Waste Valorization

Jean D. Kabongo
University of South Florida, Sarasota-Manatee College of Business, Sarasota, FL, USA

Synonyms

Beneficial reuse; Exchange or sharing of industrial by-products; Industrial symbiosis; Loop-closing; Recycling; Waste reclamation

Definition

The term "waste valorization" refers to any industrial processing activities aimed at reusing, recycling, or composting from wastes, useful products, or sources of energy. It usually takes the form of one of the following activities: processing of residue or by-products into raw materials, use of discarded finished or semifinished products as raw materials or energy sources, use of waste materials in manufacturing process stages, and addition of waste materials to finished products. Waste valorization considers the processing of large amount of production-related wastes and by-products, which differ from household wastes because they are much more homogeneous and larger in magnitude. The types of wastes used in valorization usually are classified as nonhazardous according to environmental regulations in place. This depends on jurisdictions and the types of waste classifications being considered. The term "waste valorization" is used particularly in engineering, economics, technology, business, environment, and policy literature in Canada, Europe, Asia, and South America. In the United States, the terms beneficial reuse, reuse, and waste reclamation often are used for waste valorization. Waste valorization is a ubiquitous illustration of the optimization of the use of resources in manufacturing processes. It translates into the application of certain principles of "bio-mimicry" as mentioned by Benyus: "the nature recycles everything" and "the nature utilizes only the energy it needs." In this perspective, Hawken proposed the elimination of the notion of "waste" in the systems of production and consumption. The valorization of waste puts the notion of "waste as resource" at the center of its activities. Following Hawken, there has been an effort in the environmental laws and regulations of several countries to conceive of "waste" in terms of residual material rather than simply garbage, trash, or scrap. The rationale is to infuse the idea that any residue can be reused in many different ways. For instance, the Environmental Quality Act of Quebec (Canada) as of 2012 defines residual material as any residue of a production process, processing, or end-consumer use; any substance, material, or product; or more generally any personal piece of furniture abandoned or which the holder intends to discard. Discarded automobile and truck tires, lead batteries, oil filters, used oil, dead farm animals, post-consumer glass, and demolished concrete are examples of residual materials that are valorized in many industrial sectors. The concept of by-product usually associated with waste valorization means any unintended residue of an industrial process in addition to the principal product. Used foundry sand and cupola slag from metal-casting industries; wood ash from pulp mills, sawmills, and wood-product manufacturing industries; sludge from primary clarifiers at pulp and paper mills; de-inking solids from paper-recycling companies; and serpentine tailings are examples of by-products that are valorized in several industry sectors.

The notion of waste valorization evolved as an alternative to waste disposal and landfill. Waste valorization reinforces the idea that every residual material or by-product should be used to create other useful products and remain in the production and consumption systems as long as possible. In a perspective centered more on industrial activities, waste valorization can be defined as the transformation or processing of a discarded product into another with added value, and for which there is a demand. This way of conceiving waste valorization demonstrates that it constitutes a business opportunity to capitalize on the abundance of wastes generated in many industrial sectors, as suggested by Tibbs.

Introduction

The study of waste valorization represents one of the more interesting and challenging areas of industrial ecology research for policy makers and managers. Industrial ecology emerged in the early 1990s as a discrete field of research and practice. One of its objectives is to analyze and propose manufacturing strategies intended to minimize resource and energy consumption through the recovery and processing of various products with residuals. Waste valorization represents one of the most conspicuous examples of industrial ecology conducted at the firm level. Over the past decade, waste valorization has been establishing itself as distinct field. Two reasons justified this phenomenon. First, there has been a growing interest from industry leaders to find innovative ways to process the huge amount of wastes and by-products and use them as energy source and useful materials. These leaders have been working closely with academic units to experiment and pilot new techniques in laboratories before implementing them at the larger, industrial scale. Second, policy makers have an interest in waste valorization because of its potential for changes, as well as updates in legislation and regulations. One of the major steps in the efforts to establish waste valorization as a distinct field was the launch of the journal *Waste Valorization and Biomass* in 2010, edited by Professor Ange Nzihou of the School of Mines of Albi-Carmaux in Albi, France, and chair of the WasteEng Conference Series.

As an application of industrial ecology, waste valorization enables manufacturing facilities to take advantage of the cyclic patterns of the used material streams found in industrial and consumption systems. Waste valorization also is an application of closed-loop manufacturing systems making it possible to reduce ecological impact on processes and develop products made from reused parts and materials from consumer and industrial sectors. Many experts consider waste valorization in the perspective of eco-efficiency at the firm level, which can be reinforced by various factors, especially the introduction of new technologies and the continuous rise in the cost of raw materials. In fact, according to a recent international survey among international managers, the rising cost of raw materials has become the main concern of companies. Waste valorization, even though a business opportunity, is considered as an effective solution to the problem of the generation of industrial and household wastes in our modern society. Waste management and treatment is one of major environmental concerns in industrialized economies.

Industrial ecology emerged as a field of research and inquiry in the midst of concerns over the economics of resources and environmental damages due to accelerated industrial activities. Industrial ecology often is viewed as a revolutionary vision of the analysis and effective management of wastes that could help reducing the quantity of wastes and realize loop closing of current systems of production and consumption. Frosch & Gallopoulos laid out the foundations of industrial ecology with the publication of their seminal article “Strategies for Manufacturing” in *Scientific American* in the late 1980s and clearly argued that the productive use of what would be a waste is central to resource efficiency and minimization of environmental damage. Is this not a rediscovery, by specialists of industrial ecology, of 1,000-year-old practices often ignored or overlooked?

Human history shows that recovery and valorization of wastes are not new phenomena. They do not represent new topics in the scientific literature. Producing and consuming are vital necessities of human beings. Thus, wastes constitute inevitable by-products of the production and consumption activities, as illustrated by several studies such as those by Rathje and Murphy, and Strasser. In fact, these studies indicate that thousands of years ago, three techniques were known and used to deal with wastes: dump, incineration, and reuse or recycling. If there existed any period of harmony between humans’ activities and the presence of wastes, this equilibrium was broken with the introduction of changes in lifestyles due the foundation of cities and increasing population living in them. The introduction of new laws was necessary to deal with the accumulation of wastes in many new created cities and to prevent sanitary problems. In fact, Rathje and Murphy demonstrated that for thousands of years, it was commonplace to dump rubbish on site – on the floor or out the window. Scavenging domestic animals, chiefly pigs and dogs, consumed the edible parts, and poor people salvaged what they could. The rest was covered and built upon. Over time, entire cities gradually were extended upward, rising on massive mounds called tells, which contained the remains of prior centuries.

Over the centuries, scientific progress, particularly new knowledge development in the field of bacteriology in the 1900s set the tone around a real way of managing wastes. Municipal authorities were given the responsibility to organize the management of wastes by putting in place effective methods to pick up and haul wastes, clean up streets, and educate the population about hygiene. For instance, in France, the then Mayor of Paris, Eugene Poubelle approved on November 24, 1883, a regulation that obligated homeowners to acquire and use a container to put in their rubbish. Ironically, the French word for trash bin is "poubelle." Although this practice was not successful at the start, it set the tone around the sorting of wastes. In the same period, similar practices of collecting trash were introduced in the majority of industrial cities across Europe and the United States. For instance, by 1880, 25 % of American cities had municipal services of trash collection. The city of New York was the first to implement a complete system of public waste management. As Melosi indicated, by 1910, waste management was part of public policy in 80 % of American cities.

Due to the increase amount of household and industrial wastes, the management of junkyards outside the cities was no longer an effective solution. Then (re)emerged new methods of dealing with wastes: incineration and landfill. As Benjamin documented, incineration of wastes had already been in use for more than a 1,000 years. However, the first "modern" incinerator called "destroyer" was inaugurated in the city of Nottingham, United Kingdom, in 1874. Eleven years later, an American model named "cremator" was built in New York City. Besides the problem of air pollution that incineration produces – with dreadful smells, intense smoke, and harmful gases – it seemed to have helped reducing the volume of dumped wastes in the proportion of 85–95 %. Landfills were used as a method to deal with wastes by the 1900s. The first experiences with landfill were conducted in Great Britain by 1920. From 1930 and on, landfill sites were created in the United States and Canada to replace incinerators. Thus, the burial of wastes was made possible by rationally selecting a convenient site. In the 1970s, 300–400 landfill sites were created per year in the United States. The analysis of the organization of these activities over time indicates that, overall, they constitute successful examples of the integration of systems of production or loop closing. As Wiseman argued, recycling has been carried out on a massive scale throughout human history, and undoubtedly dates from prehistoric times, when implements and animal skins were first modified and converted from one use to another. Hence, in a broad sense, recycling indeed has a "proven record."

The oil crisis of 1973 that triggered an economic and energy crisis worldwide and the growing awareness that the majority of immense industrial wastes can be used as resources helped laying out 1,000 years' practices of reuse, recycling, and valorization of wastes. Barry Commoner expressed this awareness in his book *The Closing Circle* published in 1971: "If we are to survive economically as well as biologically, industry, agriculture, and transportation will have to meet the inescapable demands of the ecosystem. These essential demands include essentially complete containment and reclamation of wastes ... essentially complete recycling of all reusable metal, glass, and paper products; and ecologically sound planning govern land use ... present productive technologies need to be redesigned to conform as closely as possible to ecological requirements."

Frosch and Gallopoulos followed the vision of Commoner when they suggested that waste from one industrial process can serve as the raw materials for another, thereby reducing the impact of industry on the environment and showing that in an industrial system that uses nature as its model, the consumption of energy and materials is optimized and waste generation is minimized. As an application of industrial ecology, waste valorization thus relies on recovery, use, and transformation of by-products and wastes in industrial processes. In this perspective, recovery is conceived as sorting – arranging or categorizing – of materials or energy contained in wastes in order to valorize them, reduce their inflow in the processing facilities, or send them to a specific processing facility. The use is conceived as the introduction of by-products and residual materials in a manufacturing process. These by-products and residual materials are introduced in the processes because they still have value in the estimates of firm managers. The introduction of discarded automobile and truck tires as tire derived fuel in cement rotary kilns for the clinker production is an example of the use of residual materials. The transformation refers to the manufacturing of new finished products or semifinished from by-products or residual materials. These new products or semi-products are manufactured to be sold to targeted markets.

This vision of recovery, use, and transformation of residual materials demonstrates that waste valorization as defined above is slightly different from other forms of waste processing, such as reuse and recycling. In fact, reuse means the second utilization of waste, a discarded product, or object in a similar manner as the first time it was utilized. It may not receive a treatment before the second utilization even though it is considered discarded. A discarded automobile tire can be reused on another vehicle without any treatment if it has some value for the new consumer. The treatment or processing of wastes constitutes a pivotal dimension of waste valorization that is not implied in the case of simple reuse of discarded products or abandoned objects. On the other hand, recycling considers the treatment or physical modification of the initial object. In fact, recycling is defined as the recovery and introduction in the production cycle of a material in partial or total replacement of raw materials. However, this treatment does not imply the transformation of this material into a different product. Waste valorization adds value to a residual using other means than reuse and recycling. According to the waste disposal hierarchy – 3RV-E (Reduce, Reuse, Recycle, Valorize, Eliminate) – waste valorization is the ultimate step before the object or material is definitely discarded and sent to a landfill or eliminated. This perspective reinforces the idea that waste valorization is an elegant way of optimizing the use of resources.

The principle whereby Mother Nature recycles everything is associated with two important notions of waste valorization: zero waste and loop closing. The search for zero waste is a philosophical management approach inspired from the idea that the nature produces without leaving a lot of wastes or leaving only minimal wastes. In industrial operations, zero waste means the reduction of the amount of wastes in the systems of production and consumption and the use of wastes as raw materials in different industrial processes. As mentioned above, industrial loop closing means that in industrial activities, wastes should be minimized and wastes generated must be used as much as possible to close the cycle. It is in application of the principles of zero waste and industrial loop closing that a growing number of industrial facilities are founding their activities around waste valorization and waste exchange, making it a conspicuous example of industrial ecology at the firm and intra-firm levels.

Key Issues

The growing interest in waste valorization and the potential for processing the huge amount of wastes and by-products and using them as energy sources or useful materials bring many issues to light. These issues can be grouped into three categories: manufacturing processes and technological innovation, variability of flows of wastes, and environmental issues. First, the activities of waste valorization often raise new technological challenges. For instance, the implementation of a pyrometallurgical process to valorize lead batteries, the serpentine electrolysis process to reclaim magnesium, and the introduction of coal fly ash to make high-quality, durable concrete require the development of new manufacturing processes. These innovations are much more innovative than what is currently available, often are narrow, and suppose a niche strategy in which the technologies developed are specific, or even unique. The key issue here is not the wastes as inputs per se, but rather the way they are used and transformed. In others words, what is important and challenging is the know-how and appropriate technology embedded in the processing technique. Thus, the development of new manufacturing processes and know-how is a major issue. The second category of issues dealing with waste valorization is the variations in wastes flow. Indeed, contrary to traditional material supplies, wastes are rarely standardized in terms of their composition, dimension, and supply regularity. These irregularities require manufacturing facilities to continuously adapt and customize their operations. For instance, it is common now for a cement plant to replace traditional fuel with more than 30 different types of wastes. All these materials come from various industry sectors and are made with various components, such as used oils, discarded automobile tires, incinerator ash, pressure-treated wood waste, and telephone poles. These residual materials are not interchangeable, and their processing often requires consideration of numerous parameters. Thus, waste valorization activities appear as a sort of recipe evolving continuously according to contingents and parameters that are hard to predict.

Third, waste valorization raises a number of environmental issues. For manufacturing facilities valorizing wastes, these environmental issues are administrative, technical, and societal problems that can be intense and complex. At the administrative level, shipping, storage, and use of wastes require permits and procedures that are very time consuming. The sluggishness, sheer volume, and constraints of administrative procedures represent the main obstacles to the practices of waste valorization. The classification and codification of different types of wastes as hazardous and nonhazardous is often unclear and vary by jurisdiction and according to the specific wastes in consideration. This problem is more intense when environmental laws and regulations are not updated. In fact, many experts believe that the environmental policy set up in the 1990s is still in vigor. This policy deals with waste management practices of that time, which were focused more on landfill and incineration. The lack of environmental policy dealing specifically with waste valorization is a big issue. At the technical level, the processing of a wide variety of wastes generates environmental impacts that must be measured and controlled. In fact, wastes may contain a number of elements that can affect the quality of the finished product. These elements often are identified as chlorine, sulfur, heavy metals, etc. Also, making sure that the manufacturing processes is energy efficient often represents a challenge. It is paradoxical when the process of optimizing the use of resources is not eco-efficient per se. Finally, at the societal level, waste valorization activities often give rise to negative or even hostile reactions from residents. The NIMBY (Not In My Back Yard) syndrome is all the more present when the toxicity of wastes processed is recognized or when negative externalities are really perceptible.

Future Directions

The growing interest in finding innovative techniques to use and process the huge amount of industrial wastes and by-products considered as a business opportunity and an effective way to deal with waste generation and management in modern industrialized economies makes waste valorization a promising area for research.

Three directions are outlined here. First, there is a need to understand the many ways different companies are trying to implement waste valorization practices, and the implications of these practices on their overall performance can take several directions. The challenges raised by waste valorization at the firm level are more strategic in nature. In this perspective, constructing models and typologies of waste valorization activities according to industry sectors can help the field develop well-grounded frameworks. Second, current methodology and techniques of waste valorization are still complex and, to some extent, less effective in terms of the emissions of pollutants and greenhouse gases. Future research may focus on more effective and efficient techniques and manufacturing processes to achieve environmental goals. Third, legislative and regulatory issues predominate in waste valorization practices. Many environmental laws and regulations are not aligned with waste valorization practices. The success of waste valorization initiatives cannot be attributed exclusively to environmental engineering progress. Because of their complexity and cross-functional implications, they require regulations that reflect current knowledge to make waste valorization operational and successful within organizations. Future research may want to focus on the analysis and evolution of the integration of waste valorization knowledge into public policy.

Cross-References

▶ Biomimicry
▶ Brundtland Report
▶ Chief Sustainability Officer
▶ Corporate Social Responsibility
▶ Cradle to Cradle
▶ Design for Environment
▶ Eco-efficiency
▶ Ecological Footprint
▶ Environmental Management System
▶ Industrial Ecology
▶ Recycling
▶ Sustainability and Sustainable Development

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Watchdog

▶ Greenpeace (NGO)

Water

Josep de Trincheria[1] and Walter Leal Filho[2]
[1]Research and Transfer Centre "Applications of Life Sciences", Faculty of Campus Bergedorf, Hamburg University of Applied Sciences, Hamburg, Germany
[2]Research and Transfer Centre "Applications of Life Sciences", Hamburg University of Applied Sciences, Hamburg, Germany

Synonyms

Corporate water sustainability