Empirical Analysis of Eco-Industrial Development in China

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ABSTRACT

The increasing resource and environmental pressures have impeded China’s efforts to quickly promote its people’s quality of life, while protecting its natural environment. Due to lack of resources, technologies and capital, China needs to seek a more integrated development strategy. Industrial ecology (IE) may be one solution as it aims at optimizing the use of materials and energy in products, processes, industrial sectors and economies by systemically mimicking natural systems in an industrial setting. The relevant practices and experiences in the developed world have proved that there is a degree of effectiveness and efficiency to development through the application of IE. It is even more critical to apply the principles of IE in China, where resources are scarce. However, compared with developed nations, China faces different environmental, economic and social constraints. Therefore, China has to adopt different approaches to implement the concept of IE. In this paper, we first review the current practices in eco-industrial development in China. Then the advantages and barriers to applying IE in China are analyzed and recommendations are provided.

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Introduction

As the biggest economy in the developing world, China has experienced the most rapid increase during the last two decades by encouraging local industrialization and attracting foreign investment. However, in the absence of a comprehensive sustainable development scheme, such increases have brought very severe environmental issues, such as water resource depletion and pollution, soil erosion, desertification, acid rain, sandstorms, forest depletion and solid waste pollution (SEPA, 2003). In accordance with the practice of ‘pollute now, clean up later’, many environmental disasters have frequently happened and cumbered further development efforts. According to the Asian Development Bank (ADB, 2001), among 41 cities ranked by particulate air pollution, eight of the worst

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10 are in China. If such environmental conditions are expected to worsen, China urgently needs a new sustainable development strategy, which has the ability to overcome the current dilemma and to ensure that future prosperity can be enhanced.

Industrial ecology (IE) is an emerging framework, which characterizes relationships between businesses by analyzing their economic and environmental performance (Lowe and Geng, 2003). IE consists of three main pillars. Firstly, it studies the relationships among players between industrial and natural system (Geng and Côté, 2002; Chiu, 2001). Secondly, IE introduces core concepts, such as industrial metabolism, as a powerful methodology (Erkman, 2000; Tibbs, 1992). Finally, IE identifies a goal roadmap, that is, route to sustainable development (Allenby, 1995). A major premise of IE is that industrial systems can leapfrog efficiencies by using sustainable value chain concepts (Chiu, 2003) and can minimize environmental impacts by mimicking the circular flows of energy and materials as demonstrated by natural ecosystems (Frosch and Gallopoulos, 1989; Tibbs, 1992).

Academically, IE is an interdisciplinary field of study where industrial systems are in concert with nature and society. Since its inception several decades ago, it has evolved from a smart theoretical ‘idea’ via a ‘somewhat fuzzy concept’ into an intellectual area that has resulted in the creation of an international society, two refereed international journals (Journal of IE, MIT, and Progress in IE, Interscience), a defined research agenda, several higher education programs and a number of other features that constitute a scientific community and thus frame a professional culture.

Practically, IE encourages eco-industrial development (EID), which in turn adds value to businesses and communities by optimizing the use of energy, materials and community resources. Several EID projects are under construction in North America, Japan and Europe (Hollander, 2001; Côté and Cohen-Rosenthal, 1998; Lowe et al., 1996). However, EID is not only applicable in developed countries, but it has relevance in developing countries. In many cases, EID is more urgently needed to be effectively applied in the developing countries, as many of them are facing severe constraints on the availability of resources (Erkman, 2000). This makes special sense in China when we consider its economic size, large population and crucial conditions of resource consumption.

Perhaps as somewhat of a surprise, IE has been practiced for some years in China (Shi et al., 2003; Geng and Côté, 2003). Some practices have been spontaneous; they are economy and technology driven. Examples can be found in the agro-business industries, where a group of companies built up a byproducts exchange network based upon the sugar refining process (Duan, 2001). Other have been introduced and partnered on purpose with international organizations, such as the United Nations Environmental Programme (UNEP), the Canadian International Development Agency (CIDA) and the Asian Development Bank (ADB). All these projects have comprehensive benefits. On the other hand, there are still many barriers and difficulties to overcome. China, unique with its political, economic, environmental and resource constraints, needs to seek strategies and tactics to put IE into place, rather than to copy directly from the experiences of the developed world.

In this paper, we first review the current applications of EID in China. Next we analyze the advantages and benefits of implementing EID, as well as barriers. The emphasis of this paper is to study how to encourage the implementation of EID in China by considering the indigenous resources. Finally, we comment on the current situation and give an outlook for the future.

Current Application of Eco-Industrial Development in China

According to Shi et al. (2003), EID was first proposed in China in the early 1980s and became popular in the late 1990s. Since then, scholars in several Chinese institutions have introduced the concept of IE as well as initiating research programs. The first Chinese book on EID was published in 2003 (Lowe
Empirical Analysis of Eco-Industrial Development in China

and Geng, 2003) and at least two Chinese books on IE were recently released (Deng and Wu, 2002; Erkman, 1999). Several Chinese universities are now offering IE courses at both undergraduate and graduate levels and are in receipt of research grants to develop theoretical frameworks and practical tools for implementing EID (Shi et al., 2003).

With regard to political support, China's central government has played a key role in encouraging EID. As the national agency on environmental protection, the State Environmental Protection Administration (SEPA) led the first eco-industrial park (EIP) project in Guigang, Guangxi Zhuang Autonomous Region, in 2000. The site is a sugar complex formed in 1954 and is one of the largest sugar refineries, employing over 3800 workers. The sugar complex, the Guitang Group, owns 14700 ha of land, which is used for growing cane. Generally, the sugar industry in China is responsible for high levels of emissions, but this complex has responded by creating a cluster of companies that reuse by-products, resulting in reduced levels of emissions. The complex mainly includes an alcohol plant, two pulp and paper plants, a toilet paper plant, a calcium carbonate plant, a cement plant and a power plant. The goal of the Group is ‘to reduce pollution and disposal costs and to seek more revenues by utilizing by-products’ (Duan, 2001). Figure 1 shows the present flows of materials and water (Zhu and Côté, 2004).

With such an integrated resource management approach, the complex has transformed traditional sugar wastes into products, which in turn have brought economic and environmental benefits together. With a comprehensive wastewater reuse program, the group has been able to reduce freshwater consumption by 40% and wastewater emission by 51% (Lowe and Geng, 2003). In the late 1990s the secondary products accounted for 40% of company revenues (Lowe, 2001; Lowe and Geng, 2003).

The Group’s example has inspired the town of Guigang to adopt a five-year plan to become an eco-city. Because of the heavy dependence on the sugar industry, part of the plan is to improve the efficiency of many processing plants (Duan, 2001). The plan also calls for smaller sugar producers to send their by-products to Guitang’s eco-industrial complex and to consolidate cane growing fields into larger hold-
ings, which facilitates technology development and gains scale benefits. Other activities include training of industry and government managers in eco-industrial principles and methods.

In October 2001, the Department of Science, Technology and Standards at SEPA initiated four EIP demonstration projects in Dalian, Tianjin, Suzhou and Yantai. The themes cover four main initial aspects on EID, that is, ISO14001 certification, regional cleaner production initiatives, emergency response system and inter-firm industrial symbiosis in Dalian, Suzhou, Tianjin and Yantan, respectively. SEPA is preparing to stipulate relevant policies to support the broader application of IE. Preventive strategies, such as Cleaner Production, were enacted in 2002. Another important project led by SEPA is the Circular Economy Demonstration Project in Liaoning Province, one of the largest heavy industry bases in China. Under this project, EID efforts will be initiated in Shenyang, Dalian, Anshan and Yingkou, such as the Dalian Development Zone EIP demonstration project. Some efforts on integrated materials management will probably take place at municipal level such as in Dalian city. A virtual eco-industrial network at the provincial level will be established in order to improve the overall eco-efficiency and to serve as a demonstration for other regions to learn from (SEPA, 2003).

At the regional level, with the dissemination of IE in China, many local governments and companies began to initiate their own EID projects. An investigation undertaken by Dalian University of Technology (DUT) revealed over 50 projects are at various stages of implementing EID principles (Figure 2). For instance, city governments such as Shanghai, Hangzhou, Yangzhou and Guiyang, and provincial governments such as Hainan, Jiangsu and Jilin, have raised their plans so as to become an eco-city or an eco-province (Lowe and Geng, 2003).

**Supports and Benefits of Implementing Eco-Industrial Development**

Encouraging EID in China has many advantages by offering strategies to achieve greater efficiency through ‘economies of systems integration’, whereby partnerships between businesses meet common
Empirical Analysis of Eco-Industrial Development in China

service, transportation and infrastructure needs (Ayres, 1996). While drawing heavily from pollution prevention approaches that focus on the efficiency of individual firms, the unique contribution of EID is the emphasis on inter-firm resource exchange linkages (Desrochers, 2002). Just as in natural ecosystems, interconnected entities have evolved to form symbiotic relationships to assure survival and to preserve resource efficiency. For business, value is added as by-products including wastes, water and energy are cycled back throughout the production stream of an industrial park or region. Closing the loop results in the conservation of natural resources and lower disposal and production costs.

Legal Support Framework for Eco-Industrial Development

Environmental control in China has a broad legal framework. The highest level is expressed in the Constitution of the People’s Republic of China. The Law of Environmental Protection, which was first promulgated in draft form in 1979 and subsequently passed and implemented on 26 December 1989, emphasizes the responsibility of each local administrative unit to initiate appropriate laws and regulatory regimes on the basis of level of economic development and the nature of its pollution problems (Chan et al., 1995). This law addresses the importance of comprehensive environmental protection policies, without hindering economic development and growth. In terms of supporting EID, the Standing Committee of the National People’s Congress (NPC) of the People’s Republic of China approved a Cleaner Production Promotion Law in the 28th Session on 29 June 2002. Effective from 1 January 2003, this law was enacted to promote cleaner production, to increase the efficiency of utilizing resources, reducing and avoiding the generation of pollutants, protecting and improving environments, ensuring the health of human beings and promoting the sustainable development of the economy and society. This law not only promotes cleaner production at the individual company level, but also encourages broad cleaner production efforts at the inter-firm level and even regional level, which in essence set up the solid foundation for China’s EID. Other related environmental regulations include (i) environmental impact assessment (EIA), (ii) ‘three synchronizations’, (iii) the pollution discharge fee system, (iv) the pollution discharge permit system, (v) the environmental responsibility system, (vi) centralized pollution control, (vii) assessment of urban environmental quality and (viii) limited time treatment (Sinkule and Ortolano, 1995; Conway, 1996; Anwar, 1999). These regulations are largely characterized by command-and-control and end-of-pipe approaches, focusing on pollution control and abatement.

In addition, China is now encouraging the decentralization of environmental protection (Lo, 1994). Local governments now have more freedom to stipulate their own environmental policies and regulations in accordance with the realities of local conditions. Once the local economic and environmental officials recognize the potential integrated benefits of implementing EID, the hope is that they will be inclined to incorporate principles of EID into the economic development plans and to begin to initiate such practices. The Circular Economy Project in Liaoning Province is such an example. The provincial governor and other key officials recognized that the whole province had to seek a sustainable industrial development approach in order to solve heavy pollution and resource depletion issues. A detailed work-plan on developing a circular economy has been implemented, including the release of a provisional regulation on circular economy and several EIP projects in selected industrial cities (SEPA, 2003).

Financial Support

Since the late 1970s, China has paid increasing attention to the important role that investment plays in improving environmental quality and accelerating economic growth. The state has begun to fund envi-
ronmental protection via national funds, which can be used to support national EID projects including research and development activities and demonstration projects (Li, 2002). At the regional level, the collection of effluent fees provides a source of financial support for EID. About 80 percent of the effluent fees collected are being used to finance pollution control and improvement projects approved by the local environmental officials. More ambitiously, the Liaoning Provincial Environmental Protection Bureau in 2004 decided to use their entire effluent fee to support EID projects. Such a model is being considered for the whole country (SEPA, 2003).

Other financial sources include international development agencies. The United Nations Environmental Programme (UNEP), the Asian Development Bank (ADB) and the Canadian International Development Agency (CIDA) have already funded China’s cleaner production activities and they should be the next sponsors for China’s EID. With their financial support and organization, both governments and industries will further participate in EID efforts. UNEP led China’s first EID project, titled ‘Environmental Management of Industrial Estates’ in 2001, in which four industrial estates, including those in Dalian, Tianjin, Yantai and Suzhou, have now completed their own EIP plans and passed SEPA’s peer review process (Zhang, 2003). Besides its large China–Canada Cooperation Project in Cleaner Production, CIDA has funded the Dalian Municipality to retrofit a traditional polluting industrial park as an eco-industrial park (Geng and Yi, 2003).

While the government and civil society may initiate actions on several sustainability issues, it is the business leaders in the corporate world who keep industry following a persistent pattern of action. Some multinational corporate giants, including Coca-Cola, Canon and Ford, have sponsored efforts that are related to programs for exchanging regional byproducts (Zhang, 2003). With the increasingly severe environmental regulations, more companies will support such efforts in order to improve their competitive ability and green image to the public.

Competitiveness

There are a few, but significantly important, groups of corporate entities in China who are not content with the status quo, but go beyond the minimum to make use of the sustainable development paradigm and gain the competitive edge. For instance, the Waste Minimization Club of Companies in the Tianjin Economic Development Area (TEDA) has designed a management assessment and rating system (MARS) to evaluate performance on Environment, Safety and Health (ESH). Such a move by the corporate world is not being driven by government and civil society alone, but by five corporate forces – supplier, buyer, competitor, threat of entry and threat of substitution (Geng and Yi, 2005).

Since China’s entry into the WTO, the tariff barrier has been abated while green barriers have become one of the main barriers for Chinese enterprises to compete with their international counterparts. As a result, to gain international competitiveness, Chinese enterprises have increasing concerns to improve their environmental performance in addition to their economic performance. There is a growing belief that the EID can develop a competitive capability for firms by optimizing the economic and environmental performance simultaneously.

Barriers

Although on the surface it looks as if EID in China is widespread, further analysis revealed that the implementation of EID still lacks the guidelines, necessary information and related technologies. In

\[\text{From the website: http://www.teda.gov.cn}\]
some cases the term EIP appears to be used to attract more investment. Some of the so-called EIP projects in China only mean a collection of companies making ‘green’ products, a collection of environmental technology companies, an industrial park increasing the degree of landscaping or a park committed to low emission efforts (Lowe and Geng, 2003).

Quantitative indicators are used for assessing an EID project’s performance, but a common question is what indicators and level of performance should be achieved for evaluating whether or not an industrial park can be called an EIP. A related question is who will certify that the criteria are being met. To facilitate the designation process, the central government should be prepared to provide criteria and guidance. Once released, more industrial parks will seek official certification as a new promotion method for attracting investment. However, the definition of IE and EIP \textit{per se} is still unclear and arguable, which discourages practitioners from implementing it.

Another barrier to implementing EID in China is that loopholes exist within the environmental legal system. For instance, according to the Chinese environmental regulations, the local Environmental Protection Bureau can only fine companies 100,000 RMB as a maximum (Chinese currency, 1 USD = 8.2 RMB) whenever they pollute and break discharge limits. To comply with the national sewage emission standards, companies may have to spend millions of RMB on installing and operating pre-treatment facilities (Zhang, 2003). In other words, the cost to be a law-abiding corporation is higher than operating illegally. Furthermore, many environmental regulations forbid or limit the exchange of by-products between companies. In an attempt to encourage local economic development and to be able to compete with other regions, local governments often discourage strict enforcement of environmental regulations. Many local officials are focused mainly on short-term economic benefits and they regard rapid industrial development as the main political contribution. Under such circumstances, companies are disposed to discharge their wastes directly, rather than seeking potential buyers of the by-products or installing pre-treatment equipment. The end result is that the local environment continues to deteriorate. Also, due to lack of clear guidelines and adequate manpower to enforce policies, on the whole the current environmental legal system is not effective.

Technologies are another barrier. Modern environmental technologies can be of assistance to help establish eco-industrial chains among companies and to facilitate by-product exchanges. For example, the Guitang Group produces toilet paper from bagasse by developing new paper-making technologies. As a result, the Group can also use bagasse from other smaller local sugar companies as a resource. Further, new environmental tools, such as eco-design, cleaner production and life cycle assessment, will help revolutionize such fields as biotechnology, information technology and material science. This revolution will then green industry by getting the same output while using less energy and less raw material at reasonable cost, thereby producing less pollution and more products with less consumption. However, this will not automatically happen in China. Demand for environmentally superior technologies is still weak, and both the technical capabilities and financial resources are inadequate, thus resulting in the levels of pollution and energy consumption outpacing economic growth (Banks, 1994). While transfers of technologies from developed countries to China are possible, they are unlikely to be implemented or sustained because of a lack of appropriate training and resources (Geng and Wu, 2000).

Possible Solutions

To overcome several of the barriers described, an integrated approach is needed. Such an integrated approach should consider all the stakeholders’ concerns and consider the Chinese reality. Figure 3 presents an integrated model for implementing EID in China.
As shown in Figure 3, industrial development managers and tenant companies should optimize all the available resources (materials, water and energy), maximize reduction, reuse and recycling both at the individual company level and at inter-firm level and minimize total discharges, and, as the last resort, emitting wastes into the local environment. This figure also shows us that the successful implementation of EID depends on four key elements: policies and regulations, economic instruments, information systems and capacity building. The following will detail these four elements.

Policies and Regulations

While legislation already exists, it is important to stress that new policies and legislation are required if EID projects are to be successfully implemented.

Policies should help to overcome institutional barriers in government. For instance, in terms of water management in China, the local Environmental Protection Bureau is in charge of wastewater discharge and pollution control; the Bureau of Infrastructure is in charge of water supply; the Bureau of Construction is in charge of water resource extraction and the Economic Planning Committee is in charge of water resources planning and allocation (Zhu et al., 2001). None of these agencies are subordinate to another, nor can any one of them assume a leading role. This segmentation makes integrated resource management almost impossible at the policy formulation stage. Institutional restructuring leading to new management arrangements is crucial and necessary. One suggestion would be to establish a new administrative institution such as the Bureau of EID that would be responsible for integrating supervisory authority over waste-related issues.

Also, policies should help adjust the industrial structure, such as limiting the development of large resource-depleting industries and polluting industries. Regulations that can help solve potential conflicts among tenants and industrial park and between tenants should be stipulated. Other policies, such as those that can encourage cleaner production and material cascading (such as water and energy) among tenants and coordinate the relation between industrial park and local communities, should also be established or revised according to local realities.

The ultimate goal of EID is to achieve sustainable management of resources and protection of the environment within an industrial system. Sustainable integrity requires that industrial park managers...
Empirical Analysis of Eco-Industrial Development in China

integrate all the relevant policies in a broader complex system including natural, social and economic contexts at an early stage in order to avoid resource and environmental problems caused by rapid economic growth and social distress. Under such a goal, four strategies, including supply management, demand management, efficiency management and emission management, should be adopted. In terms of each strategy, the respective management target should be to maximize resource input, keep demand within resource capacity, maximize the efficiency of use and limit the discharge of pollutants within the environmental capacity. Each of these management targets could be gained through various detailed measures. Figure 4 shows the outline of such an integrated policy framework. In addition, policies and regulations should remain flexible to allow for adjustments, which may be needed as conditions change or as in response to periodic evaluations.

Economic Instruments

The growing scarcity and rising cost of materials have led to the realization that resources have to be allocated and used more efficiently. Economic instruments that fall into one of two categories – incentives or disincentives – can play a key role in resource allocation and conservation, helping minimize wastage, provide incentives for the development of resource-efficient technologies and encourage reuse and recycling.

Prices can play a key role in resource conservation based on the principle that tenant companies will respond rationally to financial incentives and disincentives. A basic tenet of the current natural resource management system is that good environmental management requires that both consumers and polluters should pay prices for services in accordance with the principles of economic efficiency. Such a pricing system would equate demand and supply services at the economically appropriate level and in an environmentally acceptable way.

It is proposed that to achieve more efficient demand management the consumer and the polluter should be required to pay the full social cost (including the capital, operation, maintenance and external costs associated with its use) of providing resources and related services, including treatment and damage costs. The adoption of this principle will create more efficient administrative arrangements for
the integrated management of natural resources. For instance, if the price of water is below its real cost, then tenants are inclined to waste water, for example not identifying and repairing leakages, or the resource may be used inefficiently, such as by overuse or inappropriate use. When the price of water reflects its real cost an opportunity is created, such as an economic incentive for water to be allocated rationally between different sectors and for the development and use of water-efficient technologies (e.g. the application of cleaner production). Companies will be encouraged to seek users for their wastewater, thereby generating revenue rather than paying for wastewater treatment. A challenge for the industrial park managers and tenants is how to set up a water tariff system, based upon water quality.

Quotas for resource use serve as another powerful tool to improve the overall eco-efficiency at regional level (Zhu et al., 2001). The successful implementation of a quota system is dependent on ‘a planned resource use system’ operated by industrial park managers. Such a system sets up a penalty mechanism whenever resource use exceeds a given quota. Tenants are required to pay several times the normal rate for those resources they use whenever they exceed the quota allotted to them. Such a measure can inspire tenants to apply state-of-the-art resource conservation technologies and to seek potential collaboration opportunities with neighboring tenants within an industrial park. For instance, the Dalian Economic Development Zone implemented this system in 2002, when they were suffering from a severe water shortage. Those companies consuming more than their allocated quota were asked to pay ten times higher water rate. Therefore, many tenants decided to adopt better monitoring measures and new water-saving equipment. Thus, both the internal recycling ratio and overall system efficiency were greatly increased (Geng and Yi, 2003).

The purpose of an effluent charge is to offset the cost for the regulatory authority to undertake its mandate of pollution control. Depending upon the surcharges imposed, it is recognized as an economic disincentive. At the same time it is possible that a surcharge may act as an incentive, leading to changes in the behaviors of the dischargers, and supporting the development of related practices, including reduction, reuse and recycling.

Information Systems

When developing an industrial ecosystem, information is needed for effective planning and management, including optimal reduction, reuse and recycling scenarios. Every corporate enterprise, from a small business to a large multinational corporation, is part of a larger economic system or web. Companies are interlinked to other companies via increasingly complex supply chains. Therefore, an information system adopting a system approach is required if industrial park managers are to find more environmentally and financially beneficial ways to plan and manage their resources.

A good example is at the Tianjin Economic Development Area (TEDA), the largest industrial park in China, which has created an information platform to facilitate by-product exchanges among tenant companies, by allowing different users to upload their by-product information confidentially to be shared in a confidential fashion with tenants located within the area. This platform has now been widely used and a new waste minimization club, composed of participating companies for byproduct exchanges, has been established on the basis of this cooperation (TEDA, 2003).

Capacity Building

The need to better manage available resources and assure fair and equitable allocation among all the users within an industrial system and to protect the environment has forced industrial system planners and managers to carry out capacity building initiatives. These include strengthening of institutions, man-
Empirical Analysis of Eco-Industrial Development in China

agement systems and human resources, as well as community participation and communication. Agents for increasing capacities include industrial managers, government officials, tenants, research institutions, community and financial organizations.

Training is a cornerstone of capacity building and a critical pre-requisite for sustainability. Training should focus on environmental performance reporting and management and be directed to both industrial enterprises and governmental agents. Training materials may include sustainability reporting, design for the environment, environmental control technologies, industrial symbiosis, environmental remediation and project and logistics management. Activities of training and education, including TV promotions, newsletters and workshops, should be carried out periodically. Such initiatives can provide forums at which the experiences from different parts of the world and from different institutions can be objectively reviewed and some lessons drawn. They can also create opportunities for stakeholders to strengthen their mutual understandings and friendships, both of which are essential in building a solid foundation for further collaboration.

Capacity building should reflect the needs and overall conditions of the industrial system concerned. As such, it should be a long-term process, with clearly enunciated short-, medium- and long-term goals. Good communication, exchange of information and extensive interactions among different stakeholders are essential prerequisites for any good capacity building process if it is to be successful.

Another challenge facing China is how to transfer the most appropriate technologies in order to have a reliable operation at lower operation and maintenance costs. Transnational companies can help diffuse environmentally sound technologies and management methods through their global suppliers, affiliated networks and capacity building initiatives. Specialized investment and consulting firms can expand the application of green technologies by providing capital support and management expertise. International organizations, such as UNEP, the United Nations Development Programme (UNDP), the World Bank and other international development agencies, can cultivate and strengthen China’s capacity for technological adaptation by encouraging cooperative research, professional training and exchanging experiences with EID with China.

Conclusions

A quarter-century of robust economic growth, coupled with accession to the World Trade Organization (WTO), has ensured that China will be one of the world’s prominent arenas for business expansion well into the 21st century. Industrialization brings with it the potential for environmental degradation and depletion of valuable natural resources. It is not surprising that a country as large as China should have an environmentally friendly policy directed squarely on its economic development.

Through the implementation of IE concepts, EID represents a promising strategy to promote sustainable industrial development. EID serves as an incentive for companies to improve their environmental performance in terms of management of materials, energy and waste. Benefits also extend beyond the limits of the industrial park by helping and encouraging communities to invest in similar concepts. China faces severe constraints on the availability of resources. Due to its multiple advantages, EID strategies have been practiced in different industrial zones. Chinese environmental protection regulations have generally led to the creation of a solid foundation for sustainable industrial development; however, partly due to a poor understanding of EID processes and lack of indicators, as well as weak technological capacities, implementing EID is still in its infancy in China. An integrated approach which combines four key elements, that is, policies and regulations, economic instruments, information system and capacity building, should be adopted.
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References


Bean W. 2004. Booming port city of Dalian is getting environmental advice from the University of Waterloo. The Record (Waterloo Region) 27 March: 3.


