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Is the "dematerialization" of human societies under way? Is there, in other words, a tendency toward a decrease in the quantity of materials required to serve economic functions? The concept of dematerialization is analogous to energy conservation; both refer to achieving the same output with reduced resource inputs. "Dematerialization matters enormously for the human environment. Lower materials intensity of the economy could reduce the amount of garbage produced, limit human exposures to hazardous materials, and conserve landscapes... A general trajectory of dematerialization would certainly favor sustaining the human economy over the long term." [172]

This article review the evidence for dematerialization in the U.S. in the late twentieth century, finding a mixed picture of successes and failures. It examines four economic stages: resource extraction and primary materials; industrial production; consumer behavior; and waste generation.

Primary Materials

In 1990 the U.S. consumed 1.9 billion (metric) tons of hydrocarbons, almost entirely for fuel, and 2.5 billion tons of non-energy materials (excluding air and water) - almost 8 tons per capita of fuel and about 10 tons per capita of other materials. Construction materials, such as the huge quantities of crushed stone used for road building and other purposes, accounted for 70% of the non-energy materials; while there may be local environmental impacts associated with excavation, the available resources of stone are immense. Greater problems are associated with the use of smaller quantities of other, scarcer materials.

There is no upward or downward trend in the total weight of materials consumed in the U.S. since 1970. However, there has been a reduction of about one-third in material use per constant dollar of GDP, much of it associated with the oil shocks of 1973 and 1979.

The intensity of use has changed dramatically for individual materials. Timber, the most heavily used material of the early twentieth century, has declined steadily in intensity (measured in kilograms per constant dollar of GDP), as have copper, steel, and lead. In contrast, plastics and aluminum have shot upward in intensity, as have phosphorus and potash, key ingredients in fertilizers. Despite advances in electronic communication, the intensity of paper use has showed little change since 1930. Today more than 25 percent of timber cut in the U.S. is used to produce pulp and paper.

Small quantities of exotic, newly exploited materials (such as gallium, platinum, vanadium, and beryllium) have come into use in electronics, in the production of steel alloys, and in other “designer materials.” Mining and processing of these materials is often environmentally damaging, and the small, widely distributed quantities of rare elements are sometimes difficult to recover and recycle.

The explosive growth of plastics production was indirectly made possible by the rise of the automobile; when oil is refined to produce gasoline, refinery by-products are available for use as plastic feedstocks. However, moves toward decarbonization of the energy system will reduce oil and gas use, and encourage plastics recycling, over the next few decades.

Industry and Industrial Products

Several individual products exhibit dematerialization. Beverage containers have become lighter as steel cans and glass bottles have been replaced by aluminum cans and plastic bottles. The aluminum can itself has gotten lighter over time.

Cars were becoming lighter on average, prior to the recent growth in sales of light trucks and sport vehicles. Cars have also become more materially complex, with increasing use of plastics, composites, and specialty steels and decreasing use of carbon steel. One kilogram of the new materials replaces about three of carbon steel, but the complex mixture of materials causes difficulty in disassembly and reuse of scrapped vehicles. New high-performance materials, some of which show up in cars and other products, are constantly being developed in the aerospace industry, where the payoff for weight reduction is immense.

Dematerialization in industry is based both on downsizing or “light-weighting” of products, and on reuse of materials. Secondary materials recovery depends on the ease of isolation of the used materials, and on consumer demand for the materials. Some hazardous wastes such as cadmium and arsenic are very difficult to isolate, and therefore are rarely recovered. In contrast, lead, now used mainly for automobile batteries, is readily recovered, and secondary lead supplies more than 70% of demand. Steel, other common metals, and wastepaper are also easily recovered, and have secondary markets supplying a significant fraction of demand.

Dematerialization and Consumers

One study suggests that the size of new houses in the U.S. has grown steadily since World War II, while the average residential plot of land has actually shrunk. “Our hankering for a domicile in idyllic settings was what drove us to suburbia. Contrary to conventional belief, once we get there, we do not seem to care about how small the plot area is. Notwithstanding professed tastes for open space, we seem to build, enclose, and accrete steadily.” [187] Today’s enlarged homes house fewer people; the average number of residents per housing unit has declined from five in 1890 to fewer than three today. Thus floor area per person has almost doubled since 1945.

Other data corroborates the growing material intensity of consumption. The average weight of household goods transferred in intercity moves increased by 20% from 1977 to 1991. The number of pieces of mail per capita has more than tripled since 1940. The amount of food packaging has grown rapidly. Previously saturated markets have begun new waves of expansion, as with the sales of telephones. Each new phone is smaller and lighter, but there are many more of them; it is uncertain whether the total mass of the telecommunications system, including cables and equipment, has changed much since the early twentieth century.

Wastes

Data on wastes are incomplete and inconsistent. A comprehensive review of wastes in the U.S. in 1985 found that industrial wastes dominate the picture, but 90% of industrial wastes can be water, making comparisons with other wastes potentially misleading. Total waste in 1985 was 10 billion tons, but a large and unknown fraction of this was water.

Sewage sludge almost doubled between 1972 and 1992, due to population growth and increased treatment of waste. Ash, now produced largely by coal-burning power plants, has slumped along with the use of coal; if past statistics included estimates of coal and wood ash, the growth trend in waste would be flattened. Long-term figures are not available for hazardous wastes; in this category the quantities that are environmentally harmful are often minute. Municipal solid waste has been growing slightly in per capita terms, but decreasing when measured per constant dollar of GDP. U.S. levels of municipal waste generation per capita remain far above those of other leading industrial countries.

Conclusions

Is there an overall trend toward dematerialization? With regard to primary materials, there is some evidence of reduction in the weight of input per constant dollar of output. This change has been driven by the substitution of new, scientifically selected and designed materials for old, familiar ones. In industry, there are encouraging examples of more efficient materials use in particular products, as firms seek to economize on material and non-material inputs alike. However, the taste for complexity and high performance may intensify other problems and lead to growing use of exotic new materials.

The trends are least encouraging in consumer behavior, where there is no significant evidence of net dematerialization or saturation of material wants. In terms of wastes, spotty data make it difficult to assess trends, but international comparisons suggest that substantial further reductions can take place.

A logical next step is to develop a detailed scenario for a dematerialized economy and to explore the changes in technology and behavior needed to achieve it. The decoupling of material use from economic growth, like the decoupling of energy from economic growth, can make a substantial contribution to the creation of a sustainable future.