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Waste Valorization, Loop-Closing, and Industrial Ecology

Ange Nzihou and Reid Lifset

Recycling has always been a pivotal concept in industrial ecology. From the seminal article by Frosch and Gallopoulos (1989) in *Scientific American* that marks the beginning of this field, the productive use of what would otherwise be a waste has been seen as central to resource efficiency and the reduction of environmental damage.

In industrial ecology, recycling is often framed broadly as “loop closing,” an expression that alludes to the ecological analogy that is one of key premises of the field. The term refers to a variety of ways materials

flows can form a loop so that resources are cycled through the economy rather than being disposed of in a landfill. Loop closing includes the familiar recycling of household wastes, but it also extends to other phenomena, including industrial symbiosis, the exchange or sharing of industrial by-products and resources facilitated by geographic proximity.

One of the forms of recycling that falls within this realm is variously called *waste valorization* in Europe, Asia, and South America and *beneficial use* or *reuse* in North America. Waste val-

orization is the treatment of waste for beneficial use as raw material or as an energy carrier, with the emphasis on processes and practices that reduce emissions and related environmental impacts. The term *valorization* typically refers to

efforts to make use of bulk, production-related wastes, such as paper sludge, incinerator ash, metal slags, pressure-treated wood wastes, or foundry sands. These wastes differ from household wastes in that they are more homogenous and much larger in magnitude. The wastes of interest in valorization are also generally considered to be non-

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hazardous both in the informal sense and in the legal sense. (This, of course, varies widely by jurisdiction and according to the specific waste in question. Whether the wastes are truly benign is also a matter of contention, as the debate over the land application of industrial wastes illustrates [Lifset 2001].)

The field of waste valorization is increasingly supported and engaged in by industry and government. The interest of industry is explained by the field’s multi- and interdisciplinarity and by the focus on laboratory, pilot, and full-scale experiments with potential applications to the valorization of waste and biomass into energy and useful materials. This field is also shaped in important ways by legislation and regulation.

Various challenges in the field of waste valorization have been identified and will be the object of significant effort in research for the near future (Nzihou 2010). The emission of pollutants and greenhouse gases is of particular concern. Raw materials may contain elements, such as chlorine, sulfur, and heavy metals, that can affect the quality of the end-of-pipe product. Energy efficiency (allotherm and autotherm) of the processes is another key focus. As a result, modeling research has progressed rapidly. In that respect, scientific investigation that presents accurate data on the composition and characteristics of the materials is a basic prerequisite for any scheme in waste and biomass conversion. The challenges extend to regulation and policy: The environmental policy set in the 1990s is still in force and is mainly focused on disposal and storage of waste and residues in landfills. This regulation no longer reflects current knowledge—thanks to progress in research in recent years—of the beneficial reuse of waste and biomass.

This issue of the *Journal of Industrial Ecology* includes a special feature on waste valorization and loop-closing. The articles are derived from the second International Conference on Engineering for Waste Valorisation, held in Patras, Greece, in June 2008, and from a call for papers distributed to the membership of the International Society for Industrial Ecology. Professor Ange Nzihou, of the Ecole des Mines d'Albi-Carmaux in Albi, France; Professor Matthew Leach, of the Center for Environmental Strategy at the University of Surrey in the United Kingdom; and Professor Gerasimos Lyberatos, of the University of Patras in Greece, served as the guest editors. Partial support for the special feature was provided by the WasteEng Conferences, a series of meetings focused on research on the valorization of waste and biomass.

The result of these efforts is five articles addressing a diversity of topics in the domain of waste valorization and loop-closing. Two articles discuss treatment processes to valorize industrial wastes—to make them useful as raw materials. Barberio and colleagues (2010) investigate the viability and the environmental consequences of using municipal solid waste incineration bottom ash for production of glass frit for ceramic

glaze (glaze frit). Laboratory tests indicate that the solubility of heavy metals contained in the ash is significantly reduced and that the innovative and conventional frit are similar in their thermal behavior. The authors use life cycle assessment (LCA) to examine the environmental impacts on a comprehensive basis. To this purpose, they investigate environmental impacts of two scenarios of end-of-life of bottom ash from municipal solid waste incineration (MSWI)—namely, landfill disposal (conventional scenario) and bottom ash recovery for glaze frit production (innovative scenario).

Alonso-Santurde and colleagues (2010) examine the use of foundry sands as raw material in brick making, focusing on the leaching of problematic substances, primarily metals, during use and at end of life. This area has been extensively investigated over the last 10 years by waste valorization researchers, and it has shown tangible advantages in terms of producing ceramic materials from waste, thereby saving natural resources and reducing the amount of waste going to landfill. Alonso-Santurde and colleagues' (2010) assessment of the materials derived from the foundry sands, made according to the European leaching test standard (NEN7345:1995), show that most of the pollutants listed in the European Union's Landfill Directive¹ are lower than the threshold for the inert waste category landfill, except for arsenic, chromium, and lead.

Sablaylorles and colleagues (2010) examine the application of wastewater sludge (biosolids) to agricultural land using LCA, focusing in particular on toxic impacts to humans through plant uptake and comparing the environmental performance of dried and composted sludge from a wastewater treatment facility in France. They find that dried biosolids are more harmful to the environment than the composted biosolids for six out of the eight impact categories they study.

Posch (2010) examines the recycling of industrial wastes but asks a very different set of questions than the other contributors. Posch's research takes the existence of waste valorization or loop closing for granted; instead of asking engineering questions about treatment and environmental questions about impact, he examines the drivers and consequences. He explores whether

industrial recycling networks or other forms of industrial symbiosis projects can be used as starting points for much broader intercompany cooperation for sustainable development. Researchers have previously suggested that the interaction catalyzed by by-product exchange could generate companies' further collective efforts at sustainable development. Posch investigates this question through surveys of recycling networks in Austria and Germany. He finds that the percentage of by-products passed on to other companies for recycling purposes is not higher among companies that belong to organized recycling networks than among companies of the manufacturing sector in Austria as a whole. The relationships among recycling partners are found to be similar to conventional buyer—supplier relationships. The companies that engage in recycling activities remain notably unaware of their membership in the organized network, which raises questions about whether network membership leads to heightened possibilities for collective pursuit of sustainability.

Björklund and Johansson's research (2010) falls more in the category of loop-closing than in that of waste valorization, because it deals with end-of-life products. The authors assess the efficacy of targeted manual disassembly of discarded dishwashers to remove copper-containing parts prior to shredding. The goal is to improve the effectiveness of material recovery and the environmental performance of appliance recycling from a life cycle perspective. They find that this strategy, which emerges from a conceptual framework known as material hygiene, may reduce the abiotic depletion and global warming potential in a life cycle perspective. The preliminary dismantling leads to increased copper recovery and reduces copper contamination of the recovered steel fractions.

The articles gathered here as part of the special feature on waste valorization and loop-closing present interesting findings. As a group, they do not introduce a novel thread in industrial ecology—the need to explore opportunities to close loops, to valorize waste to enable the closing of loops, and to examine carefully the environmental consequences of these efforts is familiar. Instead, this group of articles reminds us that there are important questions and opportunities,

whether couched as waste valorization, beneficial use, or loop-closing, that go to the heart of industrial ecology and environmental engineering and that remain worthy of our attention and research.

Note

1. See http://ec.europa.eu/environment/waste/landfill_index.htm for details on the Landfill Directive.

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