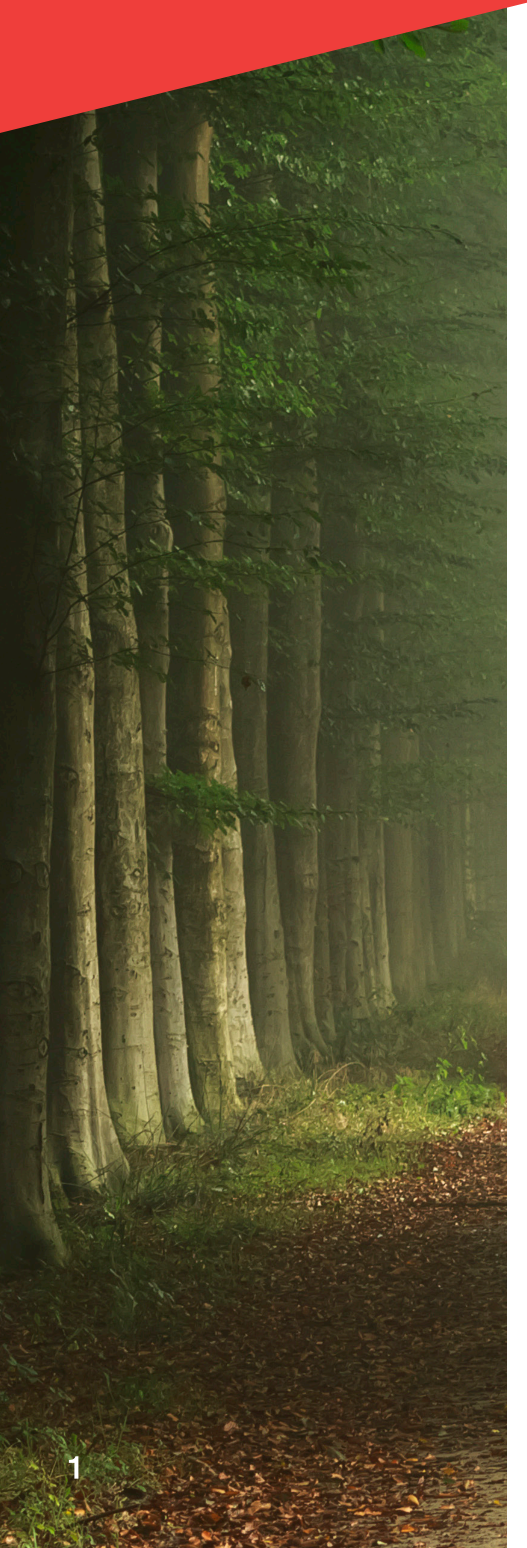
INDUSTRIAL ECOLOGY

Industrial Ecology and Engineering

"Technology and engineering will continue to play a role in reducing many environmental impacts of production and consumption"



Industrial ecology is the study of industrial systems (materials and energy flows) from the perspective of natural ecosystems. Natural ecosystems have evolved so that any available source of useful material or energy is used by some organism in the system. Animals and plants live on each other and on each other's waste matter. These systems do, of course, leave some waste materials, or fossil fuels would not exist. But on the whole, the system regulates itself and consumes what it produces.

As the green game is played out in corporate boardrooms, the shop floor, in the home, and in the community, it is clear that technology and engineering will continue to play a critical role in reducing many environmental impacts of production and consumption. Incorporated in consumption are the following points:

- planning of purchases
- the moment of purchase
- use (efficiency of consumption)
- durability
- repairs
- purchase of supplements
- disposal

Neither technology nor technological know-how are in short supply. The primary opportunities come from the continued, sustained application of existing technology to identified problems. The primary need is to create the incentives and techniques for companies to use technology and knowledge to improve environmental quality.

Humans and Material Use

"When products wear out or are replaced by newer models, they are usually thrown away"

Human economic activity has been characterized by an open and linear system of materials flows, where materials are taken in, transformed, used, and thrown out. Tools, clothing, and other products have been forged and fashioned from natural plant, animal, and mineral materials. Worn-out goods and materials left over from the production process have been dumped in backyards and landfills. Even archaeologists find discarded reminders of the past: scrap stone, flints, and potsherds - in the rubbish dumps of the Neolithic period. People moved to new habitats when the old locations became unsuitable because of accumulated wastes.

Today, there are more of us and fewer new places to which to move. We face serious pollution in many locations and have poisoned some areas into uninhabitability. As human populations grow, discarding waste material is becoming increasingly problematic.

One way for industry to be more self-sufficient and less wasteful is to improve the efficiency of materials use. It seems worthwhile to examine both production processes and product designs to see if the use of materials (and energy) can be improved. Currently, when products wear out or are replaced by newer models, they are usually thrown away. They may be used as landfill or incinerated or they may litter the landscape.

Regulatory pressures and shifting public opinion have spurred the industrial and engineering community to initiate efforts aimed at closing the materials loops more effectively and improving energy-use efficiencies. Automobile manufacturers such as BMW and Volkswagen have designed cars for easy disassembly and recycling. Companies such as Hewlett-Packard, Canon, and Xerox have begun to take back their own used components, such as toner cartridges, and to manufacture new ones using refurbished components and recycled materials from the old ones. These companies are designing new products with reuse, remanufacture, and recycling in mind. The industrial ecology perspective is beginning to influence designers of manufacturing processes. Designers of products are beginning to view their creations as transient embodiments of matter and energy with added value that can be recaptured and recreated within a continuing flow of materials extending beyond the point of sale. Products and the materials they contain are being designed so that they can be reused at the end of their lives.

The whole industrial process can be thought of as a closed cycle in which the manufacturer has overall custody for the material used. In this system, the manufacturer must consider the entire material and energy stream, from materials input and manufacturing through the life of the product and its eventual reuse or disposal. This concept has begun to be embodied in law (as in Germany), making manufacturers responsible for their products through to final disposition.

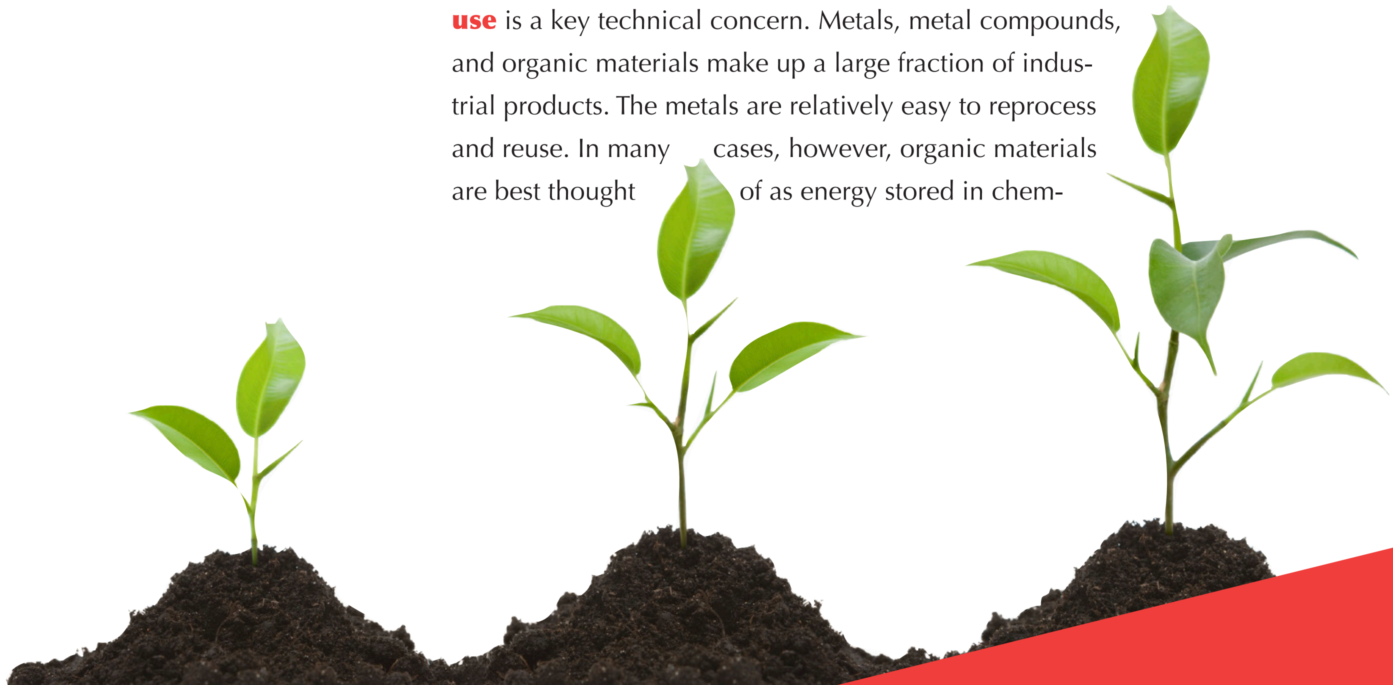
Recycled printer cartridges can be obtained for free, reducing production costs.

Reusability of Materials

"Why is there so much waste, especially of iron, steel, and precious metals, in the metal industry, which has such a long tradition of recycling?"

Automobiles, their components, and other metal products, especially those made of iron and steel, have a long history of being recycled without regulatory prodding. For other metal products and materials, progress has come later and been much slower. Why is there so much waste, especially of iron, steel, and precious metals, in the metal industry, which has such a long tradition of recycling? The barriers to industrial recycling of metals can be classified into six interrelated areas: technical hurdles, economic barriers, information barriers, organizational obstacles, regulatory issues, and legal concerns. When recycling is technically feasible, it may be economically unsound. When it is technically and economically satisfactory, a lack of information may block its adoption. Even when the requisite information is at hand, organizational problems can still stymie implementation. Finally, when all else is satisfactory, a recycling scheme can founder on the rocks of regulatory or other legal barriers.

The suitability of a material for an intended reuse is a key technical concern. Metals, metal compounds, and organic materials make up a large fraction of industrial products. The metals are relatively easy to reprocess and reuse. In many cases, however, organic materials are best thought of as energy stored in chemical bonds rather than as reusable materials. The choice between recycling the material and burning it as fuel or otherwise extracting its chemical energy might be made on the basis of comparative market values.



Waste and product materials sometimes contain unwanted "tramp" elements. These contaminants can ruin the reuse potential of the materials or make handling difficult or dangerous, and purification is often problematic. As products are redesigned for newer more cyclical material use, some of the material problems may be eliminated through smarter design. However, it will not always be possible to "design out" problematic materials. For example, zinc is often used to coat steel to prevent corrosion. It can interfere with the desirable properties of new steel forged from melted recycled scrap steel. Steel mills therefore limit the permissible content of zinc in the scrap they buy or they pay less for scrap with more than a threshold concentration of zinc.

The manufacturing process tends to mix materials that are further mixed in the process of waste disposal. In remanufacturing, one generally wants to separate things into their original components and materials. There are costs involved in collecting, sorting, and transporting used-up products, scrap, and waste. Such separation requires information, effort, and energy, which must all be paid for. These costs must be compared with the costs of new materials.

Organic material can be burned and be used as an alternate source of energy.

Cost of Recycling vs Using New

"Companies should take account of indirect costs such as the effect of wastes on the environment"

Indirect costs might not always be easily noticable.

Even when the operating costs of recycling are attractive, there may be capital costs that pose barriers. Heavy capital investment in existing systems may prevent a company from securing an easy source of new investment to start over. This obstacle may introduce a time lag, postponing the decision to recycle until it is suitable to make a capital investment, such as when the machinery requires change for some other reason. Some companies that face competitive forces of ever-shorter product lifespans, particularly those in the electronics industry, have introduced "design for the environment" techniques as a major impetus for reengineering their products and processes.

The cost of eliminating or reusing certain materials must be balanced against the cost of disposal. Disposal costs bring up the question of how companies should take account of indirect costs such as the effect of wastes on the environment. These issues have generally been handled by regulatory control of emissions but could equally be dealt with by including the costs of environmental damage in a firm's bookkeeping. The bookkeeping approach would provide an incentive to minimize such costs, and it might force a truer comparison of the costs of alternative schemes. However, it has proved very difficult to find suitable, agreed-upon measures for such costs.

The requisite information about costs is not usually available to everyone in the firm who might be able to use it to good advantage. Standard management and other accounting systems often do not track costs in a way that is useful to designers. Design engineers may not know of the real costs to the company of the materials they choose. Designers generally have no idea what waste problems will be posed by manufacturing with different materials.

The internal organization of a firm can be difficult to change. Changing the whole concept of a product or adding new criteria for environmental compatibility to the design process may not fit the ideas on which the firm operates or its internal incentive system. The business structure may make perception and solution of problems that cross organization lines very difficult.

Organizations can delay implementation because of overheads such as communication problems and conflicting internal interests

Laws and Regulations Hindering Recycling

Even the disposal of trivial things such as a cleaning cloth can be problematic because of the laws that surround dealing with hazardous materials.

The U.S. regulatory system for industrial wastes has been designed around disposal, and the rules treat recycling and reuse as forms of disposal. The designation of a material as waste, as distinguished from scrap or hazardous material, can be crucial.

There are many inconsistencies in the Resource Conservation and Recovery Act. For example, the waste classification of a solvent-laden rag used to clean machinery depends on how it was used. If the solvent is poured first on the machinery and then wiped with a clean rag, the rag is a hazardous waste. However, if the solvent is poured first on the rag and then the rag is used to wipe the machinery clean, the rag is not considered a hazardous waste.

Recycling an industrial waste material is likely to require the recycler to become a legal disposer of that material under the regulations. Obtaining a permit has significant time, financial, and bureaucratic costs attached, which are a nontrivial barrier to reuse of industrial waste materials.

Under current legal practice, liability considerations for a hazardous material often favor its disposal over its sale or transfer for reuse. Liability is often targeted at the original selzler of any material used in a product implicated in a damage suit, even if the material has been reused and remanufactured by several parties en route to that ultimate product. The trail of potential liability can be so long and so unpredictable as to be thoroughly unpalatable. A supplier of a generally harmless, minor component material in a product might be assessed high liability damages because the product caused harm, even if that supplier was not a party to the product design and the material was not at fault. This practice has serious implications for commerce generally, and it appears to explain why firms often choose to dispose of scrap and waste rather than seek users for them.

The following example from a glassmaker is illustrative. Certain nonhazardous wastes from glassmaking would make good additions to concrete, improving its properties. Nevertheless the glassmaker disposes of these wastes in a landfill, because the legal counsel worries about potential liabilities if the concrete ends up in an apartment house or a highway. Such liability risks are hard to predict and quite unacceptable in comparison with the more predictable liabilities related to landfill disposal.

Glassmakers produce wastes that can be recycled and made into concrete, but they choose to dispose of these wastes instead because of potential liabilities they may have.

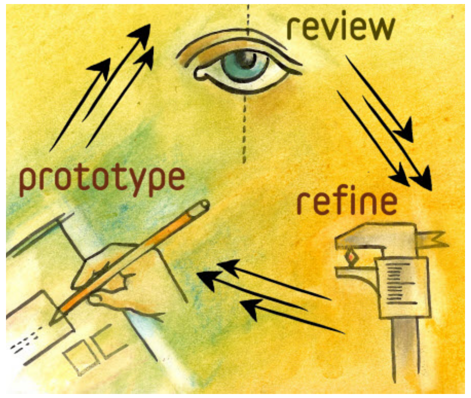
Blurring The Lines Of What A Product Is

> "Is the product simply the hardware being sold, or is it rather the services that the product can provide?"

Some firms have already begun to design their products and processes with a view to closing material loops as much as possible. However, if a product is the transient embodiment of materials (a plastic water bottle for example), then closing the loop on those value-added materials raises an important question for the firm: Is the product simply the hardware being sold, or is it rather the services that the product can provide? There was a time when it was common practice to lease rather than sell many products outright. In a lease-based system, the manufacturer controls and therefore is responsible for the end of the product's life and is always prepared to take it back for recycling, reuse, or refurbishment.

Designing a product as a temporary provider of a service, to be used later in the creation of another product, is a novel idea in modern manufacturing and raises a new set of issues. A product is generally sold with the assumption that a consumer or sequence of consumers will use it until it cannot be used anymore. If the manufacturer thinks about taking it back for remanufacturing, the length of time the product spends in the customer's hands becomes an adjustable design variable. The maker may not want the product to wear out by being used for an indefinite time and so might choose to reclaim it at an optimum time for remanufacture. Thus, the notion of "what is a product?" changes. Similarly, its life cycle may also change. The manufacturer may increasingly want to choose materials and designs that take into account the product's eventual "de-manufacture" and reuse.

Industrial ecology views industry's impact on the environment in terms of a comprehensive system that uses and disposes of materials. We can learn to close the materials loop more efficiently by thinking on a larger scale about the flow back into industry of materials that would otherwise be discarded into the environment. There are numerous means of protecting the environment from industrial wastes. We can, for example, forgo the benefits of a potentially harmful material or we can seek to replace it with a more benign substitute. We can redesign products with the intention of reusing materials and components. It is not yet clear what mix of remedies will most economically minimize the impact of industrial materials on the environment. The various possibilities hold out great promise, but there are complex problems and barriers to be overcome as we develop and implement a new, ecologically sound model for the management of materials in industry.



Creating systems that efficiently use materials can require a redesign of existing production methods and processes

Executive Summary

Industrial Ecology aims to reduce the negative environmental impact of industrial systems, of which technology and engineering play a big part of. Efforts are being made to increase corporate participation through the development of techniques and the creation of incentives. A key achievement in designing for the environment is being able to "close the loop" on the flow of consumed materials, but a wide range of factors, ranging from the nature of the materials used, to organizational concerns, to laws and regulations prevent this from happening.

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