** is characterized by quasi-cyclic flows of material throughputs that more closely resemble those of existing ecosystems. In this model, energy and limited material inputs are repeatedly cycled within the ecosystem by its members, with only limited amounts of wastes being generated as unusable by-products. In some cases, modern industrial systems have developed such characteristics because dissipative losses of materials represent tangible monetary losses. Within industrial systems, however, the *degree* of evolution toward a Type II ecology varies considerably by industry and place. In any event, the production of waste leads to entropy within the system and ultimately means that such a practice is not sustainable.

Graedel presents a **Type III ecology** as one that closely approximates natural ecosystems. It is characterized by flows of materials that are continuously recycled among the members of the ecological community or system. In its ideal state, the only exchanges with its external environment are energy (primarily solar) as inputs to the natural ecosystem. Type III ecologies can be said to have achieved sustainable relationships with their surrounding environments. Figure 3 below illustrates these three types of ecologies.

Figure 3: (a) Linear material flows in "Type I" ecology. (b) Quasi-cyclic materials flows in "Type II" ecology. (c) Cyclic materials flows in "Type III" ecology



Source: Graedel, T. 1994. In Socolow, Andrews, Berkhout, and Thomas, eds. *Industrial ecology and global change*. Cambridge, MA: Cambridge University Press, p. 25. ©1994 reproduced with the permission of Cambridge University Press.

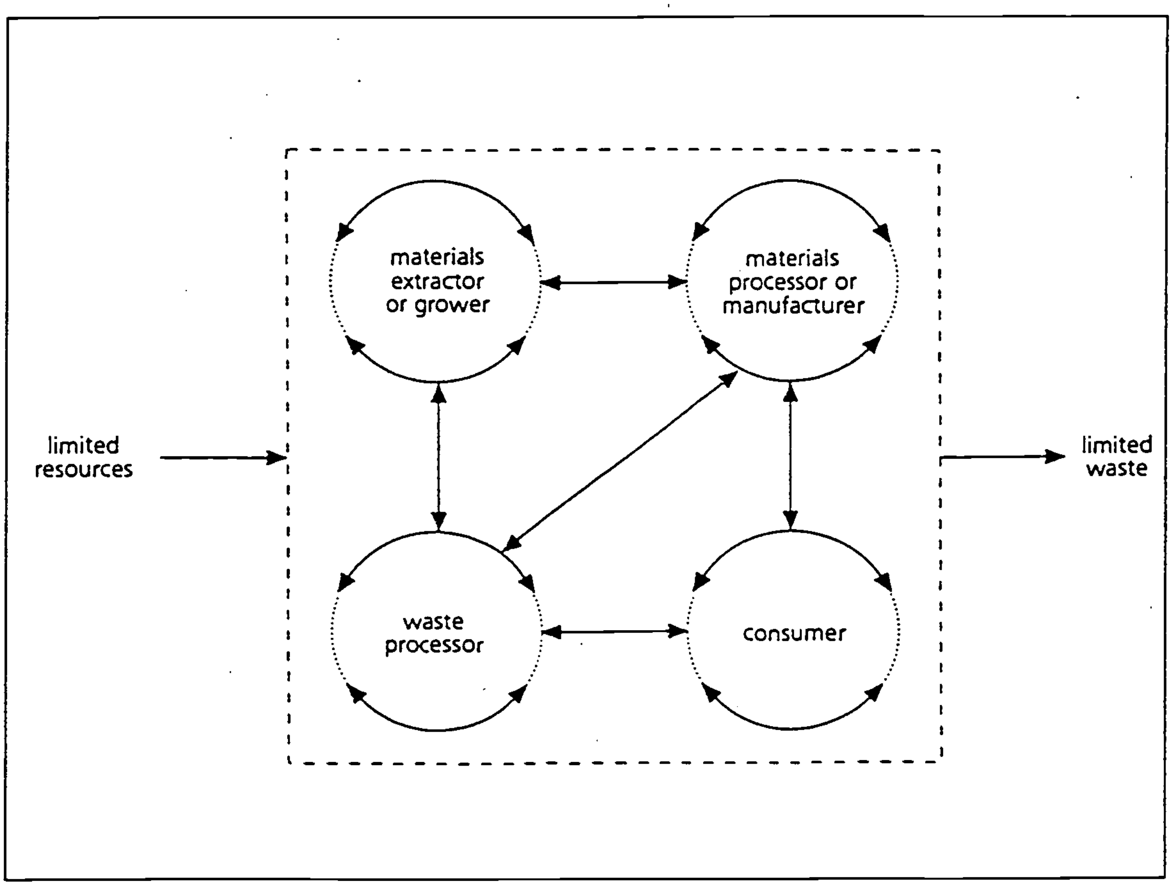
Graedel observes that the process of entropy has begun to appear within industrial systems in the form of large-scale, cumulative global changes. "Accordingly," he suggests,

> industrial systems (and other anthropogenic systems) are and will increasingly be under selective pressure to evolve so as to move from linear (Type I) to [quasi]cyclic (Type II) or cyclic (Type III) modes of operation. For the past decade or two, industrial organizations have largely been in the position of responding to legislation imposed as a consequence of real or perceived environmental crises. Such a mode of operation is essentially unplanned,

imposes significant economic costs, and may solve one problem only by exacerbating others. In contrast, industrial ecology is intended to facilitate the evolution of manufacturing . . . by explaining the interplay of processes and flows and by optimizing the ensemble of considerations that are involved. A central goal of industrial ecology, in combination with appropriate activities in other development sectors, is to achieve sustainable development (Graedel 1994: 26).

Industrial ecology, in his view, is more than a description of linkages among elements within a system. Rather, it is a *prescription* for the evolution of industrial systems to achieve an idealized state for long-term sustainability. Its ultimate goal is to transform industry and technology into something that is environmentally benign, industry that "closes the loop" between the system's operations (its internal metabolism) and its external environment. Essentially, industrial ecology means evolving from a "take-and-dump" open system to a mostly closed system of flows. Figure 4 illustrates the optimal industrial ecological system.

Figure 4: The Type III Model of the Industrial Ecosystem



Source: Graedel, T. 1994. In Socolow, Andrews, Berkhout, and Thomas, eds. *Industrial ecology and global change*. Cambridge, MA: Cambridge University Press, p. 27. ©1994 reproduced with the permission of Cambridge University Press.

2 Industrial Ecology as a System: A Conceptual Framework

Instructor's Guide to Activities

Goal
Students learn to examine local and regional industrial processes using analytical tools from systems theory and thermodynamics. Students also begin to understand the flexibility of the concept of industrial ecology and explore their own definitions of it.

Learning Outcomes
After completing the activities associated with this unit, students should:

- be able to use systems theory and the thermodynamic concept of entropy as analytical tools for examining local and regional industrial processes;
- recognize the difficulties involved in using systems theory when boundaries are not clearly defined;
- have formulated their own definition of and goals for industrial ecology;
- be able to deconstruct claims about the ecological merit of products or industries according to their own positions on the principles of industrial ecology; and
- become aware of the difficulties involved in implementing industrial ecology on a scale as small as their own home.

Choice of Activities
It is neither necessary nor feasible in most cases to complete all activities in each unit. Select those that are most appropriate for your classroom setting and that cover a range of activity types, skills, genres of reading materials, writing assignments, and other activity outcomes. This unit contains the following activities:

2.1 Defining Industrial Ecology	-- Critical reading and interpretation
2.2 Critiquing Success Stories	-- Library/Internet research and research paper
2.3 Entropy of Your Home	-- Daily log of personal habits, analysis of personal waste, and short essay
2.4 Putting Local Industry in a Global Context	-- Qualitative and quantitative research of a firm, analysis, and production of flowchart
2.5 You Are What You Buy	-- Exploration of product origins and impact, map making, and essay writing

2.6 It's Not Easy Being Green -- Critique of "green" advertising, creative writing, creation of a collage

Suggested Readings

The following readings accompany the activities for this unit. Choose those readings most appropriate for the activities you select and those most adequate for the skill level of your students.

- Background Information to Unit 2 (all students should read)
- Frosch, Robert A. 1995. Industrial ecology: Adapting technology for a sustainable world. *Environment* 37 (10): 16-24, 34-37.
- Richards, Deanna J., Braden R. Allenby, and Robert Frosch. 1994. The greening of industrial ecosystems: Overview and perspectives. In B. Allenby and D. Richards, eds. *The greening of industrial ecosystems*. Washington, DC: National Academy Press, pp. 1-19.

Activity 2.1 Defining Industrial Ecology

Goals

Because industrial ecology is a developing field, it is still defined in many ways. In this activity, students analyze existing interpretations of the concept and develop their own definitions of the character and goals of industrial ecology.

Skills

✓ critical reading and interpretation

Material Requirements

- *Supporting Material 2.1* (provided; make sufficient copies for class)

Time Requirements

20-25 minutes of class time

Tasks.

Before class, ask students to read the various definitions of industrial ecology from some principal authors in the field (provided in *Supporting Material 2.1*; photocopy and distribute as needed). In class, ask students to come up with their own definitions. Begin by asking for key elements and concepts of industrial ecology. Write these on the blackboard or on an overhead transparency. Use the students' definitions and the information below to lead a brief class discussion about the concept of industrial ecology.

For Graedel (1995), industrial ecology is a technical matter for designers; he specifies seven aspects of design that must be considered:

- choosing the right *raw materials* and avoiding (where possible) nonrenewable materials and those in short supply;
- minimizing *emissions* to the air of CFCs, halons, CH_4, N_2O, NO_x, or volatile organic compounds (VOC) by specifying more carefully the industrial processes used or by more consciously sequestering them prior to emission;
- minimizing *liquid wastes* or specifying those that are more easily recycled;
- minimizing *solid wastes* by working closely with suppliers, recyclers, and marketers;
- designing for *energy efficiency* through process design, reuse of energy used in manufacturing, and minimizing energy consumed by products once they are in circulation;
- designing for *recycling during manufacturing*, including minimizing the throughputs of packaging waste from components entering the industrial site; and
- *recycling after use* by returning used products to the manufacturer for reconditioning, disassembly, or other incorporation within the industrial cycle.

Frosch would agree -- in part -- that technical design considerations are necessary for industrial ecology to succeed. He stresses, however, that "the answer will not depend entirely on inventing breakthrough technologies. Rather, it may hinge on coordinating what are fairly conventional methods in more prudent ways and in developing legal and market structures that will allow suitable innovation." While such practices "will involve complex considerations of product and process design," equally important will be innovations in ways of thinking about "economics and optimization, as well as regulation and handling of hazardous materials" (Frosch, 1995a: 178). Socolow (1994) presents "six perspectives" on environmental management from within industrial ecology that resonate with the terminology for human dimensions of global change. These perspectives are:

- *long-term temporal scale* -- replacing the "short-term insult" of conventional industrial processes with those that provide for long-term habitability of environments;[8]
- *global scope* -- expanding our view of the boundedness of systems, moving from a focus on local impacts to a conscious effort to "think globally" (which includes overcoming the "not in my back yard" or NIMBY sentiment);
- *sensitivity of natural systems* -- identifying components of natural ecosystems that are particularly sensitive to fast-paced impacts of industrial activity;
- *vulnerability* -- identifying the sensitivity of *human* systems to the impacts of industrial activity, including: emissions, incidence of disease, bioavailability, exposure, and dose, loss of ecosystem function, and resilience or resistance;
- *mass-flow analysis* -- unifying the analysis of materials through an integrative approach that considers sources, transport media, and receptors, particularly those that are indestructible or persistent over a long term;

[8] Socolow is speaking here of the persistence of toxic chemicals, long-term depletion and physical degradation that results from human habitation and use of environments, and human-induced events that lead to extinction of species or to biological simplification (Socolow 1994: 5-7).

- centrality of the *industrial firm* and the industrial farm -- seeing industry as a central decision maker in environmental affairs, demonstrating "that environmental objectives are no longer alien, to be resisted and then accommodated reluctantly [but] part of the fabric of production, like worker safety and consumer satisfaction" (Graedel, 1994: 12-13).

Represented in this way, we see industrial ecology firmly planted within a study of the human dimensions of global change. Implicit is a "goal" for industrial ecology:

> "the evolution of the world's industrial activity into a sustainable and environmentally benign system [that] requires a long-range view and a deep analysis of the environmental implications of today's industrial systems, and a creative approach to the design of services, products, and governmental policy" (Socolow, et al., 1994: frontispiece).

Activity 2.2 Critiquing Success Stories

Goals

Students use their own principles of industrial ecology to investigate whether local industries live up to them.

Skills

✓ hypothesis formulation
✓ library/Internet research
✓ writing a research paper

Material Requirements

- *Student Worksheet 2.2* (provided)
- *Supporting Material 2.2a* and *2.2b* (provided)
- Video on McDonald's and EDF collaboration[9] or similar video[10] (optional)

Time Requirements

20 minutes in class for film; 4 to 5 weeks outside of class for research project.

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[9] Video is available from the National Pollution Prevention Center at the University of Michigan, 430 E. University, Ann Arbor, MI 48109-1115. Phone: 313-764-1412, Fax: 313-936-2195, E-mail: nppc@umich.edu. A copy of the order form is provided in *Supporting Materials 2.2b*. Video running time is 18 minutes.

[10] A six-part video series called *The Road to Sustainable Development* is available from The Gauntlett Group, Inc.: Industry Advisors for Sustainable Development, 5900 Hollis Street, Suite G, Emeryville, CA 94608. Tel: 510-658-9013 or 1-800-247-7930; Fax: 510-658-3834. The video outlines an "Environmental Quality System" for "identifying and eliminating wasteful practices throughout operations; streamlining work processes to shorten product delivery cycles; and reducing environmental impact from every stage of production and distribution."

Tasks

Introduce this activity by showing the suggested video on the collaboration between McDonald's and EDF to reduce solid waste. After the film, discuss with students whether McDonald's has really moved toward industrial ecology in any significant way.

In the remainder of the activity, students conduct extended research on the developments made within one of the four industries presented in the case studies in *Supporting Material 2.2a*. Allow students to select the industry of their choice, but try to ensure that students are spread evenly among the four cases. Encourage students to use a variety of research tools including the library, the Internet, interviews, phone calls, and other sources of information. Some sources of information are provided in each case study.

In an eight to ten page research paper, students summarize their findings and provide an analysis of their chosen industry's steps toward industrial ecology (based on the principles they defined; see Activity 2.1).

Activity 2.3 The Entropy of Your Home

Goals

Students develop an understanding of entropy by recording the flow of energy and materials through their home over a one-week period. Students gain hands-on experience in gathering and processing quantitative and qualitative data and become aware of problems involved in reducing entropy on a personal level.

Skills

- ✓ quantitative and qualitative data analysis, interpretation, and presentation
- ✓ critical examination of personal lifestyle habits

Material Requirements

- *Student Worksheet 2.3* (provided)
- *Supporting Material 2.3* (optional; provided)
- Students' own recent gas, electricity, and water bills (optional)

Time Requirements

15 minutes to introduce activity in class; one week outside of class for data collection and an additional 3 to 4 days for students to analyze their data and prepare their reports. An additional class period may be required for optional in-class presentation of results.

Tasks

Ask each student to record the flow of materials through his or her household, dorm living area, or apartment for a one-week period. By imagining their home as a system, students note the inputs and out-flows, the internal reuse, and the disposal of the materials and energy within it.

Depending on the depth at which you wish to pursue this activity, you may choose to have students simply record the materials and energy they use, recycle, and waste, or you may have them go a step further by quantifying these variables (i.e., weighing material inputs such as food, purchases, and packaging or measuring water, gas, or electric usage via recent utility bills or by reading meters). By identifying and recording the flow of energy through the home, students can see how entropy is increased by the use and transformation of energy and materials.

After collecting this information for a one-week period, students evaluate the sustainability of the home system by answering the questions on the student worksheet and preparing a table that lists the inputs, internal reuse, disposal, and final state of their material and energy flows. A blank table has been provided in *Supporting Materials 2.3*. Based on your time constraints and on the skill level of your students, you may provide the blank table as a hand-out or ask each student to create his or her own using a standard spreadsheet or word-processing software program.

Students will summarize their findings in a two to three page report that includes their table and their responses to the questions on the Student Worksheet. In addition to (or instead of) the written report, you might ask each student to prepare a poster-sized flowchart that illustrates the flow of materials and energy into and out of the home. If desired, allow one class period for students to present their findings and/or posters to the class.

This activity could be expanded by asking students to include a discussion of the geographic origin of the inputs they identified (i.e., electric power, water, vegetables, and clothing).

Activity 2.4 Putting Local Industry in A Global Context

Goals

Students put the analytical tools implied in systems theory and the second law of thermodynamics to use by researching local industrial processes. Students gain a more thorough understanding of how local industries contribute to global environmental change.

Skills

- ✓ research using the analytical framework provided in the *Background Information* to Unit 2
- ✓ team collaboration
- ✓ flow chart construction
- ✓ group discussion

Material Requirements

- *Student Worksheet 2.4* (provided)
- The original notes on the local industry discussed in Activity 1.1 may be helpful if the class decides to continue with the same company.

Time Requirements

15-20 minutes to introduce the activity; two to three weeks of research outside of class; one class period (50 minutes) to develop a flow chart with the class and discuss the results.

Tasks

Divide the class into small groups and ask each group to investigate an industrial firm to answer the questions about it below. If you live in a small community with few industrial firms, ask each group to focus on the same firm. If there are several large industrial firms in your area, ask each group to focus on a different one.

Questions to consider:

1. What are the major *products* of the industrial firm?
2. What are the major *inputs* in terms of sources of materials and energy?
3. Where do the major *materials and energy* come from? Are there any impacts at the source of extraction?
4. *How long* are the sources of materials and energy likely to be economically feasible to use?
5. What are the major *outputs* in terms of the disposition of products and byproducts?
6. *Where* do the products and byproducts go and what are the impacts of the outputs at the sites of disposition?
7. *How long* will the products and by-products last?

Encourage students to use a variety of means to answer these questions, including library and Internet research, interviews with firm representatives, company brochures and other publications, and site visits. Allow at least two to three weeks for students to conduct their research. Each group should prepare a three to four page report (to be handed in) that addresses the questions. The report should also include a list of sources and references.

On the assigned day, hold a wrap-up session for the activity. Use the information students have gathered to draw a simple systems flow chart on an overhead transparency or on the blackboard. If each group looked at the same industrial firm, use input from each group to create a single flowchart. If the groups looked at several different industrial firms, you will need to create several flowcharts. Discuss all of the inputs and out-flows connecting the business with sources and sinks for materials and energy.

Use the following questions to initiate a class discussion and to close the activity:

- What links with global change can you identify upon viewing our flowchart?
- How sustainable is this system? What do you mean by sustainable?
- How can some of the wastes be reduced? Can the industry make use of any recycled products as inputs?

Note: This activity may be combined with Activity 2.5.

Activity 2.5 You Are What You Buy

Goals
Students learn about the scale and variability of the social and environmental impacts associated with the mass production, use, and disposal of a specific product. This activity is designed to expand the level of the analysis done in Activity 2.2 to the regional scale with a focus on a particular product.

Skills
- ✓ mapping and map interpretation
- ✓ library/Internet research
- ✓ team collaboration
- ✓ poster or flowchart construction (optional)
- ✓ discerning the variability inherent in regional/global impacts
- ✓ essay writing

Material Requirements
- *Student Worksheet 2.5* (provided)
- Maps at the scale of the selected industries (i.e., regional, national, and/or global maps)

Time Requirements
2-3 weeks outside of class

Tasks
Divide the class into groups of two to three students and ask each group to choose a product that is sold on at least a regional scale. Each group investigates the type and location of the social and environmental impacts resulting from the product's production, use, and disposal. Students should attempt to answer the following questions:

1. What types of natural resources are used to produce this product? Where do they come from?
2. What adverse environmental impacts does this product create based on its constituent materials, processing, use and disposal? Where do they occur? Are they of the same magnitude and quality in all those places?
3. What adverse social impacts are involved in the product's constituent materials, processing, use and disposal? Where might these occur? Are they of the same magnitude and quality in all those places?
4. Where did the industry as a whole begin? Where is it centered now?
5. What forces have caused the industry to operate the way it has in terms of its spatial expansion or movement (if any), its targeting of consumer market(s), its method of production?

Using this information, students prepare a four to five page report that includes the answers to these questions and summarizes their findings. In addition, depending on the skill level of the class, each group should include a map of the product's origin and impacts. Students can use different colors or symbols to indicate the origins of the product's constituent materials, the disposal sites, and areas of environmental and social impacts. Introductory classes with little prior experience with maps may need additional assistance; you may need to provide students with blank maps and/or excerpts from an introductory geography or cartography text book to illustrate various types of maps. In more advanced classes, students may be able to use computer-based software programs to create their maps.

In addition to the written report, students can also create a poster that includes maps, text, diagrams, and other information from their research. If you choose to use the poster format, allow one class period for students to display and present their work to the class.

Note: This activity may be combined with *Activity 2.4*.

Alternative Activity

Use the map developed in Activity 1.2 that depicts the areas where shirts, shoes, and watches are produced around the world. Rather than allow groups of students to choose their own products, break the class into three larger groups, each of which will research the environmental and social impacts of watch, shirt, or shoe production. Within each group, individual students could take on the task of researching the product in one particular country that produces the product.

Activity 2.6 It's Not Easy Being Green

Goals

Students use their knowledge of industrial ecology to critique the claims made by producers of "green" or "environmentally friendly" products.

Skills

- ✓ critical analysis of text, advertising, and product labels
- ✓ application of recently learned concepts
- ✓ creative writing to a target audience
- ✓ collage production and artistic creativity

Material Requirements

- *Student Worksheet 2.6* (provided)
- Magazines, newspapers, catalogues

Time Requirements

7-10 days outside of class; one class period (50 minutes) for presentation of reports and collages.

Tasks

Students have been hired by a watch-dog environmental group to investigate the claims made by the producers of "environmentally friendly" or "green" products. Their task is to scrutinize these products and their advertisements based on what they've learned from systems theory and thermodynamics and to prepare a two to three page, double-spaced essay summarizing their findings to be published in the group's monthly newsletter. Students should consider whether the products' claims have any substance (according to what they identify as important factors in measuring the ecological merit of a product). Students may need to purchase and use the product, do additional library research on it or a similar product, or even request a catalog or other literature from the producer. Using these sources, students should be able to critically evaluate the advertising claims and assess their validity. For example, some "green" paper napkins now contain recycled materials. Students considering such a product should investigate how much recycled materials the product contains, whether the recycled material is pre- or post-consumer, and whether the final product requires bleaching or other inputs that affect its "environmentally friendly" image. In addition to the report, students also produce a collage of the advertisements and product labels they've examined to be published with the essay.

Encourage students to find as many examples of advertising and packaging labels as they can for the product they chose that make environmentally friendly claims. Students can use magazines, newspapers, catalogues, photographs, or other visual media for this exercise. Allow one class period for students to present their essays and collages.

2 Industrial Ecology as a System: A Conceptual Framework

Student Worksheet 2.1

Activity 2.1 The Entropy of Your Home

Think of the activities you undertake at home (your house, apartment, or dormitory). If you imagine your home as a system that serves to fulfill your needs and wants, what are the energy and material inputs and outputs of your home ; how have the inputs been transformed by the time they leave? What outputs still have a use? How does seasonality affect the flows through your home? Is there any recycling or reuse of materials before they flow out of your home? How do you dispose of the materials that leave your home?

By answering these questions, you will begin to understand the notion of entropy and the concept of a system. Keep track of all of the materials and energy that enter and leave your home for a week. For inputs, record your water use, gas use, electrical use, and all of your purchases (i.e., food, clothes, household products). You may need access to your utility meters or recent utility bills. If you live in a dormitory, you will need to devise other ways of measuring or estimating these variables. For outputs, consider your solid wastes, recyclables, waste water, and the temperature of your living space. Your instructor will provide you with additional information on just how precisely you need to measure these materials.

Keep track of your data in a table including input, use, reuse/recycle, output, method of disposal, and the physical state of the material in disposal. Indicate whether the entropy of the energy that enters your home has increased, decreased, or been unaffected by the time it leaves your home. Prepare a two- to three-page summary of your findings and include your answers to the questions listed below.

1. What are the environmental implications of your outputs? Where do they go for final disposal?
2. Do you have a sustainable supply of inputs?
3. How can you reduce your dependence on unsustainable inputs and wasteful outputs? What constraints do you face in reducing your use of unsustainable inputs and your production of wasteful outputs? What actions have you taken (or will you take)?

Student Worksheet 2.2

Activity 2.2 Critiquing Success Stories

Some industries have taken steps to "green" their production processes. You may question whether or not their steps are truly meeting the principles of industrial ecology. In this activity, you will choose one industry from a set of four case studies provided by your instructor and investigate the steps it has taken toward becoming greener. Each case study includes a list of resources that should help you get started on your research project. You should use these resources as well as the library, the Internet, industry publications and reports, interviews with industry representatives, and/or site visits to research the case study further. Your assessment of the industry's progress toward industrial ecology will depend on what you argue to be the definition, the direction, and the goals of industrial ecology.

Based on your research, write an eight- to ten-page, doubled-spaced research paper that critically analyzes the production and distribution cycle of the industry. You should identify what criteria you used to assess the industry's progress and support your conclusions with sufficient evidence from a variety of sources. Be sure to include a complete list of references.

Student Worksheet 2.4

Activity 2.4 Putting Local Industry Into a Global Context

In this activity you will do some basic research on a local industrial firm that your instructor suggests. You will work with two or three of your classmates and together you will answer the following questions:

1. What are the major *products* of the industrial firm?
2. What are the major *inputs* in terms of sources of materials and energy?
3. Where do the *major materials and energy* come from. Are there any impacts at the source of extraction?
4. *How long* are the sources of materials and energy likely to be economically feasible to use?
5. What are the *major outputs* in terms of disposition of products and byproducts?
6. *Where* do the products and byproducts go and what are the impacts of the outputs at the sites of disposition?
7. *How long* will the products and byproducts last?

You will have at least two weeks to complete your research. You should use as many types of sources as possible to answer these questions including the library, the Internet, interviews with firm representatives, company brochures and other publications, and even tours or site visits. With your group, prepare a three to four page report (to be handed in) that responds to each of the above questions and that includes a complete list of sources and references.

On the assigned day, your instructor will draw a simple systems flowchart on an overhead or blackboard based on the information in your reports and your group's input. The flowchart will include all of the inputs and outputs of the industrial firm and the sources and sinks of materials and energy. You will also discuss the sustainability of the firm, and the ways in which its wastes can be reduced, re-used as inputs, or recycled.

Student Worksheet 2.5

Activity 2.5 You Are What You Buy

Every product you purchase is derived from some type of natural resource and the use of these resources has impacts in locations that are often remote from where you live. With a group of two or three other students, select a product that you use often and that is distributed on at least a regional scale. Find out as much as you can about the product and the industry that produces it. The most useful sources of information (although quite biased) will be the brochures and annual reports that the industry produces and distributes. You can obtain these publications by calling or writing the consumer information departments of particular companies in the industry. Other typical sources will include newspaper, magazine, and journal articles. Lastly, many companies have their own Web pages on the Internet.

As you research your product and industry, try to answer the following questions:

- What types of natural resources are used to produce this product? Where do they come from?
- What adverse environmental impacts does this product create in its consumption of constituent materials, its processing, use and disposal? Where do they occur? Are they of the same magnitude and quality in all those places?
- What adverse social impacts are involved in the product's consumption of constituent materials, processing, use and disposal? Where might these occur? Are they of the same magnitude and quality in all those places?
- Where did the industry as a whole begin? Where is it centered now?
- What forces have caused the industry to operate the way it has in terms of its spatial expansion or movement (if any), its targeting of consumer market(s), its method of production?

Be careful not to choose a product whose material components are too complex to trace adequately in the limited time you have -- products like computers or automobiles. Such a project would take much more time and resources than you have.

As a group, write a four to five page report that answers the above questions. Include with your report a map depicting the source and use regions of your particular product. Use different colors, symbols, or arrows to identify the sources of inputs, the destinations of wastes, and locations of significant social and environmental impacts.

Student Worksheet 2.6

Activity 2.6 It's Not Easy Being Green

As consumers, we are often faced with a wide range of products. There are dozens of different types of breakfast cereal in the local supermarket. Aside from your own individual preferences, how do you select Cheerios over Rice Krispies or Fruit Loops? Environmentally conscious consumers often make choices based on the level of environmental sensitivity of the product. In other words, we look for "environmentally friendly" products -- those that reduce excess packaging, use natural fibers over synthetic ones, and/or contain recycled materials. The "greening" of consumer products has now become quite a cottage industry.

You have been hired by a watch-dog environmental group to investigate the claims made by the producers of an "environmentally friendly" or "green" product. Your task is to scrutinize the advertisements and the product labels for this product and to consider whether the claims they make have any substance. Find examples of environmentally friendly claims on advertising and packaging labels for this product. You can use magazines, newspapers, catalogues, photographs, or other visual media for this exercise. You may need to purchase and use the product, do additional library research on it or a similar product, or even request a catalog or other literature from the producer to help you assess the validity of the claims. In addition, use what you've learned from systems theory and thermodynamics to help you identify important factors in measuring the ecological merit of a product.

The environmental group has asked that you prepare a two- to three-page, double-spaced essay summarizing your findings to be published in the group's monthly newsletter. They have also asked that you produce a collage of the advertisements and product labels to be published with the essay.

2 Industrial Ecology as a System: A Conceptual Framework

Answers to Activities

Activity 2.1 Defining Industrial Ecology

This activity is primarily a way of initiating a class discussion; therefore, no specific answers are provided.

Activity 2.2 Critiquing Success Stories

The research papers for this activity will vary based upon the case study chosen and the research conducted by each student. Use the following list of criteria as a guide for evaluating their reports:

- Did the student define the principles of industrial ecology that he/she used to critique the industry and did he/she cite the authors who influenced these principles?
- Did the student clearly, methodically, and fairly apply these principles to the study?
- Did the student use the case study and the suggested sources of information provided by the instructor?
- Did the student use a variety of research tools (e.g., library and Internet research, interviews, site visits, etc.)?
- Is the paper well written and concise?
- Does the paper reflect a considerable amount of research, synthesized knowledge, and time commitment?

See *Notes on Active Pedagogy* for additional suggestions on evaluating students' work.

Activity 2.3 The Entropy of Your Home

Answers to this activity will vary depending upon students' access to relevant data and the level of detail you ask students to include in their diary of the material and energy flow through their homes. Students should be able to provide quantitative estimates or measurements of most of the inputs and some of the outputs of their home "system." For example, electricity, water, and gas inputs can be estimated from a recent utility bill or by monitoring existing meters. Students who live in dormitories may have to contact the physical facilities of the university or devise another way of measuring these variables. Inputs such as food products, packaging, and other purchases can be quantified in terms of weight or volume. Outputs may be a bit more difficult for students to quantify. For example, students will not be able to quantify the outflows from electric or gas inputs, but should be able to indicate the use of these materials and their final disposition. Students can weigh or record the volume of solid wastes and recyclable materials. Waste water will most likely have to be estimated based upon the amount recorded as inputs.

Students should prepare a clear and concise table that provides a comprehensive list of the types and quantities of all inputs and outputs (even those that are difficult to measure), reused and recycled materials, and waste materials. Students should also provide a concise two to three page report that summarizes their one-week investigation and considers (1) the environmental implications of their outputs (2) the sustainability of their supply of inputs, and (3) ways to reduce their dependency on unsustainable inputs and wasteful outputs and barriers that may prevent them from doing so. See *Notes on Active Pedagogy* for additional suggestions on evaluating students' written work.

Activity 2.4 Putting Local Industry in A Global Context

Student reports will vary based upon the industry chosen for analysis. Use the following general criteria as a guide for evaluating the reports.

- Did the group address all of the questions on the student worksheet?
- Did the group consult a wide range of information sources and did they provide a detailed list of references?
- Is the report well written and concise?

You can also include in the evaluation each group's contribution to the class discussion and the creation of the collective flow chart of the industry. See *Notes on Active Pedagogy* for additional suggestions on evaluating students work.

Activity 2.5 You Are What You Buy

Student reports will vary depending upon the product chosen for investigation.
Use the following criteria as a guide for evaluating the reports:

- Did students choose a product distributed on a regional or larger scale?
- Does the paper address the five questions on the student worksheet?
- Did the group produce effective maps to illustrate the sources of inputs, the destinations of wastes, and locations of significant social and environmental impacts?
- Is the paper well referenced and did the group make use of a variety of information sources?

See *Notes on Active Pedagogy* for additional suggestions on evaluating students' written work.

Activity 2.6 It's Not Easy Being Green

Students' essays will vary depending upon the product and the advertisements they choose. Students should be given the freedom to be creative in their collages, which may consist of magazine and newspaper clippings, product labels or wrappers, photographs, and/or other materials. Their essays should be written in a style that targets the audience of the environmental group's newsletter.

3 Constraints and Opportunities for Industrial Ecology

Background Information

> The evolution of the world's industrial activity into a sustainable and environmentally benign system requires a long-range view and a deep analysis of the environmental implications of today's industrial systems, and a creative approach to the design of services, products, and government policy (Socolow *et al.* 1994: frontispiece).

Near the end of Unit 2, we stated that the goal of industrial ecology is the transformation of existing wasteful industrial systems into efficient ecological industrial systems. But where does one begin this process? In this unit, we look at the constraints and opportunities for industrial ecology from a theoretical perspective and in the real-world context of individual industries and firms. Let's begin with a general look at what stands in the way of industrial ecology before we explore how the barriers actually play out.

Barriers to Industrial Ecology

The first use of the term "industrial ecology" is recent[11] and was popularized by Robert Frosch (1994, 1995a, 1995b) in his articles in *Environment* and *Scientific American*. According to Frosch, there is a great deal of interest in industrial ecology and numerous efforts to achieve it have begun, but important barriers remain. These barriers fall into six general categories: technical, economic, regulatory, legal, informational, and organizational.

A *technical* barrier is the physical impossibility of conducting industrial activities such as recycling and waste minimization. Right now, for example, there is no technology sophisticated enough to chemically transform radioactive waste into useful material, even if a nuclear power plant had the financial capability to afford it. Currently, the waste is either protected in storage or is kept in transit from one site to another.

[11] The first reference to industrial ecology is acknowledged to be Frosch and Gallopoulous (1989); see also Ayres (1989).

Economic barriers are formidable. Firms weigh the cost of retrieving and recycling their by-products and wastes against the cost of either obtaining new materials or of simply disposing of the wastes. Even if it is technically possible to reuse and recycle, a firm will not do so unless it is cost-effective. When products are created and when wastes are disposed of, materials are mixed together. Almost always, they must be separated into their constituent parts in order to be recycled. This separation requires work and some financial expense. You are probably familiar with the washing and/or sorting involved in the recycling of glass, plastic, and paper waste collected by municipal recycling programs. Of course, much of this labor is voluntary (unless recycling is mandated by law) or unpaid. Nevertheless, the work needed to turn the waste material into useful products continues inside the factory, where sophisticated dismantling and separation technologies are employed. Some materials are more easily recycled (entail a lower cost) than others. Metals are relatively easy to recycle. For example, soda cans (minus the labeling) are all essentially composed of aluminum. Thus, the extra time to consider how the product's constituent elements should be separated and the energy to do so, do not have to be expended. When you recycle aluminum, you get aluminum. Organic waste, on the other hand, is much more difficult to recycle and requires additional decisions about what to recycle (i.e., the constituent elements or the energy stored in the chemical bonds between them). These decisions will be based heavily, although not entirely as we shall see, on cost.

Regulatory provisions such as taxes, fines, and pollution quotas have been used to impose artificial (but environmentally related) costs on firms that would otherwise be ignored in an open-system method of waste control and resource usage. The intent of these regulations is to force businesses to minimize their waste and to recycle. These regulatory provisions, however, can also serve as barriers. Regulations often contradict each other, leaving industries in a bind about what they can or cannot do. In response to many regulations, some industries have simply shifted the type of waste they produce from one form to another. When firms were made responsible for air- and water-borne wastes, they often created more solid waste instead. For example, some industrial facilities use "scrubbers" to remove particulate pollution from their air emissions. Although this technology helps control air pollution, it also produces a solid waste known as sludge that must be disposed of.

Legal barriers are laws that discourage firms, usually unintentionally, from practicing industrial ecology. For example, according to a "joint and several liability" clause associated with lawsuits, all firms involved in the production, use, and/or disposal of a toxic material are responsible for any damages resulting from the product. Thus, a firm that supplies a harmless component of the product can be held responsible if the product in which that material is eventually used (by another firm) is harmful.

The remaining barriers are *informational* and *organizational*. Informational barriers refer to a firm's lack of knowledge of (or inability to find out) the costs involved in taking on an industrial ecology production system or practice. Organizational barriers are often the "corporate culture" or "internal incentive system" of a firm that conflicts with the ideals of industrial ecology. Shareholders, corporate executives, and managers can become so accustomed to placing value on increased rates of production and profit that the ideals and values implied in industrial ecology are seen as foolish and contradictory.

These barriers to industrial ecology also produce opportunities (e.g., using cost-efficient "green" technologies, implementing practical regulatory structures, facilitating the distribution of information). Overcoming the barriers to industrial ecology will require actions by individuals, firms, and governments. As you read through the rest of this unit, keep in mind these barriers and opportunities.

Product Life Cycle Assessments

It is probably not feasible to turn every individual firm or industry into a Type II or III industrial ecological system. It seems much more realistic to link different companies and industries such that what one company produces as "waste" could be used as inputs by another. For example, a company that produces waste water containing metallic elements could supply it to another company that needs it as input into its production process. In order to establish the most optimal linkages between firms and industries, it is necessary, however, to know exactly what materials go in and come out of each participant's production process. In other words, each product needs to be analyzed from "cradle to grave" for material and energy flows to identify the types and quantities of materials needed and available. One useful analytical tool to do this is a **product life cycle assessment**. It allows companies and policy-makers to integrate environmental concerns into economic decisions. According to Richards and colleagues,

> [A product life cycle] approach requires that, environmental impacts -- with "environmental" taken broadly to include relevant safety, health, and social factors -- be understood and summed up across the lifetime of the product, process, material, technology, or service being evaluated. The goal is to reduce to a minimum the overall environmental impact of a product or process, and not simply address one aspect of that impact. The goal becomes important because minimizing the impacts of the subsystem does not insure that the impacts of the entire system are minimized, or even reduced (Richards et al. 1994: 13).

The first life cycle analysis was carried out by Coca-Cola in the late 1960s to define and quantify the total material and energy requirements and the environmental impacts of all the processing steps (from mining and extraction to disposal) for each technical option available to the soft drink industry. The study forced Coca-Cola to examine issues such as material availability, energy use, and long-term opportunities for technical improvements. The company wanted to determine whether to purchase beverage cans or to produce them internally. They were also interested in developing a plastic container for carbonated beverages. Simultaneously, public concern with the environment and rising costs of waste disposal were pressuring corporations to consider the environmental impacts of their activities (Duda and Shaw 1996).

The concept of the **life cycle assessment** developed out of the Coca-Cola study and other similar studies. The fundamental goal is to help producers and consumers choose the most appropriate product or process. The choice is often made on the basis of calculating energy and materials flows, as the following example of grocery bags illustrates:

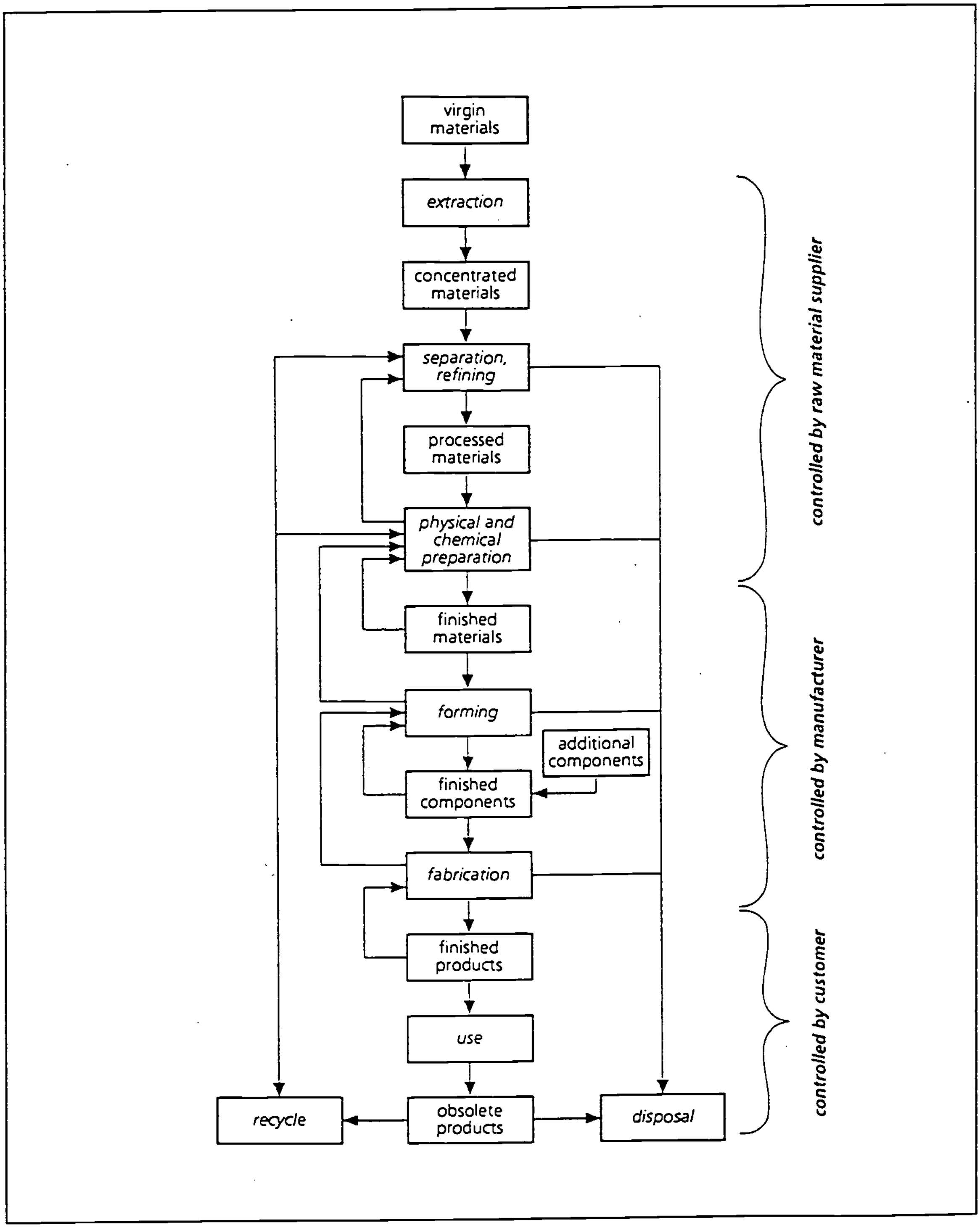
> The purpose of this study was to determine the energy and environmental impacts of polyethylene and paper grocery sacks. In this study the term impact refers to the quantities of fuel and raw materials consumed and the emissions released to the environment. The comparative recyclability, incineration, and landfill impacts of these sacks were also addressed in this analysis. (Franklin cited in Duda and Shaw 1996).

Life cycle assessments provide a snapshot of the inputs and outputs from a system. They are therefore an important tool for evaluating the opportunities and constraints for a particular product or process to close a loop in an industrial ecosystem. Life cycle inventories may be used both internally by organizations or externally to inform consumer or public policy decisions (Keoleian 1994).

Product life cycle assessments, however, do not always provide consumers with clear cut answers. Consider the ongoing debates over paper vs. styrofoam disposable cups, cloth vs. disposable diapers, and paper vs. plastic grocery bags. Numerous life cycle studies have been conducted on these products with conflicting results. One reason for the conflicting results is the problem of delineating system boundaries. How far must one take the analysis? For example, in some cases solid waste is incinerated to create energy. Should this energy production be deducted from the sum total of energy used to create the product? This also presents a geographical problem. Should life cycle assessments be different for products consumed in different places? After all, a consumer in one country may not have the same ability to recycle his or her waste as a consumer in another country because of a lack of infrastructure, incentives, and so on. The second point of contention in life cycle studies involves comparing trade-offs. How does one choose between a product that consumes less energy but produces more solid waste and an alternative product that may consume more energy but produce less waste? In all of these instances public perceptions and preferences play an important role in deciding such questions.

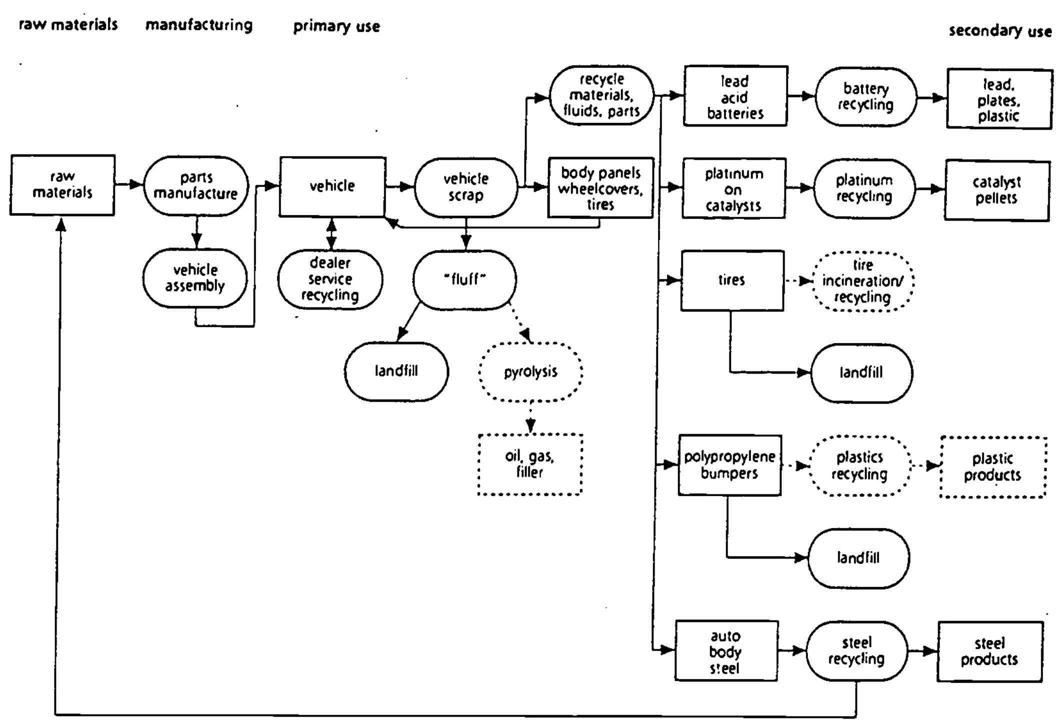
Figure 5 is a model of the entire industrial ecology cycle and Figure 6 illustrates a life cycle for one specific product -- a motor vehicle.

Figure 5: The Total Industrial Ecology Cycle



Source: Graedel, T. 1994. Industrial ecology: Definition and implementation. In R. Socolow, C. Andrews, F. Berkhout, and V. Thomas, eds. *Industrial ecology and global change*. Cambridge, MA: Cambridge University Press, his Figure 6. Reprinted with the permission of Cambridge University Press.

Figure 6: A Motor Vehicle Life Cycle



Note: Rectangles indicate products; ovals indicate processes

Source: France, W. and V. Thomas. Industrial ecology in the manufacturing of consumer motor vehicle life cycle products. In R. Socolow, C. Andrews, F. Berkhout, and V. Thomas, eds. *Industrial ecology and global change*. Cambridge, MA: Cambridge University Press, their Figure 4. Reprinted with the permission of Cambridge University Press.

In the next section, let's take the issue of barriers and opportunities from the local to the global scale. Clearly, not all industries and nations can begin the evolution toward industrial ecology from an advantaged position like those in more developed countries like the US.

Moving Toward Industrial Ecology on an Uneven Playing Field: The North/South Cleavage

Unit 1 outlined the development of the global industrial system in terms of the increasing ability that technology has given humans to transform their local, regional, and global environments and to influence culture as well. As we noted, these changes do not take place homogeneously across the globe. There was, and is, regional variability in the effects of technological change. Some people and places have been devastated by the effects of technological change while others have profited.

The global system has experienced not only marked *technological* change in the course of its creation, but also *political* and *economic* changes. In short, there is a clear division in the economic and political power among the nations of the world. The two parts of this division are commonly referred to as the developed and developing countries, the First World and Third World, or the North and the South. Knox and Agnew, borrowing from Meier and Baldwin, describe this division in terms of core and periphery countries:

> A country is at the *core* of the world economy if it plays a dominant, active role in world trade. Usually such a country is a rich, market type economy of the primarily industrial or agricultural-industrial variety. Foreign trade revolves around it: it is a large exporter and importer, and the international movement of capital normally occurs from it to other countries (Meier and Baldwin 1957: 147).
>
> In contrast, . . . a country could be considered *peripheral* if it plays a secondary or passive role in world trade. In terms of their domestic characteristics, peripheral countries may be market-type economies or subsistence-type economies. The common feature of a peripheral economy is its external dependence on the centre as the source of a large proportion of imports, as the destination for a large proportion of exports, and as a lender of capital (Meier and Baldwin 1957: 147) (Knox and Agnew 1994: 16-17).

The countries of the North are considered core countries; they include the industrialized countries of North America, Europe, the former USSR, Japan, New Zealand, and Australia. The South, representing the political-economic periphery, includes China, all of South and Southeast Asia, Latin America, Africa, and the Middle East.

Core-periphery divisions intensify barriers to industrial ecology. The periphery is at a disadvantage in its attempts to minimize its environmental impacts. People in the periphery have much lower incomes, and the core has an advantage in terms of its power to influence rules and regulations, international trade organizations, and the financial institutions of the world economy. This uneven distribution of money and power has pervaded (to a greater or lesser extent) all international meetings on the major global environmental issues such as global warming, hazardous waste trading, deforestation, and population issues.

Let's take global warming as an example. While the "developed" countries (core or Northern countries) have relied on the burning of vast amounts of fossil fuel to reach and maintain their standard of living, the "developing" (peripheral/Southern) countries, which contribute much lower greenhouse gas emissions per capita to the global total, are being asked to hold back the reins on their own development. At the same time, many in the developed world maintain that only economic development will be able to curb the exponential population growth occurring in the South. The rich nations, with only 25% of the world's population, produce more than half of all greenhouse gases. Most of this energy burning goes toward fueling what most peripheral citizens would consider luxury items: cars, TV's, microwaves, and other amenities. In the periphery, most contributions to climate change are coming from agriculture and forests, in the form of methane from cattle and rice paddies, and carbon released from the burning of trees. These activities are largely associated with survival efforts.

At the same time, Third World leaders are desperately trying to increase the availability of electricity and oil for development in their countries while millions of Third World citizens labor to increase their standard of living to one that comes closer to that of the First World. To achieve these goals, large investments are required in the periphery. The pressing issue here is that if nations on the periphery follow the same wasteful road to development as the core countries have taken, the global atmosphere and the earth's resources will be dangerously affected. Meanwhile, the periphery cannot afford the advanced pollution control technology that the core now possesses. The popular solution being proposed in international negotiation circles is for the rich core countries to finance the necessary technology, while simultaneously reducing their own emissions.

In short, the move toward industrial ecology at the global level is only to some extent a technological problem. It is also a political and economic problem involving complex issues such as population growth, lifestyle choices, economic development, equity, and international justice. Again, these challenges are daunting and will require action at all scales from the farm and firm to the international negotiating table and on all fronts (regulatory, political, organizational, and educational). Nations across the globe need to turn to systems thinking regarding their economies and the global environment. The essence of systemic and cumulative global changes is that what we do in one place can change what happens to all of us.

3 Constraints and Opportunities for Industrial Ecology

Instructor's Guide to Activities

Goal

Students explore the opportunities and constraints provided by industrial ecology in the real world at the local and regional scales. Students also read and respond to essays and articles that present unsettling arguments or that make disturbing claims about the current trends in issues related to industrial ecology.

Learning Outcomes

After completing the activities associated with this unit, students should:

- be able to compare the usefulness of data used in life cycle analyses;
- recognize the role that values play in evaluating the relative environmental impacts of certain products (e.g., cloth versus disposable diapers);
- understand the major barriers to, and opportunities for, implementing industrial ecology;
- understand how barriers to implementing industrial ecology are intensified at the international scale; and
- be able to respond critically to arguments against the feasibility of implementing industrial ecology.

Choice of Activities

It is neither necessary nor feasible in most cases to complete all activities in each unit. Select those that are most appropriate for your classroom setting and that cover a range of activity types, skills, genres of reading materials, writing assignments, and other activity outcomes. This unit contains the following activities:

3.1 Life cycle Analysis	-- Data analysis, recognition of values in assessing data, and creative writing
3.2 Industrial Ecology Game	-- In-class game on creating inter-industry cooperation
3.3 Industrial Ecology Field Trip	-- Field trip or guest presentations
3.4 Free Trade and Agriculture	-- Text comprehension, in-class debate, and critical writing
3.5 A Critical Brief	-- Writing a critical brief responding to hot-button issues in industrial ecology

Suggested Readings

The following readings accompany the activities for this unit. Choose those readings most appropriate for the activities you select and those most adequate for the skill level of your students.

- Background Information to Unit 3 (all students should read)

For Activity 3.1

- Graedel, Thomas and Braden Allenby. 1995. An introduction to life cycle assessment. In *Industrial Ecology*. New York, NY: Prentice Hall.
- Hocking, Martin B. 1994. Disposable cups have eco-merit. *Nature* 369 (12 May): 107.
- ________. 1991a. Paper versus polystyrene: A complex choice. *Science* 251 (1 February): 504-505.
- ________. 1991b. Paper versus polystyrene: Environmental impact. (Letters section). *Science* 252 (7 June): 1361-1363.
- Portney, Paul R. 1995. The price is right: Making use of life cycle analysis. *Issues in Science and Technology* 10 (2): 69-75.

For Activity 3.2

- Edgington, Stephen M. 1993. Industrial ecology: Biotech's role in sustainable development. *Bio/technology* 13 (January): 31-34. (provided)

For Activity 3.4

- Globerman, Steven. 1993. Trade liberalization and the environment. In S. Globerman and M. Walker, eds. *Assessing NAFTA: A tri-national analysis*. Vancouver, Canada: The Fraser Institute, pp. 293-314. (provided)
- Ritchie, Mark. 1993. Agricultural trade liberalization: Implications for sustainable agriculture. In R. Nader, ed. *The case against free trade: GATT, NAFTA, and the globalization of corporate power*. San Francisco, CA: Earth Island Press, pp. 163-194.

For Activity 3.5

- Helvarg, David. 1996. The big green spin machine: Corporations and environmental PR. *The Amicus Journal* 18 (2): 13-21. (provided)
- Puckett, Jim. 1994. Disposing of the waste trade: Closing the recycling loophole. *The Ecologist* 24 (2): 53-58.
- Tierney, John. 1996. Recycling is garbage. *The New York Times Magazine* (30 June): 24-29, 44, 48, 51, and 53.

Activity 3.1 Life Cycle Analysis

Goals

Students compare the material, water, and energy flows of the life cycles of the three products (paper, plastic, and ceramic cups). Students recognize the complexities involved in life cycle analyses including data quality, boundary delineation, and value judgments.

Skills

- ✓ qualitative/quantitative data assessment
- ✓ determining relevant and non-relevant data
- ✓ identifying the role of values in making data interpretations
- ✓ position formulation
- ✓ creative writing
- ✓ role playing

Material Requirements

- *Student Worksheet 3.1* (provided)
- *Supporting Material 3.1* (provided; needed for Option 2)
- Suggested Reading (for all options): Graedel and Allenby (1995); Portney (1995)
- Suggested Reading: Option 1: Hocking (1994, 1991a, and 1991b)
  Option 2: Hocking (1991a)
  Option 3: Hocking (1994)

Time Requirements

Option 1: 7- 10 days
Option 2: 7-10 days
Option 3: 2-3 days

Tasks

Note: All three options for this activity rely heavily on the three suggested readings listed above. Because of copyright restrictions and costs, these articles could not be distributed with this module. These readings should be readily available in your university's library or through interlibrary loan. Allow sufficient time to obtain them.

Option 1

Divide the class into three groups, each of which will represent paper, plastic, or ceramic cup makers. Ask each group 1) to conduct research outside of class to calculate the material flows, energy consumption, and water consumption for all three products and 2) to prepare an argument for why their product is more environmentally sound than the others. The three suggested readings by Hocking (1994, 1991a, 1991b) will be helpful to that end. Students should perform the calculations individually outside of class before meeting in group to compare results and discuss. Together they should consider how they could improve their product to make less of a problem.

On the assigned day, ask each group to present their calculations and their arguments. You may wish to structure the class discussion like a debate with each group defending their product.

Option 2:
Students practice their creative writing skills by finishing a dialogue between fictional colleagues in the life cycle analysis field about the relative environmental impacts of paper versus polystyrene cups. [The dialogue is provided in *Supporting Material 3.1*. Students will need Table 1 from the suggested reading by Hocking (1991a) to make sense of the dialogue.] Students will first summarize the dialogue in *Supporting Material 3.1* and then complete it by leading the discussion toward some sort of closure or consensus. In addition to the dialogue, students will also write a few paragraphs answering the questions below:

- Was any relevant information left out of the discussion?
- Were any of the comments in the dialogue redundant or unimportant?
- Do you agree or disagree with what anyone said? Why?
- Can all the variables in this debate really be measured quantitatively?
- Are any value judgments evident?
- What seems to be the biggest roadblocks to deciding which cup is best?

Option 3
Ask students to read Hocking (1994). In the article, the author reports the findings of a life cycle analysis comparing ceramic, glass, plastic, paper, and polystyrene foam cups.

Students write a two-page essay about the article to encourage critical thinking about the assumptions and value judgments underlying life cycle analyses. In their essays, students will address the following questions:

- What criteria did Hocking choose for his analysis?
- Where did he draw the boundary of the system?
- Does he consider the energy use associated with disposing of or recycling disposable cups? How would you determine the energy used in disposing of a cup?
- Would the test results have been different if he had selected both materials flow and energy flow as his criteria?
- What cup should *you* use and why?

Activity 3.2 The Industrial Ecology Game

Goals
Students see the potential (or lack thereof) for industries to cooperate by reusing each other's waste products.

Skills
- ✓ library/Internet research
- ✓ team and class collaboration

Material Requirements

- Suggested reading: Edgington (1993) (provided)
- 3" × 5" note cards

Time Requirements

one class period (50 minutes)

Tasks

Students read the suggested article by Edgington (1993) to get a feel for how industries can interact to recycle each other's waste. The article reviews the apparent success of an industrial park in Kalundborg, Denmark in trading and reusing the wastes of its constituent companies; this description provides a concrete example of how industrial ecology can work in the real world.

Before class, select several industries whose material and energy inputs and outputs are complementary. For example, a meat packing industry could provide hides to be used in making leather furniture, or a soda manufacturer could provide waste plastic bottles to a carpet maker. Divide the class into small groups of three to four students and assign each group one of the potentially cooperative industries (make sure that each group has a different industry). Give each group a stack of 3" × 5" index cards and ask them to write each output that their industry creates on the cards including the principal product and by-products (one per card). At the top of each card, they should also write the name of their industry. Finally, on a separate sheet of paper, students should make a "shopping list" of the material and energy inputs that their industry requires. Allow them 10 or 15 minutes to complete this task.

Next, tell the groups that their task is to create an industrial ecology park (like the one in the suggested readings). They must circulate throughout the classroom looking for sources of the inputs on their "shopping list" and attempting to find "takers" for their outputs. If they find a source of their inputs, students take the appropriate card from that industry. When they find a taker for one of their outputs, they give the appropriate card to that industry. The goal is to get rid of all of their output cards and to collect all of the necessary input cards. Allow only 5 or 10 minutes for this part of the activity to provide a fast-paced, open-market atmosphere.

After the trading, bring the class together to discuss the process. Ask them how well they did in finding buyers for their outputs and in finding sources for the materials they need. Were they successful in creating an industrial ecology park? What difficulties did they encounter? If time allows, you may choose to draw a diagram or flowchart of the industrial park on the chalkboard attempting to link all of the industries.

Variations

1. If your class has had little experience with this subject or if you have time constraints, you may choose instead to provide a set of completed cards to each group on which you have already listed the outputs for their industry; you can also provide them with the "shopping list" of inputs they need. This will require some preparation before class on your part, but it may

allow the activity to run more smoothly because you can ensure that the inputs and outputs from all the industries are complementary (although they need not be perfectly complementary).

2. If you have sufficient time and would like to make the activity more detailed, assign industries to each group and give them three or four days to research its processes and to prepare their output cards and their "shopping list." This will allow students to get a more thorough understanding of the real material inputs and outputs of the industry. Similarly, you can use some of the industries that students have already examined in earlier activities so that they are familiar with their processes. This will reduce the need for students to do additional research, and it will link this activity to others in the module.

Activity 3.3 Industrial Ecology Field Trip

Goals
Students learn about an industrial firm first-hand by visiting the site, interviewing the people who work there on a daily basis, and developing a flowchart of the firm's system.

Skills
- ✓ interviewing
- ✓ field observation

Material Requirements
- Transportation to the site for the class

Time Requirements
One day to visit the chosen site; allow additional time for in-class preparation before the visit and for a debriefing after the visit.

Tasks
Exploring industrial systems works well by taking a field trip to industrial firms or industrial farms that exemplify the elements of industrial ecology. The first step in preparing this activity is to scan the region to locate environmentally innovative industrial practices. Although not all locations are equally endowed with firms that follow the ecological or metabolic metaphors, even making a visit to one that does not permits a close comparison of ideals and realities (once you are back in the classroom).

Ask students to prepare for the site visit by investigating conventional practices within the targeted industry through their library. (Alternatively, if you are familiar with the firm, provide students with this background information.) This allows students to become familiar with the economic and social context of the firm and its industry, including a listing of categories of people who benefit (or are negatively affected) by the firm.

For additional background preparation, you can ask students to develop a flowchart of the industrial process, including inputs and outputs of the firm's operations. A useful way for them to organize this might be to borrow the formats for materials flows in raw materials processing, manufacturing, and customer use from Socolow (1994), with case examples for the automotive, beverage, camera, and clothing industries from France and Thomas (1994). This part of the activity is not necessary if you have particular time constraints or if students have had sufficient practice in previous activities creating flow charts.

Once students have gained an understanding of the firm and its industrial system, they are ready for the site visit. Companies who are proud of their environmental record are likely to be open to visits by students of environmental sciences, while those with less rosy records may be reluctant to extend a welcome. With a little persuasion and persistence, however, it is possible to get into many sites (even the grayest of industries benefit from the public relations they gain by opening their doors a little bit). Once inside, students should (1) pay particular attention to the processes of materials and energy flows, (2) ask questions about the product cycle and the firm's management practices, and (3) take notes of their visit.

After the visit and as a homework assignment, ask students to review their notes and prepare a one to two page written assessment of the performance of the firm. Using the concepts learned through classroom lectures, background readings, and other activities, students should devise their own methodology for assessing the performance of the industry. You may want to refer students to readings on impact assessment to enable them to have a firm grounding in the variety of procedures and concerns found in other assessment techniques.[12] Although the students' assessments are apt to be qualitative, you may encourage students to bring comparative quantitative data into the assessment, as well.

In the next class session after the visit, conduct a debriefing to discuss the visit and to compare students' notes and written assessments with the background information and flowcharts gathered before the visit.

Variation: Inviting Industry into the Classroom

Sometimes there are logical reasons why site visits are prohibited. Suitable sites may be too far from the school, resources for travel may be lacking, or class size may make a field trip difficult. Some firms may be unwilling to permit visitors, citing liability, staffing, or production disruption reasons; size of class may also be a factor, since most factories are designed for efficiency of operation and not as classrooms or laboratories. In any of these cases, bring the industry to the classroom!

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12 Several excellent sources on impact assessment include McAllister (1980), Morris and Therivel (1995), Ortolano (1984), Porter, et. al. (1980), Smith (1993), and Wood (1995).

Most firms maintain public relations offices, and many have programs for public education. Speakers bureaus and company officials may frequently be tapped to present a classroom discussion of the environmental affairs of the firm. With appropriate pre-planning by the instructor, this can be a reasonable alternative to taking students on site for a first-hand look. Prior to the class presentation, students should read some focused literature about the particular industry to gain some familiarity (this can include their own research, articles that you provide, or literature provided by the firm). As an in-class or out-of-class exercise, students can develop a checklist for assessing the performance of the firm (see the main activity above).

A telephone call to the local or regional office of a particular industrial firm is certain to yield information, if not an actual acceptance of an invitation. Contacting national trade organizations or industrial associations may also prove fruitful, as most industries maintain public relations offices or environmental quality assurance programs. There is nothing quite so effective, however, as finding a personal contact within a plant and exploiting that firm's image within the local community as a means of bringing the speaker to the classroom.

Activity 3.4 Free Trade's Effects on Sustainable Agriculture: A Debate

Goals
Students develop a position on an international policy issue (international trade regulation) that has serious potential effects on the future of industrial ecology.

Skills
✓ assessment and comparison of opposing arguments
✓ position formulation
✓ debating
✓ text comprehension

Material Requirements
- *Student Worksheet 3.4* (provided)
- Suggested readings: Ritchie (1993)
  Globerman (1993) (provided)

Time Requirements
Four to five days preparation outside of class before the debate; one class period (50 minutes) for the debate; allow additional time outside of class for the optional written assignment after the debate.

Tasks
Students read the suggested articles, which present conflicting opinions of the effects of free trade on the future of industrial ecology. Assign one-half of the class to one viewpoint and the other half to the opposing viewpoint before students read the articles so that they can begin to

formulate their arguments. Allow several days for students to do additional research to support their perspective.

On the assigned day, hold a class debate. You should help keep the debate on track and ensure that all students get a chance to speak.

If you wish, you can ask students to write an op-ed piece in which they defend their assigned position. Essays should be no longer than two pages.

Activity 3.5 A Critical Brief

Goals
Students write a critical brief in which they react to controversial issues in industrial ecology.

Skills
- ✓ critical reading and writing
- ✓ position formulation

Material Requirements
- *Student Worksheet 3.5* (provided)
- Suggested readings: Helvarg (1996) (provided)
  Tierney (1996)
  Puckett (1994)
- *Supporting Material 3.5a* (provided; includes a list of alternative suggested readings)

Time Requirements
one week outside of class

Tasks[13]
Students need to learn how to think critically about global environmental change issues in the news. Instructors need to teach students that to be critical is not to be harsh, negative, or judgmental, but to demand that claims and propositions be well-constructed, logical, and supported by principles of sound reasoning. The critical brief is an activity that helps students learn and practice these skills.

Students read and respond to one or more controversial articles in a three- to four-page critical brief. A critical brief should achieve two goals: 1) it should be descriptive, briefly stating the premises, major themes, or arguments of each point of view; and 2) it should be evaluative, critically analyzing and critiquing the premises, arguments, and conclusions of each viewpoint.

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13 Eflin and Eflin (1996) describe an in-class actiivity integrating critical reasoning skills and themes from global environmental perspectives; a copy is available from the authors.

Depending on your time constraints and your classroom situation, you can have students read just one, several, or all of the suggested readings. Additional topics and the references for suggested readings are provided in *Supporting Material 3.5a*.

3 Constraints and Opportunities for Industrial Ecology

Student Worksheet 3.1

Activity 3.1 Life Cycle Analysis

This activity consists of three related, but different exercises. Your instructor will tell you which of the following options you will complete.

Option 1
Your instructor will divide the class into three groups, with each group representing either paper, plastic, or ceramic cup makers. Your group must conduct research to calculate the material flows, energy consumption, and water consumption of all three cups, and then make an argument for why your product is more environmentally sound. Perform the calculations on your own outside of class and then meet with your group to compare results and discuss. Consider how you could improve your product to make it more environmentally benign. Be prepared to present your findings and your argument to the class.

Option 2
Imagine you are in a conference room with several of your colleagues in the life cycle analysis field. You have been discussing and comparing the environmental impacts associated with the production, use, and disposal of paper and polystyrene (foam) cups. Everyone in the room wants to reach an agreement on what factors need to be considered to compare the two disposable products and how these factors should be measured.

Your instructor will provide you with a written copy of the dialogue and some background information to help you understand what has been said. Your task is to finish the dialogue as if you are actually a part of the conversation in the conference room. Write down exactly what you would say. Begin by summarizing the conversation so far and suggesting how to move the discussion toward consensus. Be sure to add more than just your own words -- include additional dialogue from your colleagues. For example, if you think that Mrs. O would object to one of your statements, what would she say (besides "I object")? Feel free to expand the bounds of the initial question. If you think reusable ceramic cups, for instance, have eco-merit, you could argue that it is pointless to look at only paper and polystyrene. But be sure to support your argument!

After you've completed the dialogue, write a few additional paragraphs that respond to the following questions:

1. Was any relevant information left out of the discussion?
2. Were any of the comments in the dialogue redundant or unimportant?
3. Do you agree or disagree with what anyone said? Why?
4. Can all the variables in this debate really be measured quantitatively?
5. Are any value judgments evident?
6. What seem to be the biggest roadblocks to deciding which cup is best?

Option 3

Determining the boundaries of a system and choosing the criteria for comparison (i.e., energy flow, material waste or both) are two of the most controversial aspects of a life cycle assessment. Read the article provided by your instructor and answer the questions below in a two to three page essay. While you read, be sure to consider the assumptions and value judgments implicit in the analysis.

1. What criteria did Hocking choose for his analysis?
2. Where did he draw the boundary of the system?
3. Does he consider the energy use associated with disposing of or recycling disposable cups? How would you determine the energy used in disposing of a cup?
4. Would the test results have been different if he had selected both materials flow and energy flow as his criteria?
5. What cup should *you* use and why?

Student Worksheet 3.4

Activity 3.4 Free Trade's Effects on Sustainable Agriculture: A Debate

Before class, read the chapter provided by your instructor (Ritchie 1993) in which the author denounces the international loosening of "barriers" to commerce in food products. These so-called barriers, however, include many food safety regulations, price regulations, and other measures designed to protect the sustainability of small farms and the livelihood of those workers who cultivate them.

Also read the chapter by Globerman (1993) provided by your instructor. Although agriculture is not his main focus, Globerman presents a different perspective, arguing that free trade may be good for the environment.

Your job is to defend one of the above perspectives in an in-class debate on the liberalization of international agricultural trade. You will need to do some additional research before the debate to prepare your argument.

During the debate, be sure to take notes on the arguments made by both sides of the issue. Your instructor may ask you to write a formal essay based on the debate, your own research, and what you learned from the other perspective.

Student Worksheet 3.5

Activity 3.5 A Critical Brief

Technological change, industrial ecology, and the human dimensions of global change are controversial subjects that require critical assessment for a rich and complete understanding. You may agree with the prevailing paradigm in modern society that technology brings progress and progress is good. Likewise, the idea of an industrial ecology may seem idealistic or too complex to be practical. For many themes within the field of the human dimensions of global change, arguments are made on both sides of the debate, requiring readers to take a close, critical approach.

One way to learn this approach is by writing a *critical brief*. A critical brief should achieve two goals: 1) it should be descriptive, briefly stating the premises, major themes, or arguments of each point of view; and 2) it should be evaluative, critically analyzing and critiquing the premises, arguments, and conclusions of each viewpoint. The brief should be about three or four pages long. It is advised that you locate additional related articles to help you respond to the assigned article(s).

Choose from among the following articles for your critical brief. Your instructor will tell you how many readings you are responsible for.

- Helvarg, David. 1996. The big green spin machine. *The Amicus Journal* 18(2):13-21
- Tierney, John. 1996. Recycling is garbage. *The New York Times Magazine* (30 June):24-29,44,48,51,53.
- Puckett, Jim. 1994. Disposing of the waste trade. *The Ecologist* 24(2): 53-58.

3 Constraints and Opportunities for Industrial Ecology

Answers to Activities

Activity 3.1 Life Cycle Analysis

Option 1
There are no right or wrong answers to this activity. Student assessments will vary depending upon the data sources they use for their analysis. Use the activity to initiate a lively class discussion or a class debate about the relative environmental impacts of each product.

Option 2
Because this is a creative writing activity, student essays will vary. Make sure that students have made a serious attempt to provide additional realistic dialogue to that provided. Students should also include several paragraphs that address the questions on the student worksheet. See *Notes on Active Pedagogy* for additional suggestions on evaluating students' work.

Option 3
Because this is a creative writing activity, student essays will vary. Their essays should include responses to the questions on the student worksheet and should demonstrate a clear understanding of the suggested reading. See *Notes on Active Pedagogy* for additional suggestions on evaluating students' work.

Activity 3.2 Industrial Ecology Game

There are no specific answers to this activity. The success of the game will depend on the variation used, the industries selected, and student and instructor enthusiasm. If you provide completed 3" x 5" cards with the outputs already specified, the activity will run more smoothly because you can ensure complementarity among the various groups' outputs and inputs. If you allow students to develop their own cards and lists, the game may not result in a perfect fit among the industries' needs and wastes, but it may describe a more realistic situation.

Activity 3.3 Industrial Ecology Field Trip

Because of the nature of this activity, there are no specific answers.

Activity 3.4 Free Trade's Effects on Sustainable Agriculture: A Debate

Because this activity is a class debate, there are no specific answers. If it is necessary to grade students on this activity, you can evaluate them on the clarity of their arguments, their level of preparation, their respect for other students' perspectives, and their overall participation in the debate. You should help to keep the debate moving and to allow each student to speak.

Activity 3.5 A Critical Brief

Students' critical briefs will vary depending upon the article they choose (or are assigned) to read. Use the following criteria to evaluate their work:

- Is the brief descriptive and does it state the premises, major themes, and/or arguments of the reading(s)?
- Does the student critically analyze and critique the premises, arguments, and conclusions of the reading(s)? In other words, do they do more than summarize? Do they engage with the material?
- Is the brief well written, concise, and less than four pages (double-spaced) in length?

See *Notes on Active Pedagogy* for additional suggestions on evaluating students' written work.

Glossary

Note: Words in bold in the right-hand column appear elsewhere in the glossary.

closed system	a system that has little or no links to its external environment.
cumulative change	a type of global change resulting from individual local activities that do not directly affect a global functioning system but when widely replicated in multiple locations are globally significant.
driving forces	societal forces that bring about global environmental change, including population, economy, **technology**, ideology, and social organizations.
ecosystem	self-regulating natural community of plants and animals interacting with one another and with their non-living environment.
entropy	a measure of the amount of energy in a system that cannot be used to perform work; high entropy means that the energy in the system has very little capacity to do work.
greenhouse effect	the role of various trace components of the atmosphere (such as H_2O, CO_2, etc.) in reabsorbing certain wavelengths of the energy spectrum radiated from the earth's surface thereby increasing the global temperature. This effect occurs naturally, but is augmented by human activities such as the burning of fossil fuels and land cover changes since these changes emit trace gases that become further concentrated in the atmosphere (enhanced greenhouse effect).
greenhouse gases	a group of gases, including carbon dioxide, methane, chlorofluorocarbons, ozone, and nitrous oxide that are radiatively active, i.e., they absorb longwave radiation in the atmosphere.
Industrial Revolution	a series of social, political, and economic changes within the British economy between 1750 and 1850 that transformed the forces of production; the influences of these changes spread throughout parts of the world and were seen in the US with the growth of the steel industry, engineering, and increased electricity consumption.
nonrenewable resource	a resource that is available in fixed amounts on the earth and can be totally depleted because (1) it is not replenished by natural processes or (2) it is used more quickly than it can be replenished.

open system	a system that has flows to or links with its environment.
paradigm	the working assumptions, procedures, and findings routinely accepted and employed by a group of people; a paradigm defines one's view of the world and the approach one takes to defining problems, researching them, and solving them.
sinks	places where materials are collected or disposed of either temporarily or permanently (i.e., the global atmosphere is a sink for greenhouse gases; biomass or riverbeds are temporary sinks for carbon, nitrogen, and phosphorous.)
sustainable (-ability)	an activity that can be maintained without jeopardizing the health of humans or the environment now or in the future.
sustainable development	development that meets the needs of the present without compromising the ability of future generations to meet their own needs.
system	a group of elements organized in such a way that every element is to some degree dependent on every other element.
systemic change	a type of global change that results from human activities that directly affect a globally functioning system (e.g., release of greenhouse gases into the atmosphere may lead to changes in the global climate system)
technology	practical methods for controlling physical objects and forces; the means by which humans modify the material nature of their world.
Type I ecology	a system characterized by a linear flow of material throughputs; involves the consumption of unlimited resources and the production of unlimited wastes.
Type II ecology	a system characterized by a quasicyclic flow of material throughputs; involves the consumption of energy and limited resources and the production of limited wastes.
Type III ecology	a system characterized by a cyclic flow of materials that are continuously recycled among the members of the system; in an ideal state, involves minimal exchanges with the environment, except for energy inputs.

References to All Units

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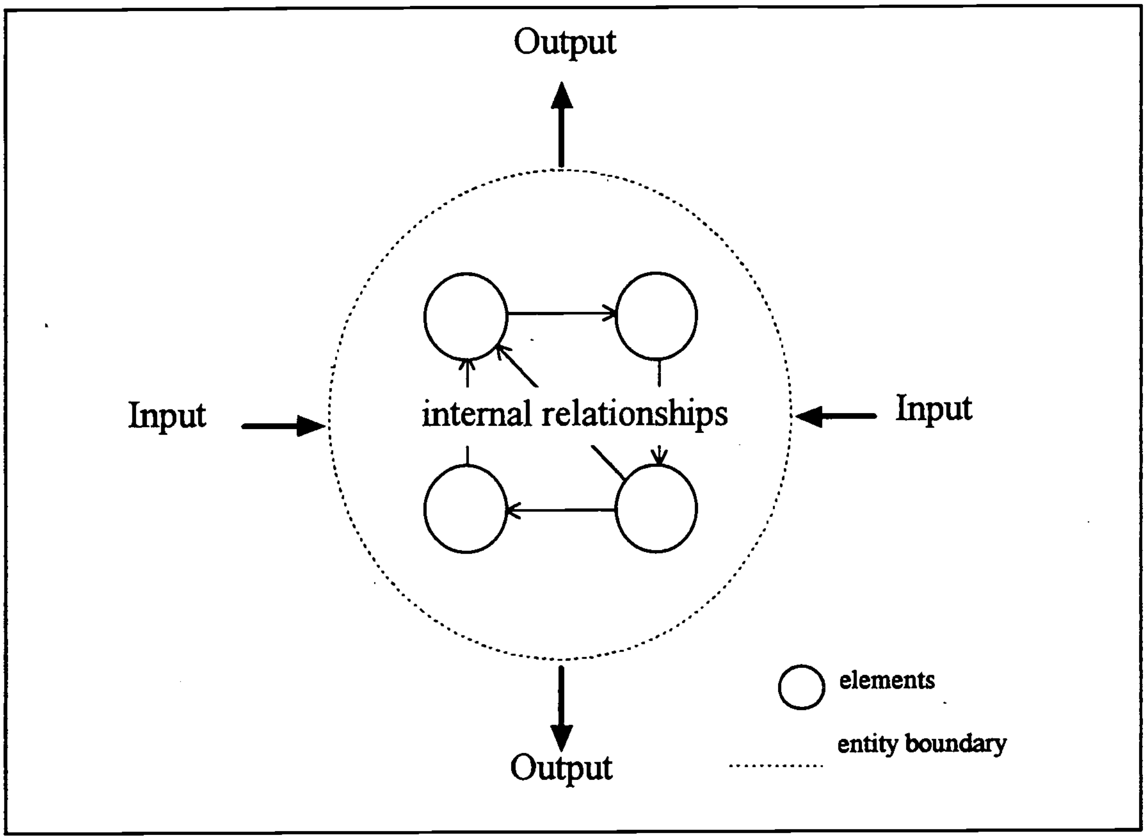
Supporting Materials

The materials in this section support the background information and the student activities. Each *Supporting Material* is numbered according to the section or activity in which it may be used. For example, *Supporting Material 1.1* accompanies *Activity 1.1*. Materials that are intended to support the *Background Information* in the module, such as overhead originals or other documents, are numbered according to the Unit. For example, *Supporting Material 3* accompanies the *Background Information* for Unit 3.

Overhead Originals for Class Discussion of Unit 2

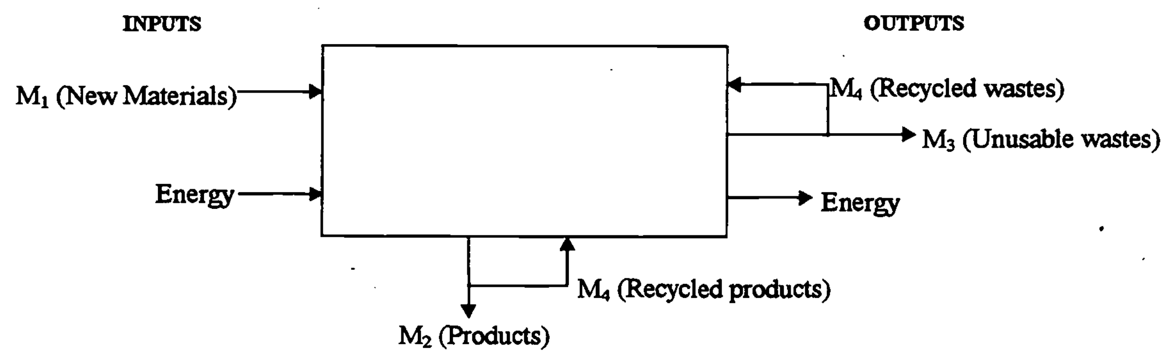
The following pages contain overhead originals that can be used to support the information presented in *Background Information* of Unit 2. The instructor may use these in class to summarize the information students read in the module or to organize lecture material.

A Simple System Model

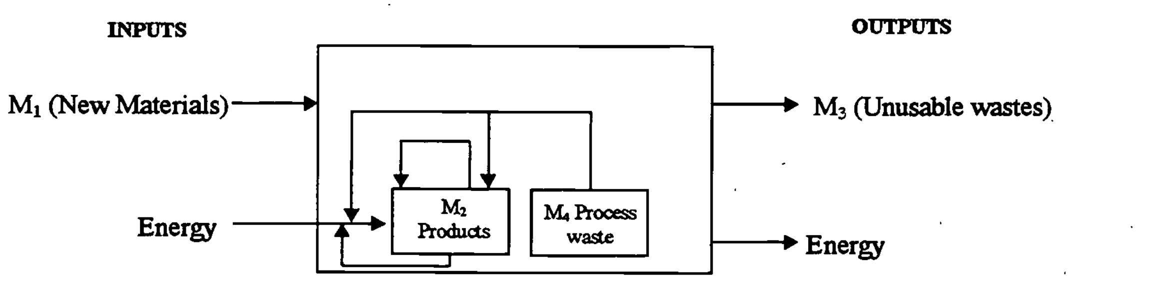


Open and Closed Systems of Materials Flow

a: An open system of materials flow.

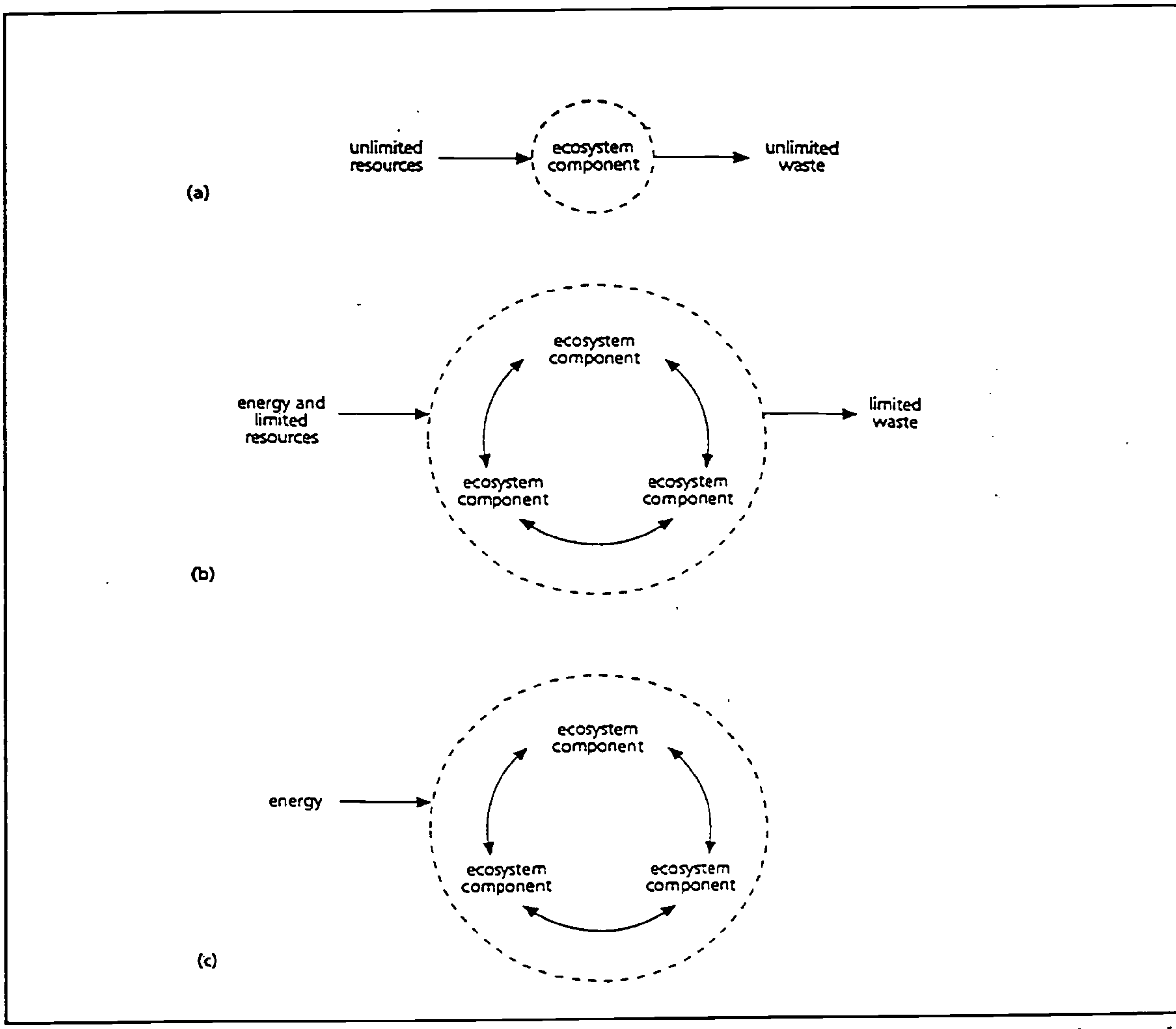


b: A closed system of materials flow.



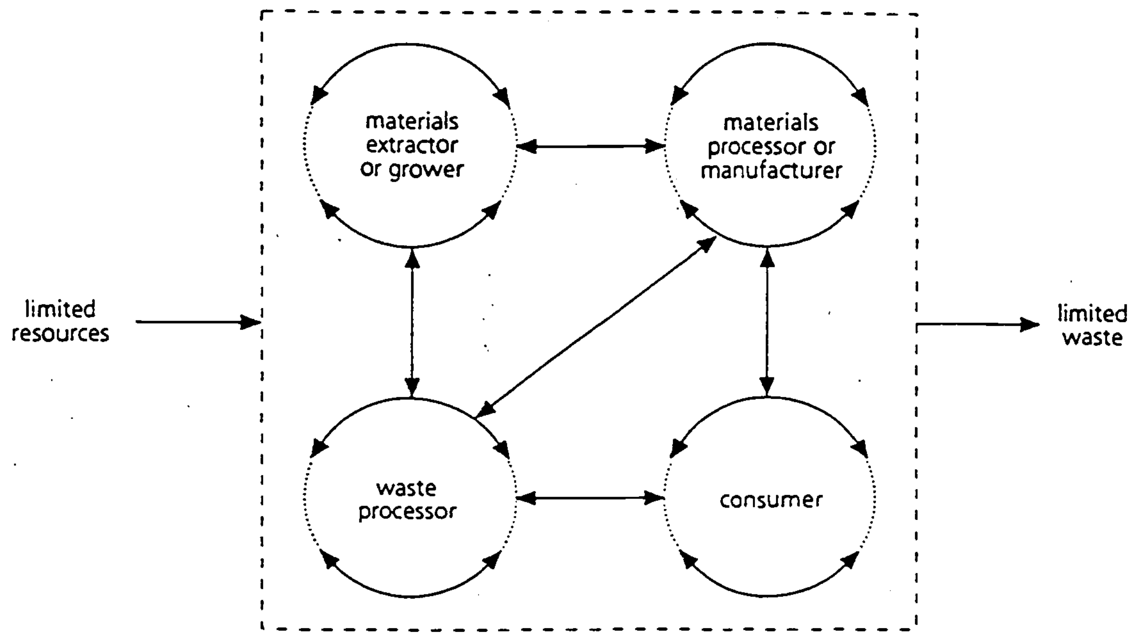
Source: Frosch, Robert. *Environment* 37 (10):20. 1995. Reprinted with permission of the Helen Dwight Reed Educational Foundation. Published by Heldref Publications, 1319 18th St. NW, Washington, DC 20036-1802. ©1997.

(a) Linear material flows in "Type I" ecology (b) Quasi-cyclic materials flows in "Type II" ecology (c) Cyclic materials flows in "Type III" ecology



Source: Graedel, T. 1994. In Socolow, Andrews, Berkhout, and Thomas, eds. *Industrial ecology and global change*. Cambridge, MA: Cambridge University Press, p. 25. ©1994 reproduced with the permission of Cambridge University Press.

The Type III Model of the Industrial Ecosystem



Source: Graedel, T. 1994. In Socolow, Andrews, Berkhout, and Thomas, eds. *Industrial ecology and global change*. Cambridge, MA: Cambridge University Press, p. 27. ©1994 reproduced with the permission of Cambridge University Press.

Selected Definitions of Industrial Ecology

Frosch, Robert A. Industrial ecology: A philosophical introduction. *Proceedings*, National Academy of Sciences 89 (February 1992): 800-803.
"The idea of an industrial ecology is based upon a straightforward analogy with natural ecological systems. In nature an ecological system operates through a web of connections in which organisms live and consume each other and each other's waste. The system has evolved so that the characteristic of communities of living organisms seems to be that nothing that contains available energy or useful material will be lost. There will evolve some organism that will manage to make its living by dealing with any waste product that provides available energy or usable material. Ecologists talk of a food web: an interconnection of uses of both organisms and their wastes. In the industrial context we may think of this as being use of products and waste products. The system structure of a natural ecology and the structure of an industrial system, or an economic system, are extremely similar."

Allenby, Braden. Achieving sustainable development through industrial ecology. *International Environmental Affairs* 4, no.1 (1992).
"somewhat teleologically, 'industrial ecology' may be defined as the means by which a state of sustainable development is approached and maintained. It consists of a systems view of human economic activity and its interrelationship with fundamental biological, chemical, and physical systems with the goal of establishing and maintaining the human species at levels that can be sustained indefinitely, given continued economic, cultural, and technological evolution."

Jelinski, L.W., T.E. Graedel, R.A. Laudise, D.W. McCall, and C. Kumar N. Patel. Industrial ecology: Concepts and approaches. *Proceedings*, National Academy of Sciences, USA 89 (February, 1992).
"Industrial Ecology is a new approach to the industrial design of products and processes and the implementation of sustainable manufacturing strategies. It is a concept in which an industrial system is viewed not in isolation from its surrounding systems but in concert with them. Industrial ecology seeks to optimize the total materials cycle from virgin material to finished material to component, to product, to waste products, and to ultimate disposal. Characteristics are: 1) proactive not reactive, 2) designed in not added on, 3) flexible not rigid, and 4) encompassing not insular."

Patel, C. Kumar N. Industrial ecology. *Proceedings*, National Academy of Sciences, USA 89 (February 1992).
"Industrial ecology can be best defined as the totality or the pattern of relationships between various industrial activities, their products, and the environment. Traditional ecological activities have focused on two time aspects of interactions between the industrial activities and the environment -- the past and the present. Industrial ecology, a systems view of the environment, pertains to the future."

Hileman, Bette. Industrial ecology route to slow global change proposed. *Chemical and Engineering News* (August 24, 1992), p.7.
"Industrial ecology is the study of how we humans can continue rearranging Earth, but in such a way as to protect our own health, the health of natural ecosystems, and the health of future generations of plants and animals and humans. It encompasses manufacturing, agriculture, energy production, and transportation -- nearly all of those things we do to provide food and make life easier and more pleasant than it would be without them."

Tibbs, Hardin B.C. Industrial ecology: An environmental agenda for industry. *Whole Earth Review* 77 (December 1992).
"Industrial ecology involves designing industrial infrastructures as if they were a series of interlocking [hu]manmade ecosystems interfacing with the natural global ecosystem. Industrial ecology takes the pattern of the natural environment as a model for solving environmental problems, creating a new paradigm for the industrial system in the process."

"The aim of industrial ecology is to interpret and adapt an understanding of the natural system and apply it to the design of the [hu]manmade system, in order to achieve a pattern of industrialization that is not only more efficient, but that is intrinsically adjusted to the tolerance and characteristics of the natural system. The emphasis is on forms of technology that work with natural systems, not against them."

Lowe, Ernest. Industrial ecology -- An organizing framework for environmental management. *Total Quality Environmental Management*, Autumn 1993.
"The heart of industrial ecology is a simple recognition that manufacturing and service system are in fact natural systems, intimately connected to their local and regional ecosystems and the global biosphere. . . . the ultimate goal of industrial ecology is bringing the industrial system as close as possible to being a closed-loop system, with near complete recycling of all materials."

Allenby, Braden and Thomas E. Graedel. *Industrial ecology* (pre-publication edition). New York: Prentice Hall, 1993.
"Industrial ecology is the means by which humanity can deliberately and rationally approach and maintain a desirable carrying capacity, given continued economic, cultural, and technological evolution. The concept requires that an industrial system be viewed not in isolation from its surrounding systems, but in concert with them. It is a systems view in which one seeks to optimize the total materials cycle from virgin material, to finished material, to component, to product, to waste product, and to ultimate disposal. Factors to be optimized include resources, energy, and capital."

Hawken, Paul. *The ecology of commerce*. New York: Harper Business, 1993.
"Industrial ecology provides for the first time a large-scale, integrated management tool that designs industrial infrastructures 'as if they were a series of interlocking, artificial ecosystems interfacing with the natural global ecosystem.' For the first time, industry is going beyond life cycle analysis methodology and applying the concept of an ecosystem to the whole of an industrial operation, linking the 'metabolism' of one company with that of another."

Source: University of Michigan. 1995. Appendix B. *Pollution Prevention Educational Resources Compendium: Industrial Ecology*. National Pollution Prevention Center, pp. 21-22. Reprinted with the permission of the National Pollution Prevention Center.

Case Study 1: "Clean Coal" and the Future of Electric Power

The United States is richly endowed with coal, a form of carbon-based fossil fuel. Much of the coal in the Western US is low in sulfur content (lignite), while that found in abundance in the Midwest is higher in sulfur content (bituminous). The trick is to balance the blends of these two coals to optimize power production while limiting air emissions, particularly of sulfur dioxide (SO_2) and nitrous oxides (NO_x). In 1986, the US Department of Energy (DOE) launched the "Clean Coal Technology Program" to demonstrate a new generation of innovative coal processes. We can envision a coal "fuel chain," along which steps can be taken that affect the amount of sulfur and nitrogen emissions released to the atmosphere from the production system. In industrial ecology, the goal is to minimize these emissions. Advanced technologies include precombustion cleaning (through physical, chemical, or biochemical means); fluidized bed combustion and advanced combustors (which clean coal in the process of its combustion); post-combustion "scrubbing" of SO_2 and catalytic reduction of NO_x, and integrated coal gasification combined cycles (which use turbines that run on conventional steam *and* waste gas).

Suggested sources of information:

- Center for Energy and Economic Development, 1800 Diagonal Road, Suite370, Alexandria, VA 22314. Tel (703) 684-6292; FAX (703) 684 -6297; online at CEEDNet via http://www.conx.com/ceed. An 11-minute video called *America's Fuel* is available online which describes clean coal technology.
- National Mining Association, 1130 17th St. N.W., Washington D.C. 20036-4677; telephone (202) 463-2665.
- Electric Power Research Institute (EPRI), P.O. Box 10412, Palo Alto, CA 94303;telephone (510) 934-4212.

Case Study 2: The Future of Steel Production -- Minimills

Once the world's leading producer of steel, the United States saw its market share drop precipitously during the 1970s and 1980s. Midwestern cities were hurt by steel mill closures, as jobs vaporized and an increasing stream of foreign-manufactured products entered the marketplace. The large steel mills that lined the south shore of Lake Michigan and elsewhere in the southern Great Lakes region -- belching smoke and acidic emissions and consuming vast quantities of coke, iron ore, and other inputs -- attested to the failure of Big Steel to adapt to a changing economic landscape and technological developments. For many years, Big Steel failed to modernize its plants, even though the adoption of new production technologies could have lessened the industry's environmental impacts and improved its efficiency. Big Steel and its industrial-social culture seemed destined -- in the US at least -- to go the way of the dinosaurs.

The integrated steel mill of the past serves as a perfect example of an immature industrial ecology -- closer to the Type I than Type II model of Graedel (1994). Its problem was waste, including wasteful material inputs (virgin ore and coke), wasteful conversions of energy (reliant on high-sulfur coal for coke in blast furnaces), wasteful outputs (sulfurous emissions and other atmospheric pollutants), and wasteful human inputs (top-heavy management and low productivity).

During the 1980s, a new model developed that turned the tide for American steel manufacturing -- the steel minimill. Richard Preston (1991) traces the rise of the minimill in a series of articles published in the *New Yorker*. Preston's particular focus is the Nucor Steel Corporation and its revolutionary process for continuous strip production of sheet metal. The phenomenon is important both from an economic geography perspective (with its implications for international trade, regional development, and location theory) and from an industrial ecology perspective. From the latter perspective, minimills represent small-scale installations whose material inputs come from scrap steel; hence, minimills serve as materials recyclers. They use electric arc furnaces instead of coal-fired blast furnaces, greatly reducing the energy inputs per unit of steel output, and having the potential to reduce atmospheric emissions.

Suggested Sources of Information (see *References to All Units* for complete citations)

- On the future of the steel industry in general: Baker, 1994b, 1995a; Boyd, et al., 1993; Clash, 1994; Church, 1994; Hogan, 1991; Miles, 1988; Ohasi, 1992; and Smith, 1995.
- On Nucor Steel Corporation in particular: Alexander, 1994; Baker, 1994a, 1995b; Boston, 1990; Brody, 1988; Lubove, 1993; Pare, 1991; Schroeder and Konrad, 1990; Wofford, 1995.

Case Study 3: Recycling Scrap: Municipal Solid Waste and Waste-to-Energy

There has been a growing recognition that the "waste stream" of municipal solid waste (MSW) represents an abundance of materials that can be reused or recycled. In particular, organic materials comprise a significant proportion of MSW and can provide a source of fuel. The process of turning waste material into an energy source is known in the industry as "waste-to-energy"(WTE). The industrial ecology cycle involved in WTE is fairly straightforward. Organic material in MSW is separated from non-combustible material, then incinerated in a WTE plant. Combustion of this organic fuel produces thermal energy that is harnessed using a steam turbine to drive an electric generator. Advanced technologies are used to capture the sulfur and NO_x byproducts, preventing them from leaving the plant.

The electrical power thus produced can be sold to the local power grid, and the uncombusted solid wastes (recyclable metals, compostable matter, glass, rock) can be sold elsewhere making the WTE business lucrative. The overall reduction in solid waste that has to be sent to a landfill is a credible environmental benefit. The appeal of WTE from MSW is great, given our industrial ecology perspective, and our recognition that technology change can serve as a positive guiding force for global change. There were approximately 125 WTE plants in the United States in 1995 and they appear to be growing in popularity (Arrandale 1993; Charles and Kiser 1995; Hocker 1991; Williams 1990).

Additional Sources of Information

- *Solid Waste Technologies* (formerly *Solid Waste & Power*) is a trade journal with a wealth of information on the solid waste industry including companies, services, and products. Each year, its annual special issue *Industry Sourcebook* provides company profiles and a guide to over fifty organizations that provide technical assistance, information, or other support functions for the solid waste industry.
- *Power Plays*, by Susan Williams, is a database of renewable energy developers, with particular focus on MSW WTE producers ($150 softbound, $200 hardbound available from Investor Responsibility Research Center, P.O. Box 50, Plainfield, NH 03781; telephone 603-675-9274)
- A catalog of government publications is available from the US Environmental Protection Agency, *Catalog of Hazardous and Solid Wastes Publications* (EPA 530-B-95-001 Sept. 1995)
- Online Sources:
  - EPA Fact Book (http://www.epa.gov or http://www.cal.net/recycle//index.html)
  - Recyclers World (http://www.recycle.net/recycle/index/index/html)
  - Use Less Stuff (http://www.com.ch.as.msen.com:70/1/vendor/cygnus/uls)
  - Also, the US Department of Energy (DOE) and the Solid Waste Association of North America (SWANA) maintain websites; access may be gained by typing "municipal solid waste" in a netsearch.

Case Study 4: Energy Crops and a New Role for Industrial Agriculture

A promising alternative to unsustainable hydrocarbon fuels may come from the farm. The biomass produced by plants represents stores of chemical energy, fixed through their metabolic processes and powered by the photosynthesis of CO_2 and H_2O. Plant tissues can be converted into thermal energy through combustion, which releases CO_2. In biomass energy conversion, however, there is the possibility of achieving a Type III ecology: if the CO_2 released during combustion is balanced by CO_2 taken up by growing plants, then biomass energy can "close the loop" and qualify as an industrial ecology.

Biomass energy stocks are derived from two principle sources -- the production of energy crops and organic wastes. Various grasses, conventional row crops that are rich in starches (e.g., corn and sorghum), fast-growing trees (or short-rotation woody crops such as hybrid poplar and honey locust in North America), and wetland species such as cattails and reeds (often used for wastewater treatment) can serve as energy crops. To provide liquid fuels that are especially attractive for use in transportation, the carbohydrates in biomass may be distilled to yield alcohols such as ethanol, which is already in use in many parts of the American Midwest and throughout Brazil. Biomass energy production has the potential to protect against soil erosion, establish wildlife habitat, provide versatile and modern energy carriers (in the form of solids, liquids, or gases), and to protect the viability of agricultural communities against increasing urbanization.

Additional Sources of Information (for complete citations, see *References to All Units*)
On ethanol production:

- *More for Less* is a video from the Annenberg/CPB Project film series *Race to Save the Planet*; it describes the ethanol program in Brazil (approx. 60 minutes in length).
- See also Goldemberg et al. (1993); Reddy and Goldemberg (1991); and Wyman et al.(1993).
- On technical problems with biomass conversion, see Hohenstein and Wright (1994); Wright (1994).
- On economic problems see Turhollow (1994).
- On environmental problems see Ramney and Mann (1994) and Williams (1994)
- Also useful is *NREL in Review*, the periodical produced by the National Renewable Energy Laboratory, Golden, Colorado.
- Oak Ridge National Laboratory has a Website on the biofuels feedstock development program (BFDP), URL is http://www.esd.ornl.gov/bfdp/bfdpmosaic/binmenu.html
- The addresses of the DOE's five regional biomass energy programs are listed below; *Biologue* is the industry's trade journal.
    - Northeast Region
      Richard Handley

CONEG Policy Research Center, Inc.
400 North Capitol Street, N.W., Suite 382
Washington, DC 20001
(202) 624-8454
(202) 624-8463 FAX

- Northwest Region
  Jeff James
  U. S. DOE Seattle Regional Support Office
  800 5th Avenue, Suite 3950
  Seattle, WA 98104
  (206) 553-2079
  (206) 553-2200 FAX

- Southeast Region
  Philip C. Badger
  Tennessee Valley Authority
  Southeast Regional Biomass Energy Program
  435 Chemical Engineering Building
  Muscle Shoals, AL 35660
  (205) 386-3086
  (205) 386-2963 FAX

- Western Region
  Dave Swanson
  Western Area Power Administration
  1627 Cole Boulevard
  P. O. Box 3402
  Golden, CO 80401
  (303) 275-1706
  (303) 275-1707 FAX

- Great Lakes Region
  Fred Kuzel
  Council of Great Lakes Governors
  35 East Wacker Drive #1850
  Chicago, IL 60601
  (312) 407-0177
  (312) 407-0038 FAX

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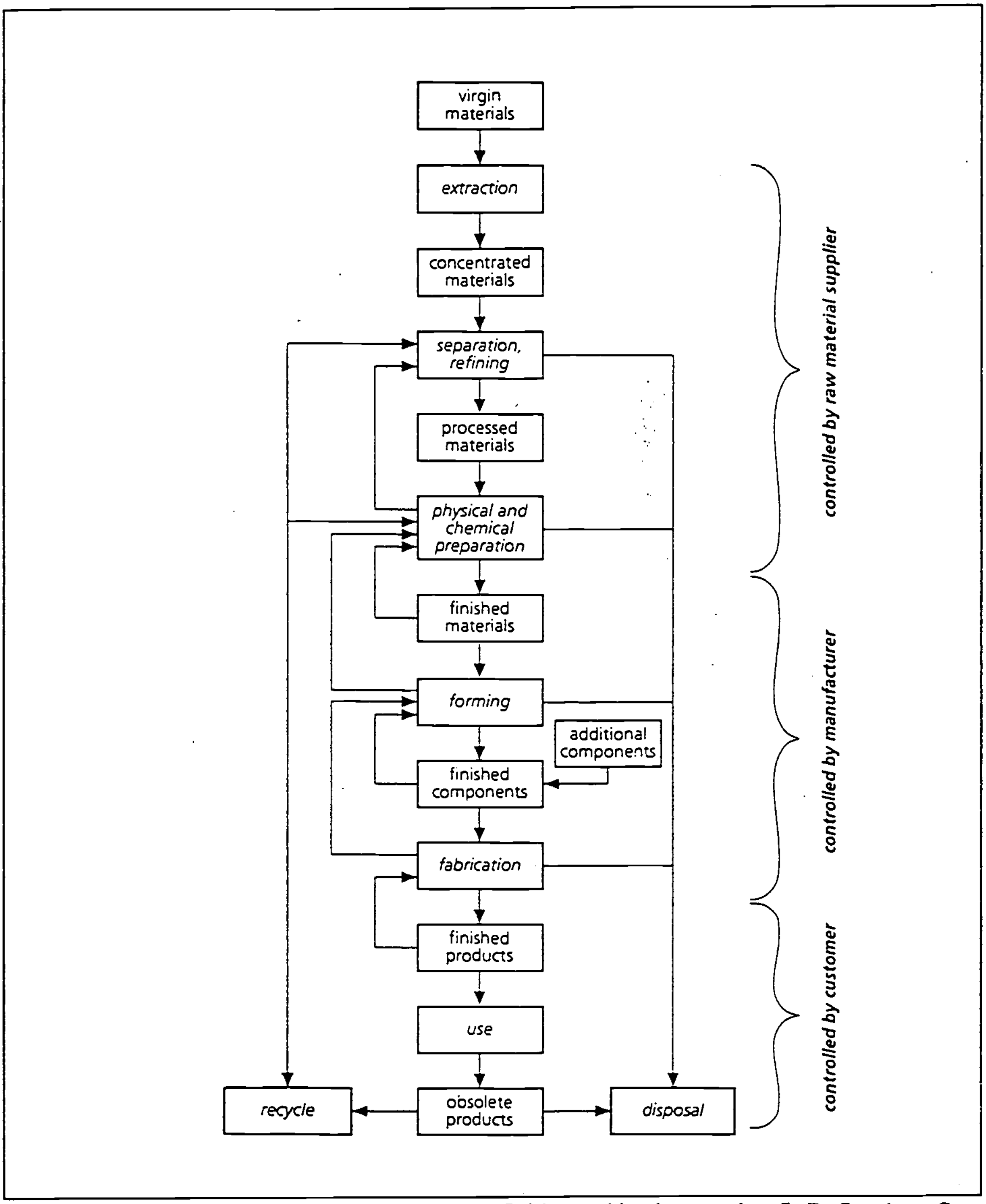
The Entropy of Your Home

Input	Use	Reuse or Recycle	Out-flow	Disposal (where or how)	Physical State of Disposal	Effect of use on Entropy

Overhead Originals for Class Discussion of Unit 3

The following pages contain overhead originals that can be used to support the information presented in *Background Information* of Unit 3. The instructor may use these in class to summarize the information students read in the module or to organize lecture material.

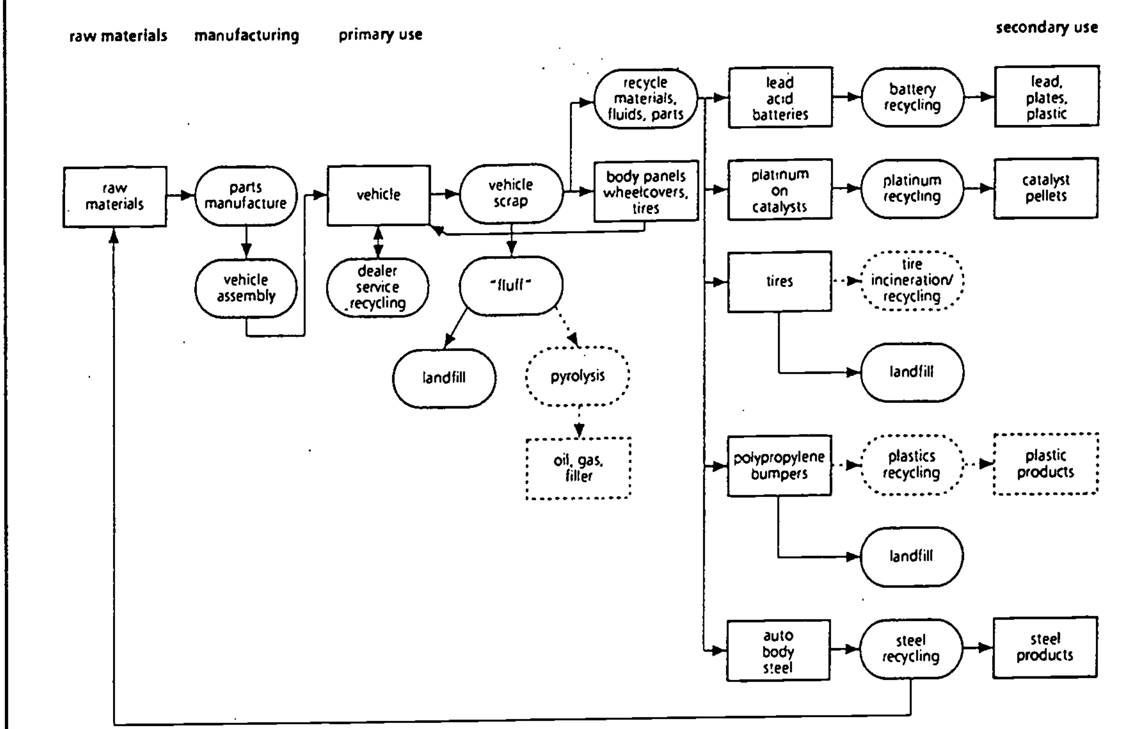
The Total Industrial Ecology Cycle



Source: Graedel, T. 1994. Industrial ecology: Definition and implementation. In R. Socolow, C. Andrews, F. Berkhout, and V. Thomas, eds. *Industrial ecology and global change*. Cambridge, MA: Cambridge University Press, his Figure 6. Reprinted with the permission of Cambridge University Press.

Supporting Material 3a

A Motor Vehicle Life Cycle



Note: Rectangles indicate products; ovals indicate processes

Source: France, W. and V. Thomas. Industrial ecology in the manufacturing of consumer motor vehicle life cycle products. In R. Socolow, C. Andrews, F. Berkhout, and V. Thomas, eds. *Industrial ecology and global change*. Cambridge, MA: Cambridge University Press, their Figure 4. Reprinted with the permission of Cambridge University Press.

BEST COPY AVAILABLE

Mr. H: Okay, so it's obvious that the major raw material for a paper cup is wood, and the major raw material for polyfoam cups is hydrocarbons, or oil and gas. The raw extraction of both of these materials involves some well- known impacts. In the first case, the clear cutting of extensive areas of watersheds increases the likelihood of flood and drought. In the second case, we are all familiar with the name Exxon Valdez, not to mention the daily leakage of oil from coastal refineries and from delivery systems.

Interestingly enough, according to my Canadian data, the production of the average 10.1g paper cup requires as much hydrocarbon fuel as that of a polyfoam cup. The table I provided you shows the petroleum needed per paper cup to be between 2.8 and 5.5g, for an average of 4.1g, versus 3.2g for polyfoam.

Ms. W: That is interesting. But I think your data is either incorrect or outdated because my own research has led me to a much lower value for oil use in paper cups. I know that in the United States today 56% of the energy used in paper production (this is an average for all grades of paper) comes from waste biomass. Of the other 44%, only about 8% comes form oil. Only 15% comes from natural gas. The 8% oil amounts to around 1.7g per cup.

Mr. M: Well, I'd personally agree with those figures for a modern integrated paper mill. But I know that lightboard paper from nonintegrated mills requires a bit more fuel, something like 2 to 3 grams per 10-gram paper cup. Also, only half the petroleum used to make polyfoam cups is burned, leaving half still available within the finished cup if recycled. In the end, paper and polyfoam cups probably leave the same amount of net nonrecycled petroleum.

Ms. O: Yeah, *if* the polystyrene is recycled to reuse that other half of fuel. . .

Mr. H: Well, I had relied on older reference material which was more readable, although admittedly less up to date. I wouldn't be surprised if the fuel use has decreased over the years, especially in the United States.

Mr. J: Let's move on, then. Could you explain your comparison of the chemicals used in the raw materials category, Mr. H?

Mr. H: Yes, the inorganic chemicals used for paper cups include sodium hydroxide, sodium sulfate, sodium chlorate, sulfuric acid, sulfur dioxide, and calcium dioxide—most of which are used only one time around, without being recycled.

The chemical requirements for the polystyrene foam cup are much smaller. One reason is that in some of the chemical reactions solid-phase catalysts are used that can react many thousands of times over before they have to be replaced.

Ms. O: Now, for the rest of your table, Mr. H, you show "per metric ton" figures rather than "per cup" figures. How do we compare these?

Mr. H: If you notice at the top of the table, I've listed 10.1g as the average paper cup weight, and 1.5g as the average polyfoam cup weight. So the mass of a paper cup is 6.73 times larger. For the data under utilities, water effluent, and air emissions, you must multiply the numbers for paper by 6.7 to compare the two on a per-cup basis.

So, looking at the amount of cooling water used per metric ton of material, we see $50m^3$ of water for paper cups and $154m^3$ of water for polyfoam cups. To compare them, multiply $50m^3$ by 6.7, which gives us $335m^3$ for paper cups. Thus, a paper cup use about 2.2 times the cooling water of a polyfoam cup.

Following the same logic, we'd find that the paper cups use 14 times the steam, 44 times the electricity, 43 times the waste water effluent, and so on, on a per-cup basis.

Mr. M: About that effluent data -- there are a few things that trouble me. I noticed your references are based on kraft mills in the 1970s which did not treat their effluent then at all. Today, any US mill would discharge only about 5kg of biochemical oxygen demand (BOD) per metric ton, not 30 to 50 kg. I also think your 5 to 7kg of organochlorides should be closer to 3kg.

Mr. H: Actually, at least some of the Canadian mills had effluent discharges between 1985 and 1989 in the amounts I listed. But I would agree that the American experience in reducing BOD, organochlorides, and the like, has to be much better to meet EPA standards.

Ms. O: Let's talk about recycling capability for a moment. I've been hearing that paper cups can't be recycled because the adhesive resin used to hold the paper fibers together is unable to be removed in the repulping process.

Mr. J: That goes for cups with plastic or wax films as well.

Ms. O: And as far as polystyrene goes, its recycled resin can't legally be reused in food applications. Food applications includes disposable cups!

Ms. W: Well now, hold on. Polyfoam can be reused as products other than just food and drink containers. We've got standard packing materials, insulation, flotation billets, patio

furniture, etc. All the technical problems with polystyrene recycling are pretty much taken care of now. What remains is the expansion of recycling programs.
As for paper cups, they in fact can and are being recycled as part of mixed office waste—resin and all. Actually, one of the biggest technical barriers to its recyclability is contamination with styrofoam!

Mr. J: The biggest plus I see for paper is that its major raw material, wood, is renewable, whereas oil for polystyrene is not -- at least not on human time scales. And polyfoam cups are basically inert, so they won't biodegrade, where paper will.

Mr. H: Actually, there's increasing evidence that paper does not degrade fully in landfill conditions, especially in dry climates. And when it does degrade, it releases methane and carbon dioxide in a 2:1 ratio of methane to CO_2. And a methane molecule has from 5 to 20 times the greenhouse warming effect of a CO_2 molecule.

Ms. O: But wouldn't the fixing of carbon dioxide by new tree growth compensate for any CO_2 emissions from degrading paper?

Mr. H: Well, I don't know about that.....

***And now your turn*.....**

Additional Readings for Critical Briefs

The following readings are selections that have been successfully used as assignments for critical briefs. You can substitute these topics and the associated readings for the ones suggested on *Student Worksheet 3.5*.

Entropy and Natural Resource Scarcity

- Rifkin, Jeremy. 1989. *Entropy: Into the greenhouse world.* New York, NY: Bantam, pp. 19-114, 207-256, 274-291.
- Dolloff, Norman H. 1975. Introduction. From *Heat death and the phoenix: Entropy, order, and the future of man.* Hicksville, NY: Exposition Press, pp. xi-xviii.
  Young, Jeffrey T. 1991. Is the entropy law relevant to the economics of natural resource scarcity? *Journal of Environmental Economics and Management* 21: 169-179.

After reading Young's article, students should also read the two Comment papers written in response to Young:

- Daly, Herman E. 1992. Is the entropy law relevant to the economics of natural resource scarcity? -- Yes, of course it is! *Journal of Environmental Economics and Management* 23: 91-95.
- Townsend, Kenneth N. 1992. Is the entropy law relevant to the economics of natural resource scarcity? Comment. *Journal of Environmental Economics and Management* 23: 96-100.

Nuclear Energy and Wastes

- Berkhout, Frans. 1994. Nuclear power: An industrial ecology that failed? In R. Socolow, C. Andrews, F. Berkhout, and V. Thomas, eds. *Industrial ecology and global change* Cambridge, MA: Cambridge University Press, pp. 319-327.
- Hafele, Wolf. 1991. Energy from nuclear power. In *Energy for planet earth*, readings from *Scientific American*. New York, NY: W. H. Freeman, pp. 95-106.
- Weinberg, Alvin M. 1991. Is nuclear energy necessary? In T. Goldfarb, ed. *Taking sides*. Guilford, CT: Dushkin Press.
- Hayes, Denis. 1991. Nuclear power: The fifth horseman. In T. Goldfarb, ed. *Taking sides*. Guilford, CT: Dushkin Press.

In addition, ask students to locate at least one secondary reading that focuses on nuclear energy or issues of nuclear waste. They should provide complete bibliographic citations for each additional article they use and include a discussion of it in their critical brief.

Industrial Ecology & Fossil Fuels

For this brief, ask students to include a discussion of the first three articles below plus one that they have selected from those noted with asterisks (**). Students should also locate at least one additional reading that focuses on the industrial use of energy. They should provide complete bibliographic citations for each additional article they use and include a discussion of it in their critical brief.

- Graedel, Thomas. 1994. Industrial ecology: Definition and implementation. In R. Socolow, C. Andrews, F. Berkhout, and V. Thomas, eds. *Industrial ecology and global change*. Cambridge: Cambridge University Press, pp. 23-41.
- Fulkerson, William, Roddie R. Judkins and Manoj K. Sanghvi. 1991. Energy from fossil fuels. In *Energy for planet earth*, readings from *Scientific American*. New York, NY: W. H. Freeman, pp. 83-94.
- Ross, Marc H., and Daniel Steinmeyer. 1991. Energy for industry. In *Energy for planet earth*, readings from *Scientific American*. New York, NY: W. H. Freeman, pp. 35-48.
- **Davis, Ged R. 1991. Energy for planet earth. In *Energy for planet earth*, readings from *Scientific American*. New York, NY: W. H. Freeman, pp. 1-10.
- **Holdren, John P. 1991. Energy in transition. In *Energy for planet earth*, readings from *Scientific American*. New York, NY: W. H. Freeman, pp.119-130. Include the associated chapter, Epilogue: Moving toward greater energy efficiency, by Robert Malpas, pp. 131-132.
- **Spitler, E. E. 1992. The energy business and conservation. In M. Oelschlaeger, ed. *After Earth Day: Continuing the conservation effort*. Denton, TX: University of North Texas Press, pp. 106-119.

Appendix: Suggested Readings

The AAG was able to obtain reprint permission from the original publishers for only some of the readings suggested in the activities of this module. To avoid copyright problems, we suggest you make these readings available to your students by putting them on reserve. The following readings are enclosed:

- Edgington, Stephen. 1995. Industrial ecology: Biotech's role in sustainable development. *Bio/Technology* 13 (January): 31-35. Reprinted with the permission of Nature America Inc.
- Globerman, Steven. 1993. Trade liberalization and the environment. In S. Globerman and M. Walker, eds. *Assessing NAFTA: A trinational analysis*. Vancouver, Canada: The Fraser Institute, pp. 294-314. Reprinted with the permission of The Fraser Institute and Steven Globerman.
- Helvarg, David. 1996. The big green spin machine: Corporations and environmental PR. *The Amicus Journal* 18,2 (Summer): 13-21. Reprinted with the permission of the Natural Resources Defense Council.

Industrial Ecology: Biotech's Role in Sustainable Development

Can an enviromental concept rally business, government, and academia to work together for long-term economic growth?

Stephen M. Edgington

In July 1994, the National Science and Technology Council (Washington, D.C.) rolled out its plan for the U.S. to regain its global competitive advantage over the next 50 years. "Our vision is of long-term economic growth that creates jobs while improving and sustaining the environment," declares its executive summary.[1] "Reconciling these goals requires an environmental technology strategy that helps industry shift from waste management to pollution prevention, efficient resource use, and industrial ecology."

Industrial ecology? While it may sound like vote-getting doublespeak, some say it represents the first reasonable plan for reconciling technological development with environmental concerns. So far, leaders of business, government, and academia are enthusiastically supporting it.

What is the driving force behind this new shade of "green?" "We are in the early phases of a new industrial revolution," says Joel Hirschhorn (Hirschhorn & Associates, Lanham, MD), a long-time observer of Washington's industrial policies. "Technology is beginning to be judged, not only for the cost of producing the product, but for the cost of its environmental impact and clean up." Hirschhorn says regulatory commitments to clean up the environment worldwide, culminating in the U.S. with the 1990 Pollution Prevention Act, have driven this process. In his view, these laws have set in motion a paradigmatic shift in which technology's new role is to prevent problems rather than to solve them.

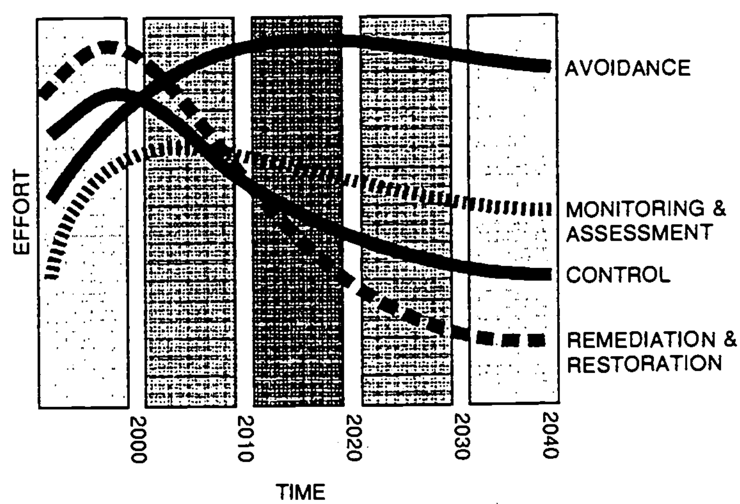
Industrial ecologists are looking to biotechnology for the tools to enable this revolution. This bodes well for expanding biotech's applications beyond health care to almost any waste-producing industrial process. But in the near term, biotech drug makers—and those who want to be—need to examine their own production facilities through the eyes of an industrial ecologist. For those companies that have already done so, reduced production costs, fewer regulatory hassles, and the public's enhanced perception of their products suggest that this new industrial revolution has already begun for them—at their bottom line.

A New Paradigm

What is this new paradigm for business? According to Suren Erkman (Journal de Genève, Geneva, Switzerland), who has spent the past year writing a book about industrial ecology,[2] the concept in its current form sprang from a *Scientific American* article proposing that business should operate more like biological ecosystems: A network of interrelationships in which everything that is produced is used by some organism in the system to support its own metabolism.[3] The analogy, although never intended to be perfect, somehow caught the imaginations of a diverse group of academics, government policy makers, and business people.

"A very basic thing about industrial ecology," says Erkman, "is that for the first time it gives you the big picture as opposed to the various segmented approaches of environmental groups." Erkman says the concept's major theoretical impact was to change the perception of industry from being opposed to nature to being a part of nature. "Carrying this biological metaphor to its logical conclusion suggests that industrial systems today are similar to the primitive ecosystems that first evolved on earth," he says. "At first there was no recycling, and toxic wastes accumulated to the point where they threatened life as it existed." Erkman says that when microorganisms learned to use this waste—by con-

FIGURE 1. Some technology development scenarios.[1] Remediation and restoration: Treat harmful materials after they enter the environment. Control: Treat hazardous materials before they enter the environment. Monitoring and assessment: Monitor the releases of pollutants. Avoidance: Avoid the production of environmentally hazardous materials.



Stephen M. Edgington is senior editor of Bio/Technology.

Business should operate more like biological ecosystems: A network of interrelationships in which everything that is produced is used by some organism in the system to support its own metabolism.

verting from anaerobic to aerobic metabolism—they established the first means of using what had been toxins to support life and to make their waste products support other existing life forms. "The idea is to evolve industrial systems like biological systems so that they too become sustainable in their development," he says.

In the face of stepped-up government regulation and increased liability, industrial ecology's real selling point for business is that it converts a problem into a potential revenue stream. Instead of standing at the end of the production pipe—trying to catch any potentially hazardous waste—they can now reengineer the process so that what "comes out of the pipe" finds ready buyers. Forecasts of tighter and tighter profit margins and less reliable raw material streams makes the idea of recycling part of their "waste" back into their own production processes very appealing.

But despite these economic imperatives, a central question that still needs answering is "What are the industrial equivalents of microorganisms?" The question of how one designs industrial processes that can deal with variability in its raw materials is also central to making the system work. This will require new technologies that are both more selective and more adaptive than most machine-driven processes at present. To answer this question, industrial ecologists are looking to biotech applications for answers.

Industrial Symbiosis

Industrial ecologists are fond of pointing to the biotech company Novo Nordisk (Kalundborg, Denmark) as a real-world example of how industrial ecology's goals might be accomplished. Located in a small industrial city of 20,000 Novo Nordisk has worked with other companies to evolve symbiotic relationships over the past 40 years that have resulted in both reduced costs and lessened environmental impact on the community. The companies have learned how to use each other's "waste" to create viable commercial products (see "Making an Industrial Ecology Park Work").

"People sometimes claim the environment will cost money," says Novo Nordisk's Jorgen Christensen, site manager of the Kalundborg plant, "and that may be true, but in our case, it has not been so—we have made money." Christensen says the process that is now called "industrial ecology," or "industrial symbiosis," began in Kalundborg, not through the execution of some well-developed plan, but through a series of projects that took place because they made economic sense.

Christensen thinks it was the close proximity of the industries involved that was an initial driving force. "The fact that these companies are located a few miles from each other," he says, "first of all made it economically feasible—if we were 100 miles away from each other it would not have worked." But Christensen is also quick to point out that it was also the "mental distance" between the employees of the various companies that made a significant contribution to its development. "In a small town like ours," he says, "people know each other: Our children go to the same schools, we compete with each other in sports, we see each other socially." He says the process started when employees at these companies beginning to talk informally about how they could share resources.

Christensen says the initial incentive was not environmental but economic. "We saw increased profits resulting from resource saving, reduction in emissions, and gains in recycling," he says. One by one, these initial projects suggested other projects until at some point in the 1980s people began to realize that something unique was occurring. "People started saying that it is nice that we cooperated," says Christensen, "and then someone said that this is a kind of symbiosis or ecology, a local journalist picked it up, then a national newspaper, and soon we were asked to give papers on this internationally." Christensen says that as a result all the companies involved are becoming more environmentally conscious.

But exactly how much has this alliance of companies saved by joining forces? "Since we are asked this question so often we have tried to make a 'guestimate' of economic benefit," he says. The group calculates that, out of a total investment of $60 million, they are annually receiving a $10-12 million payback—$120 million total so far. "We think the average payback time is less than five years," he says, "with most of the projects requiring less time, but a few taking up to seven years to begin to show a profit."

Christensen says there are other rewards from implementing these systems that are difficult to measure in hard cash. "Novo Nordisk published an environmental report in 1994 that it will issue annually," he says. "I think the fact that we did that has been well received in many places." But Christensen is quick to point out that so far it is the city itself that has received the lion's share of publicity.

With Novo Nordisk's $2 billion in annual sales and 11,000 employees worldwide, it would seem that Novo might want to replicate the successful Kalundborg model elsewhere. "It's embarrassing to say that so far we have not been able to," Christensen says, citing a lack of the kinds of proximity that launched the Kalundborg site.

Designing for the Environment

While Kalundborg demonstrates that industrial ecology's principles can work, businesses must also develop processes to replace those that are heavily polluting. At present, the chemical and electronics industries have led the way in making formal commitments to explore this path. This past summer, the American Chemical Society (Washington, D.C.) hosted four days of presentations under the banner "Design for the Environment" at their annual meeting. "Traditional chemistry has been designed to optimize yield with little regard for the impact of the chemicals or the process on the environment," says coorganizer Joe Breen (Environmental Protection Agency, EPA, Washington, D.C.). "We are trying to promote the idea among chemists that designing environmentally benign molecules is a better option overall."

In searching for alternative synthetic methods, Breen says some elegant solutions are beginning to emerge from the adaptation of enzymatic processes for specific applications. Not only does an adaptation like this decrease the number of steps in chemical synthesis, but the geometric orientation that enzymes give chemical bond formation means maximizing yields and eliminating the racemic mixtures that can produce pollutants through side reactions. "Instituting enzymatic reactions in industrial processes that can eliminate dozens of steps is definitely the trend of the future," he says.

Among drug makers, pharmaceutical giant Hoechst (Frankfurt, Germany) is one of the first to implement these methods to clean up its processes. "A new law in Germany requires companies to check each production process in order to detect any kind of byproducts that could be seen as waste for which there may be some kind of use," says Hoechst's manager, corporate research, Dieter Brauer. Hoechst asked a team of ten researchers to look at alternative processes for producing cephalosporic acid, a precursor of their antibiotic products. Working part time, the researchers were able to develop an enzymatic process within a year and a half that was optimized for modifying cephalosporin E into cephalosporic acid. After another two years of work to gain the proper regulatory permissions and modify the factory, Hoechst found that it had reduced its waste from this process alone from 20 to 2 tons per year. "Not only that," says Brauer, "but the waste left over from this process is nontoxic—instead of transporting it to another facility we can just burn it."

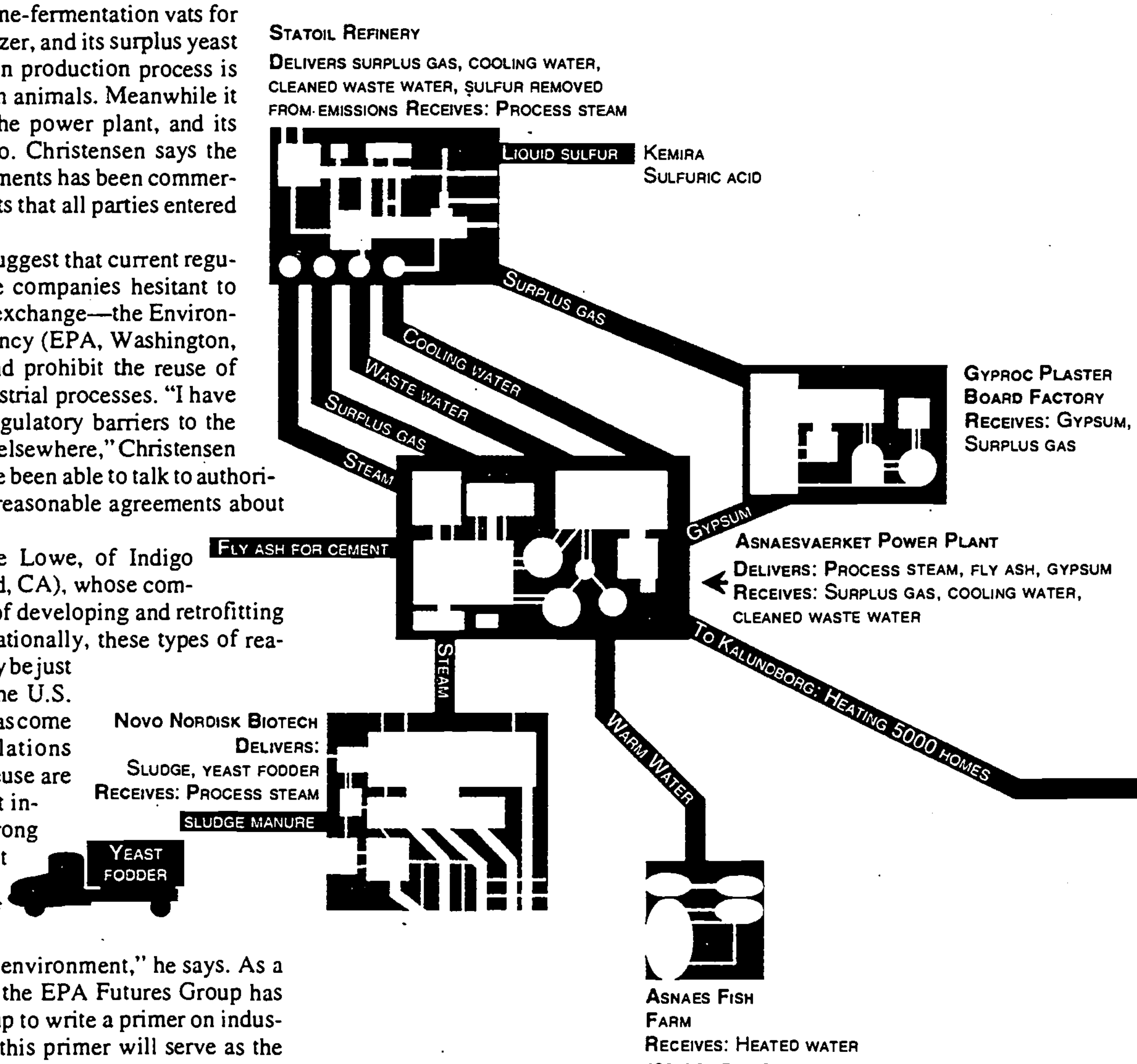
Brauer says it is difficult to pin down the exact

Making an Industrial Ecology Park Work

"We would advise companies that want to form an industrial park on our model," says Christensen, "to start with a nucleus of two or three companies that can trade something." Once the trading system is worked out among the initial players, other industries can join in. At Kalundborg, the basic units of trade are water, energy, and waste. Trades need not be directly reciprocal for the system to work. For example, Novo Nordisk delivers nitrogen-rich biomass from its enzyme-fermentation vats for farmers to use as fertilizer, and its surplus yeast from the plant's insulin production process is used as fodder for farm animals. Meanwhile it buys its steam from the power plant, and its water from Lake Tisso. Christensen says the basis for these arrangements has been commercially sound agreements that all parties entered into voluntarily.

In the U.S., many suggest that current regulations on waste make companies hesitant to engage in this kind of exchange—the Environmental Protection Agency (EPA, Washington, D.C.) may step in and prohibit the reuse of these materials in industrial processes. "I have heard that there are regulatory barriers to the sensible reuse of waste elsewhere," Christensen says. "Luckily, we have been able to talk to authorities here and come to reasonable agreements about these things."

According to Ernie Lowe, of Indigo Development (Oakland, CA), whose company is in the process of developing and retrofitting industrial parks internationally, these types of reasonable agreements may be just around the corner in the U.S. He says the EPA itself has come to realize that regulations which prevent waste reuse are not always in their best interest. "One of the strong currents in thinking at the EPA is the recognition of the limits of regulation and how they act to the detriment of environment," he says. As a result, Lowe says that the EPA Futures Group has commissioned his group to write a primer on industrial ecology. He says this primer will serve as the foundation for an EPA-funded industrial park that will put these principles into action. "The EPA demonstrates its commitment to these principles through projects like these and through a more systematic approach to regulation," he says. "This should remove the barriers to the implementation of Kalundborg-like parks in the U.S."



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A fascinating possibility is that biotech drug makers will some day be able to adapt these enzymatic processes to transform what are now chemical waste streams into difficult-to-synthesize therapeutics.

savings that result from implementing this process. "But when we considered the elimination of the costs involved in handling hazardous chemicals combined with the simplicity of the new factory's design," he says, "we decided to try and implement the program plantwide."

Brauer has heard that companies like BASF (Ludwigshafen, Germany), Bayer (Leverkusen, Germany), Eli Lilly (Indianapolis, IN), and Monsanto (St. Louis, MO) are all looking into similar processes. "This is a general development in the field prompted not only by law but by internal interest," he says. According to Brauer, the major block to this type of innovation for existing processes will not be research and development but the regulatory approvals involved. "Since a pharmaceutical or an agricultural product may require hundreds of million of dollars to get product approval, if you want to change the process you must most often also repeat all the regulatory trials—it is clear that no one will do that."

Brauer believes that a method is needed to gain regulatory approval for an approved product's bioequivalence so that all the tests do not have to be repeated. He says that, in the European community, the matter is currently under consideration. "The review is absolutely necessary if we are going to modernize our industries with environmentally friendly processes such as engineered enzymes and microorganisms," says Brauer.

Drugs from Waste

A fascinating possibility is that biotech drug makers will some day be able to adapt these enzymatic processes to transform what are now chemical waste streams into difficult-to-synthesize therapeutics. Tomas Hudlicky, in the chemistry department of Virginia Polytechnic Instate and State University (Blacksburg, VA), says he has already demonstrated this by using bacteria to produce a variety of potential drugs, including glycosidase inhibitors[4,5,6] and the precursors of taxol[7]—potentially potent cancer therapeutics. "We've also just finished working out the synthesis of the anticancer alkaloid pancratistatin in 13 steps," says Hudlicky. "The National Cancer Institute (Bethesda, MD) has requested proposals for this because they would like to do clinical trials in ovarian cancer and leukemia with it but they can't get enough of the drug." Hudlicky says that so far his group has developed 20 or so natural compounds and carbohydrates through these biocatalytic synthesis methods.

Despite these successes, Hudlicky thinks that the U.S. academic community has been less-than-receptive to his discoveries. "The U.S. is not exactly the center of open mindedness when it comes to these methods," he says. "So far, the National Institutes of Health (NIH, Washington, D.C.) has rejected 10 grant proposals I've submitted relating synthetic chemistry and biology." Hudlicky says that while Europeans have caught on to these methods, his NIH study section reviewers don't see it as new chemistry. "The people who review these grants act as if they did not want this type of chemistry to be available," he says. "Traditional synthesis of these compounds usually requires 30-plus steps, but our methods get you to the same place in six or seven."

Hudlicky feels fortunate that individual reviewers at the National Science Foundation (NSF, Washington, D.C.) are not of the same mind as NIH grant reviewers. The NSF, through a joint program with the EPA called the "Environmentally Benign Synthesis Initiative," is funding his work. But to make research ends meet, he has been forced to find support elsewhere. At present, Mallinckrodt (St. Louis, MO), and Genencor International (So. San Francisco, CA) are also supporting his research.

Genencor's Gregg Whited is particularly upbeat about the potential of Hudlicky's waste-stream-derived products. "There is tremendous potential there, once the microbiology gets polished up," he says. As for funding problems for this type of work, Whited says Genencor's history of working with enzymatic processes has taught him that there is an inherent resistance between chemists and biologists when it comes to coming up with the best way to make a compound. "For some reason," he says, "the traditional view is that if you can't order it from Sigma (St. Louis, MO) it's just not real."

Whited says he has had the experience of presenting biocatalytic reactions to chemists and have them leave the room without a question. But when he shows a similar group the same reactions without mentioning they are enzymatically catalyzed, they are fascinated. He says what will eventually turn it around is when chemists become convinced that the enzymatic reaction is the cheaper way of doing things. He thinks Hudlicky's work will help move them in that direction.

Conclusions

By considering industrial ecology, companies planning to build new facilities may find more cost-effective ways to set up their processing sites that not only reduce energy consumption but turn waste streams into profit. Researchers looking for new challenges—whether entrepreneurial or scientific—may find a ready market for translating their drug-development skills into environmental applications. New drug manufacturing strategies may even emerge as byproducts of industrial ecology strategies. The greatest short-term benefit the biotech industry may get from developing new products from waste streams is widespread public support for an industry that delivers on going "green."

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Trade Liberalization and the Environment

Steven Globerman
Department of Economics
Simon Fraser University

Introduction

FROM THE VERY START OF THE North American Free Trade Agreement (NAFTA) discussions, environmental concerns have been at the forefront of the surrounding public policy debate. Specifically, opponents of the NAFTA have consistently argued that further trade liberalization, especially between Mexico and the United States, would result in significant incremental environmental damage. Indeed, reflecting the strength of the early concerns raised in this regard, the Bush Administration agreed to carry on parallel negotiations concerning environmental issues alongside the trade negotiations in order to win Congressional approval for "fast-tracking" the NAFTA.

The signing of the NAFTA by Presidents Bush and Salinas and Prime Minister Mulroney on December 16, 1992, along with the election of Bill Clinton as the next president of the United States, have focused the free trade debate even more sharply around the question of whether the specific agreement does "enough" to recognize environmental concerns.[1] For example, President-elect Clinton has indicated that one of his concerns about NAFTA is that it does not go far enough in addressing environmental remedies and protection. In a speech given at North Carolina State University on October 4, 1992, Clinton expressed support for NAFTA, while at the same time he proposed the establishment of an environmental protection committee with substantial powers and resources to clean up water pollution and encourage the enforcement of each country's own environmental laws.

While government officials in Mexico, Canada and the United States lauded the NAFTA as being the "greenest" trade agreement ever produced, opponents are already claiming that it does not go far enough to recognize and remedy the damaging effect that increased trade will have on the environment. At this stage of the NAFTA debate, it seems fair to conclude that opponents of free trade will rely heavily upon the argument that the Agreement, as it now stands, will lead to substantial deterioration of environmental conditions, primarily along the U.S.-Mexican border.

The primary purpose of this chapter is to identify and assess the interactions between liberalized trade and the environment. Contrary to the standard argument that trade liberalization inevitably leads to further environmental degradation, this chapter argues that trade liberalization may well promote more careful use of environmental resources, as well as more extensive and widespread remedies for existing environmental pollution. It also argues that efforts to enforce environmental standards through trade policy measures invite a serious risk that importers will invoke spurious claims about environmental misbehaviour on the part of foreign exporters in order to protect domestic markets. In short, the NAFTA, if anything, may err in the direction of giving too much emphasis to environmental matters rather than too little.

The chapter proceeds in the following manner. First, environmental provisions in the NAFTA are identified and discussed. Then the chapter

1 See Government of Canada, *North American Free Trade Agreement*, Draft Legal Text, September 8, 1992.

lays out the major direct and indirect linkages between trade liberalization and the environment. It then discusses available evidence bearing upon the nature of these linkages. Finally, it assesses the overall environmental consequences of the NAFTA in light of both theory and evidence.

Environmental Provisions of NAFTA

Several important environmental provisions in the NAFTA are similar to provisions in the General Agreement on Tariffs and Trade (GATT). In particular, NAFTA allows the trade obligations of the NAFTA countries under specified environmental agreements to take precedence over NAFTA provisions. For example, NAFTA accords priority to three international agreements to which the U.S. is a party: the convention on international trade in endangered species of wild fauna and flora, 1973, the Montreal protocol on substances that deplete the ozone layer, 1987, and amended in 1990, and the Basel convention on the control of transboundary movements of hazardous wastes and their disposal, 1989, on the latter's entry into force for all three countries.[2] NAFTA affirms the right of each country to choose the level of protection of human, animal or plant life or health or of environmental protection that it considers appropriate. Moreover, each country may maintain and adopt standards and phyto sanitary measures, including those more stringent than international standards, to secure its chosen level of protection.

There are provisions in the NAFTA which establish standards subcommittees to work to make compatible standards-related measures in the areas of, for example, vehicle emissions and other motor carrier environmental pollution levels. The parties also agree to promote making compatible standards-related measures that are developed or maintained by state, provincial and local authorities and private sector organizations;[3] however, there is nothing in the agreement which

2 These agreements were cited earlier in Weintraub's chapter for this volume.

3 Ibid., Annexes 913 A–C.

obliges countries with "stricter" environmental standards to harmonize those standards with the "more lax" standards of other trading partners. On the contrary, countries are free to raise their environmental standards to whatever chosen level is desirable.

To be sure, disputes may arise over whether specific environmental provisions are merely disguised trade barriers.

In disputes regarding a country's standards that raise factual issues concerning the environment, that country may choose to have the dispute submitted to the NAFTA dispute settlement procedure rather than to procedures under another trade agreement such as GATT. The same option is available for disputes concerning trade measures taken under specified international environmental agreements. The panel hearing the dispute will presumably seek to determine if the action taken is credible on environmental (or related) grounds or whether it is transparently a trade protectionist measure. In dispute settlement, the complaining country bears the burden of proving that another NAFTA country's environmental or health measure is inconsistent with NAFTA.

In what is arguably a new departure for an international trade agreement, the NAFTA contains general statements that the signatories will work jointly to enhance the protection of human, animal and plant life and health and the environment. This ostensibly refers to earlier commitments on the part of the negotiators to carry on parallel discussions regarding environmental initiatives. The Agreement also embodies a general statement that no NAFTA country should lower its health, safety or environmental standards for the purpose of attracting investment. It is unclear at this time how effectively this latter clause can be enforced given that complaints would have to be handled through a dispute resolution procedure. Moreover, it is unclear what standards of evidence would be required to "prove" that investment patterns were changed by changes in environmental laws and standards.

Finally, as part of the parallel track negotiations, Mexico and the U.S. agreed in the spring of 1992 to a cooperative plan for improving the environment along the border. As part of this plan, the U.S. government pledged $379 million over two years for various activities, while the Mexican government's share is $466 million. Critics of the cooperative plan have focused on two issues in particular: (i) the failure of the plan

to outline any new revenue-raising measures for border environmental programs; (ii) the absence of a binational enforcement group legally empowered to enforce pollution laws on both sides of the border.[4]

In short, the NAFTA embodies several unique, albeit general commitments to protect the environment and to ensure that environmental amenities are not sacrificed to attract capital investment. The latter commitment is an obvious obeisance to arguments raised by critics of NAFTA that "environmental dumping" will take place, whereby toxic firms relocate to Mexico to evade stricter enforcement of environmental standards in the United States and Canada. Precisely how and to what extent these commitments will be carried out in practice is unclear at the present time. Individual countries retain sovereignty over their domestic health and safety standards, although these standards can be challenged as unwarranted trade restrictions.

Economic Incentives and the Environment

It is clear that the NAFTA, *per se*, does nothing directly to weaken environmental standards and their enforcement in the member countries. That is, countries are free to strengthen their environmental laws and enforcement efforts as long as "legitimate" environmental objectives are being pursued. Hence, potential environmental objections to NAFTA must be based on the adverse impacts that trade liberalization has, directly or indirectly, on environmental amenities. In this section, we consider the potential for such impacts.

The relationship between economic activity and the environment can be made more explicit by noting that all economic activities involve the transformation of specific inputs into specific outputs. Some of the inputs utilized will be closely related to environmental amenities such as clean air and clean water. For example, the activities in question might utilize water as a direct input in the production process or they

4 For a detailed discussion of the border environmental plan, see Jan Gilbreath Rich, *Planning the Border's Future: The Mexican-U.S. Integrated Border Environmental Plan*, Austin: The University of Texas, LBJ School of Public Affairs, U.S.-Mexican Occasional Paper No. 1, March 1992.

might use water indirectly, e.g. by dumping waste byproducts into nearby waterways. It is difficult to be precise in defining environmental amenities, since what is included in the definition will depend, in part, upon the tastes and preferences of the individual offering the definition. For example, some might opt for a broad definition including clean air and water, the preservation of biodiversity, the preservation of wilderness areas and so forth. Others might opt for a narrower definition.

For purposes of this discussion, we do not need to define environmental amenities precisely; however, it is useful to be able to think of these amenities as being divisible and as being "used up" by specific economic activities to a greater or lesser extent. In this context, trade liberalization would damage the environment to the extent that it accelerated the rate at which environmental amenities are used up. By the same token, other economic activities can have the effect of increasing available environmental inputs, e.g. water treatment procedures which reduce chemical and other pollutants in waterways.

In this context, there are several ways in which economic activity can affect the environment. Most directly, an increase in the overall level of economic activity would presumably lead to an increase in the utilization of environmental inputs. Changes in the mix of economic activities can lead either to increases or decreases in the utilization of environmental inputs. For example, as real incomes rise, the demand for environmental amenities should increase. While the increase in demand may be relatively small at low levels of income, it can be expected to increase at a faster rate as a nation becomes wealthier. In more technical terms, the income elasticity of demand for environmental inputs is arguably positive and larger at higher levels of income.[5] If demand turns strongly in the direction of consuming more environmental amenities, it is quite possible that increased levels of economic activity (and resulting increases in income levels) may lead to overall decreases in the utilization of environmental inputs.[6]

5 Income elasticity of demand is defined as the percentage change in the quantity demanded of a specific good divided by the percentage change in real income.

6 That is to say, a shift towards a mix of "cleaner" activities might offset the impact of an increase in the overall level of economic activity.

Ordinarily there will be several different ways to produce a given product. Put in other words, several economic activities may result in the same or similar products being produced. The activities differ in the sense that different mixes of factor inputs are used; e.g. some use more labour relative to capital, some use more capital relative to labour and so forth. In this context, some activities may use environmental resources more intensively than others. As noted above, as incomes increase, members of a society in their roles as both consumers and voters will likely spend an increasing share of their incomes on activities which use relatively small amounts of environmental inputs.

Different ways to produce any given product may persist for periods of time, even if some ways are clearly less efficient than others, because inefficient producers may be subsidized or otherwise protected by the government. Increased competition can be expected to change the mix of activities in use. Specifically, activities which are high cost relative to other activities producing similar products should be driven out of the economy. In this respect, trade liberalization can be expected to lead to such a rationalisation of production within a protected economy, at least on the margin.

One can fit the "environmental dumping" argument into the framework suggested in the preceding paragraph. Specifically, prior to free trade, it may be cheaper to produce a product in the U.S. than in Mexico, even if certain costs associated with environmental standards must be borne in the U.S., because of relatively high U.S. tariffs on Mexican imports. If these tariffs are eliminated, producers may find that it is cheaper to move from the U.S. to Mexico in order to avoid costs of complying with environmental standards.[7] In effect, a reduction in protection in the U.S. might lead to the substitution of one set of activities, i.e. production in Mexico, for another set of activities, production in the U.S., holding the product constant.

7 Note that it may not be less costly in a social sense if the costs of environmental externalities are properly attributed to production in Mexico.

It should be noted that a "reverse dumping" argument can also be made. Namely, trade liberalization might itself promote market oriented reforms in domestic economic policies including reductions in government subsidies and other pricing distortions. Such reforms, in turn, could result in a substitution of less environmentally damaging activities for more environmentally damaging activities. Probably the most relevant case in point here are subsidies extended by many developing countries to energy intensive activities such as transportation and heavy manufacturing.[8] If trade liberalization agreements lead to a reduction in trade distorting subsidies, an important byproduct might be reduced environmental pollution, since heavily polluting activities, which are often the focus of government subsidies in developing countries, would become relatively less profitable.

In the next section, we consider empirical evidence bearing upon these potential linkages. The foregoing discussion suggests that two potential linkages are particularly relevant: (i) trade liberalization leads to higher income levels which affect both the aggregate level of overall economic activity, as well as the mix of economic activities; (ii) the potential for pollution intensive activities to migrate to Mexico as a result of lower tariffs in the United States and Canada counterbalanced by the potential for market reforms in Mexico to discourage pollution-intensive activities either directly or indirectly.

Evidence on Linkages between Trade and the Environment

As noted above, one potentially important linkage between trade liberalization and the environment occurs through the impact of higher levels of economic activity. Specifically, trade liberalization can be expected to result in a faster expansion of the economies of the free trade

8 Observers have noted that in many developing countries, in particular, deliberate "underpricing" of petroleum products, chemical fertilizers and the like encourages the adoption of environmentally intensive production techniques. See Kym Anderson and Richard Blackhurst, "Trade, the Environment and Public Policy," in Kym Anderson and Richard Blackhurst, eds., *The Greening of World Trade Issues*, New York: Harvester Wheatsheaf, 1992, pp. 3-22.

area than would otherwise take place. As a consequence, there will be an even greater demand for all factors of production including environmental amenities.

At the same time, higher real income levels should encourage, at some point, increased private and public demand for greater environmental amenities, and the increased wealth associated with faster economic growth enhances the financial capacities of societies to invest in environmental protection and remedies.

The foregoing suggests that the relationship between real income levels and environmental pollution may not be linear. That is, over an initial range, the dominating influence is the overall level of economic activity. But beyond some point, the changing mix of activities towards less polluting ones will come to be the dominating influence. The "switchover point" is ultimately an empirical issue.

Available studies provide support for the hypothesis that the demand for a cleaner and healthier environment is strongly and positively related to higher real income levels, at least beyond some threshold income level. For example, Grossman and Krueger correlated the level of sulphur dioxide and smoke with per capita income and found that the level of pollution rises until income reached $5,000 per head (in 1988 dollars) and then starts to fall.[9] By way of background, Mexico's real income level per capita in 1991, measured as gross domestic product per capita in U.S. dollars, was below this threshold at $2,365. Income levels for Canada and the U.S. were well above this threshold.

In the absence of precise estimates of the impacts of trade liberalization on the three countries, it is impossible to infer the net impact of the NAFTA on sulphur dioxide emissions; however, analysts tend to agree that the major economic impacts of a NAFTA will be realized by Mexico. Hence, it is at least plausible to argue that sulphur emissions will increase as a result of the NAFTA, at least in the short run. However, to the extent that NAFTA accelerates the growth of the Mexican economy,

9 See Gene Grossman and Alan Krueger, "Environmental Impacts of a North American Free Trade Agreement," Paper prepared for a conference on the U.S.-Mexico Free Trade Agreement, Princeton University Press, October 1991.

it will lead to less sulphur dioxide pollution in the long run, since it will shorten the time it takes Mexico to reach the "crossover" income level.

It might be noted that estimates by the World Bank also indicate a curvilinear relationship between the average ambient level of sulphur dioxide and real income per capita; however, the World Bank places the switchover income level at closer to $2,500.[10] This estimate would suggest that the effects of the NAFTA are likely to be benign in both the short and long run, since Mexico will cross this income threshold in the near future with or without a NAFTA in place.

Some additional evidence on the relationship between income levels and environmental amenities is provided in a study by Walter and Ugelow.[11] Based on questionnaires sent to national officials in developed and developing countries, they found that while the strictness of environmental policies varied within each group, the level of strictness was nonetheless higher, on average, in the developed countries. This finding is also consistent with observations that urban sanitation tends to be an increasing function of income at all income levels, while ambient levels of particles tend to be a decreasing function of income over virtually all income levels.[12] This latter observation suggests that NAFTA will unambiguously reduce pollution related to sewage and ambient particles to the extent that it accelerates income growth in Mexico and, to a lesser extent, in Canada and the United States.

To be sure, some forms of environmental pollution increase with higher national income levels. For example, carbon-dioxide emissions tend to increase fairly uniformly with higher income levels, as does solid waste.[13] These observations qualify an unambiguous conclusion that the income effects of a NAFTA will either be benign or favourable for environmental amenities in North America. Nevertheless, taken on balance, one must conclude that the economic growth stimulated by a

10 See "The Environment: Whose World Is It, Anyway?" *The Economist*, May 30, 1992, p. 8.

11 Ingo Walter and J. Ugelow, "Environmental Attitudes in Developing Countries," *Resources Policy*, Vol. 4, 1978, pp. 200-209.

12 See *The Economist*, op. cit.

13 *The Economist*, op. cit.

NAFTA may well be positive, on balance, for the environment in terms of reducing the utilization of environmental amenities. The main effect here is the increased demand for a cleaner environment which is associated with a shifting away from pollution-intensive activities.[14]

Another important empirical relationship relates to the environmental dumping issue or the relocation of pollution intensive activities to Mexico. As noted earlier, one argument holds that a reduction in Canadian and U.S. tariffs will, on the margin, make it more attractive for polluting firms to relocate to Mexico in order to serve the North American market. A related concern is that increased competition associated with trade liberalization will lead domestic producers to "cheat" with respect to obeying environmental standards or that it will lead to increased and effective lobbying efforts to have environmental standards relaxed.[15]

The argument that firms facing the competitive pressures of free trade will abandon environmental responsibility and ignore codified (or uncodified) standards, i.e. use illegal, pollution-intensive production techniques, begs the question: why would they not also cheat prior to the implementation of a free trade agreement if they thought they could do so with impunity? Perhaps the risks of getting caught become worth taking when a firm is faced with the imminent prospect of bankruptcy; however, widespread increases in risks of bankruptcy cannot be realistically contemplated purely as a consequence of NAFTA.

Another scenario is that national governments will be less inclined to pass and enforce environmental standards given industrial dislocations and any short-term increases in unemployment associated with adjustments to trade liberalization. Indeed, governments might rely upon reduced regulation of business as a form of "adjustment assistance" for domestic industries. Equivalently, governments might relax domestic environmental standards in order to permit domestic firms to

14 Note that such shifting can reflect greater utilization of pollution abatement equipment or practices in activities which hitherto were relatively pollution intensive.

15 See Peter Emerson and Raymond Mikesell, *North American Free Trade: A Survey of Environmental Concerns*, San Francisco: Pacific Research Institute Policy Briefing, mimeo, December 1991.

compete on a "level playing field" with firms based in countries with weaker environmental standards and/or enforcement practices.[16]

Both the environmental dumping and the standards relaxation arguments are ultimately empirical issues. In both cases, empirical evidence provides little support for the arguments. Since the bulk of the available evidence relates to the environmental dumping issue, we shall review that evidence first.

One comprehensive review of the environmental economics literature concludes that domestic environmental measures have not induced industrial flight and the development of pollution havens. The primary reason seems to be that the costs of pollution control have not, in fact, loomed very large even in heavily polluting industries (i.e. on the order of only 1 to 2.5% of total costs in most pollution-intensive industries). Such small increments to costs are likely to be swamped in their impact on international trade by other effects such as differentials in labour cost.[17]

Specific studies can be cited to reinforce this conclusion. For example, Leonard found no evidence in overall statistics on foreign investments by U.S. companies and U.S. imports of manufactured goods that key high pollution industries have shifted more production facilities overseas in response to environmental regulations. Yet in a few high pollution, hazardous production industries, environmental regulations and workplace-health standards have become a more prominent and possibly decisive factor in industrial location and have led U.S. firms to move production abroad. Examples of such industries are those that

16 An alternative version of this argument might hold that standards in the U.S. and Canada will be "harmonized downward" to be made compatible with standards in Mexico.

17 See Maureen L. Cropper and Wallace Oates, "Environmental Economics: A Survey," *The Journal of Economic Literature*, Vol. XXX, June 1992, pp. 675-740. Another more focused literature review comes to the same conclusion, namely, there is no evidence to support the hypothesis that more stringent regulations in one country will result in loss of competitiveness, and perhaps industrial flight and the development of pollution havens. See Judith M. Dean, "Trade and the Environment: A Survey of the Literature," Background Paper, Washington, D.C.: The World Bank, 1992.

produce highly toxic, dangerous or carcinogenic products, such as copper, zinc and lead. For these latter industries, environmental regulations have combined with other changing location incentives and economic problems to speed international dispersion of capacity.[18]

In a similar vein, Walter reports that certain copper smelters, petroleum refineries, asbestos plants and ferro-alloy plants have reportedly been constructed abroad rather than in the U.S. for environmental reasons. Moreover, some recent Japanese pollution-intensive industries have reportedly been channelled to developing countries in Southeast Asia and Latin America; however, there is no evidence of a "massive" environment-induced shift in the location of production capacity. Moreover, a significant amount of the observed geographical mobility of production involves cases where major projects were absolutely barred for environmental reasons.[19]

Rubin and Graham conclude that during the decade of the 1970s, during which complex environmental regulations and high pollution costs were imposed on industries, the overall foreign investment and import trends of the mineral processing, chemical and pulp and paper industries did not differ fundamentally from those of U.S. manufacturing industries in general. The former industries are arguably among those that should have been most adversely affected by environmental legislation implemented in the U.S. In fact, only slight shifts at the margin could be detected in these industries. Specifically, only a few U.S. industries within branches of the chemical manufacturing sector have increased production overseas as a direct or indirect result of environmental regulations.[20]

18 See H. Jeffrey Leonard, *Are Environmental Regulations Driving U.S. Industries Overseas?* Washington, D.C.: The Conservation Foundation, 1984.

19 See Ingo Walter, "International Economic Repercussions of Environmental Policy: An Economist's Perspective," in Seymour Rubin and Thomas R. Graham, eds., *Environment and Trade*, Totawa, New Jersey: Allanheld, Osmun and Co., 1982.

20 See Seymour Rubin and Thomas Graham, "Environment and Trade" in Rubin and Graham, eds., op. cit.

Stafford examined whether traditional factors such as access to markets and differences in costs of labour and materials remained predominant in manufacturing-location decision-making, despite the added dimensions of environmental regulations introduced under the National Environmental Policy Act.[21] Personal interviews and mailed questionnaires were used to identify the most important factors in the location of 162 new branch plants of U.S. corporations. For most of the decisions investigated, environmental regulations did not rank among the most important factors considered. When such regulations were of some significance, uncertainties about when the necessary permits would be obtained were more important than spatial variations in direct cost. Stafford concludes that environmental regulations have had no consistent effect on the size of the search area, the number of sites considered, the sizes of the facilities built, or the decision to expand existing plants versus building new plants.

Bartik used a database of new manufacturing branch plants opened by Fortune 500 companies between 1972 and 1978 to determine if business location decisions are affected substantially by state environmental regulations. Two measures of state water pollution regulations and four measures of state air pollution regulations were used as variables. The study did not find any statistically significant effect of state environmental regulations on the location of new branch plants. Even sizeable increases in the stringency of state environmental regulations were found unlikely to have a large effect on location decisions for the average industry; however, for some highly polluting industries, the results cannot rule out the possibility of effects of environmental regulation on plant location.[22]

Finally, McConnell and Schwab estimated a statistical model to investigate the impact of a variety of country characteristics on the locations of 50 new branch plants in the motor vehicle industry during the period 1973-1982, a period when there were wide variations in

21 Howard A. Stafford, "Environmental Protection and Industrial Location," *Annals of the Association of American Geographers*, Vol. 75, 1985, pp. 227-240.

22 Timothy Bartik, "The Effects of Environmental Regulation on Business Location in the United States," *Growth and Change*, Vol. 19, 1988, pp. 22-44.

environmental regulations among regions. Most of the results indicate that environmental regulations do not exert an important influence on location decisions. At the margin, however, there is some evidence that firms may be deterred from locating where the ozone problem is severe and emission controls are correspondingly stringent.[23]

In summary, the evidence is quite persuasive that geographic differences in environmental standards and enforcement have a relatively small impact on the location decisions of firms. Indeed, any significant impacts appear to be concentrated in resource-based sectors that are arguably relocating from the United States for other reasons anyway. Moreover, there are other locations to which these activities can potentially relocate with environmental standards and enforcement that are substantially weaker than in the case of Mexico.

To be sure, critics might argue that differences in environmental enforcement between Mexico and the United States are much more substantial than those between different states within the United States or, for that matter, between different developed countries. In this regard, it should be noted that a number of the studies cited above consider potential relocation to other developing countries. Moreover, a study by the U.S. Trade Representative's Office concludes that the small share of costs ascribable to pollution abatement and the already low levels of U.S. tariffs in industries facing high pollution abatement costs argue against Mexico being a different case.[24]

There is less direct empirical evidence to appeal to regarding the potential for environmental standards or the enforcement of these standards to be relaxed in the developed economies as a result either of increased imports from other countries or of formal efforts to harmonize standards. It is certainly relevant to note that increased imports from developing countries in Asia with much weaker environmental regula-

23 Virginia McConnell and Robert Schwab, "The Impact of Environmental Regulation on Industry Location Decisions: The Motor Vehicle Industry," *Land Economics*, Vol. 66, 1990, pp. 67-81.

24 Office of the United States Trade Representative, *Review of U.S.-Mexico Environmental Issues*, Washington, D.C.: Mimeo, October 1991.

tions than those in North America have not provoked reversals of environmental legislation in the United States to date.[25]

The experience of the European Community (EC) suggests that when environmental standards differ across countries, convergence of standards will ultimately take place in the direction of the more restrictive set of standards. By mid-1991, the EC had adopted nearly 300 new directives and regulations dealing with environmental matters along with new measures applying strict liability standards in cases involving pollution. While many member countries arguably have not been aggressive in enforcing the EC environmental rules, pressure from those countries enforcing the rules and adopting their own tougher antipollution laws is apparently bringing about compliance by all members.[26]

The likelihood of NAFTA triggering a relaxation of environmental standards in the United States and Canada is reduced by the facts that Mexican imports are a relatively small part of total imports and, further, that environmental costs are a small share of all costs in virtually all industries. Furthermore, current pressures in the United States to reduce the burden of environmental regulations on companies is clearly driven by broader macroeconomic weaknesses in the U.S. economy rather than by import pressures in specific industries or from specific countries.

Overall Assessment of NAFTA and the Environment

The preceding sections suggest that existing arguments about NAFTA necessarily contributing directly or indirectly to a further degradation of environmental amenities are both simplistic and arguably incorrect.

25 A theoretical model developed by Rauscher concludes that the implications of a common market for environmental policy are uncertain. While there will likely be a relocation of emissions from one country to the other, total emissions may be higher or lower than in the initial state, i.e. prior to production factors being mobile. See Michael Rauscher, "National Environmental Policies and the Effects of Economic Integration," *European Journal of Political Economy*, Vol. 7, 1991, pp. 313-329.

26 See Rudy Portari, "Toughened Environmental Regulation Looms in the EC," *National Underwriter*, Vol. 95, 1991, pp. 52-53.

Increased pollution along the border between Mexico and the United States is frequently pointed to as a necessary consequence of increased cross-border commerce.[27] However, it can be argued in this regard that the economic activity generated by NAFTA will actually encourage less pollution along the border. This is because the incentives that maquila plants now have to congregate along the border will be blunted by a NAFTA which will make all Mexican exports, and not just those from maquila plants, eligible for tariff relief on their North American content.

Undoubtedly, the high degree of congestion along the border has exacerbated pollution problems (given limitations on the ability of the natural environment to absorb pollution), while limited enforcement of pollution standards, particularly by Mexico, has contributed to border-area problems highlighted by NAFTA critics. However, the relevant issue is whether NAFTA will exacerbate or mitigate existing environmental degradation.

As noted above, the NAFTA should mitigate environmental congestion problems at the border by encouraging the dispersal of economic activity away from the border region. Also, tariffs on pollution abatement equipment will be eliminated over time making this equipment substantially cheaper in Mexico. As a result, it will be cheaper for Mexican firms to meet environmental standards, although whether they choose to buy and install more equipment will depend, in part, on the efforts of the Mexican authorities to enforce existing standards. The freer movement of professionals in the environmental engineering area under the NAFTA should assist the Mexican government in its enforcement efforts given shortages of such expertise in Mexico.[28]

Finally, provisions in the NAFTA liberalizing cross-border trucking restrictions might indirectly encourage a reduction in vehicle pollution at major border crossing stations. For example, vehicles registered in

27 There are numerous discussions in the media documenting health and worker safety problems associated primarily with Maquiladora production along the Mexico-U.S. border. See, for example, Joel Simon, "Will Tijuana be a free trade tinderbox?" *The Globe and Mail*, December 19, 1992, D3.

28 The NAFTA includes provisions expediting the visa process for managers and many professionals including engineers.

most states currently face tighter emissions control procedures for licensing than do those registered in Mexico. Hence, to the extent that U.S.-owned vehicles displace Mexican vehicles in hauling traffic within the Mexican border, emission standards in Mexico will indirectly rise. On the other hand, Mexican vehicles entering the U.S. will presumably have to meet the same emission standards facing U.S.-registered vehicles. The opportunity to carry more traffic within the United States might therefore encourage Mexican fleet owners to reduce pollution from their vehicles.

These latter considerations add further weight to an argument that NAFTA will lead to improvements in environmental amenities rather than further deterioration, even if the relevant standards subcommittees fail to harmonize emission and other environmental pollution levels. Nevertheless, it might be argued that NAFTA is a promising vehicle for "leveraging" greater efforts from Mexico to deal with domestic pollution problems, as well as greater efforts on the part of all three countries to deal with trans-border pollution problems. In effect, one might argue that trilateral trade liberalization negotiations should be used to directly strengthen existing legislation and enforcement of environmental standards on a North American-wide basis.

One argument for directly linking trade liberalization to environmental protection measures is premised on the view that threats of trade retaliation on the part of trading partners effectively motivate a country to meet the environmental standards demanded by those trading partners.[29] In this regard, some observers argue that recent increases in Mexican budgets for environmental infrastructure and enforcement of environmental laws and regulations would probably not have come about if NAFTA negotiations had not provided the impetus.[30]

Another argument for an explicit and comprehensive linkage is that governments in high enforcement countries can and will invoke trade remedy laws, particularly countervailing duties, against exporters in weak enforcement countries. In this case, it might be more effective to

29 Equivalently, one can talk about the use of the "carrot" of trade liberalization as the motivating influence.

30 This point is made by Weintraub in his chapter for this volume.

have explicit agreements struck than to tolerate significantly higher risks of trade wars tied to escalating retaliation for specific environmental practices.[31]

A counter-argument against directly linking trade and environmental measures is that it is unlikely to be welfare maximizing for all countries to adopt identical environmental standards or environmental cost controls given that the point at which the marginal social benefit of abatement equals the marginal social cost of abatement will vary from country to country depending upon factors such as topography, climate, demography and so forth.[32] Another is that it is rarely welfare improving for countries to impose trade restrictions in response to their being "polluted upon" by another country's producers (or consumers).[33] Nevertheless, a theoretical case can be made for the "victim" country to use tariffs against the polluting country as a second best policy providing the importing country is large in world markets; however, the first best approach is the imposition of a coordinated "globally optimal" tax on trans-border pollution.

The latter observation, combined with the recognition that lobby groups will use environmental issues to extract protection against imports suggests the wisdom, on balance, of separating the treatment of environmental problems from the treatment of trade issues. The exis-

31 That this concern is becoming increasingly relevant is suggested by a report that Senator Max Baucus held hearings in December 1991 to discuss possible trade legislation requiring countervailing duties on imports from countries with less strict pollution rules than the U.S. to prevent environmental dumping. See Peter Fuhrman, "Strange Bedfellows," *Forbes*, December 9, 1991. Concern about this possibility is also expressed in GATT, Press Release: Expanding Trade Can Help Solve Environmental Problems, Geneva: Mimeo, February 3, 1992.

32 For a detailed discussion of these factors, see Charles S. Pearson, "Environmental Standards, Industrial Location and Pollution Havens," in C.S. Pearson, ed., *Multinational Corporations, Environment and the Third World: Business Matters*, Durham: Duke University Press, 1987, pp. 113-128.

33 For a full discussion of this point, see Peter J. Lloyd, "The Problem of Optimal Environmental Choice," in Kym Anderson and Richard Blackhurst, eds., *The Greening of World Trade Issues*, New York: Harvester Wheatsheaf, 1992, pp. 49-92.

tence of dispute resolution panels in the NAFTA promises to mitigate some of the more grievous abuses of environmental standards to blockade imports; however, this does not gainsay a general argument that the more the trade liberalization process is made contingent upon satisfying implicit or explicit environmental conditions, the more likely is trade protectionism.

In the last analysis, the level of inter-governmental cooperation to address border pollution problems is the single most important factor affecting environmental conditions in the member countries.[34] It is useful to repeat in this regard that eliminating explicit and implicit government subsidies, particularly to energy use, would also make a significant contribution to reducing certain emissions. Indeed, market processes can assist in rationalizing the harmonization of environmental standards. A case in point is the infamous American dolphin-protection laws which highlighted the issue of trade retaliation on environmental grounds at the GATT level. In one part of the eastern Pacific, herds of dolphin on the sea's surface signal the presence of schools of tuna farther down. Encircling the dolphins with purse-seine nets is one way of catching the deeper tuna, but at a high cost in dolphin deaths.

The most recent version of America's Marine Mammal Protection Act prevents American fleets from using this method of tuna fishing. Since 1990 the law has insisted that imported tuna must not be fished by methods that involve killing more than one-quarter more dolphin than are killed by the American fishing fleet. Mexico is one of three countries that failed to meet this target. A protest against an American ban on imports of tuna from Mexico led to a GATT ruling against the ban.[35]

34 See Office of the United States Trade Representative, op. cit. A number of studies conclude that the use of trade related measures will have at best a modest impact on natural resource activity which is a major source of environmental problems. See Peter A.G. van Bergeijk, "International Trade and the Environmental Challenge," *Journal of World Trade*, Vol. 6, 1991, pp. 105-115.

35 "GATTery v. Greenery," *The Economist*, May 30-June 5, 1992, pp. 12-15.

The GATT decision throws into doubt environmental laws that impose restrictions or penalties on foreign countries which may constrain in a substantial way the treatment of similar protests brought for dispute resolution under the NAFTA. A point which might be made is that with sufficient information, American consumers might have encouraged a reduction in the dolphin kill. Specifically, consumers could exercise their environmental preferences by buying more "American" tuna and less "Mexican" tuna. If consumers felt strongly enough about this issue, it would pay American producers to advertise their "dolphin-safe" methods of fishing. Certainly there are an increasing number of businesses that trade on a reputation of being "environmentally responsible" entities. Where individual consumption or production decisions impose no substantial third-party externalities, there is no compelling efficiency argument for government intervention, particularly given the risk that such intervention will be motivated by desires of domestic producers for protection and will likely lead to retaliation by other countries.

A contentious international trade environment is unlikely to promote an atmosphere of cooperation for inter-governmental agreements to address cross-border pollution including the harmonization of standards and the implementation of "globally-based, market-type" mechanisms to address pollution externalities.[36] Furthermore, the expertise needed to address trade issues does not necessarily overlap the expertise needed to negotiate international environmental agreements.

In summary, it seems wise to separate trade liberalization treaties from negotiations to create international environmental agreements which was essentially the procedure adopted by NAFTA negotiators. In a similar vein, it would arguably be a mistake to make trade liberalization contingent upon the trading partners resolving all major cross-border environmental problems. The NAFTA as it currently stands adopts basic GATT provisions allowing countries to exercise sovereignty in choosing environmental, health and safety standards as long as national treatment is extended to foreign producers, and the stan-

36 van Bergeijk, op. cit. briefly discusses the use of internationally tradeable emission permits.

dards are not defined and implemented in a way that is transparently protectionistic. In this respect, the NAFTA recognizes the likelihood that "optimal" environmental standards will differ from country to country, while at the same time recognizing that limits must be placed on the arbitrary use of domestic environmental legislation to disadvantage foreign producers.

In short, one can conclude that the NAFTA adopts a relatively effective position on environmental matters and that efforts to "strengthen" the environmental provisions will impose social costs that likely outweigh any associated social benefits.[37] Of course, this is not to say that inter-governmental negotiations to resolve trans-border environmental issues should be discontinued, or that efforts to harmonize standards which are impacting trade relationships should not be enthusiastically pursued. On the contrary, the successful implementation of the NAFTA will arguably facilitate successful negotiations in the environmental area in a setting where the sovereignty of the individual member countries has been formally acknowledged.

37 This caveat also applies to the provision in the NAFTA which proscribes a weakening of environmental standards to attract new investment. While it is unclear how this provision will be implemented, there is a grave risk of mischievous interventions on the part of governments that are driving away investment through policies that weaken the efficiency of markets. There is also a risk that governments may not be able to rescind environmental laws that are inefficient or even ineffective.

Helvarg, David. 1996. The big green spin machine. The Amicus Journal 18,2 (Summer): 13-21.

The big green spin machine

Corporations and environmental PR

by David Helvarg

We turn to corporations to transform our thoughts into goods and services. In this sense, corporations are the agents of our desires. How do corporations respond to the environmental concerns of consumers and regulators? One way to respond is to create "green advertising."
—*Journal of Advertising*, 1995

A young girl runs her hand over a row of Douglas fir seedlings. "When I'm a grandmother, there'll still be lots of trees," she smiles, "because people like my dad, who loves trees, will always plant them."

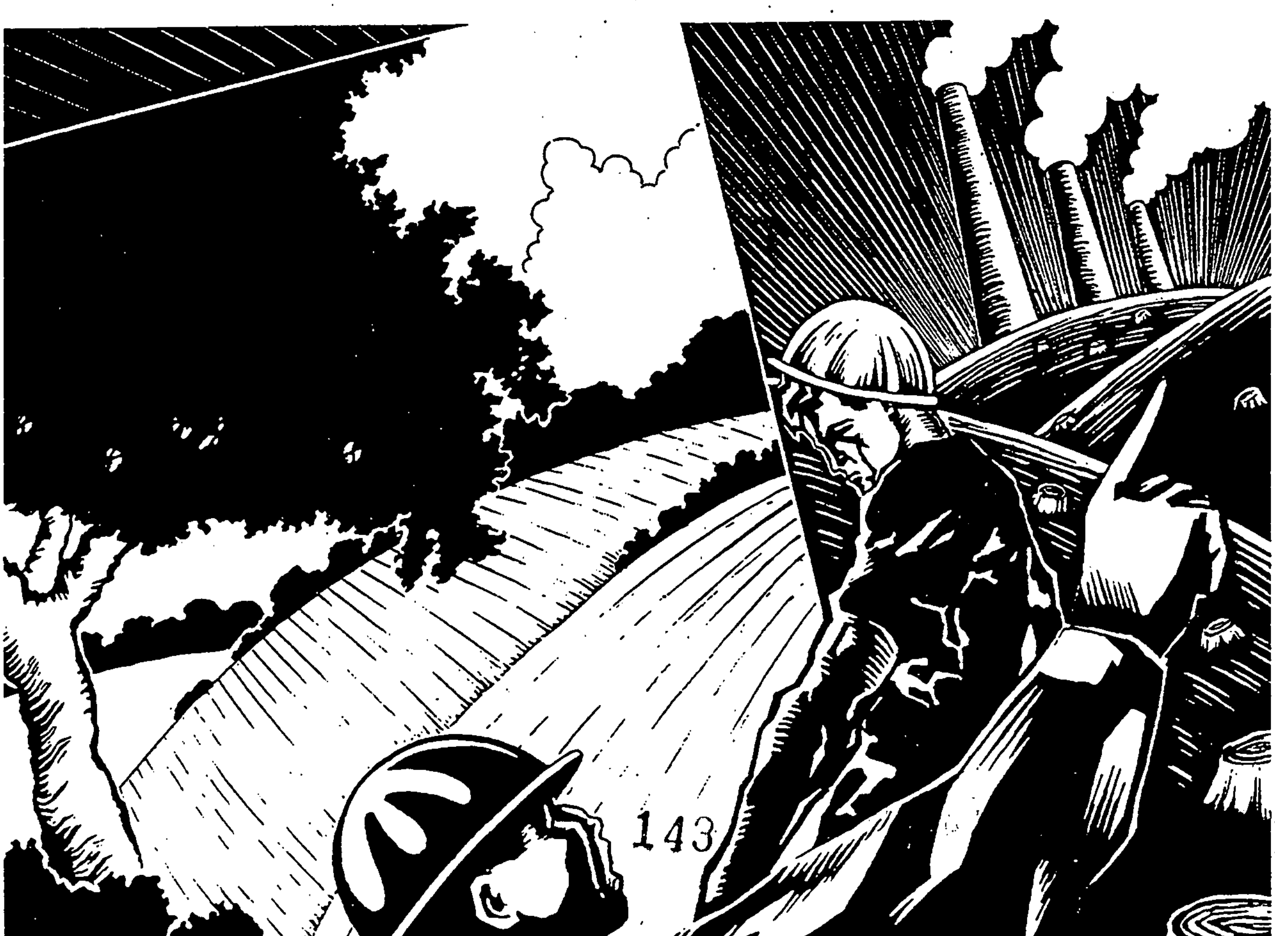
Below a photograph of a nuclear power plant on the edge of a forested river, a cut line declares in bold type: "Trees aren't the only plants that are good for the atmosphere."

A young woman in cap and gown is graduating from college, her proud parents looking on. Dissolve to a laboratory. The woman, now wearing a white lab coat, is checking a glass beaker. "When I was growing up, Mom and Dad taught me that we've only got one planet and we'd better take care of it," she says in voiceover. "Now I'm about to join a company that's committed itself to helping people preserve our wildlife ... and to protect the earth."

If you have never seen these advertisements for International Paper, the U.S. Council for Energy Awareness, or Dow Chemical, you have probably seen similar "image ads" for Phillips Petroleum, GM, Mobil, Weyerhaeuser, Georgia-Pacific, Chrysler, Mitsubishi, the Cattlemen's Association, Freeport Minerals, and others.

And if those ads have not convinced you of corporate America's commitment to a clean and healthy environment, there are hundreds of industry-backed "third-party advocacy" institutes, research centers, think tanks, professional organizers of "Astroturf" (synthetic grassroots), and public relations cam-

David Helvarg, author of The War Against the Greens *(Sierra Club Books, 1994), writes frequently for* The Nation.



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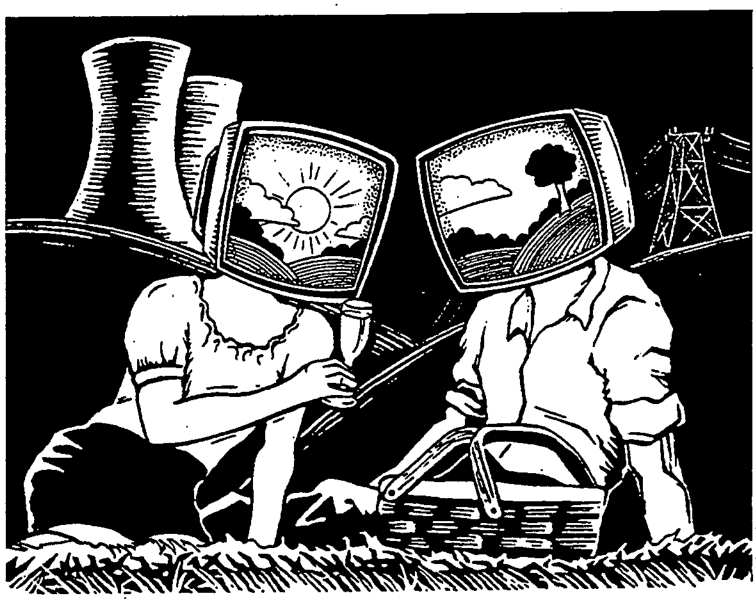
paigners who are eager to try. This massive advertising and publicity effort, whose costs to industry have been estimated at about a billion dollars a year, has been labeled "greenwashing" by its detractors.

"I see greenwashing as part of an overall strategy by corporations to defeat and marginalize environmental activism, and to a large degree it's succeeding," says John Stauber, publisher of *PR Watch* and co-author of a recent book on the public relations industry, *Toxic Sludge is Good for You.* The strategy behind greenwashing, Stauber argues, is a good cop/bad cop approach to the environment. A corporation or trade association can lobby in Congress to gut environmental laws and support "Wise Use" groups, on the one hand, and, on the other, earn environmental points with the public through corporate ad campaigns and high-profile "partnerships" with environmental groups.

Public relations executives counter that industry is simply trying to get credit where credit is due. "When you see corporate America doing green advertising, it's because they get hit so hard so often by the environmental community. So you have to let the public know what good you're doing," argues Hal Dash, president of Cerrell Associates, a Los Angeles-based PR firm that numbers oil and auto interests among its clients.

"The auto industry is doing more than anyone to promote cleaner air," adds Kathleen Ashby, until recently head of Cerrell's environmental division. "California air is 96 percent cleaner than ten years ago because of the auto industry. Environmentalists tell you that's because of pressure, but I don't agree. I think industry understands it has an obligation to its customers and is making these changes because it's the right thing to do."

Yet Cerrell Associates recently helped the auto industry to kill a California mandate requiring that, by 1998, a certain percentage of all cars sold in the state have zero tailpipe emissions. That fact is one reason why Stauber and others share the sense that in the era of the 104th Congress—when legislators are trying to roll back the basic environmental laws of the nation—much green advertising has a pointed political agenda: to persuade the public that strict environmental laws are no longer needed, because America's environmental problems have been solved and the only thing left to fear is regulation itself.



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Greenwashing has a long and illustrious history in the United States. One of the earliest and most literal examples, according to Tom Athanasiou, author of *Divided Planet: The Ecology of Rich and Poor*, goes back to 1969, when the Pacific Gas & Electric Company built a nuclear power plant at Diablo Canyon on the coast of central California. As a pristine hillside was scraped away for the construction site, the raw gash in the marine terrace became visible to passing boats and planes. PG&E decided to camouflage it by painting the exposed earth green.

Another early example of greenwashing came in the wake of the first Earth Day. In 1971, a group called Keep America Beautiful (KAB) began running public service ads featuring a Native American actor, Iron Eyes Cody, with a tear running down his cheek at the sight of roadside litter and garbage in waterways. These celebrated ads, which were co-produced by the Ad Council, moved a generation to stop throwing garbage out car windows. But they also sent the message that individual consumers are the ones most responsible for pollution—an idea consistent with the self-interest of the many members of the bottle and can industry on KAB's board. The ads told the public to "put litter in its place"; yet KAB has repeatedly taken positions against mandatory recycling and bottle deposit laws.

In recent years, green advertising has seen an upsurge. "One of the things that spurred it was Bhopal [site of a 1984 Union Carbide gas leak that killed 3,000] and the *Exxon Valdez*," admits Hal Dash. Contemporary with those disasters came the rapid growth of an environmental ethic among the American public, which reached a crescendo when millions participated in rallies, protests, and celebrations for the twentieth anniversary of Earth Day in April 1990.

Some responded to these developments with vitriol. The *National Review*, Pat Buchanan's newsletter, and others on the political right attacked environmentalism: "If Marxism has a successor," wrote one contributor to a Heritage Foundation symposium, "it is the new ideology of the Greens." But others saw opportunity in the new climate. *Fortune* magazine assured readers that in the future, environmentalism would be "more cooperative than confrontational—and with business at the center." *O'Dwyer's PR Services Report*, a respected trade publication, observed that leading business and PR executives saw the environment as "the life-and-death PR battle of the 1990s."

"There was an explosion of interest among PR firms to set up green divisions," recalls *O'Dwyer's* editor Kevin McCauley. "Spending went through the roof." Today all the major PR firms—Burson-Marsteller, Ruder Finn, Hill & Knowlton, Shandwick, Edelman, and dozens of others—maintain "environmental specialty" divisions for their corporate clients. In 1994, these divisions generated more than $86 million in fees.

No PR firm would be likely to agree with John Stauber that its work serves to defeat or marginalize environmental activism. Many insist publicly on their environmental commitment. But in case after case, corporate public relations campaigns have served to deflect attention from deeper environmental problems—or to thwart environmental initiatives altogether.

Every poll you see says the public is more willing to trust environmental groups than corporations, which is ironic since the most important environmental actions are done by corporations.

—David Meeker, 1995 Chair, Environmental Section, Public Relations Society of America

As an animated dove flies from factory smokestack to factory smokestack, each stack emits a puffy white cloud into a sky of robin's-egg blue. "When one chemical company starts cleaning up its act, that's good. When two chemical companies do it that's better," says the narrator, over the sound of chirping birds and a jazz combo. "And when 200 companies get together, they can make a real difference."

Some corporate lobbying groups "try to fudge about their goals," says a PR exec. "They want a patina of good-guyness."

The ad, by the trade consortium known as the Chemical Manufacturers Association (CMA), is one of a series extolling the recycling of pollutants and conversion of "toxic chemical waste" into energy. They run under the logo of Responsible Care, CMA's voluntary standards program, in which each company evaluates its own environmental performance. The program was recommended to CMA by its Public Perception Committee following the Bhopal disaster and a leak at Union Carbide's Institute, West Virginia, plant the following year. Although CMA can in theory revoke the membership of a company that fails to meet its Responsible Care environmental standards, to date it never has. "We're not the government," explains a lobbyist for a CMA member group. Asked whether member companies are complying, he smiles and says, "Look, if your dad didn't tell you to come home by midnight, would you come home by midnight?"

While promoting Responsible Care as an example of its commitment to "sustainable development," CMA is hard at work on Capitol Hill, doing what is considered by many environmentalists to be some of the most egregiously anti-environmental lobbying in the 104th Congress.

CMA is fighting to throw out the Community Right-to-Know Act, a low-cost law that requires its members to tell the public what they are up to. It has backed legislation, and is suing the Environmental Protection Agency (EPA), to reduce or eliminate the Toxic Release Inventory that is the keystone of that law—a public database of companies' reports on which and how much of 650 toxic chemicals they are releasing into surrounding communities. CMA has also backed the so-called "regulatory reform" legislation that would impose an impossibly complicated, twenty-six-step cost-benefit analysis on almost all environmental and safety standards; a "Superfund Reform" bill that would exempt companies from retroactive liability for toxic sites; and a Clean Water Act rewrite so damaging that President Clinton calls it the "Dirty Water Act."

Moreover, according to the Associated Press, an arm of CMA called the Chlorine Chemistry Council has been lobbying for changes to the Safe Drinking Water Act that would prevent EPA from imposing new rules aimed at reducing carcinogenic compounds in drinking water. As part of its "public education" campaign, the Chlorine Council did a mailing to municipal water managers after obtaining an unauthorized copy of the American Water Works Association mailing list. It also ran a phone-bank operation, targeting AIDS groups, to spread the claim that the new rules would put their lives at risk.

"The effect of the ads is grossly misleading," says Greg Wetstone, NRDC legislative director. "CMA runs green ads, but at the same time it is one of the most aggressive proponents for rolling back environmental protections in Congress." Like other environmental advocates in D.C., Wetstone has been rudely surprised by the degree to which even corporations that have invested in pollution reduction have bought into the anti-green backlash of the 104th Congress. "Throughout 1995, not one of the Fortune 500 raised its head to say no to these rollbacks," he says. "It's become a case of greed conquers all, no matter how much they've invested in a green image."

Greenwashing is really a sophisticated form of denial, telling us there's no problem because they're taking care of it—which they aren't," says environmental stalwart David Brower. He recalls a meeting he participated in at Stanford University several years ago entitled "Making a Difference." At one point Joan Martin

Brown, representing the UN Environment Program, turned to Ken Derr, CEO of Chevron, and said, "I'll be glad when Chevron moves its concern for the environment from Public Relations to Operations."

Sometimes, the distance between operations and public relations—between reality and greenwashed appearance—can be substantial.

"You have to tell the truth and respect the intelligence of people," claims David Soblin of the J. Walter Thompson agency. His beautifully shot TV spots show Chevron employees protecting natural habitat for foxes, grizzly bears, egrets, and other creatures (while the narrator ruminates, "Do people keep an eye on little things so we don't lose sight of the big picture? People Do!"). "You can't use corporate-speak or platitudes to be effective," Soblin says. "You merely show examples of what you're doing." Polls testify to his effectiveness: Chevron is considered far and away the most environmentally sound oil company in the areas where the ads are run, he says.

Yet at least one of those ads, originally filmed in the mid-1980s, is misleading at best. It showed an endangered San Joaquin kit fox escaping a coyote by ducking into an artificial den of buried pipe, built by people "because they care." However, says Linda Spiegel, a California Energy Commission biologist who has studied the kit fox for years, "In general, artificial dens don't do much for foxes. If a coyote chases them, they're more likely to run to where their old den was." The cost of constructing an artificial den is less than $3,000; though Chevron declines to divulge figures, the *Earth Island Journal* has estimated the cost of the "People Do" campaign that year at $5–6 million.

Moreover, Chevron did not undertake the project merely because it "cared." Den construction (whether it benefits the foxes or not) is a standard practice for oil companies operating in the kit fox area. Like other projects featured in Chevron's habitat protection ads, it is the kind of measure any industry has to commit to before it will be permitted to operate in endangered-species habitat.

Nor do Chevron's ads mention that, through its membership in the American Petroleum Institute, it is supporting an active lobbying effort in Congress to gut some of the very laws that require such projects. "The ads celebrate something their lawyers fight tooth and nail to prevent. It creates the illusion they can do it themselves and don't need regulation—that they thought this up on their own," charges Herb Chao Gunther, president of the Public Media Center, a non-profit PR firm that produces ad copy for public interest groups. "Those ads are a vile form of propaganda."

Back to 1984

At a meeting of the Public Relations Society of America a few years ago, writes environmental activist Bill Walker, a PR manager for a company called ChemLawn complained that people in their headquarters town hated the company. The problem was, she said, "It uses, you know, chemicals. But what can you do?"

"Change the name," replied her colleagues, in unison.

In a backhanded compliment to the popularity of environmentalism (and the foresight of George Orwell), many anti-green groups have adopted green-sounding names. Certainly it would be hard for someone unfamiliar with activist groups to distinguish the Natural Resources Defense Council, say, from the Alliance for Environment and Resources, the National Wetlands Coalition, Citizens for the Environment, or the Abundant Wildlife Society. These groups support, respectively, clearcutting in National Forests; wetlands development; eliminating federal environmental laws; and continued trapping and shooting of coyotes, mountain lions, and other predators.

Greenwashing has in recent years extended to name changes for ships and corporations. After the *Exxon Valdez* oil spill, the tanker was sent to a San Diego shipyard, where it was repaired, repainted, and rechristened the *Exxon Mediterranean*. Following a series of financial and environmental scandals, the nation's largest solid waste company, Waste Management, Inc., gave itself a higher-tech image with a name change to WMX. Nuclear Engineering, Inc., became US Ecology. And the National Agricultural Chemicals Association has renamed itself the American Crop Protection Association and founded its own pro-pesticide advocacy group, RISE (Responsible Industry for a Sound Environment).

Why the sensitivity to semantics? Said one PR executive, quoted in *The New York Times*, "People try to fudge a little bit about what their goals are. They want to create a patina of good-guyness." •

People think PR agencies are turning out news releases. I've written two releases in three years. We do campaigns to educate the public, we have a lobbying effort, we put together grassroots groups.

—Jeff Raleigh, Hill & Knowlton

Give them the money. You stop defending yourselves, let them do it, and you get the hell out of the way. Because citizens' groups have credibility and industries don't.

—"Wise Use" leader Ron Arnold, explaining the need to create pro-industry "grassroots" in a speech to Canadian timber company MacMillan Bloedel

Early in 1995, the trade publication *PR News* ran a cover story promoting the loose anti-green network calling itself "Wise Use," under the title, "New Environmental Grass Roots Sprouting." It suggested, delicately, that Wise Use "presents an opportunity for PR executives at corporations and firms to play the advocate role not for environmental activist groups or corporate environmentalism, but for a view that calls for consideration of economic impacts and property rights in environmental debates."

But *PR News* was years behind the curve. PR firms ranging from giants like Hill & Knowlton, Burson-Marsteller, and Edelman to lesser-known operations like the Jefferson Group ("Greenspeak. We're fluent.") have long been promoting groups and activities in the Wise Use vein. Last summer's annual Alliance for America "Fly-In For Freedom," for example, brought 300 to 400 loggers, miners, small-town developers, and industry employees to Washington, D.C., to lobby against the Endangered Species Act. Publicity and security for the Fly-In were handled by Edelman. Two of Edelman's clients, the California Forestry Association and the Western States Coalition, also sponsored the event.


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And when no grassroots coalition is at hand, many agencies will happily create one. The term now current for this practice, "Astroturf lobbying," was coined by former Senator and Treasury Secretary Lloyd Bentsen. By now, PR firms offer a wide range of *faux* grassroots products.

Ron Arnold and Alan Gottlieb's anti-enviro tome, *Trashing the Economy*, sits on Jeff Raleigh's bookshelf in the comfortably utilitarian San Francisco offices of Hill & Knowlton. "I talk to Ron Arnold about once a quarter, just to say hello, because of our involvement in mining issues," Raleigh says. "We work with miners, and of course the mining industry uses the Wise Use movement. Bob Reveles was head of public relations for Homestake [a mining company and one of Hill & Knowlton's clients], and now works for People for the West [an industry-funded Wise Use group established to defend the 1872 mining law]."

A big, bluff, friendly man, Raleigh has a number of corporate clients, and some interesting things to say about them. About Pacific Lumber, he comments, "Clearcutting is the most environmentally sensitive way to take down a tree." On Pacific Bell, which has been criticized for using British Columbian rainforest pulp in its phone books: "Old growth is whoever defines what old growth is." On US Ecology, a company that wants to open a nuclear waste dump in California's Ward Valley: "Can you explain to me why environmentalists oppose nuclear power? I just don't get it."

I ask him if Hill & Knowlton helped organize the Wise Use pro-logging rallies and counter-demonstrations I covered during the tense Redwood Summer of 1990, when environmentalist protesters and industry supporters faced off. Although his company represented Pacific Lumber and was part of the California Forestry Association, Raleigh tells me, it was the Association that orchestrated events. Yet, at the time, Hill & Knowlton was passing out photocopies of a supposed Earth First! flier calling for violence. It was later shown that the flier was a fake. An internal memo later released as part of a lawsuit revealed that some Pacific Lumber executives, at least, were aware at the time the flier was distributed to the media that it was very likely not from Earth First! at all. (Raleigh says he has no specific recollection of the incident.)

Like Dr. Frankenstein's monster, Astroturf can sometimes get out of control. During Redwood Summer, hundreds of riot police had to be called out to separate the two sides. A more recent example is the threats of violence being directed against federal land managers by "county movement" activists who want local control over federal lands. On at least two occasions, threats have escalated into armed confrontation.

Such incidents raise the question of whether resource industries should shoulder some of the moral responsibility for the violent extremism that has come to be associated with many Wise Use causes. For more than eight years, representatives of the timber, mining, cattle, and many other industries have shared Wise Use platforms, conferences, and strategies with strident anti-environmentalists, as well as John Birchers, Moonies, anti-Indian activists, county activists, and followers of Lyndon LaRouche. However limited their intentions, however sincerely they believe they are controlling the agenda, industries that promote Wise Use in effect lend credibility to extremism.

While corporations were working with the political hard right to create Wise Use, specialized "grassroots" lobbying contractors were sprouting up inside the Washington beltway. Among the better known is Jack Bonner & Associates, which uses phone banks, direct mail, and computer-assisted tracking of citizen "white hats" to generate letters, faxes, and phone calls to legislators on issues of concern—of concern, that is, to GM, Exxon, U.S. Tobacco, and other Bonner clients. Along with "grassroots," Jack Bonner also goes after "grasstops." According to the *National Journal*, B&A charges $350 to $500 for each letter or call generated from a community leader. Actual meetings between community leaders and legislators run Bonner's clients between $5,000 and $9,000.

In *Who Will Tell the People: The Betrayal of American Democracy*, William Greider writes that Bonner's biggest success to date was the mobilization of authentic grassroots groups, including the Georgia Baptist Convention, Easter Seal Society of South Dakota, and Delaware Paralyzed Veterans Association, on behalf of the auto industry's fight against tougher fuel efficiency standards. B&A did mass mailings to farmers, seniors, organizations of the handicapped, and others, without being clear about whom they represented. The mailings warned that if the standards passed, Detroit would be forced to stop producing vans, church buses, and farm trucks. B&A is said to have received between $500,000 and $1 million for its "organizing" effort.

Of course, Washington politicians understand that much of the anti-environmental "citizen input" they receive is greenwash. But for politicians about to vote against broadly popular environmental protections, it is easier to say they are responding to their constituents than to major contributors in the timber or chemical industries. "You target Senators inclined to go your way but who need some additional cover. They need to be able to say they've heard from people back home on this issue," is Bonner's explanation, as quoted in Greider's book.

Political greenwashing has focused on state and local as well as national issues. In 1994, the Western States Petroleum Association (WSPA) wanted to oppose a California plan to let utilities invest in infrastructure for servicing electric cars. Rather than work openly against the bill, WSPA's PR firm, Woodward & McDowell, organized "Californians Against Utility Company Abuse." They formed a coalition with a utility customers' group and sent hundreds of thousands of letters to taxpayers attacking the "profit-making ventures" of the utilities—without identifying WSPA as the source of their funding. (In the wake of the numerous campaigns that oil and auto companies have waged in the past few years against California's move toward electric cars, the federal Justice Department has opened an investigation into possible "anti-competitive conduct" against the electric car industry.)

In November 1995, Washington State residents voted overwhelmingly to reject Initiative 640, a ballot measure that would have banned the use of commercial gillnets in order, its backers claimed, to reduce overfishing and "save our sealife." The public turned against the

Spin city: a case study

In 1991, an organization called ICE was formed to "reposition global warming as a theory (not a fact)." Fifty-three pages of internal ICE documents, supplied by an anonymous source, shine a partial but revealing light on the making of a greenwashing campaign.

Run by the D.C.-based PR firm Bracy Williams & Co., ICE was financed by the coal mining and utility companies that make up the $400 million Western Fuels Association. The PR advantage of ICE as an acronym for a group opposing global warming legislation was agreed on at the start of the campaign. But it took extensive focus-group testing and polling to decide which of four "potential program names" ICE would stand for. The first step was a survey of 1,500 citizens, which showed that "technical (scientific) sources receive the highest overall credibility ratings, followed closely by (citizen) activist sources." Industry sources received "lower credibility ratings." Based on these findings, ICE's PR strategists decided to "favor choosing the title 'Information Council on the Environment' over 'Informed Citizens for the Environment,'" since the first name "is perceived as a technical source while [the second] carries both technical and activist connotations."

ICE's goal was to move people from advocating "extreme positions on global warming" (that is, legislation) to "less extreme positions" (that is, further study). Realizing that "members of the public feel more comfortable expressing opinions on others' motivations and tactics than they do expressing opinions on scientific issues," ICE decided to attack "the motivation and vested interests" of those reporting on the danger.

"'Some members of the media scare the public about global warming to increase their audience and their influence.' People who respond most favorably to such statements are older, less-educated males . . . who are not typically active information-seekers,"

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When no grassroots coalition is at hand to lobby against environmental legislation, many agencies will happily create one.

"green" initiative when they learned that its main supporters were hydroelectric, aluminum, and timber companies on the Columbia River. Its backers hoped 640 would cripple the state's salmon fishing industry, which, in alliance with local enviros, has become an outspoken opponent of dams, clearcutting, and other threats to upstream salmon habitat. Undeterred by their defeat on 640, the companies went on to found "Northwesterners for More Fish." This $2.6 million operation advocated continued barging of fish around dams, a technique that has failed to halt the salmon's spiral towards extinction in the region.

Another tactic some corporate image specialists recommend is forming partnerships with environmental groups. According to a book by E. Bruce Harrison, a pioneer of greenwashing, "It's smart on two levels: It avoids some legal problems, and it widens your options." In the 1993 book, *Going Green: How to Communicate Your Company's Environmental Commitment*, Harrison recommends that companies meet with citizens who criticize them, listen but reveal little information, and research their opponents, even to the point of hiring private detectives. (A number of public interest groups have had visits and requests for information from people they later had reason to believe were employed by Mongoven, Biscoe & Duchin, Burson-Marsteller, or other PR firms. Wackenhut, a security firm, has been investigated more than once for spying on environmentalists and government officials.)

One of the best-known corporate-environmental partnerships was the 1992 waste reduction program McDonald's worked out with the Environmental Defense Fund (EDF). "In the late 1980s, the company slipped into its worst sales slump ever—and the anti-McDonald's drive of [antitoxics] green activists was at least partly blamed," Harrison writes. But the plan EDF designed to reduce the company's packaging waste stream "established a landmark precedent that may alter the way environmental protection is achieved, moving away from regulation and command-and-control toward partnering."

Many environmentalists defend the concrete benefits that can come from helping large polluting corporations to reduce the environmental damage they do. But some observers are not convinced that such partnerships benefit both sides equally. "The ads these corporations run linking themselves with these organizations can make them look greener than they are. The public perception becomes, 'Oh, they must be responsible,'" says Mark Dowie, author of *Losing Ground: American Environmentalism at the Close of the Twentieth Century*. "If these deals are supposed to counterbalance [rather than correct] other mistakes and abuses, then they're a form of greenwashing."

In some cases, the partnerships take the form of contributions toward an environmental group or one of its projects. "Companies need the environmental movement, and environmental groups take a lot of money from companies," says Hal Dash. "What they want is access, cooperation, and why not? It's like if a company moves into a town and wants to pay for a school, [to]

their pollsters reported. "They are good targets for radio advertisements. . . . Another possible target segment is younger, lower-income women," the papers continue. "They are likely to be 'green' consumers, to believe the earth is warming, and to think the problem is serious. However, they are also likely to soften their support for federal legislation after hearing new information on global warming. These women are good targets for magazine advertisements."

The illustrated magazine ads for ICE included some entitled "Who told you the earth was warming . . . Chicken Little?"; "Some say the earth is warming. Some also said the earth was flat"; and "If the earth is getting warmer, why is Minneapolis getting colder?" (The Minneapolis line would seem to contradict climate data that showed 1990 to be Minneapolis's fourth warmest year and 1991 also above average. "It certainly did not show cooling," said a state climatologist quoted in the internal documents.)

ICE invested $525,000 to "test-market" their product in three cities. But the group, only one among hundreds of greenwash experiments, lasted just six months. "Had we received better input, we would have looked at a national campaign," says Ivan Brandon, the Bracy Williams executive who oversaw the project. "The issue was too complicated and the ads were a little too simple, more of a sledgehammer than a subtle effect."

Since dumping ICE, the Western Fuels Association has gone on to fund *World Climate Report*, a biweekly science-oriented publication that attacks mainstream theories on global warming. Western Fuels also funded a $250,000 video, "The Greening of Planet Earth," which was distributed by the Global Climate Coalition to over 1,000 U.S. journalists, the White House, and various oil states in the Middle East. The video argues that because industrial carbon dioxide buildup in the atmosphere acts as a kind of airborne nutrient, global warming could be the solution to world hunger. •

buy the support of the community, both sides have a lot to gain."

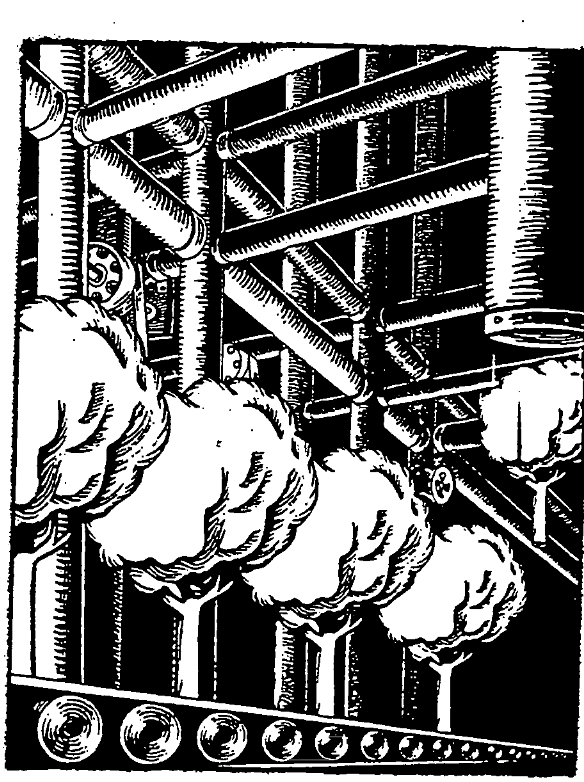
Following McDonald's lead, Anheuser-Busch and GM have run a series of ads touting their contributions to the Nature Conservancy; Canon is advertising its $1.2 million contribution to the National Park Foundation; and Exxon has contributed $5 million to captive zoo breeding programs and other efforts to "help save endangered tigers."

Once again, however, many companies that advertise their contributions to environmental groups and their dedication to environmental causes also fund and support Wise Use groups. Honda and other manufacturers of Sports Utility Vehicles (SUVs), for instance, have joined forces in a project called "Tread Lightly," which is advertised as an environmental conservation program. SUVs are now the fastest-growing sector of the auto industry (a phenomenon not unrelated to the fact that industry lobbyists have succeeded in keeping these vehicles exempt from fuel-efficiency standards that apply to other cars). Tread Lightly sponsors rallies and warns off-road vehicle users that millions of acres of public land are being closed to their 4x4s because of "potential and real damage" from their failure to "Drive responsibly." Yet Honda has also funded the Blue Ribbon Coalition, a Wise Use group fighting to open up more public lands to off-road vehicles, logging, and mining.

Burson-Marsteller's effort to defeat the Btu tax on behalf of the American Energy Alliance was credited [sic] by former Treasury Secretary Lloyd Bentsen.

—O'Dwyer's PR Services Report

E. Bruce Harrison, the PR veteran who wrote *Going Green*, made his reputation coordinating industry's attacks on Rachel Carson after the publication of *Silent Spring* in 1962. Harrison and colleagues from Monsanto, Dow, and other chemical companies created the template for today's greenwashing campaigns. They established front groups and a media outreach program. They conducted hostile mailings and public forums for "third-party experts," including doctors and scientists willing to attack Carson's personal and professional credibility while defending the use of DDT and other toxic compounds.



Joel Rodgers

Attempts were made to intimidate Carson's publisher into not printing the book. When that failed, John Stauber of *PR Watch* has written, the National Agricultural Chemical Association doubled its PR budget and began distributing its own attack reviews. Monsanto published 5,000 copies of a parody called *The Desolate Year*, in which a plague of insects (unchecked by pesticides) devastates the United States. The campaign had some initial media success when *The New York Times* questioned Carson's credibility.

As with *Silent Spring*, some issues are so big that industry is willing to pull out all the stops. Today, the chemical industry is conducting a major campaign against *Our Stolen Future*, a book linking synthetic chemicals to reproductive problems in humans and wildlife.

Months before its publication, a copy of the book's galleys came into the possession of the American Council on Science and Health (ACSH), a food, drug, and chemical industry-funded group that portrays itself as an objective source for scientific information on food, drugs, and agrochemicals. With its unauthorized copy of the manuscript, ACSH was able to prepare a report attacking *Stolen Future* before it hit the bookstores. Simultaneously, the Competitive Enterprise Institute (CEI), a conservative Washington think tank, published two reports attacking "the hypothetical risks to human health" reported on in the book. Consumer Alert, a "free-market" organization, put out a press release on the same day labeling the book "a scaremongering tract."

The following day, the Advancement of Sound Science Coalition (TASSC) called a press conference with ten scientists, five of them from the board of ACSH, who attacked the book as "science fiction." (TASSC is a recently created group run out of the offices of APCO Associates, a PR firm that specializes in environmental lobbying. Its supporters include executives of GM, Chevron, Dow, W.R. Grace, and others.) This apparently well-coordinated campaign may be having some initial success, as the first *New York Times* review questioned the credibility of the authors' work.

Another issue that is consistently a major greenwashing target is global warming. At an October 1995 panel on greenwashing at the Society of Environmental Journalists' annual conference, writer Bill McKibben pointed to the increasing scientific certainty on global warming. Asking E. Bruce Harrison, who was on the panel, to assume he was representing the coal industry, McKibben said, "What's a good fallback position for them, once you're past the point of being able to say climate change is not a problem?"

"The climate change debate has to do with science, economics, terribly complicated," Harrison responded, going into automatic spin control. "What we are advising our clients .... is to keep the debate open, keep it honest, draw out scientific experts, talk about the economics, talk about the impacts, and let's see where this all comes out."

Actually, Harrison does indeed represent the coal industry, through one of his clients, the Global Climate Coalition (GCC). Founded in 1989 by forty-six energy corporations and associations, GCC is dedicated to countering the "myth of global warming." And just as Harrison advises, so far the efforts of GCC and the many other PR firms working on climate change have served to obfuscate the issues enough to help kill national and international efforts for strong global warming policies.

For instance, GCC and others successfully lobbied to weaken both the 1992 UN Earth Summit treaty on climate change and a House energy bill that would have required industry cuts in carbon dioxide emissions. Another effort helped shoot down the Clinton Administration's 1993 proposal for a deficit-cutting energy tax (to be levied per BTU, or British Thermal Unit, of energy consumed). The BTU tax was defeated in part by computer-driven "grassroots" letter and phone-in campaigns run by the National Association of Manufacturers and by Burson-Marsteller, the world's largest public relations firm.

While environmental groups large and small debate the relative merits of working with or against corporations, and try to imagine the right balance of regulation, enforcement, and market incentives that could ensure environmental quality of life and opportunity in the future, many leaders of industry and their spin doctors insist we have already accomplished most of what needs to be done.

"The environmental movement helped us clean up and think about how we use resources," says Hill & Knowlton's Jeff Raleigh. "I make the analogy to the labor movement in the twenties and thirties. We needed unions back then. They achieved most of their objectives, and then became self-perpetuating organizations and now fight for nonsensical things. The environmental movement has done the same thing."

"Regulations have done their job and ought to be let out to pasture—or put out if they won't go peaceably."

E. Bruce Harrison concurs, writing, "To many, it's clear that ... regulation[s] have done their job and ought to be let out to pasture—or put out if they won't go peaceably."

Too many U.S. companies evidently agree. Those that choose to greenwash their images rather than green their basic operations ignore the advice proffered recently in an editorial in *O'Dwyer's PR Services Report*: "It has been shown that corporations with good environmental track records enjoy healthier bottom lines than those viewed as polluters." Moreover, companies that do greenwashing without making real environmental improvements may be making it still more difficult for themselves in the future—because greenwashing can be a sword that cuts both ways. By disseminating persuasive images and sentiments about the need for a healthy environment, green PR may help to strengthen environmental values among the public. The 1971 Keep America Beautiful ads, for instance, have proven unforgettable to many in the generation that has since put environmental issues on the national political agenda.

But by investing in advertising and lobbying designed to create the illusion that environmentally destructive practices are environmentally beneficial, greenwashing companies are also disseminating apathy. They are undermining the core of informed citizenry that is the cornerstone of democratic decision-making. And when they move beyond that to the creation of Astroturf groups, protest demonstrations, and social movements for hire, they cross a critical threshold of respect for the basic democratic institutions on which our society is supposed to be based. Even once they are exposed to the light of day, campaigns like these are poisonous to the public debate. They engender profound public cynicism about the political process; they reduce citizens' willingness to participate in a political system that is apparently hopelessly compromised by corporate special interests.

And more than anything, greenwashing disseminates ignorance. The Public Media Center's Herb Chao Gunther recalls, "I'll never forget my mother calling me on Earth Day because she saw a big picture of the earth run by the Chemical Manufacturers Association with the line, 'We're in this together.' She asked me, 'Why are you nasty to those people? They like it too.'

"When my mother calls and wonders why I bash CMA because they do nice ads, I know greenwashing is working." •

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