RECYCLING OR REUSE OF MATERIALS

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Summary

Recycling or reuse is a longstanding activity of mankind. Arguments in favor thereof are in part economic. They also may refer to resource conservation, energy conservation and limitation of pollution, though one should also be aware of possible negative environmental side-effects of recycling. In current practice resources used by economies are largely converted into wastes. Recycling of materials accounts for a limited fraction of resource inputs. For this purpose a wide variety of technologies is employed. Near term improvement is possible by making the socioeconomic environment more conducive to reuse and by design for recycling of products and processes. Choosing resources in relation to the retrievability of products, resource cascading, and fitting non-product outputs of the economy to useful inputs, are important for a steady state economy.

1. Introduction

Recycling and reuse are concepts that have a variety of meanings. Here these concepts are used as equivalents in the context of an economy. Recycling refers to all wastes or non-product outputs ("secondary resources") that emerge in the economy. Though the term is traditionally strongly associated with handling solid wastes, liquid non-product outputs, such as wastewater and gaseous wastes are to be included.

To some extent, reuse of liquid and gaseous wastes is currently practised. In many countries organocarbon compounds in aqueous wastes are partly fed back into the economy in the form of methane, following anaerobic digestion. In Japan, one may find recycling of purified domestic wastewater for low-grade domestic applications. Similarly in a number of industrialized countries gaseous sulfuroxides are taken from flue gases of power plants and converted into gypsum, which in turn is applied in building products such as plasterboard. Carbon dioxide from flue gases is occasionally recycled to a limited extent (10–15% of input) by feeding flue gas into greenhouses where plants are grown.

Two variants of recycling are distinguished: closed loop and open loop recycling. In the case of closed loop recycling, a material or product that is disposed of, or has reached the waste stage, is reintroduced in the economy in such a way that its quality is maintained. Reuse of leased copiers is an example of closed loop recycling, as is circulating new ferrous scrap in steel production.

Quality refers here to the potential to meet demands of (further) use. Because a steel drum in a copier can perform more demanding tasks than new ferrous scrap, the former does have higher quality than the latter. Quality in part comes from the ingenuity with which a product or material is designed and made. Human ingenuity is largely the basis for the relatively high quality of a drum in a copier, if compared with scrap. Similarly well-designed cardboard insert for packaging of apparatus may have the same function as a much larger amount of foamed polystyrene chips or wood fibers. Physical and chemical characteristics also contribute to quality. As low entropy and high exergy are associated with the ability to perform demanding tasks, low entropy and high exergy may have a positive impact on quality.

In case of open loop reuse, a waste also returns to the economy but in a function that is of a different quality. An example thereof is waste paper that is converted into (card)board. The latter application of cellulose fibers may be argued to be of lower quality than paper. Similarly metal parts of a discarded motorcar that are not used in the repair of other cars but as scrap for melting purposes exemplify open loop recycling. It should be noted though that reuse may also lead to applications that have higher quality. So parts of machinery that are below specification may be upgraded by remanufacturing. In such cases additional expenditure of material and/or energy is necessary for quality improvement.

Recycling or reuse of products and resources, components thereof and materials is a longstanding activity of mankind. Bone “wastes” of animals hunted for food by our ancestors, were sometimes used for tool production. Similarly there is a long tradition of food related wastes being reused in agriculture to maintain fertility of soils. Graves of Egyptian pharaohs were robbed to recycle valuables. The medieval church of Santa Maria in Cosmedin in Rome, that features in the film *Roman Holiday*, has pillars that were taken from imperial Roman buildings. There is also a considerable history of remelting metals and glass cullet and of mending textiles aimed at reuse.

In the past, scarcity of resources has been a major driving force behind recycling and reuse. The importance thereof strikingly re-emerges in space travel, where water generated by fuel cells is reused and brown water is recycled after treatment.

However on Earth, and especially in industrialized countries, resource availability has often not been regarded as a major constraint. If compared with income, costs of many virgin resources have declined. This applies to both materials and energy resources and has led to the observation that modern industrial society uses energy to turn resources into junk. Moreover, labor, that has traditionally been important in the sorting and repair activities preceding reuse, has become relatively expensive in industrial countries. Also materials and products have developed in a way that has been, to a large extent, independent of considerations concerning reuse. Tin-plated steel and glass fiber reinforced polyester meet demanding product specifications, but are a headache in view of materials recycling. On the other hand, technologies conducive to recycling and reuse of materials have further developed. Also problems surrounding waste disposal (including limitations to land filling) and pollution have emerged as pressing in a number of countries. This has given some impetus to recycling.

Moreover, environmental problems have generated renewed interest in a steady state economy that maintains an equilibrium relation with nature and natural resources and thus becomes sustainable. On implementation of a steady state economy future generations will not be worse off as to their environment ("natural capital"). As a consequence of interest in a steady state economy, industrial ecology has come to the fore. Here analogies between the economy-as-it-should-be and nature are important. Biogeochemical cycles and the intricate reuse of nutrients by living nature have become important heuristics in this context. One of the central elements of industrial ecology is that non-product outputs of economic activities should become inputs for other economic activities. Increased levels of recycling are corollaries thereof. Industrial ecology aims at a no (material) waste economy. The only non-product output of such an economy is to be waste heat, a conversion product of higher quality energy inputs.

Here, we will first deal with: why recycle or reuse? Then, we will go into the current status of recycling. Finally we will deal options for improvement both for the near term and in view of what would be necessary for a steady state relation between economy and environment.

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Biographical Sketch

Lucas Reijnders (1946) is currently professor of environmental science at the University of Amsterdam and the Open University of the Netherlands. His main research interests are in the fields of environmental evaluation of products, implementation of sustainability and the environmental improvement of production processes and products. His recent publications include: *Environmentally Improved Production Processes and Products*. (Dordrecht: Kluwer , 1996); Sustainability is an objective concept (*Ecological Economics* **27**, 139–147, 1998); Environmental evaluation of means of transport (*IATSS Research* **24**, 14–20, 2000), and A normative strategy for sustainable resource choice and recycling (*Resources, Conservation and Recycling* **28**, 121–133, 2000).