Reuse and recovery of raw materials: Towards the achievement of a resource-efficient society

Resource efficiency plays a key role in the transition from a linear to a circular economy system. During the last few decades a rapid growth in the number of materials used across complex products has occurred. Given the high economic importance of critical raw materials combined with relatively high supply risk, securing reliable and undistorted access of certain raw materials is of growing concern across the globe. Development of eco-innovative approaches devoted to closing the loop of resources is strongly needed, allowing the connection between production cycles and their territory.

DOI: 10.12910/EAI2015-009

C. Brunori, L. Cutaia, R. Morabito

Introduction

Resource efficiency is increasingly becoming a global priority, playing a key role in the transition towards the achievement of a total recycling society, for economic, environmental, and strategic reasons. From an economic point of view, resource efficiency is fundamental for ensuring economic growth and competitiveness of the production systems. With regard to environmental issues, resource efficiency is fundamental to the achievement of resource preservation, which is no longer an option. Finally, from a strategic point of view, resource efficiency is necessary to ensure the supply of essential resources even in those geographical areas that are poor in primary resources.

Contact person: Claudia Brunori
claudia.brunori@enea.it

Economic importance of raw materials

The economic and strategic importance of resources, especially raw materials, is well recognized at the global level. In particular, the European Commissionhas launched, for some years by now, the European Initiative on Raw material, identifying a strategic implementation plan for the safe and sustainable supply of raw materials. Its 3 main pillars are: sustainable mining, equity for raw materials market access and the efficient use and recycling of resources. The economic importance of raw materials is underlined in Figure 1, showing the weight of costs from materials, energy and labor on the sales price of products. The weight of energy costs on the overall cost of the production process is widely known. However, it is worth mentioning that in some specific manufacturing sectors the load of material costs over the sales price is even much higher than that of energy costs. In the particular case of basic metals and transport equipment, the weight of material costs is even higher than 60% of the overall sales price.

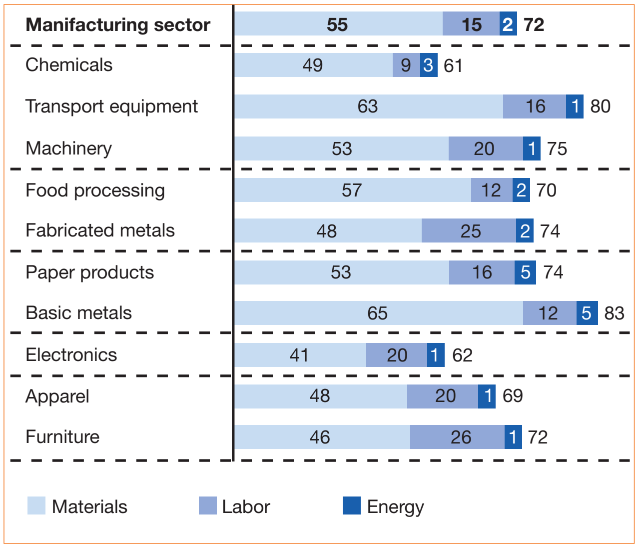

FIGURE 1 Costs over Sales price (%) in manufacturing sectors
Elaboration from "Manufacturing the future: The next era of global growth and innovation" (2006 data), McKinsey Operations Practice, McKinsey Global Institute, 2012

Eco-innovation as the driver for the shift from linear to circular economy

For both economic and environmental reasons, it is necessary to shift from the existing linear economy system, where primary resources enter into the production cycle and residues are disposed as waste, to a circular economy system, where residues are valorized and not disposed as waste. This transition is needed at any level, within the factories and even between production cycles and territory in industrial areas, as well as within the territory, for instance in the cities.

The driver to achieve this transition is eco-innovation, that is any new product, process, management system and services that allow to reduce resource and energy consumption as well as emissions to the environment. Eco-innovation is an essential tool for green economy, with the main objective to achieve a radical change towards a low-carbon and resource-efficient society, thus aiming at the total decoupling among economic growth, environmental impacts and resource consumption. However, in order to attain the highest beneficial effects for economy, society, and the environment, eco-innovation should not be limited to the so-called eco-industries, but rather be extended to any production cycle (even the so-called brown industries) and to any service and people lifestyle.

Industrial symbiosis – resource-efficient, eco-innovative solution within industrial areas

One of the most innovative and powerful tools for resource efficiency in industrial areas is represented by industrial symbiosis, i.e. a set of resource exchanges between two or more dissimilar industries. In opposition to traditional linear production systems, industrial symbiosis allows the transition to a circular production system, where the inputs are both primary and secondary resources and residues of an industry become, after proper treatment, valuable resources for dissimilar industries. This system allows the achievement of both economic and environmental benefits, consisting in the reduction of costs for energy, materials and waste management, and in the decrease of polluting emissions, energy consumption and disposed waste.

The results of the United Kingdom National Industrial Symbiosis Programme (NISP) (http://www.nispnetwork.com), obtained over an 8-year period, show interesting figures from both an environmental and economic point of view. Besides the highly consistent reduction in carbon dioxide emissions (39 million tons industrial carbon emissions less) and in water and raw materials consumption (45 million tons of materials recovered and reused, 71 million tons of industrial water savings obtained), it is worth mentioning how the 40 million pounds public investment has achieved a return of private investment around ten times higher. Furthermore, over 10,000 jobs were created or safeguarded.

As a practical example, ENEA has implemented an Industrial Symbiosis Platform (http://www.industrialsymbiosis.it) in Italy. As shown in Figure 2, its core is the cooperative database containing information provided by registered enterprises and industries' resource needs and residues produced. A

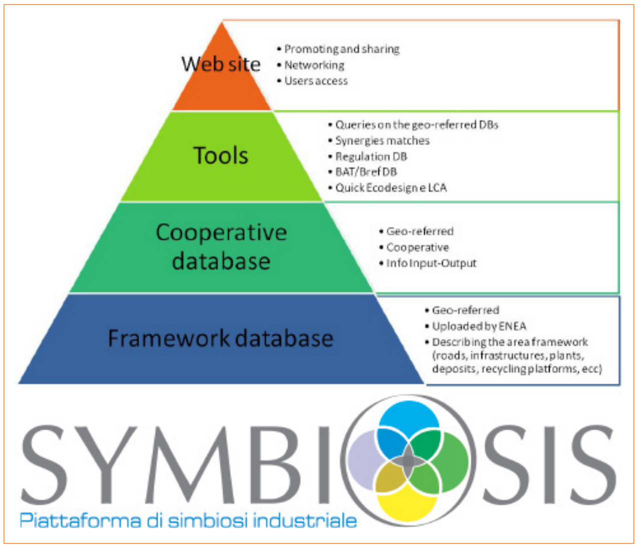

FIGURE 2 Industrial symbiosis platform structure implemented by ENEA

pool of experts, coordinated by the ENEA Technical Unit for Environmental Technologies, evaluates this information and proposes exchanges of resources among different industries.

Urban mining – resource-efficient, eco-innovation within cities

Another example of eco-innovation as related to cities is urban mining. In the past urban waste has been widely recognized much more as a problem to be solved than as a resource. It is time to start appreciating waste and exploiting all the potentialities of urban waste to become a valuable resource. In fact, cities can be considered as open pit mines, and construction and demolition materials, municipal waste, electronic waste, end-of-life automotive components are all valuable sources for plastics, metals, energy and other raw materials. Further added value is also represented by the creation of business and jobs in the recycling sector.
As a specific example, if we consider electronic waste, as shown in Table 1, the potential of secondary recovery is comparable to and in some cases even higher than primary extraction.
In addition, in some specific components such as printed circuit boards, the average content of precious metals is much higher than the average content of ore grades. In particular, it is 5 to 10 times higher for platinum and palladium, and even 20 to 100 times higher for gold. Electronic waste is not only interesting for the high content of single valuable metals, it is also particularly interesting for the wide range of metals that are contained in the components. As an example, the raw materials that can be recovered from an end-of-life personal computer by the application of an integrated product-centric approach include precious metals, specialty metals, rare earths, plastics for the recovery of chemicals and the production of syngas and energy.

	Primary extraction in 2011 [t]	Estimated world reserves [t]	Potential secondary recovery from WEEE [t]	Average content in medium grade ore [g/t]	Average content in printed circuit boards [g/t]
Gold	2.700	51.000	4.000	5-10	80-1.000
Silver	23.800	530.000	10.000	200-400	200-3.300
Platinum	192	66.000 (PGMs)	1.000	4-6	20-40
Palladium	207	66.000 (PGMs)	2.500	4-12	50-120
Copper	16.100.100	690.000.000	8.000.000	6.000-45.000	160.00-345.000

TABLE 1 Urban mining potential from WEEE
Adapted from E Waste Lab Final Report, Remedia, PoliMI, 2012

From an environmental point of view, many studies have been carried out to compare the ecological footprint of mining and recycling. In the study reported in Table 2, it is evident how carbon dioxide emissions are much higher for primary extraction than for recycling, in the case of palladium and gold even 20 and 40 times higher. These figures are even more important if we consider

RESOURCE EFFICIENCY

Metal	Scenario 1 primary mining	Scenario 2a Manual dismantling/ smelting India	Scenario 2b Mechanical dismantling/ smelting India	Scenario 3 Manual dismantling/ smelting Europe	Scenario 2d Mechanical dismantling/ smelting Europe
Aluminium	10	0,87	0,94	0,75	0,82
Nickel	20	4,8	6,7	4,7	6,6
Copper	3,4	1,2	1,5	0,98	1,2
Gold	17.000	710	1.330	690	1.300
Silver	140	20	40	20	40
Palladium	9.400	210	730	200	720

TABLE 2 Emissions per metal in ton of CO_2: Mining versus recycling
Adapted from F. Eisinger, R. Chakrabarti, C. Kruger, J. Alexeew, "Carbon Footprint of E-waste Recycling Scenarios in India", 2011

that the study is related to recycling processes conducted at high temperature. In the case of recycling processes at room temperature, such as those based on hydrometallurgy developed by the ENEA Technical Unit for Environmental Technologies, the recycling emissions are even much lower.

Conclusions

There is a need to shift from the existing life cycle of materials, where natural primary resources enter and residues exit to be disposed, to a closed cycle of materials, where the quantity of primary resources entering is much lower and the residues are ideally fully valorized within the loop. Eco-innovation represents the driving force for the achievement of a radical change towards a low-carbon and resource-efficient society aiming to achieve the total decoupling among economic growth, environmental impacts and consumption of resources.

Claudia Brunori, Laura Cutaia, Roberto Morabito
Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA)