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GEOSCIENCE

Natural Resources: Applied Basic Research

# Recycling, a Challenge for the Circular Economy

Coordinated by
Michel Cathelineau

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# Introduction

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## I.1. Sustainable management and the circular economy

The circular economy aims to increase resource consumption efficiency, reduce environmental impact and therefore reduce resource waste and the ecological impact of the materials cycle. The role of the latter in the economy had already been considered, but it emerged as a concept around 2000 and has since been widely spread in Europe by the McArthur Foundation. It relies on the sustainable production of goods and services by limiting consumption, reducing resource waste and waste generation. This perspective contrasts a linear economy, in which resources are used, consumed in the form of goods, and then disposed of in the form of waste after use. In France, the French Agency for Ecological Transition (*l'Agence de l'Environnement et de la Maîtrise de l'Energie*, ADEME) supports the initiatives aimed at improving the circular economy and keeps up-to-date statistics concerning waste destination. The cycles of materials are complex and involve many players including manufacturers, private persons or communities, within a developing legal context and according to the economic requirements governing our societies. This effective approach is complex but compelling in light of this integrated perspective involving many interactions (Figure I.1).

The circular economy relies on:

1. supply and the economic players interested in the sustainable procurement of renewable or non-renewable resources, the eco-design of goods and services, the development of industrial and territorial ecology, and implementation of the functionality economy (using services rather than owning goods, e.g. renting electric vehicle batteries instead of purchasing them, for better management of collection and recycling);
2. consumption (demand and behavior), which covers responsible purchasing, proper use of products, reuse and repair;
3. waste management, though waste must be reduced as much as possible, the objective being responsible consumption that promotes recycling and, if needed, energy recovery.

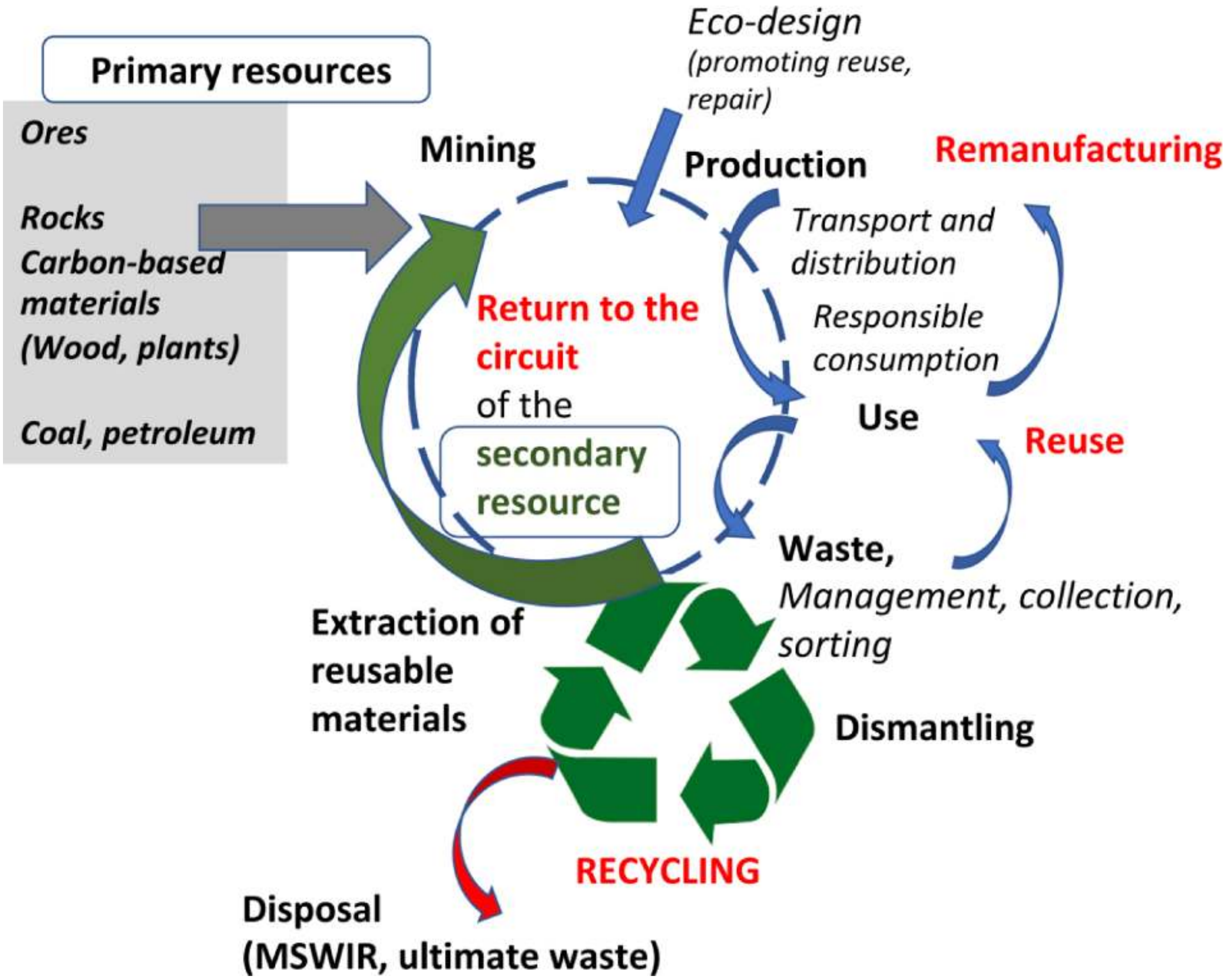


**Figure I.1** *Principle of the circular economy.*

In France, the recycling industry is represented by around 4,800 companies involved in the recovery of waste composed of ferrous and non-ferrous materials, plastic, paper and cardboard, textiles and glass materials. This book focuses on the challenges in the industry of recycling non-ferrous materials – used in high-tech and thus play a strategic role in a country's activity – like cardboard, plastic materials and building materials, to reduce the environmental impact of our activities and manage our resources sustainably.

Recycling is backed by the principle of sustainable development, according to which today's waste is not mere resources but reserves that can technically and economically be used in the future. For this reason, everything mined from natural resources to meet human needs must, from now on, enter the circle of the circular economy and never leave it. This goal must guide the development of new materials and technologies. In general, the materials and technologies upon which our societies heavily depend were originally created with different goals in mind. Adapting them to align with the principles mentioned above presents various technological challenges, which can be tackled through the development of specialized recycling technologies. Indeed, irrespective of the industry in which they are employed, the complexity of the materials designed and manufactured seems to be inexorably increasing, in correlation with increasingly advanced functionalities. Unfortunately, the complexity of functional materials seems directly correlated with difficulties in terms of feasibility and effectiveness of the various recycling stages. This complexity can be interpreted as an “energy (and economic) barrier” justifying or not the implementation of complex processes for the treatment of materials to be recycled. For example, because the demand for rare earths dropped, while fluorescent bulbs were replaced, and Chinese exports of rare earths returned to normal, Solvay group ended its production of rare earths from used low-energy lamps.

The economic model of our Western societies is probably the most important obstacle to implementing the circular economy. Companies are, in fact, expected to maintain profitability, as required by their shareholders. The latter are essential in implementing services or goods manufacturing, as they provide the initial funds (startup capital). Implementing a new plant for manufacturing semiconductors or batteries (gigafactories under construction in Europe for manufacturing batteries are, in certain cases, backed by recycling plants) requires startup capital of several billion euros. But running such activities implies maintaining economic equilibrium and growth. Considering the high cost of local production (labor costs, financial impact of social and environmental standards), companies opted for large-scale delocalization. The cost of purchased raw materials could be reduced by choosing to source from the best suppliers in the global market. Such a choice has short-term financial advantages, but also long-term fundamental drawbacks. This led to losses spanning from know-how to the entire value chain, and also to the delocalization of mining operations, then of metallurgy and finally of finite objects manufacturing. These developments particularly concern the sectors of permanent magnets and semiconductors. The greatest beneficiaries are Asian countries, particularly China. Finally, collection, local recycling limiting the energy cost of waste transportation, is not included in the economic model of the recycling industry, as it is not economically viable. The costs are thus partly borne by territorial populations and communities.

## I.2. Various categories of recycled materials

The main substances can be classified depending on the nature of the source materials. Figure I.2 can be used to identify most primary sources of materials, their use and their potential destination in recycling.

Chapters of this book are dedicated to these various substances: metals, materials resulting from the use of sands and gravels and sedimentary rocks (glass (silicon oxide obtained from quartz), cement (derived from clay-limestone sediments), organic products and their carbon-based derivatives): organic materials (wood, agricultural products, household waste, cardboard and paper resulting from animal and plant fibers) and products resulting from

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