

## The evolving role of industrial wastes and by-products in contemporary production processes: A case study of Pennsylvania

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A key element of any transition to a more sustainable society will need to include consideration of very large volumes non-hazardous industrial waste (NHIW), resulting from current production systems. Unfortunately, broader systematic studies of how NHIW flows through economic networks are hampered by the lack of available data. Few government agencies collect data on the billions of tons of non-hazardous industrial wastes (NHIW) generated every year. A major exception is the Pennsylvania Department of Environmental Protection (PA DEP). Since 1992, the PA DEP has collected data from Pennsylvania facilities producing more than 13 short tons of nonhazardous industrial waste per year. As such, this data set provides a unique opportunity to test some of the basic propositions of industrial ecology through a detailed analysis NHIW flows in a major industrial state over time.

The basic empirical questions raised by this research is how NHIW is being (re)directed to productive activities at the level of both the individual firm, and, more importantly, at the scale of the broader economy, using Pennsylvania as a case study. The key conceptual question driving the work is to examine what are the major drivers and motivations behind NHIW flows? Rather than focus on individual firms, the study offers a holistic conceptual framework for the kind of significant systematic study necessary to evaluate if firms are changing how they perceive of, and deal with, their industrial wastes.

The main concepts that are used in this work are drawn from the concept of industrial ecology (IE). At the core of IE is the relatively optimistic argument that changes in technologies and institutional structures will promote ecological sustainability without the necessity of alternating the fundamental structures of capitalism. The central strategies revolve around transforming the current production system into a 'closed loop' industrial ecosystem where NHIW would substitute for virgin materials during production processes via material recycling and related strategies (e.g., industrial symbiosis) thus significantly reducing future environmental impacts of production compared with current practices. For industrial ecologists, the logic of 'closed loop' eco-industrial systems is so obvious and profitable for business (i.e, cheaper inputs, reduction in waste disposal costs) that its widespread adoption is simply a matter of time. While the win-win promises of IE have captured the imagination of academics, policymakers and developers, empirical evidence of 'closed loop' manufacturing processes remains rather elusive. Most existing positive empirical evidence (e.g., the classic case of Kalundborg, Denmark) is based on specific case studies, with the implicit assumption that the selected cases are early adopters of a new process that is already underway.

Preliminary conclusions suggest that firms in many sectors have reduced the weight of NHIW over years, despite the fact that the total weight of manufacturing commodities shipped out of

Pennsylvania increased by an estimated 9 percent during the study period. With the exception of large increases in the generation of fly ash (the largest type of NHIW) from the utility sector all other major categories of NHIW decreased. At the same time, however, the proportion of fly ash that is treated and reused has increased substantially. Increases in reuse strategies for other sectors are less stable, but the general trends are a decrease in disposal and growth in new non conventional (i.e., industrial ecology type practices) strategies. The corresponding geography of NHIW is remarkably stable with very little NHIW shipped out of state and a steady increase in the weight of material that is reused locally.

The results will provide important new evidence on how non-hazardous industrial wastes are managed in a US state with a long tradition of industrial development. More specifically it will test some of the basic concepts of the theory of industrial ecology and the broader arguments of ecological modernization that suggest technical changes rather than structural changes to the way industrial production is organized will be sufficient to reduce the negative ecological impact of wastes and by-products generated by current industrial practices.