"Summary of article by Robert U. Ayres: Industrial Metabolism" in
Frontier Issues in Economic Thought, Volume 1: A Survey of Ecological Economics. Island Press: Washington DC, 1995. pp. 225-227

Social Science Library: Frontier Thinking in Sustainable Development and Human Well-being

"Summary of article by Robert U. Ayres: Industrial Metabolism"

The biosphere and the industrial economy are both systems that transform materials. While the biosphere is a nearly perfect system for recycling materials, industrial systems need to be modified to increase their efficiency in production and recycling. Like the early stages of biological evolution, modern industrial processes are discrete, irreversible linear sequences that are energized by fuels which are not regenerated within the system. Modern biological processes, on the other hand, are regenerative. Industrial metabolism - i.e., the energy- and value-yielding processes of economic development - can gain from the lessons learned from the biosphere. This article discusses the environmental significance of industrial processes, as well as issues related to waste emission.

Each year more than ten tons of "active" mass is extracted per person in the US. In principle, 75% of this is nonrenewable and 25% renewable. However, only about 6% of this extracted mass becomes embodied in durable goods, while the remaining 94% is ultimately converted into waste material that includes highly toxic, carcinogenic and mutagenic materials. Most of the extracted material is transformed into waste rather quickly, and is degraded, dissipated and lost in the course of a single normal use. The environmental impacts of this unused waste are harmful and can be linked to the greenhouse effect, the ozone hole, acid rain, smog, etc. The total production of waste exceeds the tonnage of crops, timber, fuels, and minerals recorded by economic statistics. Also a number of services provided by the environment are derived from common property resources like air, the oceans, the biosphere and the sun. Many of these factors are underpriced in the marketplace, resulting in their overuse. While the industrial system may be in equilibrium in terms of market relationships, this is not so in thermodynamic terms. Waste materials may disappear from the market, but not from the physical world. "The economic system is stable somewhat in the way a bicycle and its rider are stable: if forward motion stops, the system will collapse. Forward motion in the economic system is technological progress."(32)

Industrial metabolism can, however, play a role in the recycling of materials and waste products. In fact, there are many examples in the chemical industry in which the existence of waste and by-products has led to important innovations. For example, the Leblanc process used in the production of sodium bicarbonate now makes use of sodium sulfate, which was previously an unwanted by-product of the production of ammonium chloride. Also, a systematic search by German chemists to utilize by-products resulted in the use of coal-tar, leading to the development of the modern organic chemical industry. Until recently, natural gas, a by-product of petroleum production, was "flared," but it is now used in the production of synthetic rubber.

Technological innovation that will result in economic benefits should be explored as a means to reduce the amount of waste generated. We should seek innovations that can:

1) **shorten and/or reduce the process chains in a production process:** This will result in overall gains in efficiency and reductions in costs. The savings in materials and energy inputs and/or capital requirements will in most cases justify a new process that saves one link in the chain between raw materials and finished materials or final goods. The use of first-tier intermediaries or primary feedstocks can enhance the overall efficiency of production systems. Since complex molecules can be developed from biological organisms with few intermediates, biotechnology offers the prospect of long-term productivity gains at lower costs.

2) **make better use of by-products and wastes generated in the production process:** When a process can be economically justified based on the market for its primary product alone, then selling by-products as well can be highly profitable. In addition, firms are now sometimes forced to clean up their wastes retroactively, but increasing the recycling of by-products and wastes could prevent such problems in the future.

Economic evolution may be directed by a variety of either long-term or short-term goals. It may be, however, that there is a long-run evolutionary imperative that favors dematerialization of the economy. This could be accomplished through the development of industrial metabolism technologies that reduce the extraction of virgin materials, reduce wastes and dissipative uses of toxic materials, and increase multiple use and recycling of materials. Short-term economic incentives, on the other hand, are often inconsistent with this hypothesized long-term imperative. For example, market forces promote product differentiation and specialization, both of which increase the costs of repairs and recycling. Repair, reuse and recycling occur in poor countries to such an extent that wastes or "junk" are practically nonexistent, while in advanced countries goods that are difficult or impossible to repair accumulate as wastes. In addition, as products become more reliable and their warranties lengthen, they are increasingly designed in such a manner that disassembly is discouraged and often can only be done by the manufacturer. Incentive structures necessary to encourage the long-term goals proposed here must therefore ultimately arise out of social and political responses to perceived environmental problems.

Materials-balance principles can be used to analyze economic and technical data together, yielding more reliable estimates of waste residual outputs than those found by direct measurement. Technological evolution that is oriented toward long-term goals can also be used as a basis for forecasting the future of industrial processes. For example, it seems likely that the industrial system of the future will use hydrogen as a bulk energy carrier, recycle wastes with high efficiency, and eliminate the release of biologically active toxins into the environment.