Industrial Ecology in China, Part I

Research

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Eco-industrial development was first proposed in China in the early 1980s by Chinese ecologists represented by the late Shijun Ma (1985), a member of the Chinese Academy of Sciences. This helped bring about a wave of eco-agricultural development in China starting in the mid 1980s. Also noteworthy is that Deli Xi of Tsinghua University introduced the emerging discipline of industrial ecology in his book *Pollution-Free Industrial Processes: A New Paradigm for Industrial Development* (Xi 1990). This was the first time that the term "industrial ecology" appeared in a Chinese academic publication.[1] Xi systematically described how to ecologicalize industrial production by applying ecosystem rules to the planning, organization, and operation of industrial activities; closing the material loop; and developing pollution-free industrial estates. His primary inspiration stemmed from 1980s publications from the former Soviet Union. Unfortunately, these initiatives had not drawn any substantial attention from either policy makers or the research community. To launch any industrial ecology-related research was simply out of the question given the prevailing lack of awareness of and priority for industrial environmental management during that period in China.

Industrial ecology, as a young scientific discipline emerging from North America, Europe, and Japan over the last decade, may obtain unprecedented opportunities for testing of its methodological robustness and further development of its theory and tools given the size, dynamics, and diversity of China's industrial activities.

The 1996 article "Industrial Ecology: New Opportunity for the Private Sector" in the Chinese version of United Nations Environment Program's (UNEP's) magazine, *Industry and Environment Review*, introduced a new wave of industrial ecology concepts into China. To date, research on and practice of such core constituents of industrial ecology as life-cycle assessment (LCA), design for environment (DfE), materials flow analysis (MFA), and eco-industrial parks (EIPs) or industrial symbiosis have reached varying levels of development. These and related ideas have still very much been confined to a small circle of researchers and thinkers, primarily from a dozen universities and research institutes in the fields of chemical engineering, environmental engineering, ecology, and materials science. Social science institutes have not been involved in the debates except for several management schools. Only over the past two years have a few governmental officials and industrial practitioners started to show interest, principally in the topics of EIPs and the closed-loop economy.

As a matter of fact, the term "industrial ecology" has two Chinese translations, *gongye shengtaixue* and *chanye shengtaixue*. In the former, the term *gongye* implicitly refers to manufacturing and mining activities. Because the major advo-

e-supplement available on the *JIE* Web site

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cates of industrial ecology in China are those who are working in engineering circles or who have promoted cleaner production since the early 1990s, their prior experience and primary interest in the manufacturing sector determine their preference in using *gongye*.[2] Consequently, the first translation is more commonly used. A few pioneer industrial ecologists, however, represented by Rusong Wang and his group at the Research Center for Eco-Environmental Sciences (RCEES) of the Chinese Academy of Sciences, adopt the *chanye* translation, which more explicitly encompasses services and agricultural activities apart from manufacturing and has an intricate interplay with consumption.

The merit and necessity of introducing industrial ecology to China, however, have become increasingly apparent. First and foremost, China has been undergoing rapid industrialization, which has brought about severe environmental deterioration and will likely lead to even higher environmental costs if no timely, integrated, and preventative environmental policies and measures are undertaken. Industrial ecology as a systematic framework and approach for examining the industrial-ecological interaction can serve this purpose well. Second, China serves as an excellent test field for the demonstration and adaptation of policies based on industrial ecology. This experimentation is invaluable, even indispensable, for industrial ecology (which has little presence and prior exposure in developing countries) if it is to be widely and properly introduced into rapidly industrializing countries. Third, industrial ecology, as a young scientific discipline emerging from North America, Europe, and Japan over the last decade, may obtain unprecedented opportunities for testing of its methodological robustness and further development of its theory and tools given the size, dynamics, and diversity of China's industrial activities. For instance, China serves as a second-to-none case for verifying the viability of the "leapfrogging" hypothesis.

This column reviews up-to-date research on LCA, DfE, MFA, EIPs, and the closed-loop economy in China. A second column will review the teaching of industrial ecology in China and then discuss the outlook for its dissemination.

Life-Cycle Assessment

LCA was first introduced into China by Chinese materials scientists in the mid 1990s. Chinese materials scientists responded enthusiastically to the eco-materials concept, which was proposed by the Japanese researcher Ryoichi Yamamoto in the early 1990s. The Chinese Materials Research Society organized the second international conference on eco-materials in Xi'an, China, in 1995. Under the promotion of the society, a number of materials LCAs (MLCAs) have been conducted since 1995, funded by the National 863 (High-Tech) Program and the Natural Science Foundation of China. Most of the studies focused on the analysis of materials' environmental performance by integrating the analysis of energy consumption, natural resource use, and waste generation. More than 20 metals, including iron, aluminum, and zinc, have been evaluated, and related databases have been developed. Some studies have also involved the assessment of manufacturing technologies and processes, such as cement, ceramic, plastics, and construction coatings. Currently, a follow-up national project (2001–2005), titled "Materials Life-Cycle Assessment and Its Application," is being carried out. The methodology for MLCA will be further advanced, and additional materials will be selected for MLCA studies. A basic database for MLCA is under development. Leading institutes in research and teaching of eco-materials include Beijing Polytechnic University, Sichuan University, Beijing University of Aeronautics and Astronautics, Chongqing University, and Tsinghua University.

RCEES has been active in LCA methodology development and product LCA, with support from the European Commission INCO-DC [International Cooperation—Developing Countries] project "Eco-Comparability of Industrial Processes for the Production of Primary Goods," since 1997. The team has developed a life-cycle impact assessment (LCIA) methodology on the basis of the Danish EDIP [Environmental Design for Industrial Products] methodology framework, as well as a pilot life-cycle inventory (LCI) database for Chinese industrial products, which is integrated in the Boustead model. Based on the database, a small Chinese car was analyzed and compared with a European car. Further, the LCA methodology was applied to municipal solid waste management in the city of Guanghan, Sichuan Province (Xu et al. 2000). Recently, RCEES completed an LCA of mobile-phone housing manufacturing in cooperation with Motorola China Co., Ltd. RCEES contributed the bulk of the Chinese journal publications, as well as the first book on LCA in Chinese in 2002 (Yang and Wang 2002).

Another important LCA-related initiative is the China Energy Technology Program (www.cetp.ch). The initiative is led by ABB, a Swedish-Swiss multinational corporation, and involves a team of 75 scientists, academics, and engineers in China, Japan, Switzerland, and the United States from business, universities, and research institutions. The project's aim is to develop a global methodology for assessing the life-cycle impact of electric power generation, taking energy technologies and environmental impacts into account.

Despite of the above-mentioned progress, the diffusion of LCA in China is confronted with enormous challenges. The LCA methodology suitable for the Chinese context remains to be established. The wide gap between LCA application and policy making also needs to be filled. To tackle the limited LCI data availability and core LCA expertise bottleneck, it is imperative for government to support coordinated, integrative data-gathering efforts (e.g., development of a nationally representative and accessible database) and enhanced information sharing and institutional networking (e.g., formation of a national LCA society).

Design for Environment

In the late 1990s, a few Chinese technical universities started to carry out studies on DfE. Shanghai Jiao Tong University cooperated with the Technical University of Berlin on life-cycle design and held an international workshop on sustainable manufacturing in 1999. Consequently, their research has been expanded to the fields of design for disassembly and recycling.

The application of DfE in Chinese domestic industries is still at the infant stage. Given the lack of in-plant expertise, awareness of economic and environmental significance, and policy pressures such as the linking of environmental labeling schemes with LCA, Chinese enterprises have not been motivated to apply LCA and DfE approaches. Important industrial ecology tools such as DfE and LCA have only been practiced by the subsidiaries of some leading multinational corporations, such as Motorola, BASF, Mitsubishi, and Lucent Technologies.

Materials Flow Analysis

As compared to LCA, MFA is even less developed in China. Collaborative research between Beijing University and a consortium of European institutions, led by the German Wuppertal Institute and funded by the European Commission, has catalyzed a preliminary material input analysis of China (Chen and Qiao 2001). The study evaluated the resource and environmental costs of China's rapid economic growth by estimating the country's total material requirement, material consumption intensity, and material productivity from 1990 to 1996. The Beijing municipal government has also sponsored a consortium of Beijing Polytechnic University and Peking University led by Tieyong Zuo, president of Beijing Polytechnic University, to carry out an MFA for Beijing and establish related material flow databases.

The Department of Environmental Sciences and Engineering of Tsinghua University, in cooperation with Wageningen University in the Netherlands, is developing an integrated methodology combining MFA and ecological restructuring theory to evaluate the physical dimension of economic society and apply it to the case of phosphorus in China. Jingyun Fang's team at Peking University applied an improved estimation method of forest biomass and a 50 year national forest resource inventory in China to estimate changes in the stock of living biomass between 1949 and 1998 (Fang et al. 2001). Yahui Zhuang of RCEES has also conducted a preliminary study on a sustainable carbon cycle in the Beijing urban ecosystem.

These preliminary MFA studies have initially demonstrated the potential usefulness for sustainability policy making. The limited availability and quality of statistics, however, has to be remedied and more policy-relevant MFAs remain to be done before MFA can really take foot in sustainable development planning and implementation in China.

Eco-Industrial Parks

Having recognized the conflicts between economic growth and environmental protection caused by the pattern of conventional industrial development, the State Environmental Protection Administration has attached increasing importance to promoting environmental management in industrial estates and the development of EIPs in China since 2000. The Guitang Group, a state-owned sugar company based in southern China, leads in the development of EIPs in China. To deal with high levels of emissions generated by low-profit sugar production, the company has created a cluster of facilities to reuse and recycle its by-products and thereby reduce pollution in an economically viable manner. The complex includes an alcohol plant, a pulp mill, a toilet-paper plant, a calcium carbonate plant, a cement plant, and a power station. With technical support from the Chinese Research Academy of Environmental Sciences (CRAES), the city of Guigang aims to realize the first national pilot EIP in China on the basis of Guitang Group's initiative by 2005. CREAS and the Eco-Industrial Research Center of Tsinghua University are also assisting in the planning of Nanhai National Eco-Industrial Park, a new environmental industry base located in Guangdong Province, southern China.

Another ongoing initiative is to plan and construct an EIP within the Dalian Economic and Technical Development Zone in Liaoning Province in northeastern China. This project is an important activity of the pilot program for the development of a closed-loop economy in Liaoning Province (2001–2005). RPP International, a California-based corporation, and Dalian University of Technology are closely collaborating in an eco-planning process. The first phase of planning will design strategies, policies, and projects to realize an integrated resource management and recovery system. This EIP will also include renewable energy firms, especially bio-energy, and those offering products and services for integrated water management.

Although the discussions about EIPs have begun only very recently, there is an astonishingly large number of industrial estates in China claiming to be EIPs. As with many fashionable concepts, some people have misused or even abused the EIP concept, not understanding its theoretical basis, scope of use, and limitations. The EIP approach may be undermined, making it old wine in a new bottle.

Closed-Loop Economy

The Shanghai municipality, the most economically developed region in China, has become the country's leader in exploring opportunities for a closed-loop economy. As part of the Shanghai Local Agenda 21 program, the Shanghai municipal planning commission organized a study mission to Germany, which directly exposed participants to German experiences in striving for a closed-loop economy. The Shanghai municipal government prioritized the development of a knowledge economy and a closed-loop economy as the key to realizing the city's sustainability. Pursuing a closed-loop economy has been highlighted in the Shanghai Tenth Five-Year Plan for Socioeconomic Development (2001–2005). Shanghai's experience is that government should focus on creating favorable policy and regulatory frameworks to nurture concrete actions at the firm and estate levels in a market-based manner. Through more than three years of awareness raising, the development of a closed-loop economy began to draw the attention of senior policy makers. Liaoning Province formulated and started to implement its provincial plan for developing a closed-loop economy, which stresses the recycling of industrial and domestic wastes and industrial restructuring. This initiative is coordinated by the Liaoning Environmental Protection Bureau and is regarded as more of a top-down approach.

With technical support from Tsinghua University, the city of Guiyang, located in southwestern China, aims at being transformed into an eco-city by developing a closed-loop economy. Although it is too early to evaluate the outcomes of these initiatives, different approaches toward the development of a closed-loop economy will no doubt bring about valuable lessons as well as a variety of models.

Summary

In sum, a small number of Chinese academic institutions are vanguards in initiating research in industrial ecology theory and practical tools.[3] The research, however, is still near its very inception and is fragmented in nature. Institutional capacity in terms of research networks remains to be enhanced. Overall, the government has not been sensitized to the broad potential of industrial ecology, although there is some interest in development of a closed-loop economy and EIPs. The Natural Science Foundation of China, a quasi-governmental grant-making organization, has supported a few academic studies, such as an LCA of municipal solid waste management, of eco-tourism in natural reserves, and of agroproducts, as well as development of green manufacturing and eco-industry. Most science and technology programs, however, are administered by the Ministry of Science and Technology. The ministry has funded many other environmental planning and management studies, but it has not yet supported any major studies on industrial ecology except for the subjects of cleaner production and LCA for new materials.

Notes

1. This column only reviews the status of industrial ecology in mainland China, which excludes Hong Kong, Macao, and Taiwan.
2. Deli Xi, retired professor from the Department of Environmental Engineering of Tsinghua University, suggested that industrial ecology remain translated as *gongye shengtaixue*, but include services and agriculture sectors in its scope given the wider acceptance in China.
3. References to research in this and other specifics mentioned in this column can be found in an e-supplement available on the Journal of Industrial Ecology Web site at http://mitpress.mit.edu/jie.

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